Evaluation of Alternative Catch Limits for the U.S. *Illex illecebrosus* fishery in 2023

Presentation to Mid-Atlantic Fishery Management Council
Scientific and Statistical Committee
Via Webinar

Lisa Hendrickson, Northeast Fisheries Science Center
Paul Rago, Science and Statistical Committee, Chair
March 7, 2023

Objectives

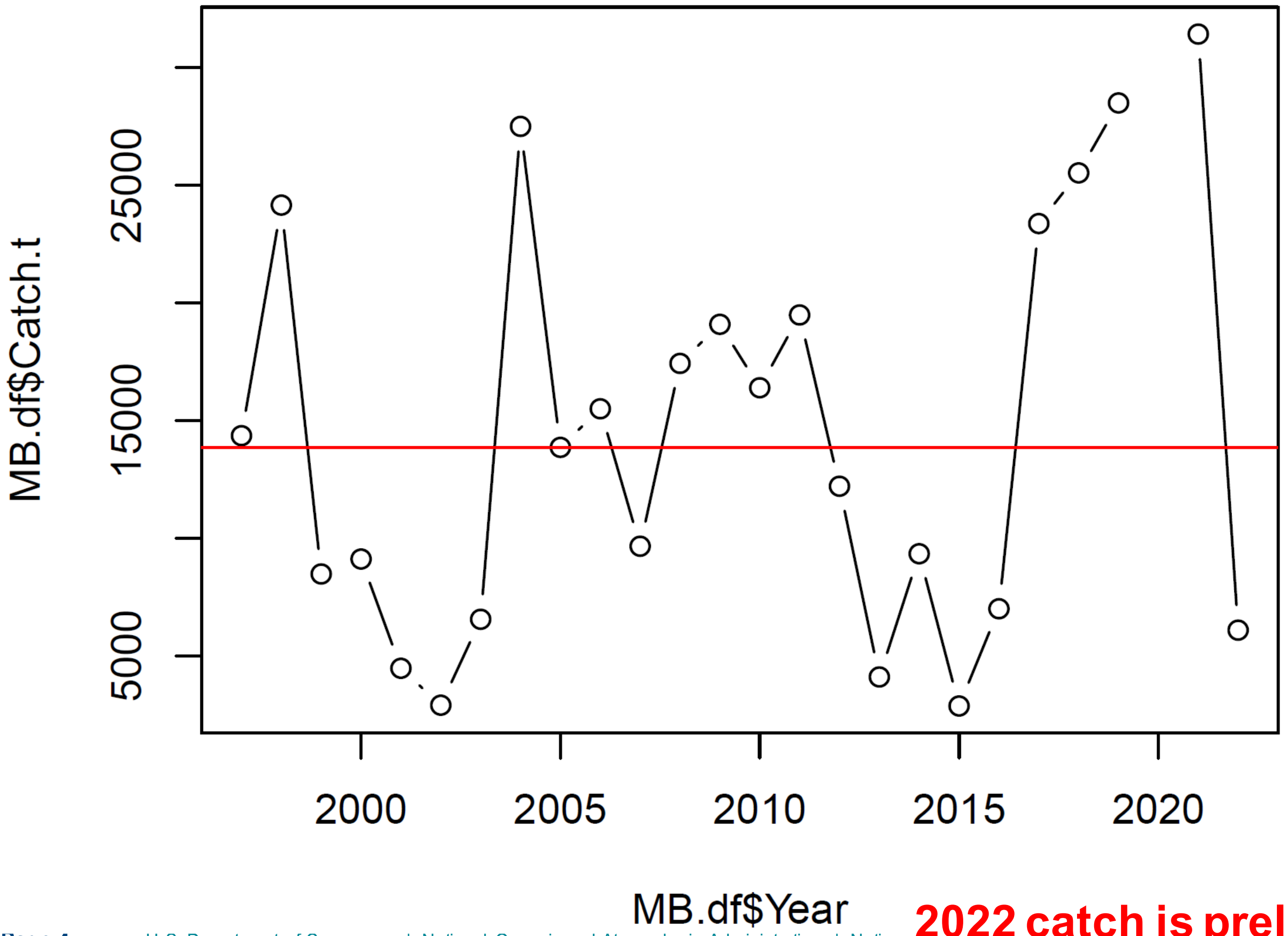
- Update and improve methods applied in 2022
- Add 2022 data for NEFSC fall survey biomass and U.S. fishery catch
- Compute probabilities of exceeding theoretical BRPs
- Summarize results

What's changed since the 2022 analyses?

- Effects of NEFSC fall survey uncertainty on risk of violating *Escapement* and F/M Thresholds (Paul's previous presentation)
- Addition of 2022 NEFSC fall survey biomass and U.S. fishery catch data
- Compared *Escapement* and F/M estimates with theoretical BRPs used for other squid stocks
    1. Percent spawner escapement (all sizes combined)
    2. F/M (used for forage finfish species)
- Updated average probability of overfishing across all years given each alternative catch limit for each theoretical BRP
- Updated results with respect to Council's P* Risk Policy

NOAA FISHERIES

U.S. Fishery Catches (mt) 1997-2022

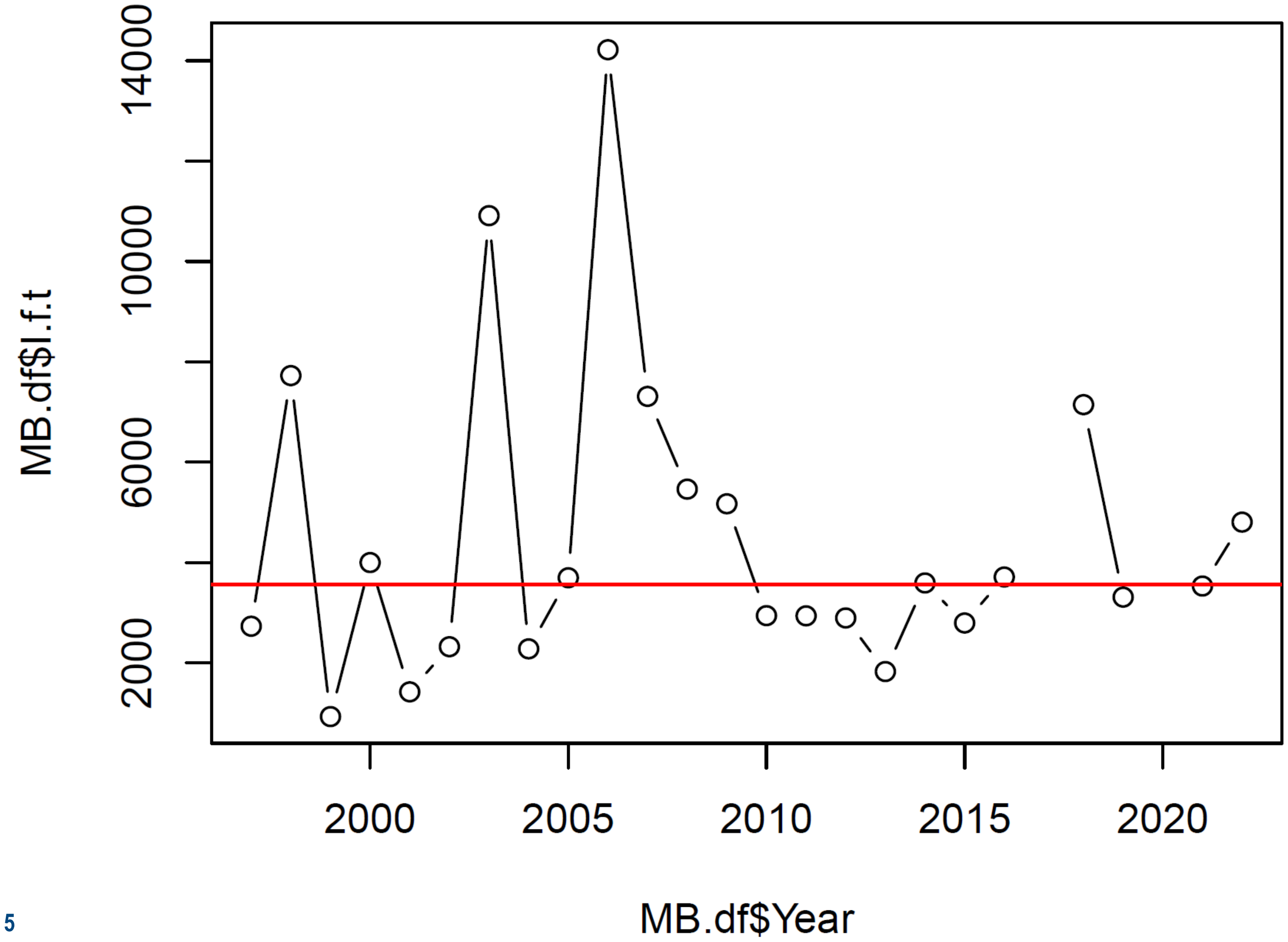


Year	Catch (mt)	NEFSC fall survey biomass (mt)	CV
1997	14,358	2,730	17
1998	24,154	7,725	51
1999	8,482	929	16
2000	9,117	3,999	22
2001	4,475	1,422	15
2002	2,907	2,322	20
2003	6,557	10,913	68
2004	27,499	2,279	12
2005	13,861	3,696	46
2006	15,500	14,220	34
2007	9,661	7,311	8
2008	17,429	5,462	18
2009	19,090	5,170	20
2010	16,394	2,941	22
2011	19,487	2,937	18
2012	12,211	2,895	12
2013	4,107	1,827	13
2014	9,342	3,592	11
2015	2,873	2,795	14
2016	7,004	3,711	26
2017	23,371		
2018	25,524	7,146	13
2019	28,495	3,310	14
2020	Not used		
2021	31,421	3,531	17
2022	6,096	4,805	33

2022 catch is preliminary

NOAA FISHERIES

NEFSC Fall Survey Swept Area Biomass (mt) 1997-2022



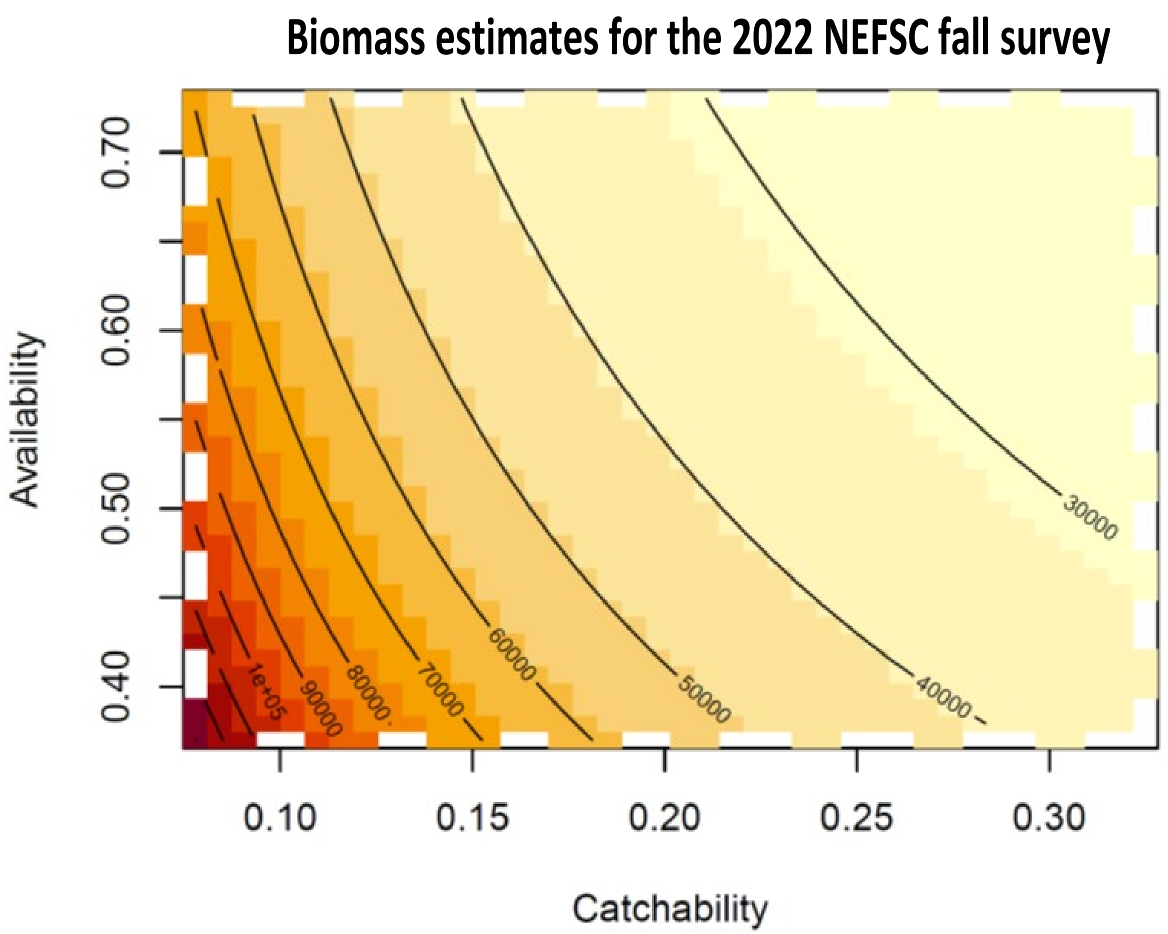
Year	Catch (mt)	NEFSC fall survey biomass (mt)	CV
1997	14,358	2,730	17
1998	24,154	7,725	51
1999	8,482	929	16
2000	9,117	3,999	22
2001	4,475	1,422	15
2002	2,907	2,322	20
2003	6,557	10,913	68
2004	27,499	2,279	12
2005	13,861	3,696	46
2006	15,500	14,220	34
2007	9,661	7,311	8
2008	17,429	5,462	18
2009	19,090	5,170	20
2010	16,394	2,941	22
2011	19,487	2,937	18
2012	12,211	2,895	12
2013	4,107	1,827	13
2014	9,342	3,592	11
2015	2,873	2,795	14
2016	7,004	3,711	26
2017	23,371		
2018	25,524	7,146	13
2019	28,495	3,310	14
2020	Not used		
2021	31,421	3,531	17
2022	6,096	4,805	33

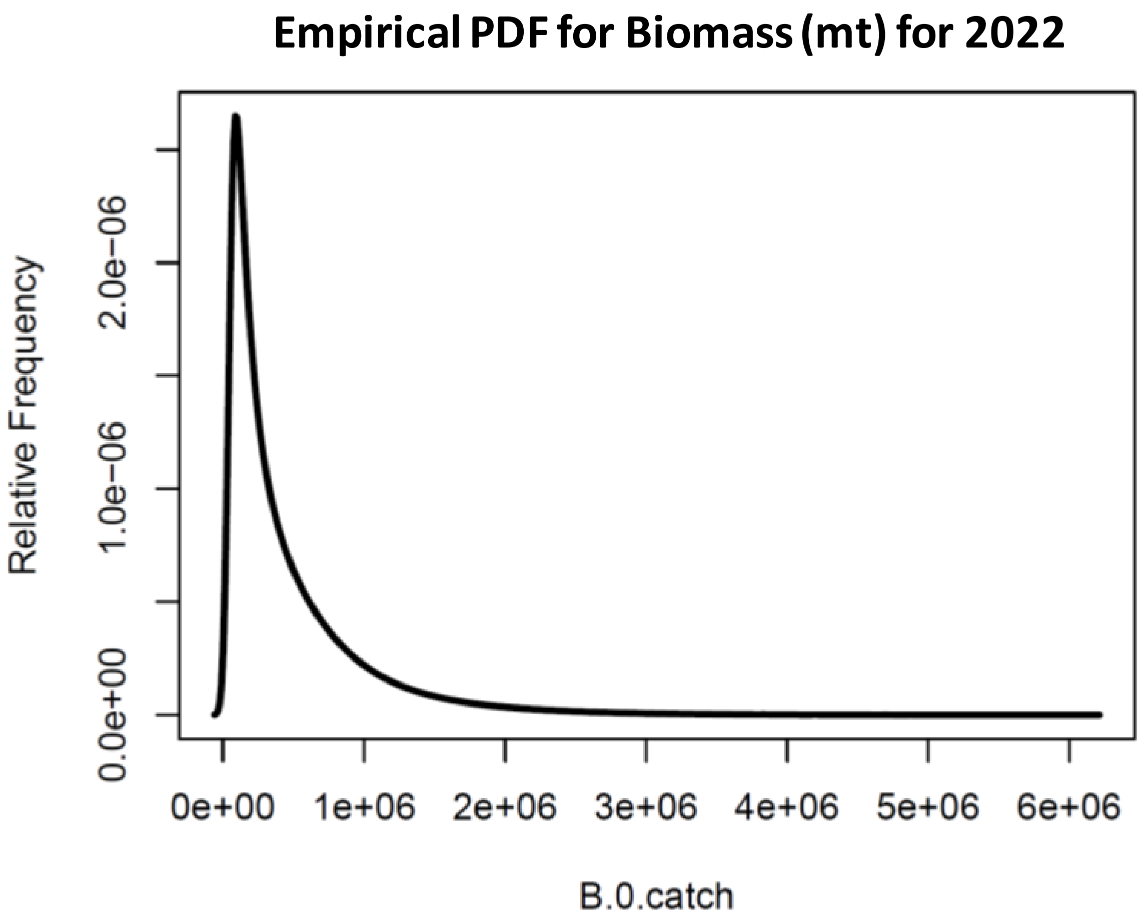
Percentiles and Probabilities of B, F and Escapement

- Compute naïve percentiles from the 250,000 realizations for each year y ($N.q*N.v*N.M=40^3$)
- Compare $Esc(y|C_H)$ to some threshold level T, e.g., 50% Escapement
- Compute probability of overfishing (i.e., falling below escapement threshold) as sum of cases over all assumed {q,v,M} for all years y where $(Esc(y|C_H, \{q,v,M\}) < T)$
- Divide this sum by product of number of years times N.q * N.v* N.M
- Composite probability assumes that all historical abundance estimates B.0(y) are equally likely. This could be refined to account for trend and/or autocorrelation in the future.

Examining the parameter space

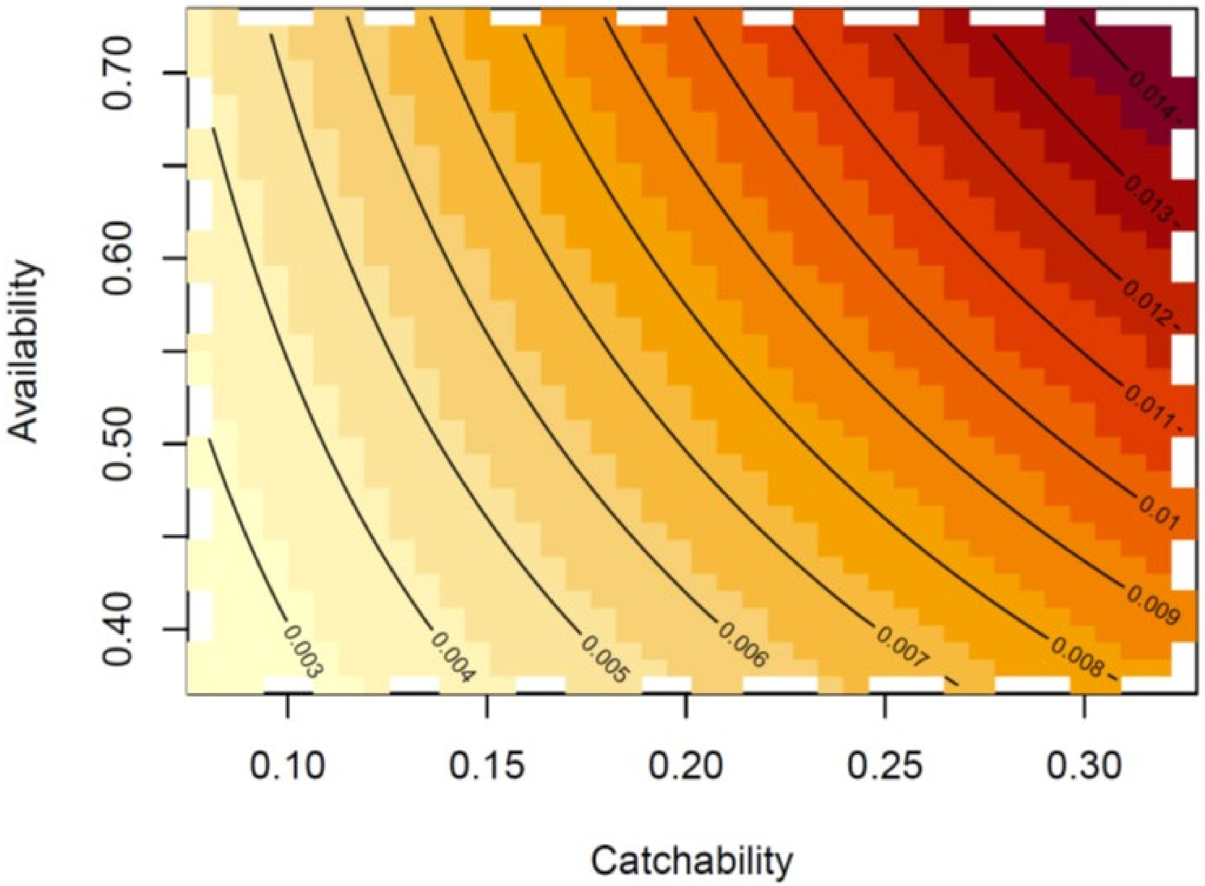
*Isopleths of Illex biomass (mt) estimates for combinations of q and v for **2022** (left) and marginal distribution of biomass estimates over all combinations of q, v, and M (right).*



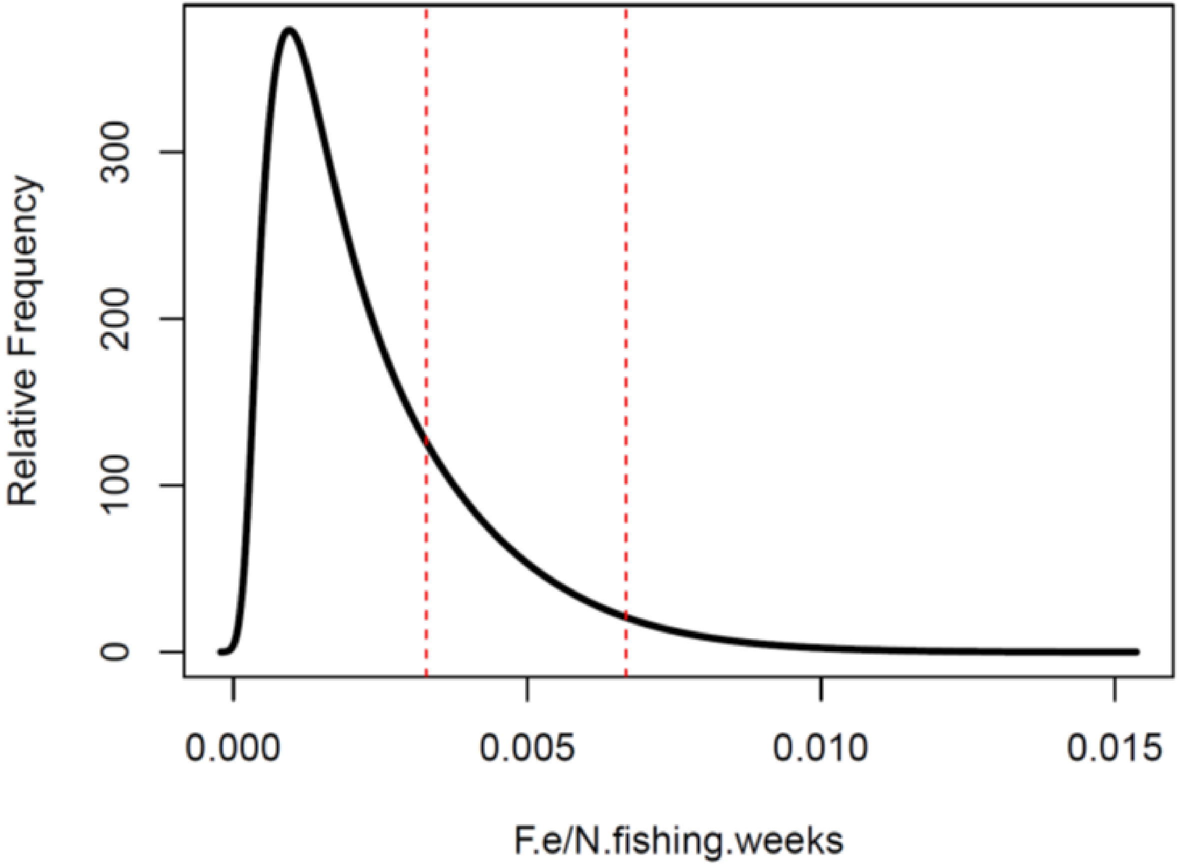


Isopleths of Illex F estimates (per week) for various combinations of q and v for 2022 (left) and derived distribution of F (per week) for 2022 (right). Dashed red lines represent the range of 2019 VMS F estimates.

Feasible F estimates for 2022 NEFSC fall survey

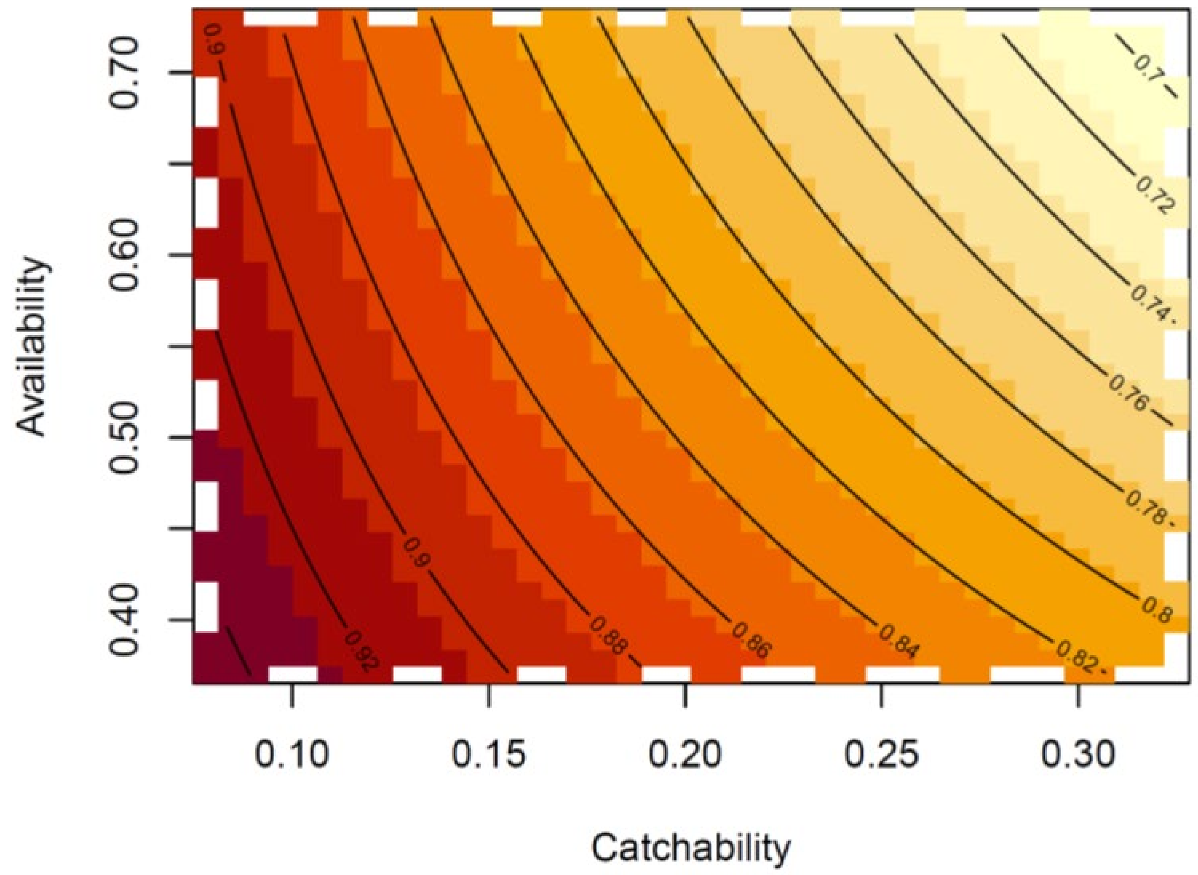


Empirical PDF for fishing mortality (weekly) for 2022 plus VMS F

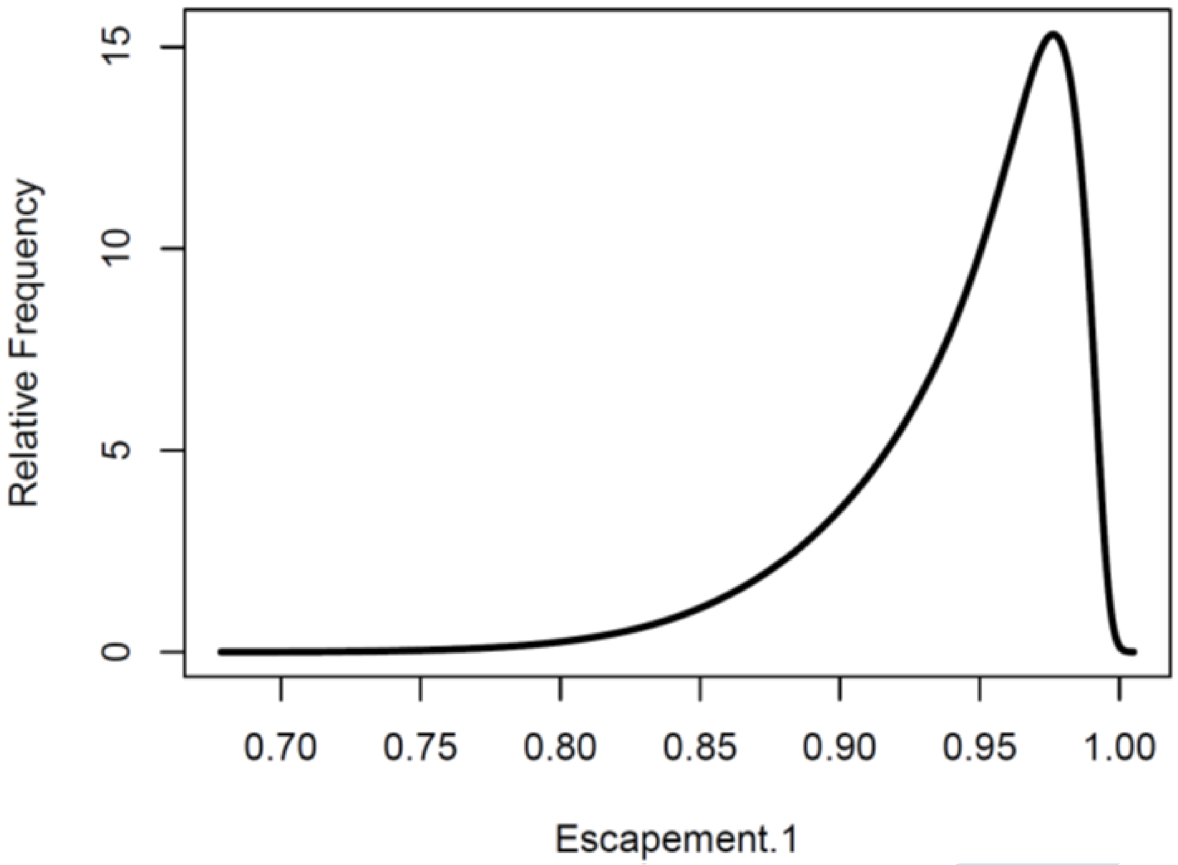


Isopleths of Escapement as a function of q and v (left) and empirical distribution of Escapement based on observed catch in 2022 and observed NEFSC fall bottom trawl indices (right).

Feasible escapement estimates for 2022 NEFSC fall survey



Empirical PDF for escapement for 2022



Percentiles of Biomass, F, and Escapement for each year

Percentiles of Initial Biomass 1997-2022

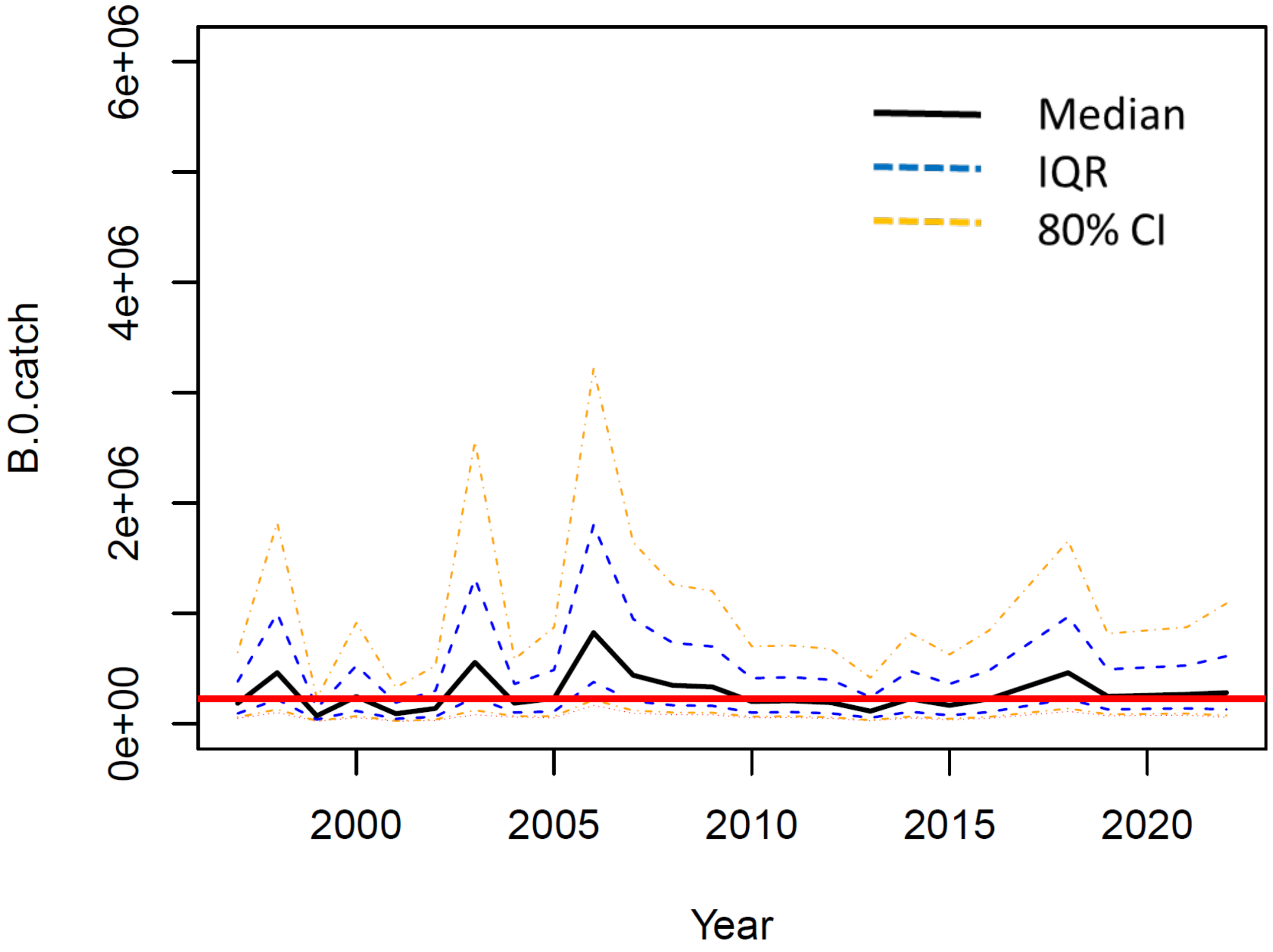


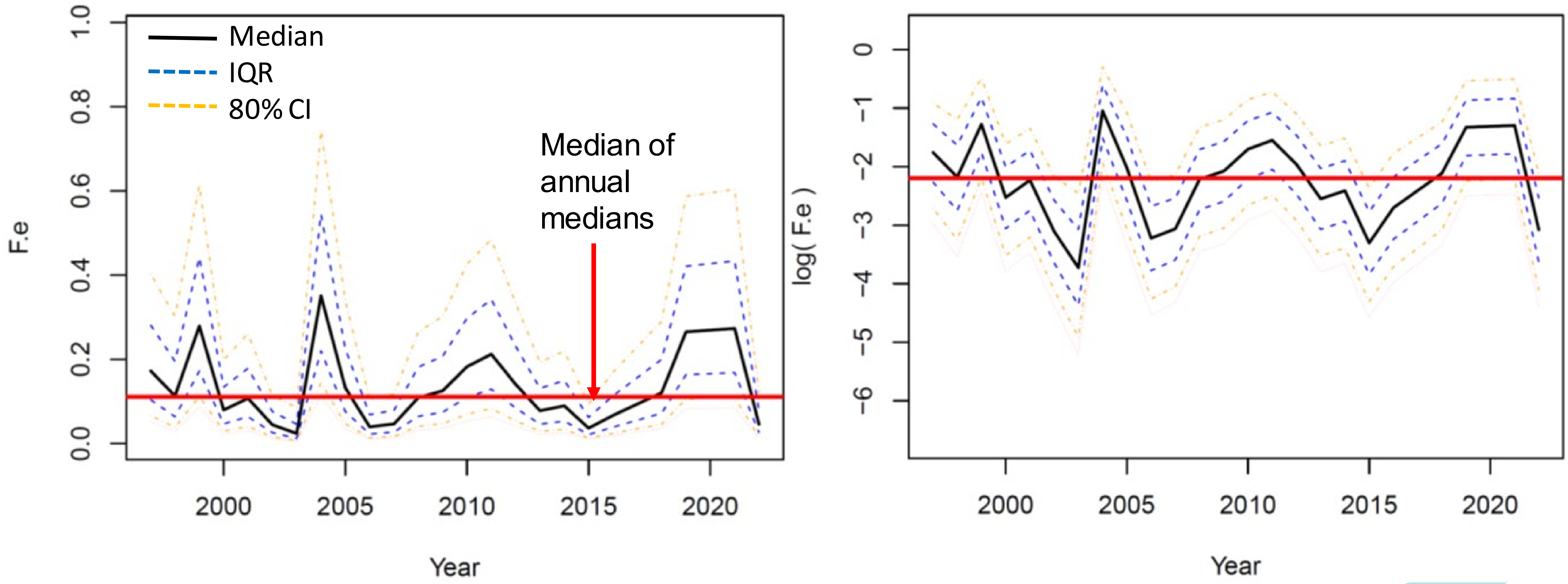
Table 2

	Percentile				
Year	*1%*	*5%*	*50%*	*95%*	*99%*
1997	36,936	47,606	185,199	865,375	1,391,943
1998	68,670	100,773	461,803	2,511,512	4,309,863
1999	16,659	20,539	70,284	305,065	484,055
2000	39,716	54,571	245,669	1,235,322	2,019,005
2001	15,880	21,181	90,438	441,055	712,910
2002	20,474	28,830	137,883	708,998	1,160,249
2003	38,093	81,196	555,374	3,620,695	6,441,818
2004	48,560	58,474	185,866	766,910	1,202,999
2005	37,365	52,649	228,845	1,195,665	2,031,464
2006	112,292	165,629	823,876	4,395,210	7,367,541
2007	67,191	93,137	438,818	2,220,827	3,594,807
2008	60,798	81,274	347,123	1,696,752	2,754,724
2009	60,209	79,882	333,176	1,616,953	2,624,473
2010	40,379	52,028	200,551	937,797	1,515,733
2011	44,257	56,041	207,244	943,577	1,513,930
2012	36,093	47,085	190,855	906,125	1,456,294
2013	18,594	25,256	112,956	561,099	908,174
2014	38,171	51,336	224,932	1,106,103	1,785,947
2015	24,409	34,331	165,564	848,404	1,381,160
2016	34,526	48,299	223,883	1,145,734	1,888,454
2018	83,637	110,417	461,407	2,224,021	3,582,213
2019	57,584	71,257	247,196	1,080,734	1,715,310
2021	62,327	77,011	265,302	1,157,927	1,841,132
2022	39,283	57,304	280,654	1,486,312	2,484,105

Range of medians reasonable but not B0 values > 1M

NOAA FISHERIES

Estimated F (per 25-wk season) (1997-2022) based on based on 250,000 combinations of q, v, and M for each year [left]. Log seasonal F [right]. Average weekly F is the total F divided by 25 weeks.



Low Fs, wide confidence intervals and lack of trend

Percentiles of Escapement, 1997-2022

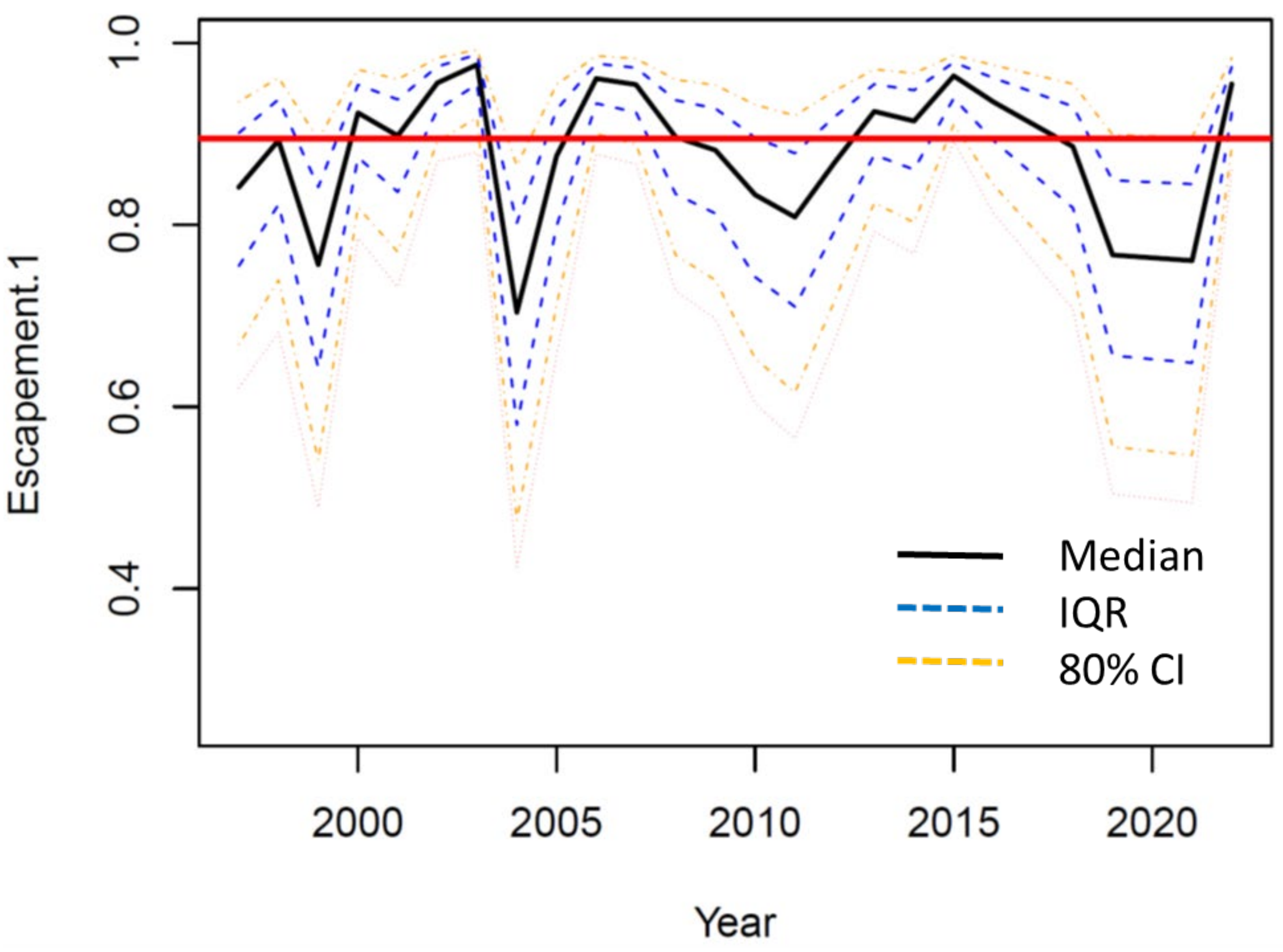
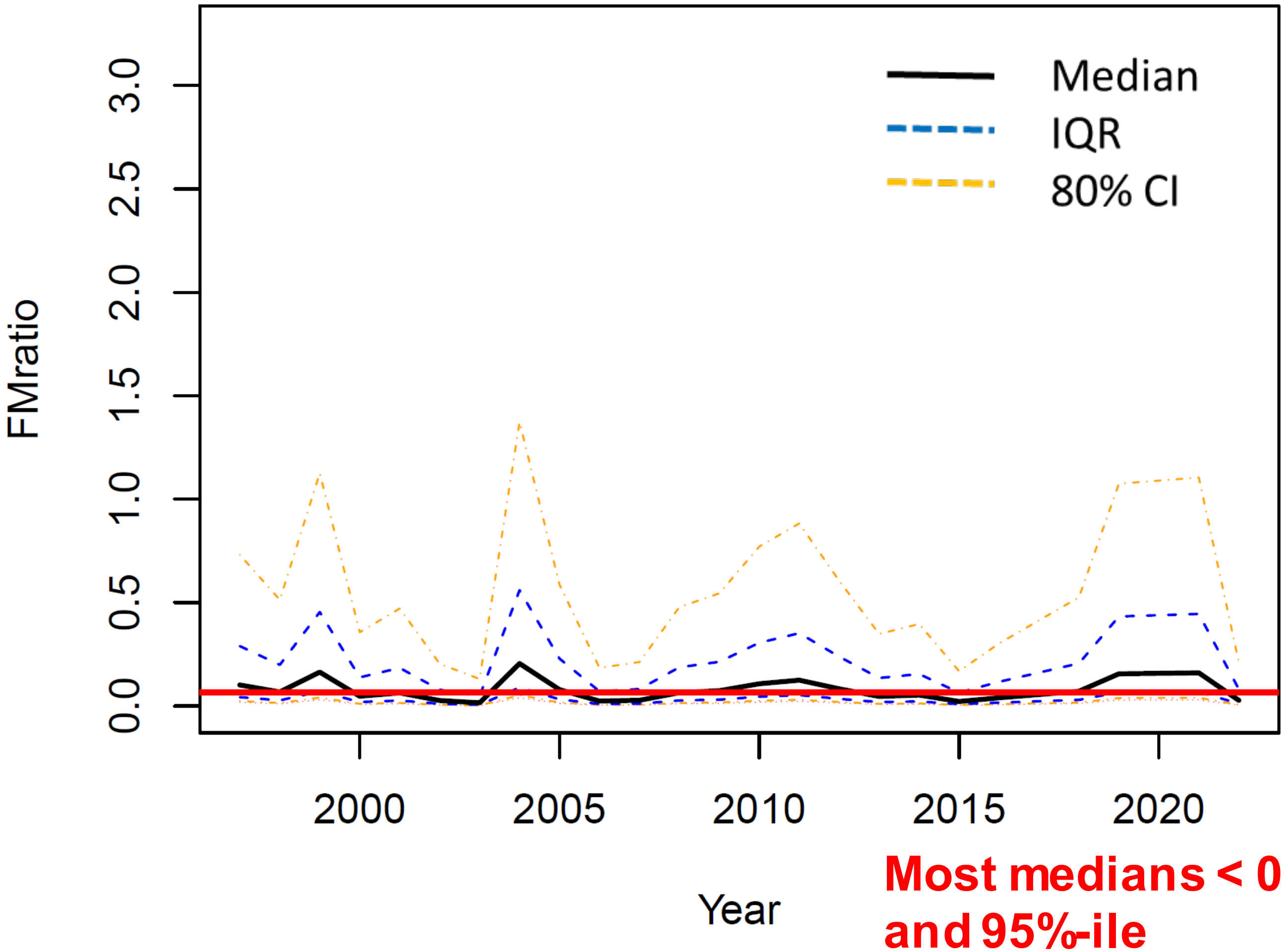


Table 3

Year	Percentile 1%	5%	50%	95%	99%
1997	0.545	0.621	0.841	0.950	0.967
1998	0.565	0.682	0.893	0.971	0.982
1999	0.412	0.489	0.756	0.917	0.945
2000	0.726	0.786	0.923	[illegible]	[illegible]
2001	0.667	0.732	0.898	[illegible]	[illegible]
2002	0.830	0.870	0.956	[illegible]	[illegible]
2003	0.762	0.880	0.976	[illegible]	[illegible]
2004	0.351	0.424	0.704	[illegible]	[illegible]
2005	0.547	0.656	0.876	[illegible]	[illegible]
2006	0.831	0.878	0.961	[illegible]	[illegible]
2007	0.829	0.867	0.954	[illegible]	[illegible]
2008	0.661	0.727	0.897	[illegible]	[illegible]
2009	0.625	0.697	0.882	[illegible]	[illegible]
2010	0.524	0.603	0.833	0.947	0.966
2011	0.487	0.565	0.809	0.938	0.959
2012	0.603	0.673	0.869	0.959	0.973
2013	0.738	0.793	0.925	0.978	0.986
2014	0.711	0.769	0.914	0.974	0.983
2015	0.860	0.892	0.964	0.990	0.993
2016	0.756	0.813	0.935	0.981	0.988
2018	0.641	0.707	0.886	0.965	0.977
2019	0.428	0.504	0.767	0.921	0.947
2021	0.417	0.494	0.761	0.919	0.946
2022	0.811	0.861	0.955	0.988	0.992

Medians > 0.7 in all yrs and also most yrs for 5%-ile, so unlikely historical catches resulted in *Escapements < 50%*

Percentiles of F/M 1997-2022



Most medians < 0.15 and 95%-ile infrequently exceeded 1

Table 4

Year	1%	5%	50%	95%	99%
1997	0.011	0.018	0.102	1.166	2.153
1998	0.006	0.010	0.068	0.836	1.664
1999	0.019	0.030	0.164	1.783	3.205
2000	0.005	0.008	0.047	0.576	1.093
2001	0.007	0.011	0.063	0.756	1.421
2002	0.003	0.004	0.026	0.331	0.636
2003	0.001	0.002	0.015	0.224	0.568
2004	0.024	0.039	0.205	2.169	3.835
2005	0.007	0.012	0.079	0.951	1.842
2006	0.002	0.004	0.024	0.301	0.590
2007	0.003	0.005	0.028	0.342	0.656
2008	0.007	0.011	0.064	0.769	1.444
2009	0.008	0.013	0.074	0.874	1.635
2010	0.011	0.019	0.107	1.231	2.270
2011	0.014	0.022	0.125	1.404	2.565
2012	0.009	0.014	0.083	0.967	1.800
2013	0.005	0.008	0.046	0.560	1.063
2014	0.006	0.009	0.053	0.637	1.203
2015	0.002	0.004	0.022	0.272	0.523
2016	0.004	0.007	0.040	0.490	0.937
2018	0.008	0.012	0.071	0.841	1.575
2019	0.018	0.029	0.156	1.704	3.071
2021	0.018	0.029	0.160	1.751	3.154
2022	0.003	0.004	0.027	0.346	0.675

Probabilities of falling below *Escapement* Thresholds or exceeding F/M Thresholds

Table 10

Probabilities (avg. 1997-2022) of falling below hypothetical Escapement Thresholds for alternative catch limits of 24,000-60,000 mt

Alternative Catch (mt)	Escapement Threshold				
	0.35	*0.4*	*0.5*	*0.6*	*0.75*
24000	0.0106	0.0198	0.0574	0.1350	0.3602
25000	0.0120	0.0221	0.0630	0.1449	0.3757
26000	0.0134	0.0245	0.0688	0.1548	0.3906
27000	0.0149	0.0271	0.0748	0.1647	0.4052
28000	0.0165	0.0298	0.0808	0.1746	0.4192
29000	0.0181	0.0326	0.0870	0.1843	0.4329
30000	0.0199	0.0356	0.0932	0.1941	0.4462
31000	0.0217	0.0387	0.0995	0.2037	0.4591
32000	0.0237	0.0418	0.1059	0.2132	0.4716
33000	0.0257	0.0451	0.1123	0.2227	0.4837
34000	0.0278	0.0485	0.1187	0.2320	0.4955
35000	0.0299	0.0520	0.1252	0.2412	0.5070
36000	0.0322	0.0555	0.1316	0.2503	0.5181
37000	0.0346	0.0592	0.1381	0.2594	0.5288
38000	0.0370	0.0629	0.1446	0.2683	0.5393
39000	0.0395	0.0667	0.1511	0.2771	0.54
40000	0.0420	0.0705	0.1575	0.2857	0.55
41000	0.0447	0.0744	0.1640	0.2943	0.56
42000	0.0473	0.0783	0.1704	0.3027	0.57
43000	0.0501	0.0823	0.1768	0.3110	0.58
44000	0.0529	0.0863	0.1832	0.3192	0.59
45000	0.0557	0.0904	0.1895	0.3273	0.60
46000	0.0586	0.0944	0.1958	0.3353	0.61
47000	0.0616	0.0985	0.2021	0.3432	0.62
48000	0.0646	0.1027	0.2083	0.3509	0.62
49000	0.0676	0.1068	0.2145	0.3585	0.63
50000	0.0707	0.1110	0.2206	0.3661	0.64
51000	0.0738	0.1152	0.2267	0.3735	0.65
52000	0.0769	0.1194	0.2328	0.3808	0.65
53000	0.0801	0.1236	0.2388	0.3880	0.66
54000	0.0832	0.1278	0.2448	0.3951	0.67
55000	0.0865	0.1320	0.2507	0.4021	0.[illegible]786
56000	0.0897	0.1362	0.2565	0.4089	0.6850
57000	0.0929	0.1404	0.2624	0.415[illegible]	0.6911
58000	0.0962	0.1446	0.2681	0.[illegible]224	0.6971
59000	0.0995	0.1488	0.2739	0.4290	0.7030
60000	0.1028	0.1530	0.2795	0.4355	0.7086

For a 50% Escapement Threshold, max avg risk of overfishing is 0.28 when catch limit = 60,000 mt

Rago humor

Probabilities (avg. 1997-2022) of exceeding theoretical F/M Thresholds for alternative catch limits of 24,000-60,000 mt

Table 11

Alternative Catch (mt)	*F/M Threshold*				
	0.33	*0.5*	*0.666*	*1*	*1.5*
24000	0.2694	0.1906	0.1446	0.0912	0.0510
25000	0.2763	0.1962	0.1494	0.0947	0.0536
26000	0.2830	0.2017	0.1540	0.0983	0.0561
27000	0.2895	0.2070	0.1585	0.1017	0.0586
28000	0.2958	0.2122	0.1629	0.1050	0.0610
29000	0.3020	0.2172	0.1672	0.1083	0.0634
30000	0.3080	0.2221	0.1714	0.1115	0.0657
31000	0.3138	0.2269	0.1755	0.1147	0.0680
32000	0.3195	0.2316	0.1795	0.1178	0.0702
33000	0.3251	0.2362	0.1834	0.1208	0.0725
34000	0.3305	0.2407	0.1873	0.1238	0.0746
35000	0.3358	0.2451	0.1910	0.1267	0.0768
36000	0.3410	0.2494	0.1947	0.1295	0.0789
37000	0.3460	0.2536	0.1983	0.1323	0.0809
38000	0.3510	0.2577	0.2019	0.1351	0.0830
39000	0.3559	0.2618	0.2053	0.1378	0.0850
40000	0.3606	0.2657	0.2087	0.1405	0.0870
41000	0.3653	0.2696	0.2121	0.1431	0.0889
42000	0.3698	0.2734	0.2154	0.1457	0.0908
43000	0.3743	0.2772	0.2186	0.1482	0.0927
44000	0.3787	0.2809	0.2218	0.1507	0.0946
45000	0.3830	0.2845	0.2249	0.1531	0.0964
46000	0.3873	0.2880	0.2280	0.1555	0.0982
47000	0.3914	0.2915	0.2310	0.1579	0.1000
48000	0.3955	0.2949	0.2339	0.1602	0.1017
49000	0.3996	0.2983	0.2369	0.1625	0.1035
50000	0.4035	0.3016	0.2397	0.1648	0.1052
51000	0.4074	0.3049	0.2426	0.1670	0.1069
52000	0.4112	0.3081	0.2454	0.1692	0.1085
53000	0.4150	0.3113	0.2481	0.1714	0.1102
54000	0.4187	0.3144	0.2508	0.1735	0.1118
55000	0.4223	0.3175	0.2535	0.1756	0.1134
56000	0.4259	0.3205	0.2561	0.1777	0.1150
57000	0.4294	0.3235	0.2587	0.1798	0.1165
58000	0.4329	0.3264	0.2613	0.1818	0.1181
59000	0.4363	0.3294	0.2638	0.1838	0.1196
60000	0.4397	0.3322	0.2663	0.1858	0.1211

For an F/M Threshold of 0.666, max avg risk of overfishing is 0.27 when catch limit = 60,000 mt

Table 12

Alternative Catch (mt)	Escapement Threshold				
	0.35	0.4	0.5	0.6	0.75
24000	0.0098	0.0164	0.0388	0.0650	0.0885
25000	0.0109	0.0183	0.0423	0.0691	0.0922
26000	0.0121	0.0202	0.0460	0.0731	0.0958
27000	0.0134	0.0222	0.0496	0.0771	0.0994
28000	0.0147	0.0244	0.0532	0.0810	0.1028
29000	0.0162	0.0266	0.0569	0.0848	0.1062
30000	0.0176	0.0289	0.0605	0.0886	0.1095
31000	0.0192	0.0313	0.0642	0.0922	0.1127
32000	0.0208	0.0338	0.0678	0.0959	0.1159
33000	0.0225	0.0364	0.0714	0.0994	0.1190
34000	0.0243	0.0390	0.0749	0.1029	0.1221
35000	0.0261	0.0417	0.0785	0.1064	0.1250
36000	0.0280	0.0444	0.0819	0.1097	0.1280
37000	0.0300	0.0472	0.0854	0.1131	0.1308
38000	0.0320	0.0500	0.0888	0.1163	0.1337
39000	0.0341	0.0528	0.0922	0.1195	0.1364
40000	0.0362	0.0557	0.0955	0.1227	0.1392
41000	0.0384	0.0586	0.0988	0.1257	0.1418
42000	0.0406	0.0615	0.1020	0.1288	0.1444
43000	0.0429	0.0644	0.1052	0.1318	0.1470
44000	0.0452	0.0673	0.1084	0.1347	0.1496
45000	0.0476	0.0702	0.1115	0.1375	0.1520
46000	0.0499	0.0731	0.1146	0.1404	0.1545
47000	0.0524	0.0760	0.1177	0.1431	0.1569
48000	0.0548	0.0789	0.1207	0.1459	0.1593
49000	0.0572	0.0818	0.1236	0.1485	0.1616
50000	0.0597	0.0846	0.1265	0.1512	0.1639
51000	0.0622	0.0875	0.1294	0.1538	0.1661
52000	0.0647	0.0903	0.1323	0.1563	0.1684
53000	0.0672	0.0931	0.1351	0.1588	0.1706
54000	0.0697	0.0960	0.1378	0.1613	0.1727
55000	0.0723	0.0987	0.1406	0.1637	0.1749
56000	0.0748	0.1015	0.1433	0.1661	0.1770
57000	0.0773	0.1043	0.1459	0.1684	0.1791
58000	0.0799	0.1070	0.1485	0.1707	0.1811
59000	0.0824	0.1097	0.1511	0.1730	0.1831
60000	0.0849	0.1124	0.1537	0.1752	0.1851

Joint probabilities ***(1997-2022 avg.)*** ***of falling below hypothetical Escapement Thresholds AND exceeding F/M = 0.66 for alternative catch limits of 24,000-60,000 mt***

For a 50% Escapement Threshold, the joint probability of overfishing is 0.15 when the catch limit = 60,000 mt

NOAA FISHERIES

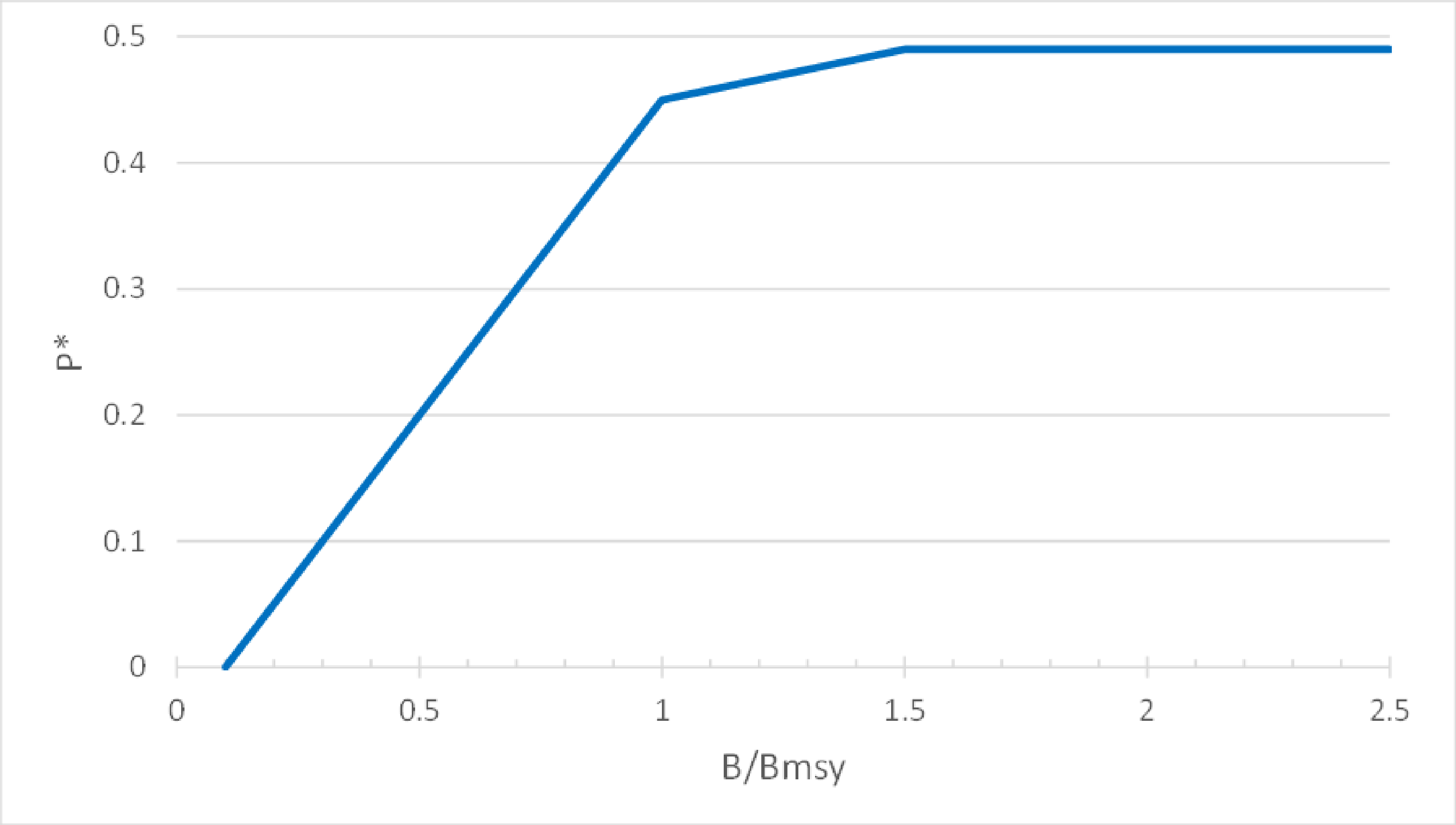
Choosing an ABC Consistent with Council Risk Policy

Risk of overfishing (P*) cannot exceed 0.49 irrespective of relative biomass

Risk decreases slowly as stock size falls below 1.5 B/B_{msy}

Risk decreases sharply when $B/B_{msy}<1$

No fishing when $B/B_{msy}<0.1$



Theoretical Reference Points

No approved Biological Reference Points for *I. illecebrosus* and promulgated BRPs are no longer considered appropriate

Percent *Escapement* levels have been used for other squid species, such as:

Illex argentinus, Doryteuthis gahi, Doscidicus gigas and Ommastrephes bartramii = F40% *Escapement*

Risk of overfishing for *Illex* can be expressed as:

1. The probability of falling below a specific *Escapement* Threshold level (e.g., 35%, 40%, 50%) or
2. The probability of exceeding F/M = 2/3, 1 or other values that attempt to preserve forage fish (but not subannual or semelparous) for its predators.

One can estimate the joint probability of exceeding F/M threshold and falling below an *Escapement* Threshold.

The ***only*** other requirement to apply the Council's Risk Policy is a guesstimate of the likely 2023 status of the U.S. *Illex* Stock Component (i.e., B_t/B_{msy}).

Is the population trending OR randomly fluctuating around a mean?
Is that mean near B_{MSY} or 0.5 B_{MSY} or ??

Figure 13. "Slinky plot" of **probability of *Escapement* < 50%**, by year (1997-2022), given alternative catch limits of 24,000 - 60,000 mt. Each dot represents an alternative catch; lowest at bottom and highest at top.

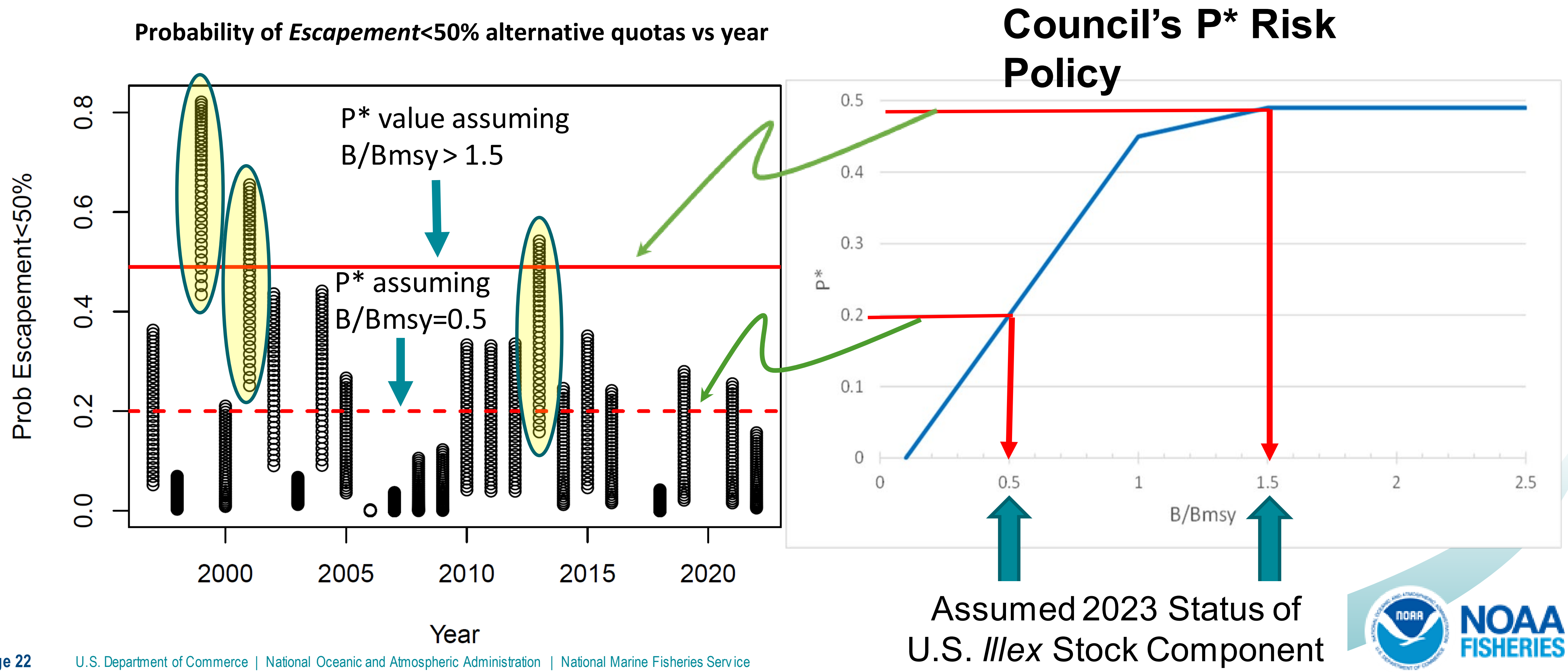
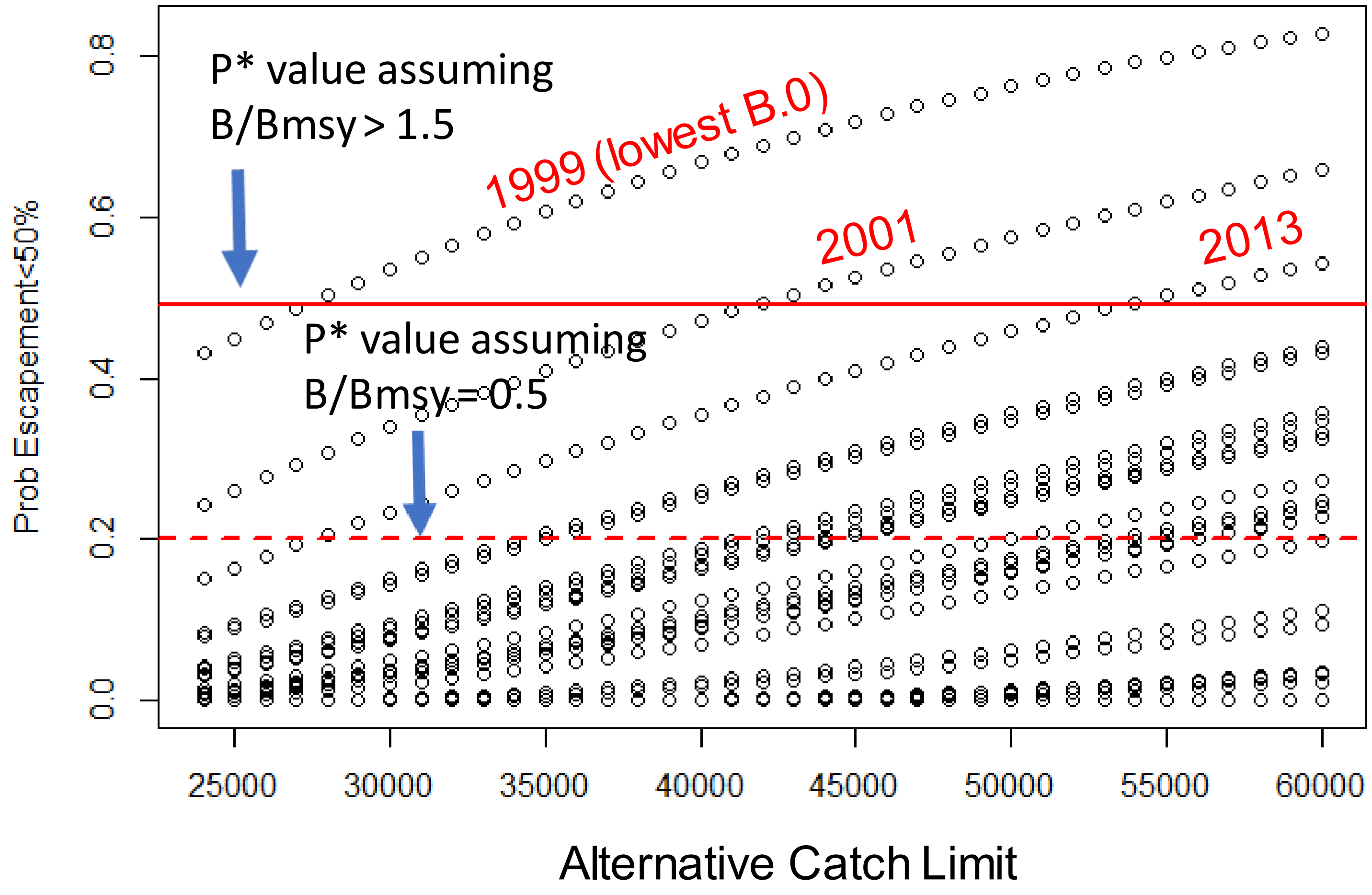
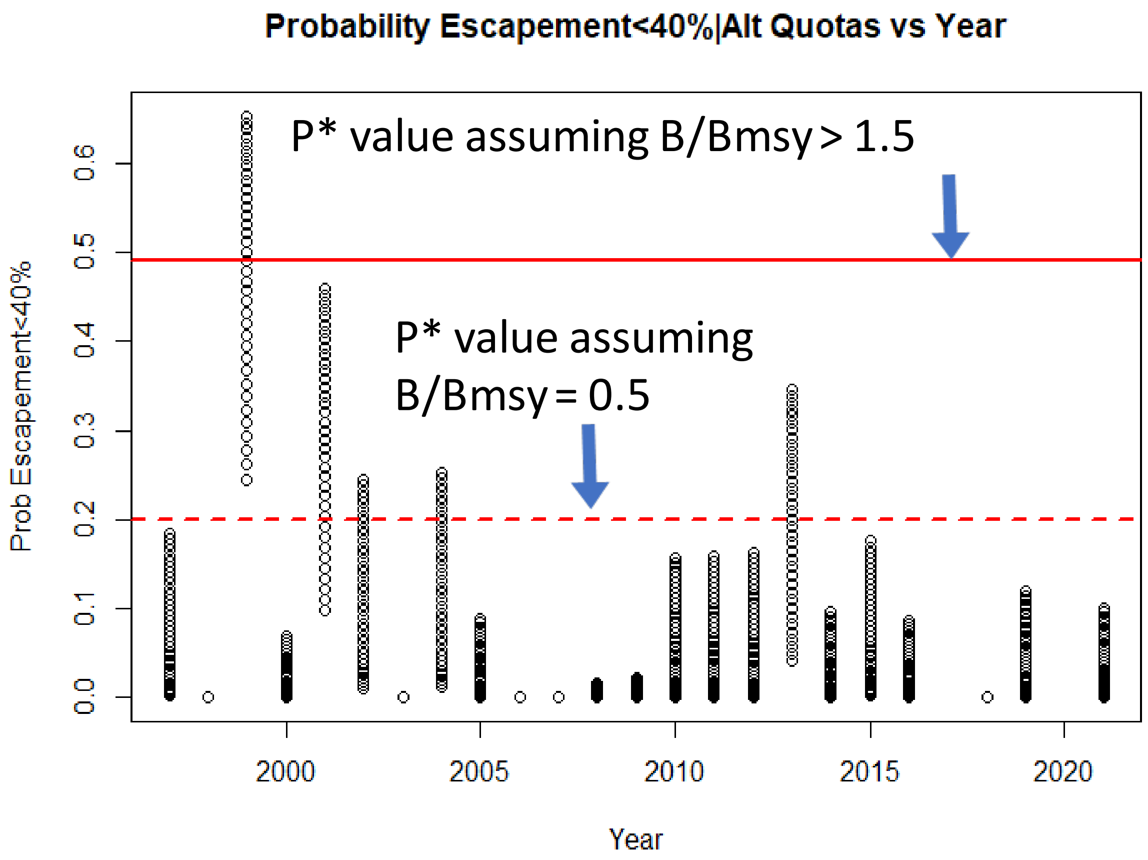


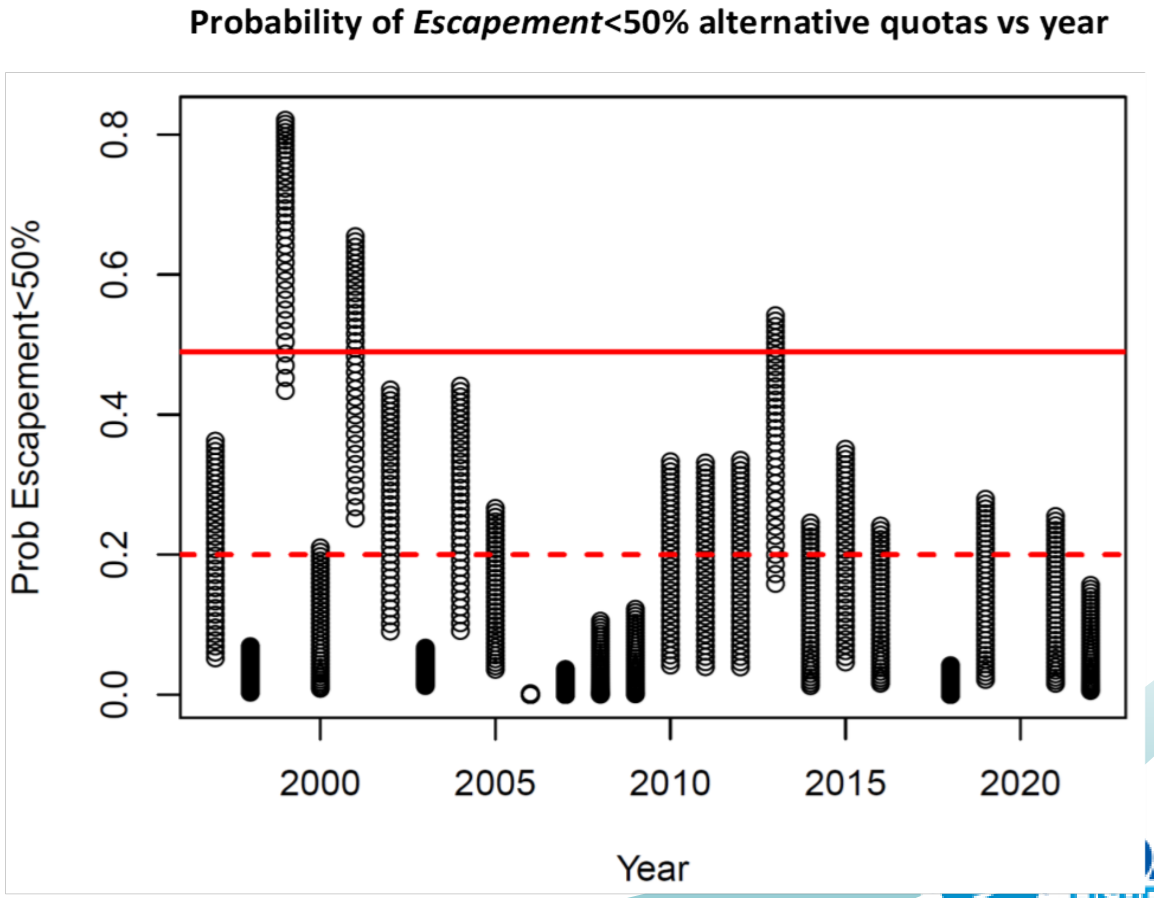
Figure 14. Probabilities of ***Escapement* < 50%** for alternative catch limits of 24,000 - 60,000 mt. Each line is the trajectory of a given year reflecting the effect of different B.0 values by year. Initial population size (B.0) in each year based on the observed catch and range of assumed q, v, and M values.



P* values are based on the assumed 2023 status of the U.S. *Illex* Stock Component.

Probabilities of *Escapement* < 40% (left) and < **50%** (right), by year, based on the assumed 2023 status of the U.S. *Illex* Stock Component. Initial population size (B.0) in each year is based on the observed catch and range of assumed q, v, and M values. Y-axis scale differences, but same P* values.





And now for some numbers….

Probabilities (1997-2022 avg.) of falling below various *Escapement* Thresholds for alternative catch limits of 24,000 to 60,000 mt.

Alternative Catch (mt)	*Escapement Threshold*				
	0.35	***0.4***	***0.5***	***0.6***	***0.75***
24000	0.0106	0.0198	0.0574	0.1350	0.3602
25000	0.0120	0.0221	0.0630	0.1449	0.3757
26000	0.0134	0.0245	0.0688	0.1548	0.3906
27000	0.0149	0.0271	0.0748	0.1647	0.4052
28000	0.0165	0.0298	0.0808	0.1746	0.4192
29000	0.0181	0.0326	0.0870	0.1843	0.4329
30000	0.0199	0.0356	0.0932	0.1941	0.4462
31000	0.0217	0.0387	0.0995	0.2037	0.4591
32000	0.0237	0.0418	0.1059	0.2132	0.4716
33000	0.0257	0.0451	0.1123	0.2227	0.4837
34000	0.0278	0.0485	0.1187	0.2320	0.4955
35000	0.0299	0.0520	0.1252	0.2412	0.5070
36000	0.0322	0.0555	0.1316	0.2503	0.5181
37000	0.0346	0.0592	0.1381	0.2594	0.5288
38000	0.0370	0.0629	0.1446	0.2683	0.5393
39000	0.0395	0.0667	0.1511	0.2771	0.5495
40000	0.0420	0.0705	0.1575	0.2857	0.5594
41000	0.0447	0.0744	0.1640	0.2943	0.5690

Alternative Catch (mt)	*Escapement Threshold*				
	0.35	***0.4***	***0.5***	***0.6***	***0.75***
42000	0.0473	0.0783	0.1704		
43000	0.0501	0.0823	0.1768		
44000	0.0529	0.0863	0.1832		
45000	0.0557	0.0904	0.1895		
46000	0.0586	0.0944	0.1958	0.3353	0.6132
47000	0.0616	0.0985	0.2021	0.3432	0.6213
48000	0.0646	0.1027	0.2083	0.3509	0.6292
49000	0.0676	0.1068	0.2145	0.3585	0.6368
50000	0.0707	0.1110	0.2206	0.3661	0.6443
51000	0.0738	0.1152	0.2267	0.3735	0.6515
52000				0.3808	0.6586
53000				0.3880	0.6654
54000				0.3951	0.6721
55000				0.4021	0.6786
56000				0.4089	0.6850
57000				0.4157	0.6911
58000	[illegible]	[illegible]	[illegible]	0.4224	0.6971
59000	0.0995	0.1488	0.2739	0.4290	0.7030
60000	0.1028	0.1530	0.2795	0.4355	0.7086

P* = 0.20
assuming 2023
B/Bmsy = 0.5

Highest Catch Limit consistent with Council Risk Policy assuming B=0.5 B_{MSY} and *Escapement* Threshold is 50%

Probabilities (1997-2022 avg.) of exceeding various F/M thresholds for alternative catch limits of 24,000 to 60,000 mt.

Alternative Quota (mt)	*F/M Threshold* 0.33	*0.5*	*0.666*	*1*	*1.5*
24000	0.2694	0.1906	0.1446	0.0912	0.0510
25000	0.2763	0.1962	0.1494	0.0947	0.0536
26000	0.2830	0.2017	0.1540	0.0983	0.0561
27000	0.2895	0.2070	0.1585	[illegible]	[illegible]
28000	0.2958	0.2122	0.1629	[illegible]	[illegible]
29000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
30000	[illegible]	[illegible]	[illegible]	0.1115	0.0657
31000	[illegible]	[illegible]	[illegible]	0.1147	0.0680
32000	[illegible]	[illegible]	[illegible]	0.1178	0.0702
33000	[illegible]	[illegible]	[illegible]	0.1208	0.0725
34000	0.3305	0.2407	0.1873	0.1238	0.0746
35000	0.3358	0.2451	0.1910	0.1267	0.0768
36000	0.3410	0.2494	0.1947	0.1295	0.0789
37000	0.3460	0.2536	0.1983	0.1323	0.0809
38000	0.3510	0.2577	0.2019	0.1351	0.0830
39000	0.3559	0.2618	0.2053	0.1378	0.0850
40000	0.3606	0.2657	0.2087	0.1405	0.0870
41000	0.3653	0.2696	0.2121	0.1431	0.0889

P* = 0.20 assuming 2023 B/Bmsy = 0.5

Highest Catch Limit consistent with Council Risk Policy assuming B=0.5 B_{MSY} and F/M Threshold is 0.66

Alternative Quota (mt)	*F/M Threshold* 0.33	*0.5*	*0.666*	*1*	*1.5*
42000	0.3698	0.2734	0.2154	0.1457	0.0908
43000	0.3743	0.2772	0.2186	0.1482	0.0927
44000	0.3787	0.2809	0.2218	0.1507	0.0946
45000	0.3830	0.2845	0.2249	0.1531	0.0964
46000	0.3873	0.2880	0.2280	0.1555	0.0982
47000	0.3914	0.2915	0.2310	0.1579	0.1000
48000	0.3955	0.2949	0.2339	0.1602	0.1017
49000	0.3996	0.2983	0.2369	0.1625	0.1035
50000	0.4035	0.3016	0.2397	0.1648	0.1052
51000	0.4074	0.3049	0.2426	0.1670	0.1069
52000	0.4112	0.3081	0.2454	0.1692	0.1085
53000	0.4150	0.3113	0.2481	0.1714	0.1102
54000	0.4187	0.3144	0.2508	0.1735	0.1118
55000	0.4223	0.3175	0.2535	0.1756	0.1134
56000	0.4259	0.3205	0.2561	0.1777	0.1150
57000	0.4294	0.3235	0.2587	0.1798	0.1165
58000	0.4329	0.3264	0.2613	0.1818	0.1181
59000	0.4363	0.3294	0.2638	0.1838	0.1196
60000	0.4397	0.3322	0.2663	0.1858	0.1211

Conclusions

- **Low q and v and high M drive the high stock biomasses in Table 2.**
- The extreme B values, > 1 million mt, seem highly unlikely but the distribution of median values during 1997-2022 seem reasonable (70,000-824,000 mt).
- **Wide fluctuations in biomass and catch levels are common in other squid fisheries (e.g., Falklands and Japan)**
- Median biomass estimates during 2011-2022 have ranged 112,000-461,000 mt (Table 2).
- **Median escapement percentiles were > 0.76 for this same period (Table 3). Exploitation rates were generally low, < 0.01/week (Fig. 11).**
- Much higher average availability and catchability rates than are used here would be required to significantly reduce median stock size or escapement.
- ***Escapement* estimates herein do not consider temporal escapement that occurs outside the fishing season.**

Conclusions (cont.)

- **Probabilities of falling below a Threshold *Escapement* level were computed for 1997-2022** (2017 and 2020 excluded).
  - Average probability depends on all of the realized B.0(y) estimates for 1997-2022
  - Assumes all initial conditions B.0(y) are equally probable.

- **Three low median biomass years observed: 1999 (70,000 mt), 2001 (90,000 mt) and 2013 (113,000 mt) (Table 2).**
  - Hypothetical catch limits that would have resulted in a median *Escapement* rate of 50% are: 28,000 mt (1999), 43,000 mt (2001) and 55,000 (2013) (Table 5).

- **Based on probabilities averaged across 1997-2022:**
  - **IF B_t is stationary and B/Bmsy=1** and *Escapement* Threshold = 50% then a catch limit of up to 60,000 mt is possible. (Table 10)
  - **IF B_t is stationary and B/Bmsy=0.5** then the **catch limit should not exceed 47,000 mt** (Table 10) or **38,000 mt using the F/M=0.66 criterion** (Table 11).

Questions?