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[Article]

Evaluating Catch, Effort, and Bag Limits on Directed Trips in the Recreational Summer Flounder Party Boat Fishery

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Abstract.—The summer flounder *Paralichthys dentatus* is one of the most sought-after recreational fish along the mid-Atlantic coast of the United States. This fishery is primarily a consumptive fishery. The stock has been successfully rebuilding but remains below statutory rebuilding goals. Managers accordingly have restrained the annual quota primarily by increasing size limits, with a resulting increase in discard mortality. The purpose of this study was to evaluate new approaches to bag and size limits that minimize discard mortality while increasing angler satisfaction within the constraints of promulgated catch quotas. Three alternative management scenarios (slot limit, reduced minimum size, and cumulative size scenarios) were tested on party boats from New Jersey and New York. Total catch (by number) was lowest for control fishing trips (2006 state regulation) and higher for all three experimental scenarios because the experimental scenarios resulted in a greater number of kept fish. Discard-to-catch ratio (by fish weight and number) was highest for control trips, and landings (by weight and number) were lowest for the control scenario. Recreational fishermen operating under the reduced minimum size and cumulative size scenarios kept the most fish; these scenarios had the lowest discard-to-catch ratios. The slot limit scenario was intermediate in the discard-to-catch ratio and also in the number of kept fish. All three alternative management scenarios resulted in landing more fish under a biomass-neutral fishery to retain catch within allocation limits. Relative to 2006 legal conditions, the alternative scenarios produced proportional increases in landings by a factor of 1.75 to 2.09, while reducing discard mortality by 41–63% and maintaining the same total fishing mortality (landings plus discards) by weight.

The summer flounder *Paralichthys dentatus* is one of the most sought-after recreational fish along the mid-Atlantic coast. The fishery is primarily a consumptive fishery. This species has a long association with recreational anglers due to its accessibility, ranking fourth in total number of recreationally caught fish (22.2 million fish) in the U.S. Atlantic and Gulf of Mexico regions during 2006 (NMFS 2006). Most of these fish were released under bag and size limit constraints: summer flounder releases ranked third among the most encountered recreational species, but the summer flounder was not one of the top-five harvested species (NMFS 2006). This is the expected corollary of the high release rate.

Overfishing of summer flounder occurred at least as early as the 1970s; consequently, by 1982 the Atlantic States Marine Fisheries Commission created the first summer flounder management plan. This plan was approved by the National Marine Fisheries Service (NMFS) in 1988. Since 1993, an annual harvest limit encompassing landings and discards has been used to manage this fishery (Terceiro 2002, 2006); however, regulations vary by individual state to meet state-distributed quotas. Application of quota-based management resulted in a steady increase in spawning stock biomass (SSB) from the mid-1990s through the early 2000s, and SSB reached historically high levels by 2004 (Terceiro 2006). Coincident improvements in size structure resulted in a greater number of older and heavier fish being made available to fishermen. To constrain landings within quota goals, fisheries man-

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agers have primarily used increased minimum size limits and reduced bag limits. The coincidence of improved population demographics and this management approach was the landing of fewer (but larger and heavier) fish, concomitant with increased regulatory discards; increased fishing mortality of older, primarily female, fish; and increased reliance on the minimum size limit as the principal regulatory tool. Increased discards resulting from increased availability of sublegal-sized fish relative to the bag limit reduced the realized number of fish that anglers could take home because the total allowable catch includes both landings and discards. By 2006, the number of fish that were discarded in the recreational fishery and assumed to die accounted for 8.5% of the total recreational catch (NMFS Fisheries Statistics Division, personal communication). In New Jersey and most other states, the size limit rather than the bag limit was the primary regulator of take in 2006. The continued reliance on size limits during a period of rebuilding SSB and expanding age structure aggravated a tendency for the recreational sector to exceed quota limits by weight while maintaining relatively stable landings measured in numbers of fish. Thus, total landings necessarily were reduced disproportionately by number to counterweigh the landing of increasingly large and heavy fish. In New Jersey, for example, managers used an artificially high bag limit in 2006 to maintain angler optimism and thus avoid a drop in participation, since the bag limit was filled in less than 2% of all summer flounder trips. Harvest during the fishing season was nearly entirely controlled by the minimum size limit.

Three issues strongly argue for the development of new approaches to constrain landings while reducing discards in the summer flounder recreational fishery. These are (1) the negative consequences of continually increasing the minimum size limit, as manifested by high discard rates; (2) the unfortunate focusing of the catch on size-classes that are least numerous in the population and the commensurate impacts on rebuilding a robust age frequency distribution; and (3) the tendency for the catch of larger and therefore heavier fish to further facilitate harvest exceedance. The purpose of this study was to test alternative approaches to bag and size limits that might increase angler satisfaction by converting discards into landings while still meeting management goals. This study focused on recreational summer flounder anglers fishing from party boats in New Jersey and southern New York, because in 2006 these two states accounted for 64.9% of recreationally caught summer flounder within the mid-Atlantic fishery. Recreational for-hire fishing vessels were used for logistical convenience because for-hire vessels specifically targeting summer flounder can provide a level of standardization for researchers while permitting complete monitoring of angler catch in terms of both landings and discards. We monitored catch rates, harvest rates, discard rates, and catch per unit effort on a series of fishing trips conducted under rigidly enforced criteria, including trips conducted under the 2006 summer flounder regulations for New York and New Jersey and three experimental approaches that deviated from these limits on each trip, to evaluate the effect of changes in bag and size limits on realized landings and discards.

Methods

Field program.—The field program used five party boats—two boats from southern New York and three boats from New Jersey—selected to encompass the variation in size of summer flounder caught and areas fished by party boat fleets from New Jersey and southwestern Long Island (Figure 1).

The four management scenarios evaluated were

1. a reduced minimum size limit set at 14.0 in (35.56 cm);
2. a slot limit in which anglers were allowed to keep a defined fraction of the state-specified bag limit between 14 in and the state-specified minimum size limit;
3. a cumulative size limit set by combining the state-specified size limit and the bag limit to produce a cumulative number of inches of fish (each fish greater than 14 in) that could be landed; and
4. the 2006 state-specified regulations, which are hereafter referred to as the control scenario.

The minimum size selected for the experimental trips was 14 in because this was the 2006 minimum size limit in the commercial fishery and because it represents a practical minimum size preferred by anglers (smaller sizes yield very small fillets). Table 1 presents a detailed explanation of the scenarios and the differences between states.

Field sampling began in June and terminated in September, with sampling occurring only on weekdays (Monday–Thursday). Weekends (Friday–Sunday) and holidays were avoided because party boats usually carry the greatest number of anglers at that time and the number of participants would have been logistically difficult to fully sample. The fishing season was split into early season (June to mid-July), midseason (end of July to mid-August), and late season (end of August to mid-September). Each boat was sampled once over a consecutive 4-d period in the early, mid-, and late seasons. The management scenario was randomly

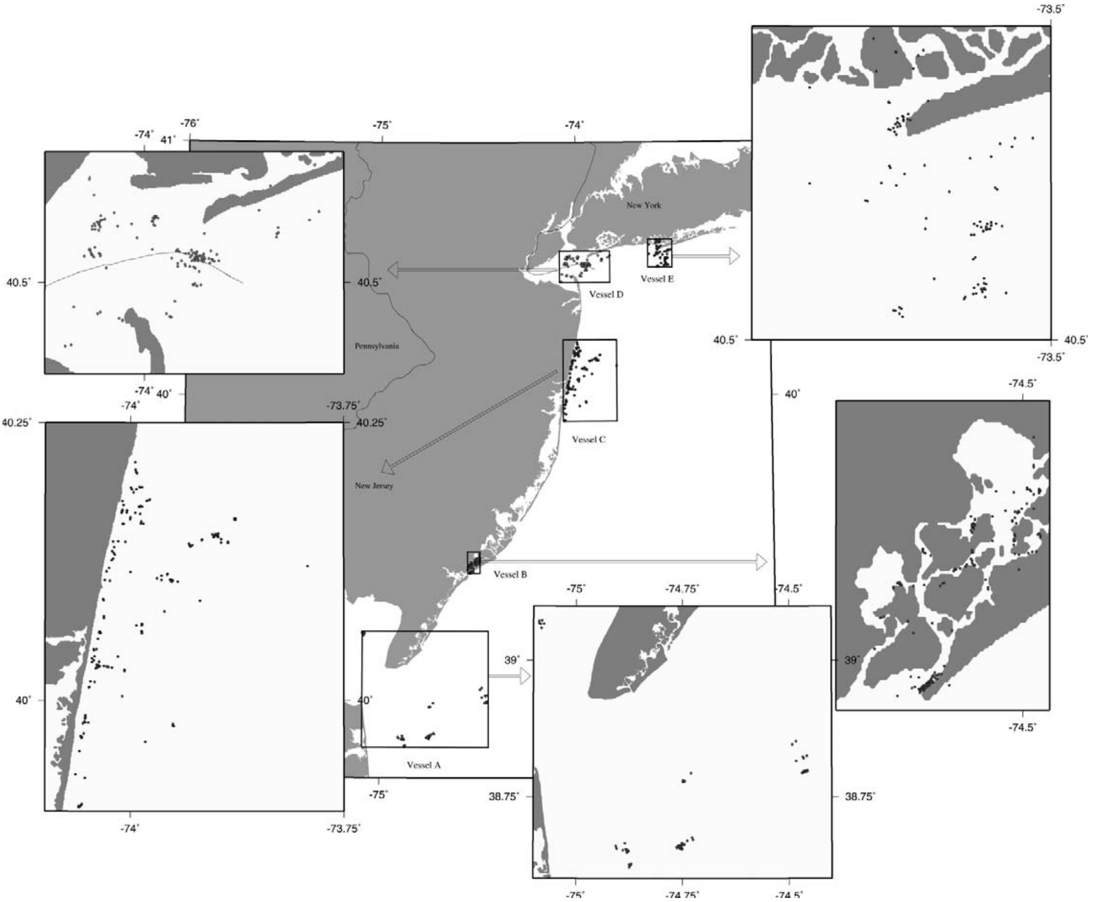

FIGURE 1.—Drift positions of New Jersey and New York party boats (vessels A–E) targeting summer flounder. Dots record the locations of each observed drift.

selected without replacement for each 4-d period such that (1) one scenario was sampled per day and (2) each scenario was fished once by each boat in each season. Most anglers were unaware of the change in regulation until they boarded the boat, although a few may have gleaned information from the boat owner/operator prior to the trip. One or two observers were present on each trip to collect data on angler performance.

Captains recorded the date, number of anglers onboard the boat, sailing time, and the time of return

TABLE 1.—Summer flounder bag and minimum size limits fished by anglers on New York and New Jersey party boat trips during the 2006 fishing season.

Management scenario	New York trips	New Jersey trips
Control (2006 state regulations)	Keep 4 fish ≥18.0 in Bag limit of 4 fish	Keep 8 fish ≥16.5 in Bag limit of 8 fish
Slot limit	Keep 2 fish 14.0–18.0 in and remaining fish must be ≥18.0 in Bag limit of 4 fish	Keep 2 fish 14.0–16.5 in and remaining fish must be ≥16.5 in Bag limit of 8 fish
Cumulative size	Total size limit of 72.0 in (18 in × 4 fish = 72 in) with a minimum size limit of 14.0 in Bag limit of all fish = 72.0 in	Total size limit of 132.0 in (16.5 in × 8 fish = 132 in) with a minimum size limit of 14.0 in Bag limit of all fish = 132.0 in
Reduced minimum size	4 fish ≥14.0 in Bag limit of 4 fish	8 fish ≥14.0 in Bag limit of 8 fish

to the dock on each trip. In addition, for each drift, captains recorded the start and end time and position, water temperature, and water depth. Each trip consisted of either a full day or one morning (AM) half-day trip plus one afternoon (PM) half-day trip. Captains were asked to maintain their normal fishing practices, with the exception of the specified bag and size limits imposed on the trip.

Each angler was given a fact sheet prior to departure that explained the bag and size limits imposed for that trip. All participating anglers were assigned a unique random number that was visibly displayed on each participant's shirt to permit tracking of summer flounder catch by individual anglers. Angler catches during each drift were recorded for the duration of the trip. Observers and sometimes the mate or captain recorded the total length of each fish to the nearest 0.125 in and noted whether the fish was kept or discarded.

Data analysis.—Analysis of drift distances recorded by the captains revealed within- and between-drift variations caused by circumstances such as boats motoring during the drift, boats not moving, and boats picking up and moving in middrift. As a consequence, distance traveled was ambiguously related to fishing effort. Effort was therefore calculated as angler-hours fished, determined by the product of the drift time and the number of participating anglers. Drifts were identified as occurring either in the AM or PM depending upon time of departure relative to 1200 hours. The shallowest and deepest recorded depths were averaged to assign a depth to the drift.

Weight was obtained by converting measured lengths to pounds based on data collected during a supplemental finfish survey (described by King and Powell 2007): weight $= 0.00007776 \times \text{length}^{3.532}$. Total fishing mortality rate assuming a 10% recreational discard mortality rate (Terceiro 2006) was calculated as [mean kept $+ (0.1 \times$ mean discard)]/ mean total catch.

Statistical analysis.—All analyses used nonparametric analysis of covariance (ANCOVA) except as noted. For elapsed drift time, the time of day (AM or PM drift), vessel, and management scenario were the main effects, whereas the number of anglers and, in some cases, depth were included as covariates. We analyzed the influence of management scenario on the number of anglers, elapsed drift time, and average depth using analysis of variance with boat and time of day as additional main effects.

Angler performance was analyzed using the total number caught, total weight caught, catch per angler (number), total weight kept, total number kept, total weight discarded, total number discarded, and the discard-to-catch ratio (by fish weight and number) as dependent variables. All drifts with zero catches were excluded; such drifts are ambiguous because they confound the environmental availability of fish with onboard fishing performance more than do other drifts and because captains routinely shift locations to minimize consecutive drifts with null catches. Main effects were management scenario fished, boat, and time of day, with depth and effort as covariates. All pairwise interaction terms between boat or management scenario and other main effects were included. Preliminary analyses permitted exclusion of other interaction terms except the depth $\times$ effort interaction.

Significant differences identified by the ANCOVA were further investigated using a posteriori Tukey's studentized range tests. We emphasize that the results of these a posteriori tests should be treated cautiously as interaction terms were frequently significant. The vessel main effect subsumed a number of confounding variables, including location fished and geographic difference in fish size frequency, as the study did not include replicate vessels fishing side by side. As a consequence, we did not explicitly evaluate the influence of different state regulations (i.e., New York versus New Jersey regulations) on vessel performance; we also did not evaluate the size frequency differences in the summer flounder catch that normally differentiate angler performance in these two states. The study was designed to evaluate a change in bag and size limit rules over much of the range of fishing experiences represented by the Middle Atlantic Bight summer flounder fishery rather than a more detailed comparison of a narrower subset. Nevertheless, in this paper we note occurrences when New York and New Jersey vessels were significantly different in fishing performance based on a posteriori tests and when size frequencies reflected stock differences rather than regulatory-induced differences.

Results

Party Boat Descriptions

The three New Jersey party boats were from ports that ranged from southern to northern New Jersey (Figure 1). Boat A hailed from the Port of Cape May, boat B was from the Port of Margate, and boat C was from the Port of Point Pleasant/Brielle (Table 2). The two New York party boats (boats D and E) were from southwestern Long Island; boats D and E hailed from the Ports of Sheepshead Bay and Point Lookout, respectively (Figure 1; Table 2). Both New York and New Jersey vessels fished in bays and estuaries and in the ocean within 3 mi of the coast (state waters) and greater than 3 mi from the coast (federal waters; Figure 1). Boat A primarily fished in the ocean in federal and

TABLE 2.—Home port, angler capacity, trip duration, and boat size of the five party boats participating in this study.

Vessel	Home port	Capacity (number of anglers)	Boat size (ft)	Daily trip time (hours)
A	Cape May, New Jersey	100	65	0800–1600
B	Margate, New Jersey	50	50	0800–1200 1300–1700
C	Pt. Pleasant, New Jersey	125	90	0800–1230 1400–1830
D	Sheepshead Bay, New York	131	90	0700–1100 1200–1600
E	Point Lookout, New York	100	85	0800–1200 1300–1700

state waters off Cape May County, New Jersey, and the state of Delaware but sometimes fished in Delaware Bay when the ocean was rough. Boat B only fished in state waters in the back bays of Atlantic County, New Jersey. Boat C fished in both state and federal oceanic waters off Monmouth and Ocean counties, New Jersey. For the New York party boats, boat D fished in Raritan Bay in New Jersey and New York as well as state coastal waters near New York City. Boat E fished in coastal and federal waters off southern Long Island (Figure 1).

All participating vessels specifically targeted summer flounder and ranged in size from 50 to 90 ft in length. Capacity varied from 50 to 131 anglers (Table 2). Boats B–E offered customers one half-day AM trip and one half-day PM trip, each about 4 h in duration. Boat A sailed once per day on an approximately 8-h trip (Table 2). For this study, a research trip was considered to be either one full day or two half-days.

Fishing Trips

Fifty-eight trips were taken onboard the five party boats: 20 trips from June 2 to July 13 (early season), 20 trips from July 17 to August 17 (mid-season), and 18 trips from August 22 to September 22 (late season). Two late-season trips were eliminated due to bad weather (one for New York boat E and one for New Jersey boat A).

Overall, 745 drifts were sampled. The number of drifts ranged from 180 under the cumulative size scenario to 193 under the reduced minimum size scenario (Table 3). The five party boats carried a total of 2,344 anglers (Table 3). Anglers ranged from children to senior citizens and from novices to individuals with over 20 years of fishing experience. The average number of anglers per trip (all boats combined) was 24 (Table 4, case A). The mean number of anglers carried by each party boat ranged from about 13 to 32 (Table 4, case B). Boats D and E from New York averaged the fewest anglers, with 16 and 13 anglers, respectively. The total number of anglers ranged from 547 under the slot limit scenario to 637 under the reduced minimum size scenario (Table 3).

Average drift time was 22.7 min (Table 4, case A). Boat B had the shortest mean drift time at 16.0 min, and boat E had the longest average drift time at 30.5 min (Table 4, case B). Mean effort was 9.7 angler-hours (range = 0.6–104 angler-hours) for those drifts in which at least one summer flounder was caught. The greatest number of drifts ($N = 193$) occurred during the reduced minimum size scenario. The cumulative size scenario had the fewest number of drifts ($N = 180$; Table 3).

Depth fished ranged from 3 to 95 ft, with a mean depth of 35.8 ft. Boat B fished in the shallowest water (mean depth = 13.1 ft), and boat A fished in the deepest water (mean depth = 68.2 ft; Table 3).

Boat had a significant effect on elapsed drift time (Table 5). Tukey's a posteriori test found that boat B had the shortest average elapsed drift time, followed by

TABLE 3.—Summary of the number of drifts and anglers by summer flounder management scenario and mean depth fished for each boat and management scenario.

Management scenario	Total drifts	Total number of anglers	Mean depth fished (m)				
			Boat A	Boat B	Boat C	Boat D	Boat E
Reduced minimum size	193	637	72.7	13.5	44.1	29.1	45.9
Slot limit	187	547	69.5	12.8	49.7	24.2	38.8
Control	185	552	72.6	13.4	49.0	28.0	37.2
Cumulative size	180	608	57.4	12.4	49.8	28.8	44.4
Total	745	2,344					

TABLE 4.—Mean (SD in parentheses), median, and range for drift time (min) and number of anglers by drift for all boats combined (case A) and by boat (case B).

Variable	Statistic			Drifts (*N*)
	Mean	Median	Range	
Case A				
Drift time	22.7 (13.51)	20.0	2.0–120.0	744
Number of anglers	23.8 (13.04)	20.0	2.0–65.0	744
Case B				
Boat A				
Drift time	27.61 (16.392)	24.0	5.0–12.0	98
Number of anglers	27.7 (11.16)	25.0	10.0–52.0	98
Boat B				
Drift time	16.0 (9.68)	14.0	2.0–67.0	232
Number of anglers	24.6 (10.34)	20.0	8.0–45.0	232
Boat C				
Drift time	20.9 (10.64)	20.0	7.0–75.0	182
Number of anglers	32.03 (14.930)	30.0	13.0–65.0	182
Boat D				
Drift time	27.8 (13.37)	25.0	3.0–72.0	136
Number of anglers	16.3 (9.56)	15.5	3.0–39.0	136
Boat E				
Drift time	30.5 (14.66)	28.5	8.0–65.0	96
Number of anglers	13.2 (6.91)	11.0	2.0–34.0	96

boat C, and that these two boats differed significantly in drift time. Boats A, D, and E had similar elapsed drift times, but drift times were greater on these boats than on boats B and C (Table 4). Elapsed drift time was also influenced significantly by the number of anglers. Spearman's rank correlation analysis showed a positive correlation between the number of anglers and drift length; however, analyses conducted separately for each vessel revealed that only boat B demonstrated a significant positive correlation ($P = 0.0001$). Boat B tended to make longer drifts with more anglers onboard, possibly due to the smaller size of this party boat in comparison with the others (Table 2). Longer drifts were probably logistically easier to handle for the crew when more anglers were onboard this vessel.

Depth was significantly influenced by boat ($P = 0.0001$) and time of day (AM versus PM drifts, $P = 0.0091$; Table 6). Based on Tukey's a posteriori tests, all boats fished at significantly different depths. Boat A fished in the deepest water, and boat B fished in the shallowest water (Table 3). Tukey's a posteriori test indicated that boats tended to fish in deeper water during the morning than during the afternoon. The boat × time of day, boat × scenario, and time of day × scenario interaction terms had a significant influence on depth (Table 6), as might be expected because boats traveled to different places to fish in response to weather conditions and based on anticipated fishing performance as assessed by the captain.

Time of day had a significant effect on the number of anglers ($P = 0.0438$; Table 6). Drifts that occurred before 1200 hours carried more anglers than drifts that occurred after 1200 hours.

Boat had a significant effect on the number of anglers present on a trip ($P = 0.0001$; Table 6), as

TABLE 5.—Results of analyses of variance (ANOVAs) evaluating the influence of boat, time of day (AM or PM drift), management scenario, number of anglers, and depth on elapsed drift time. Elapsed drift time was ranked for the ANOVA. A second ANOVA excluded depth from the analysis (NS = not significant at $\alpha = 0.05$; NA = not applicable).

Effect	*P*-value with depth	*P*-value without depth
Boat	0.0001	0.0001
Time of day	NS	NS
Number of anglers	0.0017	0.0016
Scenario	NS	NS
Depth	NS	NA

TABLE 6.—Results of analyses of variance (ANOVAs) evaluating the influence of boat, time of day (AM or PM drift), and management scenario on depth fished, number of anglers, and elapsed drift time. Elapsed drift time was ranked for the ANOVA (NS = not significant at $\alpha = 0.05$).

Effect	ANOVA *P*-value for:		
	Number of anglers	Drift time	Depth
Boat	0.0001	0.0001	0.0001
Time of day	0.0438	NS	0.0091
Boat × time of day	0.0001	NS	0.0005
Scenario	0.0065	NS	NS
Boat × scenario	0.0001	0.0021	0.0001
Time of day × scenario	NS	NS	0.031

TABLE 7.—Total number of summer flounder caught, kept, and discarded by each boat and under each management scenario. Summer flounder not recorded as discarded or kept are classified as unknown.

Boat or scenario	Kept	Discard	Unknown	Total
Boat				
A	737	418	1	1,156
B	625	630	7	1,262
C	1,138	1,814	44	2,996
D	573	1,068	5	1,646
E	301	494	2	797
Total	3,374	4,424	59	7,857
Scenario				
Control	191	1,400	12	1,603
Cumulative size	1,248	937	9	2,194
Reduced minimum size	1,095	805	24	1,924
Slot limit	840	1,282	14	2,136
Total	3,374	4,424	59	7,857

would be expected based on the range of capacities of the five boats (Table 2). However, Tukey's a posteriori test showed that performance did not track capacity. Boat C carried significantly more anglers than the other boats; boats A and B were not significantly different from each other but differed from boats C, D, and E. Boats D and E carried significantly fewer anglers than the other three boats even though boat D had the highest capacity. Interaction terms were routinely significant, confirming that the number of anglers on these boats was highly variable from boat to boat and from day to day.

The number of anglers varied significantly among the four management scenarios ($P = 0.0065$; Table 6). The slot limit scenario had the fewest anglers and differed significantly from the control, reduced minimum-size, and cumulative size scenarios; these latter three scenarios did not differ in the number of anglers. The majority of anglers were not aware of the management scenario prior to boarding, and therefore we assume that this result is merely happenstance. The boat × scenario interaction term was routinely significant. This influence is examined in more detail subsequently.

Catch: Descriptive Statistics

All anglers agreed to participate in the study. As a result, we were able to count and measure every summer flounder that was caught on each trip. In total, 7,857 summer flounder (kept and discarded) were caught; 42.9% of the catch was kept, 56.3% of the catch was discarded, and 0.8% of the catch had a disposition that was not recorded (Table 7). Most of these latter recording failures occurred during peak catches, when it was difficult to record all of the information for every fish. A total of 4,057 summer flounder were caught during morning drifts and 3,800 were caught during afternoon drifts. For 86.2% of the drifts ($N = 642$), at least one summer flounder was caught. The average total catch per drift was 12.2 fish (median = 7 fish; range = 1–209 fish) for those drifts that caught at least one summer flounder. Catch statistics are summarized for each boat in Tables 7 and 8.

Anglers on boat C caught the most summer flounder (2,996 fish), and anglers on boat E caught the fewest

TABLE 8.—Mean summer flounder total catch (both kept and discarded), mean number kept, mean number discarded, discard-to-catch ratio, and total fishing mortality per drift by each boat under each management scenario, excluding drifts in which no summer flounder were caught.

Boat	Scenario	Total catch	Kept	Discards	Discard-to-catch ratio	Mortality fraction
A	Control	14.050	4.650	9.400	0.6690	0.398
	Cumulative size	18.400	13.350	5.000	0.2714	0.753
	Reduced minimum size	6.880	5.720	1.160	0.1686	0.848
	Slot limit	15.227	10.636	4.591	0.3015	0.729
B	Control	4.482	0.411	4.018	0.8964	0.181
	Cumulative size	9.512	5.610	3.829	0.4026	0.630
	Reduced minimum size	7.151	4.434	2.717	0.3800	0.658
	Slot limit	6.342	3.605	2.737	0.4315	0.617
C	Control	10.068	1.000	8.909	0.8849	0.188
	Cumulative size	17.674	10.000	7.587	0.4293	0.609
	Reduced minimum size	15.927	8.122	7.317	0.4594	0.556
	Slot limit	31.057	8.600	22.086	0.7111	0.348
D	Control	12.086	0.743	11.314	0.9362	0.155
	Cumulative size	15.833	7.533	8.267	0.5221	0.528
	Reduced minimum size	19.360	9.960	9.280	0.4793	0.562
	Slot limit	8.800	2.400	6.400	0.7273	0.346
E	Control	13.667	0.333	13.267	0.9707	0.122
	Cumulative size	7.400	3.250	4.150	0.5608	0.495
	Reduced minimum size	10.727	6.136	4.546	0.4237	0.614
	Slot limit	8.667	4.000	4.667	0.5385	0.515

(797 fish; Table 7). Fishermen on boat C kept the most fish (1,138) and also discarded the most fish (1,814). Boat C made one trip (encompassing one AM trip with 17 anglers and one PM trip with 41 anglers) on June 26 under the slot limit scenario and caught a total of 822 summer flounder in nine drifts. This 1-d trip accounted for 29.4% of this vessel's total catch throughout the project. Neither this vessel nor any other vessel recorded such a high catch on any other single trip. Anglers on boat E kept the fewest summer flounder (301 fish), and anglers on boat A discarded the fewest summer flounder (418 fish; Table 7).

In 102 drifts (13.7% of all drifts), anglers did not catch any summer flounder; 52 of these null drifts occurred in the morning, and 50 occurred in the afternoon. Boat B had the most null drifts ($N = 46$). The remaining boats varied from 11 to 15 null drifts; thus, the performance of boat B was significantly poorer based on this measure than the other boats.

Anglers fishing under the control scenario caught the lowest number of summer flounder (1,603 fish). The most summer flounder (2,194 fish) were caught under the cumulative size scenario (Table 7). The number of kept fish ranged from a low of 191 under the control scenario to a high of 1,248 under the cumulative size scenario, whereas discards were lowest with the reduced minimum size scenario (805 fish) and highest for the control scenario (1,400 fish; Table 7).

The same trends were present when catch was standardized to drift and angler (Table 9). The lowest number and weight of kept fish per drift (excluding drifts with zero catches) occurred under the control scenario. The control scenario had the highest mean discard-to-catch ratio. The control and slot limit scenarios produced higher discards per drift (by number and weight) than the reduced minimum size and cumulative size scenarios. Total fishing mortality in terms of fish number and weight was greatest for the cumulative size scenario (Table 9).

Mean total summer flounder catch per angler ranged from 3.2 fish for the reduced minimum size scenario to 3.7 fish for the slot limit scenario. Angler performance was very similar across all management scenarios. Mean number of summer flounder kept per angler ranged from 0.3 fish under the control scenario to 1.8 fish under the cumulative size scenario. Mean number of discarded fish per angler ranged from 1.4 fish for the reduced minimum size scenario to 3.3 for the control scenario (Table 9).

Catch: Statistical Analysis

Boat and effort had significant effects on the total number of summer flounder caught (Table 10). Boats B and E caught significantly fewer fish. Spearman's rank correlation indicated that the total number of summer flounder caught was positively and significantly related to effort and to the number of anglers (Table 10).

Total catch (number of fish) per angler was strongly influenced by boat ($P = 0.0001$) but was barely influenced by management scenario ($P = 0.0485$; Table 10), ranging only from 3.2 to 3.7 fish/angler among the four scenarios (Table 9). Tukey's a posteriori test indicated that the catch per angler for boats D and E (the New York boats; catch per angler was the same for the two boats) exceeded the values for boats A and C. Boat B had the lowest catch per angler and differed significantly from the other boats. Boat appears to be the main factor affecting angler catch.

Boat, management scenario, and effort had significant effects on the total number and weight of summer flounder kept. Significant interaction terms were boat × time of day, boat × scenario, boat × effort, and depth × effort (Table 11). Boat A kept the most fish (mean = 8.5 fish), followed by boat C with the second-highest number of kept fish (mean = 6.9 fish). Boats B, D, and E kept significantly fewer fish than boats A and C. This included the two New York boats fishing under the more stringent state-regulated bag and size limits and one New Jersey boat fishing mostly in the back bays. The cumulative size and reduced minimum size scenarios produced the greatest number of kept fish, followed by the slot limit scenario and then the control scenario; these three groups were significantly different. A similar hierarchy was observed when kept fish were evaluated by weight. The greatest weight kept occurred under the cumulative size scenario, the control scenario produced the lowest weight of kept fish, and the reduced minimum size and slot limit scenarios were intermediate in terms of weight kept.

Boat and effort had significant effects on the number and weight of discarded summer flounder (Table 11). Boats D and C had the highest number of discards, followed by boat E, which had fewer discards but a similar number as boat C. Discarding was not uniformly highest on the New York boats fishing under the more stringent state bag and size limits. Boat B had the fewest discards in number of fish, which were not significantly different from the discards of boat A. Discards by weight followed a similar pattern. Boat and management scenario significantly influenced the discard-to-catch ratios by weight and number (Table 11). Boat A had the lowest discard-to-catch ratio for numbers caught (Table 8) and differed from the other boats. Boats D, E, and B had the greatest discard-to-catch ratios. The control scenario had the greatest discard-to-catch ratio in terms of numbers and weight (Table 9), and these ratios were significantly higher than those observed under the slot limit

TABLE 9.—Mean number and weight (lb) of summer flounder per drift for total catch (both kept and discarded), fish kept, fish discarded, discard-to-catch ratio, and fishing mortality (including only those drifts with at least one summer flounder caught) by management scenario. The discard-to-catch ratio by weight can be obtained from the table as the ratio of discards to total catch. Also shown are mean, median, and maximum (max) total catch per angler per trip, number kept per angler, and number discarded under each management scenario (for drifts with at least one summer flounder caught).

	Number of fish per drift					Weight of fish per drift			
Scenario	Total catch	Kept	Discards	Discard-to-catch ratio	Fishing mortality	Total weight	Kept	Discards	Fishing mortality
Control	9.4	1.1	8.2	0.873	0.207	11.1	2.7	8.4	0.314
Cumulative size	14.0	8.0	6.0	0.427	0.612	16.0	11.4	4.6	0.738
Reduced minimum size	11.6	6.6	4.9	0.418	0.611	12.8	8.9	3.7	0.726
Slot limit	14.3	5.6	8.6	0.601	0.454	16.4	9.0	7.3	0.594

scenario. The cumulative size and reduced minimum size scenarios had similar low discard-to-catch ratios that were significantly lower than those of the slot limit scenario (Table 9).

Discussion

Fishing Practices

We examined various fishing practices used by the five party boats, including depth fished, elapsed drift time, number of anglers onboard, drift time of day, and management scenario under which fishing occurred. Elapsed drift time was influenced primarily by boat rather than by management scenario. This trend was repeated for most other fishing practice measures—the number of anglers being the obvious exception in which fewer anglers participated in slot limit trips. No reason beyond happenstance can be offered to explain this occurrence.

The number of anglers differed significantly among party boats. The three New Jersey boats carried more anglers than the New York boats. However, angler usage did not reflect vessel capacity; the New York boats were particularly underutilized. The New York boats may have carried fewer anglers as a result of the lower bag limit (4 fish) and larger size limit (18 in) imposed by New York.

TABLE 10.—Results of ranked analyses of covariance evaluating the influence of boat, time of day (AM or PM drift), management scenario, depth fished, and effort on summer flounder total catch (by number and weight of fish) and total catch per angler, excluding zero catches (NS = not significant at $\alpha = 0.05$).

	P-values for total catch		
Effect	Number	Weight	Per angler
Boat	0.0001	0.0001	0.0001
Time of day	NS	NS	NS
Boat × time of day	0.0232	0.0080	0.0013
Scenario	NS	NS	0.0485
Depth	NS	0.0357	NS
Effort	0.0014	0.0008	NS
Boat × scenario	NS	0.0320	0.0416
Depth × boat	0.0001	0.0006	0.0001
Effort × boat	0.0001	0.0001	0.0095
Time of day × scenario	NS	NS	NS
Depth × scenario	NS	NS	0.0055
Effort × scenario	NS	NS	NS
Depth × effort	0.0002	0.0002	0.0014

More anglers also tended to fish on drifts taken during the morning than during the afternoon, possibly due to the perception of some anglers that more summer flounder can be caught in the morning than in the afternoon. However, the time of day actually exerted little influence on catch. Thus, angler perception may have influenced usage, but only in some cases was the basis for this preference grounded in reality, such as the obviously lower bag limits in New York.

Boats tended to fish at different depths and locations, as anticipated by the project design goal of observing vessels fishing across a wide range of depths, geographic locations, and habitats. A significant time-of-day effect showed that party boats tended to fish in deeper water during the morning, but this had little overall influence on catch. Summer flounder total catch (kept and discarded) did vary significantly between boats, however, with boats B and E catching the fewest fish. As fishing effort (angler-hours) increased, total catch increased. A positive correlation also existed between catch and the number of anglers fishing. Each of these relationships is expected. Statistical analysis included these main effects to allow exclusion of their bias from a comparison among management scenarios. VanDeValk et al. (2007) studied angler catch rates for several freshwater fish species in a New York lake and found that party size (number of anglers in the fishing group) significantly and negatively influenced angler catch rates and that trip length was also negatively related to angler catch rates. In this study, vessel appeared to be the main factor influencing catch per angler. Effort did not influence angler catch rate. Boats

TABLE 9.—Extended.

Scenario	Total catch per angler			Number kept per angler			Number discarded per angler		
	Mean	Median	Max	Mean	Median	Max	Mean	Median	Max
Control	3.6	2.0	21.3	0.3	0.2	1.7	3.3	1.8	21.3
Cumulative size	3.4	2.9	9.2	1.8	1.6	4.3	1.5	1.0	6.2
Reduced minimum size	3.2	2.2	13.3	1.7	1.5	4.8	1.4	0.9	9.1
Slot limit	3.7	2.4	25.5	1.3	1.2	3.3	2.3	0.9	21.9

D and E had the highest catch per angler, possibly because these boats carried the lowest number of anglers. Interestingly, these were also the New York boats. Boats D and E tended to fish in the most northern locations, which also may have contributed to the higher catch (Figure 1). The more stringent bag and size limits set in New York are consistent with the higher per-angler catch observed for boats fishing in these waters.

Boat B had the lowest catch per angler. Boat B was a smaller boat that tended to only fish in back bays and conducted both AM and PM half-day trips. Both characteristics are more conducive to participation by families with younger children and by less-experienced anglers. Either factor could account for the lower catch per angler and the lower total catch for boat B; one cannot exclude lower availability, however.

Boat and effort influenced the number and weight of summer flounder kept and discarded. Boat A had the lowest discard-to-catch ratio and boat D had the highest discard-to-catch ratio based on weight and number of fish. Thus, the anticipated higher discard-to-catch ratio from New York boats fishing the most stringent management scenario was not fully met. The discard-to-catch ratio for boats E and B averaged higher than that for boat C based on fish numbers but not weight. For weight, the discard-to-catch ratio for boats C and E averaged higher than that for boat B. Thus, boat B separated again from the remaining boats. Boat B tended to fish only in shallow back bays, where smaller summer flounder are located throughout the summer; this could account for the lower weight discarded relative to numbers of fish. In comparison with the other boats, boat A fished in deeper waters further offshore, where larger and heavier fish were more available (Figure 1). The pattern of smaller fish occurring inshore and in estuaries and larger fish occurring further offshore is well documented (Able and Kaiser 1994; Szedlmayer and Able 1996; Sackett et al. 2007).

Thus, significant vessel effects were the rule in this study, as was expected from the project design. The different depths and locations fished resulted in the observation of these anticipated boat differences. Such

TABLE 11.—Results (*P*-values) of ranked analyses of covariance evaluating the influence of boat, time of day (AM or PM drift), management scenario, depth fished, and effort on the total number or weight of summer flounder kept and discarded and discard-to-catch ratio (NS = not significant at $\alpha = 0.05$).

Effect	Number kept	Weight kept	Number discarded	Weight discarded	Discard-to-catch ratio (number)	Discard-to-catch ratio (weight)
Boat	0.0016	0.0055	0.0001	0.0001	0.0001	0.0001
Time of day	NS	NS	NS	NS	NS	NS
Boat × time of day	0.0333	0.0172	NS	0.0422	NS	0.0512
Scenario	0.0001	0.0001	NS	NS	0.0031	0.0045
Depth	NS	NS	NS	NS	NS	NS
Effort	0.0005	0.0009	0.0136	0.0130	NS	NS
Boat × scenario	0.0001	0.0001	NS	0.0148	0.0055	0.0009
Depth × boat	NS	NS	0.0001	0.0001	0.0001	0.0001
Effort × boat	0.0001	0.0001	0.0001	0.0001	NS	NS
Time of day × scenario	NS	NS	NS	0.00279	NS	NS
Depth × time of day	NS	NS	NS	NS	NS	NS
Effort × time of day	NS	NS	NS	NS	NS	NS
Depth effort	0.0030	0.0011	0.0008	0.0014	NS	NS

TABLE 12.—Total fishing mortality fraction, total discard mortality fraction, and total kept mortality fraction (number or weight) for summer flounder and the biomass-neutral increase in landings by management scenario. The biomass-neutral increase in landings is a proportional change in number of fish such that the value of 1.00 for the control means no change (1 × original number) and a value of 2.00 means twice as many fish.

	Number of fish			Weight of fish			
Scenario	Total mortality fraction	Total discard mortality fraction	Total kept mortality fraction	Total mortality fraction	Total discard mortality fraction	Total kept mortality fraction	Biomass-neutral increase in landings
Control	0.206	0.087	0.119	0.314	0.076	0.238	1.00
Cumulative size	0.612	0.043	0.569	0.738	0.029	0.709	2.09
Reduced minimum size	0.611	0.042	0.569	0.726	0.029	0.697	2.06
Slot limit	0.453	0.060	0.393	0.594	0.044	0.550	1.75

differences demonstrate that the study encompassed a wide range of fishing practices and vessel performances, a factor that is important in evaluating the effects of modifications in bag and size limit regulations governing the fishing experience, as discussed below.

Only on 1 out of 58 research trips did a party boat, namely boat C, have an excellent day of fishing; while fishing under the slot limit scenario, boat C caught 822 summer flounder on nine drifts with 17 anglers onboard in the morning and 41 anglers onboard in the afternoon. This trip accounted for about 29% of this vessel's summer flounder catch for the entire project. The rarity of this magnitude of catch in the present study demonstrates the need to be cognizant of atypical trips in programs designed for the collection of recreational catch data (e.g., Marine Recreational Fisheries Statistics Survey). Such trips, if observed in a program with an inadequate total sample size, could possibly bias overall catch estimates upward.

Management Scenario

This study collected catch data over a single fishing season and with only one recreational sector, namely the party boat sector. This sector was selected because it provides an easy platform for collecting catch and effort data and also facilitates the monitoring of angler catches by law enforcement officials since these vessels dock at particular locations at designated times. Party boats also provide some level of standardization that is otherwise unachievable in most recreational sector modes. The majority of the anglers onboard were not aware of the management scenario prior to boarding; however, many of the party boats had anglers that made frequent trips onboard their vessels. These frequent customers often inquired about the timing of future trips in order to participate in a trip under a management scenario that provided the opportunity to keep more summer flounder than would be possible under the control scenario. However, these frequent anglers comprised a small fraction of the total number of anglers observed, minimizing this unavoidable bias.

Total catch per angler varied little among management scenarios. The number of kept fish was lowest under the control scenario and highest under the reduced minimum size and cumulative size scenarios. The slot limit scenario fell in between. The hierarchy varied somewhat based on weight, but control trips still produced the lowest weight kept. Overall, management scenario had a greater effect on numbers of fish kept than on weight kept because the additional fish caught were smaller in size and thus lower in weight. The control scenario had the greatest discard-to-catch ratio, followed by the slot limit scenario and then the cumulative size and reduced minimum size scenarios, which produced similarly low ratios.

Observations of the three alternative management scenarios confirmed the expectation that each increases fishing mortality. In each case, the modified bag and size limits allowed more fish to be kept by permitting some fish below the legal size limit to be landed. However, fishing mortality rose by a larger factor based on fish number than fish weight. It is this tradeoff—the landing of more but lighter fish—that merits further attention.

Besides the differential distribution of mortality by number and weight, the three alternative management scenarios affected discard mortality dramatically. Note in Table 12 that discard mortality in all three alternative management scenarios declined relative to the control scenario, but this decrease was lowest in the slot limit scenario, which most resembled the control condition. The decline in discard mortality is substantive, a factor of 2.0 by number and weight for the cumulative size and reduced minimum size scenarios. Thus, some portion of the increased fishing mortality obtained through the landing of additional fish is compensated for by reducing the number of discarded fish expected to die.

The recreational fishery is managed by weight; the total allowable landings for a fishing year are expressed in units of biomass. Thus, assessing the effectiveness of the three alternative management scenarios requires determining which of them offers the highest number of kept fish under a biomass-neutral fishery; in other words, comparisons should be made under the constraint that total mortality in terms of biomass does not vary from the control scenario adopted in 2006. Assuming that the 2006 regulations are adequate and that our results are representative, the biomass-neutral option would presumably restrict recreational catch to the total allowable landings limit under each of the management scenarios. The expected increase in landings for the three alternative scenarios under a biomass-neutral fishery shows that even in the worst case (i.e., the slot limit scenario), anglers could take home 1.75 times as many fish as they did on the observed control trips without influencing total fishing mortality expressed in terms of biomass. For the other two scenarios, the increase in landings exceeds a factor of 2.0.

Conclusions

All three alternative management scenarios outperformed the 2006 legal management scenario. All three reduced summer flounder discards relative to catch and reduced discard mortality by as much as a factor of 2.0. Each alternative scenario resulted in the landing of more fish under the constraint that total mortality by weight does not change. Each of the three scenarios resulted in lessening of fishing pressure on the oldest, largest individuals in the population, thereby promoting the development of a more robust size-frequency distribution. By inference, all three scenarios should promote an increase in angler satisfaction without negatively impacting the summer flounder stock, while also meeting the objective of reducing discards as expressed in the Magnuson–Stevens Act.

Cox et al. (2002) showed that increasingly restrictive bag limits result in decreased participation by consumptive anglers. Alternatives that do not reduce participation in the summer flounder fishery should be sought so as to avoid the socioeconomic consequences of lower participation. Our analysis provides no metric that supports retention of the 2006 management scenario and further calls attention to the cumulative size and reduced size limit scenarios as options deserving consideration as alternatives. However, in comparison with the 2006 legal (control) option, any of the three alternate management scenarios examined in this study can provide a viable alternative.

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