ANALYSIS OF RETURNS OF TAGGED GULF MENHADEN

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ABSTRACT

From 1969 to 1971 nearly 76,000 adult Gulf menhaden, *Brevoortia patronus*, were tagged in the northern Gulf of Mexico with internal metallic tags. From an estimated 28,000 recaptures it was concluded that there is little east-west movement of adult Gulf menhaden during the fishing season from April to October, and that there is little mixing of menhaden from different areas when fish move offshore during the winter. Total mortality appears to be high, but could not be estimated from the returns. Few Gulf menhaden survive more than 3 yr.

Menhaden are industrial fish that are processed into meal, oil, and solubles. From 1964 to 1973, the annual purse seine catch of Gulf menhaden, *Brevoortia patronus*, which support the largest fishery in the United States, ranged from 316,000 to 728,000 metric tons. Scientists at the Atlantic Estuarine Fisheries Center, National Marine Fisheries Service, NOAA, Beaufort, N.C. have been studying the fishery since 1964.

A scientifically interesting question, as well as one of practical importance from the standpoint of resource management, is whether Gulf menhaden make extensive coastal movements during or between fishing seasons. To determine their movements in the area 75,673 adults were tagged from 1969 to 1971. In this paper we analyze recoveries from these fish through the 1973 fishing season.

FISHING AREAS

Although Gulf menhaden range from southern Florida to Veracruz, Mexico (Reintjes 1969), the purse seine fishery extends only from western Florida to extreme eastern Texas, with most fishing effort being expended in inshore waters from Mississippi to western Louisiana. The fishing season lasts from about early April until early October, but some plants may begin operations in late March while others may not begin until nearly May. For this study, we arbitrarily divided the fishery into three areas (Figure 1).

1. Western: waters and plants west of long. 92°W.
2. Central: waters and plants west of the mouth of the Mississippi River to long. 92°W.
3. Eastern: waters and plants east of the mouth of the Mississippi River to long. 86°W.

Plants were located at Moss Point, Miss. (three plants); in Louisiana—Empire (two plants), Dulac (two plants), Morgan City (one plant), Intracoastal City (one plant), and Cameron (three plants); and Sabine Pass, Tex. (one plant). The plants at Empire were considered to be in the central area.

Because refrigerated carrier vessels may remain at sea up to 6 days and fish over a wide area, we could not tell where their tagged fish were caught but only where they were processed. Two exceptions are one plant whose vessels fished exclusively in the eastern area and another plant whose vessels fished exclusively in the western area. For tags recovered at these plants, the area of capture was known. Although vessels are far ranging and often travel long distances to reported concentrations of fish, they tend to fish most of the time within a restricted radius of their plant. Most tagged fish, therefore, probably were caught in the vicinity of the plant where the tags were recovered.

METHODS OF TAGGING

Gulf menhaden, which spawn from about No-

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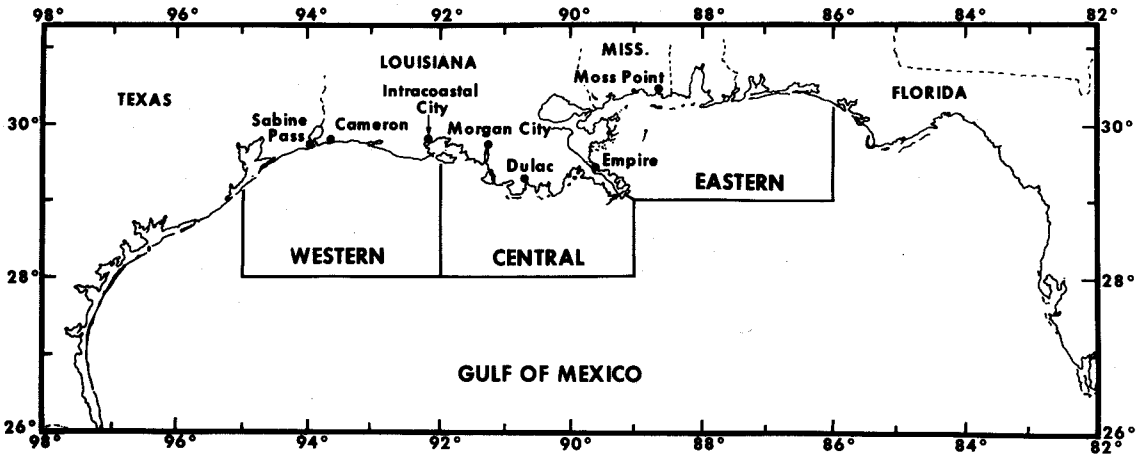

FIGURE 1.—Three areas in which adult Gulf menhaden, *Brevoortia patronus*, were tagged, 1969-71.

vember to March, may arbitrarily be divided into two broad age-classes, juveniles and adults. Juveniles are less than a year old, inhabit the estuaries and rivers during the summer, and move into the open waters of the Gulf in autumn when they are about 65 to 130 mm in fork length. Except in late summer and autumn when some of the larger fish become available, they are not vulnerable to the purse seine fishery. Adults are more than a year old (age 1 or older), inhabit the larger sounds and inshore areas of the Gulf, and are vulnerable to the purse seine fishery.

Techniques for tagging adult Gulf menhaden followed those developed for tagging adult Atlantic menhaden (Pristas and Willis 1973). A numbered internal ferromagnetic tag (14.0 × 3.0 × 0.5 mm) was injected into the body cavity with a tagging gun developed by Bergen-Nautik,[4] a Norwegian firm. Fish were obtained from commercial purse seine catches and were tagged aboard the carrier vessels.

Five percent of the fish tagged in 1969 and 10% of the fish tagged in 1970 were measured. Because measuring fish reduced the number that could be tagged, it was not done in 1971. Mean lengths of fish released in the spring of 1969 ranged from 118 to 130 mm; means of those released in the spring of 1970 ranged from 157 to 171 mm; and means of those released in autumn 1969 ranged from 148 to 164 mm.

Individual fish were not aged. On the basis of length frequencies, nearly all the fish tagged were judged to be either age 1 or age 2. Most of those tagged in spring 1969, probably were age 1. Since the mean lengths were greater in 1970 than in 1969, a greater proportion in 1970 probably were age 2. Nearly all of those tagged in autumn 1969 were age 1.

METHODS OF RECOVERING TAGS

Magnets, installed in reduction plants to recover tags moving along the conveyer system with the fish scrap and meal (Parker 1973), are classified as either primary or secondary, depending on their location. They were cleaned about once a week to remove tags and other scrap metal. Primary magnets are located between the fish scrap dryers and the storage areas. Since newly processed fish scrap moves across the primary magnets, the date tagged fish were caught can be estimated. Tags recovered on these magnets are referred to as primary recoveries. Secondary magnets are usually located in the storage, transfer, or loading areas for scrap and meal. Since fish scrap or meal that moves across the secondary magnets may have been in storage for several months or may have been moved from one plant to another, the date tagged fish were caught cannot be estimated, and the plant at which the tags were recovered cannot always be determined. Tags recovered on these magnets are referred to as secondary recoveries. In this paper we combine both types, since we are interested only in the fishing season a tag was recovered.

[4]Mention of commercial firm does not imply endorsement of product by National Marine Fisheries Service, NOAA.

Because many tags that entered a plant became lodged in machinery or passed over magnets without being captured, the total number of tags that entered a plant could only be estimated. The estimates were based on the actual number of tags recovered and the collective efficiency of the magnets that recovered them. The efficiency for each plant was estimated by adding 100 tagged fish to catches at regular intervals and then determining the number of these test tags that were recovered during the fishing season on both primary and secondary magnets. The efficiency for each plant, expressed as a percentage, was the ratio of the number of test tags recovered each fishing season to the number applied.

The number of tests varied from year to year and plant to plant. In 1969 the number at each plant ranged from 1 to 8 (100-800 tags); in 1970, 2 to 20 (200-2,000 tags); in 1971, 2 to 16 (200-1,600 tags); in 1972, 3 to 17 (300-1,700 tags); in 1973, 3 to 16 (300-1,600 tags).

The percentage of tags recovered from each series of 100 test tags varied from 10 to 90%. The mean seasonal efficiency varied from 13% for the least efficient plant to 73% for the most efficient. It also varied from year to year for each plant.

For this study, the estimated total number of field tags entering a plant was based on the actual number of field tags recovered on both primary and secondary magnets. The total number of field tags entering a plant each month was estimated by dividing the actual number of tags recovered by the mean annual plant efficiency. Tags recovered in spring before fishing began were added to recoveries from the previous year.

Tags remaining in various parts of a plant for up to 2 yr before being recovered caused errors in the recovery data. Nearly 1% of the test tags were recovered in the second or third year (Table 1), but the percentages varied from plant to plant. Test tags introduced late in the season were recovered in subsequent years in greater numbers than tags introduced early in the season. When a field tag that actually had entered a plant in a previous season was recovered, it would in effect be counted twice and expanded by the efficiency factor two or more times. For example, if 100 tags entered a plant whose efficiency was 0.50, the number recovered would be 50. If 1 of the 50 unrecovered tags were to be recovered the following year and the recovery efficiency of the plant had dropped to 0.25, the estimated number recovered would be 4 (1/0.25 = 4). The estimated number of tags recovered would be 104 instead of 100, an error of about 4%, and 4 tags would be assigned to the wrong year.

TABLE 1.—Number and percentage of test tags recovered during the year applied and after 1 and 2 yr.

Test year	No. of test tags	Years applied		After 1 yr		After 2 yr	
		No.	%	No.	%	No.	%
1969	5,600	1,964	35.1	28	0.50	7	0.13
1970	14,000	7,510	53.6	93	0.66	15	0.11
1971	11,900	5,317	44.7	65	0.55	9	0.76

SPRING RELEASES AND RECOVERIES

We tagged 26,995 fish in 1969, 17,775 in 1970, and 22,800 in 1971. Of the number of fish tagged, the estimated percentages recovered through 1973 were 30.2, 51.5, and 32.5%, for 1969, 1970, and 1971, respectively. Of the total number of tags recovered, the largest percentages were in the first year: 70.9% (1969); 84.3% (1970); 84.6% (1971). Returns in the second or following year, accounted for most of the remainder; 26.7% (1969); 15.0% (1970); 14.3% (1971). Returns after the second year ranged from 0.7 to 2.4% (Tables 2-4).

The actual numbers of field tags recovered after the second year probably were much smaller than the numbers reported. The percent-

TABLE 2.—Numbers of adult Gulf menhaden tagged in the spring of 1969 and the estimated number recaptured in subsequent fishing seasons, by area.

Release area	No. of fish tagged	Year of recapture	Area of recovery			
			Western	Central	Eastern	Total
Western	10,298	1969	1,839	273	52	2,164
		1970	316	249	20	585
		1971	14	48	1	63
		1972	0	2	0	2
		1973	0	3	0	3
		Total	2,169	575	73	2,817
Central	3,699	1969	114	1,238	62	1,414
		1970	70	172	13	255
		1971	3	20	1	24
		1972	0	0	0	0
		1973	0	0	0	0
		Total	187	1,430	76	1,693
Eastern	12,998	1969	0	7	2,188	2,195
		1970	39	519	775	1,333
		1971	2	32	47	81
		1972	2	3	14	19
		1973	0	4	2	6
		Total	43	565	3,026	3,634
Combined	26,995	1969	1,953	1,518	2,302	5,773
		1970	425	940	808	2,173
		1971	19	100	49	168
		1972	2	5	14	21
		1973	0	7	2	9
		Total	2,399	2,570	3,175	8,144

TABLE 3.—Numbers of adult Gulf menhaden tagged in the spring of 1970 and the estimated number recaptured in subsequent fishing seasons, by area.

Release area	No. of fish tagged	Year of recapture	Area of recovery			
			Western	Central	Eastern	Total
Western	9,100	1970	2,507	1,268	101	3,876
		1971	286	479	49	814
		1972	4	7	1	12
		1973	0	0	0	0
		Total	2,797	1,754	151	4,702
Central	5,100	1970	969	1,339	142	2,450
		1971	83	273	11	367
		1972	4	8	1	13
		1973	0	0	0	0
		Total	1,056	1,620	154	2,830
Eastern	3,575	1970	0	48	1,348	1,396
		1971	0	32	160	192
		1972	0	12	17	29
		1973	0	3	6	9
		Total	0	95	1,531	1,626
Combined	17,775	1970	3,476	2,655	1,591	7,722
		1971	369	784	220	1,373
		1972	8	27	19	54
		1973	0	3	6	9
		Total	3,853	3,469	1,836	9,158

TABLE 4.—Numbers of adult Gulf menhaden tagged in the spring of 1971 and the estimated number recaptured in subsequent fishing seasons, by area.

Release area	No. of fish tagged	Year of recapture	Area of recovery			
			Western	Central	Eastern	Total
Western	7,400	1971	1,711	843	48	2,602
		1972	80	143	2	225
		1973	3	5	0	8
		Total	1,794	991	50	2,835
Central	5,200	1971	642	904	57	1,603
		1972	27	56	2	85
		1973	0	6	0	6
		Total	669	966	59	1,694
Eastern	10,200	1971	0	58	2,008	2,066
		1972	3	157	589	749
		1973	1	36	33	70
		Total	4	251	2,630	2,885
Combined	22,800	1971	2,353	1,805	2,113	6,271
		1972	110	356	593	1,059
		1973	4	47	33	84
		Total	2,467	2,208	2,739	7,414

ages of test tags recovered after 1 yr (0.5%) and 2 yr (0.1%) probably underestimated the percentage of field tags that remained in a plant and were recovered after 1 or 2 yr, since a greater number of test tags were applied early rather than late in the season and therefore had a greater chance of being recovered in the year they were applied. The tendency of field tags that had been out more than 2 yr to be recovered early, rather than late, in the fishing season suggests that some, at least, had remained in plants over the winter. At plants where recovery efficencies were relatively low, mainly plants in the eastern and central areas, a greater percentage of field tags were returned after 2 yr than at plants where efficiencies were relatively high. Field tag recoveries after 2 yr were highest at those plants where test tag recoveries after 1 yr were highest. The plant for which no field tag recoveries were reported after 2 yr had the lowest percentage of test tag recoveries after 1 yr—less than 0.1%.

Eastern Releases

Nearly all first year recoveries (tags recovered the same year they were applied) were at plants in the eastern area (99.7% in 1969; 96.5% in 1970; and 97.2% in 1971), and no tags were recovered in the western area. The only tags recovered in the central area were at plants whose vessels also fished in the eastern area. Second year recoveries (tags recovered the year after they were applied) followed the same pattern as first year recoveries, although a greater proportion of tags were recovered in the central area. For 1969 releases, no tags were recovered the second year at the plant in the western area whose vessels fished only in that area. For 1970 releases, no tags were recovered the second year in the western area. For 1971 releases, only three tags were recovered in the western area, all at a plant whose vessels fished in all areas.

Central Releases

Although tags were recovered the first year at plants in all areas, the highest percentages were from plants in the central area (87.6% in 1969; 54.7% in 1970; 56.4% in 1971). The lowest percentages were at plants in the eastern area, as might be expected, since the western and central areas are continuous with each other but are separated from the eastern area by the Mississippi Delta. In 1969 and 1970 no tags were recovered at the plant in the eastern area whose vessels fished only in that area. Some tags were recovered in the western area at the plant whose vessels fished only in that area. The majority of second year recoveries also was at plants in the central area (71% for all release years combined); the fewest were at plants in the eastern area (4% for all release years combined).

Western Releases

Most of the first year recoveries were at plants in the western area (85.0% in 1969; 64.7% in 1970; 65.7% in 1971), and the fewest were at plants in the eastern area (2% in 1969 and 1971;

3% in 1970). No tags were recovered at the plant in the eastern area whose vessels fished only in that area. Fewest second year recoveries were at plants in the eastern area (3% in 1969; 6% in 1970; 1% in 1971). Most second year recoveries were at plants in the western area for fish tagged in 1969 and in the central area for fish tagged in 1970 and 1971.

AUTUMN RELEASES AND RECOVERIES

Fish were tagged in autumn (September) only in 1969, when 900 were tagged in the western area, 2,100 in the central area, and 5,103 in the eastern area (Table 5). By the end of the fishing season in October, 6% had been recaptured. In the following year 33% were recovered. For all years combined 42% were recovered.

As with tags of fish released in spring, tags of fish released in autumn were recovered mainly at plants in the area of release in both the first and second year. Few fish tagged in the western area were recovered in the eastern area and few fish tagged in the eastern area were recovered in the western area. No fish tagged in the western area were recaptured at the plant in the eastern area whose vessels fished only in that area. Approximately 90% of the tags of fish released in the eastern area and recovered in the central area were at plants whose vessels fished up to 25% of the time in the eastern area.

TABLE 5.—Numbers of adult Gulf menhaden tagged in autumn of 1969 and the estimated numbers recaptured in subsequent fishing seasons, by area.

Release area	No. of fish tagged	Year of recapture	Area of recovery			
			Western	Central	Eastern	Total
Western	900	1969	29	3	0	32
		1970	73	66	2	141
		1971	4	20	0	24
		1972	0	0	0	0
		1973	0	0	0	0
		Total	106	89	2	197
Central	2,100	1969	166	10	1	177
		1970	277	305	33	615
		1971	17	42	3	62
		1972	0	0	0	0
		1973	0	0	0	0
		Total	460	357	37	854
Eastern	5,103	1969	0	0	251	251
		1970	21	617	1,300	1,938
		1971	0	44	65	109
		1972	0	18	12	30
		1973	0	3	0	3
		Total	21	682	1,628	2,331
Combined	8,103	1969	195	13	252	460
		1970	371	988	1,335	2,694
		1971	21	106	68	195
		1972	0	18	12	30
		1973	0	3	0	3
		Total	587	1,128	1,667	3,382

CONCLUSIONS

The pattern of first year tag recoveries shows clearly that adult Gulf menhaden make no extensive east-west movement along the coast during the fishing season from April to November. Nearly all tags were recovered at plants located in the same area in which the fish were tagged. Some fish that were released in one area but whose tags were recovered at a plant in another probably were caught in the release area, since vessels at most plants, though fishing mostly within their own area, also were far-ranging. No fish tagged in the eastern area were recovered at plants in the western area; few fish tagged in the western area were recovered at plants in the eastern area. At plants whose vessels fished exclusively in either the eastern or western area, no tags were recovered except those from fish released in the same or adjacent area.

Second year recoveries also point to little or no mixing of fish from different areas during the winter. Gulf menhaden apparently move offshore during autumn and return again in spring to the same general area they previously occupied. Since the boundary between the western and central areas is arbitrary and since we do not exactly know where fish were recovered, the greater number of second year returns in the central, rather than western area of fish tagged in the western area for 1970 and 1971 does not necessarily indicate any significant shift of fish from the western to the central area.

Because there were no estimates of tag losses due to shedding or deaths caused by tagging, and because the variability in recovery efficiencies was large and some tags tended to remain in plants for long periods, calculation of fishing and total mortality rates would be no more than a mathematical exercise. We can estimate from the data, however, whether fishing mortality and exploitation rates are high or low.

Both fishing mortality and exploitation rates appear to be high. First year recoveries of spring releases ranged from 21 to 43% of the number of fish tagged. The total number of tags recovered ranged from 30 to 51% for spring releases and was 42% for the autumn releases. High tagging mortality may account for the relatively low returns for the 1969 and 1971 spring releases (30%

and 32%), since tagging mortality tends to be greater for small Atlantic menhaden than for large ones (Kroger and Dryfoos 1972), and the fish tagged in 1969 were generally smaller than those tagged in spring of 1970 or autumn of 1969.

It is unlikely that more than a small percentage of any year class survive more than 3 yr. Less than 2% of the estimated returns of fish tagged in spring, and 7% of the returns of fish tagged in autumn were recovered after the second year. Because of the tendency of tags to hang up in plants, the majority of tags recovered after the second year probably had come from fish caught in the first or second season after being tagged. If tags that hung up for 1 yr averaged 1.5% and for 2 yr or more 0.2%, and if recovery efficiencies averaged 50%, hung up tags could account for nearly all tags reportedly recovered after 2 yr. Since the majority of fish tagged were in the size class of age-1 fish, the percentage of returns after 2 yr should have been higher than it was if any significant number survived more than 3 yr.

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