AN EVALUATION OF MID-WATER ARTIFICIAL STRUCTURES FOR ATTRACTING COASTAL PELAGIC FISHES[1]

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ABSTRACT

Mid-water artificial structures positioned off Panama City, Fla. during August 1970 were evaluated to determine their ability to attract coastal pelagic fishes. Quantitative and qualitative experimental results were obtained using scuba divers and purse seine catches. The feasibility of using artificial structures to facilitate the commercial harvest of coastal pelagic fishes with purse seines was established and the methods described. Average catch values of 398 kg (875 lb) per structure were obtained during a period when coastal pelagic fishes were unavailable to the local fishery. A greater total production was obtained from structures fished daily compared with those allowed to soak for 3 days before being fished. Experimental purse seine collections established that fish leave the structures at night with new recruitment occurring daily. No significant differences were obtained from preliminary experiments to evaluate the effects of structure size and color on attraction effectiveness. A working hypothesis is presented to describe apparent behavioral mechanisms involved in the attraction of some species of coastal pelagic schooling fish to objects in the sea. This study indicates that artificial-structure fish-attraction has potential for development as a technique to facilitate the harvest of the latent coastal pelagic fishery resources in the Gulf of Mexico.

Artificial structures have been shown to be effective for attracting concentrations of pelagic fishes (Hunter and Mitchell, 1968). Klima and Wickham (1971) visually evaluated the species and number of coastal pelagic fishes attracted to experimental artificial structures in the northeastern Gulf of Mexico. These observations established the feasibility of attracting large numbers of coastal pelagic fishes with artificial structures; however, many questions concerning structure attraction characteristics and dynamics as well as their actual usefulness in augmenting conventional harvesting methods for these species still remained unanswered.

Studies were conducted during August 1970, in 5 to 10 fathoms (9 to 18 m) of water offshore of Shell Island, Panama City, Fla. to obtain quantitative samples for evaluating the validity of scuba-diver estimates of structure-attracted fish aggregations, to evaluate methods for using a conventional purse seine for capturing structure-attracted fish, and to obtain catch-production values for single structures. We also evaluated effects of structure soak time and size-color differences on attraction effectiveness. Day and night samples, plus scuba-diver observations of fish behavior, provided additional clues to the dynamics of the coastal pelagic fish aggregations attracted to artificial structures.

MATERIALS AND METHODS

Our fish attraction devices were three-dimensional structures. Each structure was constructed from vinyl-cloth covered, wood and wire frame panels. Two panels were fastened along one side, permitting the structure to be stored flat, but opened into a three-dimensional right prism when deployed for fish attraction. Two sizes of structures were used. The small structure panels were 0.9 × 1.5 m (3 × 5 ft) in size and the large structures, with twice the surface area of the smaller structures, were 1.8 × 1.5 m (6 × 5 ft). All structures were white except those painted for specific experiments.

Structures were positioned 4-6 m (15-20 ft) beneath the surface. The structure design and mooring arrangement are illustrated in Figure 1. Structures were spaced at approximately 0.8-km

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Manuscript accepted May 1973.
FISHERY BULLETIN: VOL. 72, NO. 1, 1974.

(0.5-mile) intervals. Their arrangement in the experimental site is shown in Figure 2. The eight structure mooring locations were used with different structures as required for specific experiments.

The 15-m (49-ft) single boat-rig bait purse seiner, *Gulf Ranger*, was chartered to make quantitative collections at selected artificial structures using a tom-weight type purse seine, 22 m (12 fathoms) deep and 110 m (60 fathoms) in length, with 3.2 cm (1¼-inch) stretched mesh webbing. A 6-m (20-ft) inboard-outdrive power boat was used as a diving platform and for picking up and resetting structures sampled by the purse seine.

Daily visual estimates of the number and species of fish present at each structure were made independently by scuba divers. We obtained quantitative data from selected structures by collecting all the fish around these structures with the purse seine. Diver estimates and purse seine catch data are given in Table 1.

Scuba divers made visual estimates of the fish aggregation at a structure prior to beginning the purse seine set. The structure anchor was picked

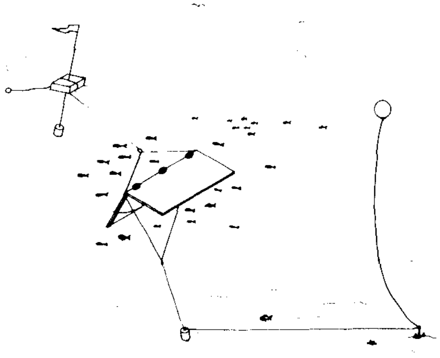

FIGURE 1.—Artificial structure design and mooring arrangement.

up by the divers as soon as the seiner began setting its net. When pursing was half completed, the structure counterweight was retrieved to prevent its being tangled in the purse line. After the purse rings were up, the dive boat would take the structure aboard, pass over the corkline, and reset the structure clear of the net.

The captain of the *Gulf Ranger* estimated the catch weight after each purse seine set and the biologist aboard sampled each catch to provide

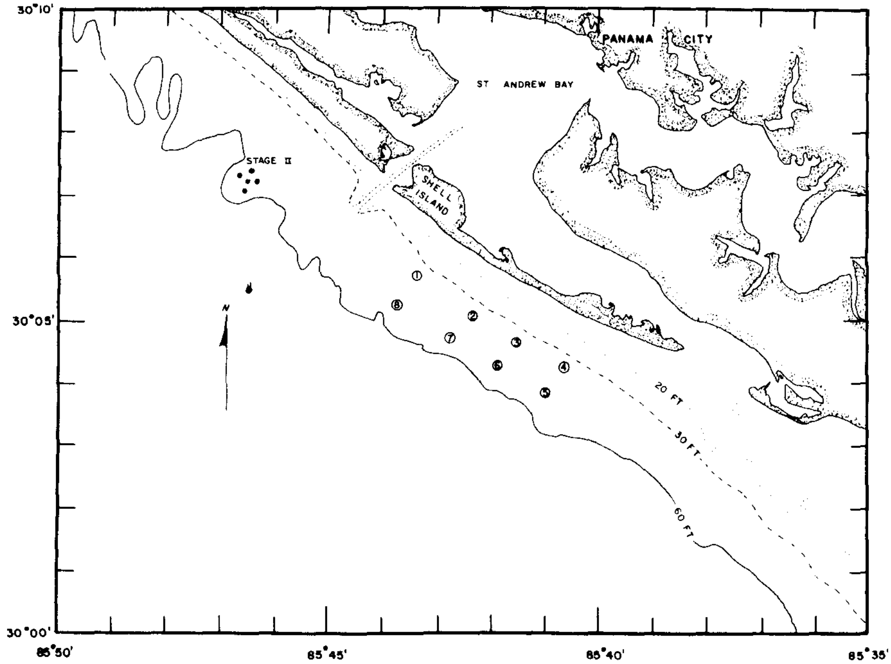

FIGURE 2.—Map of experimental site with numbered circles illustrating positions where artificial structures were deployed. Stage II is a Navy research platform west of the study area.

TABLE 1.—Diver estimates and purse seine catches.

Structure position		1		2		3		4		5		6		7		8	
Structure type		Large white		Small white		Large white		Small white		Large white		Small white		Large white		Small white	
Date 1970	Sample type	Sample time	Weight (kg)	Sample time	Weight (kg)	Sample time	Weight (kg)	Sample time	Weight (kg)	Sample time	Weight (kg)	Sample time	Weight (kg)	Sample time	Weight (kg)	Sample time	Weight (kg)
July																	
12	Diver 1	1330	227	1415	22	1531	681	1557	227	1635	136	1702	136	1726	454	Lost-No	
	Diver 2		272		68		681		136		318		227		454	observations	
	Average		250		45		681		181		227		181		454	—	—
13	Diver 1	1010	136	1034	454	1110	136	1133	136	1200	454	1235	136	1300	454	—	—
	Diver 2		227		227		136		136		272		90		227		—
	Average		181		340		136		136		363		113		340		—
14	Diver 2	1037	136	1100	227	1125	227	1215	227	1150	227	1241	136	1309	227	—	—
	Diver 3		227		136		136		227		90		363		227		—
	Average		181		181		181		227		159		250		227		—
15	Diver 2	1045	227	1130	454	1215	681	1240	454	1305	681	1345	454	Lost-No observations			
	Diver 3		227		454		909		454		909		454		—	—	—
	Average		227		454		795		454		795		454		—		—
16	Diver 1	0945	681	1015	318	1045	454	1110	454	1137	681	1207	90	—	—	—	—
	Diver 3		454		454		909		318		909		90		—		—
	Average		568		386		681		386		795		90		—		—
17	Diver 1	1202	227	1227	227	1255	136	1316	90	1356	136	1418	136	—	—	—	—
	Diver 2		227		454		227		136		136		136		—		—
	Average		227		340		181		113		136		136		—		—
18	Diver 1	0947	136	1013	227	1045	318	1105	136	1130	45	1200	136	—	—	—	—
	Diver 2		227		227		227		136		45		454		—		—
	Average		181		227		272		136		45		295		—		—
20	Diver 2	0945	136	1300	45	1010	136	1245	227	1150	136	1135	136	1315	909	1045	136
	Diver 3		90		681		136		181		90		227		909		136
	Average		113		363		136		204		113		181		909		136
	Purse seine	0945	90	1600	90	—	—	—	—	—	—	—	—	1403	1,363	1105	45
August																	
17	Diver 1	0953	454	1533	45	1031	68	1100	454	1325	1,136	1346	90	1406	454	1121	454
	Diver 3		227		136		136		454		909		90		227		454
	Average		340		90		102		454		1,022		90		340		454
	Purse seine	1100	363	1730	363	—	—	—	—	—	—	—	—	1630	681	1400	818
18	Diver 2	0940	45	1320	454	1255	454	1020	909	1130	454	1200	454	1220	363	1050	227
	Diver 3		22		454		454		2,272		454		2,272		454		90
	Average		34		454		454		1,590		454		1,363		409		159
	Purse seine	1000	90	1350	318	—	—	—	—	—	—	—	—	1230	454	1105	227
19	Diver 2	0915	90	1250	45	1415	454	1650	909	1600	227	1505	272	1140	363	1050	227
	Diver 3		136		227		454		909		227		227		227		136
	Average		113		136		454		909		227		250		295		181
	Purse seine	0830	68	1400	454	1500	454	1715	909	1620	454	1540	272	1245	681	1130	545
20	Diver 1	1225	136	1515	454	1715	454	1700	681	1630	681	1610	681	1430	363	1335	136
	Diver 2		227		454		454		454		1,136		909		454		227
	Average		181		454		454		568		909		795		409		181
	Purse seine	1300	409	1550	363	2145	45	2040	45	2305	9	2230	45	1445	454	1350	272
21	Diver 2	1240	36	1425	227	—	No observation	1700	454	1635	1,363	1620	454	1555	363	1340	227
	Diver 3		22		318		—		681		1,136		681		363		90
	Average		34		272		—		568		1,250		568		363		159
	Purse seine	1300	90	1500	45	—	—	2030	45	2115	9	2220	11	1600	454	1355	363
22	Diver 1	1243	136	1347	227	1406	454	1425	227	1505	681	1443	454	1326	227	1306	363
	Diver 3		136		454		363		227		1,363		909		363		318
	Average		136		340		409		227		1,022		681		295		340

TABLE 1.—Diver estimates and purse seine catches.—Continued.

Structure position		1-4		1-4		1-4		1-4		5		6		7	
Structure type		Small white		Small blue		Small green		Small yellow		Large white		Large white		Large white	
Date 1970	Sample type	Sample time	Weight (kg)	Sample time	Weight (kg)	Sample time	Weight (kg)	Sample time	Weight (kg)	Sample time	Weight (kg)	Sample time	Weight (kg)	Sample time	Weight (kg)
August															
24	Diver 2	1300	136	1335	227	1430	272	1535	454	—	—	—	—	—	—
	Diver 3		136		363		227		454		—		—		—
	Average		136		295		250		454		—		—		—
	Purse seine	1305	113	1400	454	1505	272	1615	318	—	—	—	—		
25	Diver 2	1500	454	1245	227	1625	454	1430	136	1725	818	1705	681	1600	909
	Diver 3		454		22		363		227		909		909		909
	Average		454		125		409		181		863		795		909
	Purse seine	1530	363	1245	113	1630	363	1430	272	1730	272	2200	13	2245	[1]454
26	Diver 1	1212	909	1455	909	1132	318	1330	136	1600	681	1437	1,363	1538	227
	Diver 3		909		909		454		227		909		1,363		909
	Average		909		909		386		181		795		1,363		568
	Purse seine	1255	409	1515	68	1145	113	1405	113	1610	363	—	—	—	—
27	Diver 1	1440	454	1345	227	1245	454	1140	454	1540	454	1420	454	1530	1,363
	Diver 2		1,363		454		454		909		909		454		909
	Average		909		340		454		681		681		454		1,136
	Purse seine	1500	90	1400	272	1300	113	1200	227	1600	181	1700	[2]1,363	—	—

[1] Set around nightlight.
[2] 1,136 kilograms little tunny.

data on species composition. It was not practical to totally weigh each catch as it came aboard or to keep the fish from individual sets separated for later weighing; consequently the captain's catch weight estimates had to serve as our quantitative standard. The accuracy of the captain's estimates was established by comparing the daily total of his estimates with the daily fish house landing records for the *Gulf Ranger* (Table 2). We believed the accuracy of these estimates (r^2 = 0.97) justified our utilizing them for evaluating diver estimates and for quantifying experimental data (Figure 3).

RESULTS

Diver Estimates

The validity of scuba-diver observations was evaluated by comparing the divers' estimates of the total number and species composition of fish present at a structure with data obtained from the purse seine catch at that structure. Numerical estimates obtained by the divers for coastal pelagic school fish were converted to weight, utilizing a catch average of approximately 22 fish per kilogram to permit comparison with purse seine catch data.

The comparison of diver estimates with the captain's estimates for the corresponding purse seine catches are plotted in Figure 4 for data collected 17-21 August 1970 (Table 1). Data from 24 August to 27 August were not included in this comparison because schools of little tunny (*Euthynnus alletteratus*) began following the purse seiner and were occasionally observed attacking and scattering the structure-attracted fish schools before the purse seine set was completed. A linear regression analysis of the mean for each set of paired diver estimates ($Y = 76.5 + 0.56X$; r^2 = 0.68) indicates that although considerable variation does exist, fish schools less than 182 kg (400 lb) tend to be slightly overestimated while the larger schools are increasingly underestimated. A linear regression analysis was also calculated for each diver's individual estimates and these calculations indicated that estimates made by diver 2 tend to be more accurate than the more conservative estimates made by divers 1 and 3.

The purse seine catch sample data indicated scuba divers were able to identify the major

TABLE 2.—Diver estimates, purse seiner captain's estimates, and fish house landing totals for daily catches from artificial structures.

Date 1970	No. daytime sets	Total average diver estimates for structures sampled	Total purse seiner captain's daily catch estimates	Fish house landings	Fish house landings by species	
					Round scad	Spanish sardine
		kilograms				
August						
17	4	1,227	2,227	2,193	830	1,363
18	4	1,057	1,091	909	614	295
19	8	2,568	3,841	4,045	1,830	2,215
20	4	1,227	1,500	1,545	727	818
21	4	830	955	852	432	420
Total	24	6,909	9,614	9,544	4,433	5,111
[1]21	4	1,136	1,159	1,034	761	273
[1]25	5	2,034	1,386	1,682	716	966
[1]26	5	3,182	1,068	693	443	250
[1]27	6	3,523	1,114	1,194	489	705
Total	20	9,875	4,727	4,603	2,409	2,194
9-day total	44	16,784	14,341	14,147	6,842	7,305

[1] Data not used for scuba-diver estimates-purse seiner catch comparisons.

species attracted to the structures. They were not, however, able to determine accurately the percent species composition for the schools of mixed coastal pelagic fishes. These mixed schools contributed over 95% of the catch weight taken from each structure. The mixed coastal pelagic school fish consisted of round scad (*Decapterus punctatus*) and Spanish sardine (*Sardinella anchovia*). The bait fish occurred at each structure in mixed schools of varying percent species composition. The difficulty encountered by the divers in obtaining accurate percent species composition data for this group was probably the result of behavioral differences between the species. Round scad usually approached closer to the divers than Spanish sardine, which tended to concentrate on the side of the school farthest away from the divers.

Jacks usually represented less than 5% of the total catch weight and consisted primarily of small 15-cm (6-inch) blue runner (*Caranx crysos*), crevalle jack (*C. hippos*), and bar jack (*C. ruber*). Among the species which comprised the major components of Klima and Wickham's (1971) jack group, amberjack (*Seriola* sp.) were only occasionally observed and rainbow runner (*Elagatis bipinnulata*) were notable by their absence in this series of experiments. The jacks are not treated separately in our paper because of their minor contribution to the total number and weight of the structure-attracted fish aggregations.

Comparison of diver estimates and purse seine catch data indicates that although purse seine data are quantitatively superior both sampling techniques are complementary and, combined, provide a more complete picture of the experimental environment than either singularly. Where diver estimates provided the only available data they are considered sufficient to permit rough evaluation of the experimental results in terms of their commercial significance.

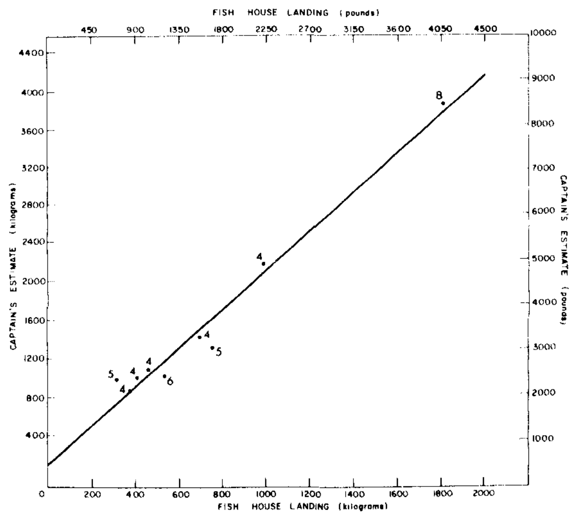

FIGURE 3.—Relationship between the daily total of the *Gulf Ranger* captain's estimates of structure-purse seine catches and the daily fish house landing records. Statistical evaluation of this data by linear regression analysis yields $Y = 216.4 + 0.876X$; $r^2 = 0.97$. N = number of set estimates in each daily total.

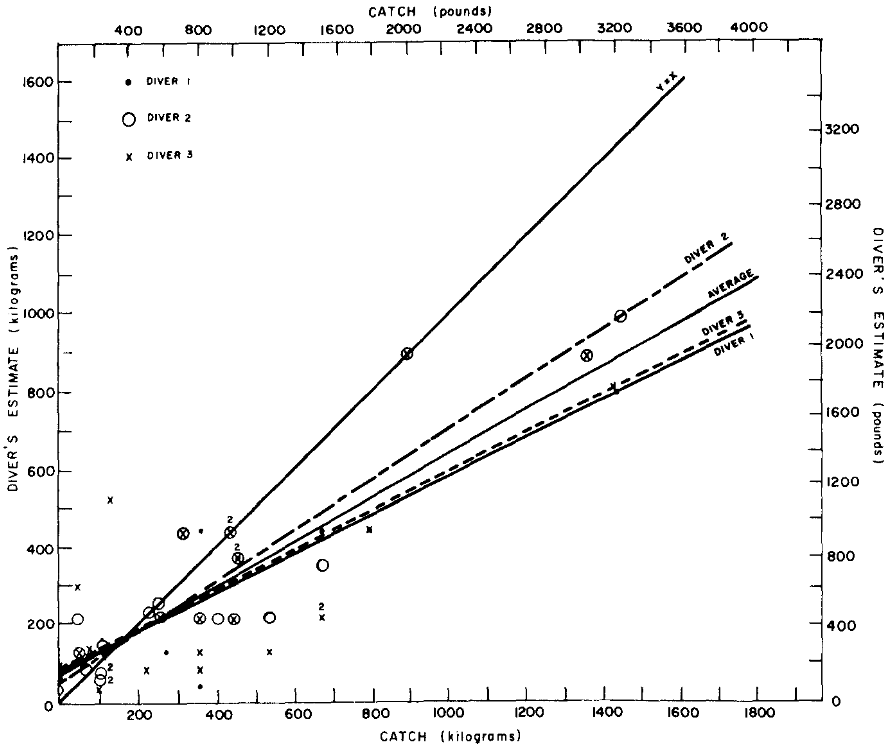

FIGURE 4.—Relationship between divers' estimates of bait fish school size and the captain's estimate of the purse seine catch at each structure. A linear regression analysis of the average paired diver estimates yields $Y = 76.5 + 0.56X$; $R^2 = 0.684$. A linear regression analysis of the estimates made by each diver yields $Y = 77.6 + 0.504X$; $r^2 = 0.285$ for diver one; $Y = 55.3 + 0.683X$; $r^2 = 0.704$ for diver two; and $Y = 98.4 + 0.501X$; $r^2 = 0.42$ for diver three.

Recruitment Patterns and Production

Our observations indicate a rapid recruitment with fish being observed at structures the day following placement. To obtain estimates of production and recruitment of bait fish to the structures, we made daily diver estimates and purse seine collections at four selected structures. Four other structures, also observed daily by divers, were set on after being in position for 3 days. During this period (17-21 August 1970), our structures produced an average of 398 kg (875 lb) per set. These catch rates are not extremely large, but they were made when bait fish were not seasonally available to the local beach seine fishery. No bait was being landed, except for fish captured around our structures. The total daily diver estimates and purse seine collections are plotted in Figure 5, along with the 3-day accumulative totals, to allow comparison of production between the four structures fished daily and the four structures set on once, following the 3-day soak period. Our day 3 catch results indicate no significant advantage in catch size was realized by allowing the structures to soak for 3 days. The potential total catch, assuming daily sets had been made on the 3-day soak structures, indicated from our consistently conservative diver estimates was three times larger than the actual catch after 3 days' soaking. The total accumulative catch from the four structures set on daily was also approximately three times larger than the actual catch from the four 3-day soak structures even though diver estimates indicated smaller total fish concentrations were present at the structures set on daily. These results show that a greater total production was obtained by making daily sets. This high rate of daily attraction and the apparent lack of fish accumulation provided further indications that fish were being attracted to the structures on a daily basis.

Comparison of Day and Night Collections

A series of day and night sets were conducted to determine whether fish leave the structures at night. Divers estimated the quantities of fish at four selected structures which were then set on during daylight hours. The quantity of fish at four other structures was estimated by divers just before dark and fish around these structures were collected after dark. Diver estimates, and day and night catch results, are plotted in Figure 6. The diver estimates were conservative for structures set on during the day, with estimates for both days being less than the actual catch for three of the four structures. The divers frequently estimated that concentrations of fish present at the structures fished at night were larger than at the structures fished in the daylight. Nighttime collections however, consistently produced only 45.5 kg (100 lb) or less of mixed species. These results provided further evidence that bait fish leave the structures at night and that new recruitment was occurring daily. The nighttime sets were made during the new moon and we lack data on whether bait fish also leave the structures at night during the full moon.

Size and Color Evaluation

The success of bait fish attraction with artificial structures appeared to be dependent upon the visibility of the structure. We evaluated two sizes of structures to determine whether doubling the structure size would increase the number of fish attracted. An analysis of variance for purse seine capture data ($F = 0.75 < F_{0.90(1,5)} = 4.06$) and diver estimates revealed no significant difference in attraction by structure size.

Structure attraction was also evaluated in terms of color visibility. We compared a white structure with ones painted fluorescent green, blue, and yellow since Kinney (1970) reported that fluorescent paints provide greater visibility under water. Structure position was rotated daily so that a structure of each color occupied each of the four positions. An analysis of variance for catch data ($F = 0.026 < F_{0.90(3,9)} = 2.8$) and diver estimates revealed no significant difference in the number of fish attracted to the structures on the basis of color. During these color evaluation studies, the bait fish schools were occasionally scattered by little tunny. These predator attacks may have affected the catch data; however our diver estimates were not affected and also indicate no significant color preference.

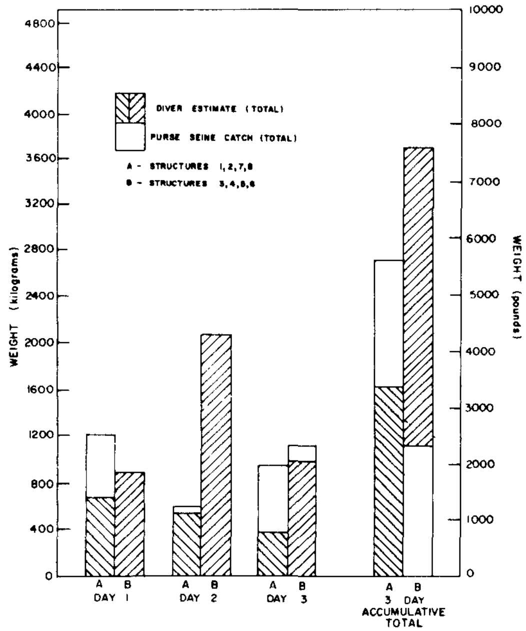

FIGURE 5.—Total of daily average diver estimates and purse seine catch weights, 17-19 August 1970. (A) Structures estimated by divers and fished daily by purse seine. (B) Structures estimated daily by divers but fished by purse seine only on day three.

Divers reported the experimental changes in size and color extended the visible range of a single structure less than 2.1 m (6 ft) which apparently was not sufficient to significantly improve the structures' attraction capabilities.

Structure placement (Figure 3) in relation to the distance offshore (water depth) or to the along-shore current direction tended to have some effect on the number of fish attracted, with larger numbers of fish being attracted to structures positioned offshore than to those positioned inshore. Structures positioned on the eastern end of the experimental area also tended to attract more fish than those on the western end. These general patterns probably vary with seasonal changes in water temperature and prevailing current direction. Our experiment was

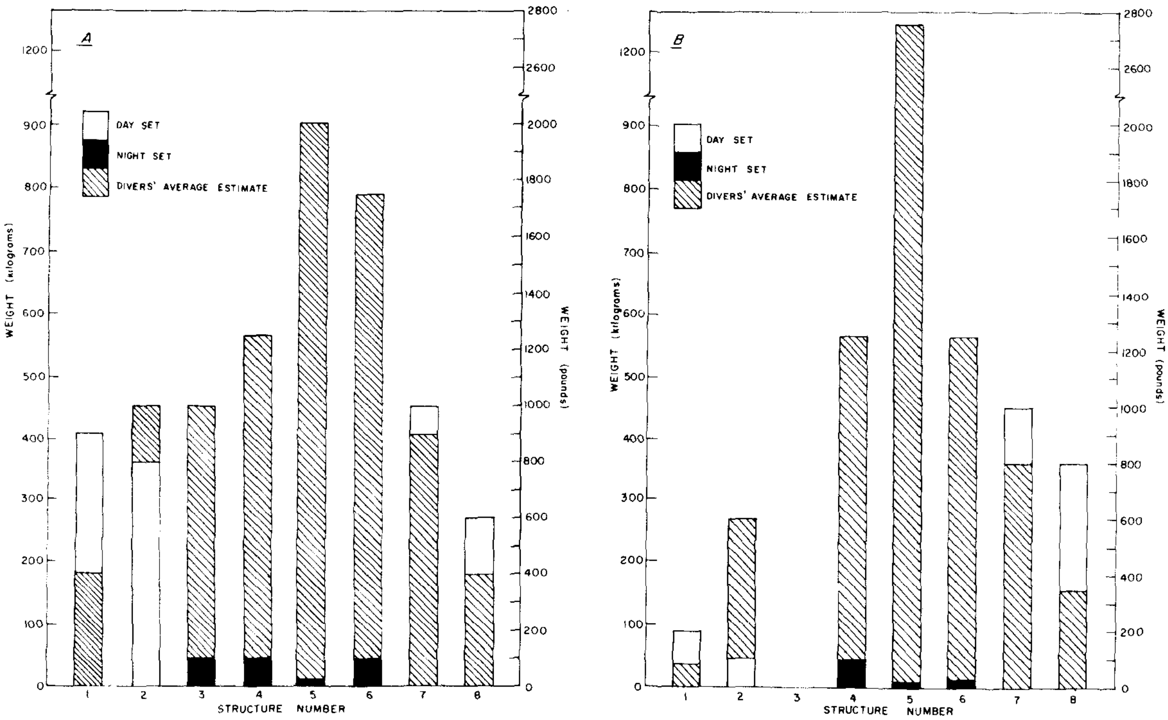

FIGURE 6.—Average diver estimates and day and night purse seine catch weights for each structure on (A) August 20, and (B) August 21, 1970. No diver observations or purse seine sets were made at structure three on August 21 due to an afternoon squall.

not designed to evaluate the effects of structure placement on fish attraction and further studies would be necessary to meaningfully evaluate these effects.

Responses to Moving Structures

A bait fish school was observed by Klima and Wickham (1971) to have remained with a free drifting artificial structure moving slower than the current. One of our structures (Structure No. 8, 19 August 1970), with a school of bait fish in attendance, was also observed dragging its anchor and moving slowly with the current. This structure was towed for 20 min at a speed of approximately 2 knots against a 0.5 knot current for a distance of approximately 0.8 km (0.5 mile) in order to return it to its experimental mooring location. The structure moved up to the surface while being towed, but the fish swam along with it, trailing out behind when the towing speed was increased. After the structure was re-anchored in position, the fish school began swimming around it in the usual manner. Divers estimated that over half the original number of fish remained around the structure after towing. A purse seine set made on this structure after repositioning produced 545 kg (1,200 lb) of fish.

Behavior Observations at Structures

Our observation of bait-fish-school behavior at the structures is in general accordance with the behavior described by Klima and Wickham (1971). The bait-fish schools normally maintained a position up-current from the structures and were observed continuously feeding on crab larvae and other particulate material in the water. During very slow or zero current conditions, the bait fish would often mill about in a loose aggregation (Figure 7) or form long streaming schools making large looping passes out and around the structures in all directions. The schools would frequently swim beyond the divers' range of visibility, remaining out of sight for periods up to 3 min or longer before streaming back in and around the structures from a different direction.

FIGURE 7.—Underwater photograph of a mixed school of round scad *(Decapterus punctatus)* and Spanish sardine *(Sardinella anchovia)* swimming past an artificial structure.

A different pattern of behavior was observed by the divers when the bait-fish schools were threatened by the presence of feeding predators, i.e., Spanish mackerel (*Scomberomorus maculatus*), king mackerel (*S. cavalla*), little tunny (*E. alletteratus*), and bluefish (*Pomatomus saltatrix*). On these occasions, relatively small bait-fish schools, i.e., 100 kg (220 lb) or less, would form a milling ring with the structure in the center or swirl in a tight group in quick passes close to the structure as the predators made darting attacks on the school. Larger schools would usually be split by the attacking predators with one group of bait fish moving to the structure and circling it as described above while the remaining fish moved off in tight, fast-darting groups.

Behavioral Mechanisms

Different sizes and species of fish apparently associate with objects in the sea for different reasons involving different behavioral mechanisms. Hypotheses advanced to explain the association of fishes with floating objects were reviewed by Gooding and Magnuson (1967). The initial attraction of pelagic fishes to objects probably results from their visually detecting the object in the optical void of the pelagic environment, since fish beyond the visual range of a structure or structure-attracted fish school are not attracted (Hunter and Mitchell, 1967). Significantly improving the visual characteristics of an object apparently increases the rate and number of fish it attracts (Hunter and Mitchell, 1967; Klima and Wickham, 1971). Objects, however, must serve a meaningful function beyond that involved in the initial visual attraction in order for pelagic fish to remain in association with them. To tentatively explain this behavior in mixed schools of round scad *(D. punctatus)* and Spanish sardine *(S. anchovia)* around artificial structures, Klima and Wickham (1971) proposed the hypothesis: "Floating objects and underwater structures provide spatial references around which fish can orient in the otherwise unstructured pelagic environment." This tentative hypothesis was given some support by our study, but it must be modified and expanded to account for our additional behavioral observations. Our studies indicate that although coastal pelagic bait fish are capable of ranging beyond sight of an object for periods of several minutes or longer, they apparently require periodic visual reconfirmation of the object's position in order to maintain their orientation with it. This assumption is supported by our observations that structure-attracted fish aggregations leave the structures at night when low light levels inhibit visual contact. Our observations of coastal pelagic bait-fish behavior around artificial structures also indicate that the structures can apparently be useful to these species for predator avoidance. Schools of bait fish associated with an artificial structure have been observed to be immediately attacked by predators upon removal of the structure from the water. Bait-fish schools threatened by the presence of feeding predators were observed to form a tight ball or ring around the structure or swirl in tightly packed formation making quick darting passes near the structure. On several occasions, we have observed the attack behavior of a predator to be interrupted at the moment the bait fish darted past the structure. Mitchell and Hunter (1970) describe laboratory experiments in which splitnose rockfish *(Sebastes diploproa)* and opaleye *(Girella nigricans)* were pursued more often, for longer periods, and captured more frequently by ocean whitefish *(Caulolatilus princeps)* in an aquarium when kelp was absent than when it was present.

Our present supposition as to the possible mechanisms involved in the association of some species of coastal pelagic schooling fish with objects in the sea are summarized in the following working hypothesis: "Objects in the sea provide visual stimuli which attract certain species of pelagic schooling fish and are used in conjunction with natural optomotor responses to provide a spatial reference for orientation in the otherwise relatively unstructured pelagic environment; however, in the presence of feeding predators stimulus priorities are restructured such that the objects become useful for predator avoidance." An increasing body of subjective evidence is available to support much of this conjecture, but its verification lacks the requisite quantitative experimental evidence.

Purse Seine Operations

The feasibility of harvesting structure-attracted coastal pelagic bait fish with conventional tom-weight type purse seines was evaluated during our development of the quantitative collection procedures. Fish aggregations normally showed little disturbance during purse seine sets while the structure remained in the water. Fish stayed with the structure even when it floated at the surface after the counterweight was lifted to prevent its tangling the purse line. The fish showed distress and attempted to escape the net only when the structure was removed from the water and the diving boat prepared to pass over the corkline and reset the structure. The only deviation from this pattern was observed when bait fish were attacked by predators, i.e., little tunny *(E. alletteratus)*, which on several occasions were following the seiner. On these occasions, the predators scattered the bait fish during the set and then escaped before the net was completely closed.

During our experimental collections, we utilized an additional small boat and several men to handle the structures during the purse seine operations. Sets have been made, however, using only the seine skiff and its operator to retrieve and reset the structures. These trials indicate that in a commercial fishing operation using artificial structures, fishing procedures can be modified so that additional men and equipment should not be required. The applicability of structure-attraction techniques for augmenting purse seining during commercial fishing operations, although technically feasible, remains dependent upon the production potential of structures and their recruitment characteristics in the geographical area under consideration.

SUMMARY AND CONCLUSIONS

An evaluation of our diver estimates and purse seine catch data indicates that a combination of these techniques provides a more complete description of the artificial structure experimental environment than either singularly. Our comparative results support the contention by Klima and Wickham (1971) that quantitative diver estimates tend to be conservative where large fish schools are involved. Our divers were able to qualitatively determine the major species present at a structure, but were unable to reliably establish the percent species composition in mixed species schools.

The quantity of fish attracted to the structures during our study was not as large as the schools reported by Klima and Wickham (1971). Coastal pelagic school fish, however, were seasonally unavailable to the local fishery during the study period and the fish captured around our structures were the only bait fish being landed.

The rapid rate of recruitment during our study was similar to the pattern of recruitment reported by Klima and Wickham (1971) with fish being observed at the structures the day following placement. Our experimental results indicated that the fish were recruited to the structures daily and no significant accumulation in the fish population was observed when the structures were allowed to soak for 3 days. Consequently, a greater total production was obtained from the structures by making daily sets. Comparative day and night sets provided further evidence that fish schools dispersed from structures at night during the new moon and new fish were being recruited each day.

We were unable to significantly improve the rate or number of fish attracted to a structure either by doubling its size in relation to our standard structure, or by painting it with fluorescent colors. The experimental changes in size and color apparently did not extend the visible range of a structure sufficiently to significantly increase the number of fish attracted. Further study is required to determine whether multiple structure units might be successful as a means for significantly improving the effective range of structure attraction.

The feasibility of harvesting structure-attracted coastal pelagic bait-fish schools with conventional tom-weight purse seines was established by the success of our quantitative collection procedures. The incidence of successful purse seine sets was greatly improved using the artificial structure techniques since the coastal pelagic fish schools remained in association with the structures during the sets and made no attempt to escape.

Our experience during this study indicates that artificial-structure fish attraction techniques can be developed to facilitate the harvest of the latent coastal pelagic resources in the Gulf of Mexico. Artificial-structure fish attraction techniques may also have sport fishing applications, potential for development as a method for providing ground truth for fishery survey remote sensor evaluation and as a method for monitoring fish movements and relative changes in abundance in certain geographical areas. These potential applications for artificial-structure fish attraction techniques will be the subject of future investigations.

ACKNOWLEDGMENTS

We would like to thank John W. Watson, Jr. for his contributions during all phases of the field work, especially for his assistance as a diver. Charles Roithmayr and Wayne Adkison provided valuable assistance by obtaining purse-seine catch samples and recording data aboard the chartered purse seiner *Gulf Ranger*.

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