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Research Paper

Catch comparison between otter and rollerframe trawls: Implications for sampling in seagrass beds

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ABSTRACT

The use of otter trawls as a sampling gear in habitats with shallow, submerged aquatic vegetation (SAV) has been criticized due to its variable and low capture efficiency. Moreover, the area swept by otter trawls is dynamic both between and within tows; capture of fauna associated with seagrass can be strongly influenced by gear-induced turbulence, and animals are able to escape under the net that often rides on top of the SAV. We compared catch from the commonly-used otter trawl with that from the rollerframe trawl, which has not been previously evaluated for fishery-independent research purposes. We found that the rollerframe trawls had higher catch rates and caught more species of fauna in seagrass beds across the northeastern Gulf of Mexico. Among the species captured, 72% were more abundant in the rollerframe trawls compared to 11% more abundant in otter trawls (17% of species were captured at equal abundances). These results were consistent across sites and for a wide range of taxa. Additionally, the rollerframe trawls captured 25% more species than the otter trawls. Our findings suggest that rollerframe trawls generally have a higher capture efficiency than otter trawls in seagrass beds. We therefore recommend that the rollerframe trawl be used as an alternative or supplemental gear for ecologists and fisheries scientists working in seagrass beds.

1. Introduction

Ecologists and fishery scientists often use trawls to collect specimens and estimate community composition, abundance and diversity of mobile animals in habitats with submerged aquatic vegetation (SAV) such as seagrass beds. Several trawl designs are available, each with associated advantages and disadvantages in their use and efficacy (review by Rozas and Minello, 1997; also see Kubecka et al., 2012 and contributions within for a special issue of *Fisheries Research* comparing other active sampling gears and techniques). The otter trawl is one of the most common gears towed in seagrass and other estuarine habitats, as it is relatively easy to use (i.e., deployment and recovery can be accomplished with 1–2 people), inexpensive and readily available from numerous gear suppliers.

However, like all sampling gears, otter trawls have some associated pitfalls that can affect the accuracy and precision of estimating the abundance of populations as well as the structure and diversity of communities. They have been criticized as having low and unstable capture efficiencies, which can be influenced by a suite of factors including the biology of target fauna (e.g., size and behavior), habitat (e.g., seagrass blade length, sediment type), gear specificities (e.g., rigging, net size), and methods employed (e.g., tow direction and speed) (see Rozas and Minello (1997) for an extensive review of the advantages and disadvantages of various sampling gears in estuarine habitats). Because researchers generally require abundances of captured fauna to be standardized to densities, the area sampled must be known or estimated. However, the area sampled by an otter trawl can change during a tow as the doors are pulled inward as the mass of the catch in the net increases (Koenig and Coleman, 1998; O'Neill et al., 2005), thus confounding estimates of the swept area and making density calculations tenuous. Additionally, the shallow depths of seagrass beds make associated fauna vulnerable to turbulence from the propeller of the vessel towing the otter trawl (commonly called "prop wash") which can alter catch characteristics of the gear (Hein and Meier, 1995). The doors

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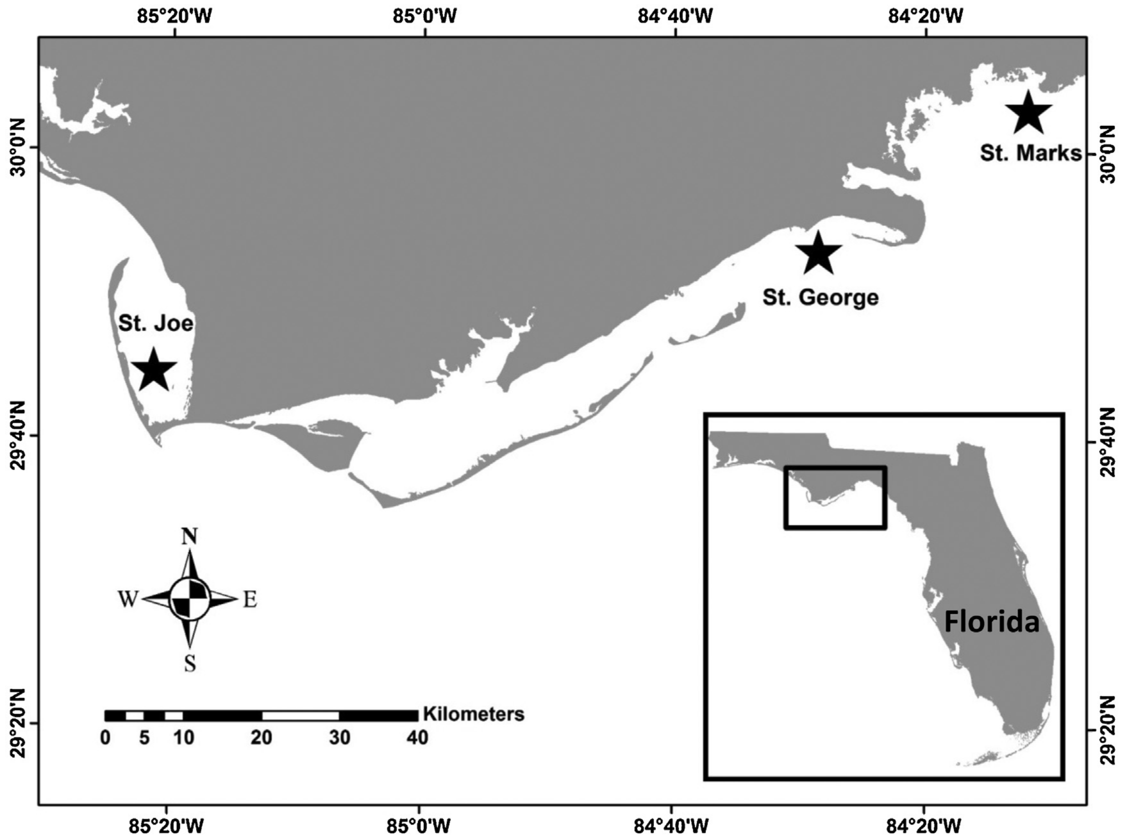

Fig. 1. Map of the study region, showing the trawling sites in St. Joe Bay, St. George Sound, and Apalachee Bay (St. Marks).

themselves can also create turbulence and sediment clouds (de Madron et al., 2005; Pusceddu et al., 2005; Schoellhamer, 1996) that may influence the vulnerability of targeted fauna (Main and Sangster, 1981). Otter trawls can also ride on top of SAV allowing animals to escape underneath the net, leading to the low capture efficiency often observed for this gear in seagrass habitats (Leber and Greening, 1986).

The use of rollerframe trawls as an alternate sampling gear may provide solutions to some of the inherent disadvantages of otter trawls in seagrass beds. Rollerframe trawls have a rigid mouth, so the area sampled remains constant both within and between tows. They are generally towed from the sides of the vessel (at about amidships) rather than astern like the otter trawl so propeller turbulence is likely minimized or eliminated. There are no doors or any other gears towed in front of the mouth opening, so sediment clouds are also eliminated. Last, the rigid frame is heavy, potentially allowing it to ride directly on the seafloor without the buffering effect of seagrass observed with the tickler chains of otter trawls. To our knowledge, rollerframe trawls have not been previously considered for research purposes, aside from studies directly aimed at understanding their catch characteristics in light of their use by a regional inshore fishery for juvenile penaeid shrimp in seagrass beds and other soft bottom habitats in Florida, USA (De Sylva, 1954; Tabb and Kenny, 1969; Berkeley et al., 1985; Upton et al., 1992; Coleman and Koenig, 1998; Meyer et al., 1999; Baum et al., 2003; Crawford et al., 2011). Some of these previous efforts have reported high bycatch by the rollerframe trawls, suggesting they may have high capture efficiencies of various fauna associated with seagrass habitats.

In the current study, we experimentally compared the catch from the commonly-used otter trawl with that from the rollerframe trawl across three sites with varying seagrass characteristics and associated faunal communities. Specifically, we compared the community composition, abundance (standardized as density), and diversity (species richness and rarefied richness) of catch from the two gears.

2. Methods

2.1. Study sites

We conducted our field sampling in seagrass beds at three locations along the coast of the Florida panhandle in the northeastern Gulf of Mexico: (1) St. Joe Bay, (2) St. George Sound, and (3) St. Marks – Apalachee Bay (Fig. 1). All three sites were of similar depths (2–3 m) but with some variation in the seagrass habitats. St. Joe Bay was dominated by 20–50 cm *Thalassia testudinum* with interspersed patches of *Syringodium filiforme*, *Halodule beaudettei* and "hard-bottom" sand. St. George Sound had large patches of *T. testudinum* and *S. filiforme* with blade lengths of 50–100 cm and few soft sand patches. Last, the site in Apalachee Bay (St. Marks) was dominated by 40–80 cm *S. filiforme* mixed with interspersed *T. testudinum* and had a soft sand bottom. Our goal in choosing these sites was not to describe how the different gears operated relative to specific differences in seagrass composition and benthic geological qualities, but to instead incorporate a range of common habitat characteristics of seagrass beds found in the northeastern Gulf of Mexico (Stallings and Koenig, 2011).

2.2. Gear descriptions and paired experimental design

We used a 5 m otter trawl (empty net working width = 3.6 m, height = 2 m, length = 4 m, net body = 1.9 cm stretch mesh, bag = 3 mm mesh) towed astern at a standard speed of 1.8–2.0 km h^{-1}

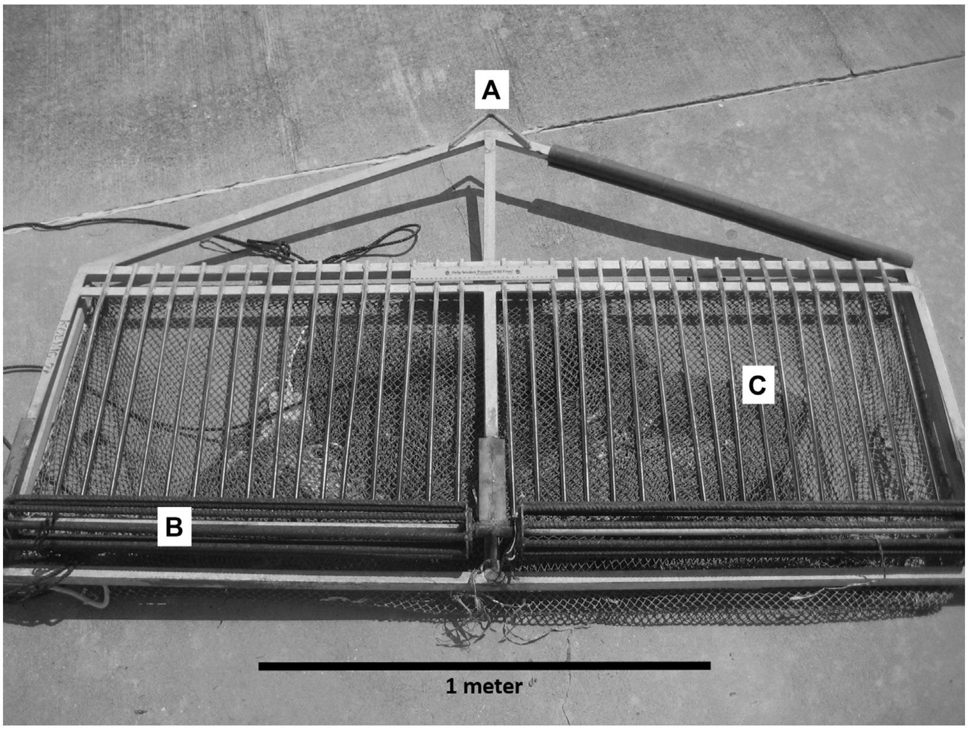

Fig. 2. Photograph of the experimental rollerframe trawl used in the study. The labels refer to the (A) tow point, (B) rollers that give the trawl its name and (C) excluder bars used in the commercial fishery to keep excess algae and seagrass blades out of the net. For more information, see Supplemental Fig. S1, which shows the experimental rollerframe trawls attached to the retractable boom system of the research vessel.

for 150 m within the seagrass beds (towing warps = 15 m). Based on direct underwater observation, this tow speed was previously determined to be the most efficient; faster tows caused the net to ride off the bottom and slower tows allowed fishes to escape (Koenig and Coleman, 1998). We used rollerframe trawls constructed specifically for a previous study (Coleman and Koenig, 1998) by a company that provides most of the commercial nets in the Big Bend-Panhandle region of Florida. The rollerframe trawls were 1.8 m wide with a frame height of 0.67 m, roller diameter of 10 cm, stretch mesh size of the net of 1.9 cm (Fig. 2). Excluder bars (diameter of 12 mm) spaced at 4 cm were installed from the top to the bottom of the frame. Coleman and Koenig (1998) determined that the experimental frames and nets did not differ in capture efficiency compared to the gears used in the commercial fishery. One net was pulled at a standard speed of 1.8–2.0 km h^{-1} for 150 m (same as the otter trawl) on each side of a 6.1 m research vessel from booms mounted on the port and starboard gunnels at about amidships (towing warps = 10 m; Fig. S1).

Supplementary figure related to this article can be found, in the online version, at http://dx.doi.org/10.1016/j.fishres.2014.03.002.

During each sampling event, we conducted paired otter-rollerframe tows at each of the three sites. The paired design ensured the trawls were pulled over comparable habitat and associated faunal communities while avoiding areas that were previously trawled. We kept the tows short in distance at 150 m, accurately determined via GPS, to avoid confounding effects of reduced net spread associated with drag resistance caused by large catches in otter trawls (O'Neill et al., 2005). Thus, we assumed that our relatively small catches did not cause the area swept by the otter trawl to vary (Queirolo et al., 2012).

A total of 104 tows were made in 2008, with 32 each at St. Joe Bay and St. Marks and 40 in St. George Sound. Each site was sampled in May, June, July and September and St. George Sound was also sampled in August (logistical problems restricted sampling to the single site in August). All sampling was conducted at night. Care was taken to minimize harm to the animals and an effort was made to release them back into the water after identification to species and counting the number for each species. However, some animals were retained to allow for identification in the laboratory, where microscopes and detailed taxonomic keys were present (*keys used*: Abele and Kim, 1986; Robins et al., 1986; Kaplan and Peterson, 1988; Humann and DeLoach, 2002; Hoese and Moore, 1998; McEachran and Fechhelm, 1998; Voss, 2002; *supplemental online resources used*: http://www.fishbase.org/, http://www.itis.gov/, http://www.marinespecies.org/, http://www.sealifebase.org/).

2.3. Data analysis

We summarized the data according to mean (se) densities per species (number of animals for each species), frequency of occurrence per tow for each species (FOC), observed species richness, and rarefied richness. We rarefied the data to account for and standardize the strong effects of abundance on the number of observed species (i.e., sampling effect – Gotelli and Colwell, 2001). We also calculated species accumulation curves for each gear. Rarefaction and species accumulation curves were conducted in the *Vegan* package (Oksanen et al., 2013) in the *R* statistical language (R Core Team, 2013).

To investigate compositional patterns in the catch data, a matrix of trawl tows by species densities were ordinated using non-metric multidimensional scaling (MDS). The MDS was performed in PC-ORD 4.14 using the "autopilot mode" with Sorensen distance measure and random starting configuration (McCune and Mefford, 1999). We limited the ordination to species that were common by excluding those that represented less than 0.05% of the total catch. The ordinations of trawl tows in species space are presented graphically. We simplified the presentation by displaying the site*gear centroids (± se) and rotated the ordinated axis to maximize the individual effects of site and gear.

Table 1
Catch comparisons for mean density (standard error) and frequency of occurrence (FOC) per tow, ranked in descending order of overall density pooled from both gears. A total of 53 species were observed, with 37 captured by both gears, 3 captured by otter trawl only and 13 captured by rollerframe only. Each species has a number superscript in the species column, which identifies its overall abundance rank.

Phylum	Species	Common name	Otter/100 m² (se)	FOC	Rollerframe/100 m² (se)	FOC
Arthropoda	*Tozeuma carolinense*[1]	Arrow Shrimp	137.29 (44.72)	0.87	321.27 (72.75)	0.97
	Farfantepenaeus duorarum[3]	Pink Shrimp	12.37 (2.15)	0.97	96.82 (10.66)	1.00
	Periclimenes longicaudatus[6]	Longtail Grass Shrimp	2.74 (1.29)	0.14	1.41 (0.60)	0.14
	Libinia dubia[10]	Longnose Spider Crab	1.38 (0.30)	0.67	0.92 (0.21)	0.64
	Metoporhaphis calcarata[19]	Arrow Crab	0.09 (0.04)	0.20	0.39 (0.09)	0.31
	Callinectes sapidus[20]	Blue Crab	0.24 (0.07)	0.39	0.25 (0.07)	0.29
	Hippolyte zostericola[45]	Zostera Shrimp	0.00 (0.00)	0.00	0.02 (0.02)	0.02
Chordata	*Lagodon rhomboides*[2]	Pinfish	40.91 (4.81)	1.00	133.14 (15.47)	1.00
	Orthopristis chrysoptera[4]	Pigfish	10.19 (1.22)	1.00	33.68 (4.52)	1.00
	Bairdiella chrysoura[5]	Silver Perch	2.60 (0.41)	0.87	2.92 (0.51)	0.83
	Opsanus beta[7]	Gulf Toadfish	0.70 (0.09)	0.93	2.22 (0.24)	0.97
	Monacanthus hispidus[8]	Planehead Filefish	1.29 (0.31)	0.69	1.44 (0.22)	0.66
	Syngnathus floridae[9]	Dusky Pipefish	0.66 (0.18)	0.46	1.85 (0.25)	0.77
	Hippocampus erectus[11]	Lined Seahorse	0.60 (0.20)	0.36	0.98 (0.36)	0.37
	Syngnathus scovelli[13]	Gulf Pipefish	0.13 (0.04)	0.26	1.21 (0.21)	0.64
	Chilomycterus schoepfi[14]	Striped Burfish	0.53 (0.09)	0.77	0.75 (0.12)	0.75
	Cynoscion nebulosus[15]	Spotted Seatrout	0.24 (0.07)	0.32	0.79 (0.17)	0.39
	Hyporhamphus unifasciatus[16]	Atlantic Silverstripe Halfbeak	0.00 (0.00)	0.00	0.96 (0.13)	0.81
	Anchoa mitchilli[17]	Bay Anchovy	0.35 (0.11)	0.22	0.31 (0.09)	0.24
	Paralichthys albigutta[18]	Gulf Flounder	0.09 (0.03)	0.38	0.45 (0.07)	0.62
	Lactophrys quadricornis[21]	Scrawled Cowfish	0.16 (0.07)	0.22	0.31 (0.13)	0.24
	Diplodus holbrooki[22]	Spottail Pinfish	0.14 (0.04)	0.39	0.25 (0.07)	0.29
	Lutjanus synagris[23]	Lane Snapper	0.09 (0.04)	0.18	0.29 (0.09)	0.24
	Sphoeroides nephelus[24]	Southern Puffer	0.19 (0.05)	0.36	0.17 (0.06)	0.24
	Eucinostomus argenteus[25]	Spotfin Mojarra	0.02 (0.02)	0.02	0.25 (0.12)	0.12
	Aluterus scriptus[26]	Scrawed Filefish	0.09 (0.04)	0.18	0.15 (0.05)	0.19
	Trinectes maculatus[27]	Hogchoker	0.00 (0.00)	0.00	0.23 (0.08)	0.24
	Mycteroperca microlepis[28]	Gag	0.12 (0.04)	0.24	0.09 (0.04)	0.18
	Eucinostomus gula[29]	Silver Jenny	0.01 (0.01)	0.02	0.17 (0.10)	0.06
	Centropristis striata[30]	Black Seabass	0.11 (0.04)	0.28	0.03 (0.02)	0.06
	Hippocampus reidi[31]	Slender Seahorse	0.05 (0.04)	0.04	0.08 (0.06)	0.04
	Gobiosoma robustum[32]	Code Goby	0.02 (0.02)	0.02	0.09 (0.06)	0.06
	Synodus foetens[33]	Inshore Lizardfish	0.02 (0.01)	0.06	0.08 (0.05)	0.12
	Engraulis eurystole[34]	Silver Anchovy	0.08 (0.04)	0.08	0.00 (0.00)	0.00
	Ariopsis felis[35]	Hardhead Catfish	0.03 (0.01)	0.12	0.05 (0.03)	0.10
	Symphurus plagiusa[36]	Blackcheeck Tonguefish	0.01 (0.01)	0.02	0.07 (0.04)	0.08
	Diplectrum bivittatum[37]	Dwarf Seabass	0.00 (0.00)	0.00	0.07 (0.05)	0.04
	Diplectrum formosum[38]	Sand Perch	0.01 (0.01)	0.04	0.05 (0.03)	0.08
	Strongylura marina[39]	Atlantic Needlefish	0.00 (0.00)	0.00	0.05 (0.02)	0.10
	Selene vomer[40]	Lookdown	0.02 (0.02)	0.02	0.02 (0.02)	0.02
	Chloroscombrus chrysurus[41]	Atlantic Bumper	0.00 (0.00)	0.00	0.03 (0.03)	0.02
	Myrophis punctatus[42]	Speckled Worm Eel	0.01 (0.01)	0.02	0.03 (0.02)	0.06
	Brevoortia patronus[43]	Gulf Menhaden	0.00 (0.00)	0.00	0.03 (0.03)	0.02
	Epinephelus morio[44]	Red Grouper	0.01 (0.01)	0.04	0.01 (0.01)	0.02
	Achirus lineatus[45]	Lined Sole	0.00 (0.00)	0.00	0.02 (0.01)	0.04
	Microgobius gulosus[45]	Clown Goby	0.00 (0.00)	0.00	0.02 (0.02)	0.02
	Monacanthus ciliatus[45]	Fringed Filefish	0.00 (0.00)	0.00	0.02 (0.02)	0.02
	Halichoeres bivittatus[49]	Slippery Dick	0.00 (0.00)	0.00	0.01 (0.01)	0.02
	Lactophrys trigonus[49]	Trunkfish	0.00 (0.00)	0.00	0.01 (0.01)	0.02
	Ophidion holbrookii[49]	Bank Cusk-Eel	0.00 (0.00)	0.00	0.01 (0.01)	0.02
	Lophogobius cyprinoides[52]	Crested Goby	0.01 (0.01)	0.02	0.00 (0.00)	0.00
	Scorpaena brasiliensis[52]	Barbfish	0.01 (0.01)	0.02	0.00 (0.00)	0.00
Mollusca	*Argopecten irradians*[12]	Bay Scallop	0.54 (0.09)	0.69	0.97 (0.18)	0.69

In addition to the MDS ordination, we have presented 1:1 plots of the mean (±se) densities per species by gear. For ease of interpretation, we separated the plots according to the relative abundance of the species: (1) high (>5 individuals/100 m^2), (2) medium (>0.5/100 m^2), (3) low (>0.1/100 m^2) and (4) rare (<0.1/100 m^2). These plots display the densities of each species captured by each gear relative to a 1:1 relationship.

We tested whether the total faunal density (i.e., across all species), observed species richness and rarefied species richness differed between the catch from otter and rollerframe trawling gears using analysis of variance (ANOVA). We included site and the gear*site interaction in each model to test whether the gear effects were consistent across sites. All three types of response data required log transformation to meet the assumption of homoscedasticity (Zar, 1999) and the ANOVAs were performed in the *R* statistical language (R Core Team, 2013).

3. Results

A total of 145,004 animals (fish, arthropods and molluscs) were captured across the three sites, comprising 53 species (from 35 families), with 37 captured by both gears (69.8%), three captured by otter trawl only (5.7%) and 13 captured by rollerframe only (24.5%) (Table 1). Species accumulation curves approached the asymptote rapidly for both gears, with slightly slower and higher relative values from the rollerframe trawls (Fig. 3).

Twenty-three species with at least 0.05% of the catch for each species (cumulatively = 99.5%) were included in the MDS

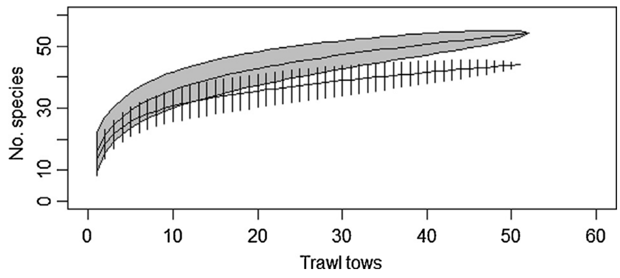

Fig. 3. Species accumulation curves with 95% confidence intervals for tows made with the otter trawls (bottom line with bar CIs) versus those made with the roller-frame trawls (top line with grey CI envelope).

ordination. The MDS converged on a stable, two-dimensional solution (final stress = 8.64, final instability = 0.00045, number of iterations = 51). The first axis accounted for the majority of variation in the MDS (r^2 = 62.4%), representing a strong effect of site while the second axis (r^2 = 25.1%) corresponded with a gear effect (Fig. 4). Although there was some minor overlap in the ordinated data, the separation of sites and gears was both striking and consistent. Indeed, all rollerframe centroids were located on the negative side of axis 2, below the associated centroid for otter trawls at the site. The patterns along axis 1 appeared to be driven by site-specific differences in dominant species, while those along axis 2 were driven by higher within-site catch in rollerframe trawls of several species (Table 2). The higher catch in rollerframe trawls was the primary driver of the multivariate response, as eight species had moderate to strong correlations with the rollerframe trawl side of axis 2, while only one species moderately correlated with the otter trawl side of the axis.

For most species, from common to rare, the rollerframe trawl tended to catch a greater number than the otter trawl (Fig. 5a–d). Indeed, of the 53 species observed in our study, 38 (71.7%) were captured in higher densities in rollerframe trawls (i.e., above and not crossing the 1:1 line), while only six (11.3%) were observed in higher densities in otter trawls (i.e., below and not crossing the 1:1 line) and nine (17.0%) did not differ between the two gears (i.e., crossing the 1:1 line). All four of the most abundant species were captured at higher densities in rollerframe trawls (Table 1 and Fig. 5a).

Across species, rollerframe trawls captured more animals ($F_{1,97}$ = 70.88, P < 0.001; Fig. 6a) and more species ($F_{1,97}$ = 614.10, P < 0.001; Fig. 6b) than otter trawls. After accounting for abundance, rarefied richness was higher in the otter trawls compared to the

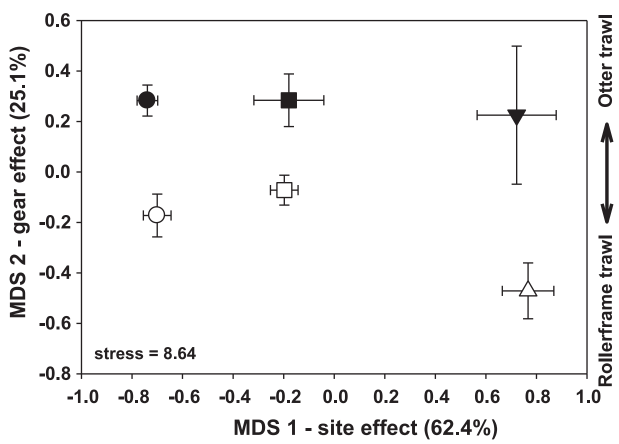

Fig. 4. MDS plot of the trawl tows in species space. The gear-by-site centroids (±se) are plotted with filled (otter trawl) and open (rollerframe trawl) symbols, respectively. Sites are represented with shapes for St. Joe Bay (circles), St. George Sound (triangles) and St. Marks (squares).

Table 2
Pearson correlations with MDS ordination axes, arranged from strongest positive to negative with axis 2 (gear effect). For the gear effect, species with weak-moderate correlations (0.20–0.49) are highlighted in light grey, those with moderate-strong correlations (0.50–0.80) in dark grey, and those with no-weak correlations (<0.20) are not highlighted.

Species	Axis 1 – r	Axis 2 – r
Libinia dubia	0.020	0.265
Diplodus holbrooki	0.038	0.132
Anchoa mitchilli	−0.133	0.130
Argopecten irradians	0.347	0.121
Sphoeroides nephelus	−0.232	0.077
Callinectes sapidus	−0.383	0.076
Chilomycterus schoepfi	−0.481	0.063
Paralichthys albigutta	−0.165	0.012
Bairdiella chrysoura	0.065	−0.009
Metoporhaphis calcarata	0.064	−0.019
Orthopristis chrysoptera	−0.576	−0.036
Lactophrys quadricornis	−0.121	−0.049
Opsanus beta	−0.270	−0.064
Hippocampus erectus	−0.193	−0.086
Cynoscion nebulosus	0.011	−0.103
Syngnathus scovelli	0.001	−0.207
Lagodon rhomboides	−0.631	−0.226
Periclimenes longicaudatus	0.230	−0.242
Hyporhamphus unifasciatus	0.137	−0.245
Monacanthus hispidus	0.573	−0.280
Syngnathus floridae	0.572	−0.513
Farfantepenaeus duorarum	0.353	−0.621
Tozeuma carolinense	0.756	−0.637

rollerframe trawls ($F_{1,97}$ = 117.82, P < 0.001; Fig. 6c). Site was also a significant factor for all three response variables [fauna density ($F_{2,97}$ = 4.25, P = 0.02), observed richness ($F_{2,97}$ = 19.25, P < 0.001), rarefied richness ($F_{2,97}$ = 8.61, P < 0.001); Fig. 6a–c], and there was no support for a gear*site interaction. Thus, it can be concluded that: (1) the rollerframe trawls collected higher densities and diversity of fauna across three significantly different seagrass habitats and associated communities, (2) the effects on observed species richness were attributable to larger catches, and (3) the gear effects were not contingent upon site.

4. Discussion

In general, the rollerframe trawl captured higher abundances and more species of fishes and invertebrates than the otter trawl. Our findings are consistent with previous studies showing that the otter trawl has a relatively low capture efficiency for many of the fauna found in seagrass habitats (see review by Rozas and Minello, 1997). Moreover, our study demonstrated that the higher capture rate in rollerframe trawls was consistent across different seagrass beds as well as for species ranging in density from high to low and occurrence from common to rare. Future studies may benefit from the inclusion of this gear that has thus far been largely overlooked by field researchers.

The differences we observed between the two gears were consistent across three sites with different seagrass habitats and different associated communities. Despite site-specific variance in compositions of seagrass species, blade lengths, and substrate, rollerframe trawls consistently captured higher abundances of animals than the otter trawls. Thus, the increased catch was not contingent upon site or any within-site characteristics across the habitats included here, which are themselves representative of that found across the seagrass beds of the greater northeastern Gulf of Mexico region (Stallings and Koenig, 2011). The higher catch in rollerframe trawls was also a general pattern across a wide range of taxa of varying shapes, sizes, and relative densities, which suggests the effectiveness of this gear at capturing the predominant species observed in seagrass beds. Moreover, the rollerframe trawls

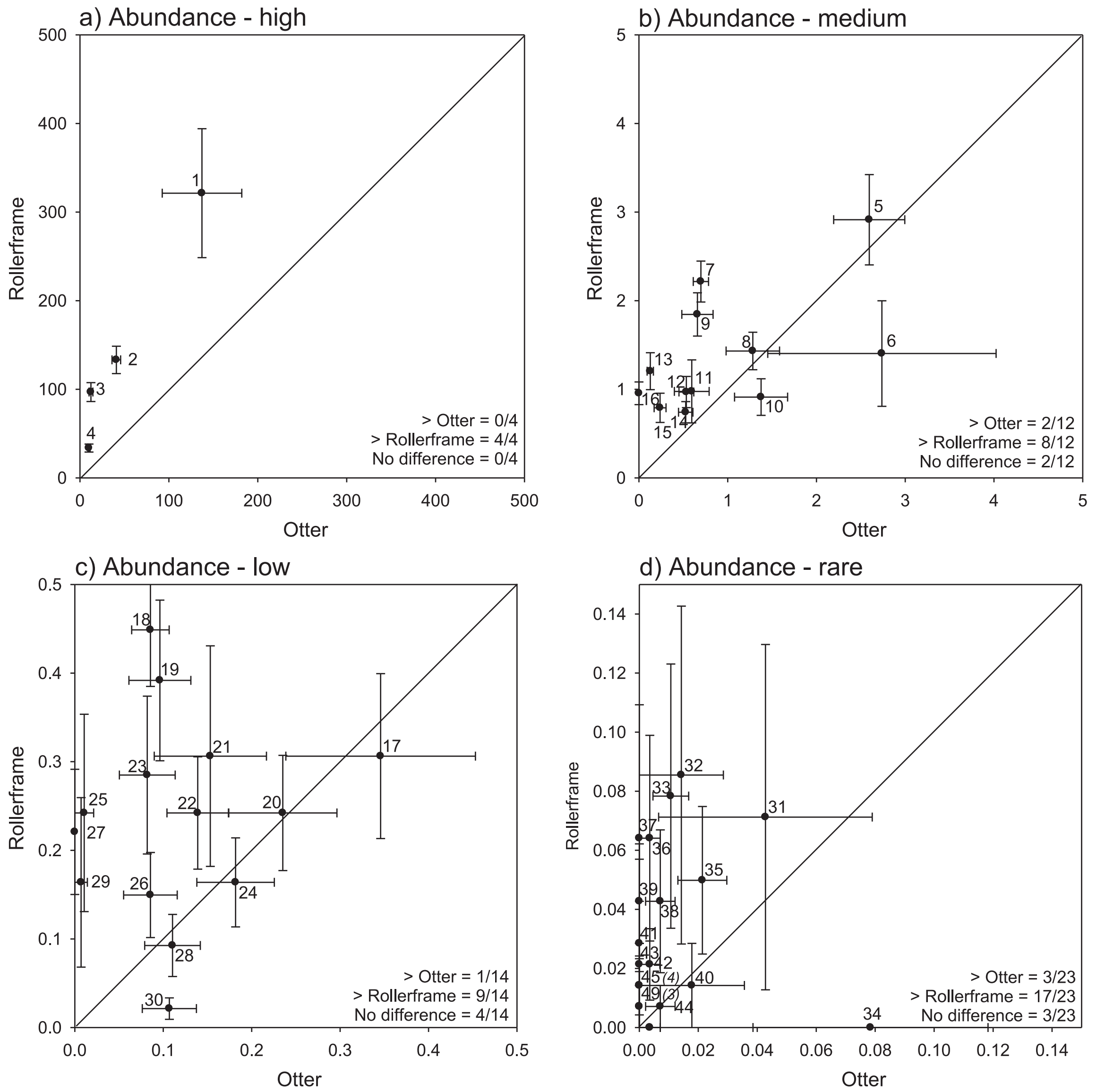

Fig. 5. Mean density (±se) observed for each species in the catch from otter trawls versus rollerframe trawls per 100 m^2 of seagrass. To simplify visualization, the plots are separated by relative abundance: (a) high (>5 individuals/100 m^2), (b) medium (>0.5/100 m^2), (c) low (>0.1/100 m^2) and (d) rare (<0.1/100 m^2). The 1:1 values are shown with the diagonal line. Species below the line (including error bars) were captured in higher densities by otter trawls, those above the line were higher in rollerframe trawls, and those that cross the line were not significantly different between the two gears. The fractions observed for each of these three possible outcomes are shown in the bottom right corner of each plot. Numbers represent species abundance rank (see Table 1).

captured 13 species that were not collected by otter trawls (compared to only three in the otter trawl, but absent in the rollerframe gear) for a net difference of 10 additional species (50 in rollerframe, 40 in otter). This 25% increase in species richness from otter to rollerframe trawls can affect estimates of gamma diversity and related biodiversity metrics that are important to ecosystem-level models and management.

Leber and Greening (1986) also found that the otter trawl did not perform as well as another commonly-used gear, the crab scrape, in seagrass beds of the northeastern Gulf of Mexico. The authors suggested a mechanism to explain the reduced catch in otter trawls, whereby despite the weight of the tickler chain, the net tended to ride above the substrate in seagrass beds. Thus, many animals that seek refuge from the oncoming gear by diving towards the bottom are not captured by the otter trawl. Observations (in situ) made while testing the two gears before the study began, as well as our catch data, support the same conclusions and mechanism as Leber and Greening (1986). In comparison, we noticed that the rigid and relatively heavy rollerframe trawls did not ride on top of the seagrass, thus eliminating the refuge afforded by otter trawls and leading to greater catches. Although otter trawls can be equipped with rollers across the footrope, the primary purpose of doing so is to lift the trawl off the bottom to reduce damage to both the net and benthic habitats (Ball et al., 2003; Watling, 2005), thus they may also allow animals to escape under the net in seagrass habitats. Note that despite the mass of the rollerframe trawl, Meyer et al. (1999) did not find evidence that it caused damage to the seagrass habitats. Moreover, the upward "rolling" mechanism on the aft-side of the rollers may kick animals into the water column from the substrate and into the net of the rollerframe trawl as it moves forward, thus increasing its capture efficiency. Additionally, the fixed mouth opening in beam trawls, like that in rollerframe trawls, has been attributed to having higher and less variable capture efficiencies compared to otter trawls (Kuipers et al., 1992), which may have been an important factor here. Future tests of capture efficiency by the rollerframe trawl may be accomplished by

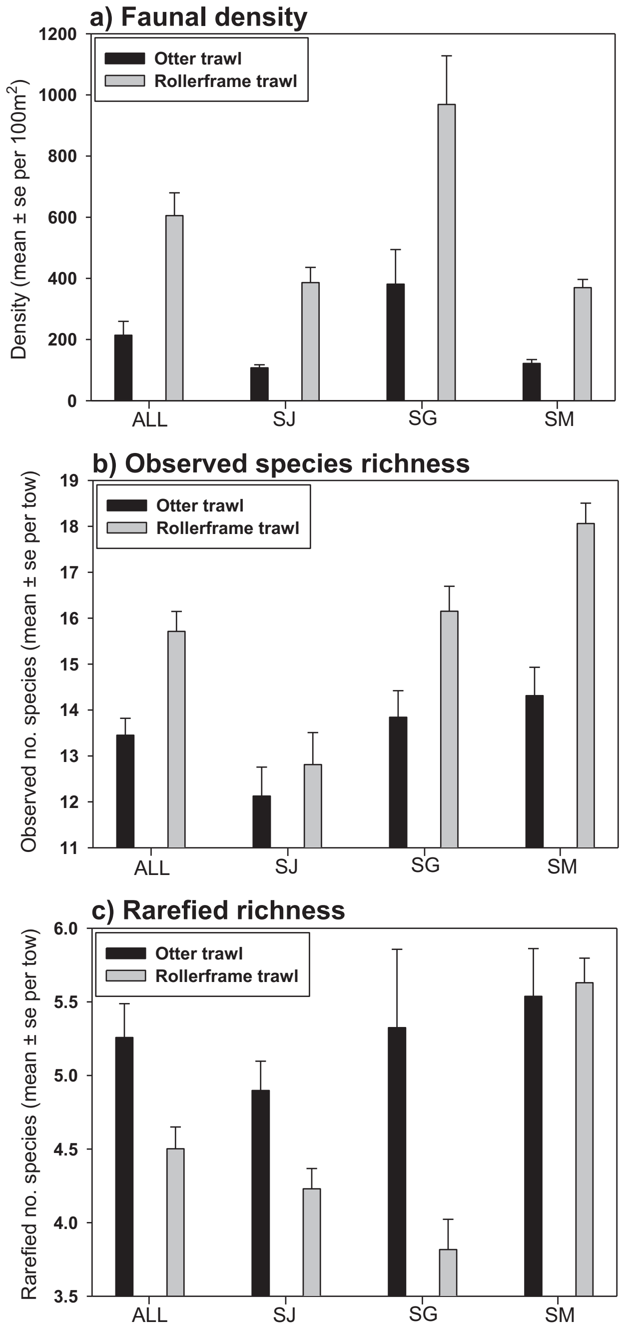

Fig. 6. Mean (±se) catch comparisons of catches from otter trawls (black bars) and rollerframe trawls (grey bars) for (a) faunal density, (b) observed species richness, and (c) rarefied species richness. Data are summarized both across (ALL) and within sites (SJ = St. Joe Bay, SG = St. George Sound, SM = St. Marks).

first estimating absolute abundances either for particular species of interest via mark-recapture approaches (e.g., Koenig and Coleman, 1998) or more generally via a catch-effort method (Krebs, 1989; Reiss et al., 2006).

The otter trawl had a higher capture rate for six of the 53 species we observed, which may provide some clues about the capture mechanisms and selectivity of the rollerframe trawl. The relatively low capture rate of the Longnose Spider Crab (*Libinia dubia*) and the Longtail Grass Shrimp (*Periclimenes longicaudatus*) by the rollerframe trawl, suggests the presence of the vertical excluder bars may select against large fauna with a hard exoskeleton and those associated with large clumps of drift algae, respectively. However, the horizontal or vertical spacing of the excluder bars can be modified to accommodate specific research needs, which may reduce selectivity. The rollerframe trawl likely passed under fishes that swam in the upper water column (e.g., *Engraulis eurystole*). A substantial modification of the rollerframe height would be required to increase capture of upper water column species due to the gear's towing angle of approximately 30°, thus otter trawls are likely better for such fishes. Interestingly, Black Seabass (*Centropristis striata*) were captured at higher rates in otter trawls, perhaps due to their attraction to disturbances from the trawl doors followed by a herding effect (C. Stallings pers. obs.). The remaining two species captured in higher abundances in the otter trawl (*Lophogobius cyprinoides and Scorpaena brasiliensis*) were the least common in the study, suggesting a sampling effect rather than gear selectivity (Gotelli and Colwell, 2001).

Although rollerframe trawls had higher catch rates in seagrass beds, the gear has several disadvantages relative to otter trawls that likely explain its limited use thus far by ecologists and fisheries scientists. The otter trawl is readily available from numerous commercial suppliers, while the rollerframe trawl would require a special order or fabrication. Additionally, field researchers generally need no more than a seaworthy vessel with at least one cleat located astern to tow an otter trawl. Contrarily, towing rollerframe trawls from amidships required fabrication (after some considerable thought on the design) of a retractable boom and winch system on the vessel. Small rollerframe trawls, such as those used here, could also be towed astern, but a boom or A-frame system would still be required due to their weight and rigidity relative to otter trawls. Last, otter trawls are relatively easy to deploy and retrieve; generally requiring no more than two people when used in seagrass beds. Indeed, an experienced field researcher alone can make short tows with the otter trawl by switching from net deployment, to vessel operation, and back to net retrieval after the tow has been completed. On the other hand, the rollerframe trawls are heavy and cumbersome, requiring a minimum of three people, and preferably four, for proper and safe deployment and retrieval; the vessel operator must keep the boat moving forward and relatively straight to keep the nets away from the propeller(s), one person each on the starboard and port winches, and one person on the cheater lines attached to the cod ends of the nets. Researchers must therefore weigh the advantages of higher catch rates and precision afforded by rollerframe trawls against the logistics and costs of using them.

Despite the few logistical difficulties that must be overcome to use rollerframe trawls, we hope that our findings garner interest among researchers working in seagrass beds and other soft-bottom habitats with SAV where otter trawls may not provide the most efficient means to capturing associated fauna. We recognize that otter trawls have become, and will continue to be, a common gear for research in seagrass beds. Moreover, otter trawls have been used extensively over several decades of research in seagrass beds, so efforts aimed at understanding population, community or state change in these ecosystems over time (e.g., Fodrie et al., 2010; Buchheister et al., 2013; Sobocinski et al., 2013) are best accomplished by keeping all aspects of the gears and methodologies as consistent as possible. However, given the higher capture rate and increased precision compared to otter trawls, we suggest the rollerframe trawl can be an excellent alternative or supplemental gear for the toolbox of ecologists and fisheries scientists working in seagrass beds and for other SAV habitats.

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References

Abele, L.G., Kim, W., 1986. An Illustrated Guide to the Marine Decapod Crustaceans of Florida. State of Florida, Dept. of Environmental Regulation, Tallahassee, FL.

Ball, B., Linnane, A., Munday, B., Davies, R., McDonnell, J., 2003. The rollerball net: a new approach to environmentally friendly ottertrawl design. Arch. Fish. Mar. Res. 50, 193–203.

Baum, J.K., Meeuwig, J.J., Vincent, A.C.J., 2003. Bycatch of lined seahorses (*Hippocampus erectus*) in a Gulf of Mexico shrimp trawl fishery. Fish. Bull. 101, 721–731.

Berkeley, S.A., Pybas, D.W., Campos, W.L., 1985. Bait shrimp fishery of Biscayne Bay. In: Florida Sea Grant Extension Program, Gainesville, FL, USA.

Buchheister, A., Bonzek, C.F., Gartland, J., Latour, R.J., 2013. Patterns and drivers of the demersal fish community of Chesapeake Bay. Mar. Ecol. Prog. Ser. 481, 161–180.

Coleman, F.C., Koenig, C.C., 1998. Florida inshore bait shrimping: experimental analysis of bycatch reduction efficiencies of rollerframe trawls and capture-related mortality of selected seagrass-associated finfish species. NOAA MARFIN Final Report (Award No. NA57FF0048).

Crawford, C.R., Steele, P., McMillen-Jackson, A.L., Bert, T.M., 2011. Effectiveness of bycatch-reduction devices in roller-frame trawls used in the Florida shrimp fishery. Fish. Res. 108, 248–257.

de Madron, X.D., Ferre, B., Le Corre, G., Grenz, C., Conan, P., Pujo-Pay, M., Buscail, R., Bodiot, O., 2005. Trawling-induced resuspension and dispersal of muddy sediments and dissolved elements in the Gulf of Lion (NW Mediterranean). Cont. Shelf Res. 25, 2387–2409.

De Sylva, D.P., 1954. The Live Bait Shrimp Fishery of the Northeast Coast of Florida. State of Florida, Board of Conservation, Coral Gables, FL.

Fodrie, F.J., Heck, K.L., Powers, S.P., Graham, W.M., Robinson, K.L., 2010. Climate-related, decadal-scale assemblage changes of seagrass-associated fishes in the northern Gulf of Mexico. Glob. Change Biol. 16, 48–59.

Gotelli, N.J., Colwell, R.K., 2001. Quantifying biodiversity: procedures and pitfalls in the measurement and comparison of species richness. Ecol. Lett. 4, 379–391.

Hein, S., Meier, P., 1995. Skimmers: their development and use in coastal Louisiana. Mar. Fish. Rev. 57, 17–24.

Hoese, H.D., Moore, R.H., 1998. Fishes of the Gulf of Mexico, Texas, Louisiana, and Adjacent Waters. Texas A&M University Press, College Station, TX.

Humann, P., DeLoach, N., 2002. Reef Fish Identification. New World Publications, Jacksonville, FL.

Kaplan, E.H., Peterson, R.T., 1988. A Field Guide to Southeastern and Caribbean Seashores: Cape Hatteras to the Gulf Coast, Florida, and the Caribbean. Houghton Mifflin, Boston, MA.

Koenig, C.C., Coleman, F.C., 1998. Absolute abundance and survival of juvenile gags in sea grass beds of the Northeastern Gulf of Mexico. Trans. Am. Fish. Soc. 127, 44–55.

Krebs, C.J., 1989. Ecological Methodology. Harper and Row, New York.

Kubecka, J., Godo, O.R., Hickley, P., Prchalova, M., Riha, M., Rudstam, L., Welcomme, R., 2012. Fish sampling with active methods. Fish. Res. 123, 1–3.

Kuipers, B.R., Maccurrin, B., Miller, J.M., Vanderveer, H.W., Witte, J.I.J., 1992. Small trawls in juvenile flatfish research: their development and efficiency. Neth. J. Sea Res. 29, 109–117.

Leber, K.M., Greening, H.S., 1986. Community studies in seagrass meadows – a comparison of two methods for sampling macroinvertebrates and fishes. Fish. Bull. 84, 443–457.

Main, J., Sangster, G.I., 1981. A study of sand clouds produced by trawl boards and their possible effects on fish capture. Scottish Fisheries Research Report No. 20.

McCune, B., Mefford, M.J., 1999. PC-ORD. Multivariate Analysis of Ecological Data. MjM Software, Gleneden Beach, OR.

McEachran, J.D., Fechhelm, J.D., 1998. Fishes of the Gulf of Mexico. University of Texas Press, Austin, TX.

Meyer, D.L., Fonseca, M.S., Murphey, P.L., McMichael, R.H., Byerly, M.M., LaCroix, M.W., Whitfield, P.E., Thayer, G.W., 1999. Effects of live-bait shrimp trawling on seagrass beds and fish bycatch in Tampa Bay, Florida. Fish. Bull. 97, 193–199.

Oksanen, J., Blanchet, F.G., Kindt, R., Legendre, P., Minchin, P.R., O'Hara, R.B., Simpson, G.L., Solymos, P., Stevens, M.H.H., Wagner, H., 2013. vegan: Community Ecology Package. R package Version 2.0-7, http://CRAN.R-project.org/package=vegan

O'Neill, F.G., Knudsen, L.H., Wileman, D.A., McKay, S.J., 2005. Cod-end drag as a function of catch size and towing speed. Fish. Res. 72, 163–171.

Pusceddu, A., Gremare, A., Escoubeyrou, K., Amouroux, J.M., Fiordelmondo, C., Danovaro, R., 2005. Impact of natural (storm) and anthropogenic (trawling) sediment resuspension on particulate organic matter in coastal environments. Cont. Shelf Res. 25, 2506–2520.

Queirolo, D., Hurtado, C.F., Gaete, E., Soriguer, M.C., Erzini, K., Gutierrez-Estrada, J.C., 2012. Effects of environmental conditions and fishing operations on the performance of a bottom trawl. ICES J. Mar. Sci. 69, 293–302.

R Core Team, 2013. A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria, ISBN 3-900051-07-0, URL: http://www.R-project.org/

Reiss, H., Kroncke, I., Ehrich, S., 2006. Estimating the catching efficiency of a 2-m beam trawl for sampling epifauna by removal experiments. ICES J. Mar. Sci. 63, 1453–1464.

Robins, C.R., Ray, G.C., Douglass, J., Freund, R., National Audubon Society, National Wildlife Federation, 1986. A Field Guide to Atlantic Coast fishes of North America. Houghton Mifflin, Boston, MA.

Rozas, L.P., Minello, T.J., 1997. Estimating densities of small fishes and decapod crustaceans in shallow estuarine habitats: a review of sampling design with focus on gear selection. Estuaries 20, 199–213.

Schoellhamer, D.H., 1996. Anthropogenic sediment resuspension mechanisms in a shallow microtidal estuary. Estuar. Coast. Shelf Sci. 43, 533–548.

Sobocinski, K.L., Orth, R.J., Fabrizio, M.C., Latour, R.J., 2013. Historical comparison of fish community structure in lower Chesapeake Bay seagrass habitats. Estuar. Coasts 36, 775–794.

Stallings, C.D., Koenig, C.C., 2011. Faunal communities of the Big Bend seagrass meadows. FWC State Wildlife Grants Initiative Final Report (Grant # 08007).

Tabb, D.C., Kenny, N., 1969. A brief history of Florida's life bait shrimp fishery with description of fishing gear and methods. FAO Fish. 3, 1119–1134.

Upton, H.F., Hoar, P., Upton, M., 1992. The Gulf of Mexico Shrimp Fishery: Profile of a Valuable National Resource. Center for Marine Conservation, Washington, DC.

Voss, G.L., 2002. Seashore Life of Florida and the Caribbean. Dover, Mineola, NY.

Watling, L., 2005. The global destruction of bottom habitats by mobile fishing gear. In: Norse, E.A., Crowder, L.B. (Eds.), Marine Conservation Biology: The Science of Maintaining the Sea's Biodiversity. Island Press, Washington, DC.

Zar, J.H., 1999. Biostatistical Analysis. Simon & Schuster, Upper Saddle River, NJ.

Supplemental Fig. I. Photograph of the experimental trawls attached to the retractable boom system fabricated for the research vessel used in the current study. When fully deployed in shallow seagrass beds (2-3m depths), approximately 10m of tow warp is required from the extended boom (A). During the tow, the frames will orient at an approximately 30º angle from the substrate (whereas they are at 90º angle in the photo). The booms serve to hold the trawls off the side of the vessel, while the tension is placed on a forward-located cross bar through the tow cable (B). The hinged booms are retractable to mount flush with an A-frame located amidships (C).