Discard Reduction Concerning Selectivity and Overall Gear design in the Black Sea Bass, *Centropristis striata*, Trap Fishery

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Abstract

The use of an escape vent in the black sea bass trap fishery has been demonstrated to reduce the capture of sub-legal size fish, thus reducing discard mortality. However, when the single vent becomes blocked by near-legal size fish trying to escape, further escapement of sub-legal fish is prevented. Efficiency of escapement can theoretically be increased by the use of multiple escape events within the trap. This study evaluated the effectiveness of a new trap design with multiple escape avenues on the release of black sea bass and resulting potential discard mortality. Experimental wire mesh traps were constructed using traditional 1.5"square mesh on only half of the trap, with the other half consisting of 2" mesh. The experimental traps were deployed with control traps (1.5" mesh throughout with no escape vent) and vented traps (control traps with a single 2" escape vent). The trials were conducted during September 2002 and October 2003 off Chincoteague, VA. There were significant differences (ANOVA $p<0.007$ and Kruskal-Wallis $p=0.011$) in total CPUE between the three treatments, with a demonstrated difference between the experimental gear and both the control and vented. There was no difference in CPUE between the vented and control. There were statistical significant differences (ANOVA $p<0.0005$ and Kruskal-Wallis $p=0.001$) in CPUE between the pot configurations with respect to sub–legal fish (<28cm). Comparisons between the three trap configurations demonstrated differences between the experimental gear and both the control and vent. There was no difference between the catch of sub-legal sea bass between the vented and control traps. The experimental trap retained 78.1% less sub-legal fish than the control trap, and 73.7% less than the vented trap. There was no difference in CPUE of legal size sea bass between the three trap types. This study indicates that a selectivity process occurred within the experimental trap which successfully culled out sub-legal sea bass before they reached the surface, while not impacting the potential capture of legal size fish.

Introduction

In 2001, Mid-Atlantic States produced over 69% of all black sea bass *(Centropristis striata)* commercially landed on the US Atlantic Coast, with landings of 1,078 mt valued at $3.6 million (Personal communication from the National Marine Fisheries Service, Fisheries Statistics and Economics Division, Silver Spring, MD, 2003). Fish traps are widely used in the Mid-Atlantic black sea bass fishery, which accounted for 38.3% of total sea bass landings in the Mid-Atlantic in 2001. Traps are fished at depths to 40 meters and quickly hauled to the surface with trap-pullers, where the catch is culled, sorting legal from sub-legal size fish with the sub-legal fish placed back overboard (discarded). Black sea bass, like other reef dwelling fish as grouper, tilefish and tautog, have a gas-filled internal organ called a swim bladder that enables them to control their buoyancy, thereby allowing them to position themselves at different depths. When these fish are brought up quickly from the bottom, the trapped gas in the swim bladder expands, due to the reduced atmospheric pressure, and can burst the bladder, expelling the gases into the fish's body cavity (Burns and Restrepo, 2002). The resulting internal pressure is sufficient to push the stomach out through the mouth and the intestine out through the anus, and create bulging of the eyes. Discarded fish that are released in this condition are not able to dive until they are able to control their buoyancy, leaving them floating on the surface and highly vulnerable to predation. During the summer fishing periods, temperature shock, fish quickly going from a cool bottom temperature to a warm surface temperature during hauling, may also impact discard mortality.

Traps are typically fished on or near bottom structure either baited or un-baited. Amendment 9 to the Mid-Atlantic Fishery Management Council (MAFMC, 1996) Summer Flounder, Scup, and Black Sea Bass Fishery Management Plan (FMP) implemented new management measures for black sea bass pot fishermen which included minimum fish size and the use of an escape vent (MAFMC 1996). Research conducted by Fisher and Rudders (2003), and Shepherd et al., (2000), demonstrated the significant reduction of sub-legal size bass caught in traps with a vent. Though the escapement of targeted sub-legal fish can be attained to some degree by the use of a single vent within a trap, efficiency of escapement can theoretically be increased by the use of multiple vents per trap (Fisher and Rudders, 2003).

The basis for Amendment 9 management measures was to initiate a fishing mortality rate reduction strategy that would allow for black sea bass stock rebuilding. The implementation of an escape vent within the trap allows for the release of undersize fish while on the bottom. However, because only a single vent is used to allow escapement, the likelihood of that opening being blocked by near-legal size fish, especially during initial stage of haul-back, is high. Once the vent is blocked, further escapement is prevented. Tended baited traps typically result in a larger density of fish per trap compared to habitat traps due to the presence of, and competition for food. If more avenues for escapement are available, more sub-legal fish can passively exit trap when larger ones enter or hurriedly exit trap during haul-back, thereby resulting in less mortality associated with discard. Due to their protogynous hermaphrodism, where the majority of smaller fish are females (Mercer 1978), the escapement of sub-legal fish should increase spawning potential and therefore enhance stock recruitment. The present study was designed to test the impact multiple vents would have on black sea bass discard mortality within a trap fishery that experiences high fish densities per trap.

Methods

The research entailed testing two different trap designs to quantify fish size selectivity and potential discard mortality. Sixty traditional wire mesh sea bass traps were constructed, all uniform in dimensions and design: dual funnel 36" x 24" x 24" rectangular traps made from vinyl coated mesh 16 gauge wire divided into separate kitchen and parlor section, with a centrally located bait column extending from top to bottom within the kitchen section. The traps were bridled and weighted so as to lift traps off the bottom during haul-back in a vertical manner, with the trailing trap panel being the back of parlor section. Twenty traps were constructed as "controls", with a uniform mesh size of 1 ½" square throughout the trap and no escape vent. Twenty traps were constructed as representing a legal trap design for 2002, which were the control traps fitted with a single 2" square (inside measurement) vent placed in a side panel of traps parlor near the bottom as per MAFMC study (1996). These traps represented "vented" traps in this study. The remaining 20 traps served as the "experimental" traps which were constructed with half the wire mesh being 1 ½" and the other half 2". The trap top, back, and bottom panels consisted of the 2" mesh. The traps were constructed using only two sections of mesh, one 1 ½" and the other 2", which were bent and hog ringed together. The 2" mesh panels served as multiple escape vents for sub-legal size fish. The actual inside measurements of the vinyl coated 2" square was 1 7/8". All traps had a ghost panel located in the parlor section fixed with degradable fasteners.

The study employed a randomized block design of three traps per block (control and the two trap designs). Traps were randomly placed within a block spaced 10-15 meters apart and fished individually. Each block was fished in relation to bottom structure. Equal amounts of squid per trap was used as bait in all traps tested. Soak times for each set were dependant upon fish size and densities at specific sites, however, imposed desired soak periods were introduced for efficiency evaluation. Soak times of 4 hours were targeted to allow for multiple re-sets per day, adhering to typical commercial drop-pot fishing practices. However, soak times ranged from 45 minutes to 1 week periods.

Fishing occurred off Chincoteague, VA at depths of 20-30 meters on-board a commercial vessel with a black sea bass moratorium permit. Fishing methods followed commercial practices of Mid-Atlantic black sea bass baited trap fishermen. A total of 9 sites were fished in September 2002 and again in October 2003. All black sea bass and by-catch was quantified by species and measured to nearest half centimeter. The amount of bait remaining was also noted and estimated. Comparative analysis was conducted for size selectivity and relative efficiency of tested trap designs.

The catch data were examined with respect to both number and weight of the sea bass caught. The weights (in kg) were estimated by the following length-weight relationship:

$$\ln W = \ln a + b * \ln L$$

where W=weight in kilograms, L=length in centimeters, a = y-intercept and b=slope. The parameters a and b used were: –11.4782 and 3.0742, respectively (Wigley, 2003). CPUE was defined as the number of sea bass per pot haul. The catch data was not adjusted for soak time. The raw catch data was tested for normality and equality of variance. Results from a Shapiro-Wilk test (normality) and a Bartlett's test (homogeneity of variance) indicated that the raw data was both non-normal and heteroscedastic. The raw data was transformed with an ln (x+1) transformation and tested again. This transformation failed to normalize the data; however the transformation did homogenize the variance of the three treatments.

A one factor analysis of variance was used to compare the CPUE of the three pot types with respect to both the total catch and the catch of the two market categories (legal (>28cm) and sub-legal) of sea bass. A Tukey test was used to determine which treatments differed from the others. While the ANOVA is fairly robust to departures from the assumptions of normality and equal variances, the untransformed data was analyzed with a non-parametric test for comparative purposes (Zar, 1996). The non-parametric Kruskal-Wallis test evaluated whether the ranked CPUE for all three pot types were equal. Non-parametric Tukey-type multiple comparisons were performed to assess which pot configurations were different from the others (Zar, 1996).

Selectivity

Analytical techniques for the estimation of fishing gear selectivity have been surveyed by Wileman *et. al.*, (1996) and Millar and Fryer (1999). The SELECT (Share Each Length's Total Catch) method, developed by Millar (1992) can be used to estimate selectivity using the comparative catches from multiple gears fished simultaneously. This approach has been applied to many forms of fishing gears including trawls (trouser trawl and twin trawl) and pot fisheries (Millar and Walsh, 1992; Xu and Millar, 1993). The SELECT method fits the data to the logistic function given by:

$$r(l) = \frac{\exp(a + bl)}{1 + \exp(a + bl)}$$

where r(l) is the probability of a fish at length l will be retained by the gear. Parameters a and b are estimated.

Characteristics of the fitted selectivity curve are generally described as L_{25}, L_{50}, L_{75} (lengths at which a fish has a 25%, 50% and 75% chance of being retained by the gear) and selection range (selection range is defined as L_{75}-L_{25} and gives insight into the slope of the ascending limb of the logistic curve). In addition, the SELECT model can also estimate a split parameter, p. The split parameter describes relative fishing intensity (Millar, 1992). The SELECT method was used to estimate retention lengths, the selection range and the split parameter of the experimental gears.

Results

A total of 180 trap hauls were made over 7 trips resulting in a catch of 7,761 black sea bass with an estimated weight of 2,766.85 kg. Due to fishing directly on structure that support large numbers of fish, bait was quickly consumed, with bait rarely lasting beyond 4 hours of soak time. Length frequency distributions for the three trap configurations are shown in Figure 1. Fish size ranged from 18.5 to 56.5cm in total length. Mean total number and weight caught in the control, vented and experimental traps were 50.4, 46.6, 32.2 and 16.7, 15.9, 13.6 kg, respectively. Comparisons of the catch in both numbers and weight captured with respect to total catch and the two legal classifications (sub-legal and legal) are shown in Figures 2 and 3. The percentage of sub-legal fish captured by each trap configuration relative to the total catch is shown in Figure 4. The experimental trap retained 78.1% less sub-legal fish than the control trap, and 73.7% less than the vented trap. Mean catch of sea bass in both numbers and weight captured with respect to the two legal classifications are shown in Figures 5 and 6.

Results from the ANOVA, Kruskal-Wallis and multiple contrast tests evaluating differences in CPUE between the three trap configurations with respect to the two market designations are shown in Tables 1 through 4. Results from the parametric and non-parametric tests yielded identical results and those will be reported together.
There were significant differences (ANOVA $p<0.007$ and Kruskal-Wallis $p=0.011$) in total CPUE between the three experimental treatments (control, vented and experimental). Comparisons between the three pot configurations demonstrated differences in CPUE between the experimental gear and both the control and vent. There was no difference in CPUE between the vent and control. More insight into the selective properties of the experimental gear was seen upon the individual examination of the two legal classifications of fish.

As evidenced by the length frequency distributions, differences in the catch of sub-legal (<28 cm) fish were the driving factor in the observed differences in overall CPUE of the three pot types. When the CPUE of both the sub-legal and legal fish were examined separately, there were statistical significant differences (ANOVA $p<0.0005$ and Kruskal-Wallis $p=0.001$) in CPUE between the pot configurations with respect to sub–legal fish. Comparisons between the three trap configurations demonstrated differences between the experimental gear and both the control and vent. There was no difference between the catch of sub-legal sea bass between the vented and control traps.

Additionally, there was no evidence to support a difference in CPUE of legal size sea bass between the three trap types.

Given trap design, it was hypothesized that the catch of all sea bass would decrease as soak time increased (and bait was consumed). An analysis of the mean number of sea bass captured per pot haul as a function of soak time is shown in Figure 7. Mean catch decreased as soak time increased for all pot types.

Selectivity

Size selection properties of the experimental and vented pots were examined by fitting the logistic function to the data. The vented treatment did not exhibit size selective characteristics and we were unable to fit the data to the logistic function. Retention probabilities were estimated by the SELECT method for the experimental treatment. The data was truncated at 43 cm. where the numbers of fish captured at larger length intervals was minimal. Model fits were compared by holding the split parameter, "p" fixed at 0.5 (equal fishing efficiency) and also by estimating that parameter. The estimated split model provided a better fit to the data as evidenced by an inspection of the model deviances. Those results are presented in Table 5. The L_{50} was 27.33 cm with a selection range of 2.63 cm for with the experimental configuration. A comparison of the actual versus observed proportions retained by the experimental pot and the deviance residuals are shown in figure 8. The logistic curve for this configuration is shown in Figures 9.

Table 1. Results of Analysis of variance and Tukey test for the total catch of sea bass. An X represents a significant difference between the two configurations and ns represents no significant difference.

Analysis of Variance for the total catch of sea bass (α=0.05)

Source	DF	SS	MS	F	P
Pot configuration	2	11067	5534	5.09	0.007
Error	177	192242	1086		
Total	179	2003309			

Tukey Test

	Control	Vent	Experimental
Control	-	ns	x
Vent		-	x
Experimental			-

Table 2 Results of Kruskal-Wallis Test and Tukey-type multiple comparisons for the total catch of sea bass.

Kruskal-Wallis test for the total catch of black sea bass

Treatment	N	Median	Ave Rank	Z
Control	60	48.5	101.6	2.03
Vent	60	43	95.5	0.9
Experimental	60	31.5	74.4	-2.93
Overall	180		90.5	

H=9.02 DF=2 P=0.011
H=9.02 DF=2 P=0.011 (adjusted for ties)

Non-parametric Tukey-type multiple comparisons

	D	SE	Q	Critical Value	Conclusion
Control vs. Vent	371	403.61	0.92	2.394	Accept Ho: Catch in the Control and Vented pots is the same
Control vs. Experimental	1634.5	403.61	4.05	2.394	Reject Ho: Catch in the Control and Experimental pots is the same
Vent vs. Experimental	1263.5	403.61	3.13	2.394	Reject Ho: Catch in the Vented and Experimental pots is the same

Table 3. Results of Analysis of Variance and Tukey test for the total catch of sub-legal sea bass. An X represents a significant difference between the two configurations and ns represents no significant difference.

Analysis of variance for the catch of sub-legal sea bass ($\alpha=0.05$)

Source	DF	SS	MS	F	P
Pot configuration	2	12911	6456	11.33	<0.0001
Error	177	100847	570		
Total	179	113758			

Tukey test

	Control	Vent	Experimental
Control	-	ns	x
Vent		-	x
Experimental			-

Table 4 Results of Kruskal-Wallis Test and Tukey-type multiple comparisons for the total catch of sub-legal sea bass.

Kruskal-Wallis test for the total catch of black sea bass

Treatment	N	Median	Ave Rank	Z
Control	60	19	110.5	3.64
Vent	60	12	104.9	2.63
Experimental	60	3	56.1	-6.27
Overall	180		90.5	

H=39.61 DF=2 P=0.000
H=39.61 DF=2 P=0.000 (adjusted for ties)

Non-parametric Tukey-type multiple comparisons

	D	SE	Q	Critical Value	Conclusion
Control vs. Vent	334	403.61	0.83	2.394	Accept Ho: Catch in the Control and Vented pots is the same
Control vs. Experimental	3264.5	403.61	8.09	2.394	Reject Ho: Catch in the Control and Experimental pots is the same
Vent vs. Experimental	2930.5	403.61	7.26	2.394	Reject Ho: Catch in the Vented and Experimental pots is the same

Table 5 Parameter estimates from fits of the SELECT model for fixed and estimated relative fishing intensity (p) for the experimental trap configuration. L_{25}, L_{50} and L_{75} are the lengths at which a fish has a 25%, 50% and 75% probability of being retained by the gear. Selection range is L_{75}-L_{25}.

	SELECT model logistic selection curve	
	Fixed p	Estimated p
a	-24.103	-22.816
b	0.892	0.835
p	0.500	0.529
L_{25}	25.778	26.014
L_{50}	27.008	27.330
L_{75}	28.240	28.646
Selection Range	2.462	2.632
Model Deviance	33.847	26.148

Discussion

With the implementation of Amendment 9, MAFMC strategy was to enhance the potential for black sea bass stock rebuilding through reducing the mortality associated with fishing gear and/or practices. Improving stock recruitment can be achieved by the retention of smaller black sea bass, which are predominantly female, within the fishery, thus increasing spawning potential. This study indicates that a selectivity process occurred within the experimental trap which successfully culled out sub-legal sea bass before they reached the surface. The use of a single vent in the baited, drop-pot fishery demonstrated little affect on reducing the capture of sub-legal fish. While discard mortality was not explicitly quantified, it is hypothesized that allowing fish escapement while still on the bottom will prevent the potential physical and physiological damage to sea bass from pressure and/or temperature changes during haul-back. Even when mechanical graders are used on-board to speed the culling process, the trauma to the fish will have already occurred to some degree upon haul-back, increasing the potential for discard mortality.

While the experimental trap was effective in reducing sub-legal fish, no statistical difference in catch of legal-size fish was observed between all trap designs. The experimental trap allowed the majority of sub-legal fish to escape without impacting the harvest of targeted legal-size fish. These gear selectivity results provide for possible operational ramifications. In part, the use of the experimental trap would indicate less time and/or labor involved to sort and process the catch.

With states individual quotas currently in place, the practice of "high-grading" at sea affectively extends the minimum size of landed fish beyond the targeted selectivity of the current gear. However, the use of traps, as the experimental trap in this study, would continue to reduce discards regardless of individual fishing practices. Traps with mesh sizes greater than 2", or with multiple standard vents larger than currently mandated, could theoretically be employed for high-grading while the traps are on the bottom and during initial stage of haul-back instead of on deck.

Though this study evaluated the use of multiple escape avenues in the drop-pot fishery, similar gear alterations within the sea bass habitat-pot fishery should experience similar results as to fish size selectivity and reduced discard mortality. The location of the 2" mesh is only along the top, back, and bottom trap panels. The side panels, where the fish interact with the entrance funnels, and the front panel remain 1.5", providing similar appearance as habitat traps.

A decline in catch was observed in all traps tested as soak time extended beyond the point were bait remained in the trap. The overall design in the traps (funnels configuration and size) allowed for fish of all sizes to escape once the bait stimulant was exhausted. Thus these traps are most efficient within a "tended" trap fishery, where they are actively worked daily, as apposed to the "habitat" trap fishery, where traps are left for extended periods.

The basic design of the experimental trap in this study is standard to that of industry wire mesh sea bass traps. This similarity allows for re-construction of current traps using 2" mesh without a loss of material. Basically, traps are put together in two U-shaped sections using two separate equal pieces of wire mesh that are hog ringed together at the seems . Separating the two 1.5" mesh pieces, then re-assembling using a new 2" inch wire section with one of the used 1.5" wire mesh section, gives one up-graded trap plus a 1.5" mesh section remaining to build the next trap.

Literature Cited

Burns, K.M. and V. Restrepo, 2002. Survival of reef fish after rapid depressurization: Field and laboratory studies. Pages 148-151, In J.A. Lucy and A.L. Studholm, editors. Catch and release in marine recreational fisheries. American Fisheries Society, Symposium 30, Bethesda, MD.

Fisher, Robert A., Rudders, David B., 2003. The effect of circle and square escape vents on discard mortality in the Black Sea Bass, *Centropristis striata*, Trap Fishery. VIMS Marine Resource Report No. 2003-4.

MAFMC. 1996. Amendment 9 to the Summer Flounder Fishery Management Plan: Fishery Management Plan and Final Environmental Impact Statement for the Black Sea Bass Fishery. June 1996. 152 pp +appendices.

MAFMC. 1998. Amendment 12 to the Summer Flounder, Scup and Black Sea Bass Fishery Management Plan. October 1998. 398 pp +appendices.

Mercer, L. P., 1978. The reproductive biology and population dynamics of black sea bass, *Centropristis striata*. Ph.D. Dissertation. College of William and Mary, Williamsburg, VA.

Millar, R. B. 1992. Estimating the size-selectivity of fishing gear by conditioning on the total catch. J. Am. Statist. Assoc. 87: 962-968.

Millar, R.B. and Fryer, R.J. 1999. Estimating the size-selection curves of towed gears, traps, nets and hooks. Rev. Fish Biol. Fish. 9: 89-116.

Millar, R.B., Walsh, S. J. 1992. Analysis of trawl selectivity studies with an application to trouser trawls. Fish. Res. 13: 205-220.

Northeast Fisheries Science Center, 1997. Report of the 25th Northeast Regional Stock Assessment Workshop (25th SAW), stock assessment review committee (SARC) consensus summary of assessments. NEFSC Ref. Doc.97-14.

Weber, A.M. and P.T. Briggs. 1983. Retention of black sea bass in vented and un-vented lobster traps. NY Fish and Game J. 30(1):67-77

Wigley, S.E., McBride, H,M, and McHugh, N.J. 2003. Length-weight relationships for 74 species collected during the NEFSC research vessel bottom trawl surveys, 1992-99. NOAA Technical Memorandum NMFS-NE-171. 36 pp.

Wileman, D. A., Ferro, R.S.T., Fonteyne, R., and Millar, R.B. 1996. Manual of methods of measuring the selectivity of towed fishing gears. ICES Cooperative Research Report No. 215, Copenhagen, 126 pp.

Xu, X., and R.B. Millar. 1993. Estimation of trap selectivity for male snow crab (Chionectes opilio) using the SELECT modeling approach with unequal sampling effort. Can. J. Fish. Aquat. Sci. 50: 2485-2490.

Zar, J.H. 1996. Biostatistical Analysis. Prentice-Hall Inc., Upper Saddle River, N.J. 662 pp.