SSC Recreational Models Peer Review 9/20/2021

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Outline

- Objectives and previous applications

- Current recreational demand model
  - Angler behavioral model
  - Fishery simulation

Objectives and previous applications

Recreational demand model objectives

- Predict the impact of management options on fishery outcomes

- Evaluate the economic and biological tradeoffs posed by alternative management options

Approach

- Estimate demand for rec. fishing using utility-theoretic model of angler behavior

- Predict outcomes of individual fishing trips (harvest, release, angler welfare, likelihood of taking the trip, etc.) under current and alternative policies

- Previous applications of recreational demand modelling in fishery settings:
  - Carr-Harris and Steinback 2020
  - Lee et. al 2017

Carr-Harris and Steinback 2020
Overview

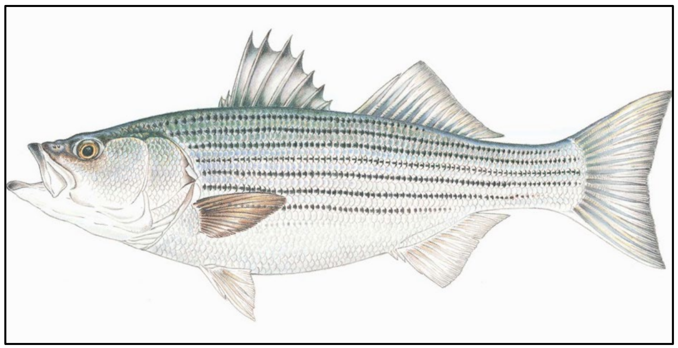
- Recreational demand model for striped bass

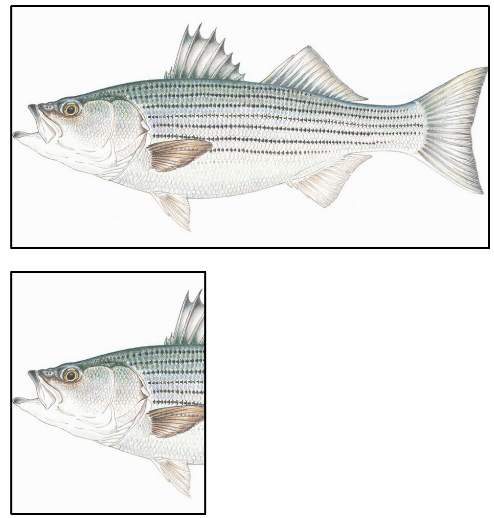
- Choice experiment survey data to estimate angler preferences/values for keeping and releasing striped bass

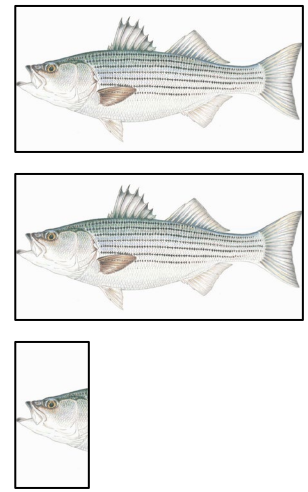
- Fishery simulation to evaluate the effect of alternative policies on total fishing mortality, SSB fishing mortality, angler welfare

Carr-Harris and Steinback 2020

Choice experiment survey results

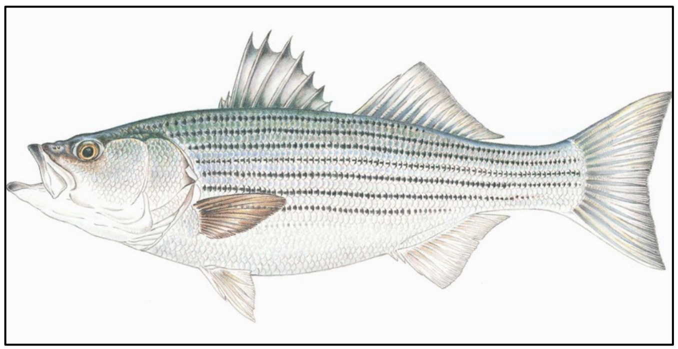


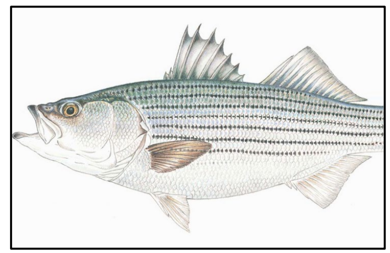


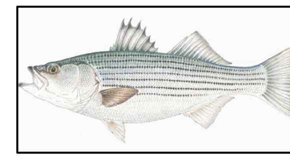


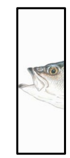
Keeping one trophy striper (~$32) = Keeping 1.4 medium stripers = Keeping 2.2 small stripers

Carr-Harris and Steinback 2020
Choice experiment survey results



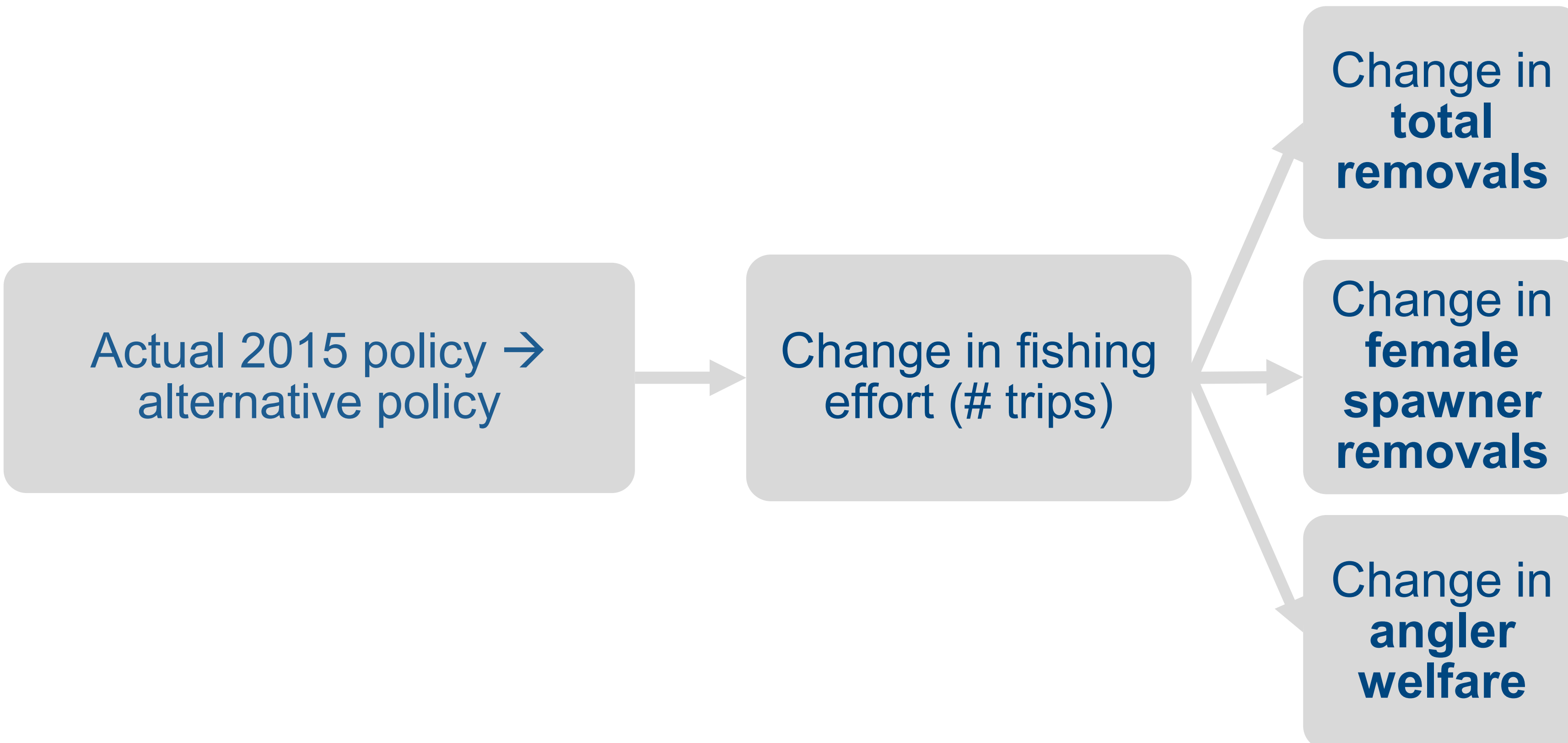






Releasing one trophy striper (~$16) = Keeping 0.7 medium-sized stripers = Keeping 1.1 small stripers

Carr-Harris and Steinback 2020
Simulation framework



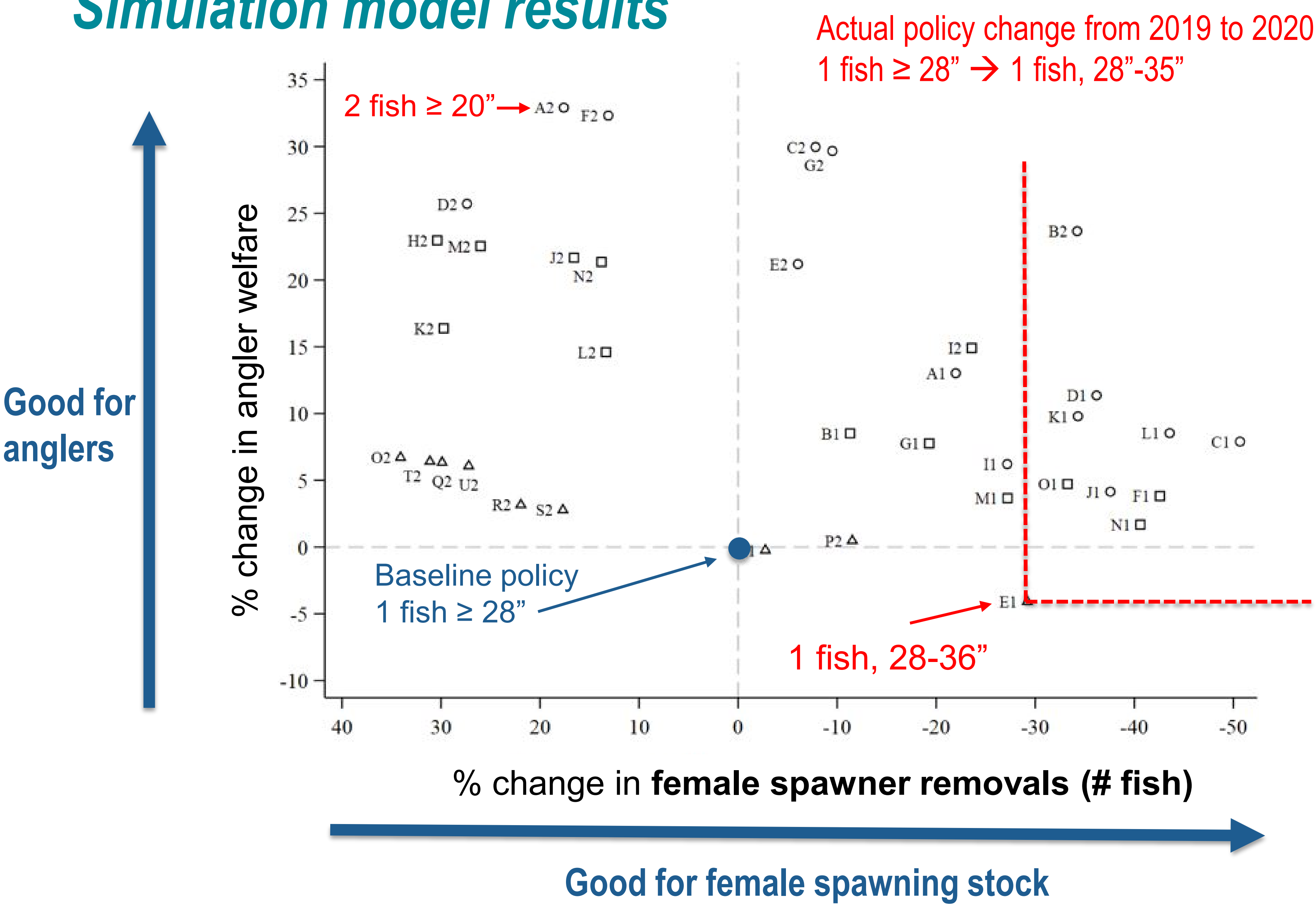
Carr-Harris and Steinback 2020
Simulated policies

TABLE 6 | Alternative 2015 policies evaluated.

	Minimum size limit					
Policy type		**20″ (◯)**		**24″ (□)**		**28″ (△)**
Minimum length only	A1:	1 fish ≥ 20″	B1:	1 fish ≥ 24″		
	A2:	2 fish ≥ 20″	H2:	2 fish ≥ 24″	O2:	2 fish ≥ 28″
Narrow harvest slot	C1:	1 fish 20–28″	F1:	1 fish 24–32″	E1:	1 fish 28–36″
	B2:	2 fish 20–28″	I2:	2 fish 24–32″	P2:	2 fish 28–36″
Wide harvest slot	D1:	1 fish 20–36″	G1:	1 fish 24–40″	H1:	1 fish 28–44″
	C2:	2 fish 20–36″	J2:	2 fish 24–40″	Q2:	2 fish 28–44″
Dual harvest slot	E2:	1 fish 20–28″ and 1 fish > 28 to 36″	L2:	1 fish 24–32″ and 1 fish > 32 to 40″	S2:	1 fish, 28–36″ and 1 fish > 36 to 44″
Partial harvest slot	D2:	1 fish 20–28″ and 1 fish > 28″	K2:	1 fish 24–32″ and 1 fish > 32″	R2:	1 fish 28–36″ and 1 fish > 36″
Dual harvest slot option	G2:	2 fish total, 20–28″; only 1 fish > 28 to 36″	N2:	2 fish total, 24–32″; only 1 > 32 to 40″	U2:	2 fish total, 28–36″; only 1 fish > 36 to 44″
Partial harvest slot option	F2:	2 fish total, 20–28″; only 1 fish > 28″	M2:	2 fish total, 24–32″; only 1 fish > 32″	T2:	2 fish total, 28–36″; only 1 fish > 36″
Protected harvest slot	I1:	1 fish 20–24″ or >32″	M1:	1 fish 24–28″ or >36″		
	J1:	1 fish 20–24″ or >36″	N1:	1 fish 24–28″ or >40″		
	K1:	1 fish 20–28″ or >36″	O1:	1 fish 24–32″ or >40″		
	L1:	1 fish 20–28″ or >40″				

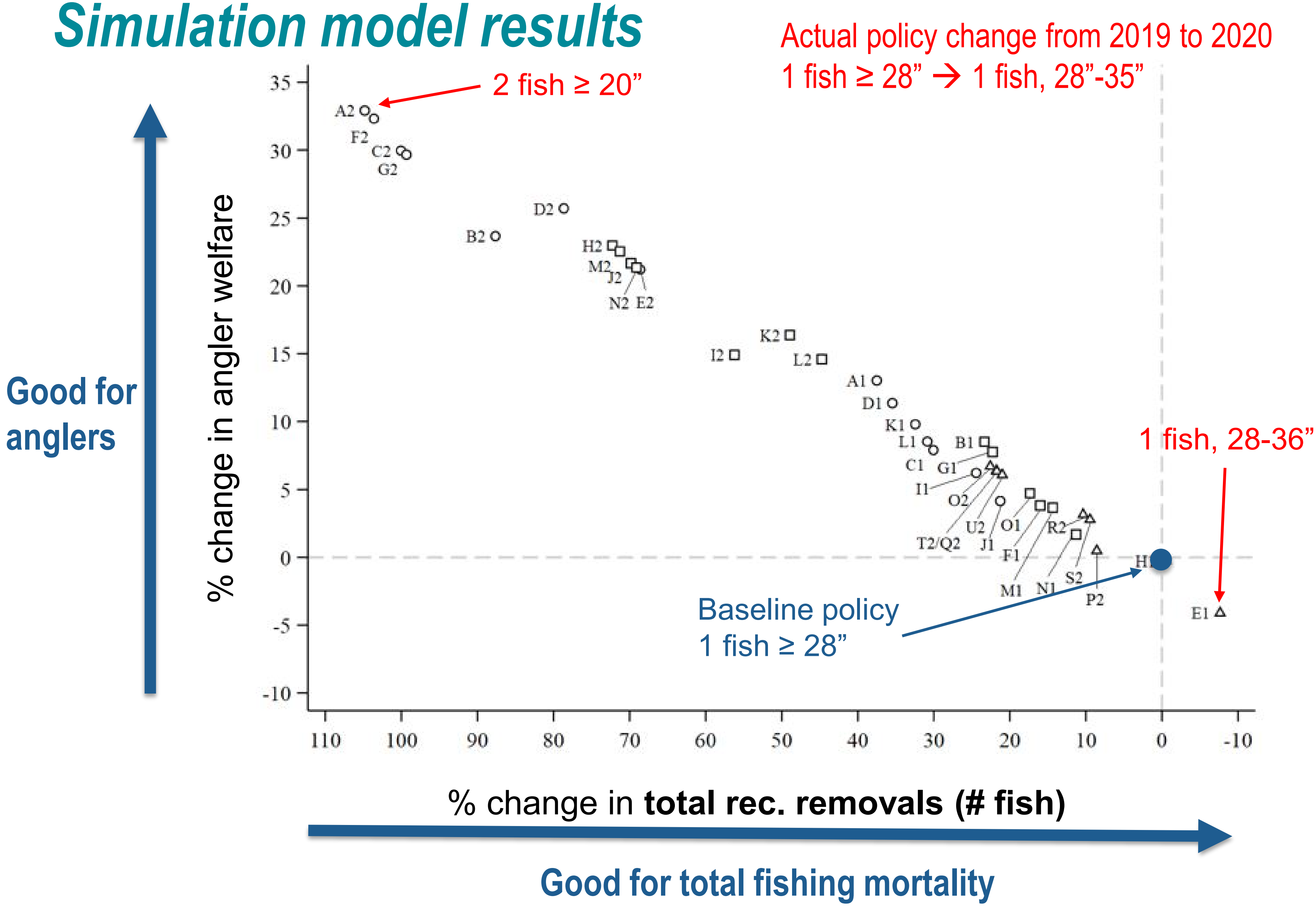
Carr-Harris and Steinback 2020

Simulation model results



Carr-Harris and Steinback 2020

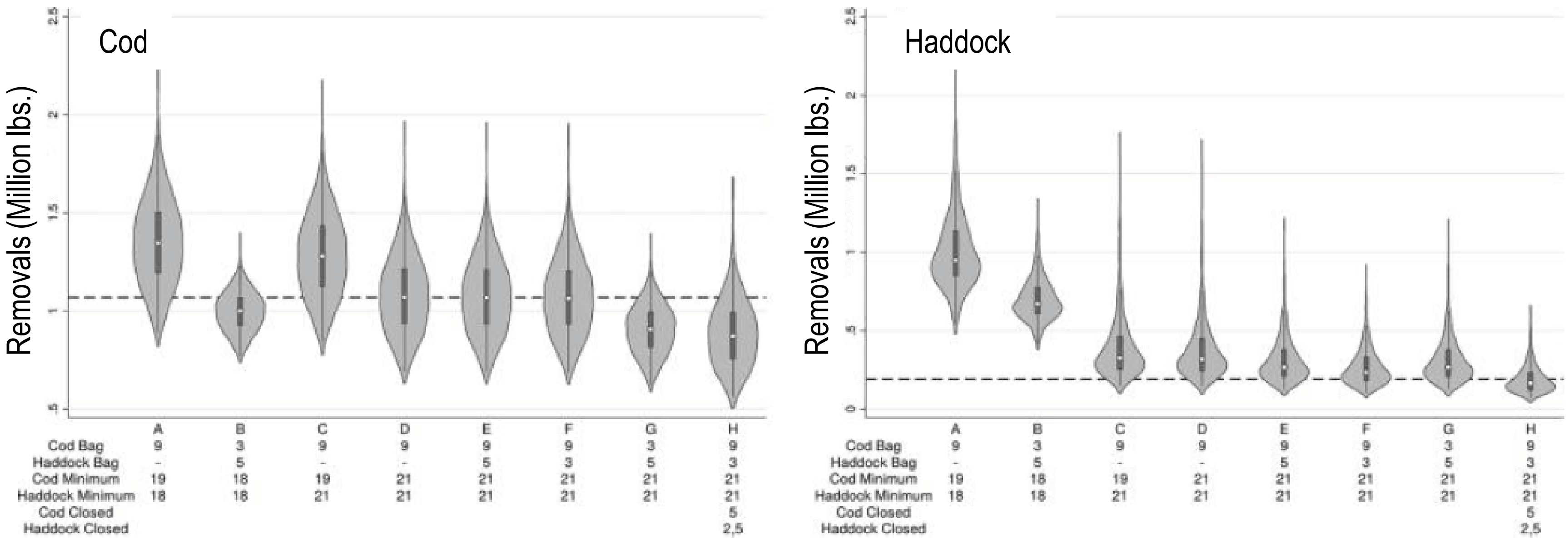
Simulation model results



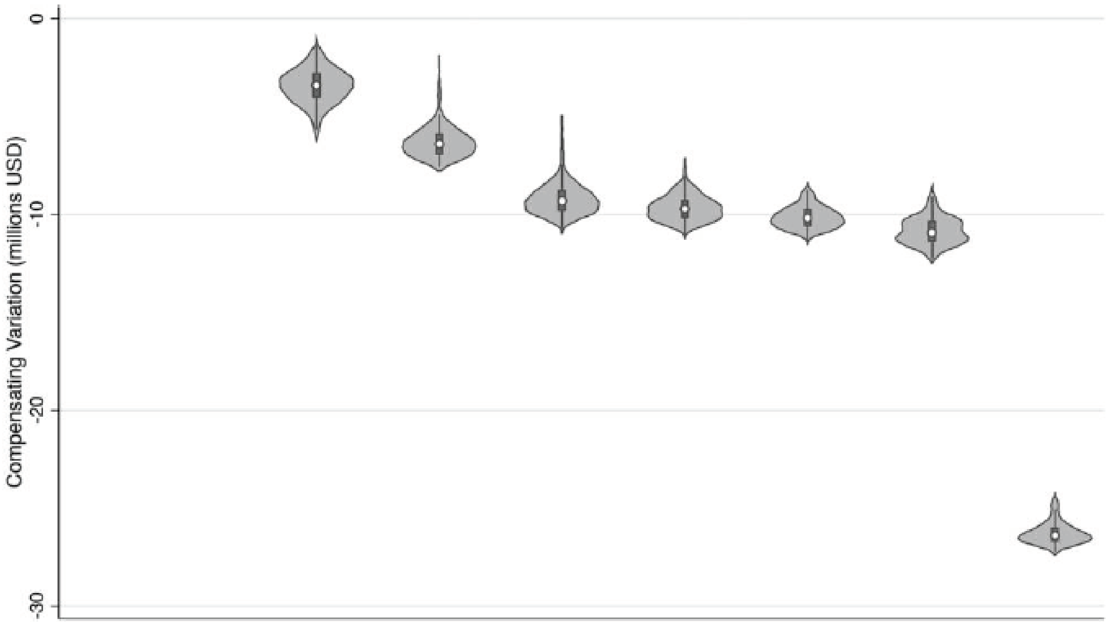
Lee et al. 2017
Overview

- Recreational demand model for GoM cod and haddock
- Choice experiment survey data to estimate angler preferences for keeping/releasing cod and haddock
- Bio-economic simulation to evaluate the effect of alternative policies on SSB, removals, angler welfare
  - Population dynamics model
  - Recreational catch-at-length adjusts to pop. abundance

Lee et al. (2017)
Results - predicted removals in 2014



Lee et al. (2017)
Results – predicted angler welfare in 2014



	A	B	C	D	E	F	G	H
Cod Bag	9	3	9	9	9	9	3	9
Haddock Bag	-	5	-	-	5	3	5	3
Cod Minimum	19	18	19	21	21	21	21	21
Haddock Minimum	18	18	21	21	21	21	21	21
Cod Closed								5
Haddock Closed								2,5

Figure 4. Aggregate Angler CV in 2014 Evaluated Over Seven Alternative Fishing Policies
Note: Policy A is used as the baseline policy.

Current recreational demand model

Recreational demand model approach

1. Estimate angler preferences
   - Data from a 2010 choice experiment (CE) survey

2. Simulate the fishery
   - Historical catch and effort data from MRIP
   - Parameterized with results of angler behavioral model
   - Captures aggregate effect of policies on angler welfare/behavior and fishing outcomes

Estimate angler preferences
Angler behavior model

- Data from a 2010 choice experiment (CE) survey
  - Stated preference method for **non-market valuation**

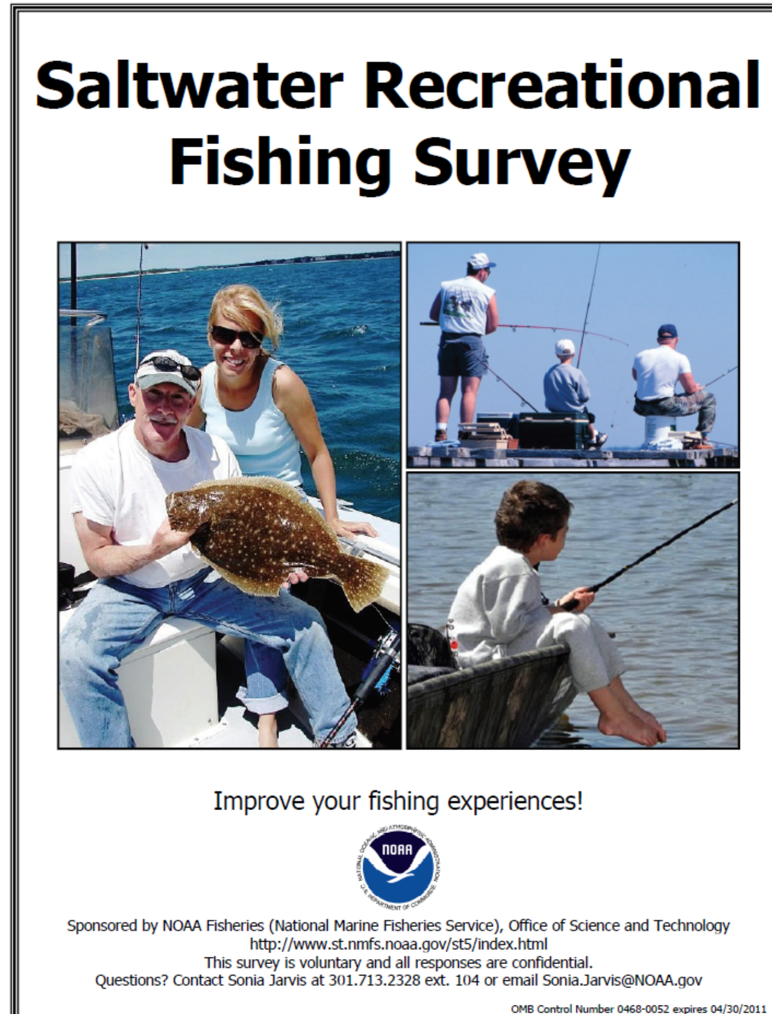
- Non-market goods or attributes do not have well-defined markets, necessitating the use of alternative methods of valuation

- CEs ask people a series of questions that can be used to infer economic values, such as willingness-to-pay (WTP)

- Allow for valuation of virtually any policy-relevant attributes of interest (e.g., harvest, regulations, environmental quality), including those for which observational data are nonexistent or do not vary

Choice experiment data

- 2010 saltwater fishing survey
- Administered in conjunction with MRIP intercepts
- Four regional sub-versions (ME-NY, NJ, DE/MD, VA/NC)
- 10,244 surveys distributed, 3,234 returned (RR=31.5%)



Choice experiment data

SECTION B: SALTWATER FISHING TRIPS

The following questions help us understand tradeoffs made by anglers when they go fishing. **Compare** Trip A, Trip B, and Trip C in the table below, then **answer** questions **2A** and **2B**. **Compare only the trips on this page**. Do **not** compare these trips to trips on other pages in this survey.

Trip Features		Trip A	Trip B	Trip C
Summer Flounder (Fluke)	Regulations	2 Fluke, 20" or larger	5 Fluke, 21" or larger	Go fishing for striped bass or bluefish
	Fish Caught	0 to 4 Fluke, 25" TL	8 Fluke, 12" TL	
	Fish Kept	0 to 2 Fluke	0 Fluke	
Black Sea Bass	Regulations	10 Bl. Sea Bass, 12.5" or larger	15 Bl. Sea Bass, 10" or larger	
	Fish Caught	15 Bl. Sea Bass, 9" TL	20 Bl. Sea Bass, 12" TL	
	Fish Kept	0 Black Sea Bass	15 Black Sea Bass	
Scup (Porgy)	Regulations	15 Scup, 11.5" or larger	20 Scup, 11" or larger	
	Fish Caught	80 Scup, 13" TL	60 Scup, 10" TL	
	Fish Kept	15 Scup	0 Scup	
Total Trip Cost		$90	$105	$160

<u>Definitions</u>:

- **Regulations:** The legal minimum size restriction and bag limit for this trip.
- **Fish caught:** The number of fish caught on this trip and the total length (TL) of those fish.
- **Fish kept:** The number of fish you can legally keep on this trip.
- **Total trip cost:** ***Your portion*** of the costs associated with this trip, including bait, ice, fishing equipment purchase or rental, daily license fees, boat rental fees, boat fuel, trip fees, and round trip transportation costs associated with traveling to and from the fishing location. Travel costs may include vehicle fuel, car rental, tolls, airfare, and parking.

2A Choose your favorite trip. (Please mark only **one** trip with a ☑ or a ☒.)

- **Trip A** ☐
- **Trip B** ☐
- **Trip C** ☐
- **I would not go saltwater fishing** ☐

Behavioral model

- Random utility model framework
  - $U_i = V_i + e$
  - Select alternative with largest U

- $V_i = f(\sqrt{\text{\# BSB kept}}, \sqrt{\text{\# BSB released}}, \sqrt{\text{\# other fish kepts}}, \sqrt{\text{\# other fish releaseds}}$, Trip cost, Striper/bluefish alternative, No trip alternative)

- Panel mixed logit model

Behavioral model results

Fluke parameters

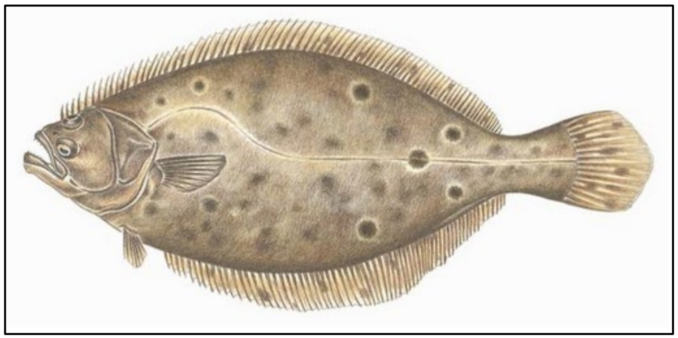
BSB parameters

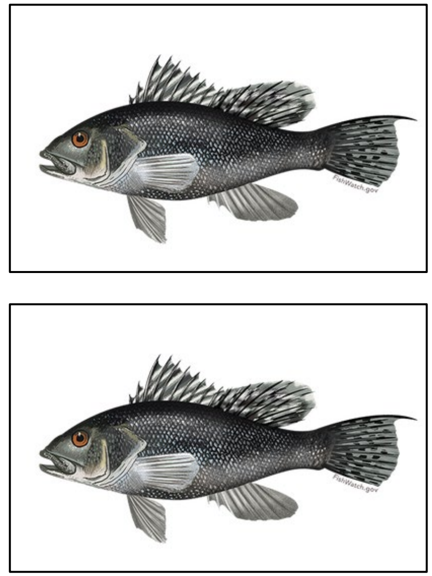
Table 2. Estimated utility parameters from panel mixed logit models.

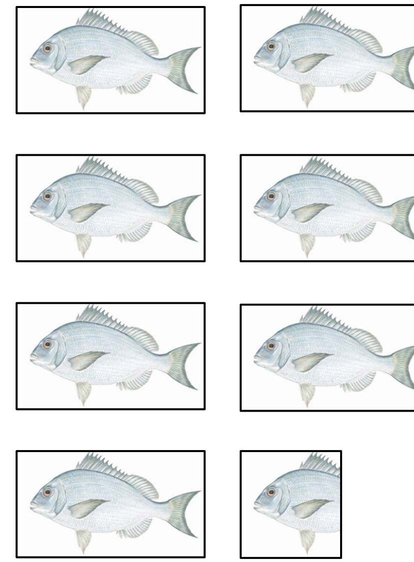
	ME-NY		NJ		DE/MD		VA/NC	
Mean parameters	*Estimate*	*St. Error*	*Estimate*	*St. Error*	*Estimate*	*St. Error*	*Estimate*	*St. Error*
trip cost	-0.012***	0.000	-0.009***	0.000	-0.009***	0.000	-0.008***	0.000
$\sqrt{\text{SF kept}}$	0.559***	0.063	0.762***	0.067	0.807***	0.051	0.521***	0.033
$\sqrt{\text{SF released}}$	-0.061	0.046	0.013	0.043	0.040	0.034	0.108***	0.022
$\sqrt{\text{BSB kept}}$	0.275***	0.034	0.174***	0.034	0.239***	0.027	0.192***	0.019
$\sqrt{\text{BSB released}}$	-0.021	0.024	0.015	0.025	-0.011	0.020	0.020	0.013
$\sqrt{\text{scup kept}}$	0.075***	0.021	0.097***	0.021				
$\sqrt{\text{scup released}}$	-0.010	0.015	-0.039**	0.016				
$\sqrt{\text{WF kept}}$			0.394***	0.056	0.379***	0.045	0.231***	0.032
$\sqrt{\text{WF released}}$			0.093**	0.044	0.064*	0.036	0.030	0.024
$\sqrt{\text{RD kept}}$							0.454***	0.040
$\sqrt{\text{RD released}}$							0.081***	0.025
do not fish	-2.641***	0.252	-2.095***	0.288	-2.963***	0.259	-3.908***	0.259
fish for other species	1.429***	0.181	1.139***	0.208	0.645***	0.159	0.454***	0.121
No. choices	3460		2768		4514		8340	
No. anglers	449		359		594		1072	
Pseudo R^2	0.332		0.274		0.323		0.307	
LL	-3203.6		-2785.2		-4236.5		-8010.3	
LL(0)	-4796.6		-3837.3		-6257.7		-11561.7	
AIC	6441.1		5612.3		8506.9		16062.6	
BIC	6569.2		5765.9		8639.6		16239.4	

Notes: *,**, and *** represent significance at the 10%, 5%, and 1% level of significance, respectively. SF = summer flounder, BSB = black sea bass, WF = weakfish, RD = red drum.

Estimated willingness-to-pay for keeping fish (ME-NY)







keeping 1 summer flounder = keeping ~ 2 black sea bass = keeping ~ 7.5 scup

Willingness-to-pay for the first fish kept:

$23.29	$11.45	$3.13

Fishery simulation

- Uses historical MRIP catch and effort data to simulate individual fishing trips under baseline (state 0) and alternative (state 1) conditions

- Calculate expected utility (V^0 and V^1)

- Probability of taking a trip: $P = \frac{e^V}{1+e^V}$

- Compensating variation:

$$CV_n = \frac{1}{\beta_{trip\ cost}}\left(\ln\left(\sum_{j=1}^{J} e^{V_{nj}^1}\right) - \ln\left(\sum_{j=1}^{J} e^{V_{nj}^0}\right)\right)$$

Example choice occasion

Trip outcomes from a change in attributes based on 100 utility parameter draws.

Trip attributes	Baseline scenario (s^0)	Alternative scenario (s^1)
# summer flounder kept	1	3
# summer flounder released	4	1
# black sea bass keep	1	4
# black sea bass released	3	0
# scup kept	0	0
# scup kept	0	0
Trip cost	$55.85	$55.85
Trip outcomes		
Trip probability	0.51 (0.44, 0.58)	0.69 (0.62, 0.75)
Expected BSB harvest (prob. × BSB keep)	0.50 (0.43, 0.57)	2.75 (2.49, 3.00)
Expected BSB releases (prob. × BSB release)	1.52 (1.31, 1.73)	0
Expected BSB mortality (harvest + 0.1×releases)	0.66 (0.58, 0.74)	2.75 (2.49, 3.00)
CV $s^0 \rightarrow s^1$	-$64.90 ($52.45, $77.35)	

Fishery simulation
Method

- Simulated choice occasions are assigned:
  - #'s fish kept/released
  - sizes of fish kept/released
  - trip cost (2017 expenditure survey)

- Calibrate the model to baseline year (2019)
  - Select *N* simulated trips so that $\sum_{n=1}^{N} p =$ actual # of trips

- Calculate baseline levels of welfare, harvest, release

- Re-run the simulation under alternative conditions

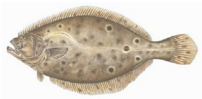
Fishery simulation
Data scale

- Regulations: state level

- Catch-per-trip and catch-at-length: MRIP aggregated across 3 regions (MA-NY, NJ, DE-NC)

- Survey results: 4 regions (MA-NY, NJ, DE/MD, VA/NC)
  - Fluke and BSB parameters available for all regions

- Trip cost data: state level by mode



Fishery simulation
Data

2019 actual regulations

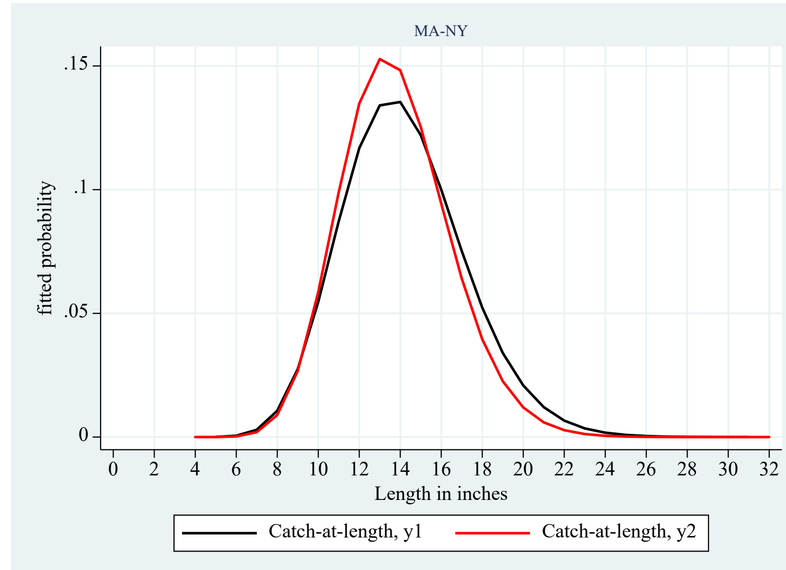
State	Period	Dates	Fluke regs.	BSB regs.	Scup regs.	Weakfish Regs.	Red drum regs.	Estimated # directed fluke trips
MA	1	Jan 1. - May 17	closed	closed	30 fish, 9"	N/A	N/A	0
MA	2	May 18 - Sep. 8	5 fish, 17"	5 fish, 15"	50 fish, 9"	N/A	N/A	92,813
MA	3	Sep. 9 - Oct. 9	5 fish, 17"	closed	30 fish, 9"	N/A	N/A	9,978
MA	4	Oct. 10 - Dec 31	closed	closed	30 fish, 9"	N/A	N/A	1,460
NJ	1	Jan. 1 - May 14	closed	closed	50 fish, 9"	1 fish, 13"	N/A	2,463
NJ	2	May 15 - June 30	3 fish, 18"	10 fish, 12.5"	50 fish, 9"	1 fish, 13"	N/A	960,362
NJ	3	July 1 - Aug. 31	3 fish, 18"	2 fish, 12.5"	50 fish, 9"	1 fish, 13"	N/A	2,763,076
NJ	4	Sep. 1 - Sep. 30	3 fish, 18"	closed	50 fish, 9"	1 fish, 13"	N/A	810,316
NJ	5	Oct. 1 - Oct. 31	closed	10 fish, 12.5"	50 fish, 9"	1 fish, 13"	N/A	41,088
NJ	6	Nov. 1 - Dec. 31	closed	15 fish, 13"	50 fish, 9"	1 fish, 13"	N/A	1,891

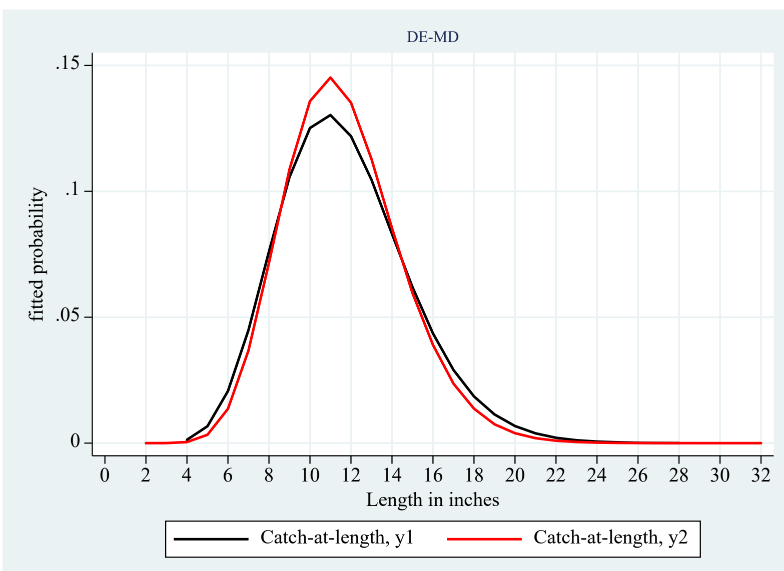
Fishery simulation
Data

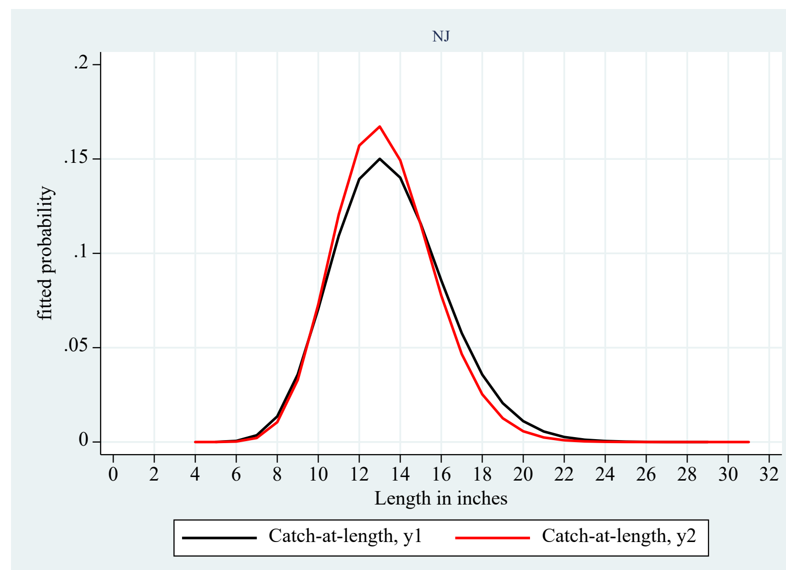
- Catch-at-length
  - In baseline year, use distribution fitted (gamma) to recent MRIP data
  - In prediction year, calculate and fit based on population abundance-at-length (equations 6 & 7)

Abundance-based catch-at-length example (fluke)

Age	Numbers at age y1	Numbers at age y2	
0	50361.35	75542.03	Year 2 values 50% higher for ages 0-3
1	32063.45	48095.18	
2	19979.2	29968.8	
3	11473.4	17210.1	
4	10145.7	5072.85	Year 2 values 50% lower for ages 4-7+
5	4716.905	2358.453	
6	2377.51	1188.755	
7+	4155.28	2077.64	





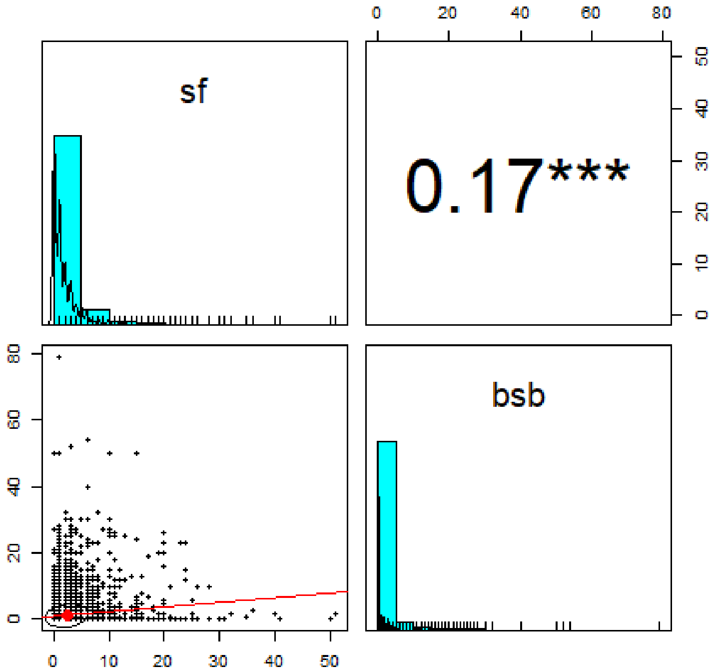


Fishery simulation
Data

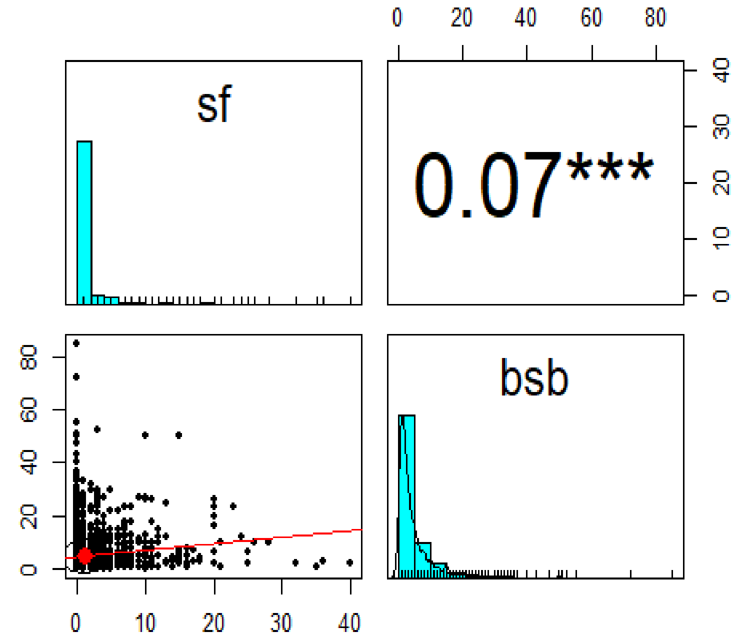
- Catch-per-trip based on recent MRIP data
  - Account for correlation in fluke and BSB catch through the use of copulas
    - Specify marginal distributions for each series, select copula function that generates data with similar correlation structure
- Catch-per-trip of other species assumed independent

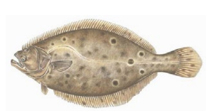
Correlation between fluke and BSB

Observed catch on directed fluke trips, MA-NY 2019



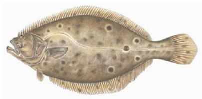
Observed catch on directed BSB trips, MA-NY 2019





Fishery simulation (summer flounder)
Calibration

- Calibrate the model to baseline year (2019)
  - Select *N* simulated trips so that $\sum_{n=1}^{N} p$ = actual # of trips

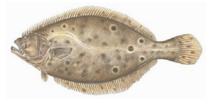


Calibration results for summer flounder

Harvest

Table 1. Simulated vs. estimated 2019 fluke harvest (#'s fish)

state	Simulation (95% CI)	MRIP (95% CI)	Difference	% difference
MA	57,627 (56,938 58,316)	55,386 (26,630 84,142)	2,241	4.0
RI	104,350 (103,250 105,449)	213,592 (59,161 368,022)	-109,242	-51.1
CT	91,145 (90,136 92,153)	89,843 (56,326 123,360)	1,302	1.4
NY	709,441 (701,566 717,316)	561,173 (321,106 801,240)	148,268	26.4
NJ	1,058,311 (1,047,499 1,069,124)	1,108,158 (740,721 1,475,595)	-49,847	-4.5
DE	55,132 (54,733 55,532)	91,025 (58,913 123,137)	-35,893	-39.4
MD	75,912 (75,395 76,429)	79,371 (66,857 91,885)	-3,459	-4.4
VA	106426 (105,963 106,889)	149,785 (72,911 226,659)	-43,359	-28.9
NC	8,660 (8,604 8,716)	34,895 (23,833 45,956)	-26,235	-75.2
Total	2,267,008 (2244221 2289795)	2,383,228 (1,908,190 2,858,266)	-116,223	-4.9



Calibration results for summer flounder

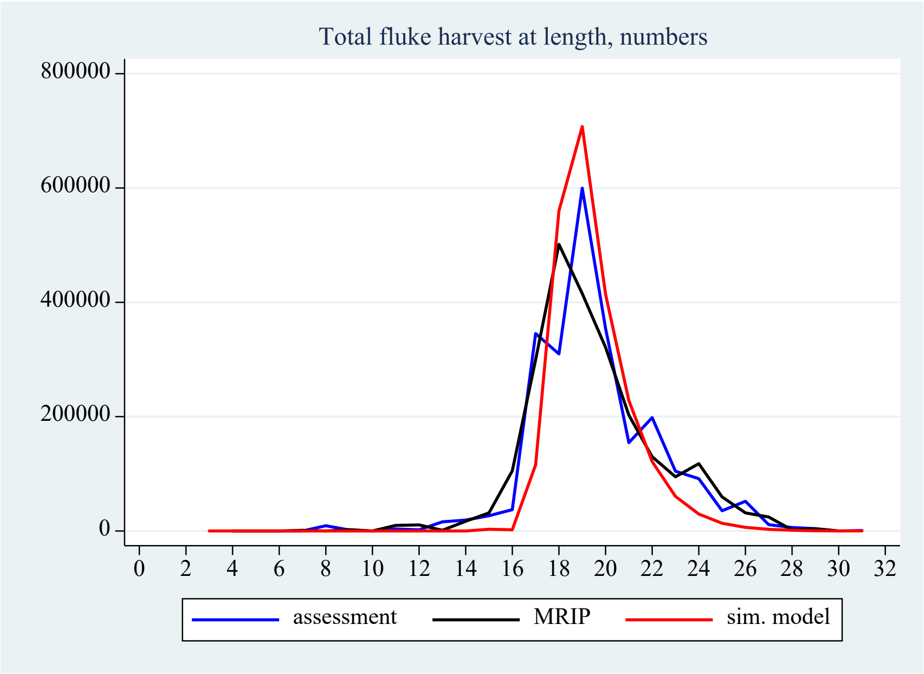
Discards

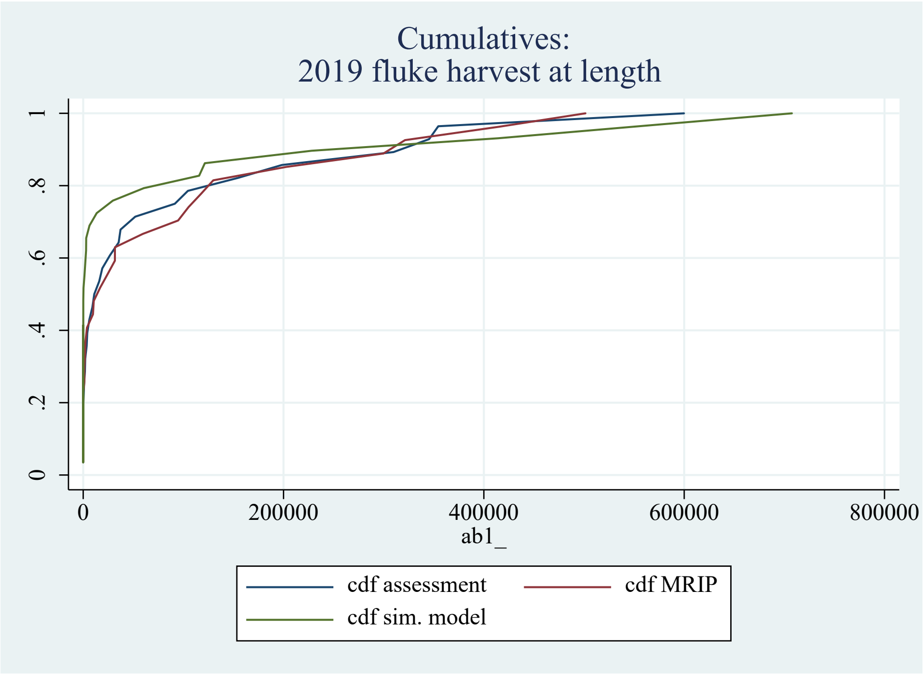
Table 2. Simulated vs. estimated 2019 fluke discards (#'s fish)

state	Simulation (95% CI)	MRIP (95% CI)	Difference	% error
MA	226,302 (224,099 224,099)	224,421 (83,344 365,498)	1,881	0.84
RI	1,168,887 (1,159,973 1,177,801)	1,319,352 (400,194 2,238,510)	-150,465	-11.40
CT	1,025,365 (1,017,481 1,033,250)	1,065,404 (674,356 1,456,452)	-40,039	-3.76
NY	8,620,060 (8,551,801 8,688,317)	9,001,801 (6,144,099 11,859,503)	-381,741	-4.24
NJ	12,703,465 (12,607,124 12,799,806)	13,068,170 (8,729,440 17,406,900)	-364,705	-2.79
DE	663,235 (660,637 665,833)	441,178 (302,647 579,708)	222,057	50.33
MD	902,174 (898,782 905,567)	938,193 (781,958 1,094,428)	-36,019	-3.84
VA	1,307,589 (1,304,510 1,310,668)	1,367,380* (761,049 1,973,711)	-61,986	-4.53
NC	39,621 (39,442 39,801)	1,469 (-1,410 4,348)	38,152	2,597.14
Total	26,656,701 (26,465,040 26,848,362)	28,359,562 (22,868,977 33,850,147)	-772,865	-2.82

*estimate exclude two anomalous observations that account for 933k discarded fish

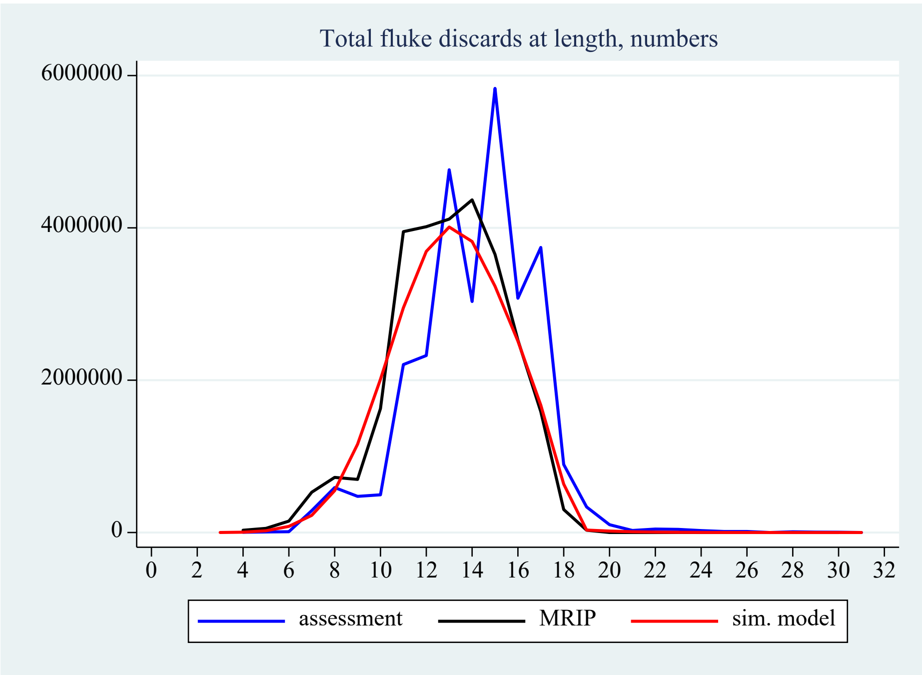
Calibration results for summer flounder

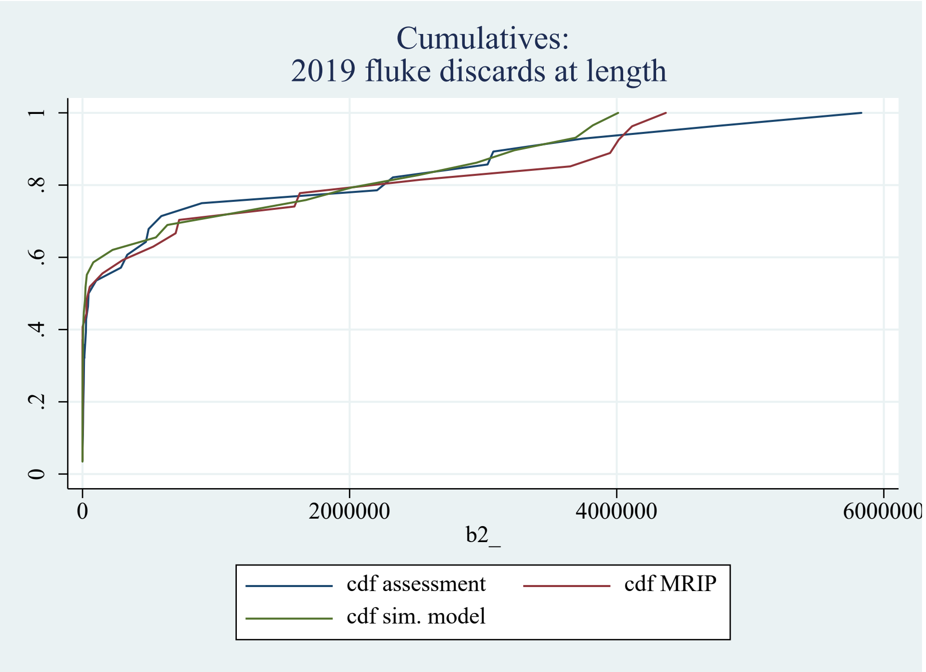




Kolmogorov-Smirnov test for equality of distribution functions:
Sim. model vs. assessment p-value =0.084
Sim. model vs. MRIP p-value =.175

Calibration results for summer flounder





Kolmogorov-Smirnov test for equality of distribution functions:
Sim. model vs. assessment p-value =0.390
Sim. model vs. MRIP p-value =0.043

Calibration results for black sea bass

Harvest

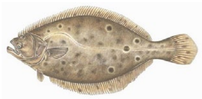
Table 1. Simulated vs. estimated 2019 black sea bass harvest (#'s fish)

state	Simulation (95% CI)	MRIP (95% CI)	Difference	% difference
MA	327,511 (326,810 328,211)	526,593 (321,668 731,519)	-199,083	-37.8
RI	456,037 (455,216 456,856)	517,032 (337,340 696,724)	-60,996	-11.8
CT	668,207 (666,873 669,540)	515,601 (276,600 754,602)	152,606	29.6
NY	1,575,259 (1,571,983 1,578,534)	157,7042 (1,069,013 2,085,070)	-1,783	-0.1
NJ	599,326 (597,729 600,922)	831,241 (539,811 1,122,671)	-231,915	-27.9
DE	51,861 (51,758 51,962)	43,434 (19,184 67,684)	8,426	19.4
MD	139,200 (138,939 139,460)	129,431 (58,667 200,196)	9,768	7.5
VA	198,073 (197,808 198,336)	230,843 (-33,141 494,828)	-32,771	-14.2
NC	221,275 (220,980 221,570)	151,998 (-17,270 321,268)	69,276	45.6
Total	4,236,748 (4,228,184 4,245,311)	4,523,220 (3,762,717 5,283,723)	-286,472	-6.3

Calibration results for black sea bass *Discards*

Table 2. Simulated vs. estimated 2019 black sea bass discards (#'s fish)

state	Simulation (95% CI)	MRIP (95% CI)	Difference	% difference
MA	2,392,956 (2,388,455 2,397,456)	2,728,800 (1,734,077 3,723,522)	-335,844	-12.31
RI	3,263,576 (3,258,043 3,269,109)	8,646,693 (6,471,292 10,821,676)	-172,647	-5.02
CT	3,239,776 (3,234,031 3,245,519)	2,624,762 (1,673,134 3,576,389)	615,014	23.43
NY	8,596,060 (8,580,162 8,611,958)	9,725,431 (7,401,427 12,048,987)	-1,129,371	-11.61
NJ	5,367,557 (5,352,499 5,382,613)	5,352,818 (4,002,933 6,702,703)	14,739	0.28
DE	463,846 (463,116 464,575)	378,300 (203,933 552,667)	85,545	22.61
MD	1,240,920 (1,238,929 1,242,909)	1,635,747 (4,005 3,267,489)	-394,827	-24.14
VA	1,950,094 (1,948,118 1,952,068)	1,903,352 (1,045,363 2,761,340)	46,742	2.46
NC	2,708,943 (2,706,037 2,711,847)	2,802,990 (1,756,042 3,849,9370)	-94,047	-3.36
Total	29,223,726 (29,169,744 29,277,708)	30,588,422 (26,593,505 34,583,339)	-1,364,696	-4.46

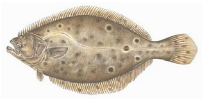


Simulation

- Implemented a variety of regulations across states
- Assumed 100% compliance
- Same catch-at-length distribution used for baseline and prediction year

Actual and hypothetical regulations used in summer flounder simulation.

State	2019 actual regulations	2019 alternative regulations	Change actual → alternative
MA	5 fish, 17”	5 fish, 19”	Min. size +2
RI	6 fish, 19”	6 fish, 21”	Min. size +2
CT	4 fish, 19”	4 fish, 17”	Min. size -2
NY	4 fish, 19”	4 fish, 16”-19”	Slot limit
NJ	3 fish, 18”	3 fish, 18”	No change
DE	4 fish, 16.5”	4 fish, 16.5”	No change
MD	4 fish, 16.5”	No harvest	Harvest moratorium
VA	4 fish, 16.5”	No harvest	Harvest moratorium
NC	4 fish, 16.5”	No harvest	Harvest moratorium



Simulation results – angler welfare

Expected welfare responses to alternative regulations

state	Regulation change	CV ($) (95% CI)
MA	17” → 19” min	1,491,783 (1,100,243 1,883,322)
RI	19” → 21” min	5,807,945 (4,288,726 7,327,164)
CT	19” → 17” min	-9,434,245 (-11,909,176 -6,959,314)
NY	19” → 16”-19” slot	-103,299,312 (-130,189,418 -76,409,206)
NJ	No change	-60,721 (-151,228 29,786)
DE	No change	61,426 (44,612 78,239)
MD	4 fish, 16.5”→ Harvest moratorium	12,329,541 (10,463,853 14,195,228)
VA	4 fish, 16.5”→ Harvest moratorium	12,359,496 (10,378,030 14,340,962)
NC	4 fish, 16.5”→ Harvest moratorium	996,390 (834,756 1,158,025)
Total		-79,747,696 (-10,3296,553 -5,6198,839)

Expected changes are in relation to actual regulations in 2019

Simulation results – harvest

Expected harvest responses to alternative regulations

state	Regulation change	Change in harvest (# fish) (95% CI)	% change in harvest (# fish) (95% CI)
MA	17” → 19” min	-44,721 (-45,241 -44,202)	-77.6 (-78.5 -76.6)
RI	19” → 21” min	-72,528 (-73,527 -71,528)	-69.5 (-69.78 -69.2)
CT	19” → 17” min	149,119 (143,972 154,266)	163.6 (159.3 167.9)
NY	19” → 16”-19” slot	1,652,488 (1,589,013 1,715,964)	232.9 (225.9 225.9)
NJ	No change	1,440 (725 2,156)	0.14 (0.069 0.20)
DE	No change	-215 (-235 -196)	-0.39 (-0.42 -0.35)
MD	4 fish, 16.5”→ Harvest moratorium	-75,912 (-76,429 -75,395)	-100 ( )
VA	4 fish, 16.5”→ Harvest moratorium	-106,426 (-106,889 -105,963)	-100 ( )
NC	4 fish, 16.5”→ Harvest moratorium	-8,660 (-8,716 -8,604)	-100 ( )
Total		1,494,583 (1,428,199 1,560,966)	65.9 (63.52 68.31)

Expected changes are in relation to actual regulations in 2019

Simulation results – discards

Expected discard responses to alternative regulations

state	Regulation change	Change in discards (# fish) (95% CI)	% change in discards (# fish) (95% CI)
MA	17” → 19” min	-80,810 (-86,432 -75,188)	-35.71 (-38.42 -33.00)
RI	19” → 21” min	14,058 (872 27,245)	1.20 (0.071 2.33)
CT	19” → 17” min	-68,641 (-85,964 -51,317)	-6.69 (-8.39 -4.99)
NY	19” → 16”-19” slot	-729,826 (-903,398 -556,255)	-8.46 (-10.49 -6.43)
NJ	No change	12,545 (7,817 17,273)	0.09 (0.06 0.13)
DE	No change	493 (405 580)	0.07 (0.06 0.08)
MD	4 fish, 16.5”→ Harvest moratorium	20,475 (12,424 28,527)	2.26 (1.37 3.16)
VA	4 fish, 16.5”→ Harvest moratorium	55,728 (48,546 62,911)	4.26 (3.70 4.81)
NC	4 fish, 16.5”→ Harvest moratorium	4,956 (4,309 5,603)	12.51 (10.84 14.17)
Total		-771,019 (-932,499 -609,538)	-2.89 (-3.50 -2.27)

Expected changes are in relation to actual regulations in 2019

Simulation results – effort

Expected demand responses to alternative regulations

state	Regulation change	Change in expected # trips (95% CI)	% change in expected # trips (95% CI)
MA	17” → 19” min	-45,466 (-47,900 -43,033)	-43.61 (-45.93 -41.28)
RI	19” → 21” min	-16,396 (-20,797 -11,994)	-3.47 (-4.4 -2.54)
CT	19” → 17” min	26,625 (19,399 33,851)	6.4 (4.69 8.19)
NY	19” → 16”-19” slot	287,612 (209,778 365,445)	8.28 (6.037 10.51)
NJ	No change	261 (-321 844)	0.01 (-0.01 0.02)
DE	No change	-142 (-178 -106)	-0.04 (-0.04 -0.03)
MD	4 fish, 16.5”→ Harvest moratorium	-27,129 (-31,274 -22,983)	-4.98 (-5.74 -4.21)
VA	4 fish, 16.5”→ Harvest moratorium	-22,807 (-26,424 -19,191)	-2.90 (-3.36 -2.44)
NC	4 fish, 16.5”→ Harvest moratorium	-1,686 (-1,972 -1,399)	-6.32 (-7.39 -5.25)
Total		(200,870) (128,216 273,523)	1.85 (1.18 2.51)

Expected changes are in relation to actual regulations in 2019

Other model outputs

- Harvest-, discards-, total rec. fishing mortality-at-length
  - Could feed into operating model

- Harvest, discards of other species on directed fluke trips

Advantages compared to current process

- Model accounts for:
  - changes in availability
  - changes in angler behavior
  - species interactions

- Can be used to model the effect of slight to extreme changes in regulations

Thank you!