Absolute Abundance and Survival of Juvenile Gag, *Mycteroperca microlepis* (Pisces: Serranidae), in Seagrass Beds of the Northeastern Gulf of México

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ABSTRACT

The absolute abundance and survival of early juvenile gag grouper, *(Mycteroperca microlepis)* in a 15.4 km^2 shallow seagrass meadow in St. George Sound, Florida were estimated by the Jolly-Seber mark-recapture method. The method was used within each of three square sampling stations, each 150 m on a side, by standard (150 m, 1.8 km/hr) tows with a 5-m otter trawl The average absolute abundances for the three stations sampled every 1–2 weeks from June to mid-September 1991 were 496, 424, and 549 juveniles per hectare. Trawl capture efficiencies (catch per unit area/estimated number per unit area) were calculated and the effects of seagrass habitat conditions and size of juvenile gag on those efficiencies were estimated. We estimated absolute abundance outside the sampling stations by trawling in those areas and dividing gag captures per standard tow by trawl-capture-efficiency estimates. The estimated absolute abundance of juvenile gag for the entire 15.4 km^2 area was 943,615 juveniles. Survival estimates were generally variable but were confounded by emigration from the sampling areas. The small-scale spatial pattern of juvenile gag was random. The results of this work are discussed in relation to habitat alteration, recruitment indices, and enhancement potential.

KEY WORDS: gag, grouper, juvenile, seagrass, *Mycteroperca*, Gulf of Mexico. absolute abundance

INTRODUCTION

Gag (*Mycteroperca microlepis:* family Serranidae) is an important species for fisheries along the gulf coast of Florida and the south Atlantic coast of the United States. Gag range from Massachusetts to Brazil (Smith, 1978) but are in fishery abundance only from North Carolina to northwest Florida. In that area gag are common along shallow reef tracts as well as shelf break areas in depths of only a few meters to at least 150 m (Bullock and Smith, 1991). Total fishery landings of gag in the United States are between one and two million kg per year (Hood and Schlieder, 1992; Burton, unpublished manuscript).

Peak spawning of gag occurs in February and March (Collins *et al.*, 1987; Gilmore and Jones, 1992; Hood and Schlieder, 1992) and pelagic juveniles settle in high salinity estuaries during April and May (McErlean, 1963; Keener *et al.*, 1988; Mullaney, 1991). After five to six months of rapid growth, juvenile gag leave the estuarine habitat in early fall and migrate to shallow offshore reef habitats (Keener *et al.*, 1988; Mullaney, 1991).

Shallow estuarine seagrass beds appear to be an important habitat of early juvenile gag along the Gulf coast of Florida (McErlean 1963). Juvenile settlement is well-synchronized with the spring increase in primary and secondary productivity in the northwest Florida seagrass habitat (Koenig, unpublished data). On the Gulf coast of Florida there is extensive potential seagrass nursery habitat; 3,000 km^2 occurs in the Big Bend area alone (Zieman and Zieman, 1989).

Recent evidence indicates declining stocks on gag and other reef-fish fishery species of the south Atlantic region (GMFMC, 1989) and reduced reproductive capacity on gag resulting from fishing of spawning aggregations (Koenig *et al.*, in prep.[b]). Also, extensive loss in Florida of seagrass habitat, important to juvenile gag and other estuarine-dependent reef species, has been documented (Livingston, 1987; Zieman and Zieman, 1989). management of gag and other fishery species depends on detailed biological information, especially involving reproduction and early life history. At present a basic foundation of biological knowledge for the majority of reef species is lacking.

In 1991 we began a major study of the reproduction and early life history of gag and red grouper (*Epinephelus morio*), the two major shallow-water grouper fishery species in the Gulf of Mexico. Our studies of juvenile gag were designed to define habitat characteristics, trophic relationships, spatial and temporal recruitment patterns and population parameters. As part of this larger work and as a basis for the comparison of juvenile gag abundances in a variety of seagrass habitats, we set out to estimate the absolute abundance (number per unit area), survival, and spatial pattern of juvenile gag in two seagrass beds in St. George Sound.

MATERIALS AND METHODS

Although a variety of methods have been proposed for the determination of absolute abundance (Ricker, 1975; Krebs, 1989), few are designed for open populations. After a preliminary survey in 1989 of juvenile gag distribution and abundance in the vicinity of the Florida State University Marine Laboratory (FSUML) in St. George Sound (northeastern Gulf of Mexico), we chose the Jolly-Seber mark-recapture method for open populations. This method provides information on the probability of survival as well as the absolute abundance and provides the opportunity to examine individual growth rates, movement patterns, and small-scale spatial patterns. From Krebs (1989), the probability of survival from sample time t to t + 1 = size of marked population at the start of sample t + 1/size of the marked population at the end of sample t. Survival in this context combines remaining alive with remaining in the study area. That is, marked fish that leave the study area are counted as deaths; thus, high survival estimates indicate both low mortality and low emigration.

The Jolly-Seber method requires that animals be marked individually or that marks be specific to the sampling time. We chose marks that would identify individuals so that we could follow individual movements and growth. Juveniles were marked by freeze-branding with liquid nitrogen-cooled devices. Branding devices were made of 8–10 gauge copper wire were used to brand a three-digit number on the left side of the fish (Figure 1). Care was taken not to hold the branding devices against the side of the fish for more than 3–4 sec. Longer contact could cause freeze damage to muscle tissue.

The Jolly-Seber method assumes random sampling. Specifically, it assumes: (1) that every individual in the sampling area, whether marked or unmarked, has the same probability of being caught in every sample; (2) that every marked individual has the same probability of surviving from one sampling time to the next; (3) that marks are permanent and legible throughout the sampling period; and (4) that sampling time is small relative to intervals between samples. Sampling time in this study was one to two days, and the interval between samples was one to two weeks. A drawback of this method is that assumptions 1, 2, and 3 could not be tested until the study was complete. Assumption 1, equal catchability, or the lack of avoidance or affinity for recapture, is a critical assumption. It was tested within the marked population of

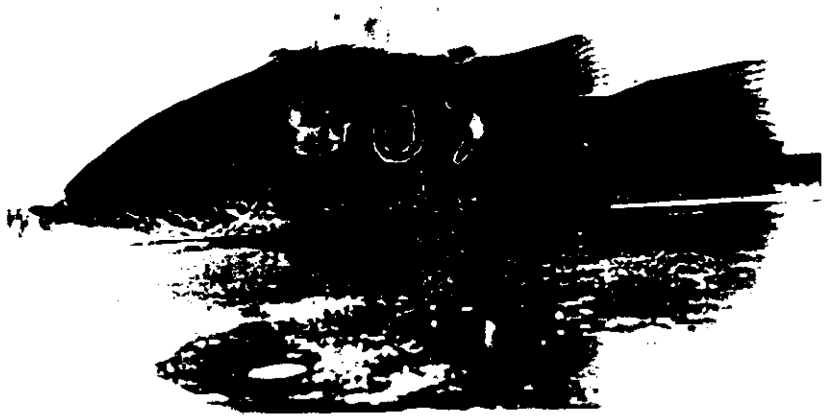

Figure 1. Photograph of freeze-branded juvenile gag.

station 2 with the Leslie, Chitty and Chitty test (in Krebs, 1989) and found to be supported. We tested assumption 2 by holding 40 marked fish in a 2,000-l laboratory tank for over six months. None died, and there was no evidence of irritation or infection around the brand marks in the laboratory-held fish or in the field-recaptured fish. Marks were typically legible throughout the sampling period of June to mid-September 1991 (assumption 3), but when the mark on a recaptured fish showed signs of fading that fish was remarked with the same number.

The study areas were within two adjacent seagrass beds located just off the FSUML in St. George Sound in the northeastern Gulf of Mexico (Figure 1). Three sampling sites were chosen to be representative of the areas. The criteria for selecting the sampling sites were (1) that they were located in the shallow (1-2 m) uniform (not patchy) seagrass beds; (2) that they had different seagrass compositions and characteristics; and (3) that gag juveniles were present. Each of the three sampling areas was marked by buoys anchored at the corners of a square area, 150 m on a side (Figure 3). The square was subdivided into six lanes (each 25 m x 150 m). The middle two lanes (lanes 3 and 4) were buoyed at the corners and designated as the mark-recapture (M-R) lanes and the outer lanes (lanes 1, 2, 5, and 6) were designated reference lanes (R).

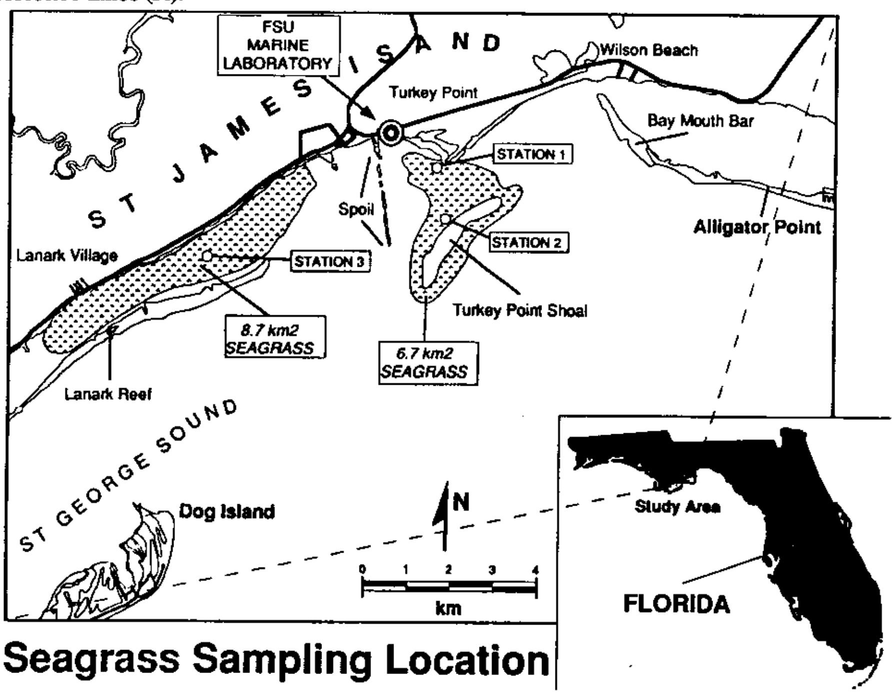

Figure 2. Seagrass sampling area, showing station locations off the Florida State University Marine Laboratory in St. George Sound, Florida.

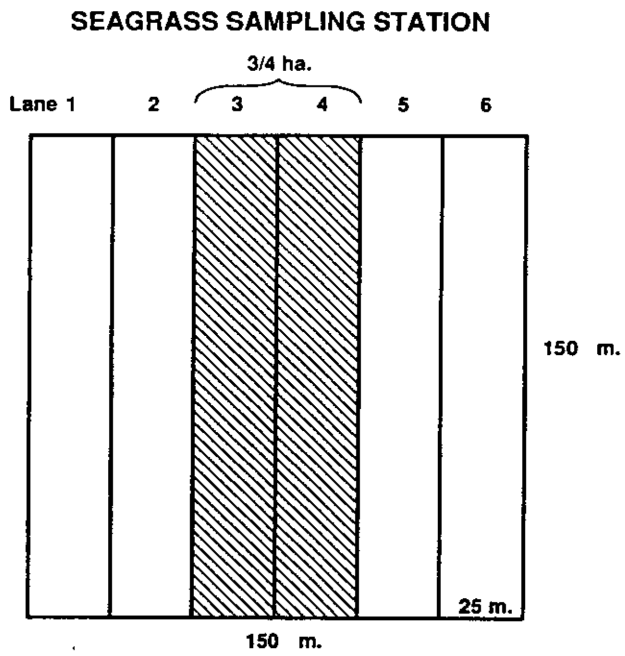

Figure 3. Seagrass sampling station arrangement. Shaded lanes are mark-recapture lanes. Clear lanes are reference lanes.

All lanes were sampled with a 5 m otter trawl outfitted with a 3 mm mesh liner in the bag end. All sampling tows were done at a standard tow speed (1.8 km/h) and distance (150 m); therefore, each tow was completed in 5 minutes. This speed of tow was determined in preliminary work to be the most efficient speed. We determined through direct underwater observation that faster tows may cause the net to ride off the bottom and that slower tows allowed fishes to escape. We determined the length of tow (sample size) by balancing the opposing factors of (1) the collection of sufficient numbers of gag for the mark-recapture study and (2) practical considerations of the physical size of the sample. Tows were randomized within lanes by designation of ten 2.5 m wide tracks (unmarked) within each 25-m wide lane and use of a random number table to select tracks. It was nearly impossible to tow precisely within tracks, but this procedure eliminated unconscious sampling bias. At each sampling time, 16 tows were made in the M-R lanes, 8 tows per lane, and a single tow was made in each of the four R lanes. R lanes served as controls for the effects of trawling on the abundance estimates; therefore, trawling in those lanes was kept to a minimum.

To extrapolate our absolute-abundance estimates to the entire 15.4-km^2 seagrass system, we needed to determine trawl capture efficiency and factors that might change the efficiency. Trawl capture efficiencies may depend upon (1) the seagrass habitat characteristics (such as seagrass species composition, density, and blade length) and (2) the avoidance abilities of the species being sampled, which are related to behavior and size (age).

Seagrass species composition, density (number of blades per unit area), and blade length were measured at the three sampling sites (depth was uniform among the sites) in August. We chose eighteen 625-cm2 quadrats from each site by picking three random coordinate sets within each land to maximize dispersion and still retain randomness. Square quadrat frames were placed against the sediment, and all grass within the quadrat area was cut off at sediment level. Samples were then taken back to the FSUML, identified, counted, and measured.

Because pelagic juveniles settled in St. George Sound in 1991 as a single cohort (Koenig, unpublished data) with a rather narrow size range, the influence of size on capture efficiency could be estimated over the sampling period. The influence of juvenile gag size on capture efficiency was determined by comparison of the absolute abundance estimates in the M-R lanes with the relative abundance estimates (captures per tow) made in the R lanes over the sampling period. If both remained relatively constant over the sampling period, the influence of size on capture efficiency would be considered negligible over that size range (ca. 50–200 mm SL).

The area sampled by standard trawl tow was estimated by SCUBA divers, who measured the width of the trawl mouth while a series of actual tows were being made. The opening of the trawl was wide at the beginning of a tow, but as the tow progressed and the bag filled, the width of the trawl mouth narrowed. Longer grass blades also produced a greater drag on the lead line of the net while in tow, which caused the trawl mouth to narrow and to ride higher off the bottom. The average trawl mouth width at sites 1 and 2 was 2 m and at site 3, 1.5 m. The significantly greater blade lengths at station 3 (Figure 4a) accounted for the smaller area sampled per standard tow. The effect of seagrass density on sample size and net efficiency could not be determined because densities were similar at all three stations (Figure 4b). Sample sizes at stations 1 and 2 were 300 m^2 (2-m mean trawl mouth width x 150 m tow length), and sample size at station 3 was 225 m^2 (1.5 m x 150 m).

At each sampling time, water temperature and salinity were measured. At several times during the sampling period, dissolved oxygen was measured just above the sediment surface and just before dawn, the place and time at which minimum dissolved oxygen concentrations would be expected. Sampling was scheduled to avoid extreme low tides (when sampling depth was less than about 0.7 m), as the propeller wash from the sampling boar was considered disruptive to the seagrass and to benthic organisms and would probably influence juvenile gag catch rates.

Juvenile gag captured fish from the M-R lanes were immediately placed in aerated coolers and transported back to the FSUML, where they were placed in labeled plastic mesh baskets immersed in a 5000 liter tank which was supplied with running seawater. First-time captures from each sampling time were branded, and

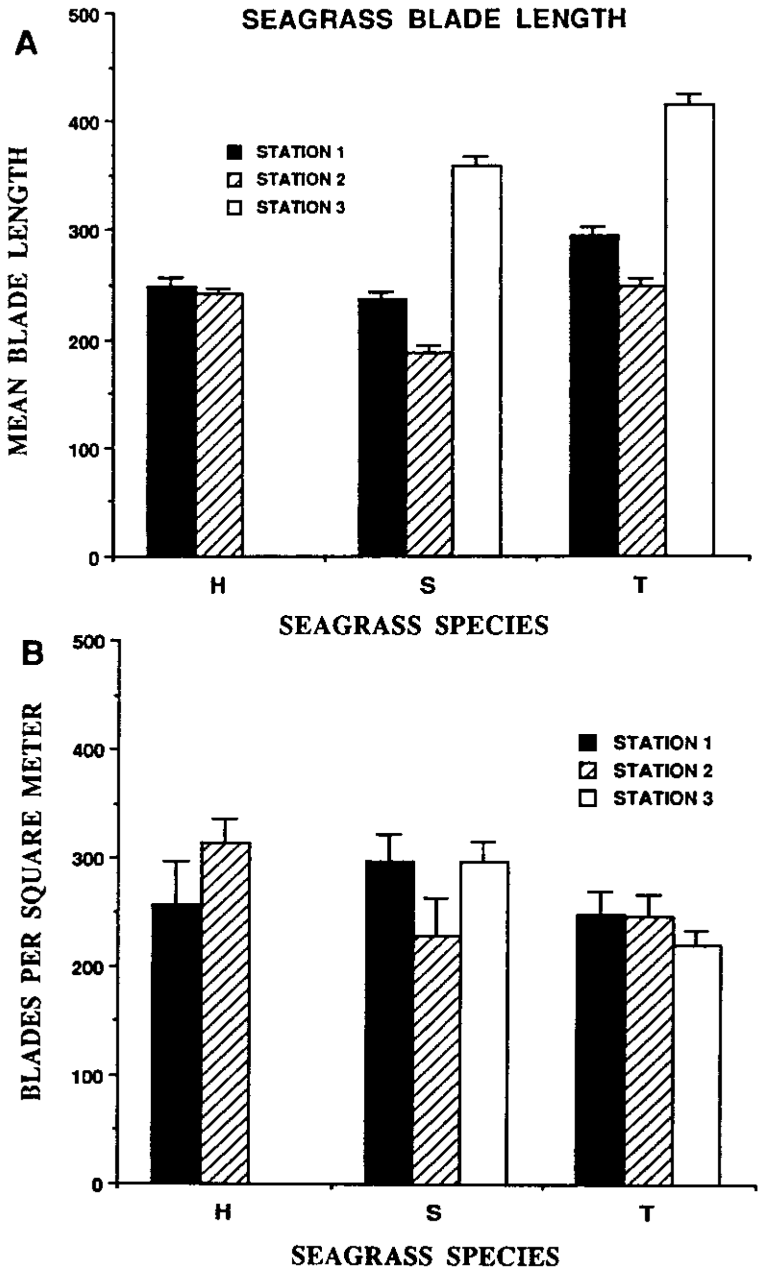

Figure 4. (A) Seagrass blade length (mm) and (B) Seagrass density (blades/m^2) for sampling stations in St. George Sound.

their standard lengths (mm SL) and brand numbers were recorded. Lengths of recaptured fish and their brand numbers were also recorded. All captured juveniles, whether from R lanes or M-R lanes, were released immediately (after less than 24 h) in the lanes from which they were captured. The release procedure involved driving the boat in a zig-zag fashion across lanes 3 and 4 and releasing fish haphazardly along the way. No fish died or were injured during any of these procedures.

Trawl capture efficiencies were calculated for each station. That is, the mean number of juveniles captured by a standard tow was divided by the estimated number (determined by the M-R method) of fish occupying the area sampled by a tow. The absolute abundance in seagrass areas outside of the sampling stations could then be determined from the following relationship:

Juvenile gag per hectare - (10,000 / S) (C /E)

where: S = sample area in square meters per standard tow; C = mean number of juveniles captured per standard tow; and E = capture efficiency estimate.

The absolute abundances of the various seagrass areas around the sampling stations were then multiplied by the estimated sizes of those areas to yield absolute abundances (total number of juveniles in the entire area) of each area. The absolute abundances of the various seagrass areas were then summed to yield a total abundance for the entire 15.4-km2 seagrass area.

Spatial patterns (random, clumped, or regular) were evaluated for juvenile gag in the seagrass beds by the variance-to-man ratio of captures per standard tow and the χ^2 test statistic and by comparison of the sampling distribution with the Poisson distribution.

RESULTS

At all stations over the sampling period salinity varied from 26 to 32 ppt and temperature varied from 28° to 31.5° C. No dissolved oxygen concentrations below 5.0 ppm were observed over the sampling period. During the period from October 4 to October 6, 1991, the water temperature dropped from 29°C to 19°C as the first major cold front of the season passed through north Florida. Because juveniles were relatively rare in the seagrass immediately after this event, we assume that the major egress took place at that time. This assumption is supported by the appearance of first-year juveniles on offshore reefs and in offshore crab traps within several weeks following this event.

Mean capture of juvenile gag per standard tow declined in response to repeated trawling in the M-R lanes during each sampling time. Figures 5a, b, and c depict this trend for consecutive tows averaged over the sampling period in M-R lanes of stations 1, 2, and 3 respectively. This effect caused a diminishing return per effort and, in effect, limited sample size. Because of this decline, only the first three tows in each M-R lane were used to estimate relative abundance (captures per tow) in those lanes.

Over the sampling period a significant decline in the gag captures per tow occurred in the M-R lanes at all three stations, whereas captures per tow in the R lanes

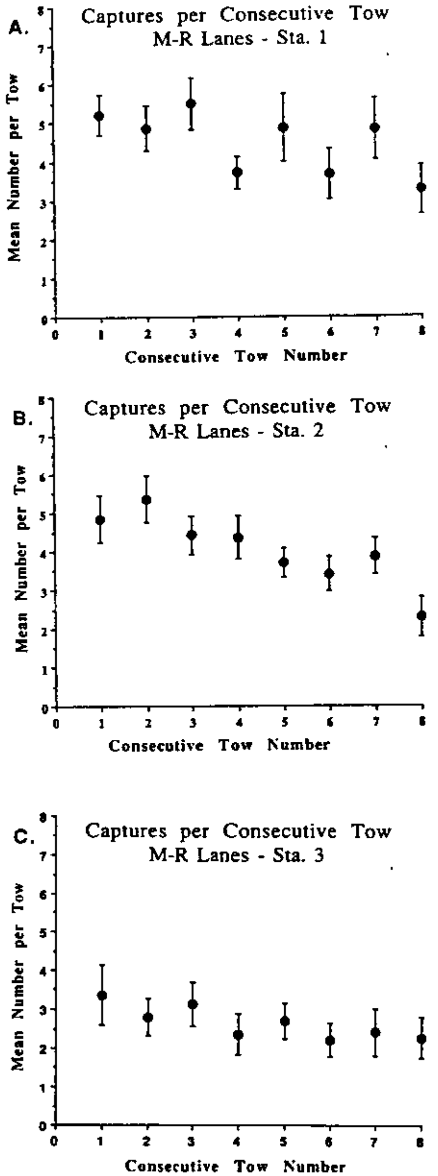

Figure 5. Number of juvenile gag captured in M-R lanes of station 1 (A), 2 (B), and 3 (C) in consecutive tows averaged over the sampling period. Error bars represent standard error of the mean.

showed no significant ($\alpha = 0.05$) trends (Figures 6a, b, and c). Table 1 summarizes regressions of gag captures per tow in R lanes and M-R lanes over the 16-week sampling period (late June to mid-September). Significant declines in the M-R lanes of the stations occurred apparently in response to the high sampling effort in those lanes, even though all captured gag were returned. Thus, M-R estimates of absolute abundance underestimate the absolute abundance of the general area. This underestimation increases from about the middle of July to the end of the sampling period. Absolute abundance estimates were corrected for July, August, and September sampling times by the following procedure. (1) The R-lane mean captures per tow (averaged over the sampling period) for each station was divided by M-R-lane mean capture per tow (estimated from M-R lane regression equations at the specific sampling time). (2) The resulting factor was then multiplied by the absolute abundance estimate of the same sampling time to get a corrected absolute abundance estimate.

Because captures per tow in the M-R and R lanes diverged significantly over time, interlane differences for each station were compared for the first part of the sampling period only (*i.e.*, before the divergence occurred). Analysis of variance indicated no significant difference ($\alpha = 0.05$) between lanes in the relative abundances of gag at any station sampled.

The absolute abundance estimates of gag captured per hectare for each sampling time for stations 1, 2, and 3 were high, and confidence intervals were large when M-R sample sizes were relatively small and/or the proportion of the marked population was low (Table 2-4). Because relative abundances (captures per standard tow) were relatively constant over the sampling period (*i.e.*, showed no significant trend in the R

Table 1. Linear regression of gag captures per standard tow over the sampling period: Comparison of mark-recapture lanes with reference lanes. b = slope; a = intercept.

								Mean Captures/Tow[a]				
Sta	Lane	b	a	r	df	F	P	Total	Jun	Jul	Aug	Sep
1	M-R	-0.286	7.811	0.51	56	19.7	<0.001	5.28	6.34	5.95	4.69	3.45
1	Ref	-0.142	7.451	0.25	33	2.14	0.153	6.34	6.34	6.34	6.34	6.34
2	M-R	-0.299	7.521	0.52	56	20.6	<0.001	4.93	5.59	5.58	4.26	2.96
2	Ref	-0.110	6.462	0.19	40	1.50	0.228	5.59	5.59	5.59	5.59	5.59
3	M-R	-0.240	5.079	0.45	55	14.0	<0.001	2.98	3.69	3.52	2.46	1.42
3	Ref	-0.049	3.297	0.09	43	0.37	0.547	3.69	3.69	3.69	3.69	3.69

[a] — M-R values from July, August, and September were calculated from regression equations as mid-points of months. June M-R values were made equivalent to those of reference lanes.

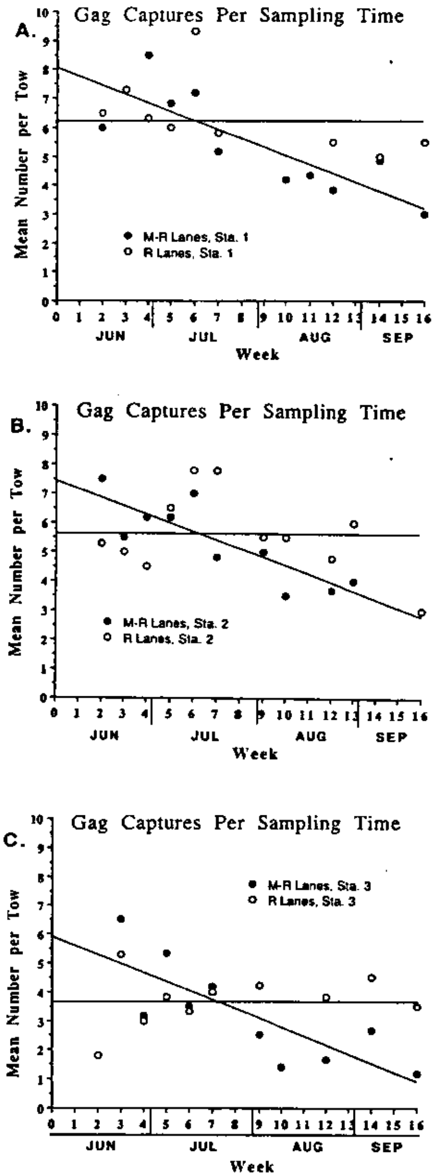

Figure 6. Mean number of gag captured per standard tow in M-R lanes (closed circles) and R lanes (open circles) at station 1 (A), 2 (B), and 3 (C) over the sampling period. Regression equations and significance levels are given in Table 1.

Table 2. Mark-recapture estimates of absolute abundance and survival for juvenile gag grouper from Station 1, St. George Sound in 1991.

Sample Time	Proportion of Population Marked	Number per ha.	Probability of Survival	95% Confidence Limits[a] Number/ha. lower	upper	Survival lower	upper
26 Jun			1.000			0.545	1.000
1 Jul	0.075	1132	0.338	398	2814	0.154	0.794
8 Jul	0.153	497	0.466	218	1039	0.226	1.000
20 Jul	0.086	1146	0.309	393	2817	0.180	0.553
5 Aug	0.169	378[b]	1.000	186	613	0.660	1.000
9 Aug	0.258	587[b]	0.818	292	860	0.490	1.000
20 Aug	0.406	524[b]	1.000	274	758	0.506	1.000
4 Sept	0.458	1109		340	3324		
16 Sept	0.533						

[a] determined by the method of Manley (1984)
[b] best estimates averaged for overall absolute abundance estimates
Note: Estimates of N and 95% confidence limits of N are adjusted to compensate for trawling effect on M-R lanes.

Table 3. Mark-recapture estimates of absolute abundance and survival for juvenile gag grouper from Station 2, St. George Sound in 1991.

Sample Time	Proportion of Population Marked	Number per ha.	Probability of Survival	95% Confidence Limits[a] Number/ha. lower	upper	Survival lower	upper
25 Jun			0.587			0.275	1.000
1 Jul	0.065	449	0.767	184	1166	0.437	1.000
9Jul	0.138	799	0.409	341	1458	0.240	0.727
15 Jul	0.242	364[b]	0.598	186	561	0.376	0.979
1 Aug	0.218	484[b]	1.000	233	780	0.838	1.000
5 Aug	0.256	1052	0.578	483	1675	0.294	1.000
19 Aug	0.216	1168	0.871	515	2004	0.317	1.000
27 Aug	0.348	1038		340	2730		
16 Sept	0.346						

[a] determined by the method of Manley (1984)
[b] best estimates averaged for overall absolute abundance estimates
Note: Estimates of N and 95% confidence limits of N are adjusted to compensate for trawling effect on M-R lanes.

lanes, Figures 6a, b, and c), it is assumed that natural mortality was low and that absolute abundance in the general area remained constant. Therefore, estimates of absolute abundance with relatively small confidence intervals were averaged for each station. Sampling times included in the station averages were, for station 1, 5, 9, and 20 August; station 2, 15 July and 1 August; and station 3, 31 July and 2 August. The

Table 4. Mark-recapture estimates of absolute abundance and survival for juvenile gag grouper from Station 3, St. George Sound in 1991.

Sample Time	Proportion of Population Marked	Number per ha.	Probability of Survival	95% Confidence Limitsa Number/ha. lower	upper	Survival lower	upper
24 Jun			0.421			0.141	1.000
2 Jul	0.062	593	0.702	164	2506	0.251	1.000
10 Jul	0.086	959	0.617	262	3374	0.210	1.000
18 Jul	0.078	1319	0.361	381	4266	0.127	1.000
31 Jul	0.182	475b	0.693	147	1474	0.219	1.000
2 Aug	0.146	623	0.841	183	2073	0.180	1.000
22 Aug	0.214	783		169	4205		
4 Aug	0.269						

[a] determined by the method of Manley (1984)

[b] best estimates averaged for overall absolute abundance estimates

Note: Estimates of N and 95% confidence limits of N are adjusted to compensate for trawling effect on M-R lanes.

Table 5. Summary of absolute abundance and capture efficiency estimates for juvenile gag captured from June to mid-September 1991 in seagrass beds in St. George Sound, Florida.

Location	Area Sampled per Tow (m^2)	Estimated Number of Gag per ha[a]	Estimated Number of Gag in Area Sampled by One Tow	Mean Number of Gag Captured in One Tow[b]	Capture Efficiency (%)
Station 1	300	496	14.9	5.6	42.6
Station 2	300	424	12.7	5.3	43.9
Station 3	225	549	12.4	3.4	29.9

a — Average of selected M-R estimates
b — Determined from reference lanes only

average absolute abundance estimates for stations 1, 2, and 3 were similar; 496, 424, and 549 per hectare, respectively (Table 5).

Estimates of survival probabilities were sometimes high but were typically variable, and 95% confidence limits were broad (Tables 2, 3, and 4). Survival estimates were confounded by emigration from the M-R lanes, but a high probability of survival indicates low mortality and low rates of emigration. We assume that survival of juvenile gag is high because their behavior and coloration are highly cryptic in the seagrass habitat and because very few (ca. 0.1%, 2 of 1500 juveniles) were found in poor or injured condition.

Table 6. Estimates of abundance of juvenile gag in selected seagrass beds in St. George Sound, Florida.

Seagrass Location	Number of Tows	Area Sampled per Tow (m2)	Capture Efficiency (%)	Mean No. Captured per Tow	Absolute Abundance (per ha.)	Seagrass Area (ha.)	No. of Gag in Seagrass Areas
S.E. and S.W. of Sta. 1	30	300	42.6	3.7	290	286	82,940
S.W. of Sta. 2 (*i.e.*, Sta. 2A)	25	225	29.9	8.0	1,185	50	59,250
N.E. of Sta. 2	21	300	43.9	7.6	577	335	193,295
N., E., S., and W. of Sta. 3	7	225	29.9	4.7	699	870	608,130

The estimated total number of juveniles in the eastern seagrass bed (stations 1 and 2) was 312,890 (average abundance = 467 gag / hectare x 670 hectares); average 95% confidence limits were 156,780 and 478,380 gag (234 and 714 gag per hectare x 670 hectares, respectively) (Table 5). The total number of juveniles in the eastern seagrass bed estimated form the relative abundance estimates in the various areas of that bed outside of the sampling stations (Table 6) summed to 335,482, which is within the confidence limited given above. An estimate of the total number of juveniles in the western seagrass bed is less precise than that in the eastern, presumably because of the habitat conditions. The length of the seagrass blades is assumed to be the major factor responsible for the lower trawl sample size and in the low capture efficiency. The estimated total number of juveniles in the western seagrass bed was 477,630 (549 gag / hectare x 870 hectares) with average 95% confidence limits of 143,550 and 1,542,510 (165 and 1773 gag per hectare x 870 hectares, respectively). From Table 6 the total number in both eastern and western seagrass areas was 943,615. The low abundance values for areas southeast and southwest of station 1 are probably due to the patchy nature of the seagrass in that area. In general, rounded estimates of juvenile gag abundances in the shallow seagrass beds in St. George Sound in 1991 were about 500 per hectare or about 50,000 per km^2. The mobility of juvenile gag in the grass beds during the sampling period was low. that is, marked juveniles were caught repeatedly over the sampling period in the relatively small M-R sampling area (3/4 hectare) even though sampling intervals were from one to two weeks. Low mobility is also evident from high survival estimates, which specifically indicate low rates of emigration of marked fish.

Within a seagrass locality the spatial pattern of juvenile gag was not significantly different from random. The index of dispersion (I = variance/mean) and the χ^2 test statistic ($\chi^2 = I_{[n-1]}$, where n = number of samples) for reference-lane captures per tow over the sampling period indicated no significant ($\alpha = 0.05$) departure from the assumption of randomness: station 1, I = 1.20 $\chi^2 = 40.9$, 34 df; station 2, I = 1.18, $\chi^2 =$

48.3, 41 df; station 3, I = 1.48, χ^2 = 64.9, 44 df. Sample frequency distributions of reference lanes were also compared with theoretical Poisson distributions by means of the χ^2 test statistic and found not to differ significantly (station 1, χ^2 = 15.1, 14 df; station 2, χ^2 = 12.2, 11 df; station 3, χ^2 = 13.4, 8 df). Juvenile gag also showed random spatial patterns in other seagrass areas, such as along the northwestern end of Turkey Point Shoal (I = 1.13, χ^2 = 27.1, 24 df), just north of station 2 (I = 1.64, χ^2 = 32.9, 20 df), and just south of station 1 (I = 1.31, χ^2 = 39.3, 30 df). Significant departure from randomness was not observed at any sampling locality.

The relative abundance of juvenile gag (as well as associated species) was lower in depths greater than about 2 m. Bait-shrimp fishermen who catch juvenile gag as bycatch also observe that juvenile gag are more abundant in shallow seagrass beds and relatively rare in deeper beds. Our observations in other localities suggest that shallow, dense, high-salinity (> 25 ppt) beds are the habitats of greatest abundance.

DISCUSSION

Keener *et al.*, (1988) and Ross and Moser (in review) considered the estuarine environment to be a consistent and integral component of the requirement of early juvenile stages of gag. Their conclusions were based primarily on the observation that early juveniles were in high abundance in high-salinity estuaries and virtually absent offshore. Other authors, including McErlean (1963), Gilmore (1977), Heck and Thoman (1984), and Mullaney (1991), have also noted the common occurrence of early juvenile gag in high-salinity estuaries. Within estuaries, seagrass appears to be a significant nursery habitat for this species, although the relative suitability of other estuarine habitats, such as oyster reefs, is unknown. In South Carolina, where seagrass is absent, oyster reef is the dominant habitat for juvenile gag (Mullaney, 1991). Our study is the first to document the high absolute abundances of juvenile gag in the seagrass habitat, and it support the contention that gag are dependent on estuaries.

Several studies have suggested that the mass emigration of juvenile gag from estuaries is coordinated with weather patterns and/or rapid declines in water temperature (Keener *et al.*, 1988; Mullaney, 1991; Ross and Moser, in review). Observations made during the present study strongly support this contention, but other factors appear to be involved because there is evidence in a number of studies (Hastings, 1979; Ross and Moser, in review; Koenig, pers. obs) that some juveniles emigrate before the presumed mass emigration that occurs during declining water temperatures.

The settlement of reef fish, such as gag, in seagrass provides fishery scientists with an opportunity to develop annual estimates of year-class strength.. The feasibility of such estimates in the Gulf of Mexico is increased because the vast majority of gulf seagrass habitat and the dominant area of gag recruitment occurs off the west coast of Florida (Zieman and Zieman, 1989; Koenig et al., in prep. a). As suggested by Kleppel and Seaman (1989, p. 24), "... an index of juvenile gag grouper during their estuarine resident phase could predict recruitment to the reef fishery one or two years later." Such estimates may be important not only for their predictive value but also for their value in the study of recruitment processes.

Many characteristics exhibited by juvenile gag in the seagrass habitat simplify the estimation of year-class strength. Recruitment by a single cohort occurs over a short period of time (approximately six weeks) in April and May. Therefore, all recruits are within a narrow size range at any sampling time during summer months (McErlean, 1963; Keener et al., 1988; Hood and Schlieder, 1992; Ross and Moser, in review). Also survival rates are high, and the sampling efficiency of an otter trawl is similar over the summer months. Thus, juveniles can be sampled by otter trawl in many localities during the summer. The resulting estimates of abundance in the various localities can be combined without introducing errors related to survival or size-related avoidance of the trawl.

In this study, we showed that juvenile gag in the seagrass habitat exhibit random spatial patterns and low rates of movement. These behavioral characteristics allow simpler, more cost-effective methods to be used to determine absolute abundance. For example, catch-effort methods (Ricker, 1975; Krebs, 1989) would be quick and simple and may provide adequate estimates of absolute abundance. Catch-effort methods, like most others, assume a closed population, but because rates of movement in juvenile gag are so low, the error introduced by violations of this assumption may be insignificant. The small-scale random spatial patterns exhibited by juvenile gag simplify sample-size determination and sampling site selection.

There is considerable interest world-wide in the enhancement of marine fisheries. Such enhancement can be accomplished through the deployment of artificial habitat (Seaman and Sprague, 1991) or through the production of laboratory-reared juveniles for release in the environment. Both forms of enhancement are especially well suited for gag. Abundant food combined with abundant cover in the seagrass habitat improves the probability of survival and reduces the negative impact of juvenile naiveté. In some areas of the eastern Gulf of Mexico, suitable reef habitat may be at considerable distance from gag nursery areas. Although nothing is known about the survival of gag during or after egress, it appears likely that a prolonged lack of protection during long migrations would increase susceptibility to predation. Artificial reefs could be strategically positioned to provide suitable and easily accessible habitat for juveniles after their egress from estuaries.

In the present study, we recorded absolute abundances of juvenile gag of about 50,000/km^2 in the shallow seagrass habitat of St. George Sound. Although all seagrass habitat is not equally suitable to support such abundances, extensive juvenile habitat is nevertheless available along the west coast of Florida, especially in the Big Bend. Approximately 3,000 km^2 of seagrass occurs in the Big Bend as a coastal band 11 to 35 km side between St. Marks and Tarpon Springs, Florida (Iverson and Bittaker, 1986). This area is relatively pristine and has not been as adversely affected as other west Florida seagrass habitats, such as those that border highly urbanized areas (Livingston, 1987; Zieman and Zieman, 1989). For example, Tampa Bay is estimated to have lost 81% of its seagrass coverage as a result of anthropogenous impacts (Zieman and Zieman, 1989). In addition, the 5,500 km^2 of seagrass that occurs south of Cape Sable in Florida Bay is presently undergoing radical ecological changes, and its value as a nursery habitat is questionable. Because critical seagrass habitats are generally in close proximity to shore, they are susceptible to anthropogenous disturbance, including storm-water runoff (and its wide variety of dissolve contaminants), siltation through shoreline erosion, damage by recreational boats, additions of waste water from pulp mills, and oil spills. Associated economic losses through the loss of fishery production cannot presently be estimated accurately, but quantitative estimates of the production of specific economically important species such a gag give perspective to the high economic value of such habitats.

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