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Biomass estimates for YTF based on Bigelow surveys and prior information

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Canada

Plan of attack

- Background and intent
- Choices and definitions
- Upper bounds for capture efficiency
- Whole net capture efficiency estimates from literature
- Uncertainty in stock area, area swept, capture efficiency and survey data
- Swept-area biomass distributions for fall and spring Bigelow surveys, 2009-2013

Background and intent

- Biomass/abundance estimates by usual methods implausible
  - Complex situation
  - Major diagnostic = scale problem
    - Q for Bigelow surveys (doors) > 1
    - Retrospective pattern too
- Try to fall back on swept-area biomass
  - More like direct measurements
  - Account for capture efficiency and “all” uncertainties
- Need (prior) information not always used in assessment models
  - YTF are a perfect case (lots of other information)
- Want to use “other” information objectively and quantitatively to improve biomass estimates

Need to pass red face test and get Bigelow Q < 1

Age specific capture efficiency for surveys in TRAC-2013 VPA (based on door spread, see Ghost Survey WP)

Age	SprBigNoCal1	FallBigNoCal1	SprAlbPure1	FallAlbPure1	ScallopSWAN1	DFOdoors1
1	0.045	0.140	0.003	0.037	0.300	0.002
2	0.236	1.235	0.078	0.119	0.749	0.082
3	1.666	2.689	0.248	0.291	1.233	0.299
4	2.528	1.049	0.302	0.272	1.233	0.439
5	1.481	0.646	0.260	0.291	1.247	0.377
6	1.123	0.228	0.282	0.263	0.002	0.247

Need to double (?) biomass estimates to reach plausible range

Choices – vessel/survey

- Bigelow spring and fall surveys provide most useful information
  - Most efficient survey in terms of catch/area swept
    - So simple swept area biomass close to stock biomass and less work to do
  - Results more robust to uncertainty in capture efficiency

    -Inverse relationship (1/0.6 more stable than 1/0.01)
  - Accuracy of tow distance
    - Sensors give time on bottom
    - Fast winches so time winches lock close to net off bottom
    - SOP designed to improve tow distance data

Choices – door spread

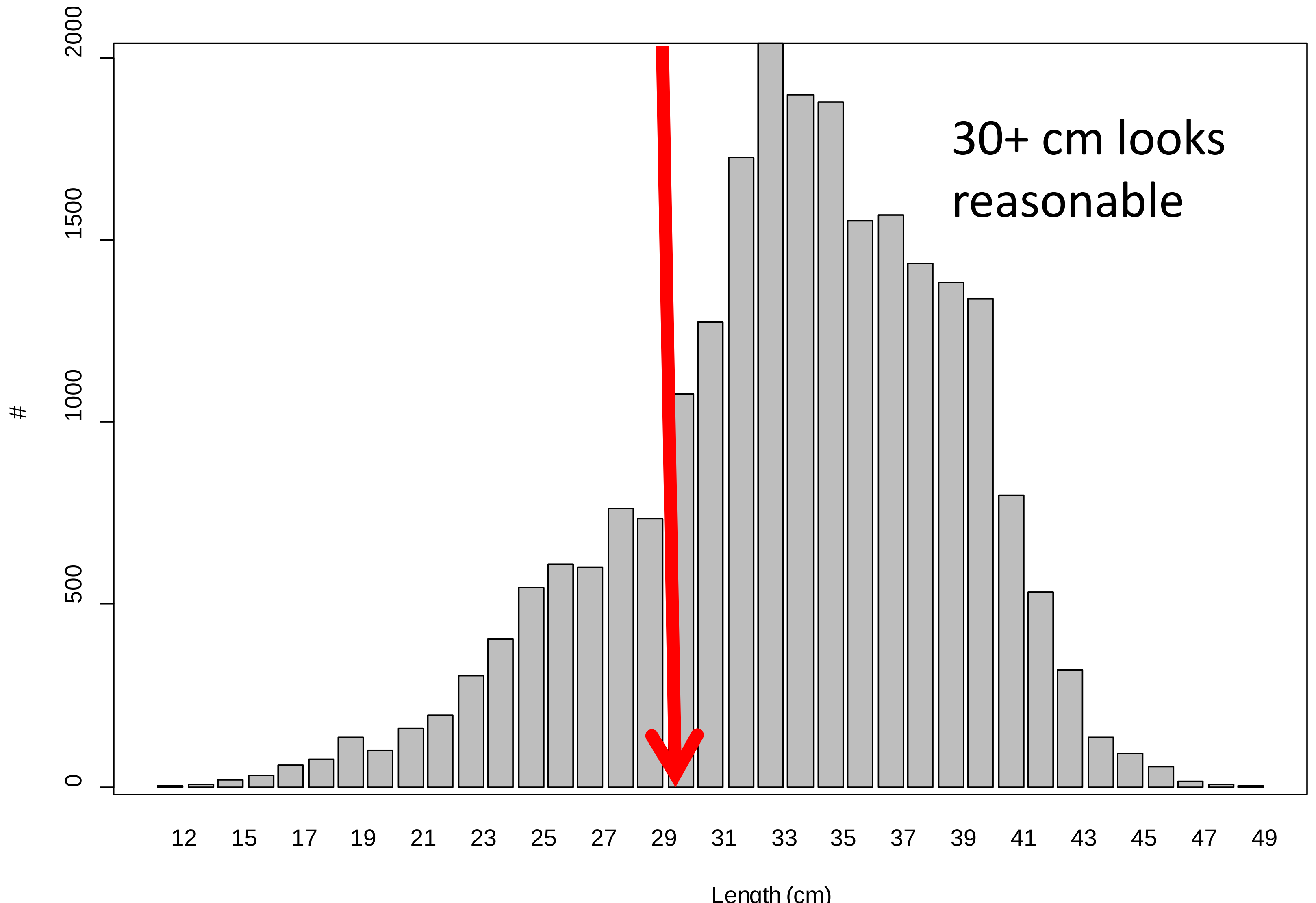
- Make the choice that increases information
- Effective width of the net is uncertain but we know:
  - Wingspread < effective width < door spread
  - Capture efficiency (true density / catch per area) reckoned between doors has ***upper and lower bounds*** (0 < E ≤ 1)
    - Have only 0 < E for wings (can't tell if its too high)
  - Need experimental estimates from literature for flatfish in bottom trawls (all based on door spread)

– **All efficiency estimates here are for doors**

Choices – aggregate catch (not by size)

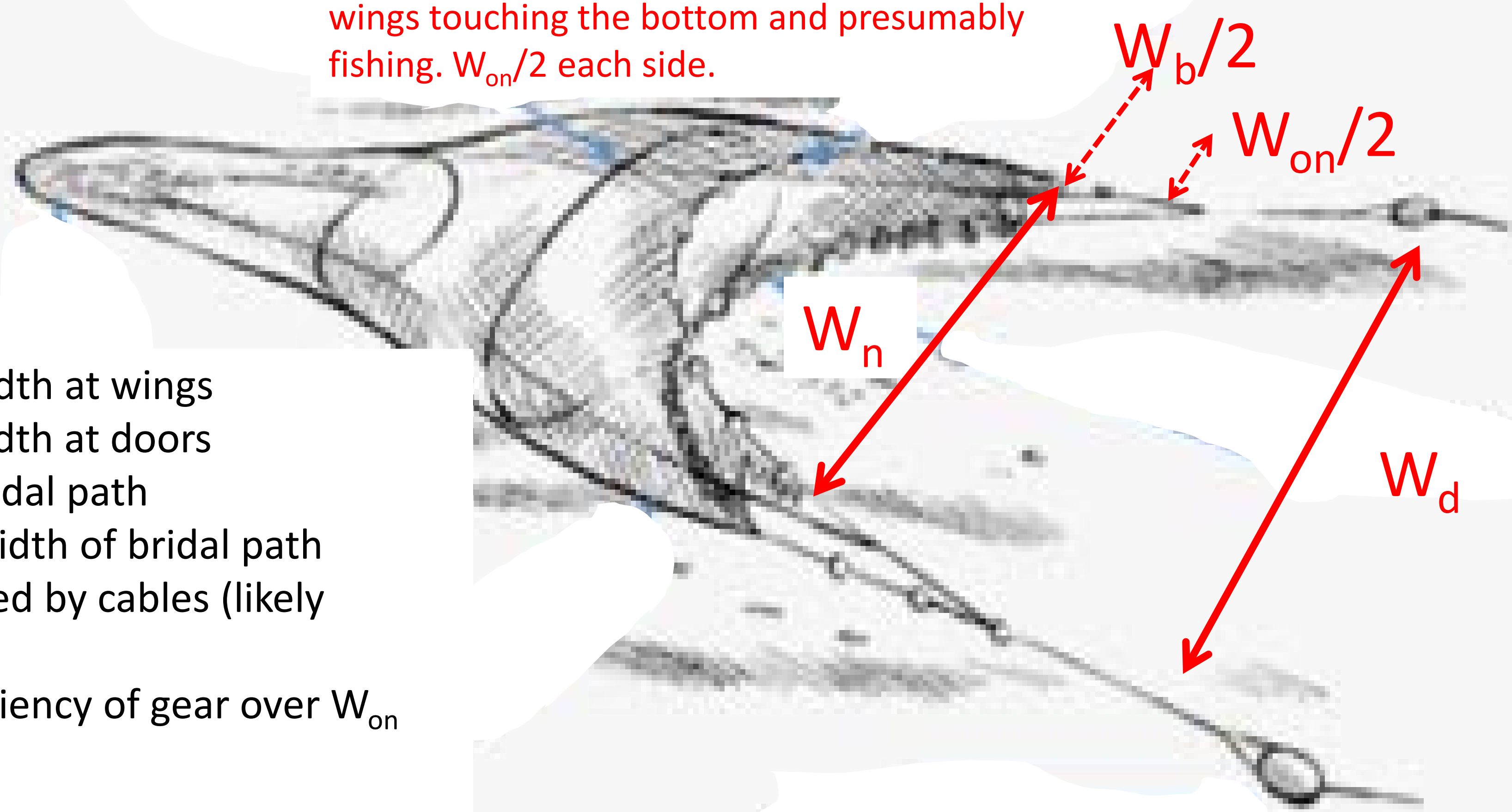
- YTF 30+ cm
  - About the same as fishable
- Simple
- Estimates are weighted averages over all size groups
  - Applicable to total catch in numbers or weight 30+ cm
- Size selectivity not included in calculations
  - But cancels out as shown below
- Biomass estimates biased low if selectivity is logistic
  - Bias reduced if selectivity near one for 30+ cm YTF

Lengths from paired tow experiment



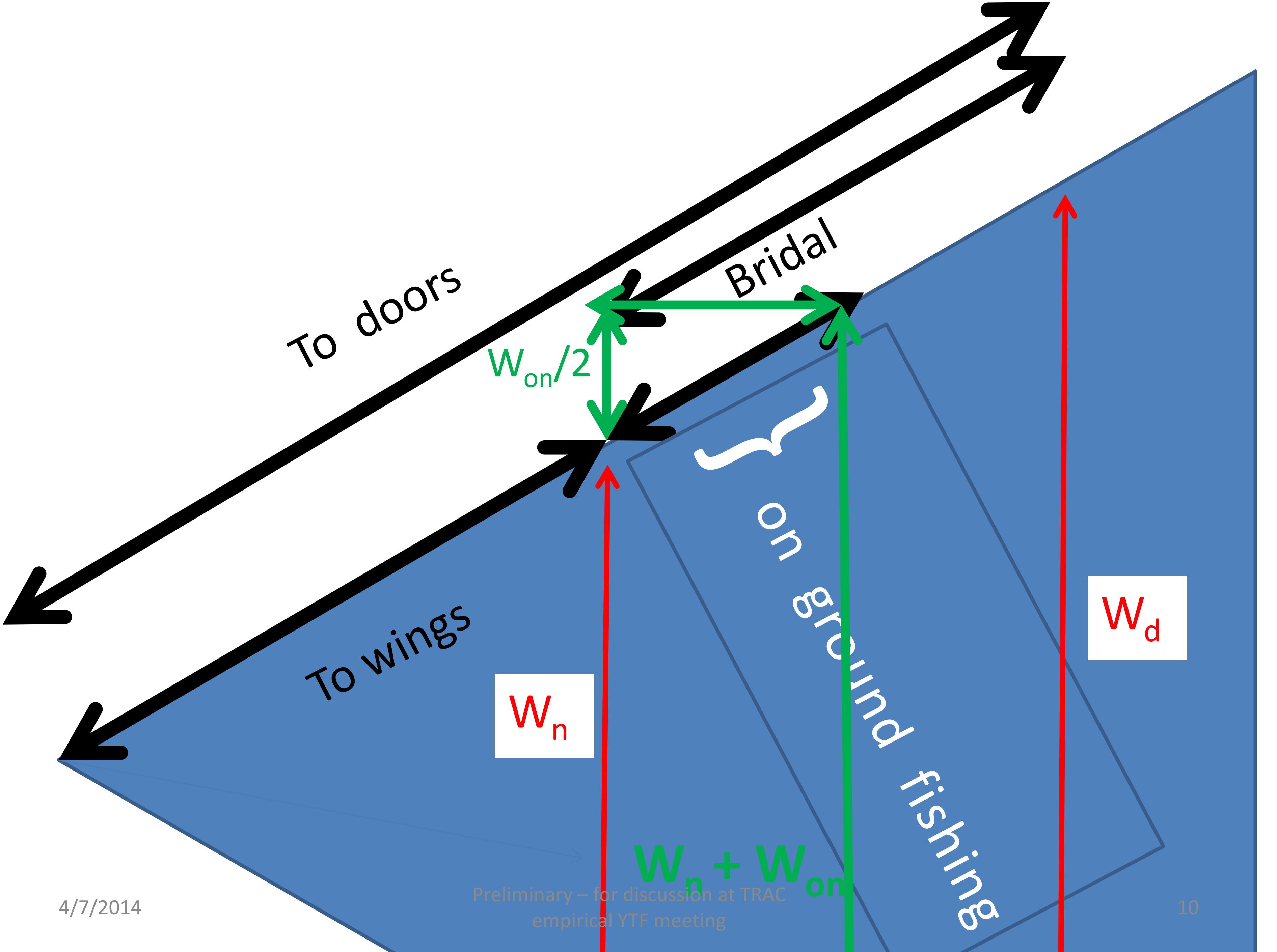
Define notation for theory and field experiments

W_{on} is the for parts of the bridal nearest wings touching the bottom and presumably fishing. $W_{on}/2$ each side.



W_n = width at wings
W_d = width at doors
W_b = bridal path
W_{on} = width of bridal path contacted by cables (likely fishing)
h = efficiency of gear over W_{on}

Gear works the area in front of the wings and in front of the bridal patch where it touches the bottom. Generalize: the area in front of the bridal and the area "effectively" swept by the bridals.


To doors
Bridal
To wings
W_on/2
on ground fishing
W_n
W_d
W_n + W_on

Define whole net vs. bridal efficiency

- We have prior information about both - clarity important
- k_n = bridal efficiency = probability of capture between wings (W_n)
- h = relative efficiency for areas swept by bridals where they touch the bottom
- E = whole net or gear efficiency

$$E = \frac{k_n(W_n + hW_{on})}{W_d}, \quad h \le 1, \quad k_n \le 1, \quad E \le k_n$$

- Can also take $hW_{on} = W_{on}'$ = distance bridal effectively fishing, then
- Sommerton et al. (2007) measured W_n and W_d and estimated k_n and h by size and W_{on} to estimate E at size

Upper bounds for capture efficiency

- Upper bounds are information about E
- Ratio catch by Bigelow to catch / more efficient test gear
- If E=1 for other gear, then the ratio would estimate E for the Bigelow
- No bottom trawl is 100% efficient between doors so ratio gives an upper bound on Bigelow capture efficiency
- Not a mathematical upper bound
  - "Sally probably shorter than Billy" not "Sally shorter than 5 ft"
- Bound provides more information if standard gear is efficient and the bound is precise
  - Want large N, low variance among tows and big difference in catches by the two gear types
- Based on diel effects and comparative net experiments
  - Don't forget uncertainty

What we know about upper bounds for door efficiency

- C_2 = mean catch at night and C_1 = mean catch 24 hr sampling (C_2 consistently > C_1 for YTF in bottom trawls)

$$\frac{C_1}{C_2} = \frac{\dfrac{k_{n,1}(W_n + hW_{on})}{W_d} LD}{\dfrac{k_{n,2}(W_n + hW_{on})}{W_d} LD} = \frac{E_1}{E_2} = \frac{k_{n,1}}{k_{n,2}}$$

  - D is YTF density, L = length of tow
  - Var(C_1/C_2) by bootstrapping
- Ignoring variance, C_1/C_2 is <u>*simultaneously*</u> an upper bound on bridal efficiency and net efficiency
- But if $k_{n,2} \leq 1$, then $k_{n,1}$ <<< C_1/C_2
- If C_1/C_2 is a robust bound for k_1, then it is doubly robust for E_1
- C_1/C_2 as an upper bound for E_1 is a good bet to make…

Upper bounds for *E* based on diel effects

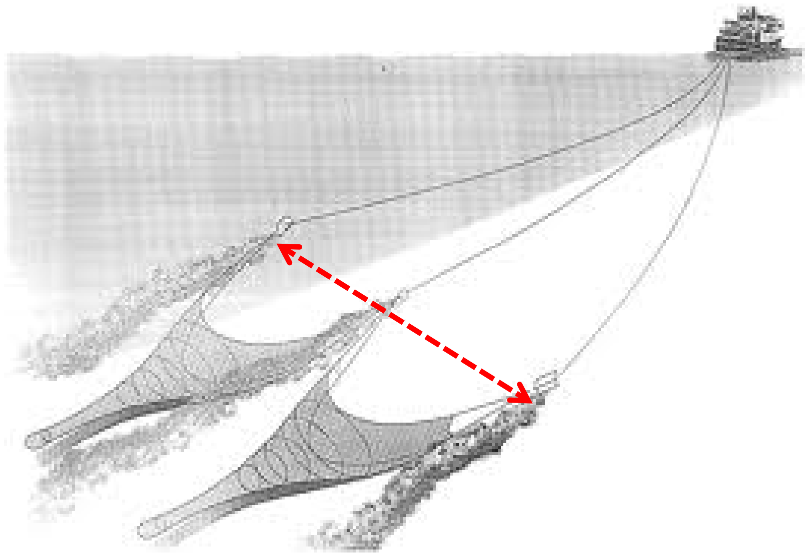
- YTF catches higher for bottom trawls at night
- Mean total catch / Mean total night catch at night
  - Spring and fall surveys, successful random tows

Upper bounds from 2 ground gear experiments

- Two upper bound estimates from each
  - Diel comparisons (as above)
  - Cookie gear vs. rockhopper – most efficient gear (cookies) in denominator of C_1/C_2
- Gear/protocols similar to Bigelow
- Ratio estimator (with CV) because tows paired
- Twin trawl experiment (pers. comm. Nathan Keith)
- Paired tow experiment (Mike Martin)

Twin trawl

- Commercial vessel
- 2003, 10 fishing days, two 5 day legs
- Bigelow towing protocols except winch lock/reengage
- 92 useful tows
- 30-50m (shallow on smooth bottom)
- Sunup to ~2200-2300.



Paired tow experiment

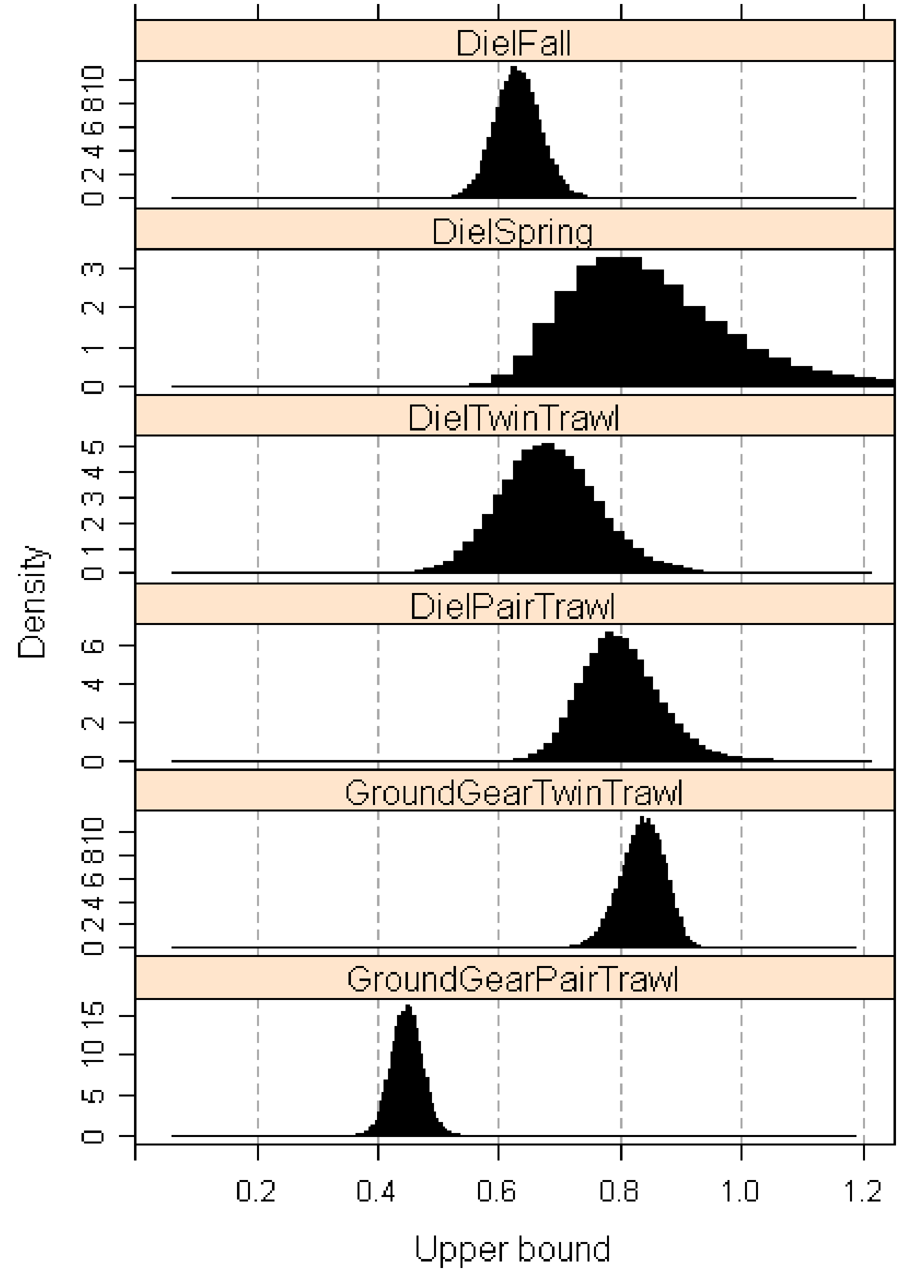
- 2009-2010
- Three commercial vessels
- 26-206 m (smooth bottom?)
- 235 useful tows
- Day and night sampling
- Bigelow protocols

Bounds for YTF capture efficiency

Data	N tows or pairs	Estimate	CV	low 95%	high 95%
Based on diel effects					
Fall survey	207	0.63	0.06	0.56	0.58
Spring survey	270	0.83	0.16	0.65	0.68
Paired trawl	234	0.79	0.08	0.69	0.72
Twin trawl	58	0.68	0.12	0.54	0.57
Based on ground gear experiments					
Paired trawl	228	0.45 ?!	0.05	0.40	0.49
Twin trawl	58	0.84	0.04	0.76	0.90
Average	176	0.70	0.09	0.60	0.66
Min	58	0.45	0.04	0.40	0.49
Max	270	0.84	0.16	0.76	0.90

Bootstrap distributions for upper bounds

- Precise enough to be useful (CV 4%-16%)
- Ground gear paired trawl
  - Lowest upper bound, looks like an efficiency estimate
  - Apparently precise (?)
  - CI doesn't overlap others
  - Either the best estimate or symptom of extra variance
- Cookie gear may provide best comparison (cookie E close to one for YTF?)
  - But what happened to the ground gear twin trawl case?



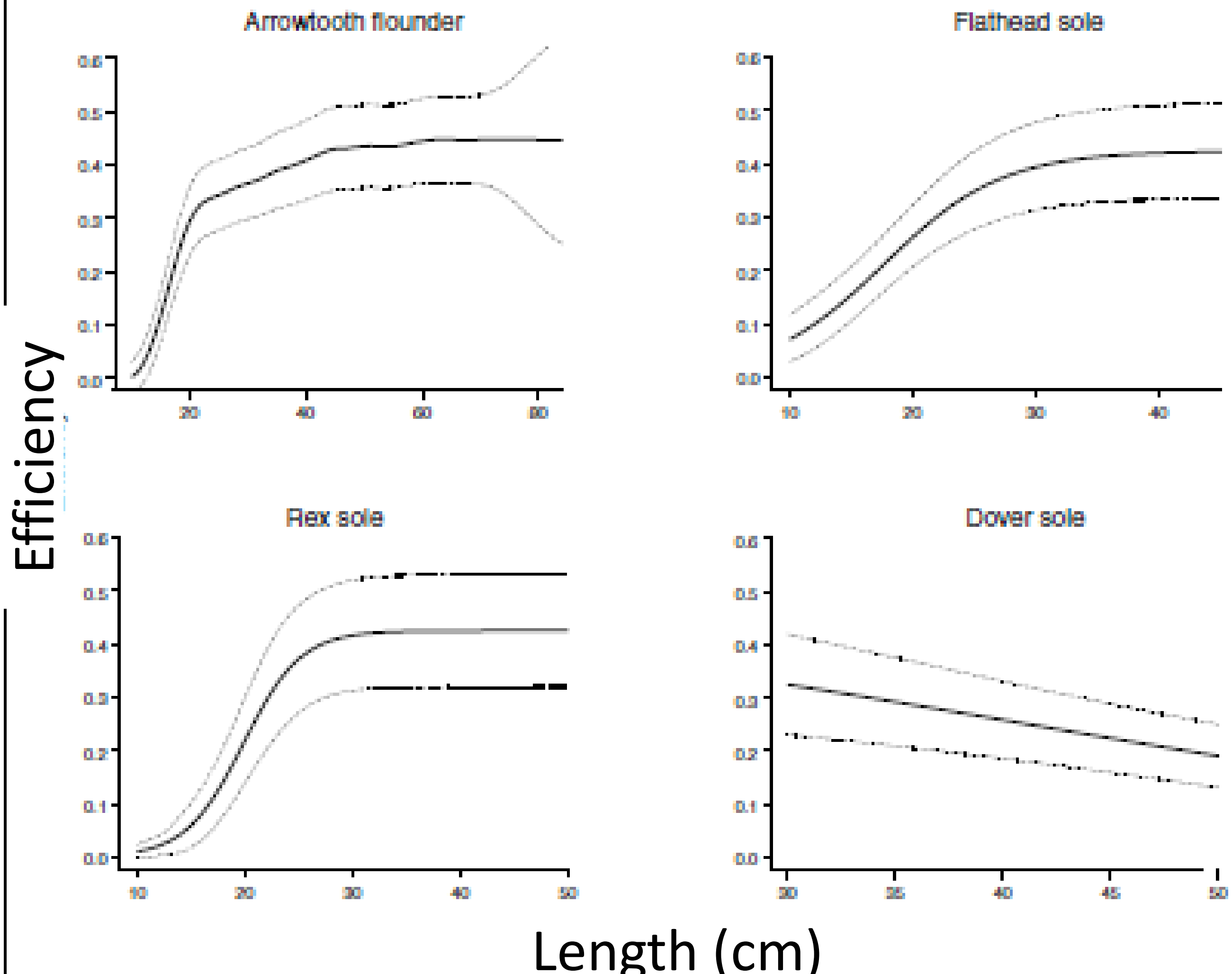
Experimental whole net efficiency estimates

- Five flatfish species in two lined survey bottom trawls
  - Sommerton et al. (2007)
  - Harden Jones et al. (1977)
- Other species and gear for context/comparison
  - Goosefish in two bottom trawls
  - YTF in 8’ scallop survey dredge
  - Sea scallops (GBK and MAB) in scallop dredge
- Gear specs at end

Sommerton et al. (2007)

- "Whole-gear efficiency of a benthic survey trawl for flatfish" Fish. Bull. 105:278–29
- Polynor'eastern survey trawl (see below)
- Gulf of Alaska, off Kodiak Island
- Arrowtooth flounder, flathead, rex and Dover sole
- Results: "*Whole-gear efficiency varied with fish length and reached maximum values between 40% and 50% for arrowtooth flounder, flathead sole, and rex sole. For Dover sole, however, whole-gear efficiency declined from a maximum of 33% over the length range sampled* "
- Size dependent estimates, maximum used here (biased high for whole catch and low for biomass)

Sommerton et al.



Whole-gear efficiency (solid line), and 95% confidence intervals (dotted lines), as a function of fish length for each of the four flatfish species: arrowtooth flounder (*Atheresthes stomias*), flathead sole (*Hippoglossoides elassodon*), rex sole (*Glyptocephalus zachirus*), and Dover sole (*Microstomus pacificus*).

Harden Jones et al. 2007

- "*The efficiency of the granton otter trawl determined by sectorscanning sonar and acoustic transponding tags*" (Rapp. P.-v. Reun. Cons. int. Explor. Mer, 170: 45-51.)
- English plaice, 30-50 cm, 1971-1974
- Southern North Sea, daylight sampling (efficiency estimates bias low?)
- General purpose 24 m Granton otter trawl with bunt and mid-wing tickler chains
- Two research vessels
- Plaice fitted with acoustic, ship driven over them with net deployed
- 166 valid attacks
- Overall efficiency for whole gear was 0.22 (SE=0.10, CV=45%)

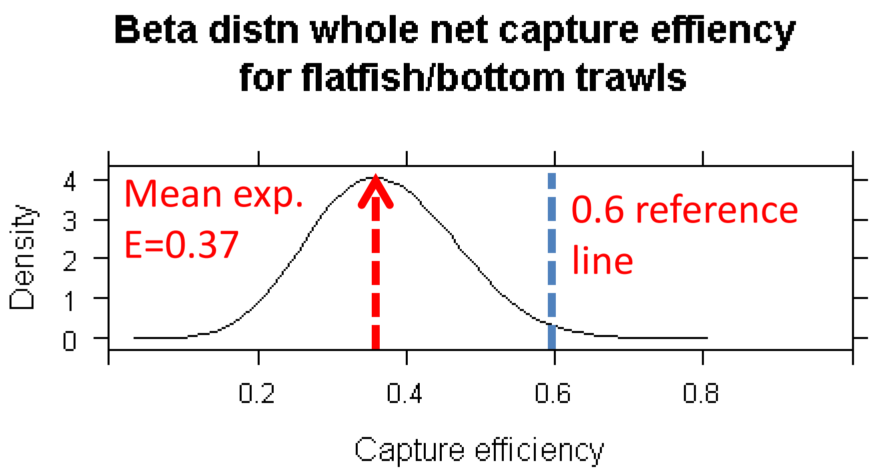
Experimental whole gear efficiency estimates (all species and years)-flatfish at top

Species	Study area	Gear	Size selectivity	Fully selected sizes (cm)	Efficiency: Bridal (k)	Efficiency: Whole net (E)	Method	Source
Arrowtooth flounder	Gulf of Alaska	Poly Nor'eastern bottom trawl	increasing	40+	0.95	0.45	Measured sweep contact, assumed *h* (efficiency relative to bridals) =1 for area contacted	Sommerton et al. (2006)
Flathead sole			increasing	25+	0.8	0.42		
Rex sole			increasing	30+	0.85	0.43		
Dover sole			decreasing	31	0.6	0.33		
Plaice	North Sea, Southern Bight	Granton Otter Trawl (general purpose)	n/a	n/a	n/a	0.22	Trawling over fish with acoustic tags	Harden Jones et al. (1977)
Yellowtail flounder	Closed Area II South, 2010 & 2012	Lined 8' survey dredge, R/V Sharp	n/a	n/a	n/a	0.62	Comparative dredge - HabCAM tows	Hart and Shank (WP)
Goosefish	Gulf of Maine + Georges Bank	F/V Drake (nets 1 & 2)	n/a	n/a	n/a	0.28	Depletion experiments (wing spread-no herding)	NEFSC (2004 SARC-34 Tables C29, C34 and Figures C43) - check this
	Southern New England	F/V Mary K	n/a	n/a	n/a	0.48		
	~ 40°N and 70°W	F/V Mary K (2009) - cookie sweep	n/a	n/a	n/a	0.52	Mean of 3 (MK) + 2 (ER) depletion experiments (wing spread-no herding), one high estimate for MK (0.95) excluded by authors	NEFSC (2010, SARC-50 Table A14)
		Endurance (2009) - cookie sweep	n/a	n/a	n/a	0.5		
Sea scallops	Georges Bank (gravel, cobble and rock)	Lined 8' survey dredge, R/V Albatross	flat	40+ mm SH	na	0.38	Comparative dredge - HabCAM tows	NEFSC (2010, SARC-50, App. B9-B10)
	Mid-Atlantic (sandy)					0.44		

Summary experimental estimates

Results	N	Min	Max	Mean	CV (SD/mean)	95% CI (+/- 1.96*SD) low	95% CI (+/- 1.96*SD) high
Flatfish in bottom trawls	5	0.22	0.45	0.37	26%	0.18	0.56
Other species and gears	7	0.28	0.62	0.46	0.24	0.25	0.67
All	12	0.22	0.62	0.42	26%	0.21	0.64

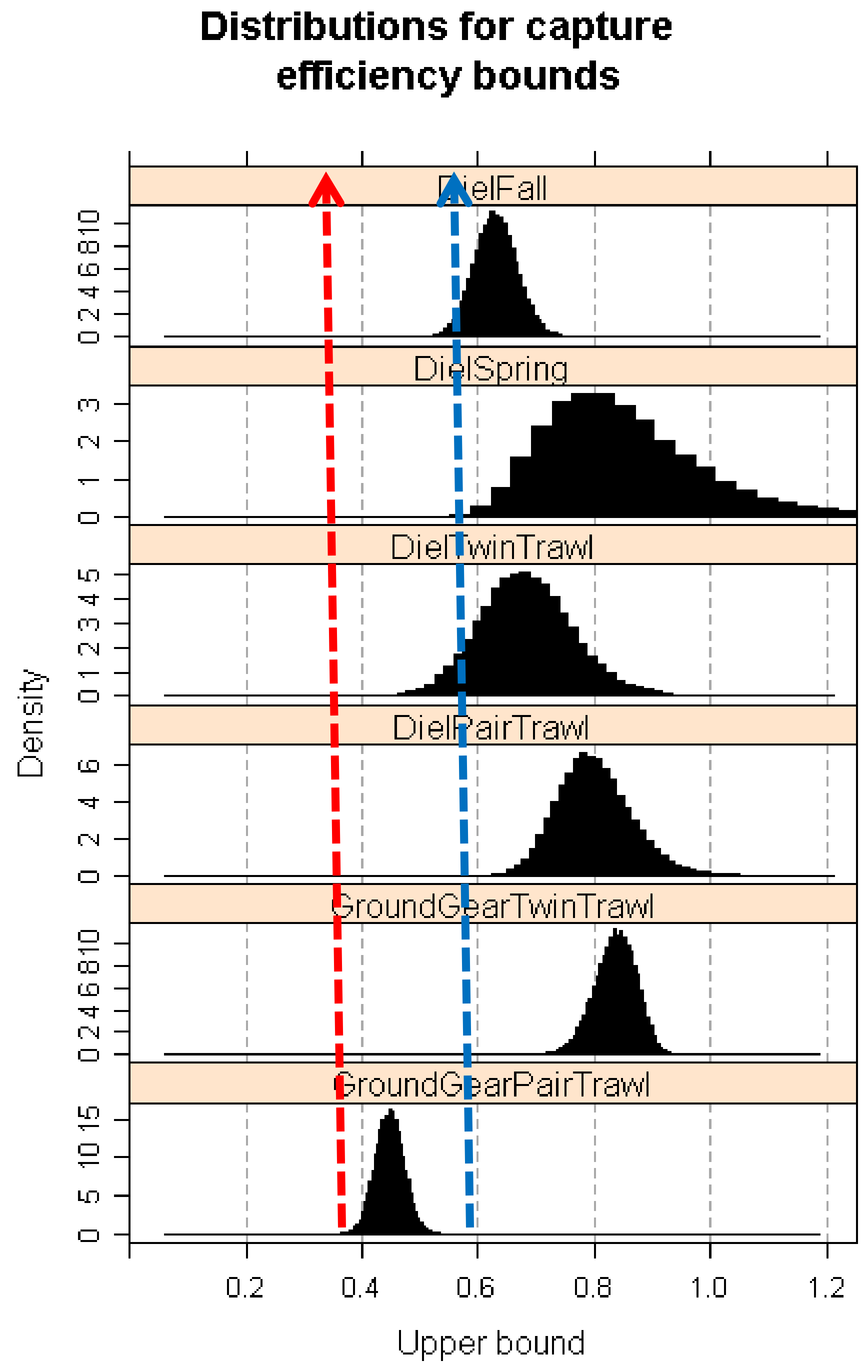
- Alaska and plaice more consistent then apparent because of different size assumptions
- Means for all three groups 0.37-0.46 but flatfish biased high
  - Bias (?) swamped by other differences
- Confidence intervals broadly overlap (0.2-0.7)
- Results should be robust to choice of group
  - We will use flatfish in bottom trawls
- Fit beta distribution by method of moments with mean 0.37 and CV 0.26



Mean of experimental efficiency estimates < means for bounds

Lots of overlap with upper bound from pair trawl ground gear

Experimental estimate seems plausible re bounds (with uncertainty)



Prior for Q and swept-area biomass

- Use formulas:

$$I = QB$$

$$Q = E\frac{a}{A}$$

$$B = \frac{I}{Q}$$

  - I=survey index, A=catchability, N=stock abundance, B=stock biomass, a = area swept (doors), A=stock area
- "Fishable" sizes, e.g. 30+ cm
- Form prior for Q based on information about a, A and e
- Calculate swept-area abundance = I/Q as a distribution that includes uncertainty in all factors

Range and distribution for stock area A

- Use information about bottom type and tow deployment at random stations to get a lower bound for A
  - Bigelow 2008/2009-2013
  - 93% of US portion of GBK is trawlable
  - Assume same on Canadian side
- Trawlable stations as a proxy for habitat
- Use uniform distribution with bounds = 93% and 100% of survey area
  - 34,657 and 37,286 km2

Category	# tows	percent
trawlable	438	80%
tear or hang	21	4%
alternate	18	3%
outside 1 nm	73	13%
total	550	100%

1-(trawlable+ outside 1 mi) = 0.93

Range and distribution for area swept (a)

- Swept-area measured for each tow
  - Tow start time based on several sensors
  - Tow end based on winch lock
    - Fast powerful winches
- Mean swept area hardly changes from year to year and survey to survey
  - Grand mean = 0.0606 km^2
- Trawl may continue fishing at end of tow after winch lock for a short period of time
- Use uniform distribution with bounds at 0.060624 to 1.05* 0.060624 (0.0606 to 0.0637 km2)

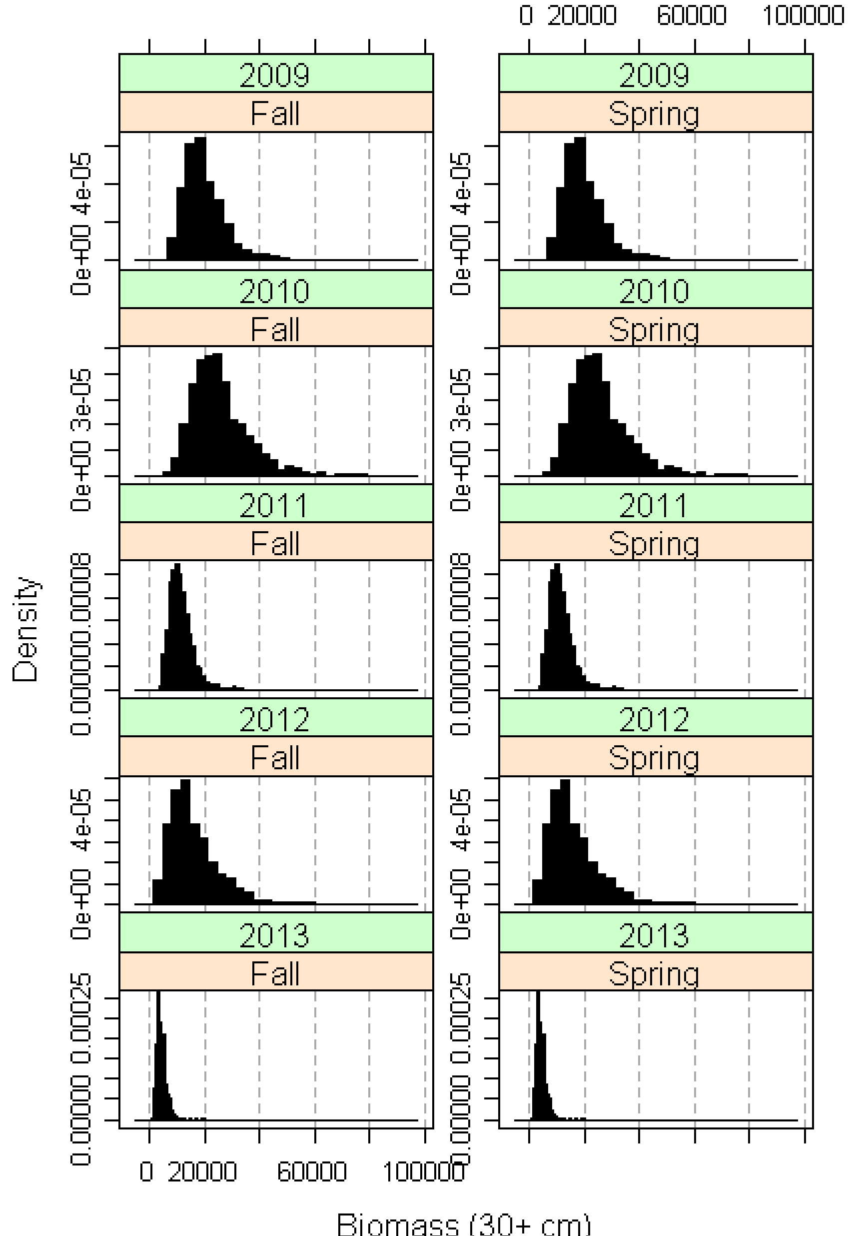
Uncertainty in survey data

- Survey index is stratified mean kg/tow and variance
- Fit a gamma distribution to stratified mean and variance for each year by method of moments

Estimated biomass and uncertainty based on survey data and prior information

- Draw a, A, E and I from uniform, beta and gamma distributions
- Compute B=I*A/(e*a)
  - Repeat 50000 times
- Plot and summarize distributions
- We are done!

Biomass distributions



Preliminary – for discussion at TRAC empirical YTF meeting

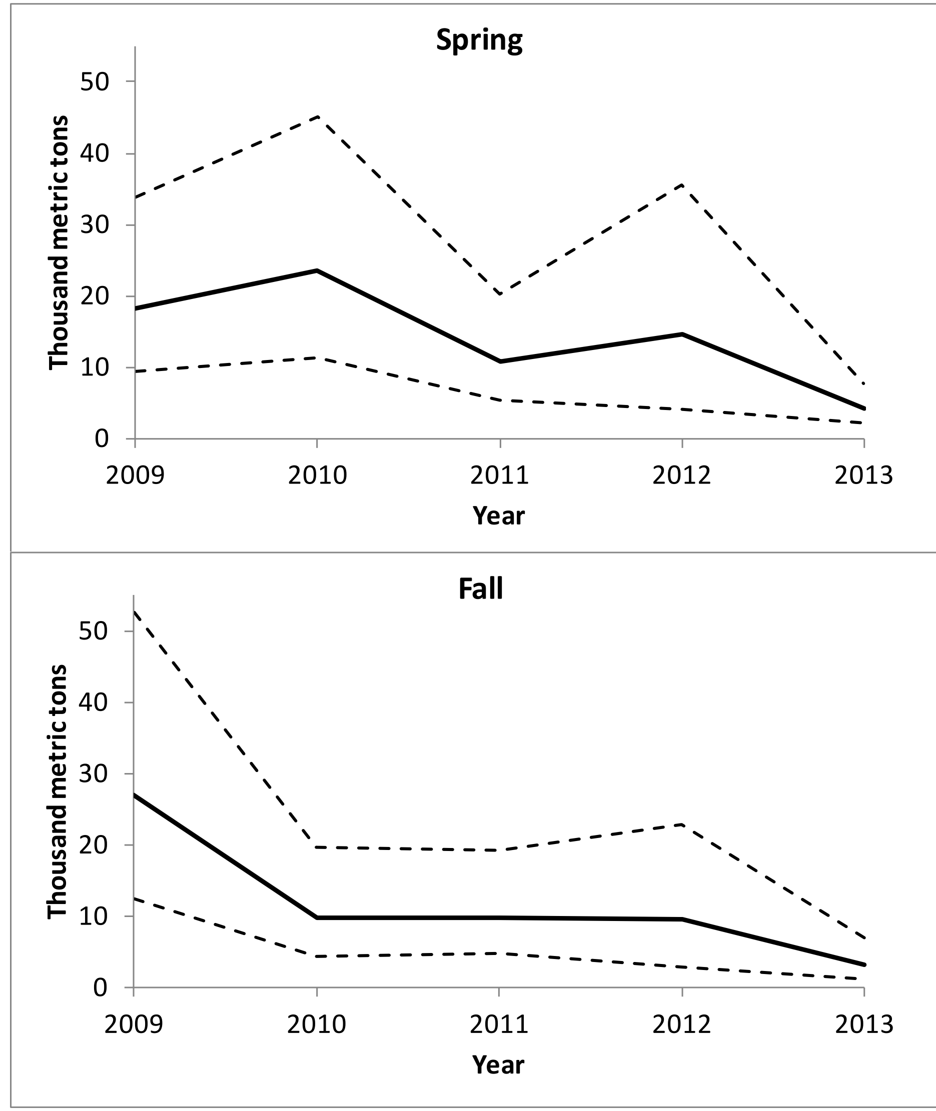
Biomass estimate (30+ cm) summary

Year	Mean	Quantiles										
		Min.	2.5%	5%	10%	25%	Median	75%	90%	95%	97.5%	Max.
						Spring survey						
2009	19,900	7,669	9,411	10,614	11,893	14,580	18,270	23,760	29,840	34,506	11,792	67,140
2010	25,840	6,624	11,592	12,764	14,528	17,980	23,490	31,440	39,964	47,271	14,408	78,230
2011	11,440	3,728	5,422	6,029	6,820	8,340	10,850	13,510	16,728	19,169	6,722	40,020
2012	16,890	1,440	4,426	5,640	6,992	10,350	15,120	20,800	28,146	34,911	6,954	102,900
2013	4,442	1,358	2,030	2,334	2,681	3,249	4,079	5,350	6,734	7,724	2,667	15,300
						Fall survey						
2009	29,590	7,144	12,897	14,394	16,726	20,950	27,570	35,640	44,381	51,790	16,685	125,300
2010	10,700	2,768	4,635	5,098	5,960	7,416	9,684	13,150	16,840	19,473	5,922	38,750
2011	10,750	2,536	4,439	5,238	6,059	7,626	9,988	13,010	16,419	18,878	6,030	41,170
2012	10,700	688	2,947	3,802	4,603	6,506	9,254	13,670	18,360	22,840	4,582	48,020
2013	3,630	592	1,230	1,429	1,729	2,253	3,232	4,463	6,002	7,375	1,722	17,400

- Means and median similar (use either)

Biomass estimates 30+ cm w/90% CI

- Spring and fall surveys results similar
- We can update these figures under different assumptions easily and quickly



The end (finally)

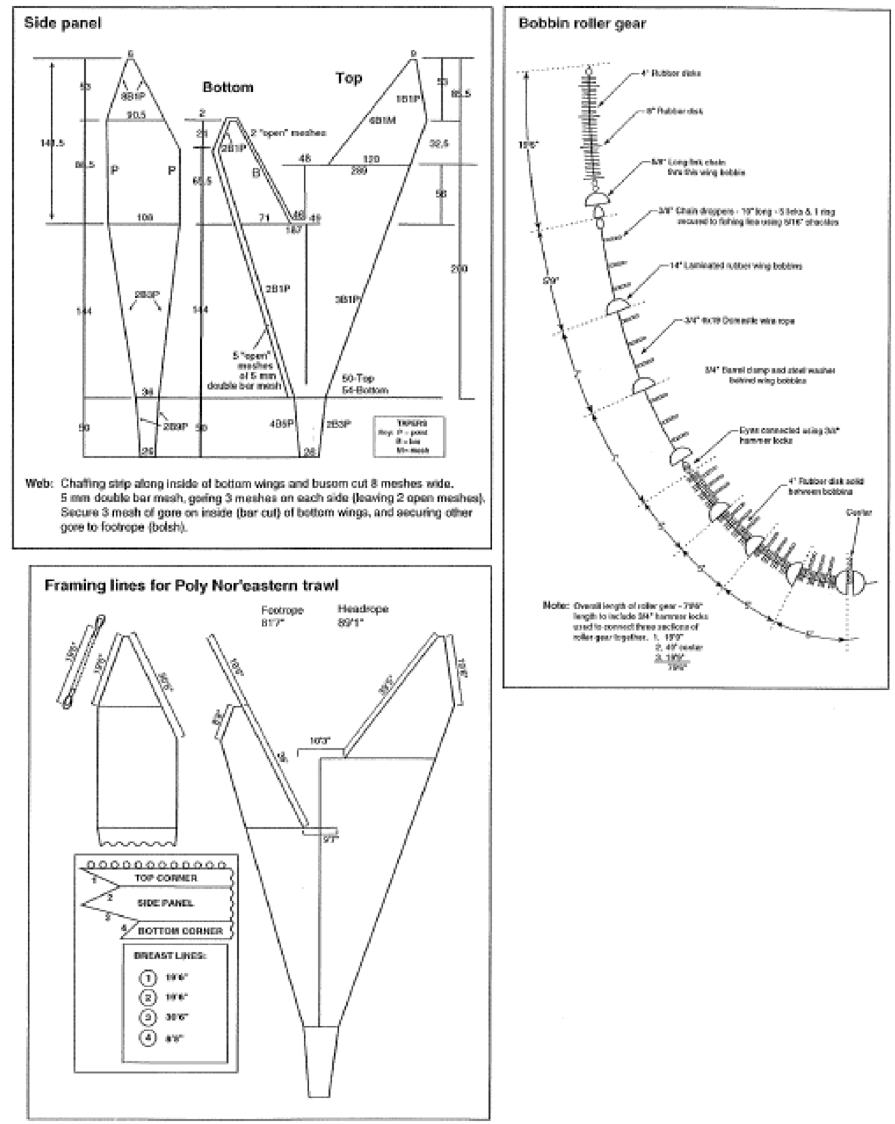
Gear info follows

Compare Bigelow and Polynor'estern bottom trawls

Agency	NEFSC	AKFSC
	Bigelow 4-Seam	Poly-Nor'Eastern
Liner (mm)		
Trawl Design	3-bridle, 4-seam	3-bridle, 4-seam
	3 wings/jibs	
Sweep Type	Rockhopper	Roller bobbin
Center (diameter, cm)	40.6	12.2
Wings (diameter, cm)	35.6	10 and 20 cm rubber discs
Trawl Door	2.2m², 550kg Poly-Ice Oval	1.8x2.7m, 816kg, steel V
Headrope Length (m)	21.6	27.2
Sweep Length (m)	25.3	36
Bridle Length (m)	36.6	54.9
Ground Cable Length (m)	none	none
Total Door-Wing Dist (extension+backstrap, m)	48.9	70.1
Avg. Door Spread (m)	33.5	47.8
Avg. Wing Spread (m)	12.6	16.1
Bridle Angle	12.3°	15º
Avg. Height (m)	3.7	

Polynor'eastern

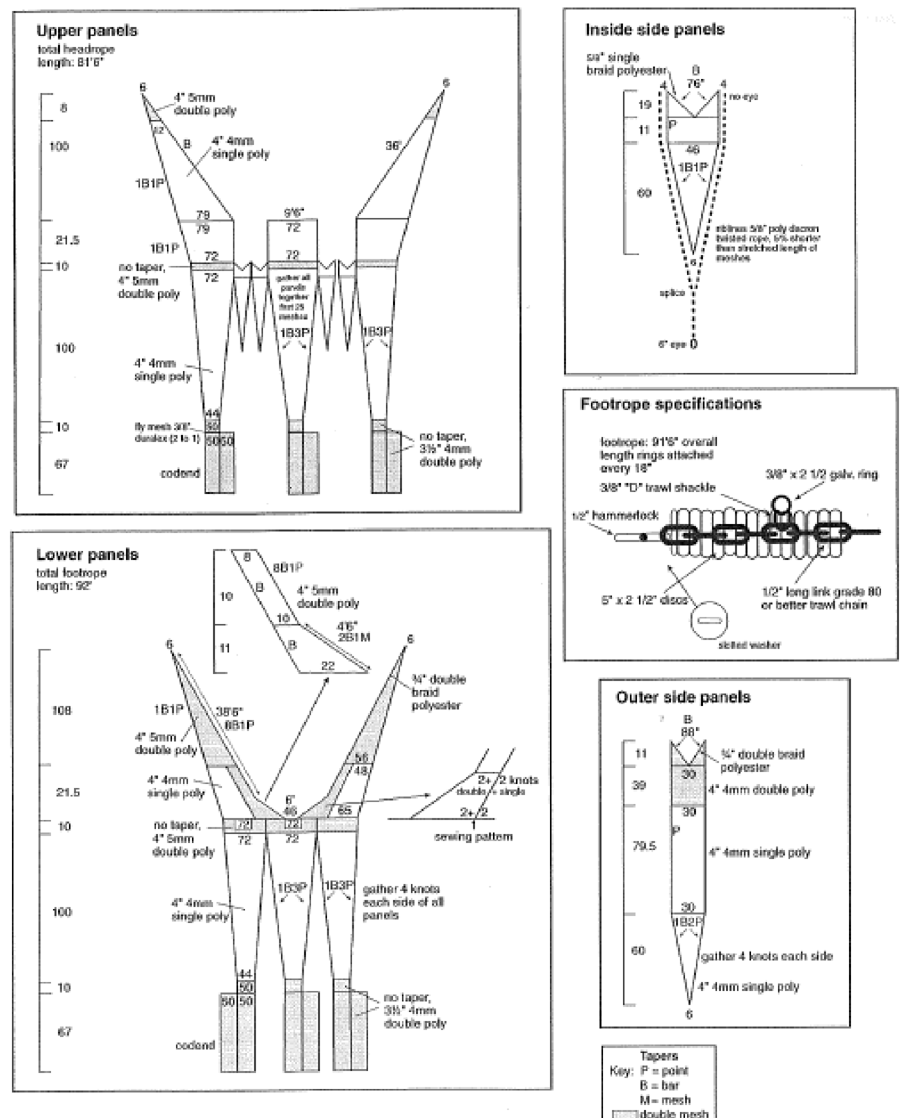
four-seam design ,27.2-m headrope ,a 36.5-m footrope with 36-cm bobbins for moderately rocky terrain…doors are "V" style 1.8 m by 2.7 m and 816 kg each… Tailchains two 3-m lengths 13-mm long-link chain joined to single 19-mm diameter steel cable. 3.2 cm mesh liner (Sommerton et al. 2007)



Appendix Figure 1
Diagram of the Poly Nor'eastern bottom trawl.

Polynor'eastern

Somerton et al.: Whole-gear efficiency of a benthic survey trawl for flatfish 291



Appendix Figure 2

Diagram of the auxiliary net that was attached under the Poly Nor'eastern bottom trawl to capture fish escaping under the footrope.

Bigelow bottom trawl from Phil Politis

- Poly Nor'eastern Chris Legault
Lines significantly longer
    - Means higher vertical opening
    - Less significant (or non-significant) for flatfish catchability