Effects of Survey Uncertainty on Risk of Violating Escapement and F/M Thresholds for Illex Squid: 1997-2021

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Overview

- Review previous methods for estimating escapement and probability of falling below candidate thresholds
- Method for considering additional uncertainty of survey biomass estimates for period 1997-2021
- Compute effects of additional uncertainty
  - Side by side comparison for Biomass, F, Escapement and F/M
  - Side by side probabilities of violating escapement and F/M ratios for estimates with and without survey uncertainty
  - Probabilities that potential quotas from 24,000 to 60,000 mt violate candidate thresholds.

Review of Model Theory

- Input data
  - Time series of catch(C_t), fall survey index $I_{F,t}$, coefficient of uncertainty in fall survey (CV_t)
- Parameters
  - Catchability (q), Availability (v), Natural Mortality (M),
- Simulation Controls
  - Upper and Lower bounds for q, v, M and $I_{F,t}$ via selection of confidence interval α.
  - Number of intervals for each parameters
  - Candidate thresholds for Escapement and F/M
- Number and magnitude of alternative quotas to be evaluated

Finding F

- 1. Expand Fall survey index to total assuming q and v

$$B_t = \frac{I_t}{q}\frac{A}{a}\frac{1}{v} = \frac{AI_t}{qav}$$

- 2. Write Bt as function of B.o and Z

$$B_t = B_0 \; e^{-Z\,t}$$

- 3. Baranov catch equation assuming M

$$B_0 = \frac{C_t}{\frac{F}{F+M}\left(1-e^{-(F+M)}\right)}$$

- 4. Combine Eq. 2 and 3

$$B_t e^{(F+M)} = \frac{C_t}{\frac{F}{F+M}\left(1-e^{-(F+M)}\right)}$$

- 5. Plug Eq. 1 into Eq. 4

$$\frac{AI_t}{qav} e^{(F+M)} = \frac{C_t}{\frac{F}{F+M}\left(1-e^{-(F+M)}\right)}$$

- 6. Solve for F given assumed levels of q, v, M and observations of I_t and C_t in Eq. 5

Escapement Estimation for OBSERVED Catches

- Find B.0 and F for each year given C(t), I(t) and assumed q,v,M.
- Project terminal population without fishery

$$B_{t,without\ fishery} = B_0 e^{-Mt}$$

- Compute escapement as ratio of observed B(t) over B(t|F=0)

$$Escapement = \frac{B_t}{B_{t,without\ fishery}}$$

- Or equivalently

$$Escapement = \frac{B_t}{B_{t,without\ fishery}} = \frac{B_0 e^{-(F+M)}}{B_0 e^{-M}} = e^{-F}$$

- This formulation is useful for evaluating alternative quotas

Escapement Estimation for ALTERNATIVE Catches

- Find B.0 and F for each year given observed C(t), I.f(t) and assumed q,v,M.
- Assume alternative catch C_H
- Find F_H associated with alternative catch C_H

$$B_0 = \frac{C_H}{\frac{F_H}{F_H + M}\left(1 - e^{-(F_H+M)}\right)}$$

- Compute escapement as ratio of observed B(t) over B(t|F=0)

$$Escapement(B_0, C_H) = \frac{B'_t}{B_{t,without\ fishery}} = \frac{B_0 e^{-(F_H+M)}}{B_0 e^{-M}} = e^{-F_H}$$

Revised methodology includes all of the above steps PLUS uncertainty in the survey derived estimates of minimum biomass.

Parameterization of model

	A	B	C	D	E
1	Par.Name	Min	Max	N	Comment
2	q	0.078	0.325	25	# Efficiency
3	v	0.37	0.73	20	#Availability
4	M	0.01	0.13	20	#Natural Mortality
5	I.f.alpha	0.1	0.9	25	# 80%CI range for eval of observation error
6	F.range	0.000001	5	1	# Admissible range of F to search in Newton Ralphson

N.q * N.v * N.M * N.I= N.sim
25 * 20 * 20 * 25=250,000 evaluations for each year (23) times 37 alternative quotas

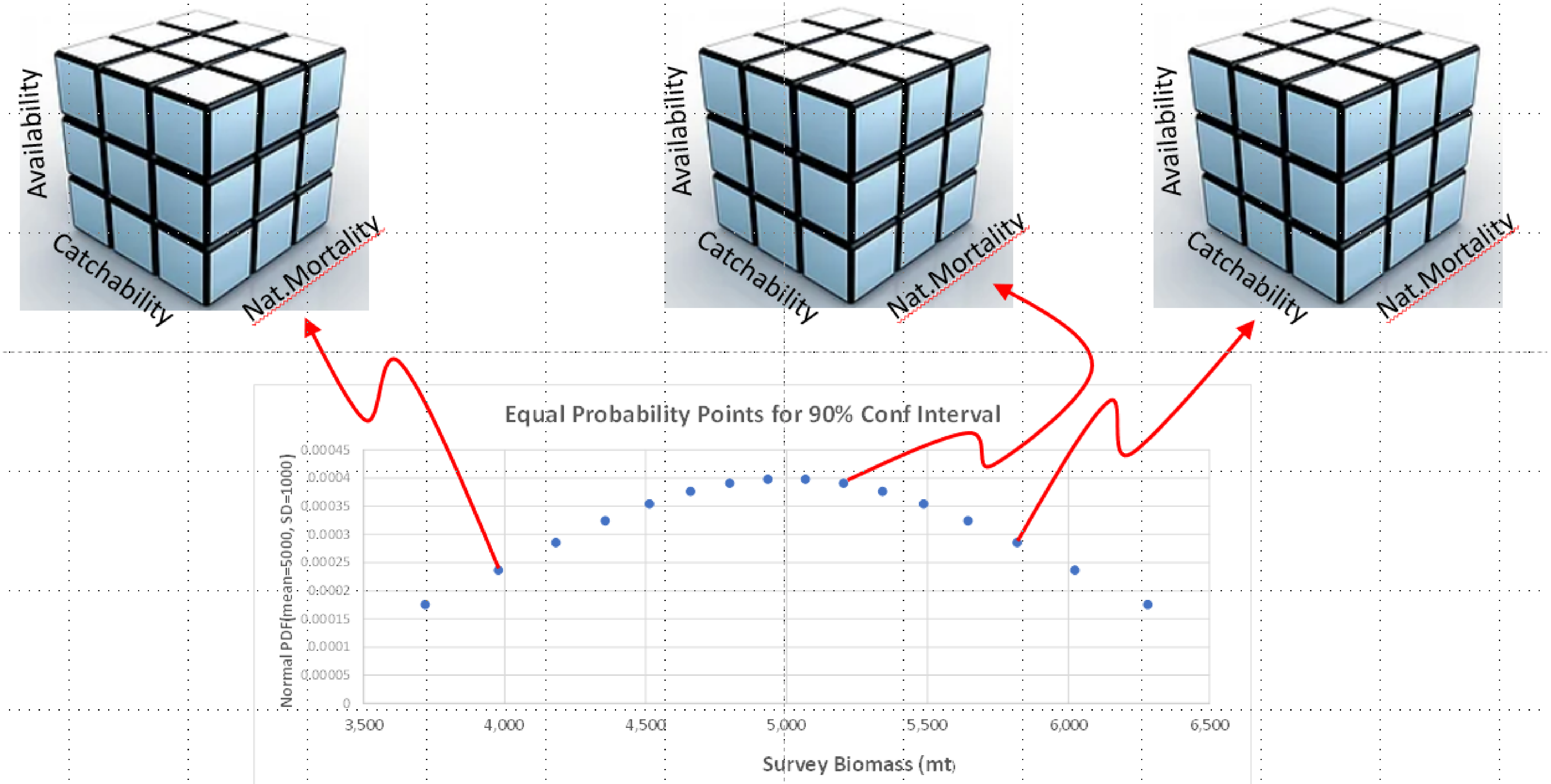
Parameter	Range =Max/Min	Distribution
Catchability	4X	Uniform (min,max)
Availability	2X	Uniform (min, max)
Natural Mortality	13X	Uniform (min, max)
Survey Estimate (α=0.1) Z_α=1.28 $(1+CV*Z_\alpha)/(1-CV*Z_\alpha)$.	Ave~2X Range 1.2-14X over years	Normal(mean, SE| 80%CI)

Stochastic Escapement Model: Turning 69 numbers into 212,750,000 estimates

Alternative Quotas = {24,000, 25,000, 26,000,… 58,000, 59,000, 60,000 mt}

Year	Catch(mt)	Spring Survey (mt)	Fall Survey (mt)	CV Fall Survey (%)
1997	14,358	511	2,730	17
1998	24,154	226	7,725	51
1999	8,482	149	929	16
2000	9,117	35	3,999	22
2001	4,475	110	1,422	15
2002	2,907	68	2,322	20
2003	6,557	23	10,913	68
2004	27,499	139	2,279	12
2005	13,861	14	3,696	46
2006	15,500	121	14,220	34
2007	9,661	147	7,311	8
2008	17,429	54	5,462	18
2009	19,090	404	5,170	20
2010	16,394	101	2,941	22
2011	19,487	294	2,937	18
2012	12,211	1,099	2,895	12
2013	4,107	22	1,827	13
2014	9,342	NA	3,592	11
2015	2,873	217	2,795	14
2016	7,004	2,641	3,711	26
2017	23,371	314	NA	NA
2018	25,524	382	7,146	13
2019	28,495	1,901	3,310	14
2020	not used	NA	NA	NA
2021	30,714	NA	3,531	17

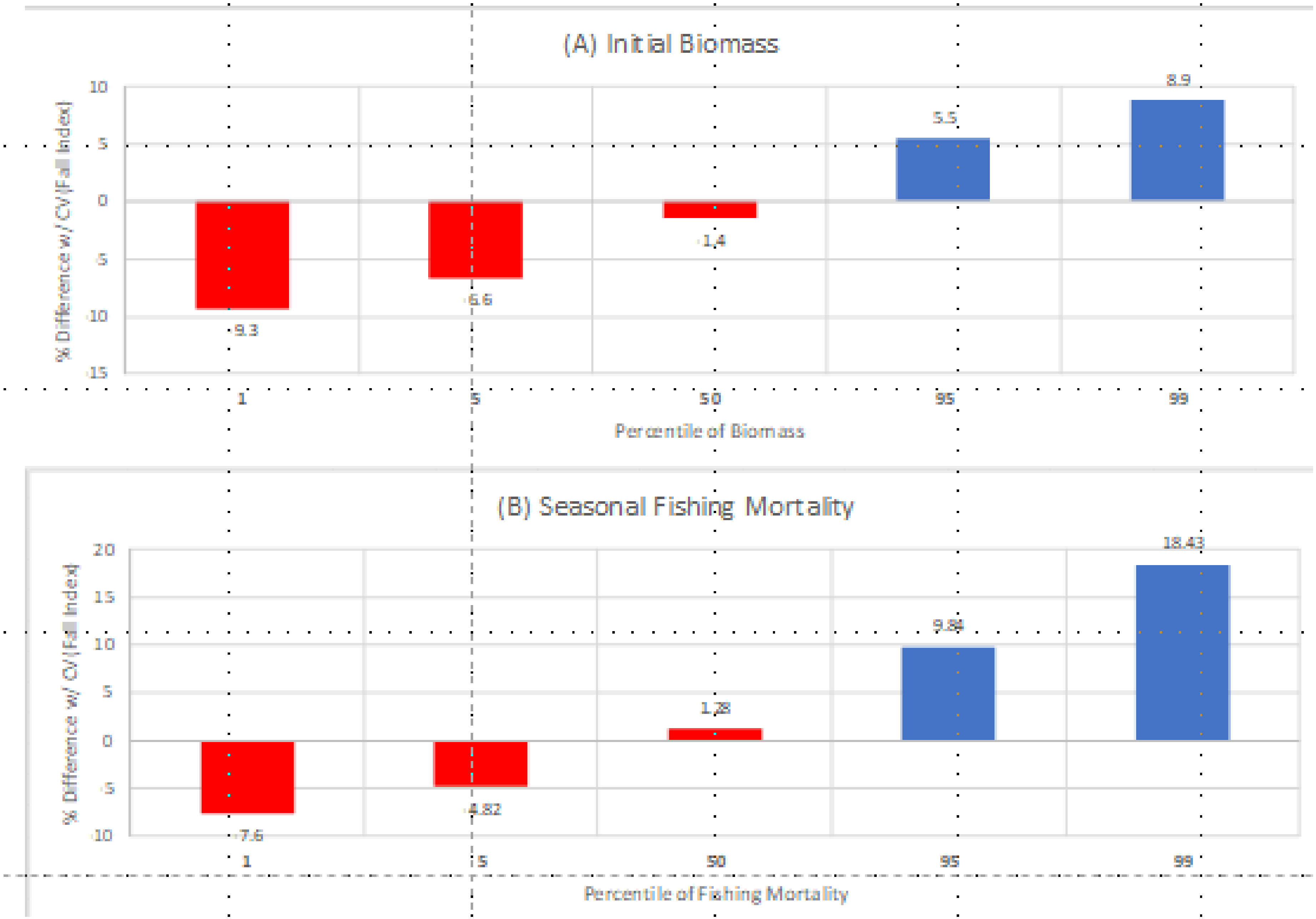
Integrating over ranges of uncertainty in q, v, M, $I_{F,t}$



Results

- See Tables 2-8 in report
- General Format of Tables
  - Estimates from Last year using original methods
  - Estimates for same data, using revised method
  - Percentage difference for each parameter
  - Average value over columns
- Tables 2, 3, 4, 5 = Estimates of percentiles of Biomass, F, Escapement, F/M, respectively for each year
- Tables 6, 7, 8= Probabilities of violating Escapement Thresholds, F/M thresholds and Joint escapement & F/M thresholds for each quota.

Effects on Initial Biomass (B.0) and total Season Fishing Mortality Percentiles for 1997-2021



Effects on Escapement and F/M ratio by percentile for 1997-2021

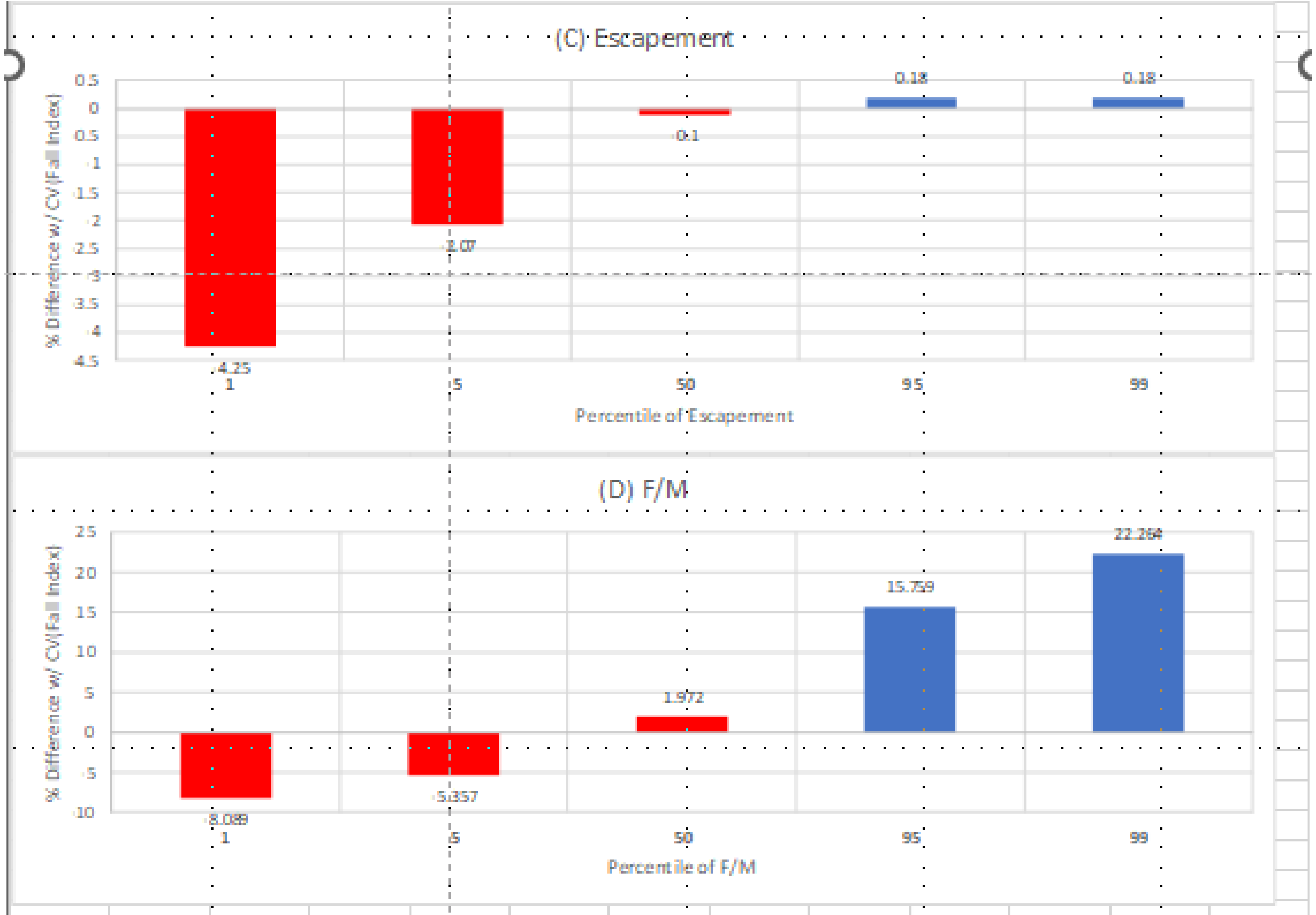


Figure 2. Summary of average percentage change in (A) Initial Biomass, (B) Fishing Mortality, (C) Escapement, and (D) F/M for selected percentiles of each variable. Averages are computed over the period 1997-2021.

Figure 3. Empirical relationship between the percent difference in the confidence interval width of initial biomass (B.0) vs the Coefficient of Variation of fall bottom trawl survey.

The y-axis is the percentage change in the ratio of the 90% confidence interval width when the Survey CV is included over the 90% CI width when the Survey CV is NOT included.

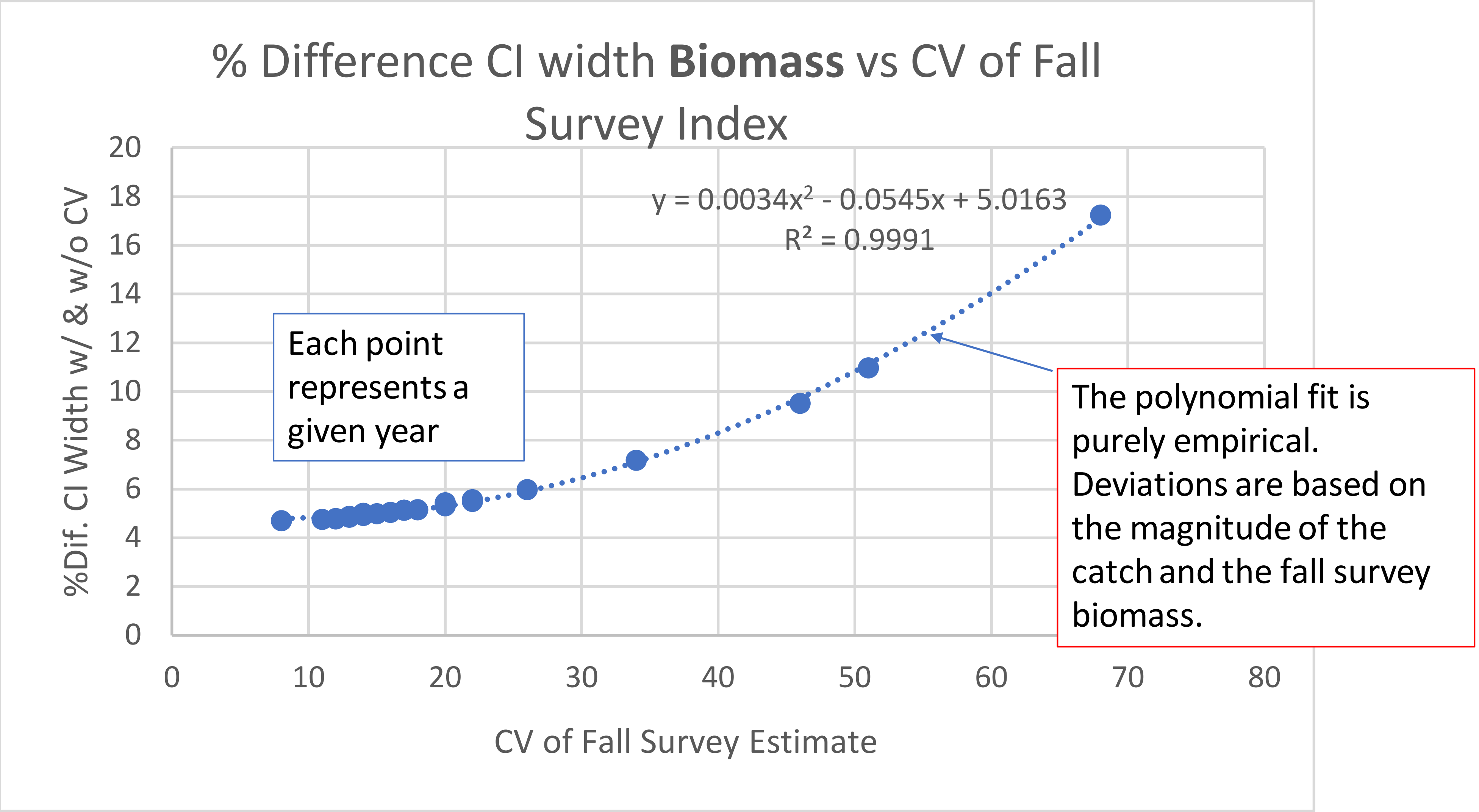
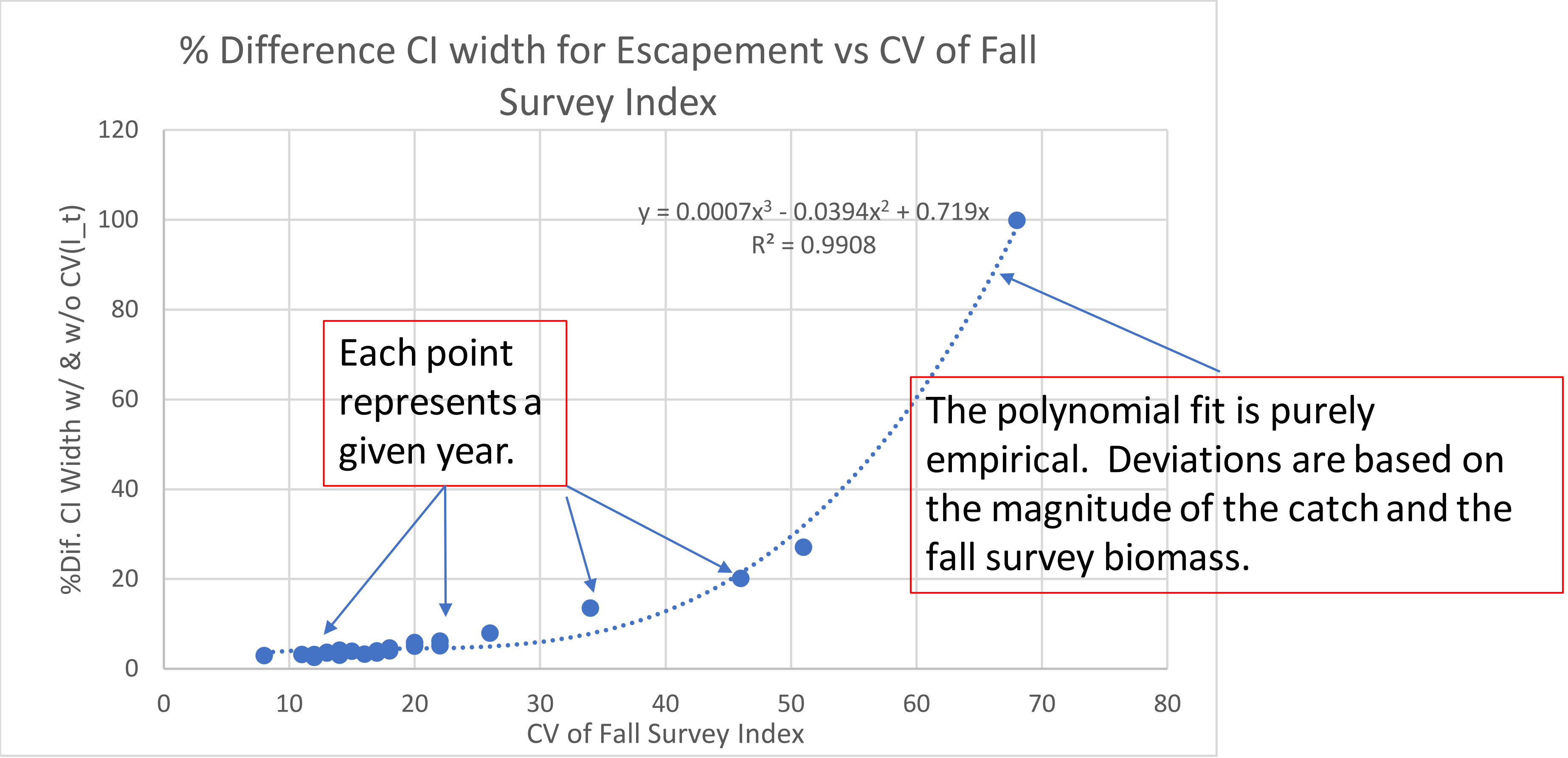


Figure 4. Empirical relationship between the percent difference in the confidence interval width of Escapement (Esc) vs the Coefficient of Variation of fall bottom trawl survey.

The y-axis is the percentage change in the ratio of the 90% confidence interval width when the Survey CV is included over the 90% CI width when the Survey CV is NOT included.



Effects Survey Uncertainty on Risk of Overfishing for 40,000 mt Quota on Escapement

- In March and July, 2022 the SSC recommended an ABC of **40,000 mt for** 2023. The probability of falling **below** Escapement thresholds (Table 6) were:

Escapement Threshold	0.35	0.40	0.5	0.6	0.75
Probability	0.0384	0.0657	0.1519	0.2802	0.5575

The inclusion of uncertainty in survey biomass increased these probabilities to:

Escapement Threshold	0.35	0.40	0.5	0.6	0.75
Probability	0.0437	0.0731	0.1620	0.2912	0.5641

The ratio of these probabilities is

Escapement Threshold	0.35	0.40	0.5	0.6	0.75
Probability	1.1392	1.1130	1.066	1.0392	1.0118

Conclusions

- Effects of adding uncertainty in survey biomass is relatively minor and does not significantly affect the basis for quota decisions made in 2022.
- WHY?
  - Range of variation considered is relatively small compared to ranges for other parameters, especially M.
  - CVs are relatively low except in a few years.
  - Effect show up in the tails of the Escapement and F/M distributions. The dispersion of the sampling distributions increases. Medians relatively unaffected.
  - Index Uncertainty is normally distributed and symmetric, implies equal # of increases and decreases
  - Less probability mass in the tails relative to uniform distribution