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Using Kappenman's Model to Compare the Relative Fishing Power of 42-Foot Shrimp Trawls and 65-Foot Fish Trawls During Summer and Fall in the Western and North-Central Gulf of Mexico

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Kappenman's fishing power correction (FPC) model was used to compare the fishing efficiency between a 42-ft shrimp trawl and a 65-ft fish trawl towed simultaneously at 985 stations by the National Oceanic and Atmospheric Administration ship *Oregon II* in the western and north-central Gulf of Mexico. The shrimp trawl was consistently more efficient, both summer and fall, and regardless of whether using no./hr or kg/hr to calculate the FPC factors, for four species of fish, three species of crustaceans, and paper scallops. During summer, the shrimp trawl was more efficient, when using FPC factors calculated using no./hr as the catch per unit of effort (CPUE), at catching 13 of the 42 species of fish, 11 of the 12 species of crustaceans, and paper scallops. It was more efficient at catching 18 of the 42 species of fish, 10 of the 12 species of crustaceans, and paper scallops when FPC factors were calculated using kg/hr as the CPUE. In the fall, the shrimp trawl was more efficient, when using no./hr or kg/hr as the CPUE, at catching five species of fish, three species of crustaceans, and paper scallops. Fishing power correction factors were then compared between summer and fall seasons for 42 species of fish and 16 species of invertebrates. During summer, FPC values ranged from a low of 0.15 for Gulf menhaden to 4.94 for shoal flounder; fall FPC values ranged from 0.05 for yellow box crab to 2.52 for broad-striped anchovy. With the exception of three species, when using number of individuals caught per hour as the CPUE, all FPC factors were significantly different between summer and fall catches.

INTRODUCTION

Abundance estimates of fish stocks are based on catch-per-unit-of-effort (CPUE) data using standard vessels, fishing gear, and techniques. Fishing gear and vessels change over time, causing difficulties in determining characteristics of species composition of the communities, characteristic species of the assemblages, and characteristics of a particular species between different vessels and gears (Wantiez, 1996). A standardized CPUE is accomplished by calibrating the fishing powers exerted by different vessels, gears, and/or vessel and gear combinations using several methods for determining fishing power correction (FPC) factors (Gulland, 1956; Beverton and Holt, 1957; Robson, 1966; Fanning, 1985).

Kappenman (1992) developed a fishing power correction estimator based on the ratio of scale parameters of the distributions of two positive random variables (CPUE). Kappenman stated that, because estimates of abundance are sensitive to the estimate of the FPC used, a good estimate of the FPC is critical, and he argued that his FPC estimator provided a good, robust estimator. He recommended that it be used specifically in cases where a vessel's CPUE data were to be adjusted by multiplying them by an estimate of the FPC and that the specified vessel need not be the least efficient one. The Kappenman FPC estimator assumes that the two CPUE variables have unknown but identical distributions, except possibly for the values of the scale parameters of the distributions.

Munro (1998) suggested using mean square error (MSE) as a measure of error between the estimator of mean CPUE and the true CPUE. If applying the fishing power correction factor reduces MSE, then the decision is made to use the FPC transformed catch rates as abundance estimators.

Adjusting data from multiple surveys and combining the CPUE data can result in significant changes in estimates of relative abundance of a species (von Szalay, 2003). Von Szalay and Brown (2001) applied the MSE decision rule in a study to decide whether to transform CPUE catch rates and found three significantly different length-based FPC values for three size classes of walleye pollock (*Theragra chalcogramma*). Von Szalay (2003) integrated data from separate surveys using Kappenman's model-derived FPC to adjust CPUE data, and the resulting relative abundance estimate was 22% higher than using only National Marine Fisheries Service (NMFS) survey data. The following year, estimates of abundance were 82% higher when combining survey data. Brown and Zenger (1998) also noted differences in size selectivity of FPC values for some species.

NMFS surveys are designed to account for many species simultaneously rather than being stratified to account for density variations of a single species. Resulting yield estimates can result in less precision for an individual species than if a stratified sampling design was used specifically for that species. Combining data from multiple surveys with different vessel/gear combinations can result in reducing the variance of the yield estimates for a particular species of interest.

The objectives of this study were to use Kappenman's model to examine the differences in fishing power between a 42-ft shrimp trawl (ST) and a 65-ft fish trawl (FT) in order to determine both the suitability of applying the FPC to the CPUE data and to determine whether seasonal-based, species-specific differences in CPUE FPC factors are significant. The two trawls were towed side-by-side off the National Oceanic and Atmospheric Administration (NOAA) ship *Oregon II* (*O-II*). Only species of fishes and invertebrates in which the CPUE was nonzero in both nets simultaneously were selected for analyses, resulting in a total of 58 species of fishes and invertebrates considered in this study.

Methods and Materials

In 1972 the NMFS Mississippi Laboratory initiated a resource survey program for collection, management, and dissemination of fishery independent data for determining the abundance and distribution of the multispecies demersal fishery resources in the Gulf of Mexico. These surveys are referred to as groundfish surveys. The data were primarily collected by the *O-II* between 88°00″ west longitude to the U.S.–Mexico border, and in depths from the 5 fathom (fm) isobath seaward to the 60 fm isobath. Summer groundfish surveys are conducted each year in June and July, and fall surveys are conducted in Oct. and Nov. Stations are randomly selected prior to the cruise using a stratified random design with NMFS shrimp statistical subareas (Patella, 1975), depth zones, and day–night (diel) as strata. Tows are usually made perpendicular to the depth contours, although tows at steep bottom profiles are made at an angle to minimize significant depth changes. Samples are acquired with a 42-ft shrimp trawl (Fig. 1) towed at a speed of approximately 3 knots. The duration of the tow is determined by the change in bottom depth and can range from 5 to 55 min. Multiple tows are sometimes required at a station when the change in bottom slope is gradual. The tows are ended with a 5-min pulse in the vessel's speed to flush the catch to the cod end of the net.

NMFS also does other types of surveys using other nets, longlines, cameras, etc. With new ships under construction and new surveys under consideration, other size nets are being considered for deployment that might be more efficient for sampling other fish species and/or at greater depths. One net under consideration for new surveys is a 65-ft fish trawl (Fig. 2). Prior to deploying a different vessel or net, the gear is calibrated with the 42-ft shrimp trawl so that catches of species caught in both nets can be merged to learn more about a species' range and density. Extensive data have been collected with the 65-ft fish trawl to calibrate it with the 42-ft shrimp trawl prior to deploying it on any new surveys.

The *O-II* acquired over 1,000 paired trawl samples during seven summer groundfish cruises from 1987 through 1993 and six fall groundfish cruises from 1987 through 1992 at randomly selected stations to conduct a gear intercalibration study. The 42-ft shrimp trawl was towed from an outrigger (usually on the port side), while the 65-ft fish trawl was towed simultaneously from an outrigger on the starboard side of the vessel. Which side of the vessel a net was on and the depth and direction of tow were not important variables because the bottom terrain of the Gulf of Mexico shelf in the study area is relatively flat. Both nets were deployed and retrieved simultaneously. The CPUE data were to be used to determine whether fishing power corrections were needed between the two separate nets.

Data from 985 stations were selected for further analyses after some stations were deleted for reasons related to net and gear performance, e.g., torn or lost nets, or trawl doors failing to separate. Data were used from a total of 516 stations from summer cruises and 469 stations from fall cruises. Organisms captured in the nets were identified, sorted, enumerated, and weighed, and length-frequency measurements were collected for a subsample of individuals from all species. Catches were standardized to 1 hr so that all catches for the purpose of this analysis were expressed as number of individuals per hour (no./hr) and kilograms per hour (kg/hr). Depending on the species and season, the number of data pairs available in which the CPUE of the species of interest was nonzero in both nets simultaneously ranged from 3 to 322.

A total of 42 species of fish and 16 species of invertebrates were selected for further analyses. These CPUE data were examined using Kappen-

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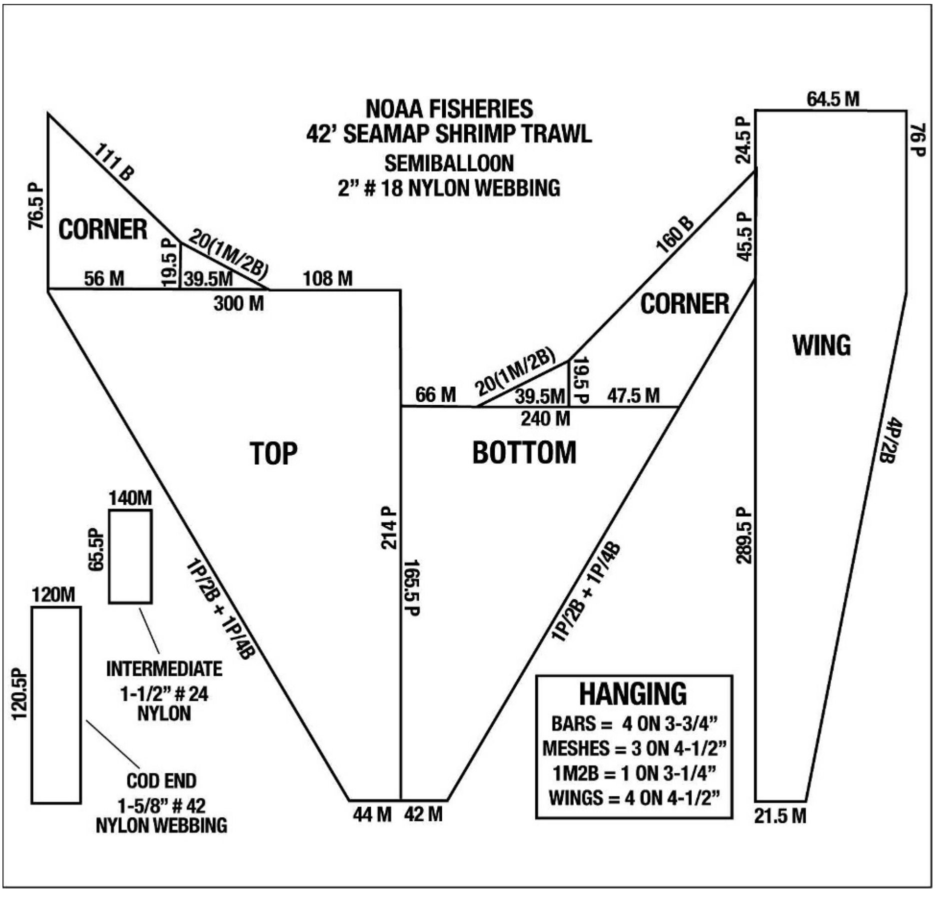

Fig. 1. Diagram of NOAA Fisheries' (NMFS) 42-ft shrimp trawl used in the comparative tow project.

man's fishing power correction factor model. Kappenman's model was used because it is robust, because paired trawl samples are not required, because it is the method currently used by the NMFS Alaska Fisheries Science Center, and because it is less sensitive to infrequent large catches (Munro and Hoff, 1995). Although paired tows are not required by the Kappenman model, only paired tows were used in this study. Paired tows in which either net had a zero catch for a particular species were deleted from the analyses because Kappenman's model does not support zeros (Wilderbuer et al., 1998; Troncoso and Paz, 2003; Troncoso, 2004) and the CPUE values are required to be positive random variables (von Szalay and Brown, 2001).

The same approach was used in this study that was used by von Szalay and Brown (2001). Variances and root mean square errors (RMS) were estimated by using the original data sets to bootstrap 1,000 new data sets and calculating FPC factors for all data sets, for all species, for both summer and fall. A root mean square error was used instead of mean square error simply because it was more convenient. This is a valid approach because the RMS is the square root of the absolute value of the MSE. Each data set for each species for each season was resampled with replacement (Troncoso and Paz, 2003) to create the 1,000 new data sets and to calculate the subsequent 1,000 FPC factors for all species for each season. The 1,000 FPC factors were averaged and compared for each species by season using analysis of variance (ANOVA).

Kappenman's model-derived FPC was then applied to the 65-ft fish trawl CPUE values, and the RMS was compared between preapplied 65-ft fish trawl CPUE values and the postapplied 65-ft fish trawl CPUE values. FPC values were calculated for CPUE data from the 42-ft shrimp trawl (the standard for this study) and the 65-ft fish trawl. The 65-ft trawl CPUE data were then multiplied by the derived FPC. If the RMS was reduced after applying the FPC to the fish trawl CPUE from the RMS calculated from the original 65-ft trawl CPUE data, then the decision was

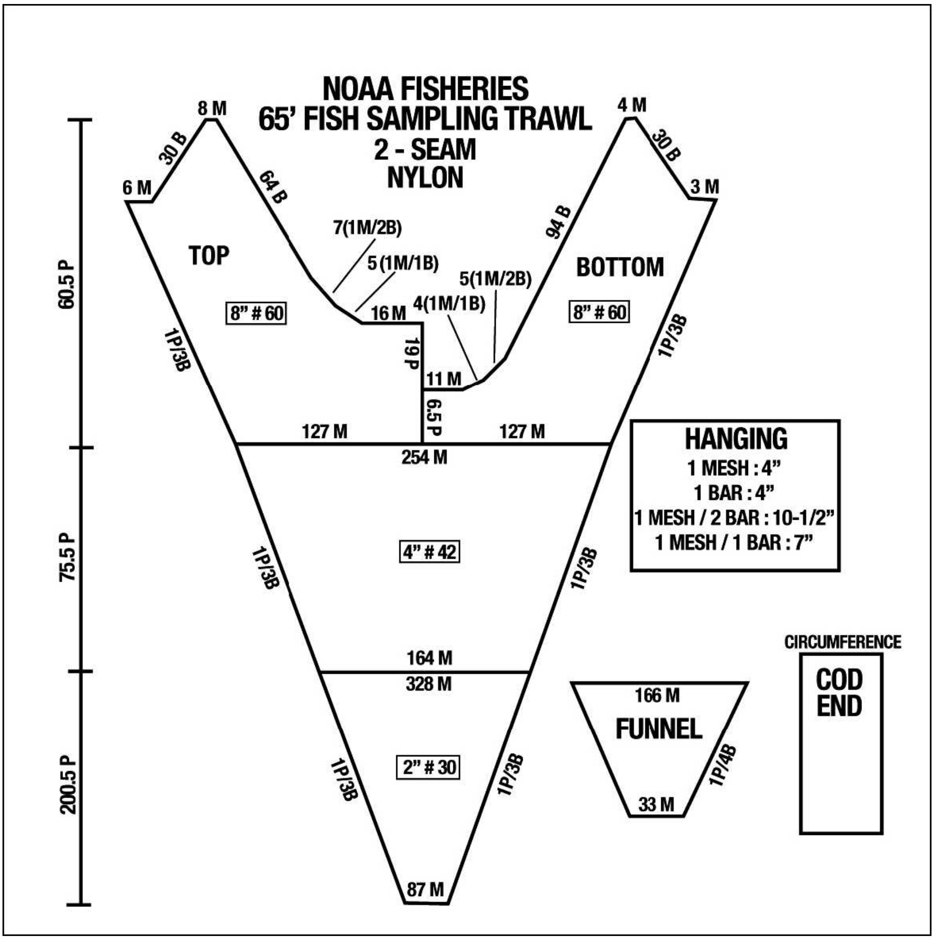

Fig. 2. Diagram of NOAA Fisheries (NMFS) 65-ft fish trawl used in the comparative tow project.

made to use the derived FPC to transform the data.

Results

Longspine porgy were caught simultaneously in both trawls more often (571 of the 985 paired tows) (Table 1) than any other species, followed by brown shrimp (525 of the 985 paired tows) and inshore lizardfish (475 pairs). The yellow box crab was caught the fewest number of times simultaneously in both nets (15 of 985 paired tows), followed by planehead filefish (21 pairs) and bigeye scad (21 pairs). In the summer surveys, longspine porgy were also the most often caught simultaneously in both nets (322), followed by Gulf butterfish (252 pairs), and brown shrimp (278 pairs). Mexican flounder was caught the least often in both nets simultaneously in the summer surveys (6 pairs), followed by bigeye scad (6 pairs) and sash flounder (8 pairs). In the fall, however, Atlantic croaker was caught the most often in both nets simultaneously (272), and yellow box crab was caught the least often (3 times) in both nets.

The mean CPUE (with no zero catches used in the calculations) declined in the fall, when expressed as both no./hr and kg/hr, for 16 species (10 fish, 3 crustaceans, and 3 other invertebrates) (Table 1). They both increased in the fall for 13 species (11 fish and 2 crustaceans). For 13 species (8 fish, 4 crustaceans, and paper scallops), the mean CPUE went down in the fall for both catch rates in the shrimp net but up in the fall for both catch rates in the fish trawl. For five species of fish, mean catch rates went down in the fall for no./hr in both nets, but up in both nets for kg/hr, suggesting an overall size increase for these species. For the remaining nine species of fish and two species of crustaceans, mean catch rates varied with no discernable pattern.

There was variation in species-specific FPC values depending on whether no./hr or kg/hr was used for the CPUE (Table 2). However, FPC values tended to reflect each other in terms of increasing or decreasing values. A linear regression analysis of the 58 summer FPC factors (no./hr) against the summer FPC factors (kg/hr) resulted in an r^2 of 0.8973 and a slope of 0.7938 ($F = 489.2010$, $P < 0.01$). A linear regression of the 58 fall FPC values (no./hr) on fall FPC values (kg/hr) resulted in an r^2 of 0.9102 and a slope of 1.0052 ($F = 567.5499$, $P < 0.01$).

In summer, the FPC factors ranged from 4.94 (shoal flounder, no./hr) to a low of 0.15 for Gulf menhaden when using no./hr (Table 2). The 42-ft shrimp trawl was more efficient, when using FPC factors calculated using no./hr as the CPUE, at catching 13 of 42 species of fish, 11 of the 12 species of crustaceans, and paper scallops. It was more efficient at catching 18 of the 42 species of fish, 10 of the 12 species of crustaceans, and paper scallops when FPC factors were calculated using kg/hr as the CPUE. The shrimp trawl was more efficient at catching Atlantic bumper when using kg/hr to calculate the FPC (1.01), but less efficient when using no./hr to calculate the FPC (0.27). The same pattern was observed for lane snapper, bigeye scad, sash flounder, and southern codling. The shrimp trawl was more efficient at catching lesser rock shrimp when using no./hr to calculate the FPC (1.13) but less efficient when using kg/hr to calculate the FPC (0.79).

In the fall, FPC values ranged from a high of 2.52 for broad-striped anchovy when calculated using no./hr to a low of 0.05 for yellow box crab when using no./hr. The shrimp trawl was more efficient, when using no./hr as the CPUE, at catching five species of fish, three species of crustaceans, and paper scallops. When using kg/hr as the CPUE for calculating the FPC, the shrimp trawl was also more efficient at catching five species of fish, three species of crustaceans, and paper scallops. It was more efficient at catching blackear bass when using no./hr, but less efficient when using kg/hr, and less efficient at catching sash flounder when using no./hr but more efficient when using kg/hr as the CPUE. It was more efficient at catching the crustaceans and paper scallops regardless of whether using no./hr or kg/hr.

Bootstrapped FPC data sets were used to compare summer and fall data sets. The FPC values calculated from no./hr CPUE data were not significantly different for Atlantic brief squid, red snapper, and shortwing searobin. All other FPC values, from both no./hr and kg/hr CPUE data sets, were highly significantly different between summer and fall (ANOVA, $P < 0.02$). The shrimp trawl was consistently more efficient, both in summer and fall and regardless of whether using no./hr or kg/hr to calculate the FPC factors, for four species of fish (broad-striped anchovy, Atlantic midshipman, short-beard cusk-eel, and Brazilian lizardfish), three species of crustaceans (brown shrimp, white shrimp, and brown rock shrimp), and paper scallops.

The calculated FPC factors tended to be lower in the fall than in the summer when using no./hr as the CPUE. The FPC was lower in the fall for 32 of the 40 species of fish under consideration, 11 of the 12 species of crustaceans, and paper scallops. It remained unchanged for three fish species, one crustacean species, and Atlantic brief squid. The FPC value increased in the fall for only five species of fish and longfin inshore and arrow squids. The pattern was similar when using kg/hr to calculate FPC values. Again, 32 species of fish, 11 species of crustaceans, and one species of other invertebrates had FPC values lower in the fall than in summer.

During summer, the RMS decision rule resulted in the decision to transform the fish trawl no./hr CPUE data for 30 of the 42 species of fish (Table 3). When the decision rule was applied to crustaceans and other invertebrates, the decision was made to transform both no./hr and kg/hr CPUE data for all 11 species of crustaceans and four of the five species of other invertebrates; the exception was paper scallop, which required no transformation on either CPUE data set. When using kg/hr as the CPUE and applying the decision rule, the decision was made to transform only 25 of the 42 fish CPUE data sets. The decision to transform the fish trawl CPUE data changed for five species: Atlantic bumper, lane snapper, bigeye scad, sash flounder, and southern codling. The results for these five species changed from requiring a transformation of the no./hr CPUE data to not requiring a transformation of the kg/hr CPUE data.

In the fall, the RMS decision rule resulted in the decision to transform the fish trawl no./hr CPUE data for 37 of the 42 species of fish (Table 3), but this number changed to 38 when using kg/hr as the CPUE. The results were reversed from deciding to transform kg/hr CPUE data to not transforming no./hr CPUE data for blackear bass. The rule resulted in the decision to transform both no./hr and kg/hr CPUE data for all nine species of crustaceans and three of the five species of other invertebrates. There were no reverses in the RMS rule decision for any of the invertebrates regardless of the CPUE used to calculate the FPC.

TABLE 1. Scientific and common names of species considered in this analysis, the number of times they were captured simultaneously in both nets, and mean catch per unit of effort in number per hour and kg per hour for both summer and fall (ST, shrimp trawl; FT, fish trawl).

Species	Common name	Summer					Fall				
		n	ST (no./hr)	FT (no./hr)	ST (kg/hr)	FT (kg/hr)	n	ST (no./hr)	FT (no./hr)	ST (kg/hr)	FT (kg/hr)
Fishes											
Anchoa hepsetus	Broad-striped anchovy	83	502.86	293.94	3.63	3.12	81	31.30	14.06	0.44	0.16
Centropristis philadelphica	Rock sea bass	133	20.83	15.01	0.84	0.78	175	52.24	60.00	2.27	2.93
Chloroscombrus chrysurus	Atlantic bumper	152	738.22	1,957.29	8.52	64.27	230	452.11	1,603.71	6.73	44.30
Cynoscion arenarius	Sand seatrout	75	108.49	96.43	5.42	7.09	178	61.92	96.61	6.59	8.92
Cynoscion nothus	Silver seatrout	58	115.92	225.78	5.90	11.38	92	62.44	2,116.18	2.87	5.57
Diplectrum bivittatum	Dwarf sand perch	113	17.38	28.28	0.44	0.27	123	15.91	18.06	0.28	0.39
Harengula jaguana	Scaled herring	100	104.44	273.20	2.65	7.20	89	141.26	178.82	3.50	5.84
Lagodon rhomboides	Pinfish	84	34.46	92.48	1.40	4.86	184	56.72	1,766.97	3.37	7.62
Leiostomus xanthurus	Spot croaker	65	275.52	276.71	16.97	19.28	200	176.29	247.71	18.85	30.71
Lutjanus campechanus	Northern red snapper	77	19.20	36.59	1.37	2.61	145	20.57	30.04	1.09	2.94
Micropogonias undulatus	Atlantic croaker	149	2,175.51	2,641.11	47.48	62.24	272	1,480.99	660.26	26.09	33.80
Peprilus burti	Gulf butterfish	252	352.77	476.96	9.38	16.62	190	158.57	531.55	10.15	36.64
Porichthys plectrodon	Atlantic midshipman	78	19.23	18.87	0.46	0.48	62	18.13	16.29	0.34	0.34
Prionotus longispinosus	Bigeye searobin	119	209.08	280.28	1.67	1.87	117	50.44	107.44	1.78	4.22
Prionotus paralatus	Mexican searobin	86	2,660.90	73.44	0.91	1.31	65	100.34	131.30	2.03	2.87
Prionotus stearnsi	Shortwing searobin	106	43.73	60.46	0.43	0.61	55	75.26	78.52	0.89	0.96
Pristipomoides aquilonaris	Wenchman	132	40.96	69.25	2.03	3.64	63	68.52	93.59	2.73	5.40
Serranus atrobranchus	Blackear seabass	76	28.64	22.61	0.51	0.40	103	42.48	36.22	0.52	0.52
Sphoeroides parvus	Least puffer	56	19.43	29.13	0.20	0.25	82	51.80	71.38	0.33	0.51
Stenotomus caprinus	Longspine porgy	322	1,373.80	1,971.28	8.88	17.42	249	371.90	917.68	13.24	32.66
Synodus foetens	Inshore lizardfish	206	26.67	33.18	2.17	2.08	269	29.75	49.29	3.22	4.77
Trachurus lathami	Rough scad	183	230.59	238.53	3.83	4.03	146	136.68	239.84	3.78	7.06
Trichiurus lepturus	Largehead hairtail	75	82.92	311.47	4.14	14.20	71	122.83	193.60	6.54	17.64
Upeneus parvus	Dwarf goatfish	126	42.07	58.32	0.93	1.50	85	33.90	79.49	0.93	2.58
Brevoortia patronus	Gulf menhaden	15	53.30	799.51	3.57	45.52	48	7.13	30.90	0.90	2.46
Cyclopsetta chittendeni	Mexican flounder	6	15.01	7.17	2.06	0.46	21	10.13	14.02	0.96	1.94
Etropus crossotus	Fringed flounder	43	96.36	29.99	1.31	0.62	44	32.78	49.69	0.53	0.75
Etrumeus teres	Round herring	75	202.87	383.29	1.52	3.46	31	161.32	81.10	3.28	1.32
Halieutichthys aculeatus	Pancake batfish	20	66.09	17.67	0.44	0.17	37	38.63	54.20	0.39	0.60
Lagocephalus laevigatus	Smooth puffer	20	15.24	16.82	0.18	0.57	21	5.94	7.47	0.35	0.88
Lepophidium brevibarbe	Shortbeard cusk-eel	19	23.23	10.32	1.12	0.50	28	37.51	31.52	1.46	1.22
Lutjanus synagris	Lane snapper	10	7.35	7.98	0.75	0.78	33	3.29	3.98	0.27	0.28

TABLE 1. Continued

Species	Common name	Summer					Fall				
		n	ST (no./hr)	FT (no./hr)	ST (kg/hr)	FT (kg/hr)	n	ST (no./hr)	FT (no./hr)	ST (kg/hr)	FT (kg/hr)
Monacanthus hispidus	Planehead filefish	14	11.86	12.75	0.40	0.47	7	3.74	7.22	0.16	0.38
Peprilus alepidotus	Harvestfish	29	10,824.41	79.86	0.51	1.85	45	2.97	7.52	0.08	0.51
Rhizoprionodon terraenovae	Atlantic sharpnose shark	18	14.40	25.41	4.37	8.03	24	1.90	4.26	2.48	8.18
Saurida brasiliensis	Brazilian lizardfish	102	10.76	10.41	0.10	0.08	29	9.05	5.20	0.05	0.04
Selar crumenophthalmus	Bigeye scad	6	9.61	12.11	1.30	0.73	15	4.81	25.88	0.57	3.14
Selene setapinnis	Atlantic moonfish	30	18.95	28.25	1.09	1.50	31	2.45	10.36	0.21	0.98
Syacium gunteri	Shoal flounder	19	74.38	13.83	1.37	0.38	24	27.57	42.39	0.83	0.94
Synodus poeyi	Offshore lizardfish	16	18.54	10.47	0.16	0.08	17	14.59	10.07	0.17	0.14
Trichopsetta ventralis	Sash flounder	8	19.70	7.54	0.61	0.19	26	27.33	24.77	0.76	0.74
Urophycis floridana	Southern codling	34	16.66	14.68	0.86	0.91	7	6.96	13.08	0.88	1.70
Crustaceans											
Callinectes similis	Lesser blue crab	228	410.27	402.20	5.38	4.60	183	108.11	266.54	2.26	5.61
Farfantepenaeus aztecus	Brown shrimp	278	313.09	183.32	3.95	2.37	247	20.94	18.81	0.56	0.44
Litopenaeus setiferus	White shrimp	105	48.25	45.28	1.75	1.68	147	91.32	96.15	1.77	1.78
Portunus spinicarpus	Longspine swimming crab	85	187.89	122.02	1.12	0.89	57	537.85	517.82	4.25	3.99
Portunus gibbesii	Iridescent swimming crab	57	70.77	99.68	0.33	0.46	111	75.18	120.27	0.47	0.76
Sicyonia brevirostris	Brown rock shrimp	98	303.37	105.75	2.99	1.12	68	155.99	142.64	2.44	2.30
Farfantepenaeus duorarum	Pink shrimp	55	68.25	42.78	1.24	1.01	45	4.96	5.70	0.14	0.15
Squilla empusa	Mantis shrimp	46	142.00	171.63	1.05	1.09	26	70.04	77.17	0.74	0.73
Sicyonia dorsalis	Lesser rock shrimp	36	73.82	146.78	0.16	0.32	20	57.24	69.57	0.43	0.55
Portunus spinimanus	Blotched swimming crab	27	33.39	42.91	0.66	0.60	18	8.33	14.63	0.14	0.25
Callinectes sapidus	Blue crab	31	107.98	16.41	2.44	1.10	5	14.83	27.43	0.62	4.16
Calappa sulcata	Yellow box crab	12	6.44	7.17	0.81	1.06	3	2.26	16.48	0.21	4.17
Other invertebrates											
Loligo pealei	Longfin inshore squid	129	159.90	188.26	2.73	3.50	91	59.02	43.02	1.07	1.23
Lolliguncula brevis	Atlantic brief squid	83	235.94	287.55	1.77	2.56	70	54.85	73.15	0.58	0.88
Loligo pleii	Arrow squid	161	244.80	332.33	4.65	7.28	33	79.67	62.60	0.78	1.03
Amusium papyraceum	Paper scallop	27	122.29	20.97	1.38	0.28	28	55.80	39.76	0.81	0.44

TABLE 2. Fishing power correction factors calculated using Kappenman's model for both summer and fall and for both no./hr and kg/hr CPUE data.

Common name	Summer FPC (no./hr)	Summer FPC (kg/hr)	Fall FPC (no./hr)	Fall FPC (kg/hr)
Fishes				
Broad-striped anchovy	1.17	1.07	2.52	2.43
Rock sea bass	1.14	1.09	0.73	0.71
Atlantic bumper	0.27	1.01	0.26	0.23
Sand seatrout	0.65	0.58	0.56	0.57
Silver seatrout	0.53	0.54	0.47	0.52
Dwarf sand perch	1.78	1.64	0.90	0.78
Scaled herring	0.29	0.33	0.51	0.49
Pinfish	0.59	0.53	0.49	0.49
Spot croaker	0.76	0.72	0.58	0.58
Northern red snapper	0.67	0.69	0.67	0.62
Atlantic croaker	0.84	0.87	0.66	0.68
Gulf butterfish	0.58	0.57	0.41	0.39
Atlantic midshipman	1.23	1.14	1.16	1.04
Bigeye searobin	0.78	0.83	0.44	0.45
Mexican searobin	0.93	0.81	0.55	0.54
Shortwing searobin	0.75	0.69	0.75	0.85
Wenchman	0.60	0.52	0.56	0.49
Blackear seabass	1.32	1.07	1.04	0.88
Least puffer	0.78	0.80	0.71	0.69
Longspine porgy	0.73	0.69	0.46	0.45
Inshore lizardfish	1.11	1.17	0.58	0.64
Rough scad	0.79	0.75	0.59	0.58
Largehead hairtail	0.38	0.39	0.47	0.44
Dwarf goatfish	0.87	0.69	0.37	0.39
Gulf menhaden	0.15	0.19	0.39	0.47
Mexican flounder	2.10	1.22	0.62	0.61
Fringed flounder	2.31	2.19	0.72	0.71
Round herring	0.71	0.70	0.74	0.76
Pancake batfish	1.52	1.67	0.65	0.53
Smooth puffer	0.79	0.62	0.81	0.98
Shortbeard cusk-eel	2.30	2.30	1.35	1.19
Lane snapper	0.90	1.09	0.70	0.70
Planehead filefish	0.74	0.77	0.54	0.59
Harvestfish	0.57	0.47	0.57	0.52
Atlantic sharpnose shark	0.71	0.65	0.59	0.48
Brazilian lizardfish	1.04	1.05	1.23	1.24
Bigeye scad	0.91	1.65	0.28	0.29
Atlantic moonfish	0.91	0.97	0.48	0.57
Shoal flounder	4.94	3.91	0.55	0.57
Offshore lizardfish	1.08	1.29	0.78	0.80
Sash flounder	0.99	1.67	0.92	1.19
Southern codling	0.94	1.10	0.75	0.55
Crustaceans				
Lesser blue crab	1.21	1.36	0.46	0.49
Brown shrimp	1.89	1.81	1.31	1.44
White shrimp	1.13	1.12	1.13	1.13
Iridescent swimming crab	1.38	1.06	0.72	0.64
Longspine swimming crab	1.63	1.36	0.87	0.91
Brown rock shrimp	2.75	2.57	1.11	1.15
Pink shrimp	1.34	1.33	0.95	0.92
Mantis shrimp	1.43	1.66	0.89	0.97
Lesser rock shrimp	1.13	0.79	0.59	0.47
Blotched swimming crab	1.03	1.30	0.55	0.54
Blue crab	1.17	1.25	0.77	0.27

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Table 2. Continued

Common name	Summer FPC (no./hr)	Summer FPC (kg/hr)	Fall FPC (no./hr)	Fall FPC (kg/hr)
Yellow box crab	0.91	0.68	0.12	0.05
Other Invertebrates				
Longfin inshore squid	0.77	0.63	0.92	0.74
Atlantic brief squid	0.68	0.63	0.68	0.61
Arrow squid	0.75	0.61	0.93	0.68
Paper scallop	4.65	3.89	1.68	2.00

Discussion

Differences in mean catch rates occurred by season, but there was no widespread increase or decrease by season. In the fall, mean catch rates increased for 13 species in both nets, but declined in both nets for 16 species. Both mean catch rates for 13 species declined in the fall in the shrimp net but increased in the fall in the fish net. For another four species, mean no./hr catch rates declined in both nets but increased in both nets for mean kg/hr. The mean catch rates might be expected to decrease in the fall for species commercially exploited in the summer such as brown, pink, and white shrimp, northern red snapper, Gulf menhaden, Gulf butterfish, and, possibly, Atlantic croaker. This did not always occur. Brown shrimp, Gulf menhaden, and Atlantic croaker mean catch rates did decline in the fall in both nets, but mean catch rates of white shrimp increased in the fall in both nets. Mean no./hr of pink shrimp declined in both nets, but mean kg/hr increased in both nets. Mean no./hr of northern red snapper increased in the shrimp net in the fall but decreased in the fish net, but mean kg/hr catch rates declined in the shrimp net and increased in the fish net.

The mean catch rates do not include stations where the catch rate of an individual species was zero in either or both nets and do not represent the mean catch rates when computed for the entire study area because zeros are not factored into the estimate. A zero catch for an individual species is deleted from the analysis because Kappenman's model does not allow zeros. Therefore caution should used when trying to make assumptions about the overall mean catch rates and density estimates.

FPC values in this study appear to vary little for a species in a particular season whether using no./hr or kg/hr CPUE data to derive them. One major exception was Atlantic bumper; where a summer FPC of 0.27 was derived from the no./hr CPUE data, and an FPC of 1.01 was derived from the kg/hr CPUE data. These results suggest that a FPC should be derived for each type of CPUE used.

FPC values derived during this study ranged from a low of 0.05 to a high of 4.94. There were no extremely high values, such as the value of 32.95 for length interval I walleye Pollock caught in a trawl comparison study in Alaskan waters (von Szalay and Brown, 2001). This result was attributed to the small size of the length interval (<15 cm) and suggested that small fish were more likely to pass through an empty cod end than one with a substantial catch in it. The exceptionally low FPC values of 0.5 (fall, kg/hr) and 0.12 (fall, no./hr) were derived for yellow box crab; however, these results can be attributed to the small sample size (three) for this species in the fall.

Size was not used as a separate category for any species in this study. Most of the species sampled by the 42-ft shrimp trawl are relatively small, i.e., less than about 40 cm. Thus the 42-ft shrimp trawl would be expected to be more efficient at sampling smaller sized species than the 65-ft fish trawl, based on von Szalay's suspicions. Based on these results, meaningful conclusions, concerning net efficiencies and relative sizes of individual species as adults, could not be made.

The 42-ft shrimp trawl was more efficient at capturing all species of crustaceans in the summer months except yellow box crab. However, in the fall, the 42-ft shrimp trawl was more efficient at capturing only 3 of the 11 species of crustaceans: brown, white, and brown rock shrimp. The 42-ft shrimp trawl is specifically designed to catch shrimp, so trawl design may have impacted these results.

Von Szalay and Brown (2001) demonstrated that FPC values for different length classes of the same species can be significantly different, as did Troncoso and Paz (2003). Although FPC values for size classes were not examined in this study, differences in FPC values for species by season were examined. There were significant differences in FPC values between summer and fall for most species (ANOVA, $P < 0.02$). Although the data were not examined for species-specific size

TABLE 3. The decision, based on RMS values, whether to use the FPC to transform the 65-ft fish trawl CPUE data to standardize it with the 42-ft shrimp trawl.

Common name	Summer sample size	Apply FPC for no./hr in summer?	Apply FPC for kg/hr in summer?	Fall sample size	Apply FPC for no./hr in fall?	Apply FPC for kg/hr in fall?
Fishes						
Broad-striped anchovy	83	Yes	Yes	81	No	No
Rock sea bass	133	No	No	175	Yes	Yes
Atlantic bumper	152	Yes	No	230	Yes	Yes
Sand seatrout	75	Yes	Yes	178	Yes	Yes
Silver seatrout	58	Yes	Yes	92	Yes	Yes
Dwarf sand perch	113	No	No	123	Yes	Yes
Scaled herring	100	Yes	Yes	89	Yes	Yes
Pinfish	84	Yes	Yes	184	Yes	Yes
Spot croaker	65	Yes	Yes	200	Yes	Yes
Northern red snapper	77	Yes	Yes	145	Yes	Yes
Atlantic croaker	149	Yes	Yes	272	Yes	Yes
Gulf butterfish	252	Yes	Yes	190	Yes	Yes
Atlantic midshipman	78	No	No	62	No	No
Bigeye searobin	119	Yes	Yes	117	Yes	Yes
Mexican searobin	86	Yes	Yes	65	Yes	Yes
Shortwing searobin	106	Yes	Yes	55	Yes	Yes
Wenchman snapper	132	Yes	Yes	63	Yes	Yes
Blackear bass	76	No	No	103	No	Yes
Least puffer	56	Yes	Yes	82	Yes	Yes
Longspine porgy	322	Yes	Yes	249	Yes	Yes
Inshore lizardfish	206	No	No	269	Yes	Yes
Rough scad	183	Yes	Yes	146	Yes	Yes
Largehead hairtail	75	Yes	Yes	71	Yes	Yes
Dwarf goatfish	126	Yes	Yes	85	Yes	Yes
Gulf menhaden	15	Yes	Yes	48	Yes	Yes
Mexican flounder	6	No	No	21	Yes	Yes
Fringed flounder	43	No	No	44	Yes	Yes
Round herring	75	Yes	Yes	31	Yes	Yes
Pancake batfish	20	No	No	37	Yes	Yes
Smooth puffer	20	Yes	Yes	21	Yes	Yes
Shortbeard cusk-eel	19	No	No	28	No	No
Lane snapper	10	Yes	No	33	Yes	Yes
Planehead filefish	14	Yes	Yes	7	Yes	Yes
Harvestfish	29	Yes	Yes	45	Yes	Yes
Atlantic sharpnose shark	18	Yes	Yes	24	Yes	Yes
Brazilian lizardfish	102	No	No	29	No	No
Bigeye scad	6	Yes	No	15	Yes	Yes
Atlantic moonfish	30	Yes	Yes	31	Yes	Yes
Shoal flounder	19	No	No	24	Yes	Yes
Offshore lizardfish	16	No	No	17	Yes	Yes
Sash flounder	8	Yes	No	26	Yes	Yes
Southern codling	34	Yes	No	7	Yes	Yes
Crustaceans						
Lesser blue crab	228	No	No	184	Yes	Yes
Brown shrimp	278	Yes	Yes	247	No	No
White shrimp	105	No	No	147	No	No
Iridescent swimming crab	57	No	No	111	Yes	Yes
Longspine swimming crab	85	No	No	57	Yes	Yes
Brown rock shrimp	98	No	No	68	No	No
Pink shrimp	55	No	No	45	Yes	Yes
Mantis shrimp	46	No	No	26	Yes	Yes
Lesser rock shrimp	36	Yes	Yes	20	Yes	Yes
Blotched swimming crab	27	No	No	18	Yes	Yes

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TABLE 3. Continued

Common name	Summer sample size	Apply FPC for no./hr in summer?	Apply FPC for kg/hr in summer?	Fall sample size	Apply FPC for no./hr in fall?	Apply FPC for kg/hr in fall?
Blue crab	31	No	No	5	Yes	Yes
Yellow box crab	12	Yes	Yes	3	Yes	Yes
Other invertebrates						
Longfin inshore squid	129	Yes	Yes	129	Yes	Yes
Atlantic brief squid	83	Yes	Yes	83	Yes	Yes
Arrow squid	161	Yes	Yes	161	Yes	Yes
Paper scallop	27	No	No	27	No	No

differences in FPC values, size alone might not account for all the differences in FPC values between seasons.

Intuitively, the expectation might be that, since the FPC value diverges further and further from a value of one, the RMS decision rule would result in a decision to transform the CPUE data. While generally true for this study, this was not necessarily the case for all species. For example, the FPC value for summer no./hr and kg/hr catches of shoal flounder was 4.94 and 3.91, respectively, but the RMS decision rule resulted in the decision not to transform either CPUE fish trawl data set. In the fall, shoal flounder FPC values were 0.55 and 0.57 for no./hr and kg/hr CPUE data sets, respectively, but the RMS decision rule resulted in a decision to apply the FPC to both data sets.

The same was true for paper scallop summer catches that had a no./hr FPC of 4.65 and a kg/hr FPC of 3.89, but the decision rule resulted in the decision not to transform either data set. However, paper scallop had fall FPC values of 1.68 and 2.00 for no./hr and kg/hr CPUE data sets, respectively, but the decision rule again resulted in the decision not to transform either fish trawl data set.

FPC values can vary for the same species between different vessels and gear types for several reasons, as suggested by von Szalay (2003). They can also vary even though the vessel and gear do not change because of extrinsic factors. Vertical and horizontal migration, both diurnal and seasonal, can affect the estimated FPC. Depth strata affect the vertical openings of the nets, thereby affecting the volume sampled by a particular net at different depths. The bottom type in different areas might affect the nets differently, resulting in changes in CPUE and therefore FPC values. Size of the individuals of a species at the time of sampling can affect catch rates and therefore FPC values, but season at the time of sampling is also a contributor to catch rates and FPC values. Season can incorporate factors mentioned, such as horizontal migration and, more probably, size composition.

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