SEDAR10-RD06

By-catch, discard composition, and fate in the snapper/grouper commercial fishery, North Carolina.

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Abstract Minimum size regulations may be ineffective for heavily exploited snappers, groupers, and porgies because these reef fishes often sustain hyperbaric trauma. We undertook a cooperative study with commercial fishermen to: a) characterize discard percentages and depths where commercially important species are captured, and b) evaluate the efficacy of minimum size limits on vermillion snapper (*Rhomboplites aurorubens*) and red porgy (*Pagrus pagrus*) by documenting hooking location, gastric distention, presence of bleeding, and quantifying post-release indices of sub-legal specimens. Hook and line sampling took place on 32 trips from May-November 2004 in Onslow Bay, North Carolina in waters from 19 to 143 m deep. A total of 2,345 fish were captured, representing 30 species. The six most captured species - vermillion snapper (n=577), red porgy (n=442), gray triggerfish (n = 438; *Balistes capriscus*), red grouper (n = 365; *Epinephelus morio*), white grunt (n=110; *Haemulon plumieri*), and gag (n=101; *Mycteroperca microlepis*) – represented 86.6% of the catch. Discard rates of sub-legal fish were 14.6 and 30.5% for vermillion snapper under current and proposed regulations, 25.6% for red porgy, 5.2% for red grouper, and 28.7% for gag. Sub-legal vermillion snapper and red porgy survived almost equally as well as legal conspecifics; there were higher incidences of fish swimming down than floating at the surface (presumed dead). Released sub-legal red grouper and gag also had high rates of presumed immediate post-release survival. Catches of each species were from a narrow depth range. For each species, jaw hooking occurred in at least 89% of the cases. Gastric distention was more common in groupers than snappers or porgies. Post-release indices were not correlated with water depth for either of the two most abundant species. There was no significant difference in average post-release index among fish with- and without gastric distention

for each of the two most abundant species. Red porgy and white grunt that bled had higher average release indices than non-bleeding conspecifics, but not for vermillion snapper or gag (the other two species with enough comparative data). While released reef fishes may experience delayed post-release mortality from predation or barotrauma, the low rates of gastric distention, gut hooking, and bleeding for these two species along with generally favorable observed post-release outcomes suggest that minimum size limits may help reduce rates of fishing mortality for some reef species.

Introduction North Carolina represents the northernmost range of commercially exploitable populations of fishes in the lutjanid (snapper) family and epinephelinaeid (grouper) subfamily that inhabit deepwater reef habitats along the continental shelf of the South Atlantic Bight. Members of the sparidae (porgy) family are also caught in these commercial and recreational fisheries.

Stocks of many reef species are overexploited in the South Atlantic Bight (Coleman et al. 2000). Commercially important species overfished or at risk of being overfished include vermillion snapper (*Rhomboplites aurorubens*) (Zhao and McGovern 1997; Zhao et al. 1997), red porgy (*Pagrus pagrus*) (Huntsman et al 1995; Harris and McGovern 1997), red grouper (*Epinephelus morio*) (Schirripa and Legault 1999), and gag (*Mycteroperca microlepis*) (McGovern et al. 1998). Decreased landings of some species have placed pressure on others. For example, estimated biomass for red porgy has declined (Huntsman et al. 1994) along with commercial landings (Potts and Burton 1999) while landings of vermillion snapper, white grunt (*Haemulon plumieri*), and gray triggerfish (*Balistes capriscus*) have increased (National Marine Fisheries Service 1998).

Snappers and groupers have traits that render them susceptible to over-harvest (Coleman et al. 2000), including slow growth, late maturity (Musick 1999), high site fidelity, seasonal concentrations, and hemaphroditism (Coleman et al 1999). Stock declines of target species are often associated with increased fishing effort in deeper waters where hooking mortality in sub-legal fish makes species protection less successful (Coleman et al. 2000). Restrictions in the southeastern U.S. snapper-grouper fishery intended to protect individual species often fail because species targeted for protection continue to experience fishing mortality from effort targeting other species (Coleman et al. 2000). Time and area closures may aid over-exploited species but have inherent drawbacks, including increasing effort in adjacent areas (Coleman et al. 2000), lack of enforcement, and adverse economic effects on existing fishing operations.

Depth of capture can influence post-release survival (Gitschlag and Renaud 1994). Traumas sustained by fishes retrieved rapidly from deep waters include ruptured swim bladders, emboli, bloating, and protrusions of digestive tissues and eyes (Shirripa and Legault 1999; Burns and Restrepo 2002). While these specimens may be alive at release, rates of mortality may be high (Shirripa and Legault 1999). Experienced commercial fishermen question the purpose of minimum size limits in reef fish fisheries because they frequently observe released fish dying or floating away due to trauma caused by angling them from deepwater.

Information on the status of reef fish stocks in the South Atlantic Bight is collected using a logbook program that records landings (pounds), areas fished, and gear used (SEDAR 2004). This program does not document numbers or sizes of fish caught, discard percentages of important species, and the fate of released individuals. Fishery-dependent data which are not part of the logbook reporting might assist assessment biologists estimate more accurate rates of fishing mortality and help the South Atlantic Fishery Management Council determine the utility of using minimum size limits to reduce mortality. For minimum size limits to be effective, a high percentage of sub-legal or non-target discards must either not be caught or survive catch and release over the range of depths captured (Burns and Restrepo 2002). Adoption of minimum size rules for deepwater snapper and grouper fisheries assumes that sub-legal fish will experience only natural mortality and minimal discard mortality until they reach legally harvestable size (Wilson and Burns 1996). Thus, mortality estimates have to be increased for species that experience high rates of discard mortality. Conversely, low rates of discard mortality suggest that minimum size limits are of value in conserving overfished stocks.

Minimum size regulations are only effective if post-release survival is high (Wilson and Burns 1996). One study that estimated post-release indices of red snapper (*Lutjanus campechanus*) in a commercial fishery found that discard mortality was double the estimate used in stock assessment models (Baker et al. in press). Snapper and grouper stocks assessments may also benefit from measuring characteristics that can indicate mortality (i.e. gastric distention or bleeding). The fate of discarded snapper, grouper, and porgy species has not been estimated for the North Carolina commercial fishery.

Accurate data on rates of discard mortality is difficult to obtain and evaluate. The use of cages to evaluate the long-term fate of released fishes introduces problems with repeated ascent and descent of caged fish, stress or mortality associated with confinement, high costs of monitoring, and low sample sizes. Scoring fish for post-release has been used in lieu of cages to monitor discard mortality in some fisheries (Patterson et al. 2000). While released fish can only be observed within roughly six meters of the surface in North Carolina offshore waters, documentation of release condition, and associated hooking location and barotraumas, can aid in estimates of discard mortality rates.

Our objectives in this study were to: characterize the North Carolina snapper-grouper fishery by depth of collection for major species; determine the length frequencies and discard percentages for dominant species; document hooking location, presence of gastric distention, and bleeding for major species, and; characterize the fate of discards by scoring post-release condition.

Methods Thirty-two trips were made aboard a 9.5 mm commercial fishing vessel between 13 May and 2 November, 2004 to collect species commonly targeted by commercial fishermen. Fifteen trips were made with a fishery observer and 17 were made without an observer (Table 1). Fishing with electronic reels was conducted between sunrise and sunset. Terminal tackle consisted of a high-low bottom rig consisting of 130-pound line, two three-way swivels, a sinker ranging from 16 to 32 oz, and two J-hooks ranging from 2-0 to 12-0 in size. These rigs, hook types, and hook sizes are typical commercial terminal tackle used for catching reef fishes in North Carolina. Hooks were fished with natural baits, including herring (*Alosa* spp.) and squid (*Ilex* spp.). Between three and four rods were fished simultaneously by an equal number of fishermen. Angling for this study took place in waters between 19 and 143 m deep from 32 to 97 km offshore in Onslow Bay, North Carolina.

The following information was recorded upon capture of each specimen: species, fish size (total length, mm), water depth, hook size, hooking location (e.g. jaw, gut, gills, eyes, or body), presence of bleeding, and presence of gastric (stomach or intestinal) distention. Upon release, sub-legal fish were scored for post-release condition (see Patterson et al. 2000). The release index scores fish as: 1) alive, oriented themselves toward the bottom, and swam down vigorously; 2) alive, oriented themselves toward the bottom, and swam down slowly or erratically; 3) alive but floated at the surface; 4) dead or unresponsive. While the eventual fate of fish scored as 1 or 2 is unknown, fish that are scored as 3 or 4 were assumed to eventually die. Our data on hook size, hooking location, and bleeding was supplemented with unpublished data from a previous North Carolina Sea Grant project (#03-FEG-10) that focused on the effects of hook type in the North Carolina commercial grouper fishery. We used one-way analysis of variance to compare the depths from which major species were captured. The decision whether to combine post-release data from observed and unobserved trips was based on the statistical comparison (Mann-Whitney ranks test) of observed vs. non-observed release indices for the two numerically dominant species.

The current minimum size is 356 mm total length for red porgy and 330 mm for vermillion snapper in the commercial fishery in the South Atlantic Bight. For vermillion snapper, there is a proposed 356 mm minimum. The current and proposed minimum length limits for vermillion snapper, and the minimum length limit for red porgy, were used to categorize legal and sub-legal conspecifics. Within legal and sublegal groups, we used to a chi-square contingency test to determine whether observed post-release indices were distributed randomly with respect to the expected frequency (25%). To analyze the effect of size on post-release index we used a Mann-Whitney ranks test to compare average post-release indices among legal and sub-legal conspecifics.

Spearman rank correlation was used to test the relationship between water depth and PR index, and between water depth and gastric distention, for each of the six most abundant species. The Mann-Whitney test was used to compare average release indices among fish with- and without gastric distention, and among fish that were and were not visibly bleeding. For species with enough data ($n \geq 3$ within a hooking location), a Kruskal-Wallis or Mann-Whitney ranks test was used to compare average release indices among hooking location.

Results A total of 2,345 individual fish representing 30 species were captured. Vermillion snapper, the most prevalent species accounted for 24.6% of the catch. The next five species were red porgy, gray triggerfish, red grouper, white grunt, and gag (in decreasing order of abundance) which, along with vermillion snapper, accounted for 86.6% of the catch (Table 2).

Sub-legal vermillion snapper under current and proposed minimum length limits comprised 14.6 and 30.5% of the catch of that species, respectively (Figure 1). Sub-legal red porgy were 25.6% of the catch (Figure 1). Sub legal red grouper and gag comprised 5.2 and 28.7% of the catches of those two species, respectively (Figure 2).

Depth had a significant influence on capture location of the six most abundant species ($F=95.0$; $p=0.000$), with each main species caught from a small variation of depths (Table 2). Gray triggerfish were captured from a significantly greater average depth than any of the other five major species (Tukey pair-wise test; $p<0.008$ in each case). Gag were captured from a significantly lesser depth than each of the other major species ($p<0.002$ in each case). For the six main species, the only pair not captured from significantly different average depths were red grouper and white grunt.

There was no significant difference in vermillion snapper post-release indices among observed ($n=95$; average=1.86) and unobserved specimens ($n=89$; average=1.81) ($U=4221$; $p=0.984$). However, there was a significant difference (borderline) in red porgy post-release indices among observed ($n = 95$; average=1.82) and unobserved specimens (n=58; average=1.55) (U=2209; p=0.040). We felt the post-release values were close enough for each of these two species that the data for observed and unobserved data could be combined.

Across all species, fish that were dead or presumed dead (post-release indices of 3 or 4) comprised 13% (68) of the 525 released specimens. Presumed mortality (indices of 3 and 4) comprised small percentages of the total release indices for vermillion snapper (11.5%), red porgy (15.7%), red grouper (6.7%), gag (0%), gray triggerfish (12.5%), and white grunt (7.1%) (Table 2). Distributions of release indices were significantly different than random for sub-legal vermillion snapper (χ^2=90.5; p=0.000), legal vermillion snapper (χ^2=38.83; p=0.000), sub-legal red porgy (χ^2=126.3; p=0.000), legal red porgy (χ^2=17.4; p=0.001), sub-legal red grouper (χ^2=132.7; p=0.000), and sub-legal gag (χ^2=186.1; p=0.000); in each case there were higher percentages of fish with release indices of 1 and 2 instead of 3 and 4. There were no significant differences among release indices between legal and sub-legal conspecifics using current and proposed minimum length limits for vermillion snapper (Mann-Whitney U=3843, p=0.589; U=2775.5, p=0.132, respectively), and the current length limit for red porgy (U=2132.5, p=0.104) (Figure 3). (Not enough data was collected on the release fate of legal fish of other main species to make similar intraspecific comparisons.) Post-release index was negatively correlated with water depth for red grouper (p=0.009) and white grunt (p=0.002) but not correlated with water depth for any of the other four main species.

For the six main species, gastric distention ranged from 12.9% (red porgy) to 67.4% (red grouper) (Table 3). Rates of gastric distention for observed vermillion snapper and red porgy were higher (38.0 and 4.9%, respectively) than unobserved conspecifics (31.9 and 3.5%, respectively), although not significantly for either species (U=38292, p=0.206; U=22518, p=0.810, respectively). Gastric distention was positively correlated with total length of gray triggerfish (p=0.003) and red grouper (p=0.003) and negatively correlated with total length of vermillion snapper (p=0.013). Gastric distention was positively correlated with water depth for red grouper (p=0.002) and gag (p=0.002), and negatively correlated with water depth for vermillion snapper (p=0.000) and red porgy (p=0.000). For the 391 released fish without gastric distention, 10.5% had release indices of 3 or 4. For the 134 released individuals with gastric distention, 19.4% had release indices of 3 or 4 (presumed dead). Enough data was available for four species - vermillion snapper, red porgy, red grouper, and gag – to compare release indices among conspecifics with- and without gastric distention: average post-release indices among groups were not significantly different for each of these species (Figure 4).

The presence of bleeding was less than 10% for each of the six main species except for gag (16.8%) (Table 4). There was sufficient data for vermillion snapper, red porgy, gag, and white grunt to compare release indices among bleeding and non-bleeding conspecifics. There were no significant differences in release indices between bleeding and non-bleeding vermillion snapper and gag, respectively. For red porgy and white grunt the average release index was significantly higher for bleeding than non-bleeding specimens (U=324, p=0.015; U=4.5, p=0.028, respectively).

For vermillion snapper, red porgy, gray triggerfish, and white grunt, the percentage of gut-hooked fish decreased with increasing hook size. For red grouper and gag, the percentage of gut hooked fish was unrelated to hook size (Table 5). For each main species, jaw hooking occurred in at least 89% of the cases (Table 6).

Eye-hooked and gut-hooked vermillion snapper did not have significantly different average release indices than jaw-hooked conspecifics (Kruskal-Wallis H=4.77, p=0.092). Gut hooked red porgy had a significantly higher average release index than jaw-hooked conspecifics (U=380.5, p=0.007) (Figure 5). Gill-hooked vermillion snapper and eye-hooked red porgy were not included in the statistical comparison of release indices among hooking locations because of low sample size.

Discussion, Impacts, Benefits

Sub-legal specimens comprised substantial percentages of our catches of vermillion snapper, red porgy, and gag. Our data indicate that the discard rate would roughly double by increasing the minimum size limit for vermillion snapper from 330 to 356 mm. Red grouper was the only species that had a low discard rate (5.2%).

Catch compositions of reef fishes are greatly affected by fishing methods, season, and location (reef habitats are patchy; fish aggregations can be rapidly depleted (Huntsman et al 1999)). Fine-scale variations in sizes and species composition of catches make fishery-dependent and independent assessments of reef-fish species notoriously difficult (see Huntsman et al (1999), and others). Data from our experiment and the 2003 collection by Overton and Zabawski (2004) strongly suggest that high percentages of several commercially important reef species in North Carolina are composed of sub-legal specimens. Thus, it is important to evaluate the fate of discarded fishes to incorporate these estimates of mortality into stock assessments.

Without citing specific depths, Huntsman and Manooch (1978) reported that most undersize specimens in snapper-grouper-porgy reef fisheries will likely die from injuries sustained due to changes in pressure. While discarded fish in this study may have suffered from longer-term effects of hyperbaric trauma or predation suggested by Huntsman and Manooch (1978), the immediate survival observed from the surface to ~6 m below the surface (the approximate range of our visibility when we released fishes) was high; 87% and 93% of proposed sub-legal and legal vermillion snapper, respectively, had post-release indices of either 1 or 2. Similar results were found for all other major species. While mortality was low for major species, of concern for stocks of long-lived species is relatively low rates of hooking mortality that nonetheless result in high rates of cumulative mortality even if an individual is caught and released once per year.

However, gastric distention and other pressure-related trauma may increase rates of longer-term mortality. In analyzing the survival of caged vermillion snapper, Collins et al. (1999) found that significantly more fish survived when caught from waters 29-35 m deep (100% survival) than when caught from waters 43-55 m (82% survival) due to differences in pressure at each depth. Gastric distention increased the likelihood of immediate post-release mortality, but not significantly for vermillion snapper, red porgy, red grouper, and gag. Increased sample sizes of these species may help elucidate the effects of gastric distention.

Among the six main species, there were substantial differences among percentages of fish with gastric distention: red grouper, in particular, had a far greater rate of gastric distention (67%) than other species. Red grouper were caught from water depths that increased their pressure change roughly one atmosphere compared to gag (37.6% distention). Previous studies have addressed methods that ameliorate gastric distention for groupers captured from deepwater. Rapid depressurization (venting) of bloated grouper stomachs, for example, increased short-term (<1 month) survival of two species with ruptured swim bladders in Florida waters > 21.3 m deep (Burns and Restrepo 2002): coupled with short on-board de-hooking and handling times common among experienced commercial anglers, this easy method may hold promise of increasing post-release survival of sub-legal reef fishes angled from North Carolina waters.

Because release indices of fish with- and without gastric distention did not significantly differ for any major species, gastric distention should not be used as a proxy for immediate post-release mortality. Comparisons of release fate among bleeding and non-bleeding conspecifics also indicate that bleeding may not be a reliable proxy for immediate discard mortality.

Across all hook sizes, the rate of jaw hooking was at least 89% for each of the six main species. Our data indicates that hooking reef fishes in areas other than the jaw (such as gut, gills, and eyes) occurs in only a small percentage of cases, at least with terminal tackle used in this study. The 8/0-12/0 hook sizes targeting grouper and the 2/0-6/0 hook sizes for targeting snapper and porgy are commonly used in the North Carolina commercial reef fishery. Larger hook sizes may decrease catches of gape-limited species such as snappers and porgies, although these larger hooks appear to reduce the rate of gut hooking (Bacheler and Buckel 2004; this study), and therefore will tend to increase survival of released sub-legal fish.

Since the vast majority of fish in this study were jaw hooked, barotrama is likely a larger issue than hooking location in dictating survival of reef fish after release. The presence of gastric distention in commercially important red grouper and gag was positively correlated with water depth. While the presence of gastric distention was negatively correlated with water depth for vermillion snapper and red porgy, this non-intuitive finding was likely confounded by the fact that both species were captured over a narrow variation of depths. Capture of each species over a broader variation of depths may clarify these trends.

In attempting to return to the bottom, released reef fish may suffer predation mortality. Mid-water apex predators in North Carolina include king mackerel (*Scomberomorus cavalla*), amberjack (*Seriola dumerili*), and Atlantic sharpnose sharks (*Rhizoprinodon terraenovae*). Caging and immediate post-release survival (this study) experiments do not quantify predation. Novel approaches to estimate the combined effects of barotrauma and predation are needed.

Compared to groupers, small increases in minimum length limits may be more effective at protecting species that mature at younger ages. Survival of a single release event for snappers and porgies caught at the rate of once per year, for instance, will more likely result in subsequent captures taking place when individuals have reached legal and reproductive size. Female vermillion snapper, for example, experience exponential increases in fecundity with increasing size (Grimes and Huntsman 1980), so seemingly small increases in minimum limits (such as the proposed 25 mm increase) may substantially raise the reproductive potential of a population. While our sampling design allowed us to observe only the immediate fate of released fishes, our data nonetheless indicates that increases in minimum sizes may benefit stocks. Sub-legal and potentially sub-legal vermillion snapper had roughly equal rates of observed survival (release indices of 1 or 2) compared to legal and potentially legal conspecifics, respectively.

Minimum size limits are easy to apply and enforce, and may discourage angling at places and times where sub-legal fish are frequent (Huntsman and Manooch 1978). In the absence of vast geographic closures for deepwater fisheries, it is likely that minimum size limits will continue to be heavily used to attempt to reduce fishing mortality for sub-legal snappers, groupers, and porgies.

If the South Atlantic Fishery Management Council increases the size limit for vermillion snapper, the discard percentage is likely to increase substantially. Our data suggests that the immediate post-release survival rate of vermillion snapper will be high. As minimum size limits are increased, knowledgeable commercial reef anglers may modify fishing times, locations, hook sizes, and bait types to reduce catches of sub-legal fish. The high rates of immediate post-release survival found herein, coupled with inherent desires of commercial anglers to simultaneously maximize catches of legal fish and minimize catches of sub-legal or unmarketable discards, suggest that minimum size limits can be effective. Commercial anglers have the experience to rapidly assess whether fish will be landed or released and, by so doing, can minimize time needed to process (de-hook, measure, and release) potential discards. Thus, minimum size limits for deepwater reef fishes cannot be viewed only in the context of post-release mortality rates but must also be viewed for their potential to modify fishing practices so that catches of discarded fishes are reduced.

Extension of Results Paul Rudershausen presented the results of the study to the February 2005 meeting of the Southern Division of the American Fisheries Society and will present results to the national meeting of the American Fisheries Society in September 2005.

Students Several of the trips were observed by undergraduate students attending N.C. State University.

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Table 1. Dates of reef-fishing trips in Onslow Bay, NC, 2004

Trip Number	Trip Date	Trip Observed?
1	May 13	No
2	May 14	No
3	May 17	No
4	June 2	No
5	June 15	No
6	June 22	Yes
7	July 1	No
8	July 2	Yes
9	July 10	No
10	July 12	Yes
11	July 16	No
12	July 22	Yes
13	August 10	No
14	August 18	Yes
15	August 20	Yes
16	August 27	Yes
17	September 1	Yes
18	September 10	No
19	September 16	Yes
20	September 23	No
21	September 29	No
22	September 30	No
23	October 1	Yes
24	October 3	Yes
25	October 4	Yes
26	October 12	No
27	October 13	No
28	October 18	Yes
29	October 28	Yes
30	October 29	No
31	November 1	No
32	November 2	Yes

Table 2. Sample size, average total length (TL, mm) (±S.D.) average water depth (m) (± S.D.), and range of water depths for snapper, grouper, and porgy species.

Common name	Scientific name	n	%	Ave. length	Fish length range	Ave. depth	Depth range
Vermillion snapper	*Rhomboplites aurorubens*	577	24.6	375±59	203-584	41.8±5.8	31.2-56.7
Red porgy	*Pagrus pagrus*	442	18.9	377±48	229-533	45.8±17.5	35.2-100.0
Gray triggerfish	*Balistes capriscus*	438	18.7	446±56	305-635	48.9±7.2	31.2-64.2
Red grouper	*Epinephelus morio*	365	15.6	709±126	254-991	40.2±3.8	34.8-61.2
White grunt	*Haemulon plumieri*	110	4.7	324±45	203-483	37.3±2.9	19.1-40.9
Gag	*Mycteroperca microlepis*	101	4.3	683±119	368-1067	29.2±10.3	18.8-85.2
Knobbed porgy	*Calamus nodosus*	62	2.7	384±42	305-464	49.2±5.7	38.5-62.7
Sand tilefish	*Malacanthus plumieri*	44	1.9	517±77	406-711	60.6±28.6	38.2-142.4
Margate	*Haemulon album*	42	1.8	221±26	152-267	38.4±3.5	31.2-40.9
Scamp	*Mycteroperca phenax*	34	1.5	601±131	305-838	48.3±20.0	37.6-100.0
Snowy grouper	*Epinephelus niveatus*	24	1.0	482±122	203-711	137.6±18.1	78.8-143.3
Bank sea bass	*Centropristis ocyura*	23	1.0	235±29	152-279	38.2±2.2	31.2-40.9
Black sea bass	*Centropristis striata*	21	0.90	323±85	178-457	34.4±9.7	19.1-71.2
Rock hind	*Epinephelus adscensionis*	10	0.43	419±80	254-508	44.1±7.3	37.6-55.5
Spottail pinfish	*Diplodus holbrooki*	10	0.43	257±30	203-305	20.7±3.5	19.1-28.2
Silk snapper	*Lutjanus vivanus*	8	0.34	421±46	356-483	41.7±4.1	39.4-56.7
Speckled hind	*Epinephelus drummondhayi*	7	0.30	439±73	305-514	73.6±31.8	39.7-100.0
Gray tilefish	*Caulolatilus microps*	6	0.26	538±67	457-660	143±0	-
White bone porgy	*Calamus leucosteus*	5	0.21	396±34	356-432	44.2±7.3	34.8-51.8
Bigeye snapper	*Priacanthus arenatus*	4	0.17	378±50	305-419	47.1±16.1	39.1-71.2
Red snapper	*Lutjanus campechanus*	3	0.12	677±103	584-787	49.4±10.9	36.7-55.8
Warsaw grouper	*Epinephelus nigritus*	1	0.04	1041	-	71	-
Yellowedge grouper	*Epinephelus flavolimbatus*	1	0.04	495	-	73	-
Marbled grouper	*Epinephelus inermis*	1	0.04	356	-	53	-
Parrotfish	*Scarus vetula*	1	0.04	229	-	52	-
Queen triggerfish	*Balistes vetula*	1	0.04	597	-	52	-

Table 2. continued.

Ocean surgeon	*Acanthurus bahianus*	1	0.04	330	-	40	-
Tomtate	*Haemulon aurolineatum*	1	0.04	203	-	40	-
Mutton snapper	*Lutjanus analis*	1	0.04	533	-	40	-
Red hind	*Epinephelus guttatus*	1	0.04	381	-	38	-

Table 3. Number of fish at each release index and average (± S.D.) for the six most abundant species captured. Vermillion snapper and red porgy are separated by legal and sub-legal specimens. The PR index scored fish as: 1) alive, oriented themselves toward the bottom, and swam down vigorously; 2) alive, oriented themselves toward the bottom, and swam down slowly or erratically; 3) alive but swam at the surface; 4) dead or unresponsive.

Species	n	n, Index 1	n, Index 2	n, Index 3	n, Index 4	Average
Total vermillion snapper	183	61	101	11	10	1.84±0.77
Vermillion snapper <330 mm	74	25	37	6	6	1.91±0.86
Vermillion snapper <356 mm	136	42	76	9	9	1.89±0.80
Vermillion snapper ≥330 mm	109	36	64	5	4	1.79±0.69
Vermillion snapper ≥356 mm	47	19	25	2	1	1.68±0.66
Total red porgy	153	79	50	12	12	1.72±0.91
Red porgy <356 mm	104	59	31	6	8	1.64±0.90
Red porgy ≥356 mm	49	20	19	6	4	1.88±0.93
Red grouper	30	22	6	2	0	1.33±0.60
Gag	29	24	5	0	0	1.17±0.38
Gray triggerfish	16	12	2	2	0	1.38 ±0.72
White grunt	14	7	6	1	0	1.57±0.65

Table 4. Percent bleeding and distended stomachs for the six most abundant species, all hook sizes and types combined. Results for vermillion snapper, red porgy, and white grunt includes unpublished data from a previous North Carolina Sea Grant study (# 03-FEG-10).

Species	n	% gastric distention	% bleeding
Vermillion snapper	577	35.0	4.4
Red porgy	442	12.9	3.5
Gray triggerfish	438	28.8	2.1
Red grouper	365	67.4	7.1
White grunt	110	15.6	3.6
Gag	101	37.6	16.8

Table 5. Percentage hooking location by hook size and type (J-hook and circle hook (C)) for the six most abundant species. Results for vermillion snapper, red porgy, and white grunt includes unpublished data from a previous North Carolina Sea Grant study (# 03-FEG-10).

		Hook Location				
Species	Hook size, type, n	Jaw	Gut	Gill	Eye	Body
Vermillion snapper	2/0 J n=155	91.0	5.2	0.6	2.6	0.6
	3/0 J n=344	90.1	9.0	0.3	0.3	0.3
	4/0 J n=30	100	0	0	0	0
	5/0 J n=36	100	0	0	0	0
	7/0 J n=2	100	0	0	0	0
	8/0 J n=4	100	0	0	0	0
	9/0 J n=11	100	0	0	0	0
	12 C n=3	100	0	0	0	0
Red porgy	2/0 J n=110	93.6	6.4	0	0	0
	3/0 J n=150	85.3	14.7	0	0	0
	4/0 J n=22	77.3	22.7	0	0	0
	5/0 J n=141	89.4	9.2	0	0	1.4
	7/0 J n=103	93.2	3.9	1.0	0	1.9
	8/0 J n=22	100	0	0	0	0
	9/0 J n=96	96.9	0	0	1.0	2.1
	12/0 J n=26	100	0	0	0	0
Gray triggerfish	2/0 J n=105	96.2	1.9	0	0	1.9
	3/0 J n=251	97.6	2.0	0	0.4	0
	4/0 J n=2	100	0	0	0	0
	5/0 J n=23	100	0	0	0	0
	8/0 J n=2	100	0	0	0	0
	9/0 J n=9	66.7	0	0	0	33.3
Red grouper	2/0 J n=9	100	0	0	0	0
	3/0 J n=26	88.5	11.5	0	0	0
	4/0 J n=1	100	0	0	0	0
	5/0 J n=3	100	0	0	0	0
	7/0 J n=29	69.0	31.0	0	0	0
	8/0 J n=87	89.7	10.3	0	0	0
	9/0 J n=171	91.8	8.2	0	0	0
White grunt	2/0 J n=7	85.7	14.3	0	0	0
	3/0 J n= 76	100	0	0	0	0
	4/0 J n=4	100	0	0	0	0
	5/0 J n=20	95.0	0	0	0	5.0
	7/0 J n=12	91.7	0	8.3	0	0
	9/0 J n=17	82.4	5.9	0	0	11.8
	12/0 C n=3	100	0	0	0	0
Gag	3/0 J n=5	100	0	0	0	0
	5/0 J n=1	100	0	0	0	0

Table 5. continued

	7/0 n=38	100	0	0	0	0
	8/0 n=19	100	0	0	0	0
	9/0 n=34	97.1	2.9	0	0	0
	12/0 J n=1	100	0	0	0	0

Table 6. Average post-release index (PR) (± S.D.) by hooking location for vermillion snapper and red porgy. Percent dead were those specimens with PR of 3 or 4. The PR index scored fish as: 1) alive, oriented themselves toward the bottom, and swam down vigorously; 2) alive, oriented themselves toward the bottom, and swam down slowly or erratically; 3) alive but swam at the surface; 4) dead or unresponsive.

Species	Hooking location	Number	Average PR	% dead
Vermillion snapper	Jaw	167	1.79±0.73	9.5
	Gut	12	2.33±1.15	33.3
	Eye	3	2.33±0.58	33.3
	Gill	1	2	0
Red porgy	Jaw	136	1.64±0.84	13.2
	Gut	11	2.64±1.21	45.5
	Eye	1	1	0

Fig 1. Length frequencies of vermillion snapper (A), and red porgy (B). Vertical lines on panel A designate minimum (330 mm) and proposed increased minimum length limits (356 mm) for vermillion snapper. Vertical line on panel B designates minimum length limit (356 mm) for red porgy.

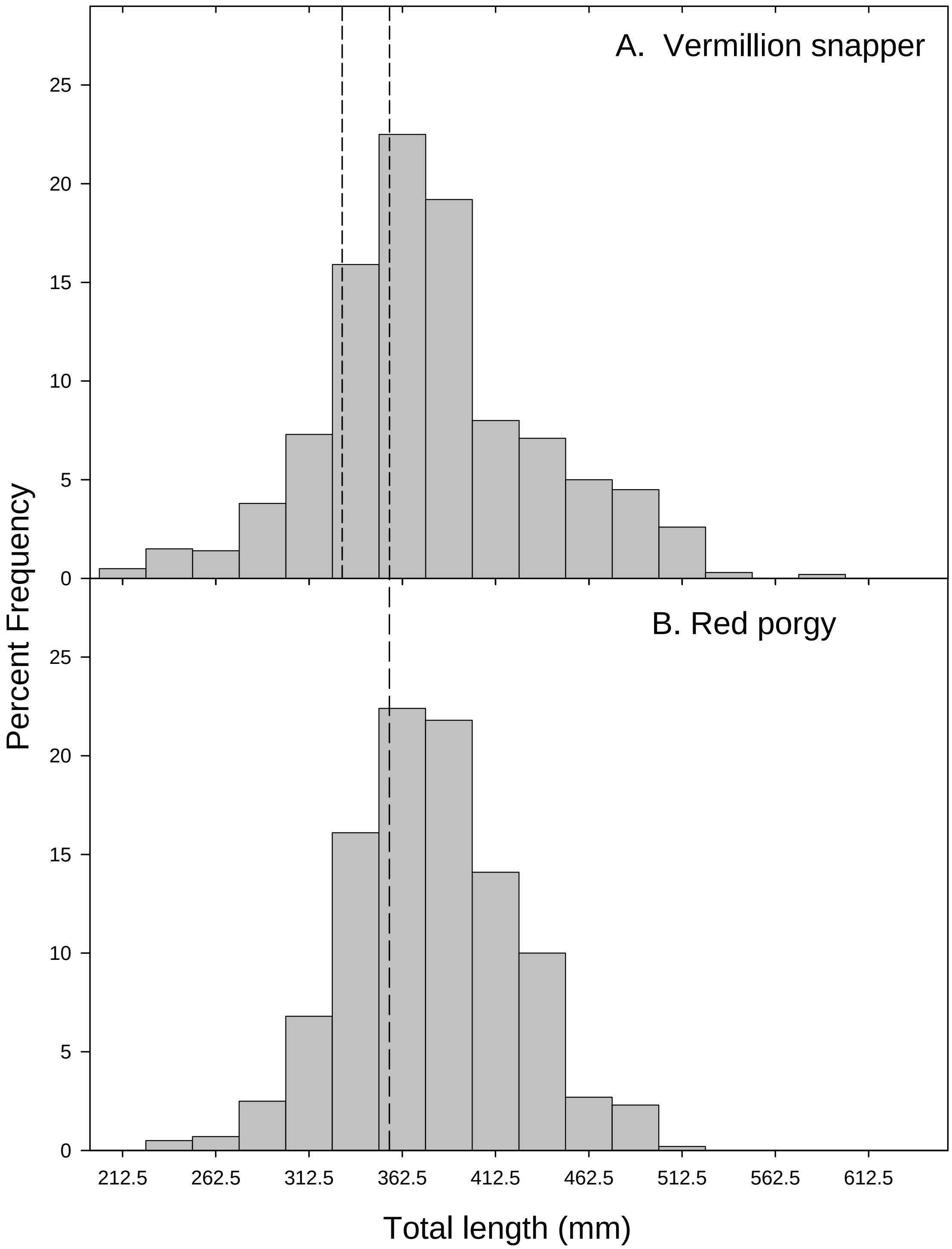

Fig 2. Length frequencies of red grouper (A) and gag (B). Vertical lines on panels designate minimum length limit for red grouper (508 mm) and gag (610 mm), respectively.

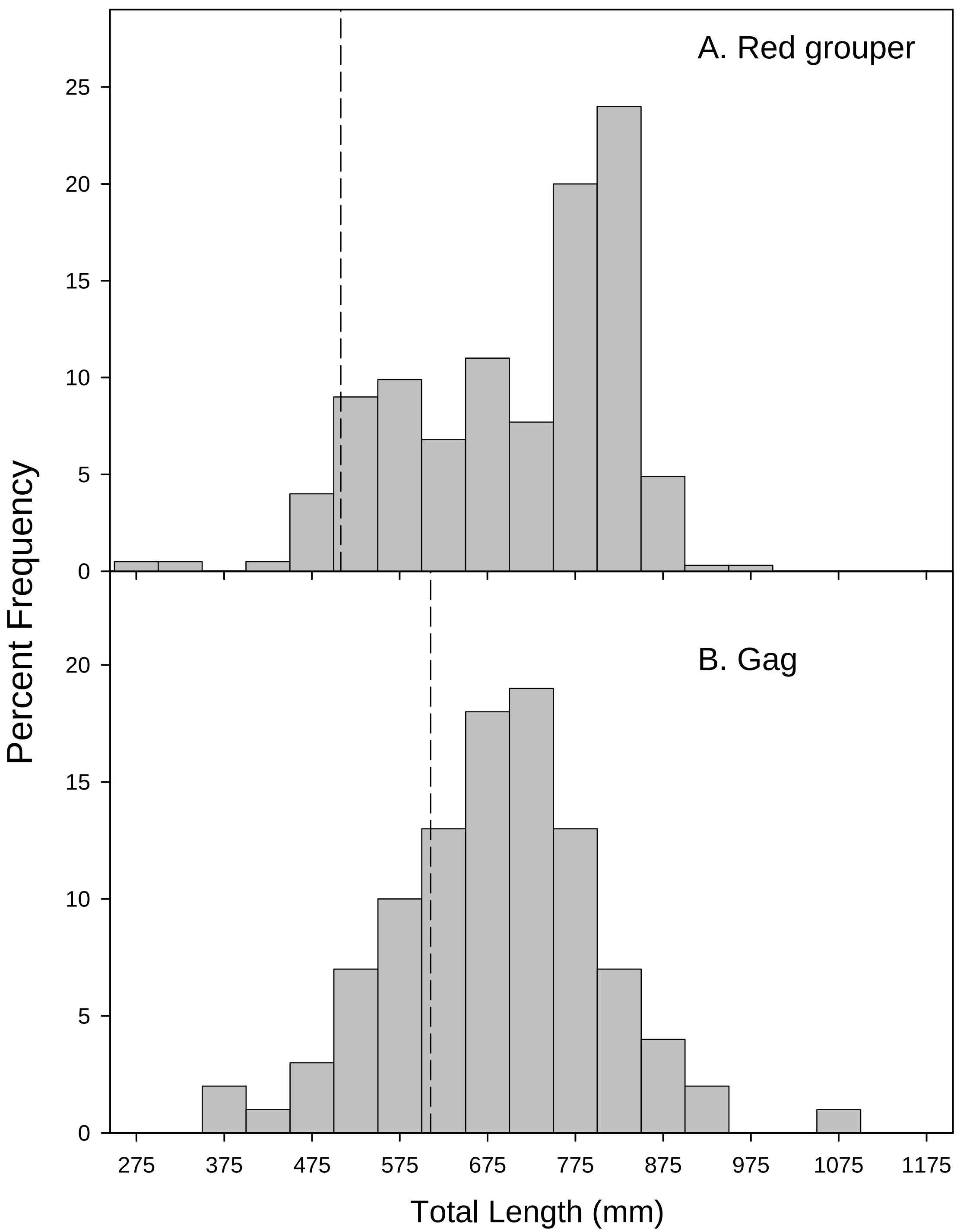

Figure 3. Percentages of legal and sub-legal vermillion snapper and red porgy at each release index. Current minimum size of vermillion snapper is 330 mm total length; proposed minimum size of vermillion snapper is 356 mm total length. Legal minimum size of red porgy is 356 mm total length.

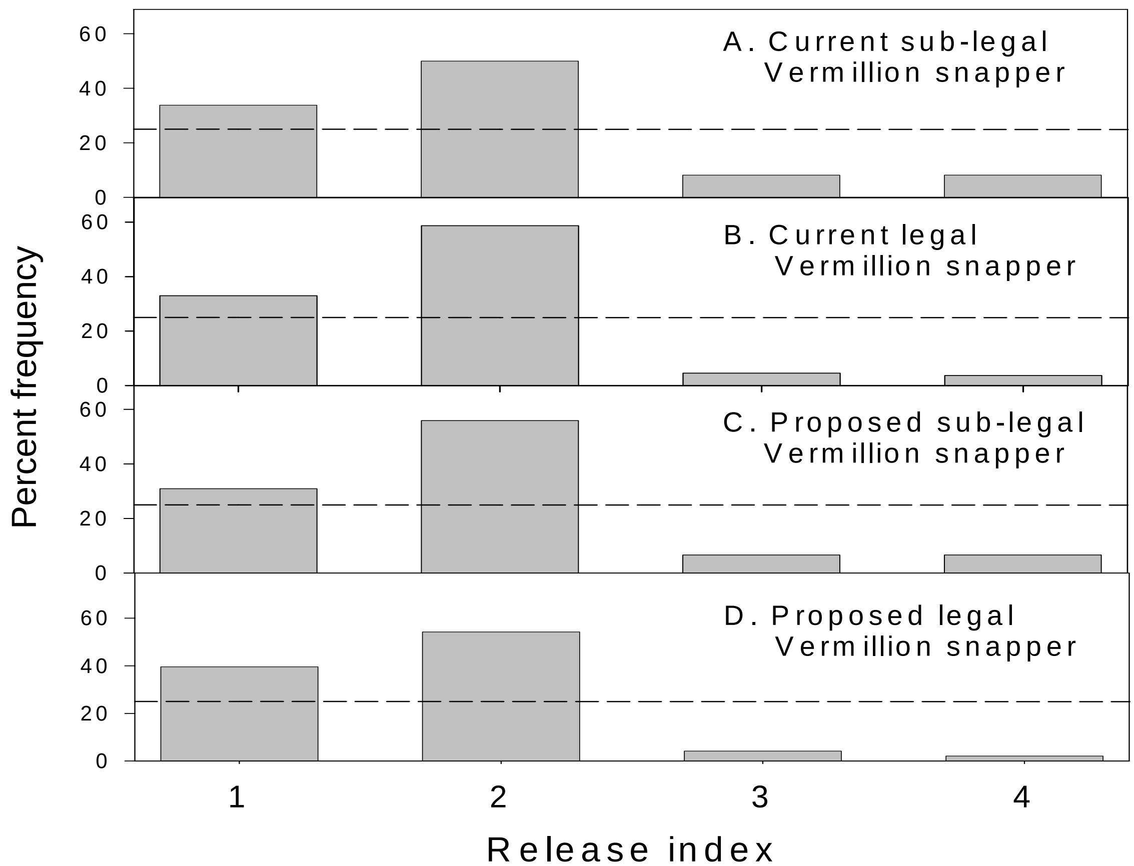

Figure 3. continued.

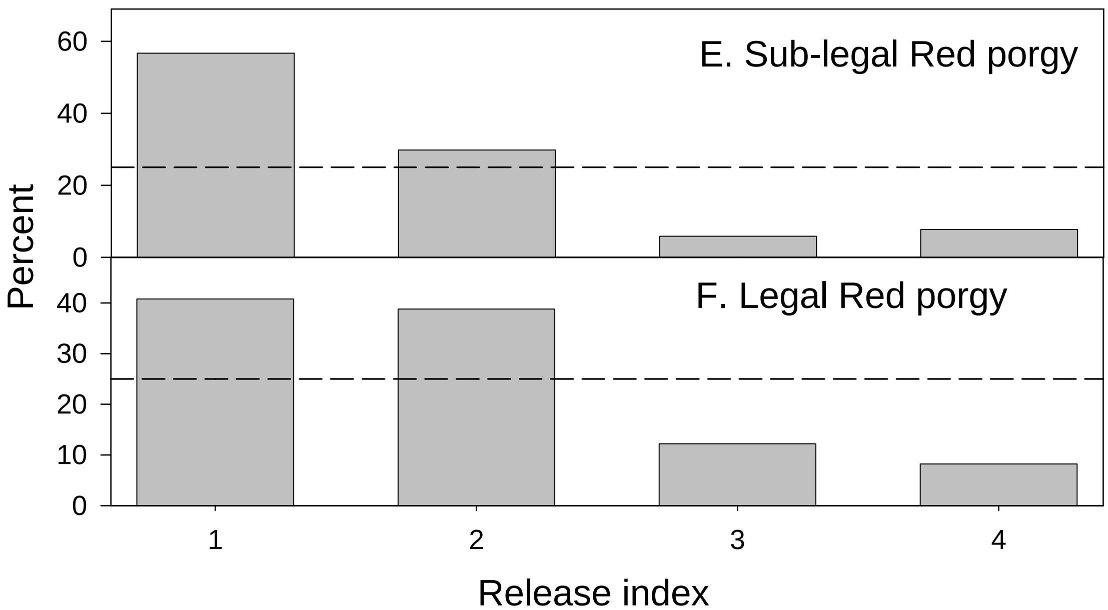

Figure 4. Average post-release indices (± S.E.) for vermillion snapper, red porgy, red grouper, and gag with- and without gastric distention. Shaded bars for each species represent fish with gastric distention.

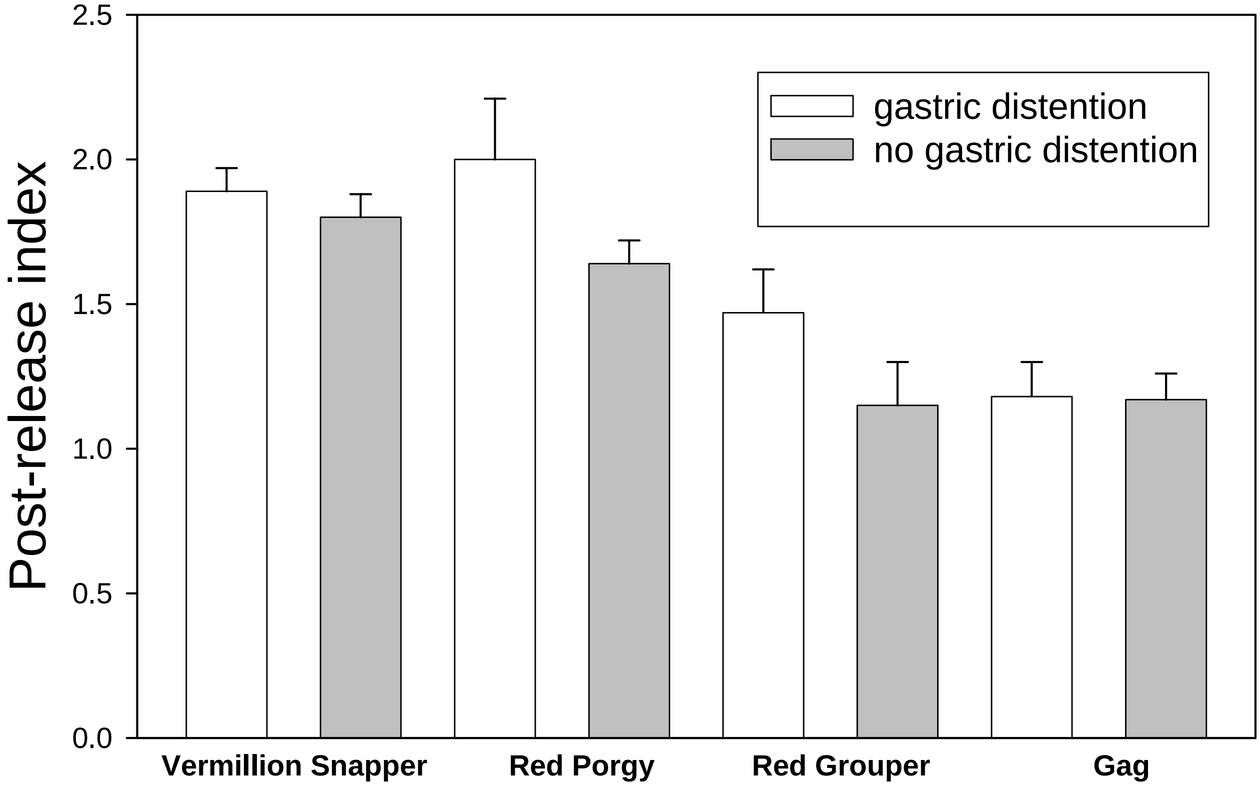

Figure 5. Average post-release indices (± S.E.) for vermillion snapper and red porgy, by hooking location.