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Meta population modelling of narwhals in East Canada and West Greenland

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ABSTRACT
This paper combines the catch allocation model for narwhals in East Canada and West Greenland with Bayesian population modelling of the eight summer aggregations of narwhals in the region. The catch allocation model allocates the catches in different hunting areas and seasons to the different summer aggregations, and the population models analyse the impact of these catches on the population dynamics of the eight narwhal aggregations.

The population models run from 1970, and the catch allocation model needs population trajectories from 1970 to the present in order to estimate the catches taken from the different summer aggregations during this period. In an initial run it uses linear transitions between the available abundance estimates; but more elaborate population trajectories are estimated by the fit of the population models to the abundance data. The two models are therefore run in an iterative manner until the catch histories that are estimated by the allocation model, and the abundance trajectories that are estimated by the population models, converge between runs.

Given a converged model and potential future catch options for the different hunts, the model estimates the probabilities of fulfilling management options for eight summer aggregations of narwhals.

MODEL

In this paper I develop a meta population dynamic model for eight summer aggregations of narwhals in East Canada and West Greenland. For this I combine the catch allocation model that was developed at the 2014 meeting of the JWG (JWG 2014) with eight population dynamic models, which resemble the Bayesian models that have been used previously in the JWG in relation to harvest recommendations for narwhal and beluga in West Greenland.

Catch allocation model

The catch allocation model is described in detail in JWG (2014), and it allocates catches taken in different hunting regions and seasons to eight summer aggregations of narwhals in East Canada and West Greenland.

The model uses an availability matrix (Table 2 and 1) to describe the availability of the narwhals from the different summer aggregations to the hunts in the different regions and seasons, and it uses a catch matrix (Tables 10 and 11) to describe the annual total removals (catches plus loss) in the different hunts.

Hunt	Season	Smith	Jones	Inglefield	Melville	Somerset	Admirality	Eclipse	Baffin
Qaanaaq	Spring	1	$0/n$	0	0	0	0	0	0
Qaanaaq	Summer	0	0	1	0	0	0	0	0
Grise Fjord	Spring	$0/n$	1	$0/n$	0	$0/n$	0	0	0
Grise Fjord	Summer	0	1	0	0	0	0	0	0
Grise Fjord	Fall	$0/n$	1	$0/n$	0	$0/n$	0	0	0
Upernavik	Summer	0	0	0	1	0	0	0	0
Ummannaaq	Fall	$0/n$	$0/n$	$0/n$	$1/9$	1	$0/42$	$0/26$	$0/n$
Disko Bay	Winter	$0/n$	$0/n$	$0/n$	$1/7$	$0/n$	$1/42$	$1/6$	$0/n$
Resolute	Spring	0	0	0	0	1	$0/4$	$0/5$	0
Resolute	Summer	0	0	0	0	1	0	0	0
Resolute	Fall	0	0	0	0	1	$7/42$	$1/26$	0
Arctic Bay	Spring	0	0	0	0	1	1	$1/5$	0
Arctic Bay	Summer	0	0	0	0	0	1	0	0
Arctic Bay	Fall	0	0	0	0	$0/n$	1	$6/26$	0
Pond Inlet	Spring	0	$0/n$	$0/n$	0	$2/2$	$4/4$	1	$0/n$
Pond Inlet	Summer	0	0	0	0	0	0	1	0
Pond Inlet	Fall	0	$0/n$	$0/n$	0	$0/14$	$4/42$	1	$0/n$
East Baffin	Spring	0	$0/n$	$0/n$	0	$0/2$	$0/4$	$0/6$	1
East Baffin	Summer	0	0	0	0	0	0	0	1
East Baffin	Fall	0	$0/n$	$0/n$	0	$0/5$	$10/42$	$16/26$	1
Pangnirtung	Spring	0	0	0	0	$0/2$	$0/4$	$0/6$	n/n
Pangnirtung	Summer	0	0	0	0	0	0	0	1
Pangnirtung	Fall	0	0	0	0	$0/5$	$0/42$	$2/26$	n/n
Pangnirtung	Winter	0	0	0	0	$0/2$	$0/42$	$1/6$	n/n

Table 1: The availability of narwhals from summer aggregations to hunting regions [x/n: available (x) over total (n)]. Black numbers are fixed, green and red beta distributions ($\alpha = x{+}1$; $\beta = n{+}1$); red for sensitivity by changes in n.

Hunt	Season	Smith	Jones	Inglefield	Melville	Somerset	Admirality	Eclipse	Baffin
Qaanaaq	Spring	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Qaanaaq	Summer	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
Grise Fjord	Spring	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
Grise Fjord	Summer	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
Grise Fjord	Fall	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
Upernavik	Summer	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00
Ummannaaq	Fall	0.00	0.00	0.00	0.11	1.00	0.00	0.00	0.00
Disko Bay	Winter	0.00	0.00	0.00	0.14	0.00	0.02	0.17	0.00
Resolute	Spring	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00
Resolute	Summer	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00
Resolute	Fall	0.00	0.00	0.00	0.00	1.00	0.17	0.04	0.00
Arctic Bay	Spring	0.00	0.00	0.00	0.00	1.00	1.00	0.2	0.00
Arctic Bay	Summer	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00
Arctic Bay	Fall	0.00	0.00	0.00	0.00	0.00	1.00	0.23	0.00
Pond Inlet	Spring	0.00	0.00	0.00	0.00	1.00	1.00	1.00	0.00
Pond Inlet	Summer	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00
Pond Inlet	Fall	0.00	0.00	0.00	0.00	0.00	0.1	1.00	0.00
East Baffin	Spring	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
East Baffin	Summer	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
East Baffin	Fall	0.00	0.00	0.00	0.00	0.00	0.24	0.62	1.00
Pangnirtung	Spring	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
Pangnirtung	Summer	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
Pangnirtung	Fall	0.00	0.00	0.00	0.00	0.00	0.00	0.08	1.00
Pangnirtung	Winter	0.00	0.00	0.00	0.00	0.00	0.00	0.17	1.00

Table 2: The availability of narwhals from summer aggregations to hunting regions. Black numbers are fixed, green and red point estimates of beta distributions; red for sensitivity only.

Year	Smith	Jones	Inglefield	Melville	Somerset	Admirality	Eclipse	Baffin
1975	-	-	-	-	-	28260 (0.22)	-	-
1981	-	-	-	-	32520 (0.1)	-	-	-
1985	-	-	-	-	-	16400 (0.43)	-	-
1986	-	-	8710 (0.25)	-	-	-	-	-
1996	-	-	-	-	45360 (0.35)	-	-	-
2001	-	-	-	-	-	-	-	-
2002	-	-	-	-	35810 (0.43)	-	-	-
2003	-	-	-	-	-	-	-	10070 (0.31)
2004	-	-	-	-	-	-	20230 (0.36)	-
2007	-	-	8370 (0.25)	6020 (0.86)	-	-	-	-
2009	-	-	-	-	-	-	-	-
2010	-	-	-	-	-	18050 (0.22)	-	-
2012	-	-	-	2980 (0.39)	-	-	-	-
2013	16360 (0.65)	12690 (0.33)	-	-	-	-	-	-
2014	-	-	-	3090 (0.5)	-	-	-	-

Table 3: Abundance estimates for summering aggregations of narwhal (CV in parenthesis).

To allocate the catches from the different hunts to the different summer aggregations, the model needs an additional matrix that describes the abundance in the different stocks per year. These abundance estimates are needed to estimate the relative availability of the different stocks to the different hunts, so that the catches from the different hunts can be allocated to the different summer aggregations.

The abundance matrix in the initial run of the model is constructed as linear transitions between the abundance estimates in the abundance estimate matrix of Table 3. In subsequent runs, the abundance matrix is given by the abundance trajectories that the population dynamic modelling is estimating for eight summer aggregations of narwhals, given the catch histories that are estimated by the previous run of the allocation model. This iterative running of the two models was then conducted three times to ensure a large degree of convergence of the catch histories and abundance trajectories.

Population dynamic models

A separate population dynamic model was constructed for each of the eight summer aggregations of narwhals. All the models were based on the Bayesian modelling framework that I used in the model for beluga in West Greenland (see 2015-JWG/09 for details), i.e., they were age and sex structured with density regulated growth.

All models had the same priors on the biological parameters (see Table 4), and they were all initiated in 1970. All the summer aggregations with only one or two abundance estimates available (Smith, Jones, Eclipse, Baffin) and Admirality seems to have had a very low exploitation rate in the beginning of the period, so for these I assumed that the population was close to the carrying capacity in 1970. For the remaining aggregations (Inglefield, Melville and Somerset), with a somewhat larger early exploitation, I assumed that the abundance in 1970 was lower than the carrying capacity.

The catch histories in the modelling were those that were estimated by the previous run of the allocation model, with the catch histories being drawn from a prior to capture the distribution of possible takes. For each aggregation, this prior was constructed from the distribution of possible total removals that was estimated for 2011 (Figure 1), together with two catch histories, a minimum catch history (c_{min}, represented by the 1th percentile of this distribution over time) and a maximum catch history (c_{max}, represented by the 99th percentile). The distribution was then rescaled to run from zero to one, with a value (x) drawn at random from the distribution for each parameterisation, with the catch history calculated as $c_t = c_{min,t} + x(c_{min,t} - c_{max,t})$.

M	N_0	N^*	p	p_0	b	a_m	ϑ	γ	c_h
smith	-	$2{,}80^U$	$.97{,}1^u$	$.5{,}1^u$	$26{,}62^b$	$8{,}12^u$	.5	$2{,}4^u$	$0{,}200^f$
jones	-	$2{,}60^U$	$.97{,}1^u$	$.5{,}1^u$	$26{,}62^b$	$8{,}12^u$	.5	$2{,}4^u$	$0{,}200^f$
ingle	$1{,}25^U$	$3{,}30^U$	$.97{,}1^u$	$.5{,}1^u$	$26{,}62^b$	$8{,}12^u$	.5	$2{,}4^u$	$0{,}200^f$
melvi	$.8{,}20^U$	$3{,}30^U$	$.97{,}1^u$	$.5{,}1^u$	$26{,}62^b$	$8{,}12^u$	.5	$2{,}4^u$	$0{,}200^f$
somer	$5{,}60^U$	$25{,}90^U$	$.97{,}1^u$	$.5{,}1^u$	$26{,}62^b$	$8{,}12^u$	.5	$2{,}4^u$	$0{,}200^f$
admir	-	$10{,}40^U$	$.97{,}1^u$	$.5{,}1^u$	$26{,}62^b$	$8{,}12^u$	.5	$2{,}4^u$	$0{,}200^f$
eclip	-	$5{,}50^U$	$.97{,}1^u$	$.5{,}1^u$	$26{,}62^b$	$8{,}12^u$	.5	$2{,}4^u$	$0{,}200^f$
eastb	-	$3{,}60^U$	$.97{,}1^u$	$.5{,}1^u$	$26{,}62^b$	$8{,}12^u$	.5	$2{,}4^u$	$0{,}200^f$

M	β_a
smith	-
jones	-
ingle	$.01{,}1^U$
melvi	-
somer	-
admir	-
eclip	-
eastb	-

Table 4: **Prior distributions** for the different models (M). The list of parameters: N_0 is the initial abundance, N^* the population dynamic equilibrium abundance, p the yearly survival, p_0 the first year survival, b the birth rate, a_m the age of the first reproductive event, ϑ the female fraction at birth, γ the density regulation, c_h the catch history, and β_i the abundance estimate bias (i: data reference). Abundance is given in thousands. The prior probability distribution is given by superscripts; p: fixed value, u: uniform (min,max), U: log uniform (min,max), and b: beta (a,b).

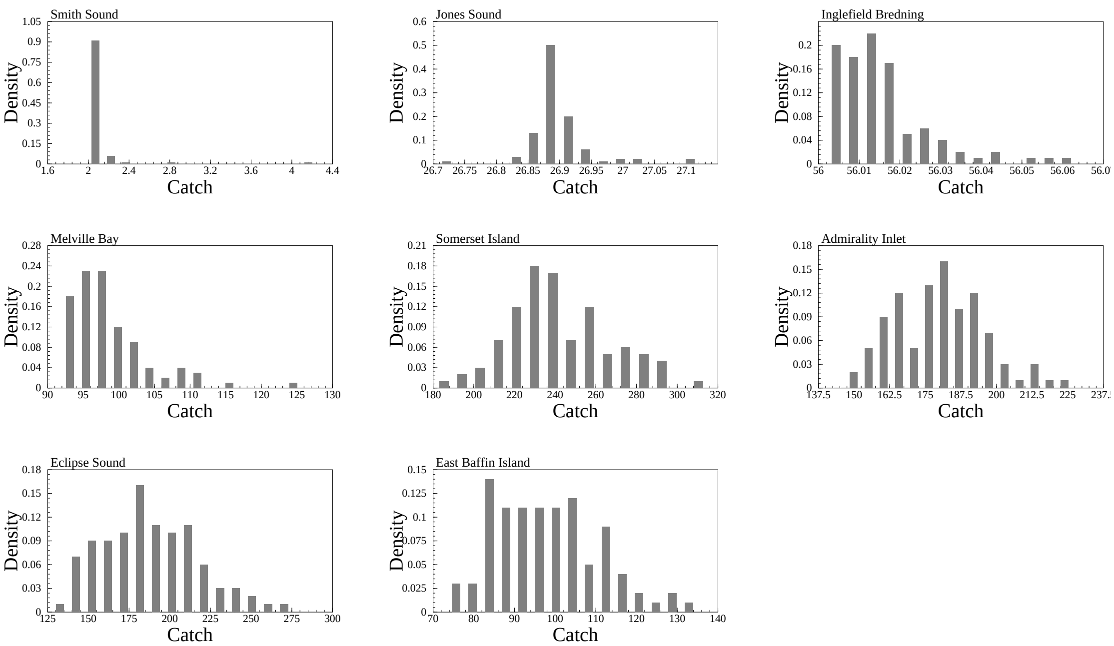

Figure 1: Catch distributions per summer aggregation, estimates for year 2011.

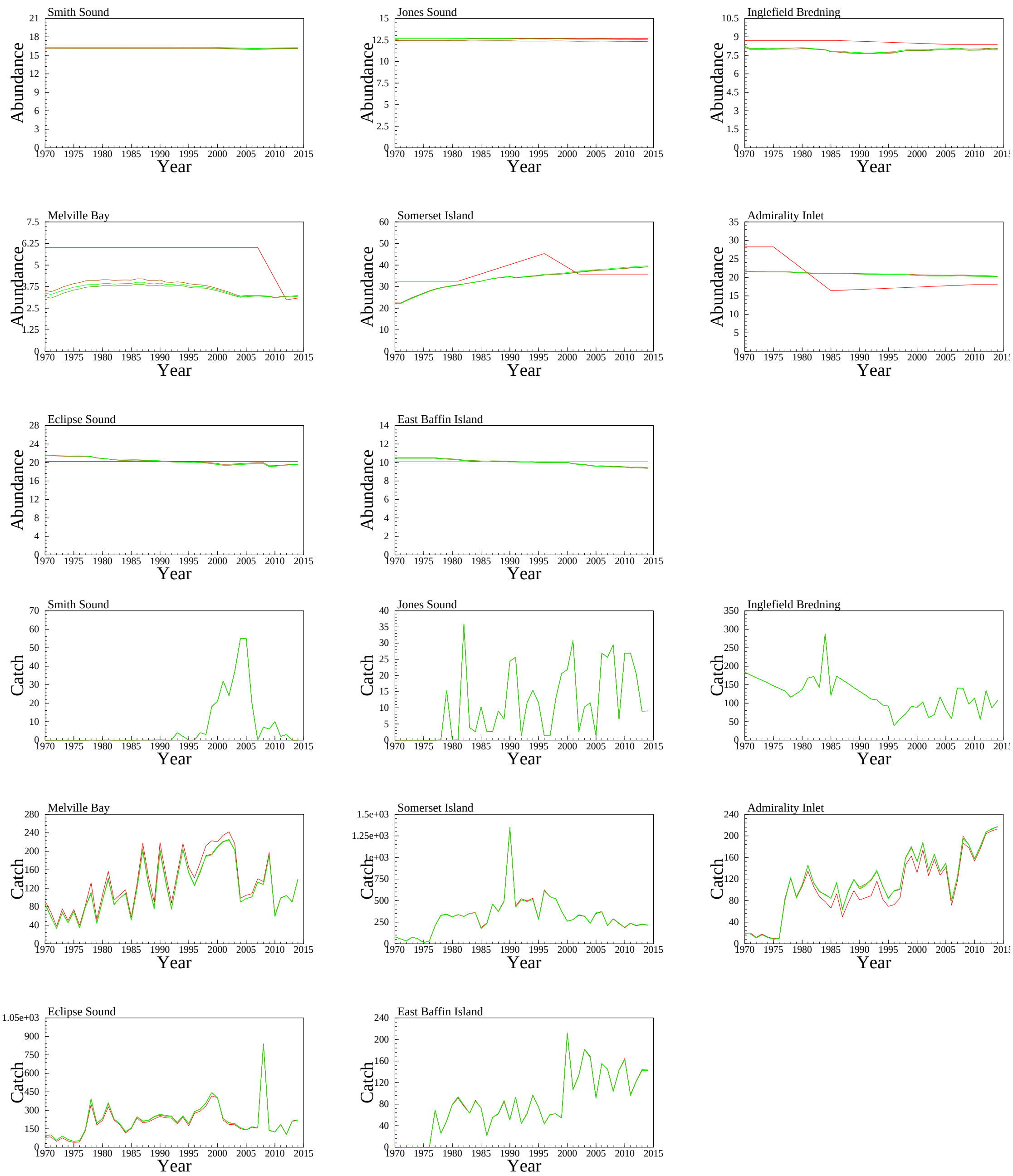

Figure 2: The convergence of the abundance trajectories and catch histories as a function of the number of iterations of the complete meta aggregation model, with iteration number increasing with colour transient from clear red to clear green. Abundance is given in thousands.

M	n_S	n_R	Weight	Unique	Max
smith	100	2	0	1974	2
jones	100	2	0	1961	2
ingle	500	2	0.0051	1290	13
melvi	100	2	0.0001	1848	3
somer	100	2	0.0001	1879	3
admir	100	2	0	1947	2
eclip	100	2	0	1962	3
eastb	100	2	0	1947	3

Table 5: **Sampling statistics** for the different models (M). The number of parameter sets in the sample (n_S) and the resample (n_R), the maximum importance weight of a draw relative to the total importance weight of all draws, the number of unique parameter sets in the resample, and the maximum number of occurrences of a unique parameter set in the resample. n_S and n_R are given in thousands.

RESULTS

The convergence of the catch and abundance trajectories over the five iterations of the allocation and population dynamic models are shown in Figure 2.

The sampling statistics of the last run of the Bayesian population models are shown in Table 5. The estimated trajectories of the eight summer aggregations are shown in Figure 3, and the posterior parameter estimates in Table 6, with plots of the posterior and realised prior distributions given in Figures 5 to 12. The final estimates of the catch histories per summer aggregation are shown in Figure 4.

Let us assume a management objective that aim for increasing populations if these are below the maximum sustainable yield level, and allows for catches up to 90% of the maximum sustainable yield if the population is above the maximum sustainable yield level. Given this, Table 7 list the estimated total allowable takes for the different summer aggregations that will meet this criterion with probabilities from 0.5 to 0.95.

But management should define the total allowable takes for the different hunts (region and season), as these cannot generally be allocated directly to the different summer aggregation. Hence, Table 8 define possible total allowable takes for the different hunts, with Table 9 giving the associated estimates of the probabilities that these takes from 2015 to 2020 will allow the management objective to be fulfilled for the different summer aggregations. These latter probability estimates have 90% confidence limits that reflect the uncertainty of the summer aggregation origin of the animals taken in the different hunts.

I have given two hypothetical catch options in Table 8 to illustrate the transformation of future allowable catches in the hunts into probabilities of fulfilling the management objectives for the different summer aggregations. The first option (C0) is the average take over the five year period from 2009 to 2013, and the second option (C1) is the maximum annual take during that period. I expect that we need a third option as a recommendation from the JWG.

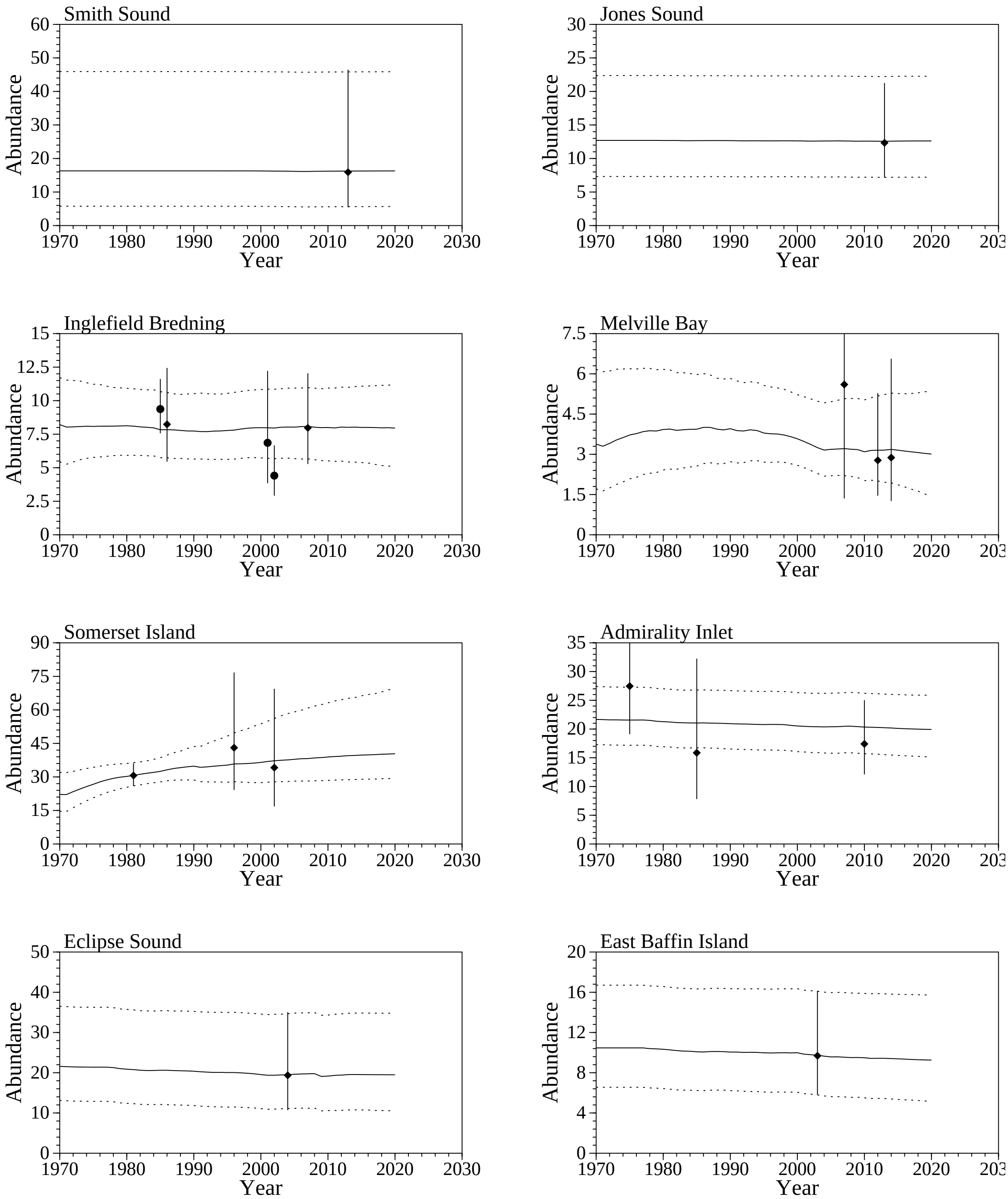

Figure 3: The trajectories of the different narwhal aggregations. Points with bars are the abundance estimates with 90% CI, solid curves the median, and dotted curves the 90% CI, of the estimated models. Abundance is given in thousands.

M		N_0	N^*	r	msyr	p	p_0	b	a_m	γ	msyl
	$x_{.5}$	-	16	.041	.033	.98	.75	.29	10	3	.63
	$x_{.05}$	-	5.8	.017	.013	.97	.53	.18	8.2	2.1	.58
smith	$x_{.95}$	-	46	.067	.056	.99	.97	.44	12	3.9	.67
	$x_{.5}$	-	13	.041	.034	.98	.75	.29	9.9	3	.63
	$x_{.05}$	-	7.3	.016	.012	.97	.53	.18	8.2	2.1	.58
jones	$x_{.95}$	-	22	.068	.057	.99	.97	.45	12	3.9	.67
	$x_{.5}$	8.2	11	.031	.024	.98	.71	.27	10	3	.63
	$x_{.05}$	5.4	7.6	.0035	.0028	.97	.52	.12	8.3	2.1	.58
ingle	$x_{.95}$	12	25	.07	.058	.99	.98	.45	12	3.9	.66
	$x_{.5}$	3.4	6.7	.043	.035	.98	.78	.3	9.9	3	.63
	$x_{.05}$	1.7	3.9	.017	.014	.97	.53	.18	8.2	2.1	.58
melvi	$x_{.95}$	6.2	24	.07	.059	.99	.98	.45	12	3.9	.67
	$x_{.5}$	22	44	.043	.035	.98	.78	.3	9.9	3	.63
	$x_{.05}$	15	32	.019	.015	.97	.53	.19	8.2	2.1	.58
somer	$x_{.95}$	32	81	.069	.059	.99	.98	.45	12	3.9	.67
	$x_{.5}$	-	22	.04	.033	.98	.74	.29	10	3	.63
	$x_{.05}$	-	17	.013	.011	.97	.52	.17	8.2	2.1	.58
admir	$x_{.95}$	-	27	.066	.055	.99	.97	.44	12	3.9	.67
	$x_{.5}$	-	22	.042	.034	.98	.75	.3	9.9	3	.63
	$x_{.05}$	-	13	.017	.013	.97	.52	.18	8.1	2.1	.58
eclip	$x_{.95}$	-	37	.068	.057	.99	.98	.44	12	3.9	.67
	$x_{.5}$	-	10	.041	.034	.98	.76	.29	10	3	.63
	$x_{.05}$	-	6.6	.016	.013	.97	.53	.18	8.2	2.1	.59
eastb	$x_{.95}$	-	17	.067	.055	.99	.97	.44	12	3.9	.67

M	c_h	N_t	d_t	$\dot{r}_t$	β_a
	.012	16	1	.00049	-
	.002	5.6	.98	.00013	-
smith	.13	46	1	.0017	-
	.37	13	.99	.0016	-
	.28	7.2	.98	.0008	-
jones	.57	22	1	.0028	-
	.05	8	.82	.012	.32
	.0061	5.4	.27	.0034	.23
ingle	.27	11	.97	.019	.45
	.16	3.2	.48	.034	-
	.029	1.9	.12	.016	-
melvi	.58	5.3	.86	.053	-
	.39	40	.94	.0086	-
	.18	29	.61	.0047	-
somer	.71	65	.99	.021	-
	.35	20	.94	.0079	-
	.095	15	.84	.0047	-
admir	.7	26	.97	.011	-
	.48	20	.92	.01	-
	.14	11	.74	.0044	-
eclip	.87	35	.98	.02	-
	.34	9.4	.91	.012	-
	.068	5.4	.78	.0059	-
eastb	.72	16	.97	.019	-

Table 6: **Parameter estimates** for the different models (M). Estimates are given by the median ($x_{.5}$) and the 90% credibility interval ($x_{.05}$ - $x_{.95}$) of the postreior distributions. Abundance is given in thousands. The selected models are indicated a superscript +

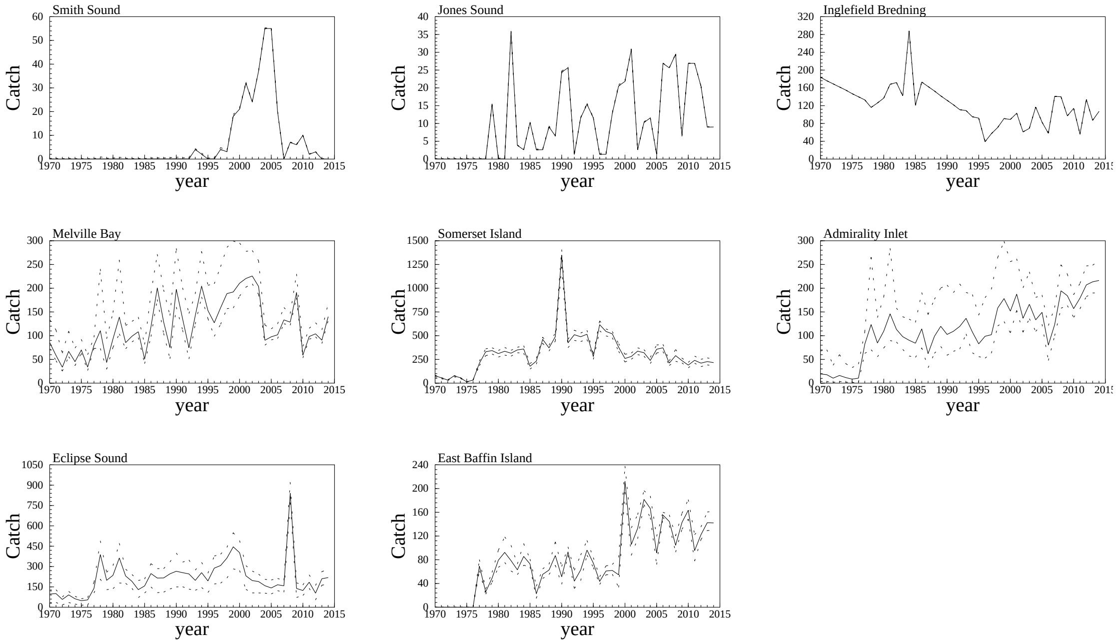

Figure 4: Yearly catches per summer aggregation with 90% confidence intervals.

P	smith	jones	ingle	melvi	somer	admir	eclip	eastb
F	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
0.50	284	231	147	108	914	394	398	192
0.55	259	215	135	102	871	371	377	180
0.60	231	200	123	97	828	347	354	169
0.65	206	186	111	90	780	325	332	158
0.70	185	171	98	82	732	301	310	147
0.75	165	156	83	72	684	273	287	135
0.80	144	141	68	63	635	243	262	123
0.85	123	126	52	53	580	213	234	110
0.90	100	106	33	40	512	177	198	94
0.95	67	78	5	21	403	124	151	72

Table 7: **Catch objective trade-off per stock.** The total annual removals per stock that meet given probabilities (P) of meeting management objectives. The simulated period is from 2015 to 2020, and F is the assumed fraction of females in the catch.

Hunt	Season	C0	C1	C2
Qaanaaq	Spring	4	10	5
Qaanaaq	Summer	98	134	98
Grise Fjord	Spring	7	14	9
Grise Fjord	Summer	11	18	15
Grise Fjord	Fall	0	0	0
Upernavik	Summer	100	177	70
Ummannaaq	Fall	86	118	154
Disko Bay	Winter	73	116	97
Resolute	Spring	4	9	6
Resolute	Summer	74	82	118
Resolute	Fall	2	10	3
Arctic Bay	Spring	31	49	41
Arctic Bay	Summer	141	161	188
Arctic Bay	Fall	0	0	0
Pond Inlet	Spring	58	124	77
Pond Inlet	Summer	55	110	73
Pond Inlet	Fall	4	10	5
East Baffin	Spring	12	18	11
East Baffin	Summer	100	136	91
East Baffin	Fall	44	92	40
Pangnirtung	Spring	5	14	5
Pangnirtung	Summer	9	21	8
Pangnirtung	Fall	12	21	11
Pangnirtung	Winter	0	0	0

Table 8: Catch option examples (C#) of maximum yearly removal per hunting region.

	Smith	Jones	Inglefield	Melville	Somerset	Admirality	Eclipse	Baffin
C0	$4\,^{4}_{4}$	$18\,^{18}_{18}$	$98\,^{98}_{98}$	$109\,^{141}_{101}$	$219\,^{265}_{175}$	$185\,^{226}_{161}$	$155\,^{207}_{104}$	$134\,^{152}_{120}$
P0	$1.00\,^{1.00}_{1.00}$	$1.00\,^{1.00}_{1.00}$	$0.7\,^{0.7}_{0.7}$	$0.49\,^{0.56}_{0.26}$	$0.99\,^{0.99}_{0.99}$	$0.89\,^{0.92}_{0.83}$	$0.95\,^{0.98}_{0.89}$	$0.76\,^{0.81}_{0.68}$
C1	$10\,^{10}_{10}$	$32\,^{32}_{32}$	$134\,^{134}_{134}$	$191\,^{239}_{179}$	$321\,^{412}_{240}$	$243\,^{317}_{198}$	$291\,^{389}_{202}$	$206\,^{241}_{179}$
P1	$1.00\,^{1.00}_{1.00}$	$0.99\,^{0.99}_{0.99}$	$0.55\,^{0.55}_{0.55}$	$0.07\,^{0.09}_{0.02}$	$0.98\,^{0.99}_{0.95}$	$0.8\,^{0.87}_{0.67}$	$0.74\,^{0.9}_{0.52}$	$0.45\,^{0.55}_{0.33}$
C2	$5\,^{5}_{5}$	$24\,^{24}_{24}$	$98\,^{98}_{98}$	$83\,^{126}_{72}$	$343\,^{399}_{283}$	$243\,^{296}_{212}$	$198\,^{262}_{134}$	$122\,^{138}_{110}$
P2	$1.00\,^{1.00}_{1.00}$	$1.00\,^{1.00}_{1.00}$	$0.7\,^{0.7}_{0.7}$	$0.7\,^{0.75}_{0.36}$	$0.97\,^{0.98}_{0.95}$	$0.8\,^{0.85}_{0.71}$	$0.9\,^{0.96}_{0.8}$	$0.8\,^{0.85}_{0.74}$

Table 9: Examples of future annual removals (C#) per summer aggregation, with assosiated probabilities (P#) of fulfilling management objectives. The different removals follow from the catch options in Table 8, and the 90% confidence intervals of the estimates are given by the sub and super scripts.

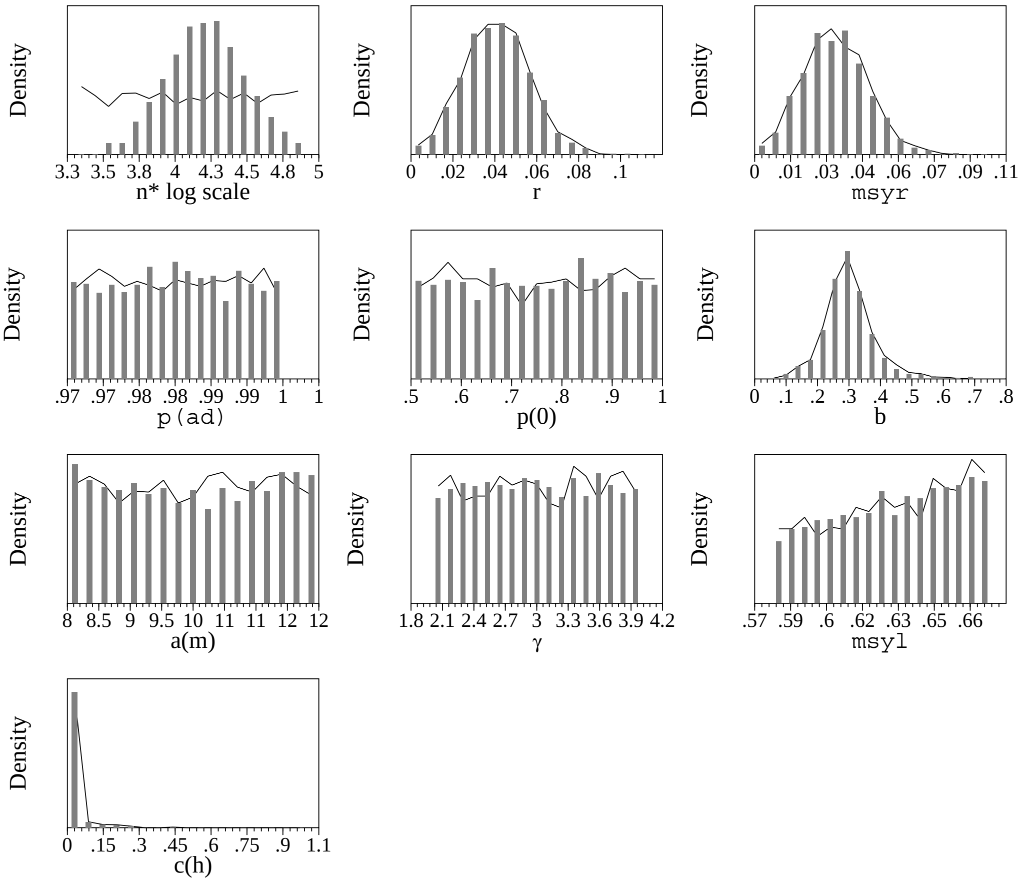

Figure 5: **Smith Sound** Realised prior (curve) and posterior (bars) distributions.

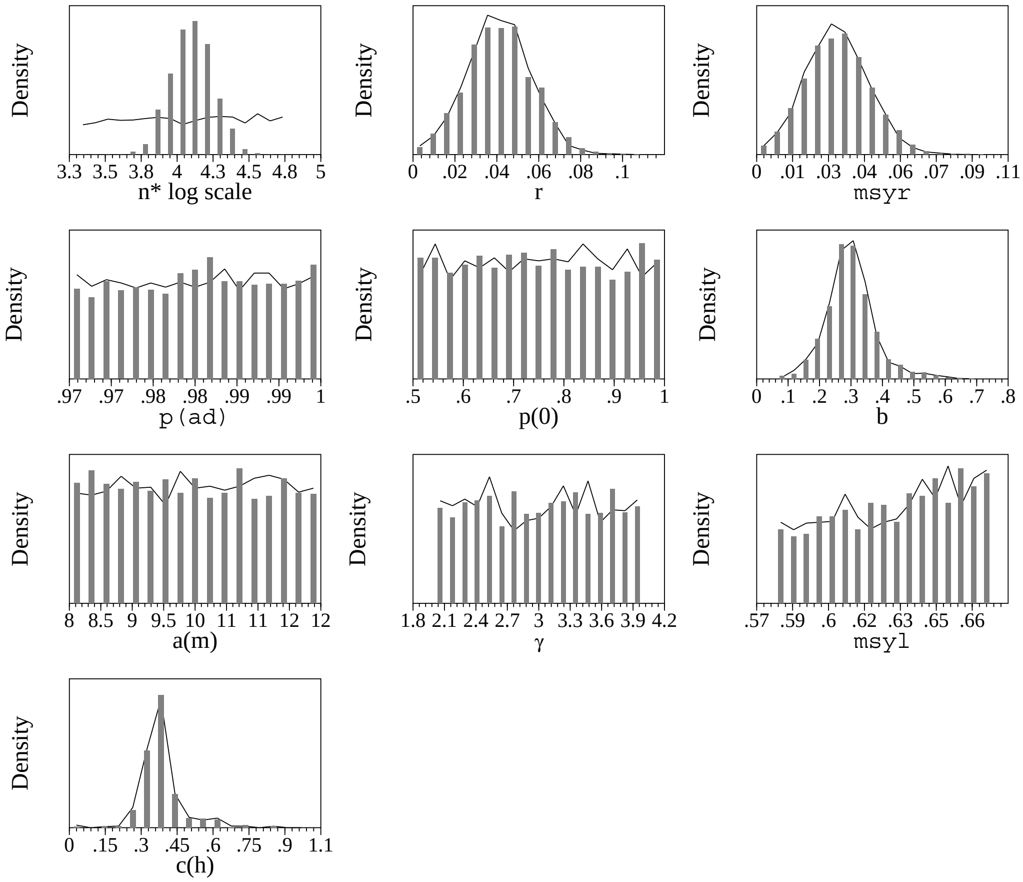

Figure 6: **Jones Sound** Realised prior (curve) and posterior (bars) distributions.

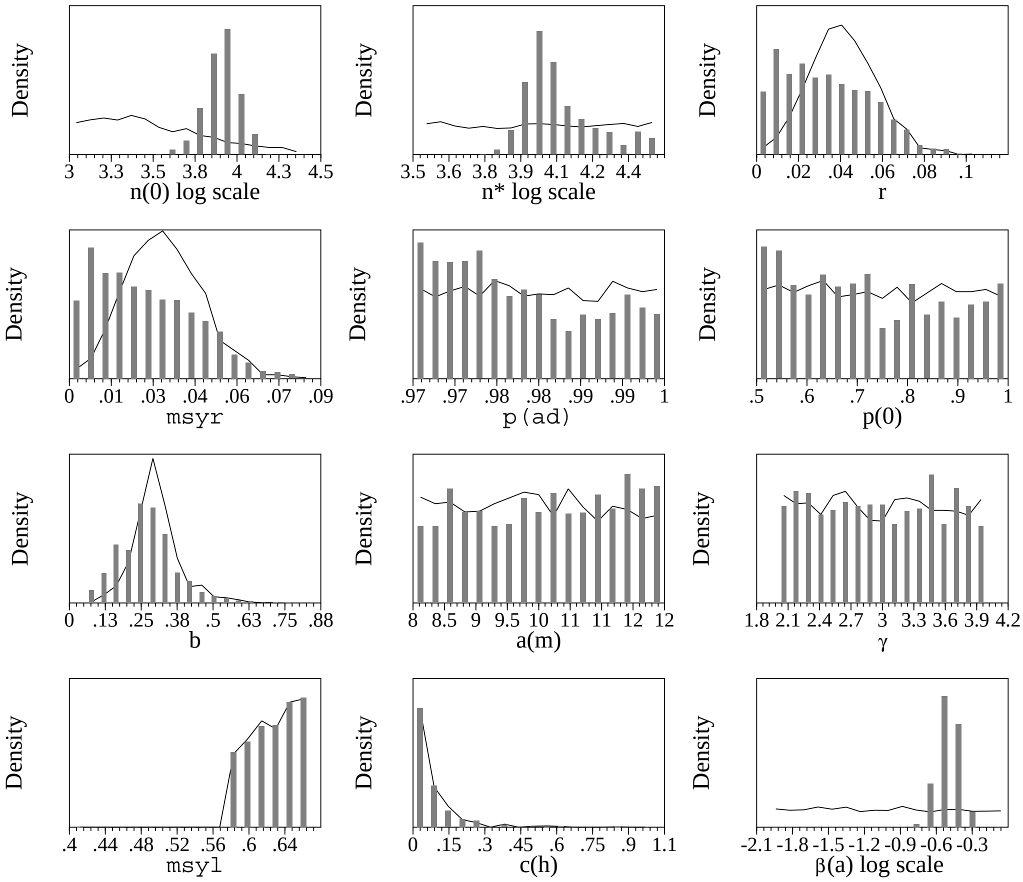

Figure 7: **Inglefield Bredning** Realised prior (curve) and posterior (bars) distributions.

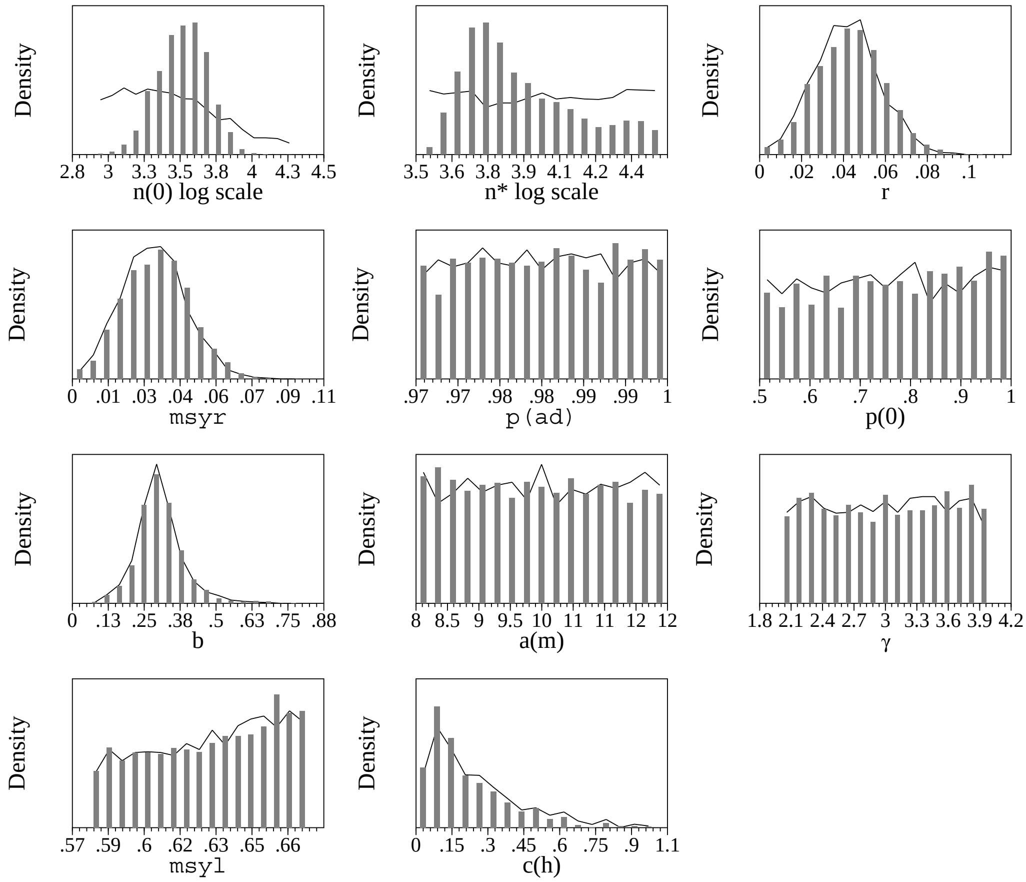

Figure 8: **Melville Bay** Realised prior (curve) and posterior (bars) distributions.

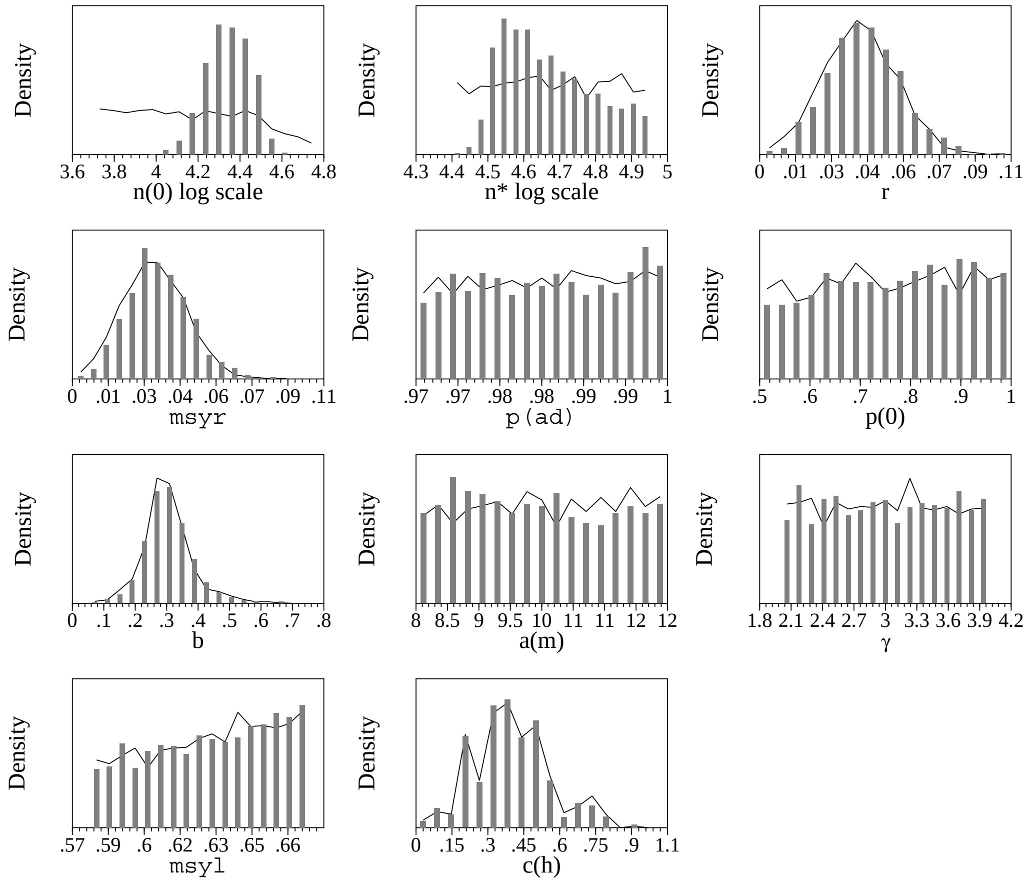

Figure 9: **Somerset Island** Realised prior (curve) and posterior (bars) distributions.

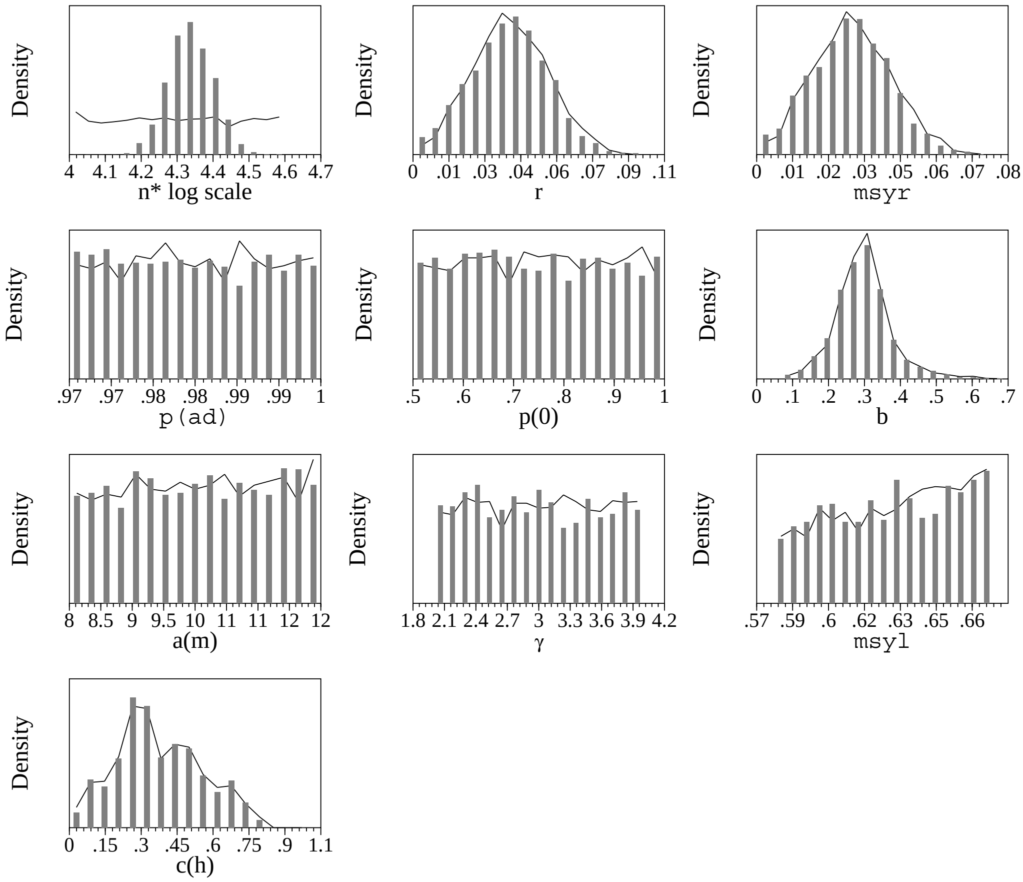

Figure 10: **Admirality Inlet** Realised prior (curve) and posterior (bars) distributions.

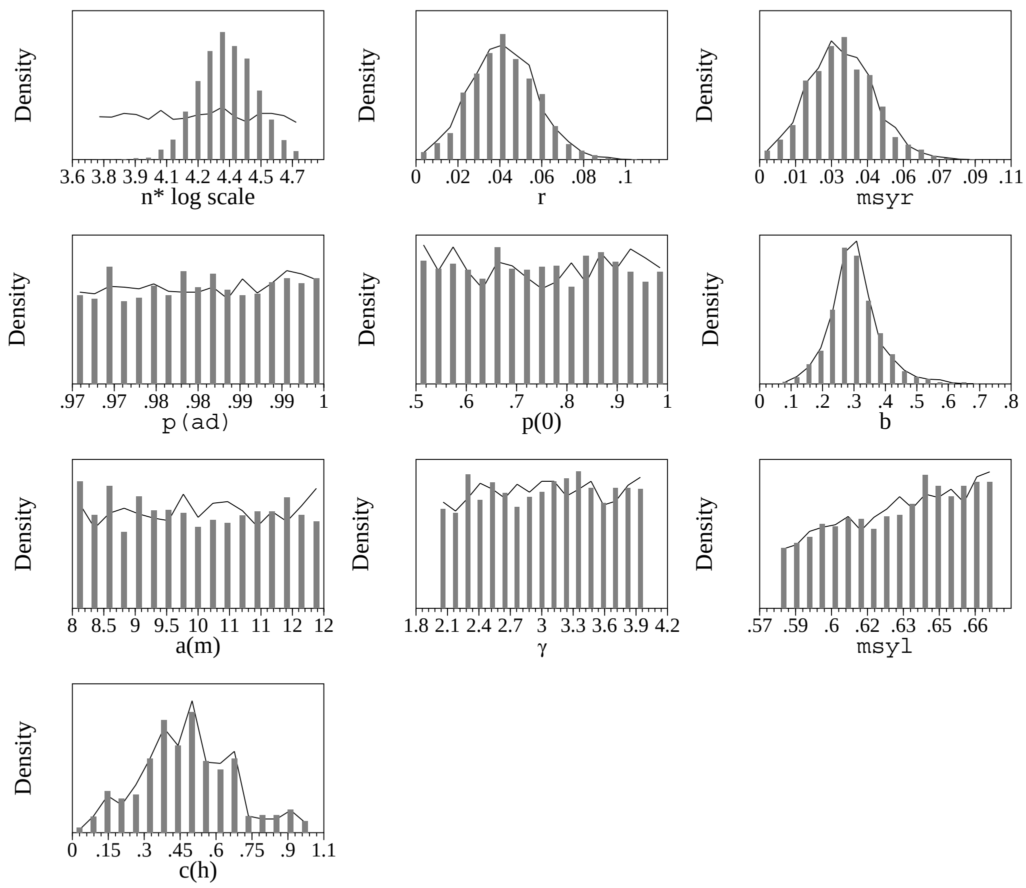

Figure 11: **Eclipse Sound** Realised prior (curve) and posterior (bars) distributions.

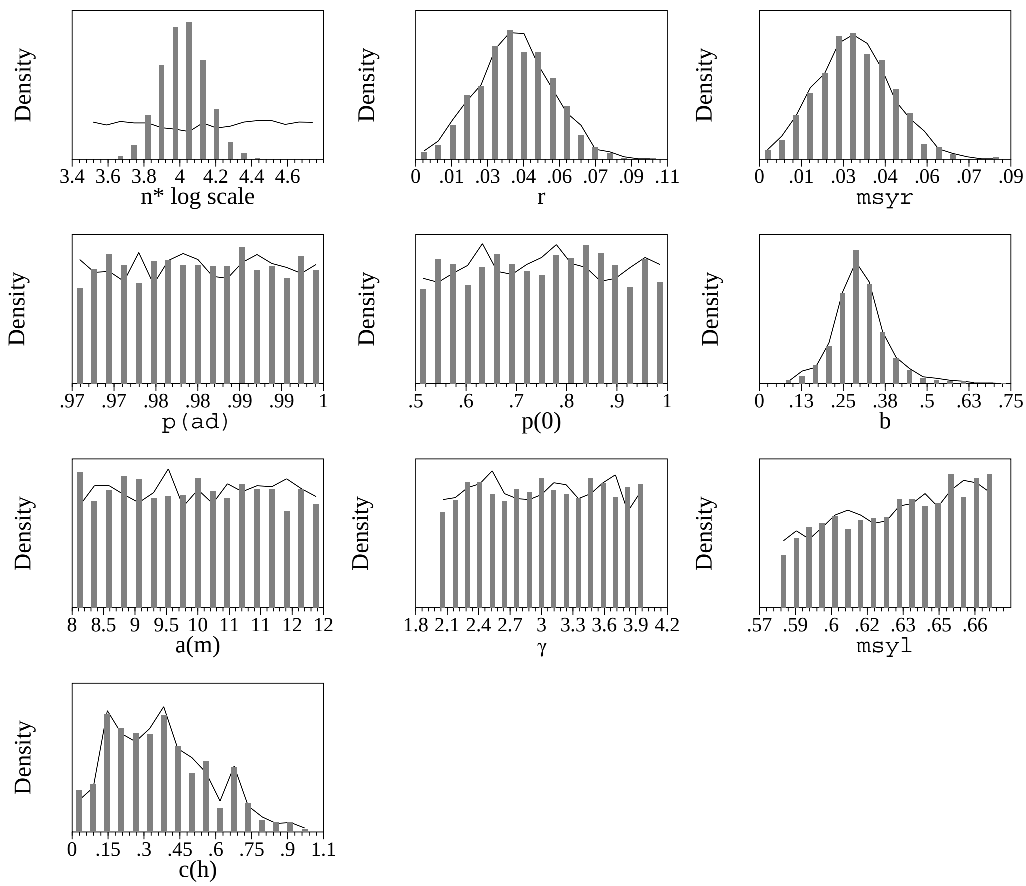

Figure 12: **East Baffin Island** Realised prior (curve) and posterior (bars) distributions.

Year	S_s	Q_s	U_s	M_f	D_w
1970	0	184	70	86	129
1971	0	176	45	60	134
1972	0	169	24	35	78
1973	0	162	53	83	120
1974	0	155	35	61	83
1975	0	147	62	14	66
1976	0	140	25	35	74
1977	0	133	71	147	40
1978	0	116	64	238	342
1979	0	126	25	172	134
1980	0	137	70	190	163
1981	0	168	95	182	348
1982	0	172	68	211	99
1983	0	142	83	213	88
1984	0	288	92	273	87
1985	0	121	39	51	88
1986	0	173	93	126	203
1987	0	163	167	434	203
1988	0	153	98	294	203
1989	0	142	43	374	203
1990	0	132	146	1325	203
1991	0	122	104	290	203
1992	0	111	43	374	203
1993	4	109	117	391	134
1994	2	95	173	386	203
1995	0	92	130	207	163
1996	0	39	89	527	224
1997	4	57	113	495	272
1998	3	71	147	447	295
1999	18	91	150	329	335
2000	21	89	177	138	255
2001	32	103	198	124	182
2002	24	61	204	234	163
2003	37	69	182	226	157
2004	55	117	78	87	99
2005	55	83	89	209	51
2006	20	58	92	94	73
2007	0	141	123	87	86
2008	7	140	120	113	61
2009	6	97	177	118	116
2010	10	114	52	55	59
2011	2	56	91	100	52
2012	3	134	96	55	72
2013	0	87	82	101	66
2014	0	107	130	90	81

Table 10: Estimated total removal per hunting region in Greenland per year. S_s:Qaanaaq (Spring). Q_s:Qaanaaq (Summer). U_s:Upernavik (Summer). M_f:Ummannaaq (Fall). D_w:Disko Bay (Winter).

Year	G_s	G_s	G_f	R_s	R_s	R_f	A_s	A_s	A_f	O_s	O_s	O_f	B_s	B_s	B_f	P_s	P_s	P_f	P_w
1970	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1971	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1972	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1973	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1974	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1975	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1976	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1977	0	0	0	0	33	0	16	38	0	73	64	0	0	54	44	4	0	0	0
1978	0	0	0	2	26	5	72	12	0	102	91	0	4	18	17	2	0	0	0
1979	0	15	0	0	3	156	29	13	0	60	60	0	15	21	2	22	14	0	0
1980	0	0	0	1	31	0	120	8	0	65	58	0	11	54	42	24	0	0	0
1981	0	0	0	1	38	29	110	18	0	56	49	0	11	56	44	54	3	0	0
1982	0	36	0	3	57	0	59	53	3	0	128	0	9	43	37	60	3	0	0
1983	0	4	0	0	73	0	102	25	1	41	92	0	25	47	13	3	1	0	0
1984	0	2	0	0	0	0	115	4	0	48	10	0	9	56	44	41	1	0	0
1985	1	10	0	3	19	3	128	0	0	71	54	0	5	63	1	22	1	0	0
1986	0	2	0	1	11	3	110	18	0	68	60	0	2	8	6	38	2	0	0
1987	0	2	0	1	12	2	28	4	0	35	31	0	8	41	35	0	0	0	0
1988	0	9	0	1	17	2	95	15	0	36	32	0	10	48	32	2	0	0	0
1989	0	6	0	1	24	4	109	18	0	52	46	0	11	53	41	49	2	0	0
1990	3	21	0	0	28	0	74	12	0	33	55	0	4	26	68	3	2	1	0
1991	1	24	0	0	36	0	143	3	0	68	60	0	5	81	22	10	0	0	0
1992	1	0	0	0	33	0	131	0	0	97	30	0	5	20	69	5	0	0	0
1993	0	12	0	0	44	0	49	58	1	59	42	0	12	26	72	24	0	6	0
1994	3	13	0	0	43	0	116	10	0	52	64	0	10	79	6	42	0	0	0
1995	1	10	0	1	33	0	34	25	0	58	35	0	7	59	31	3	0	5	0
1996	1	1	0	0	19	0	127	0	0	44	84	0	1	20	21	10	14	0	0
1997	0	1	0	0	34	0	52	32	0	12	84	0	5	47	31	0	3	0	0
1998	2	11	0	1	67	0	20	97	0	22	113	0	0	48	38	2	2	1	0
1999	0	20	0	4	18	1	14	100	0	18	151	0	3	13	88	24	0	18	0
2000	0	22	0	5	45	1	68	60	0	50	164	0	9	134	92	9	44	0	0
2001	4	27	0	0	96	0	51	116	1	29	54	0	13	69	82	20	0	5	0
2002	3	0	0	0	58	0	23	77	0	50	30	0	0	99	63	8	1	29	0
2003	0	10	0	4	33	0	63	102	0	34	49	3	12	166	1	36	0	1	0
2004	0	12	0	0	72	0	83	74	0	28	53	3	32	136	19	12	1	19	0
2005	1	0	0	0	81	0	79	87	1	29	50	0	14	55	93	0	0	6	0
2006	0	27	0	1	172	0	161	5	0	28	82	3	5	148	14	0	0	1	0
2007	4	22	0	0	65	0	86	73	0	9	72	3	10	130	27	4	1	0	0
2008	0	29	0	0	59	3	61	108	0	173	682	37	3	58	64	0	27	0	0
2009	5	1	0	4	79	0	22	143	0	27	26	4	9	100	23	10	21	21	0
2010	10	17	0	3	73	0	49	115	0	22	47	10	18	136	24	14	1	20	0
2011	14	13	0	9	77	0	36	131	0	50	93	0	8	63	92	0	1	5	0
2012	3	18	0	1	82	10	4	156	0	124	0	0	9	102	31	0	4	9	0
2013	3	6	0	4	57	0	43	161	0	67	110	8	16	101	51	2	18	4	0
2014	3	6	0	4	57	0	43	161	0	67	110	8	16	101	51	2	18	4	0

Table 11: Estimated total removal per hunting region in Canada per year. G_s:Grise Fjord (Spring). G_s:Grise Fjord (Summer). G_f:Grise Fjord (Fall). R_s:Resolute (Spring). R_s:Resolute (Summer). R_f:Resolute (Fall). A_s:Arctic Bay (Spring). A_s:Arctic Bay (Summer). A_f:Arctic Bay (Fall). O_s:Pond Inlet (Spring). O_s:Pond Inlet (Summer). O_f:Pond Inlet (Fall). B_s:East Baffin (Spring). B_s:East Baffin (Summer). B_f:East Baffin (Fall). P_s:Pangnirtung (Spring). P_s:Pangnirtung (Summer). P_f:Pangnirtung (Fall). P_w:Pangnirtung (Winter).