Supporting Information. Scavia, D., I. Bertani, J.M. Testa, A.J. Bever, J.D. Blomquist, M.A.M. Friedrichs, L.C. Linker, B.D. Michael, R.R. Murphy, and G.W. Shenk. 2021. Advancing estuarine ecological forecasts: seasonal hypoxia in Chesapeake Bay. Ecological Applications.

Appendix S1

Definition of metrics of model predictive performance used in the manuscript.

$$\text{NSE} = 1 - \frac{\sum_{i=1}^{n}\left(pred_i - obs_i\right)^2}{\sum_{i=1}^{n}\left(obs_i - \overline{obs}\right)^2}$$

$$r^2 = \left(\frac{\sum_{i=1}^{n}\left(obs_i - \overline{obs}\right)\left(pred_i - \overline{pred}\right)}{\sqrt{\sum_{i=1}^{n}\left(obs_i - \overline{obs}\right)^2}\sqrt{\sum_{i=1}^{n}\left(pred_i - \overline{pred}\right)^2}} \right)^2$$

$$\text{RMSE} = \sqrt{\sum_{i=1}^{n}\frac{\left(obs_i - pred_i\right)^2}{n}}$$

$$\text{MAE} = \frac{\sum_{i=1}^{n}\left|obs_i - pred_i\right|}{n}$$

$$\text{RSTDE} = \sigma_{est}$$

where obs = observed values, pred = predicted values, n= total number of observations.

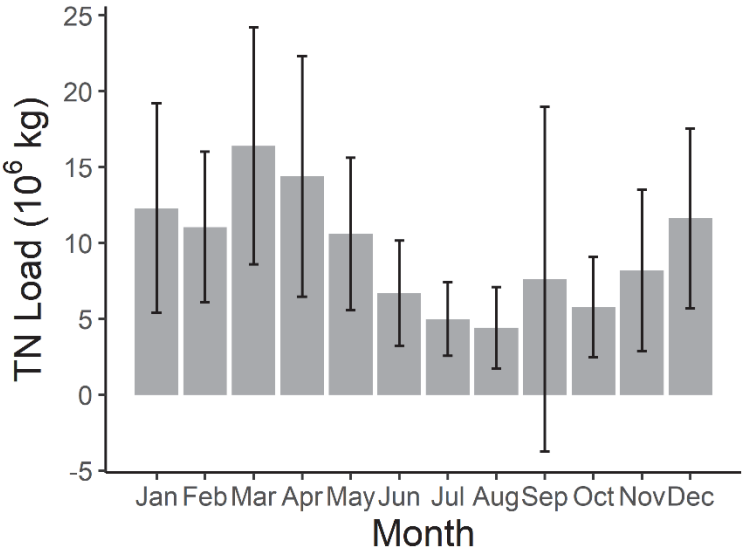

Fig. S1 - Long-term (1985-2018) average monthly TN loads from nine tributaries and downstream point sources. Error bars represent standard deviations.

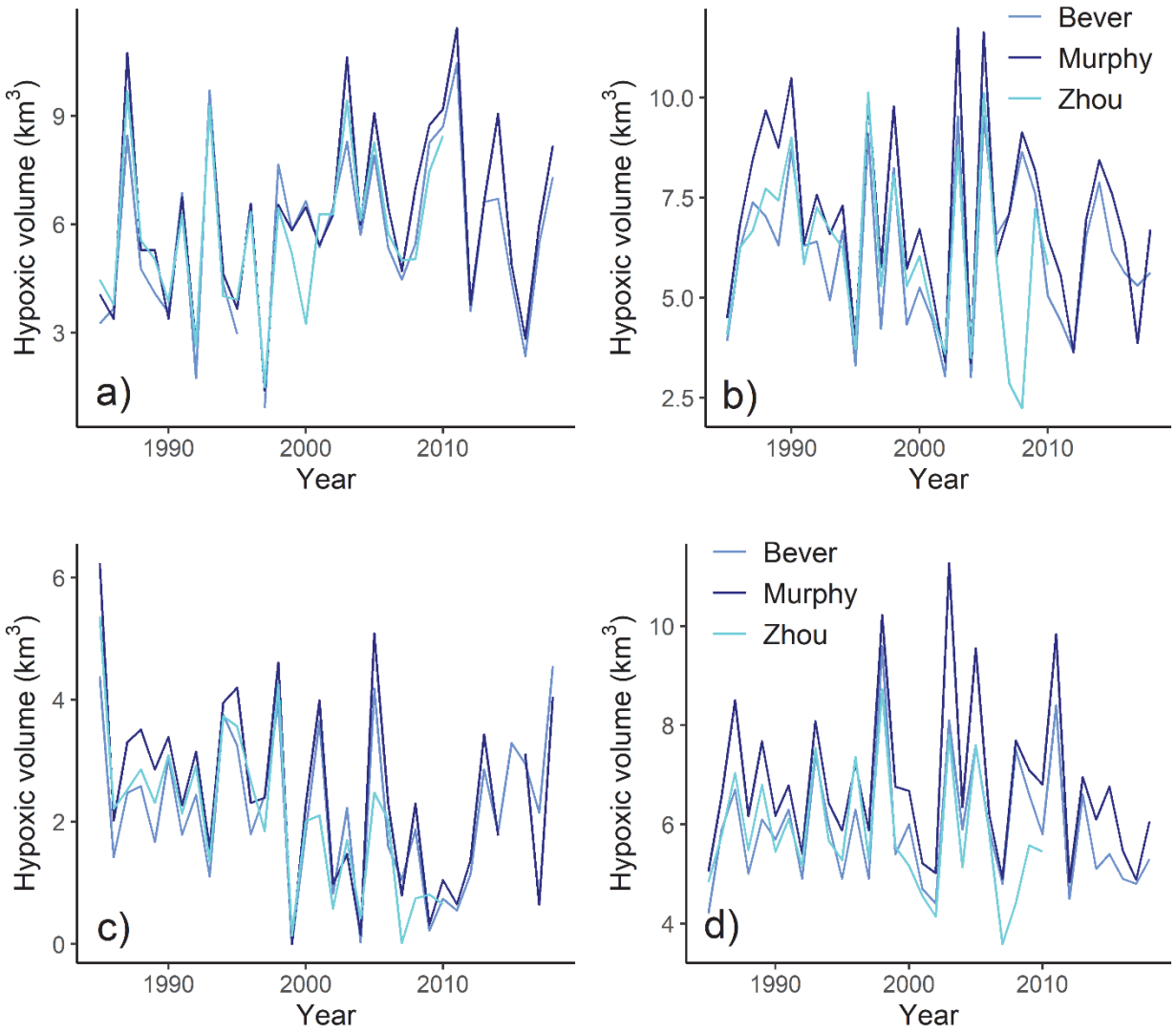

Fig. S2 - Average June (a), August (b), September (c), and summer (d) HVs estimated using three different interpolation methods over 1985-2018. Zhou estimates are available only through 2010.

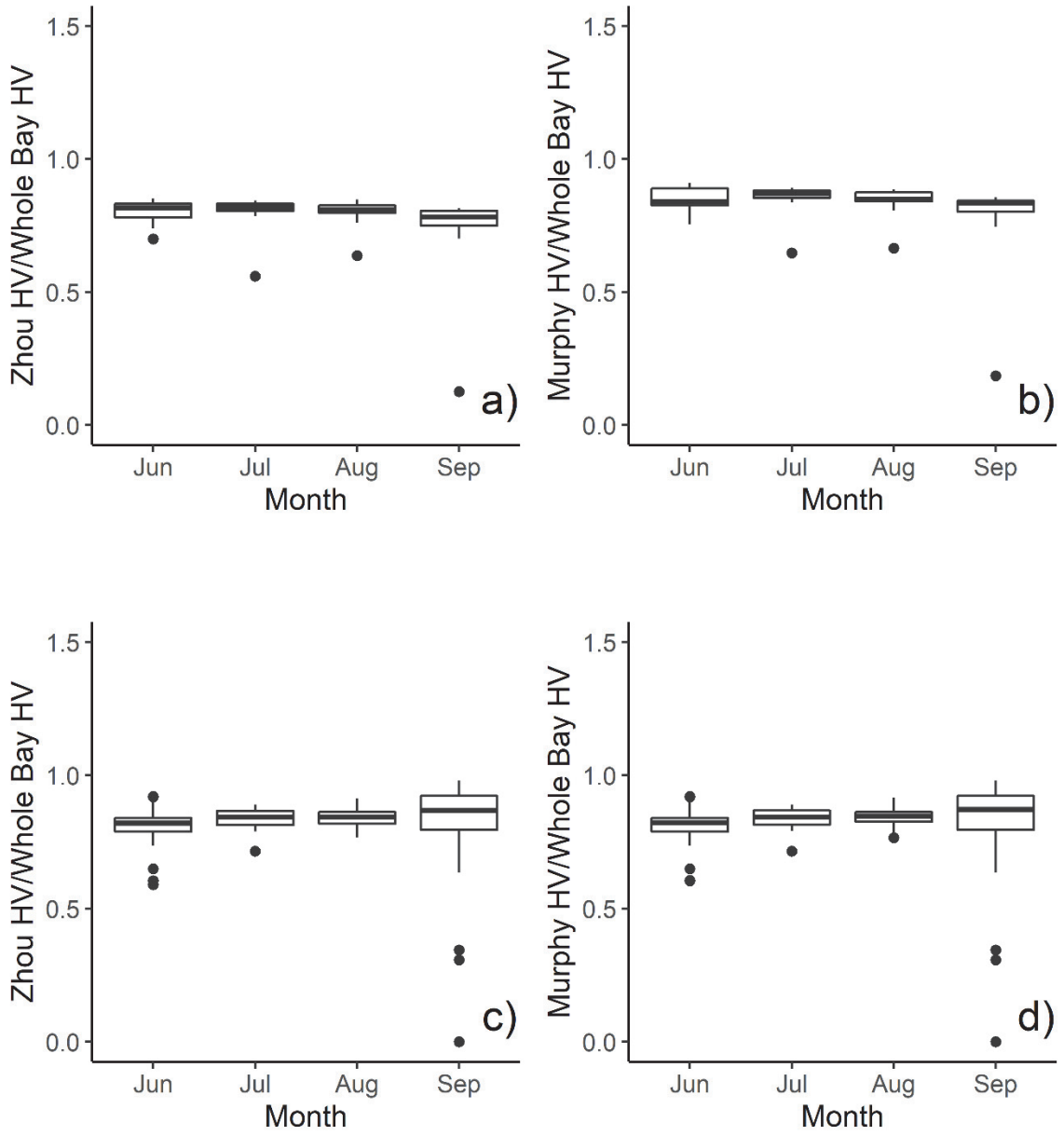

Fig. S3 - Ratios of mainstem-only monthly hypoxic volume (HV) to Bay-wide monthly HV simulated by the CBP Water Quality and Sediment Transport Model (a, b) and estimated by the CBP interpolator (c, d) for the months when hypoxia is most consistently detected in the Bay. Because the interpolation methods used by Zhou et al. (2014) and Murphy et al. (2011) use slightly different definitions of mainstem, the ratios were calculated separately for the mainstem as defined in Zhou et al. 2014 (a, c) and in Murphy et al. 2011 (b, d), respectively. Each data point represents a year. Boxes indicate the first and third quartiles, whereas the horizontal thick line shows the median. Whiskers indicate the most extreme values less than 1.5 times the interquartile range, and open circles represent values outside 1.5 times the interquartile range. The fact that the two approaches used provide very similar mainstem to Bay-wide ratios gives confidence in the robustness of these estimates.

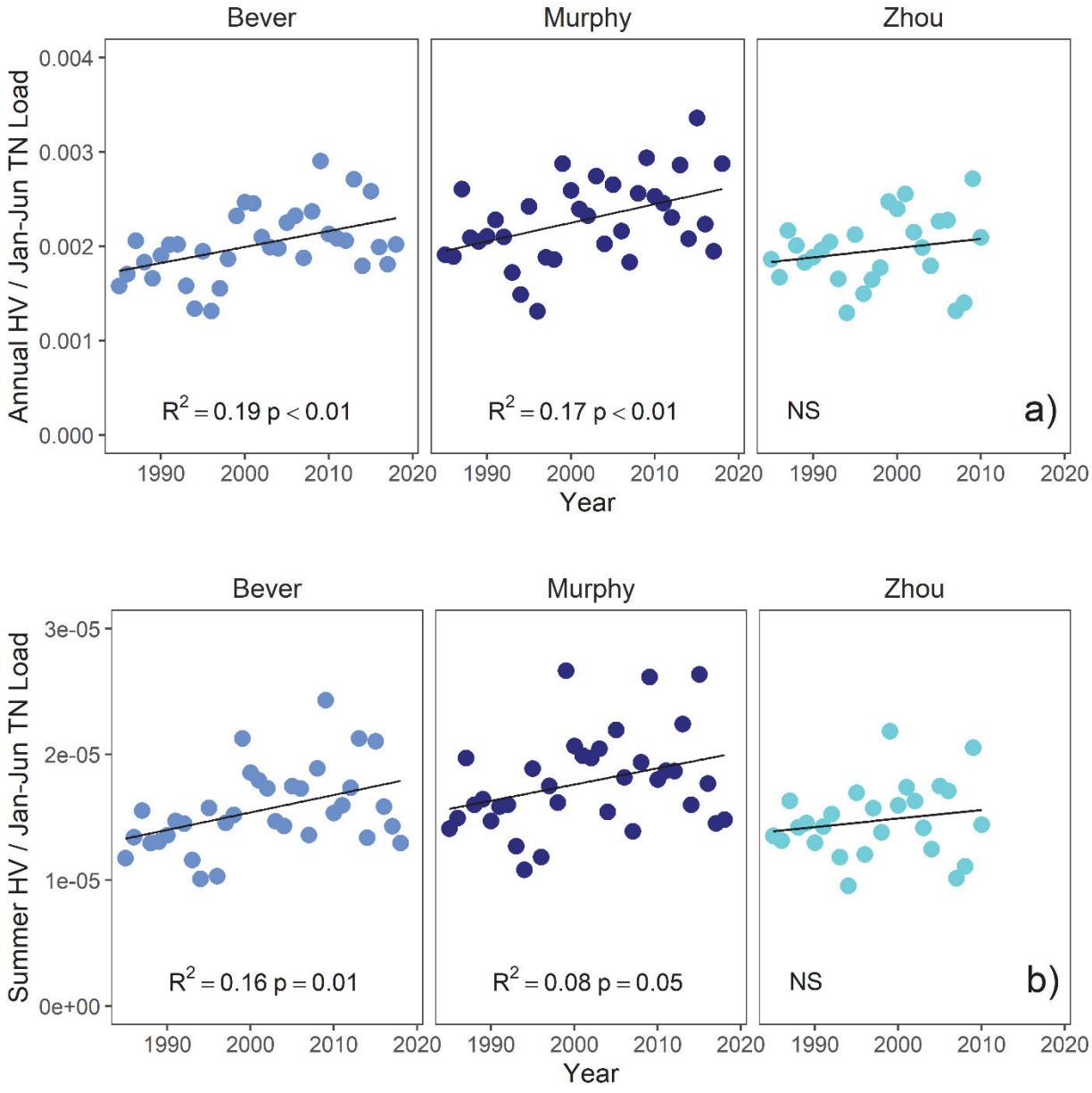

Fig. S4 - Ratio of total annual (a) and summer average (b) HV over Jan-Jun TN load from nine major tributaries and downstream point sources over time for three different sets of HV estimates. Zhou estimates available only through 2010. NS = non significant ($p > 0.05$). Units of measure are km^3*days for total annual HV, km^3 for summer average HV, and kg/day for Jan-Jun TN load.

Table S1 - Estimates of average monthly, average summer, and total annual hypoxic volume (HV) generated for the Chesapeake Bay through three different interpolation approaches over the years 1985-2018. Long-term mean, standard deviation (St. Dev.) and coefficient of variation (CV) are reported for each HV metric and interpolation approach. For more details and references on how these three sets of estimates were obtained, see manuscript text.

	Jun HV (km3)			Jul HV (km3)			Aug HV (km3)			Sep HV (km3)			Summer HV (km3)			Annual HV (km3*day)		
Year	Bever	Murphy	Zhou	Bever	Murphy	Zhou	Bever	Murphy	Zhou	Bever	Murphy	Zhou	Bever	Murphy	Zhou	Bever	Murphy	Zhou
1985	3.2	4.1	4.5	5.3	5.4	5.4	3.9	4.5	4.1	4.4	6.2	5.4	4.2	5	4.8	564	683.4	665.9
1986	3.7	3.4	3.8	12.5	14.1	10.9	6.2	6.8	6.3	1.4	2	2.2	5.9	6.6	5.8	750	832.3	734.5
1987	8.5	10.8	9.7	8.7	11.5	9.3	7.4	8.5	6.7	2.5	3.3	2.5	6.7	8.5	7	889	1123.8	935.1
1988	4.8	5.3	5.6	5.5	6.2	5.8	7	9.7	7.7	2.6	3.5	2.9	5	6.2	5.5	707	806.6	775.5
1989	4.1	5.3	5	12.4	13.8	12.4	6.3	8.8	7.4	1.7	2.9	2.3	6.1	7.7	6.8	775	957.4	853.8
1990	3.6	3.4	3.9	7.5	7.4	6.3	8.7	10.5	9	3	3.4	3.1	5.7	6.2	5.5	798	883.3	791.1
1991	6.9	6.7	6.3	10.3	11.8	10.2	6.3	6.4	5.8	1.8	2.3	2.1	6.3	6.8	6.1	864	975.8	839.3
1992	1.7	2.6	2.6	9	8.3	7.8	6.4	7.6	7.3	2.4	3.2	2.9	4.9	5.4	5.2	683	710.3	691.4
1993	9.7	9.3	9.3	13.8	14.9	12.8	4.9	6.6	6.7	1.1	1.6	1.4	7.4	8.1	7.5	1008	1096.8	1054.5
1994	4.3	4.6	4	9.2	9.8	8.7	6.7	7.3	6.2	3.8	4	3.7	6	6.4	5.7	795	883.9	768.1
1995	3	3.7	3.9	10.1	11.8	9.9	3.3	3.9	3.7	3.2	4.2	3.6	4.9	5.9	5.3	606	754.1	661.4
1996	NA	6.6	6.3	5.7	7.2	7.4	9.1	10	10.1	1.8	2.3	2.7	6.3	7.2	7.4	803	801.2	914.7
1997	0.9	1.4	1.5	8.9	10	8.9	4.2	5.8	5.3	2.4	2.4	1.8	4.9	5.9	5.3	522	633	553.4
1998	7.7	6.5	6.4	14.8	15.3	12.8	8.2	9.8	8.1	4	4.6	4.3	9.6	10.2	8.7	1180	1176.2	1121
1999	5.8	5.8	5.2	9	11.6	8.7	4.3	5.7	5.3	0	0	0.1	5.4	6.8	5.5	589	729.8	627.8
2000	6.6	6.5	3.2	8.4	8.9	7.8	5.2	6.7	6	1.9	2.3	2	6	6.7	5.2	798	838.3	774.9
2001	5.4	5.4	6.3	5.2	5.8	6.1	4.4	5.2	4.6	3.6	4	2.1	4.7	5.2	4.6	643	626.9	669.5
2002	6.5	6.3	6.3	6.4	8	7.2	3	3.4	3.6	0.8	1	0.6	4.4	5	4.1	533	591	547
2003	8.3	10.6	9.4	12.3	16	12.2	9.5	11.7	8.8	2.2	1.5	1.7	8.1	11.3	7.8	1097	1511.8	1095.7
2004	5.7	6	6.1	12	12.8	10.5	3	3.4	3.5	0	0.2	0.4	5.9	6.4	5.1	815	835.1	738.9
2005	7.9	9.1	8.3	7.1	10.2	9.5	9.5	11.6	10.1	4.2	5.1	2.5	7.6	9.6	7.6	980	1154.2	986.2
2006	5.4	6.5	5.7	7.9	8.1	7.8	6.6	6	5.9	1.6	2.3	2	5.9	6.2	5.8	794	737.7	777.4
2007	4.5	4.7	5	4.8	4.9	4.7	7.1	7.1	2.9	1.1	0.8	0	4.8	4.9	3.6	662	646.1	464.6
2008	5.5	7	5	11.1	9.6	7.8	8.7	9.1	2.2	1.9	2.3	0.7	7.5	7.7	4.4	941	1016.1	556.2
2009	8.3	8.7	7.5	7.9	8.6	6.8	7.6	8.2	7.2	0.2	0.3	0.8	6.6	7.1	5.6	788	797.3	737.2
2010	8.7	9.2	8.5	6.7	8.4	8.3	5	6.5	5.8	0.7	1	0.7	5.8	6.8	5.5	805	956.5	791
2011	10.5	11.4	NA	14.1	17.1	NA	4.4	5.6	NA	0.6	0.7	NA	8.4	9.8	NA	1097	1293.3	NA
2012	3.6	3.8	NA	7.8	8.8	NA	3.6	3.6	NA	1.1	1.4	NA	4.5	4.8	NA	534	597.6	NA
2013	6.6	6.6	NA	8.5	9	NA	6.5	7	NA	2.9	3.4	NA	6.6	7	NA	841	888.1	NA
2014	6.7	9.1	NA	2.2	2.9	NA	7.9	8.4	NA	1.8	1.8	NA	5.1	6.1	NA	683	792.5	NA
2015	4.4	4.9	NA	6.7	7.8	NA	6.2	7.6	NA	3.3	NA	NA	5.4	6.8	NA	663	861.8	NA
2016	2.4	2.8	NA	7.6	8.3	NA	5.6	6.4	NA	3	3.1	NA	4.9	5.5	NA	616	690.5	NA
2017	5.5	6	NA	5.1	6.9	NA	5.3	3.9	NA	2.1	0.6	NA	4.8	4.9	NA	608	654.5	NA
2018	7.3	8.2	NA	3.5	4.3	NA	5.6	6.7	NA	4.6	4	NA	5.3	6.1	NA	826	1175.1	NA
Mean	5.7	6.2	5.7	8.5	9.6	8.7	6.1	7.1	6.2	2.2	2.5	2.1	5.9	6.8	5.8	772.3	873.9	774.1
St. Dev	2.3	2.5	2.1	3.1	3.5	2.3	1.9	2.3	2.1	1.3	1.5	1.3	1.3	1.6	1.2	168.3	216.9	169.2
CV	40.6	39.8	36.9	36.4	36.2	26.3	30.6	31.9	34.2	58.3	61.1	62.9	21.1	23.4	21.1	21.8	24.8	21.9

Table S2 - Posterior parameter means and 95% credible intervals (95% CI) estimated by the model driven by Jan-Jun TN loads from all tributaries and point sources and calibrated to three sets of total annual HV estimates.

Parameter	Units	Posterior Mean	Posterior 95% CI
F	unitless	0.77	0.57-0.97
k_d	1/day	0.13	0.06-0.22
K	unitless	0.69	0.43-0.93
v	km/day	2.49	1.59-3.38
σ_{est}	km^3*days	98.33	83.04-117.20
σ_{res}	km^3*days	99.03	67.11-1.39

Additional material

WinBUGS code and metadata can be found in DataS1.zip.