Examples of criteria assessment using 4-D interpolation results for entire CB4 segment and a comparison of 4-D interpolation results to observed data from the Gooses Reef vertical arrays.

Presentation to CAP
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Speaking for

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(note: Table and Figure numbers correspond to the written report)

Reminder of Criteria:

Table 1. Chesapeake Bay dissolved oxygen criteria.

Designated Use	Criteria Concentration/Duration	Protection Provided	Temporal Application
Migratory fish spawning and nursery use	7-day mean $\geq$ 6 mg liter^{-1} (tidal habitats with 0-0.5 ppt salinity)	Survival/growth of larval/juvenile tidal-fresh resident fish; protective of threatened/endangered species.	February 1 - May 31
	Instantaneous minimum $\geq$ 5 mg liter^{-1}	Survival and growth of larval/juvenile migratory fish; protective of threatened/endangered species.	
	Open-water fish and shellfish designated use criteria apply		June 1 - January 31
Shallow-water bay grass use	Open-water fish and shellfish designated use criteria apply		Year-round
Open-water fish and shellfish use	30-day mean $\geq$ 5.5 mg liter^{-1} (tidal habitats with 0-0.5 ppt salinity)	Growth of tidal-fresh juvenile and adult fish; protective of threatened/endangered species.	Year-round
	30-day mean $\geq$ 5 mg liter^{-1} (tidal habitats with >0.5 ppt salinity)	Growth of larval, juvenile and adult fish and shellfish; protective of threatened/endangered species.	
	7-day mean $\geq$ 4 mg liter^{-1}	Survival of open-water fish larvae.	
	Instantaneous minimum $\geq$ 3.2 mg liter^{-1}	Survival of threatened/endangered sturgeon species.[1]	
Deep-water seasonal fish and shellfish use	30-day mean $\geq$ 3 mg liter^{-1}	Survival and recruitment of bay anchovy eggs and larvae.	June 1 - September 30
	1-day mean $\geq$ 2.3 mg liter^{-1}	Survival of open-water juvenile and adult fish.	
	Instantaneous minimum $\geq$ 1.7 mg liter^{-1}	Survival of bay anchovy eggs and larvae.	
	Open-water fish and shellfish designated-use criteria apply		October 1 - May 31
Deep-channel seasonal refuge use	Instantaneous minimum $\geq$ 1 mg liter^{-1}	Survival of bottom-dwelling worms and clams.	June 1 - September 30
	Open-water fish and shellfish designated use criteria apply		October 1 - May 31

[1] At temperatures considered stressful to shortnose sturgeon (>29°C), dissolved oxygen concentrations above an instantaneous minimum of 4.3 mg liter^{-1} will protect survival of this listed sturgeon species.

Examples:

Instantaneous Minimum Criterion (open water)

- CFD assessment (existing assessment method)
- 10% rule (alternative to illustrate uncertainty)

Weekly Mean Criterion (open water)

- Sequential Weeks
  - CFD assessment
  - 10% rule

- Moving Window Weeks
  - CFD assessment
  - 10% rule

Interpolation Data for 2022 in CB4:

886 1 km x 1 km surface cells

Depths at 1-meter increments - 3,809 cells

Time at 8,760 hourly increments - 33,366,840

100 simulations – 3,336,684,000

Examples use reduced data set:

Open Water (1-5 meters),

6/1/2022-8/31/2022 (for comparison to vertical arrays)

8,410,272 spatial-temporal cells

x10 simulations 84 million data points

Instantaneous Minimum Methods:

CFD Assessment

- Fraction of Space Violations computed for each hour
- Hourly fractions ranked as plotted using CFD method
- Process repeated for each simulation

10% Rule

- Fraction of Space-Hour violations computed for each simulation
- Distribution Function fitted to fractions of Space-Time
- Estimate likelihood of exceeding 10%

Instantaneous Minimum Results:

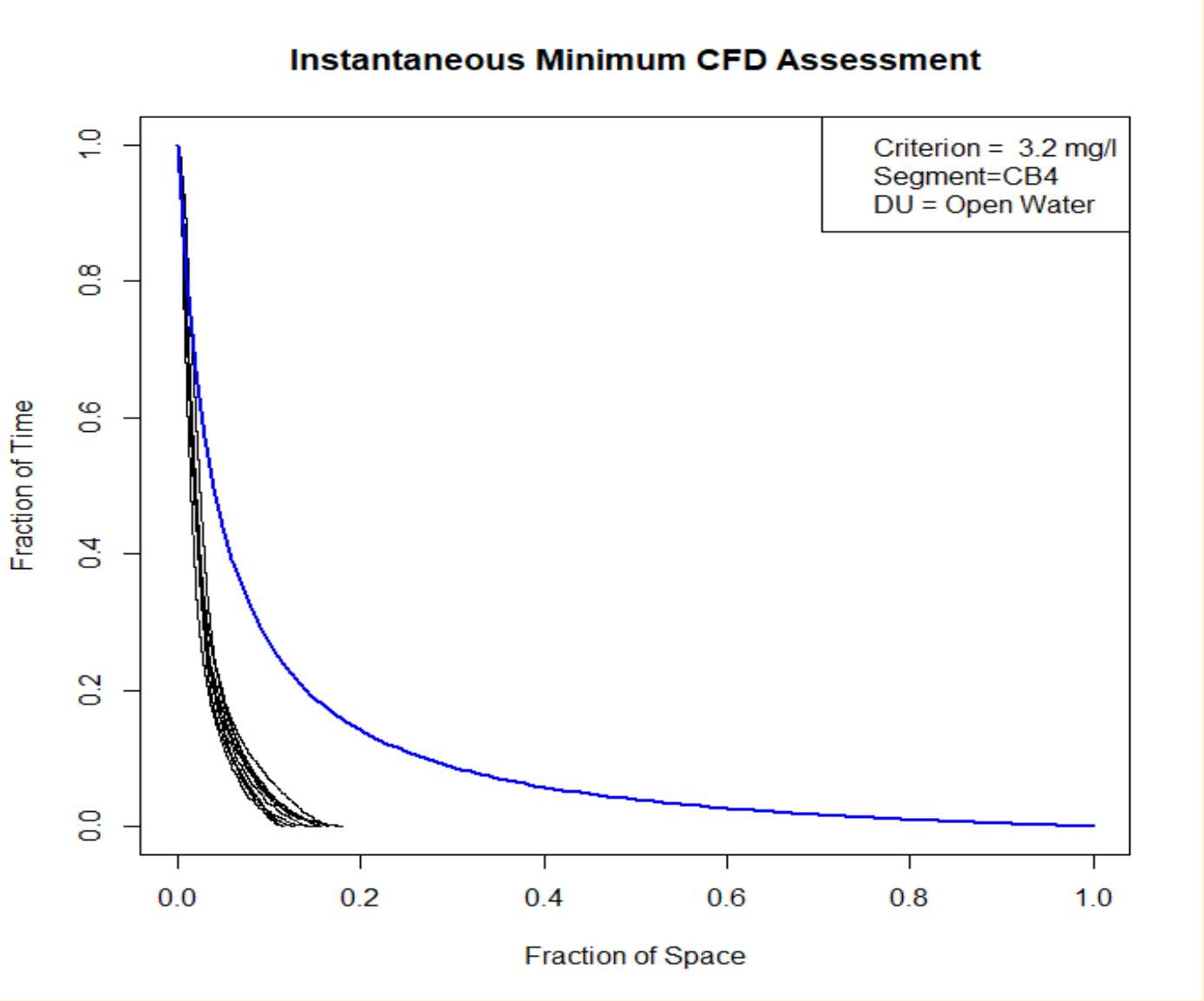

Figure 1. CFD assessment curves for the instantaneous minimum criterion in segment CB4 for the period 6/1/2022-8/31/2022.

Table 1. Fraction of Instantaneous Minimum Violations Over Space and Time for Each of Ten Simulations.

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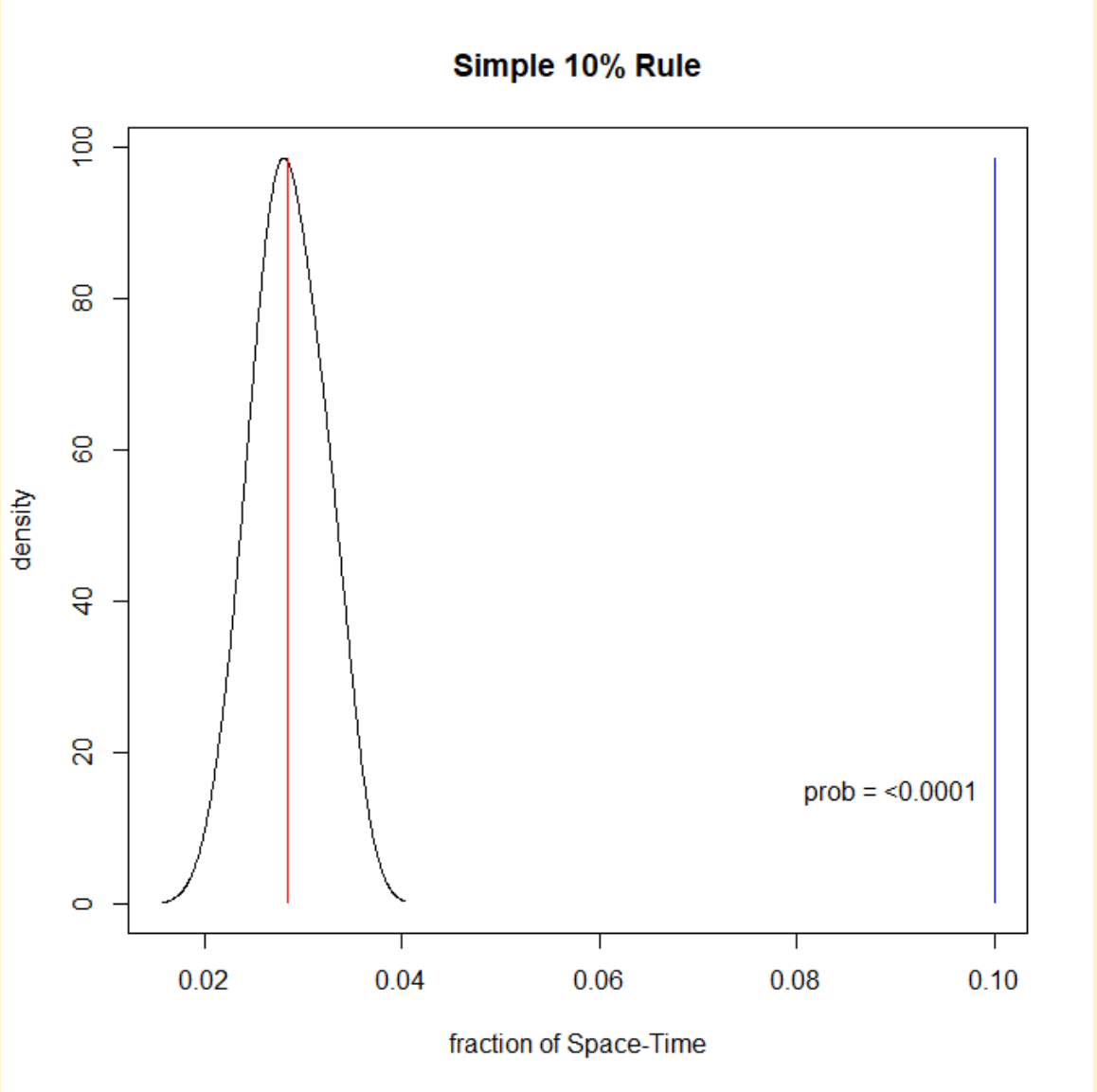
simulation	criteria violations	count	fraction violations
1	222070	8410272	0.026
2	245999	8410272	0.029
3	281274	8410272	0.033
4	274834	8410272	0.033
5	224135	8410272	0.027
6	189384	8410272	0.023
7	259074	8410272	0.031
8	240456	8410272	0.029
9	233703	8410272	0.028
10	215423	8410272	0.026

Count = 3809 spatial cells x 2208 hours = 8,410,272 interpolator cells



Weekly Mean Methods:

CFD Assessment

Mean DO computed over week within each spatial cell.

Fraction of Space Violations computed for each Week

Weekly fractions ranked as plotted using CFD method

Process repeated for each simulation

10% Rule

Mean DO computed over week within each spatial cell.

Fraction of Space-Week violations computed for each simulation

Distribution Function fitted to fractions of Space-Time

Estimate likelihood of exceeding 10%

Sequential Weeks vs. Moving Window Weeks

Table 2. Illustration of Sequential Week Means vs. Moving Window Week Means using artificial data.

Day	Daily DO	Sequential Week Means	Moving Window Weeks							MWW Means
1	8.04									
2	6.96									
3	6.43									
4	5.82									
5	7.74									
6	8.27									
7	6.15	7.06	7.06							7.06
8	6.45			6.83						6.83
9	6.43				6.76					6.76
10	8.01					6.98				6.98
11	8.11						7.31			7.31
12	5.75							7.02		7.02
13	8.66								7.08	7.08
14	7.08	7.21	7.21							7.21
15	8.88			7.56						7.56
16	8.07				7.79					7.79
17	8.84					7.91				7.91
18	5.06						7.48			7.48
19	8.25							7.83		7.83
20	9.47								7.95	7.95
21	5.62	7.74	7.74							7.74
22	8.82			7.73						7.73
23	5.31				7.34					7.34
24	8.62					7.31				7.31
25	8.08						7.74			7.74
26	7.69							7.66		7.66
27	6.83								7.28	7.28
28	6.99	7.48	7.48							7.48
29	7.18			7.24						7.24
30	7.47	7.33			7.55					7.55

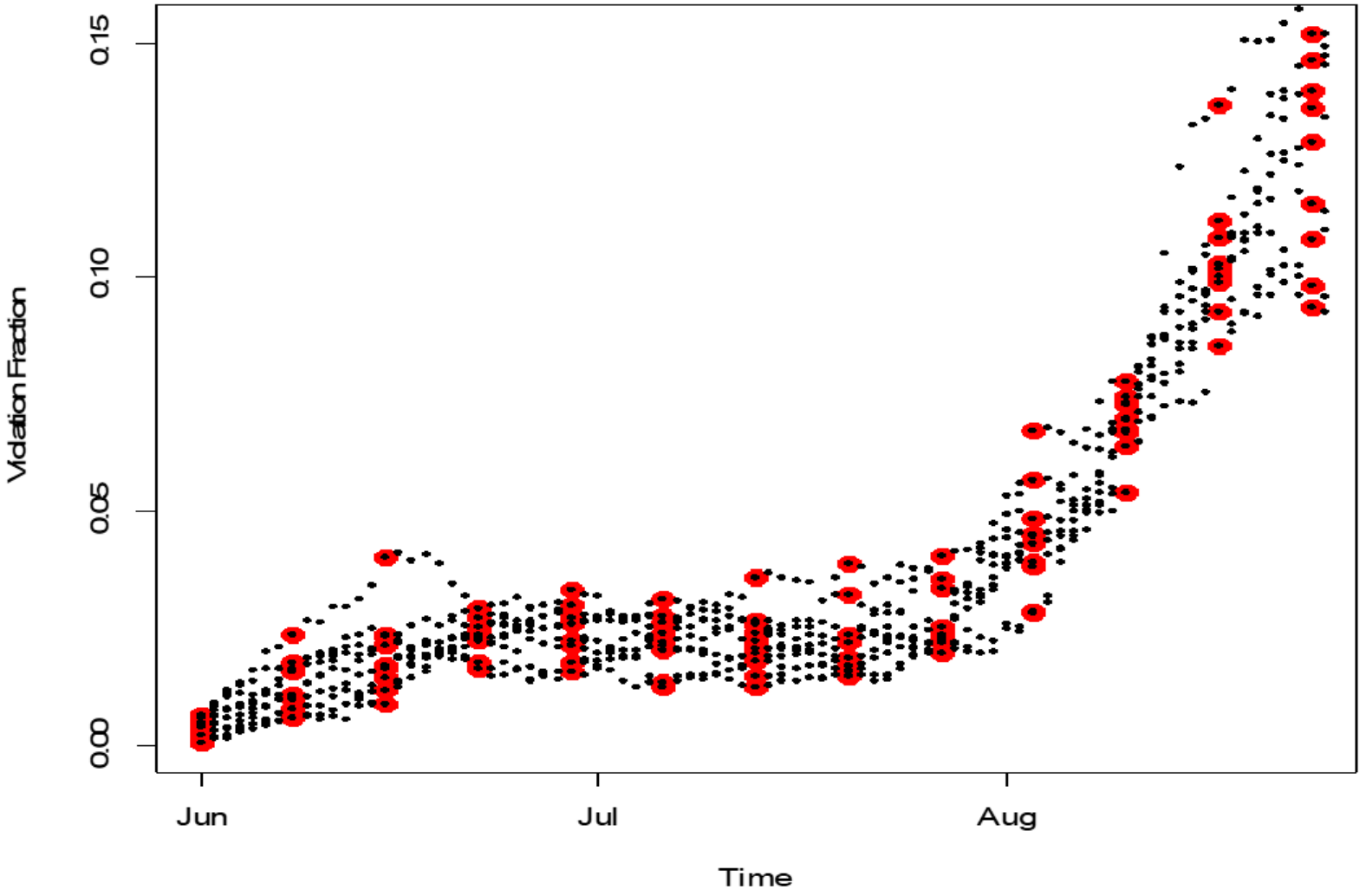


Figure 2. Sequential Weekly Means (red) and Moving Window Weekly Means (black) of fraction of violations as a function of time for 10 simulations in segment CB4 during the period 6/1/2022 – 8/31/2022.

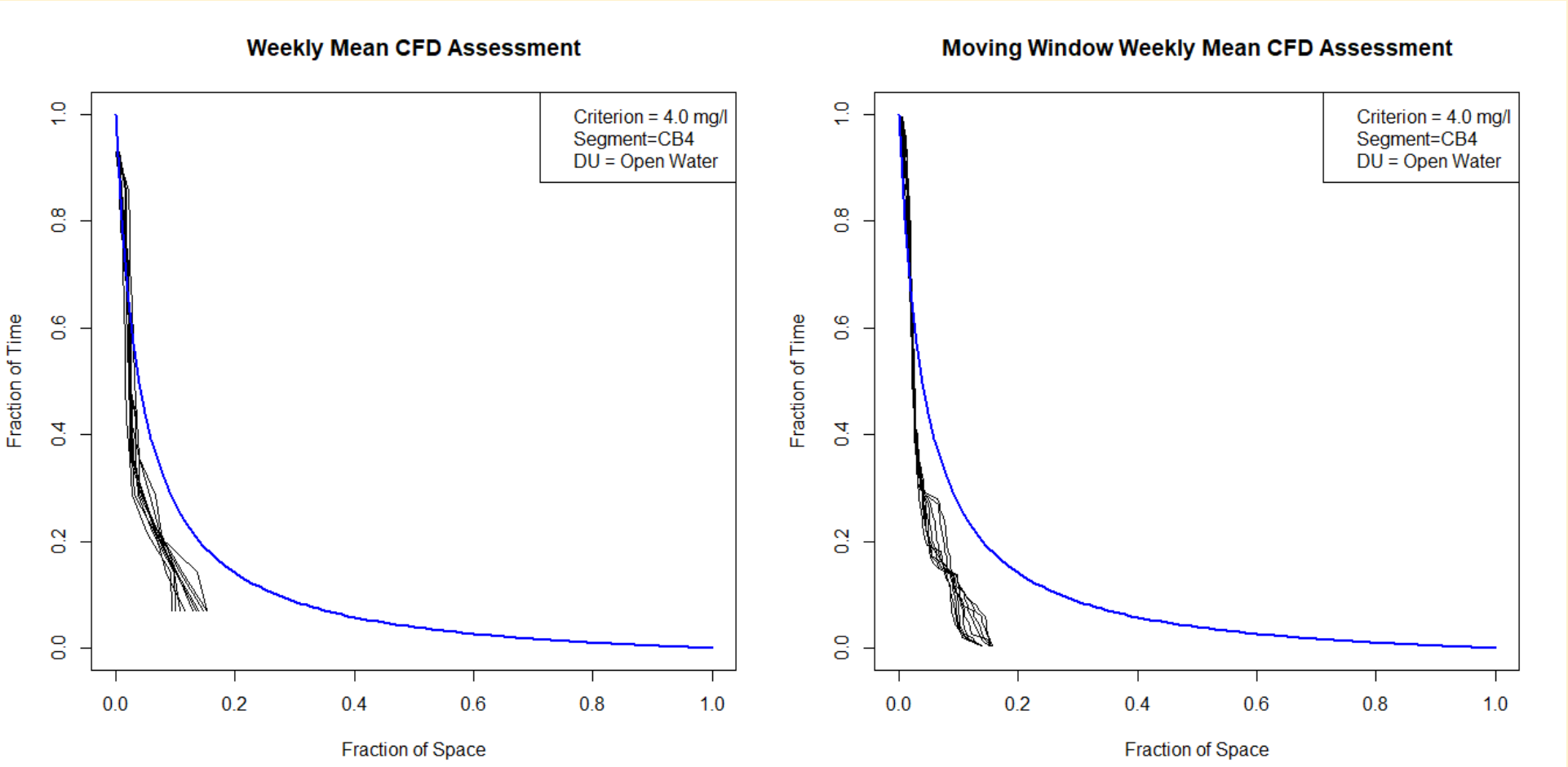
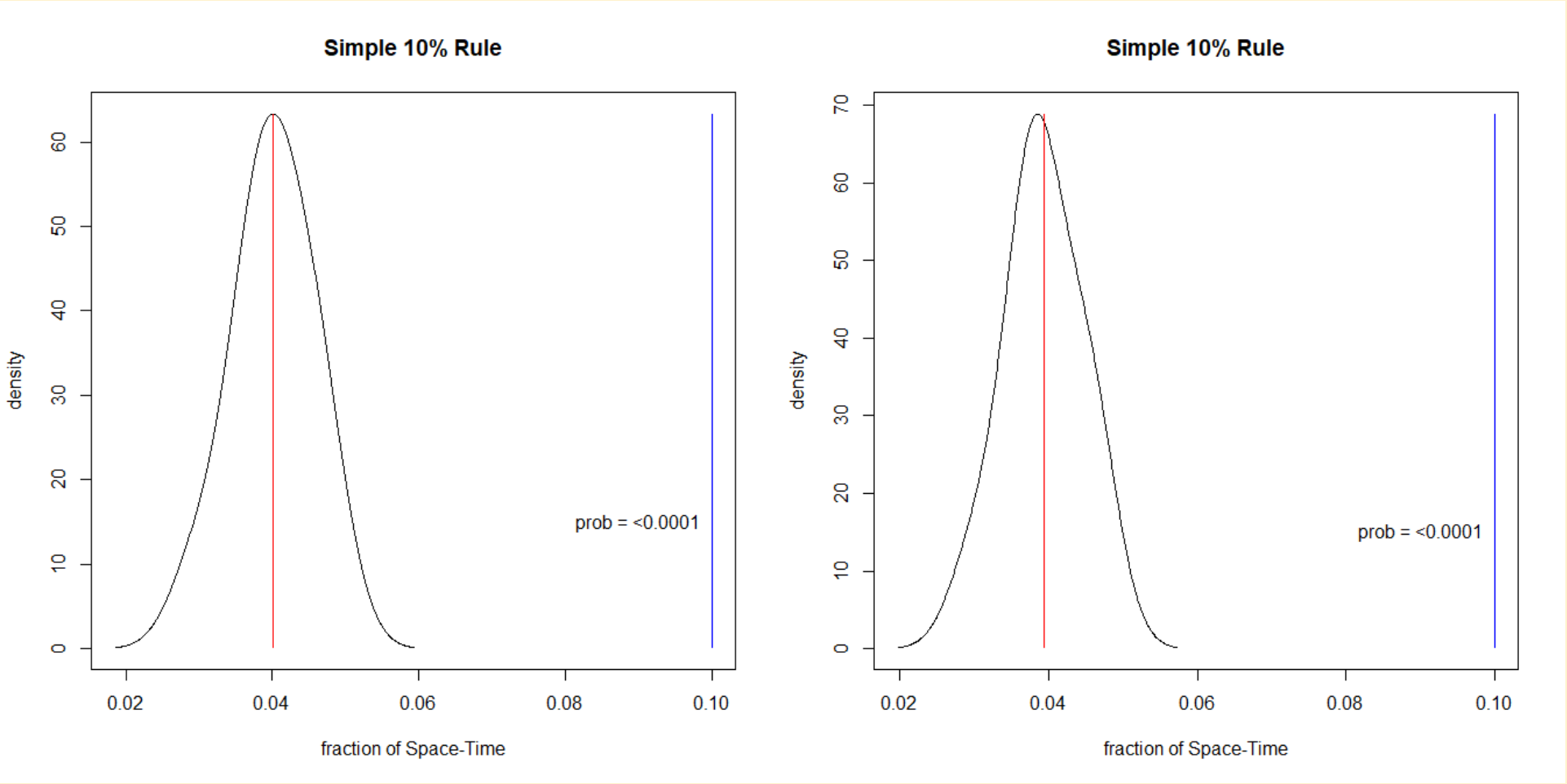


Figure 3,5. CFD assessment curves for the weekly mean criterion in segment CB4 for the period 6/1/2022-8/31/2022 using 13 sequential weeks and 86 moving window weeks.

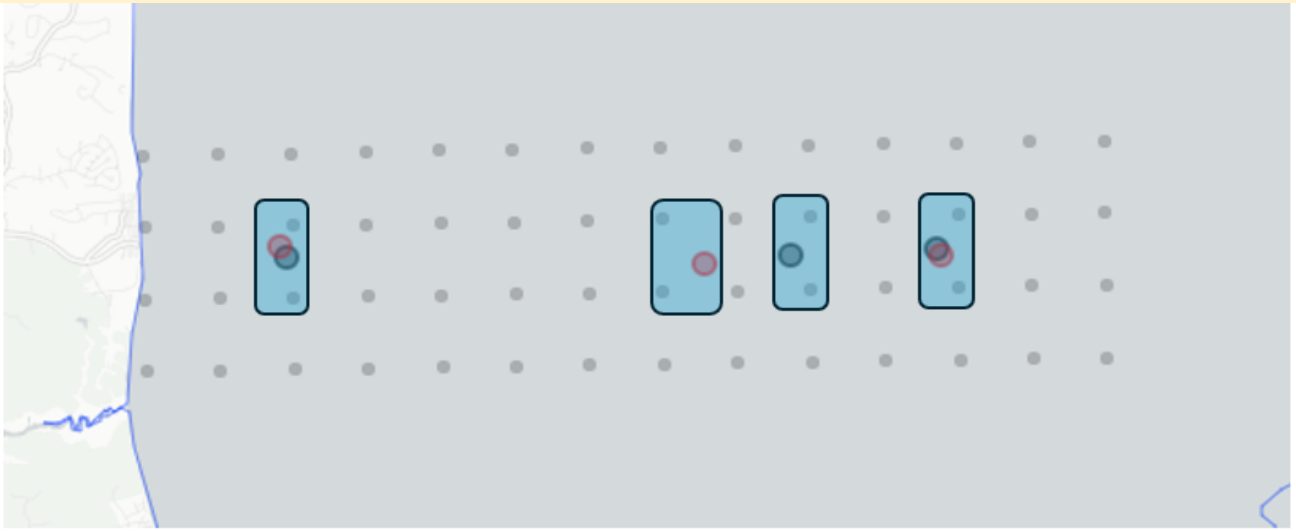


Sequential Weeks

Moving Window Weeks

Figure 4,7. The Density function (black line) is estimated from 10 simulations of fraction of violations of the weekly mean criterion in segment CB4. The mean violation rate is shown in red.

Comparison to Gooses Bottom Reef Vertical Array Data



Station	UIDSTR	Depths
CB4.3W west-gooses	3700004269000, 3700004268000 i=2, j=3	1, 3, 5, 7, 9
CB4.3C	3750004269000, 3750004268000 *(bottom depth closest to CB4.3C)*	1, 3, 5, 7, 9, 11, 13, 15, 17, 19, 21, 23, 25
XEF3551	3770004269000, 3770004268000	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12
CB4.3E east-gooses	3790004269000, 3790004268000	1, 3, 5, 7, 9, 11, 13, 15, 17, 19, 21, 23, 24

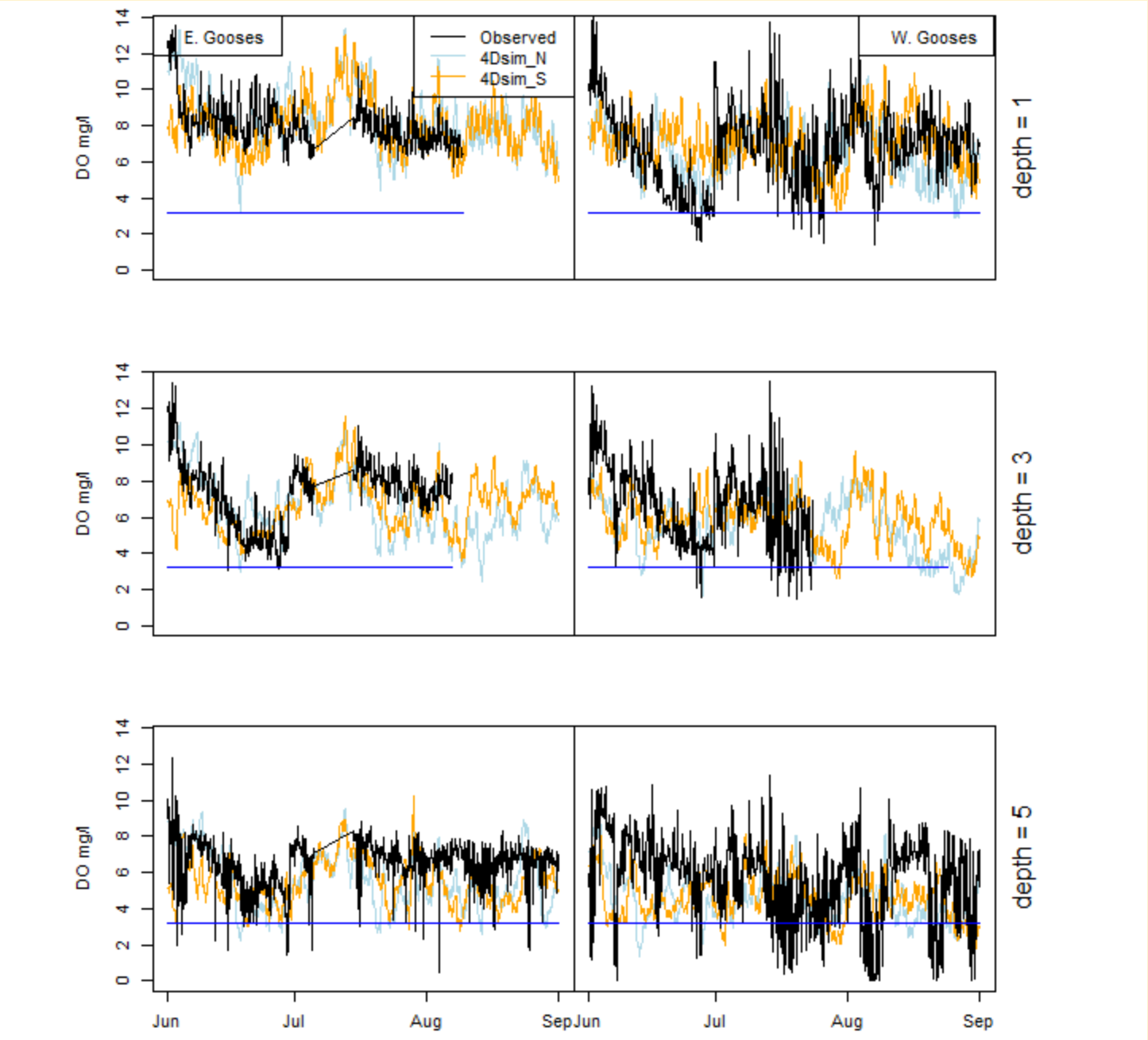


Figure 5. Comparison of simulated 4-D data (blue and orange) to observed data (black) for the Gooses Reef vertical array sites. The horizontal blue line shows the instantaneous minimum criterion. Simulated data just to the north of the observed site is in blue and to the south is in orange. Three depths (1,3,5) for the assessment period (6/1/2022 – 8/31/2022) are shown.

Table 5. Fraction of violations for East Gooses Vertical Array for depths 1-5 for period 2022-06-01 to 2022-08-31.

Location	Violations	Count	Fraction
East Gooses Vertical Array	42	4747	0.0088
West Gooses Vertical Array	442	5624	0.0786

The observed data for West Gooses site shows a higher violation rate than the East Gooses Site (Table 5.).

Table 6. Open Water Interpolator Predictions from 10 Simulations Near Gooses Reef Vertical Array.

Simulation	West Goose grid cell 1	West Goose grid cell 2	East Goose grid cell 1	East Goose grid cell 2
1	0.0457	0.076	0.0025	0.0146
2	0.0507	0.0517	0.0208	0.0027
3	0.1293	0.0818	0.001	0.0014
4	0.1121	0.1431	0.0272	0.0092
5	0.0418	0.0766	0.0106	0.0088
6	0.0971	0.154	0.0093	0.0151
7	0.1555	0.076	0.0065	0.0036
8	0.0617	0.1064	0.0168	0.0032
9	0.0683	0.0542	0.0176	0.0012
10	0.0644	0.0991	5e-04	0.0064

Range for East Gooses Cells: 0.00005 - 0.0272 - Vertical Array 0.0088
Range for West Gooses Cells: 0.0418 - 0.1555 - Vertical Array 0.0786

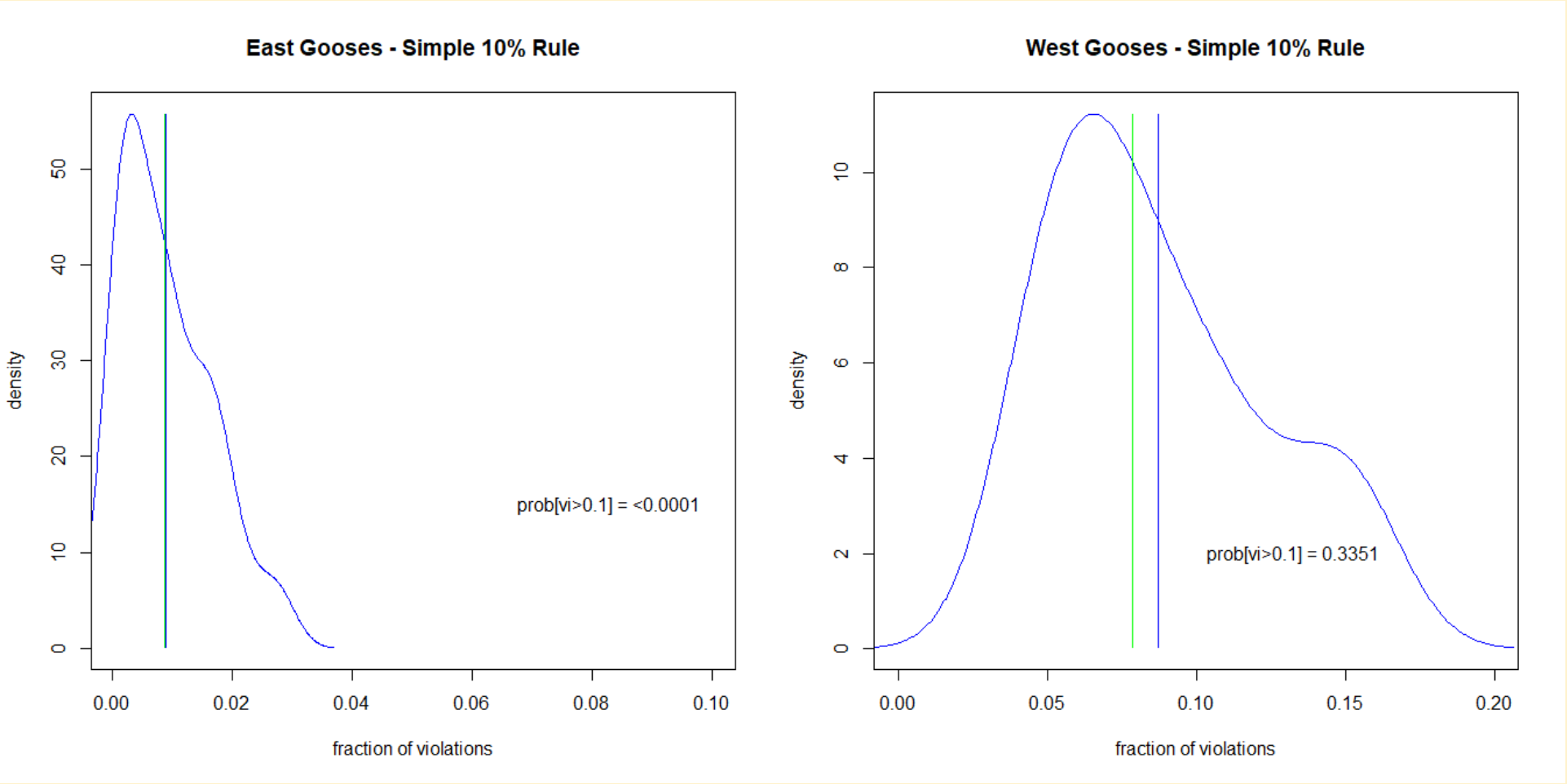


Figure 6,11. Density function (blue) estimate for interpolator predictions near the East and West Gooses array site with the mean observed violation rate (green) based on array observations.

Next Steps:

Implementing Dynamic Pycnocline for delineating designated uses.

Conduct assessment testing in Deeper Water.

Implement assessment using more simulations?: Test approach with 100 simulations

Additional case study comparison in segment with intensive monitoring
(i.e., Fishing Bay example)