Dissolved Oxygen Criteria Assessment at Virginia's Chesapeake Bay Continuous Monitoring Stations

Tish Robertson
Virginia Department of Environmental Quality

Criteria Assessment Protocol Workgroup Meeting

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Chesapeake Bay Designated Uses and DO criteria

Designated Use	Criteria Concentration/Duration	Temporal Application
Migratory fish spawning and nursery	7-day mean 6 mg/l (tidal habitats with 0-0.5 pptsalinity)	February 1 - May 31
	Instantaneous minimum 5 mg/l	
Open water[1]	30 day mean 5.5 mg/l (tidal habitats with 0-0.5 pptsalinity)	year-round[2]
	30 day mean 5 mg/l (tidal habitats with > 0.5 pptsalinity)	
	7 day mean 4 mg/l	
	Instantaneous minimum 3.2 mg/l at temperatures <29°C Instantaneous minimum 4.3 mg/lattemperatures 29°C	
Deep water	30 day mean 3 mg/l	June 1 - September 30
	1 day mean 2.3 mg/l	
	Instantaneous minimum 1.7 mg/l	
Deep channel	Instantaneous minimum 1 mg/l	June 1 - September 30

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Open water[1]	30 day mean 5.5 mg/l (tidal habitats with 0-0.5 pptsalinity)	year-round[2]
	30 day mean 5 mg/l (tidal habitats with > 0.5 pptsalinity)	
	7 day mean 4 mg/l	
	Instantaneous minimum 3.2 mg/l at temperatures <29°C Instantaneous minimum 4.3 mg/lattemperatures 29°C	
Deep water	30 day mean 3 mg/l	June 1 - September 30
	1 day mean 2.3 mg/l	
	Instantaneous minimum 1.7 mg/l	
Deep channel	Instantaneous minimum 1 mg/l	June 1 - September 30

Short-duration criteria not currently being assessed

From 2017 Technical Addendum: Recommended Methods for Assessing Short-Duration DO Criteria Attainment

Zone	Zone Description	Applicable Criteria Assessment Procedures
1	Open, well-mixed mainstem Bay and tidal tributary waters	• CFD-based assessment of the 30-day mean • CFD-based assessment of the 7-day mean with enhanced temporal frequency of monitoring • Conditional attainment assessment of the 7-day mean • Continuous monitoring-based assessment of the instantaneous minimum
2	Shallow-water waters	• Continuous monitoring-based assessment of the instantaneous minimum
3	Tributaries of tributaries off of the mainstem Chesapeake Bay and its tidal tributaries	• Discrete sampling-based assessment of the instantaneous minimum

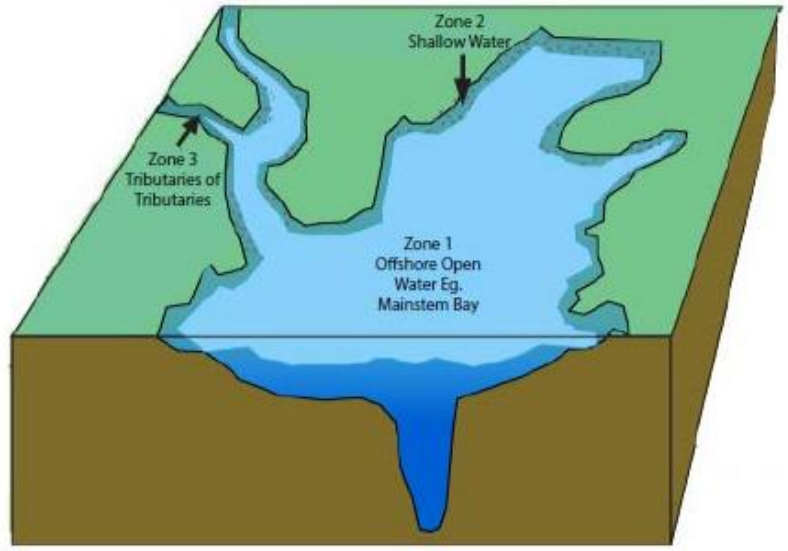
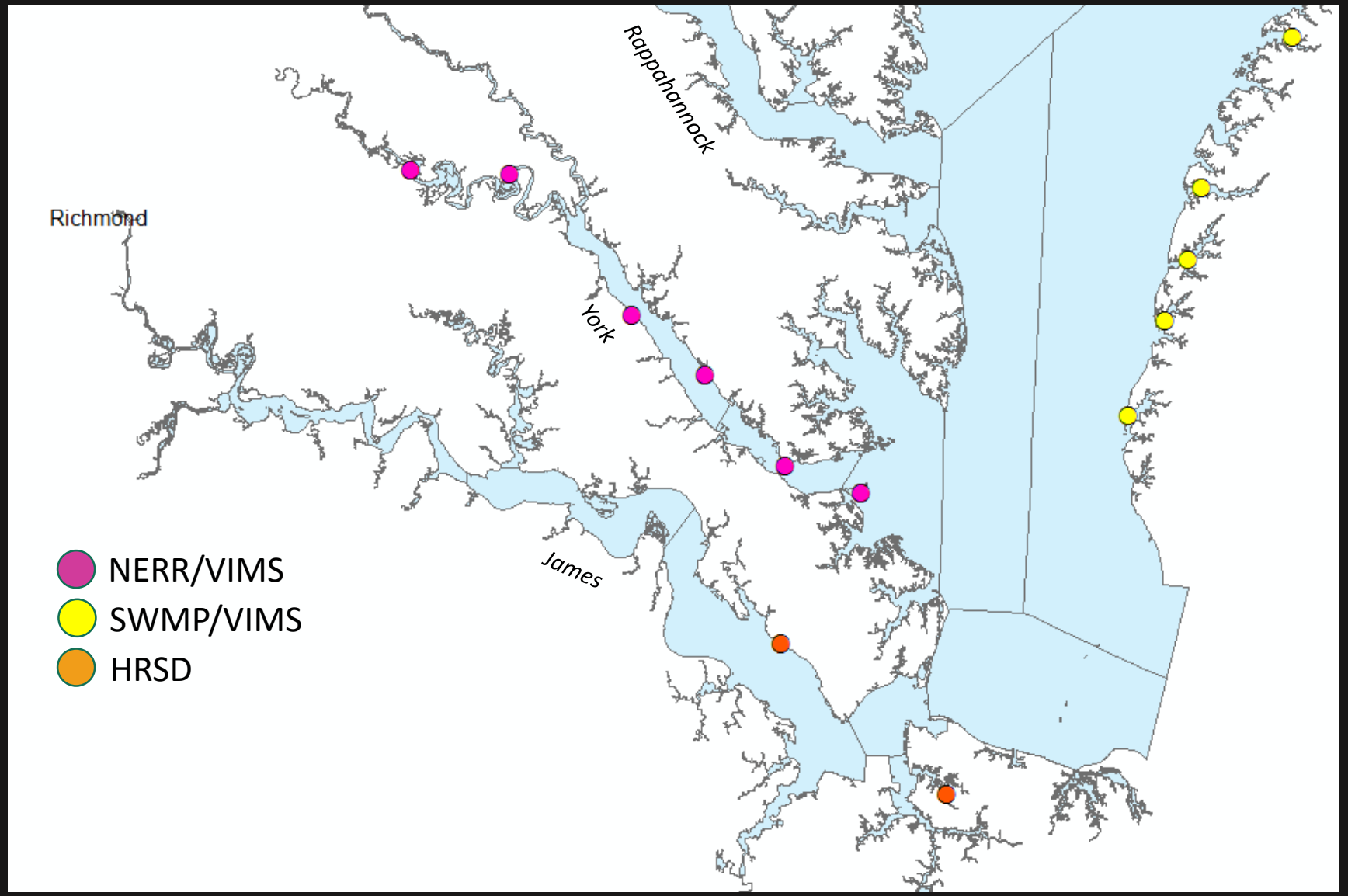


Figure II-4. Applying the concept of three zones to Chesapeake Bay open-water habitats.

Virginia says:

“We have a bunch of ConMon DO data! We’ve got the methodology! So let’s get ‘er done!”

Locations where VA ChesBay ConMon DO data were generated over the 2016-2018 period



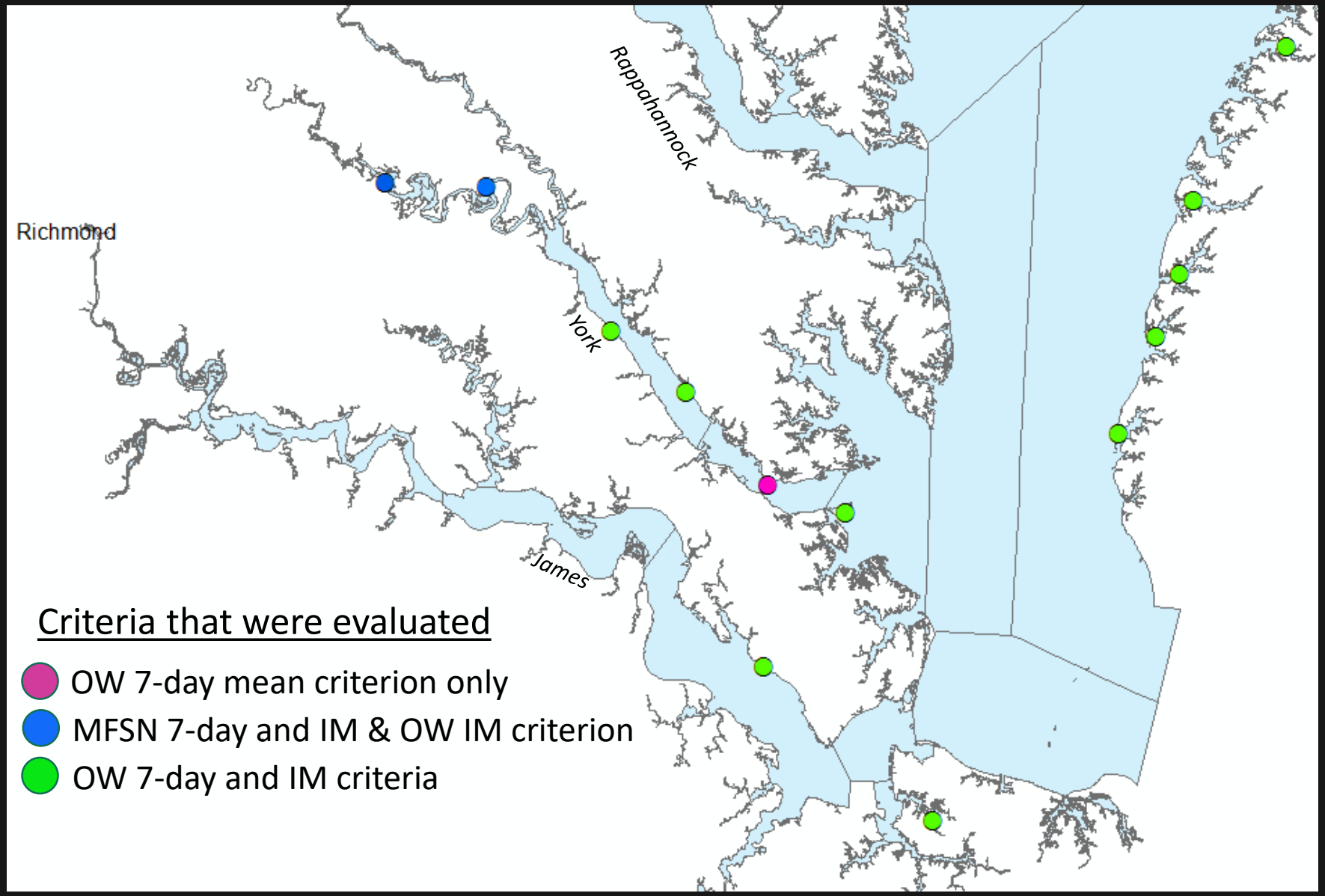
The following DO criteria were assessed (where applicable) at the VA ChesBay ConMons:

Year round, all salinities

- Open Water 7-day mean (4 mg/l)
- Open Water instantaneous minimum (3.2 or 4.3 mg/l depending on temp)

Feb-May, low salinity

- Migratory Fish Spawning Nursery 7-day mean (6 mg/l)
- Migratory Fish Spawning Nursery instantaneous min (5 mg/l)


Rappahannock
Richmond
York
James
Criteria that were evaluated
OW 7-day mean criterion only
MFSN 7-day and IM & OW IM criterion
OW 7-day and IM criteria

Criteria	Criteria are attained if dataset shows…	Source of Decision Rule
Migratory Fish Spawning Nursery 7-day mean (6 mg/l)	No more than 10% violation rate over all monitored weeks in Feb-May where salinity is ≤ 0.5 ppt.	Interpretation of EPA-recommended "10% rule"
Migratory Fish Spawning Nursery IM (5 mg/l)	No more than two consecutive days with 2.5+ hours of violations during days in Feb-May where salinity is ≤ 0.5 ppt.	2017 Technical Addendum (Rule 2-Alternative)
Open Water 7-day mean (4 mg/l) SUMMER Open Water 7-day mean (4 mg/l) (Rest of Year)	No more than 10% violation rate over all monitored summer weeks (June-Sept) No more than 10% violation rate over all monitored non-summer weeks	Interpretation of EPA-recommended "10% rule"
Open Water IM (3.2 or 4.3 mg/l) SUMMER Open Water IM (3.2 or 4.3 mg/l) Rest of Year	No more than two consecutive days with 2.5+ hours of violations during the summer days. No more than two consecutive days with 2.5+ hours of violations during the non-summer days.	2017 Technical Addendum (Rule 2-Alternative)

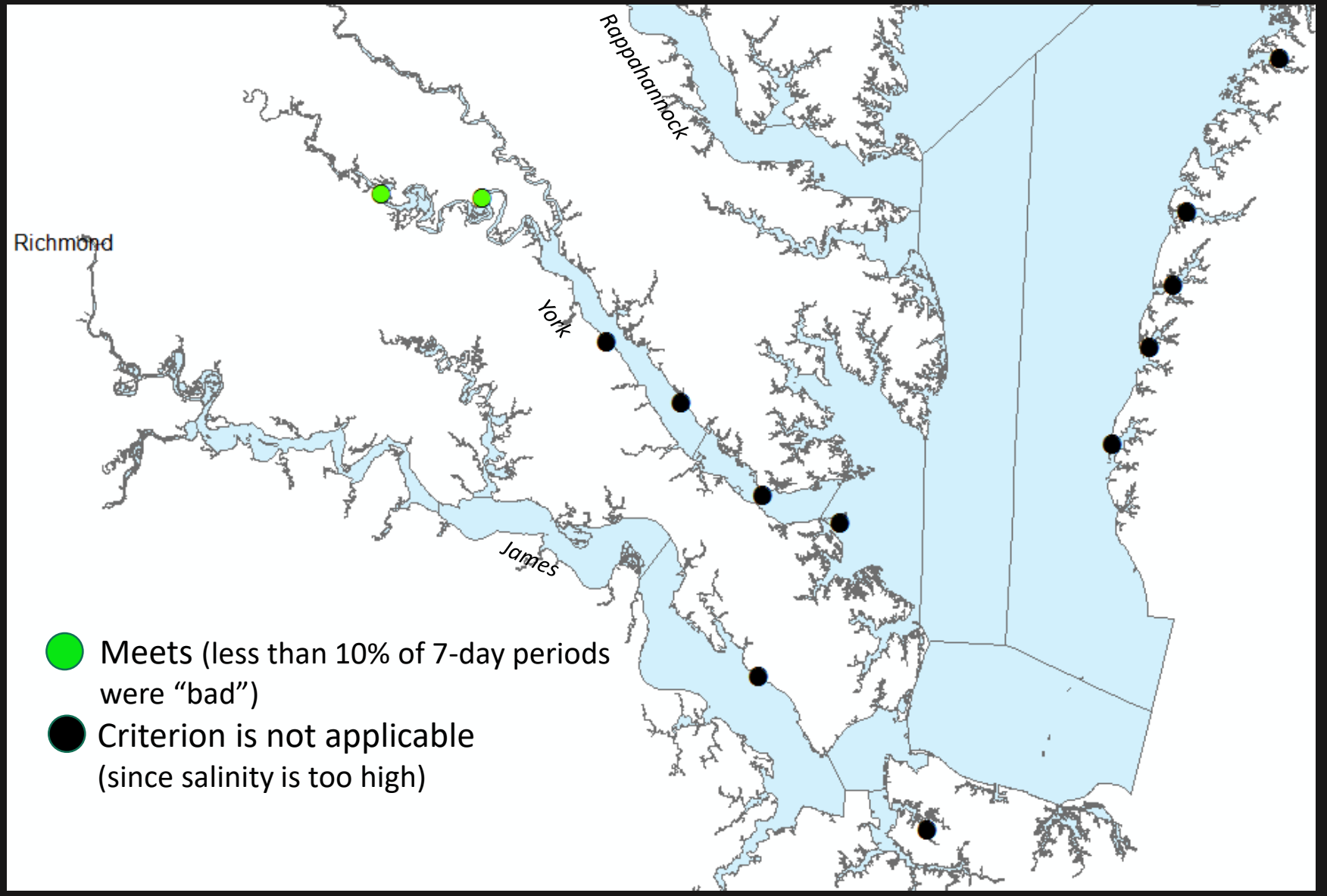
Other decision rules

- 7-day means are calculated over static 7-day periods (not rolling). The series of assessed 7-day periods for a particular year starts on the first monitored day of the applicable season (e.g., June-Sept for Open Water Summer or Feb-May for MFSN).

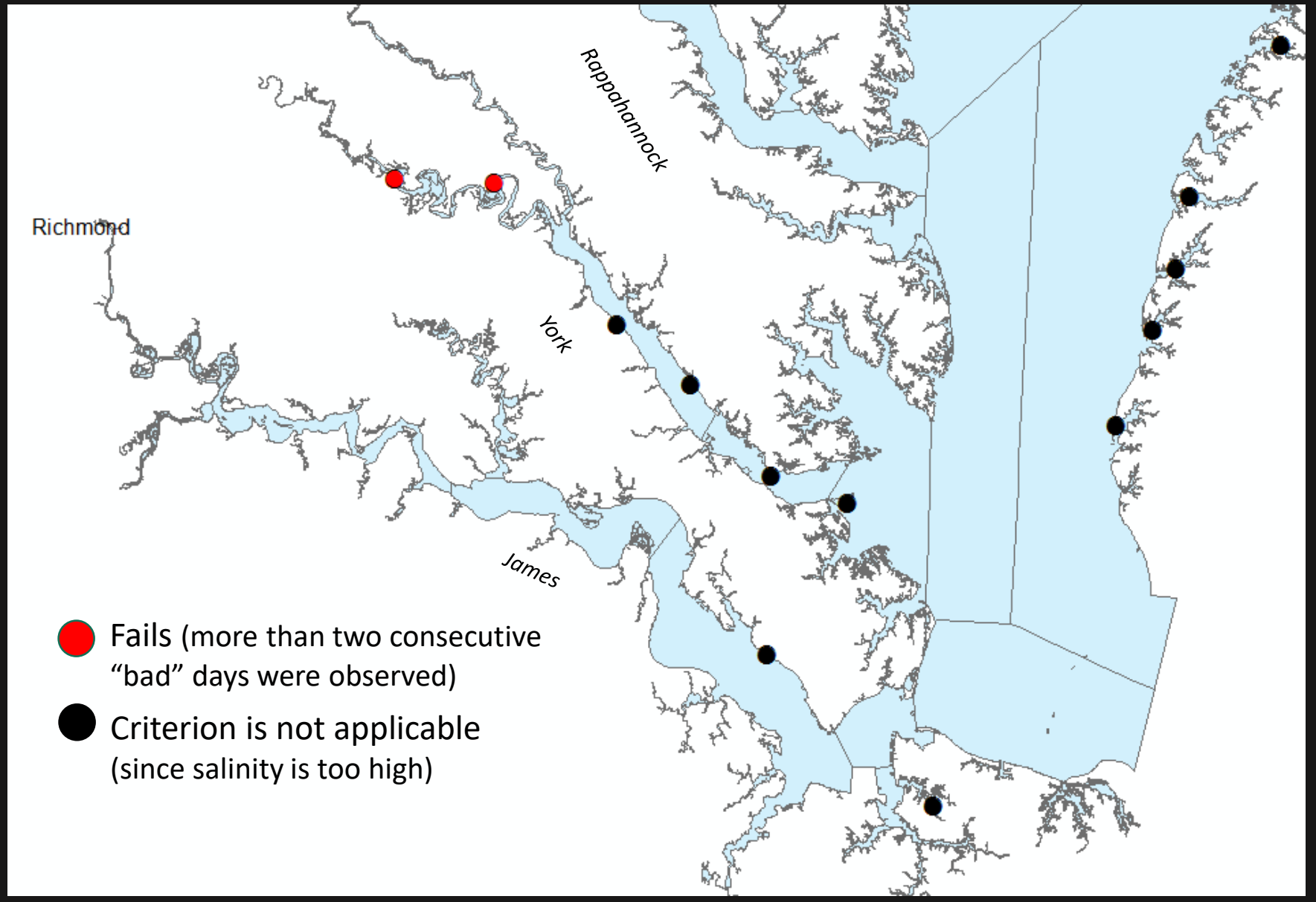
- To be an assessed week, a 7-day period must be represented by at least five monitored days. A 7-day mean is calculated from all DO observations taken over that period (no hourly or daily averaging).

- To be a “monitored” day, 75% of the diurnal cycle must have been observed and the observations must have passed QA/QC checks.

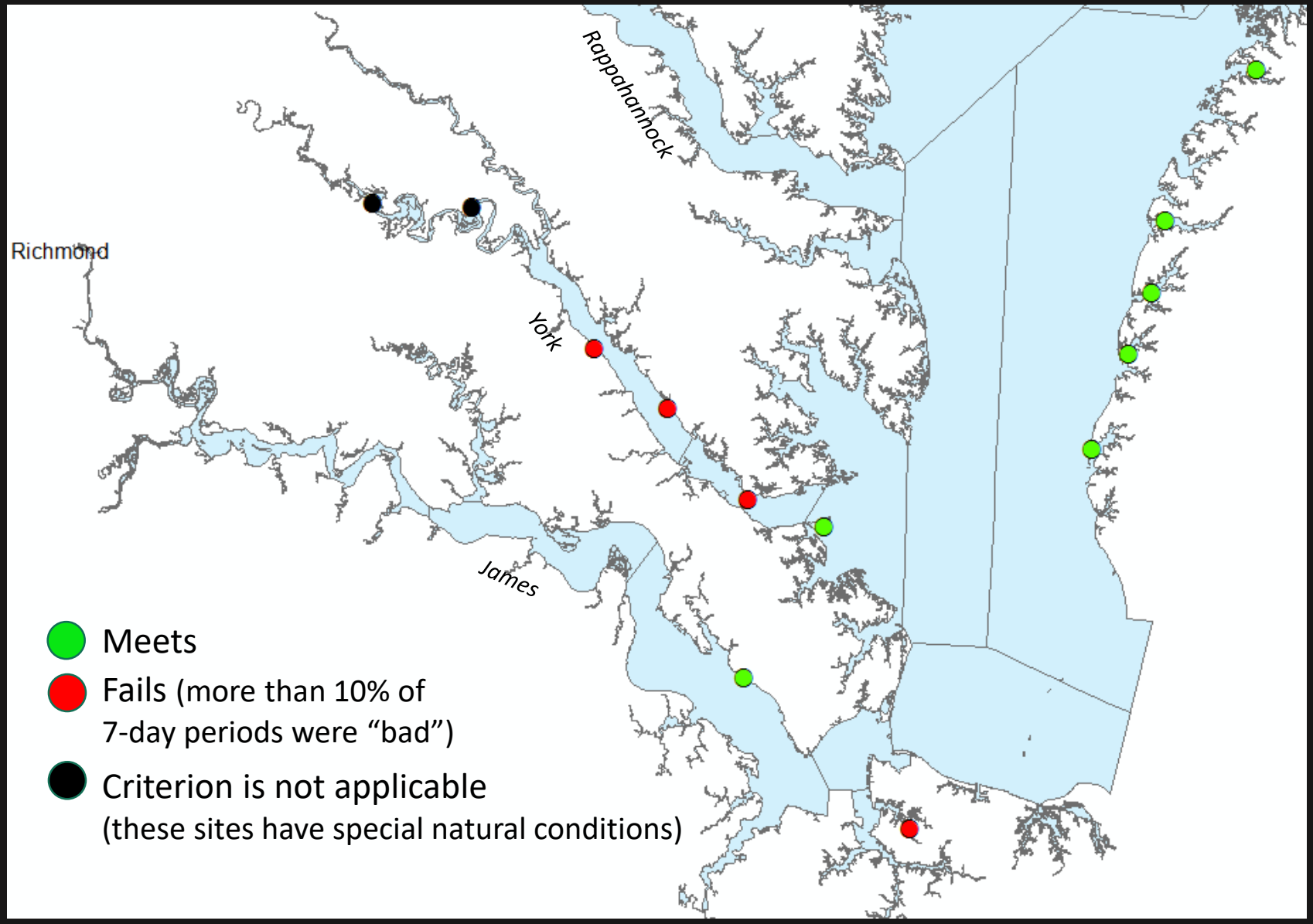
Assessment Results for Migratory Fish Spawning Nursery 7-Day Mean Criterion (6 mg/l) for 2016-2018



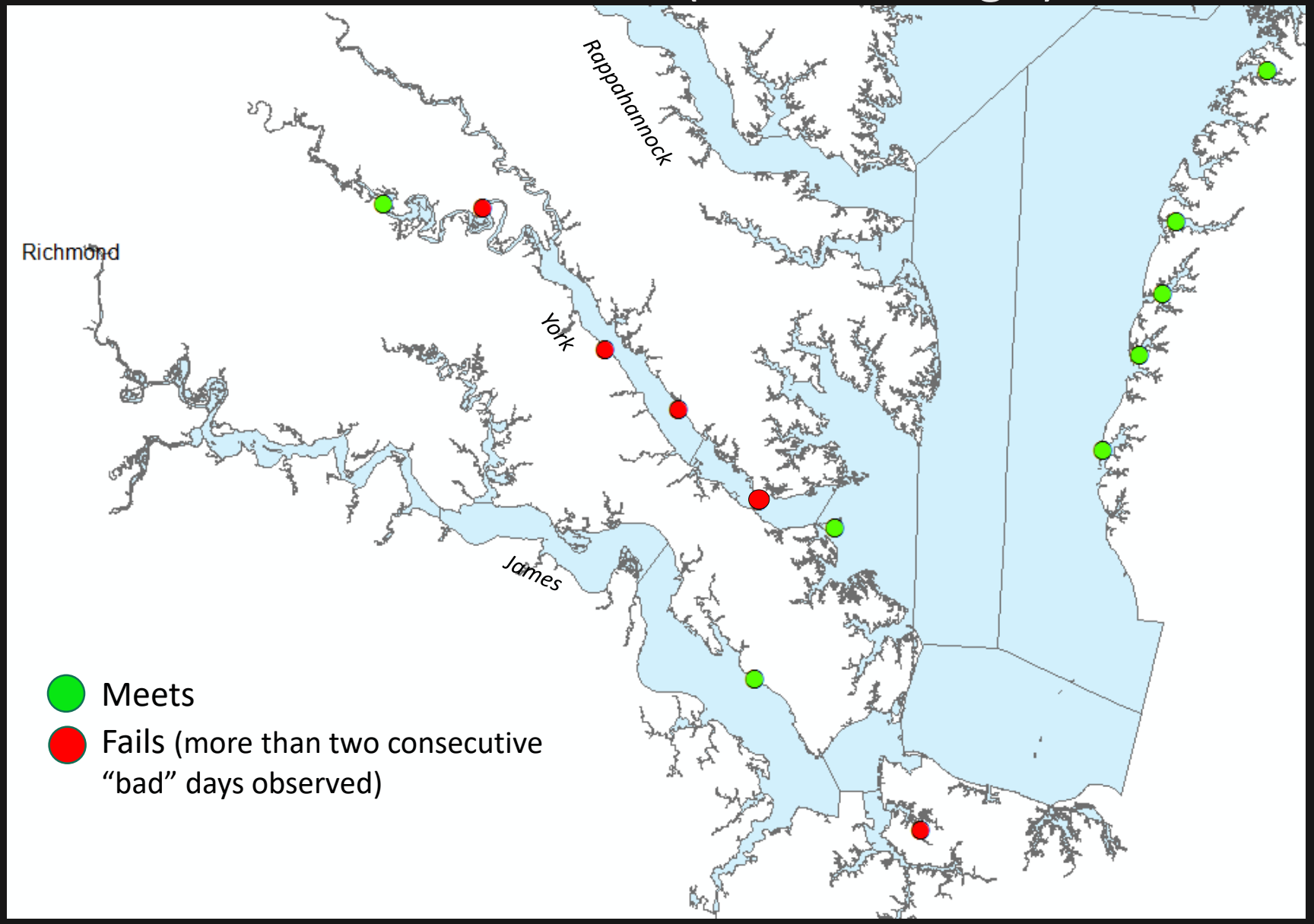
Assessment Results for Migratory Fish Spawning Nursery Instantaneous Minimum Criterion (5 mg/l) for 2016-2018



Assessment Results for Open Water (Summer) 7-Day Mean Criterion (4mg/l) for 2016-2018



Assessment Results for Open Water (Summer) Instantaneous Minimum Criterion (3.2 or 4.3 mg/l) for 2016-2018

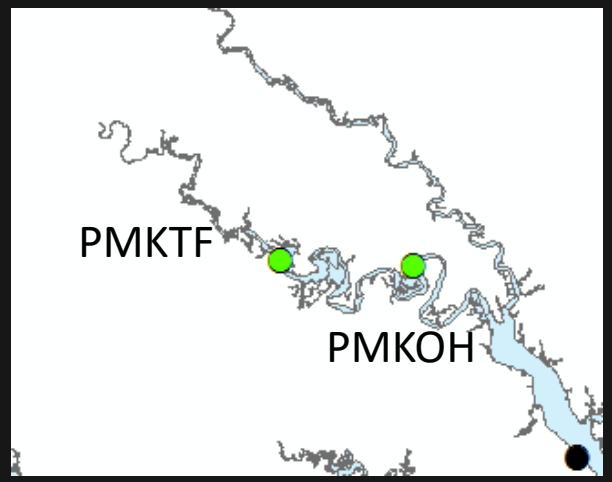


Are we comfortable with VA's use of the "10% rule" on 7-day DO means?

It is consistent with EPA's recommendation that conventional parameters be granted a 10% allowable frequency, it is easy to calculate, and the waters you'd expect to not attain the OW 7-day mean criteria (the York and Lafayette) violate this rule.

7-day DO means during Feb-May period (MFSN use) from 2016-2018

MFSN 7-day mean criterion = 6 mg/l



PMK034.00 (PMKTF)	
7-Day period starting on…	7-day Mean DO (mg/l)
3/7/2016	9.9
3/14/2016	8.6
3/21/2016	9.4
3/28/2016	8.9
4/4/2016	9.3
4/11/2016	9.5
4/18/2016	8.5
4/25/2016	7.7
5/2/2016	7.0
5/9/2016	6.8
5/16/2016	7.4
5/23/2016	6.2
2/7/2017	11.0
2/14/2017	10.7
2/21/2017	10.2
2/28/2017	9.7
3/21/2017	10.5
3/28/2017	8.7
4/4/2017	8.3
4/11/2017	7.6
4/18/2017	7.0
4/25/2017	6.7
5/2/2017	7.2
5/9/2017	7.2
5/16/2017	7.2
5/23/2017	6.1
2/1/2018	11.8
2/8/2018	11.5
2/15/2018	8.8
2/22/2018	8.6
3/1/2018	9.9
3/8/2018	10.4
3/15/2018	11.0
3/22/2018	11.0
3/29/2018	9.7
4/5/2018	9.5
4/12/2018	8.9
4/19/2018	7.5
4/26/2018	7.5
5/3/2018	6.6
5/10/2018	6.6
5/17/2018	4.9
5/24/2018	4.5

← 5% exceedance rate

PMK012.18 (PMKOH)	
7-Day period starting on…	7-day Mean DO (mg/l)
2/1/2016	12.0
2/22/2016	11.3
2/29/2016	10.4
3/7/2016	9.8
3/14/2016	8.8
3/21/2016	9.2
3/28/2016	9.0
4/4/2016	9.2
4/11/2016	9.3
5/2/2016	7.5
5/9/2016	6.9
5/16/2016	7.3
5/23/2016	7.1
2/1/2017	10.5
2/8/2017	10.7
2/15/2017	10.4
5/3/2017	7.4
5/10/2017	7.4
5/17/2017	7.3
2/1/2018	11.7
2/15/2018	10.5
2/22/2018	9.0
4/19/2018	8.6
4/26/2018	7.6
5/3/2018	7.0
5/10/2018	6.3
5/17/2018	5.2
5/24/2018	4.2

←7% exceedance rate

Only 7-day periods with an average salinity ≤ 0.5 ppt were assessed.

Assessment Guidance Language for the 2020 IR

Continuous dissolved oxygen data collected in Chesapeake Bay waters (mainstem and tributaries) should only be assessed against the Open Water 7-day mean and instantaneous minimum criteria and Migratory Fish Spawning 7-day mean and instantaneous minimum criteria. A continuous DO dataset that indicates an applicable 7-day mean criterion was exceeded in more than 10% of the observed 7-day periods in a three-year assessment period should be considered evidence of impairment. A 7-day DO mean should be calculated from observations taken over at least five days, and each day must have been monitored for at least 75% of the diurnal cycle. Per Rule 2-A of the 2017 EPA addendum (EPA 903-R-17-002 , CBP/TRS 320-17), a continuous DO dataset that indicates there were more than two consecutive "violating days" of the applicable instantaneous minimum criterion in a three-year assessment period should be considered evidence of impairment. A "violating day" is defined as one where the DO concentration was below the applicable instantaneous minimum criterion for at least 10% of the time over that day. To support evidence of criteria attainment, the continuous monitoring dataset should span at least one summer season (June-September).

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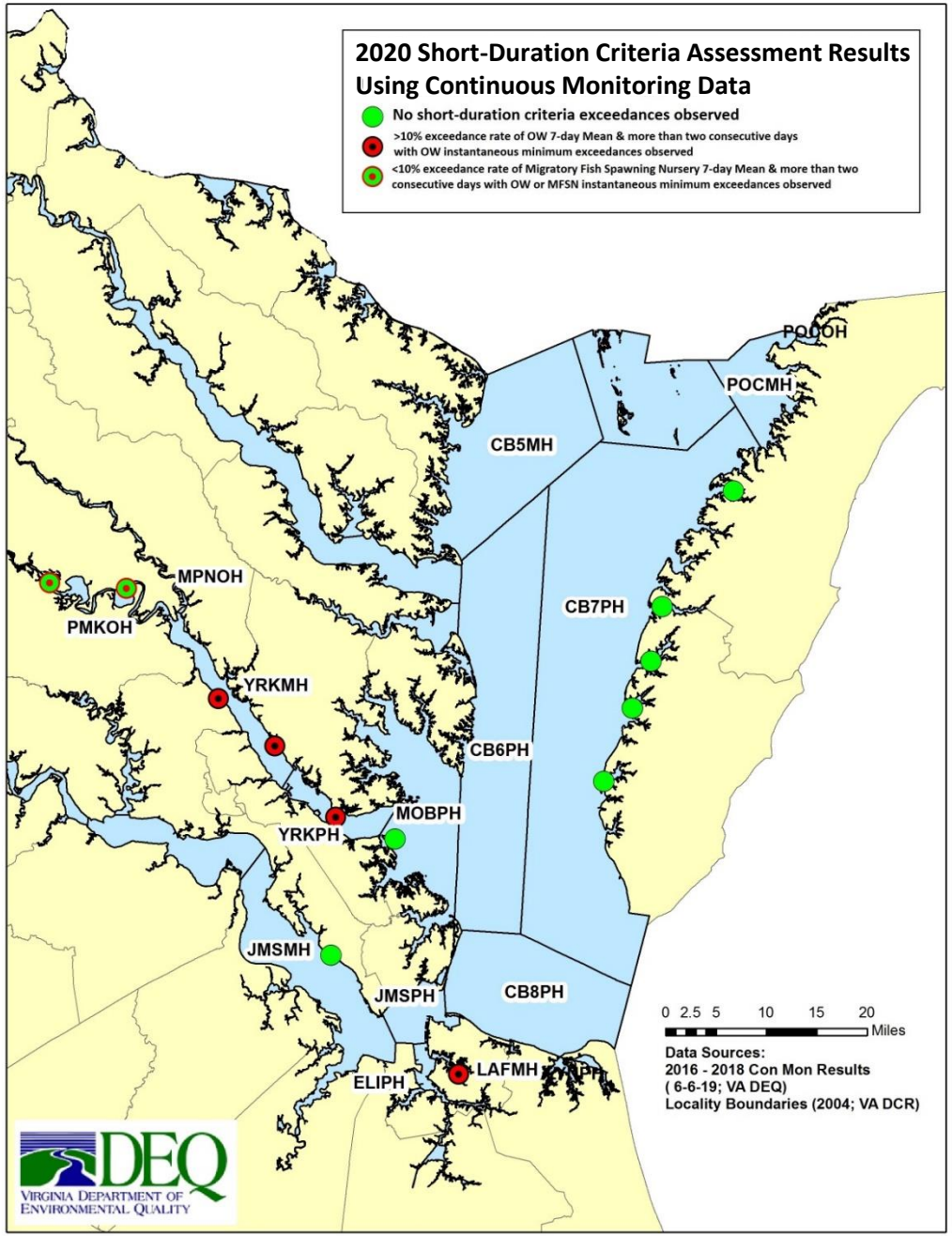
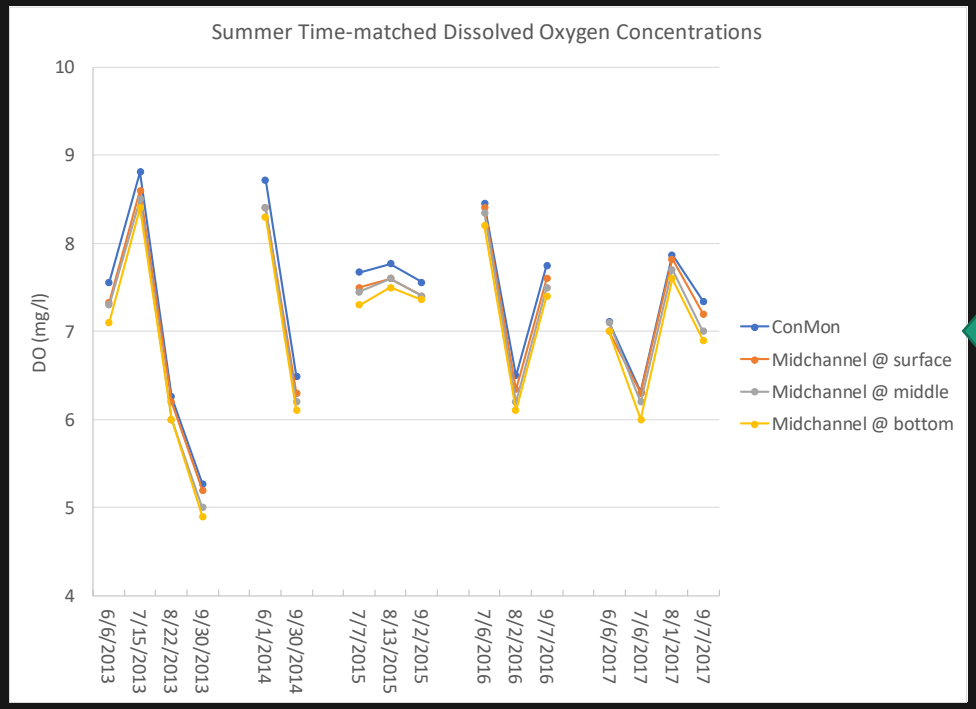

2020 Short-Duration Criteria Assessment Results
Using Continuous Monitoring Data
No short-duration criteria exceedances observed
>10% exceedance rate of OW 7-day Mean & more than two consecutive days with OW instantaneous minimum exceedances observed
<10% exceedance rate of Migratory Fish Spawning Nursery 7-day Mean & more than two consecutive days with OW or MFSN instantaneous minimum exceedances observed
POCOH
POCMH
CB5MH
CB7PH
MPNOH
PMKOH
YRKMH
CB6PH
MOBPH
YRKPH
JMSMH
JMSPH
CB8PH
LAFMH
ELIPH
0 2.5 5 10 15 20
Miles
Data Sources:
2016 - 2018 Con Mon Results
(6-6-19; VA DEQ)
Locality Boundaries (2004; VA DCR)
DEQ
Virginia Department of Environmental Quality

Can we use ConMon data to determine whether a segment *meets* a short-duration criterion as opposed to just reporting when the segment fails?

A ConMon could be considered “adequately representative” of a segment if it generates data that are similar to data generated at mid-channel stations throughout the 3-dimensional Open Water use.

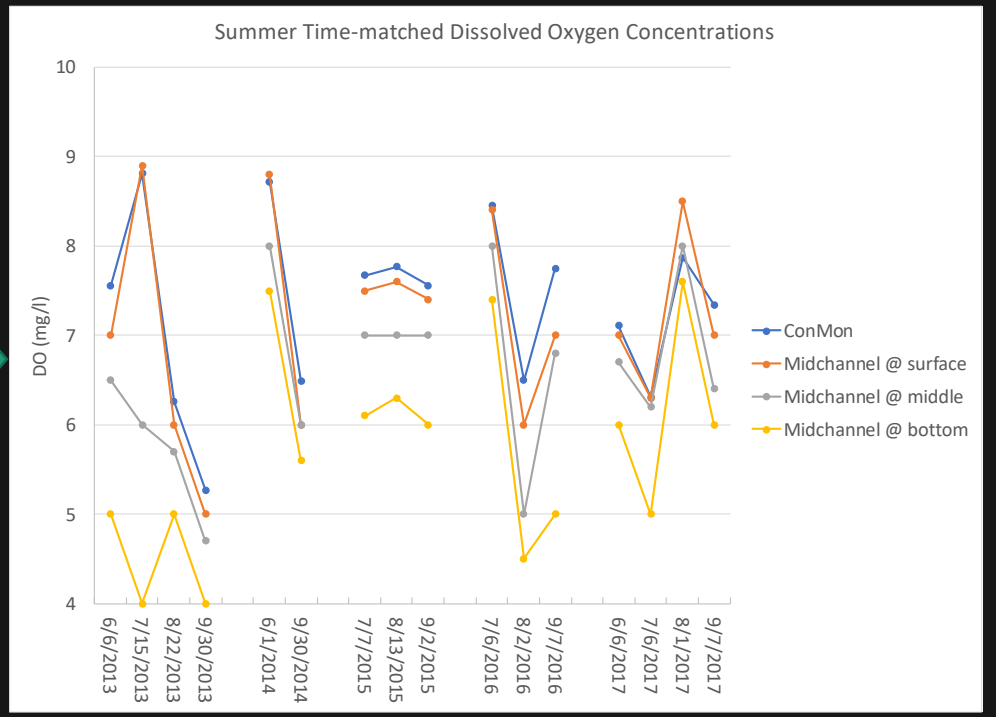


IDEAL DATASET FOR "SENTINEL" CONMON

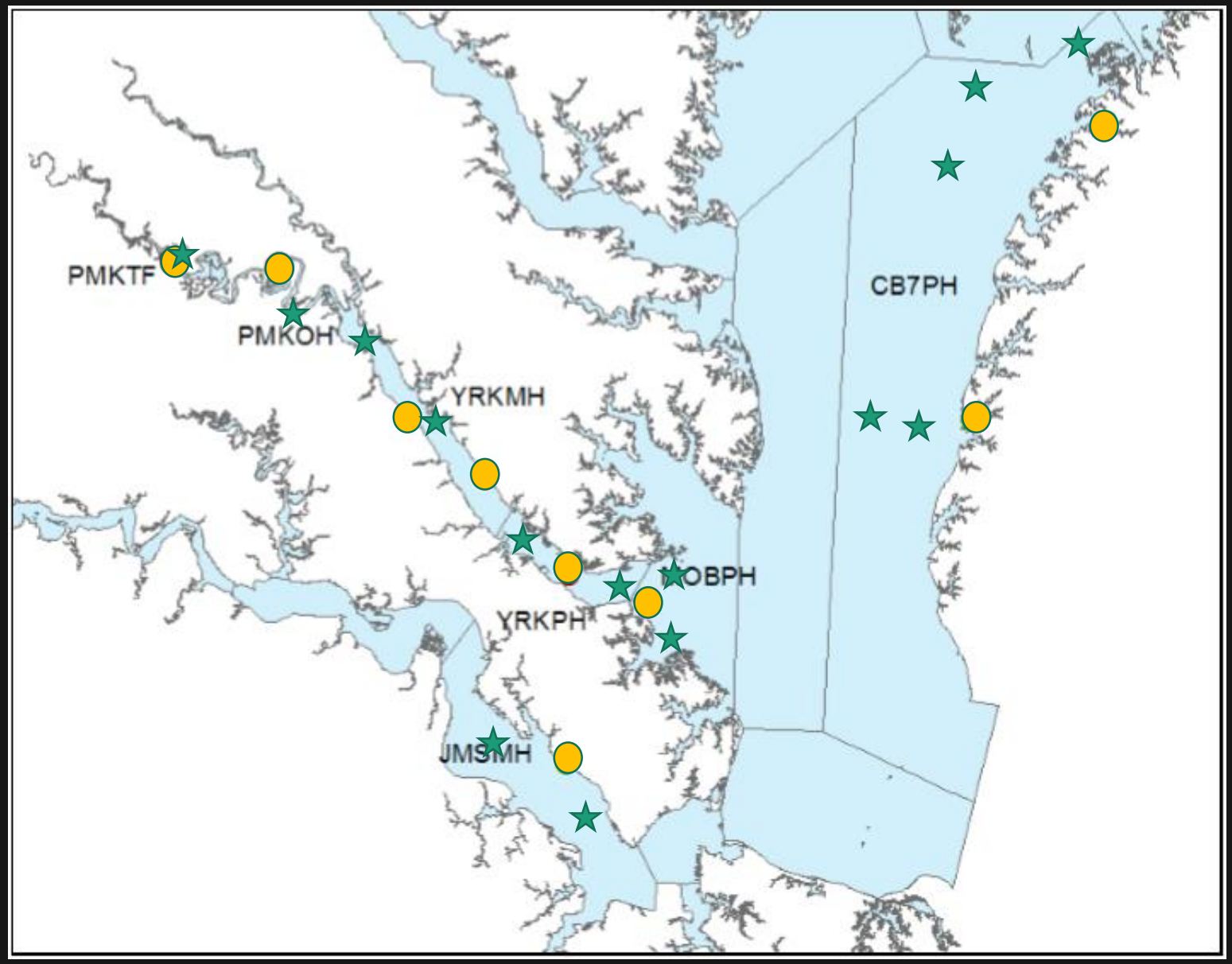
- ConMon and midchannel DO observations are similar
- Strong positive correlation between ConMon and midchannel DO @ each depth

NOT IDEAL FOR "SENTINEL" CONMON

- ConMon and midchannel DO observations are NOT similar
- Weak positive correlation between ConMon and midchannel DO @ each depth

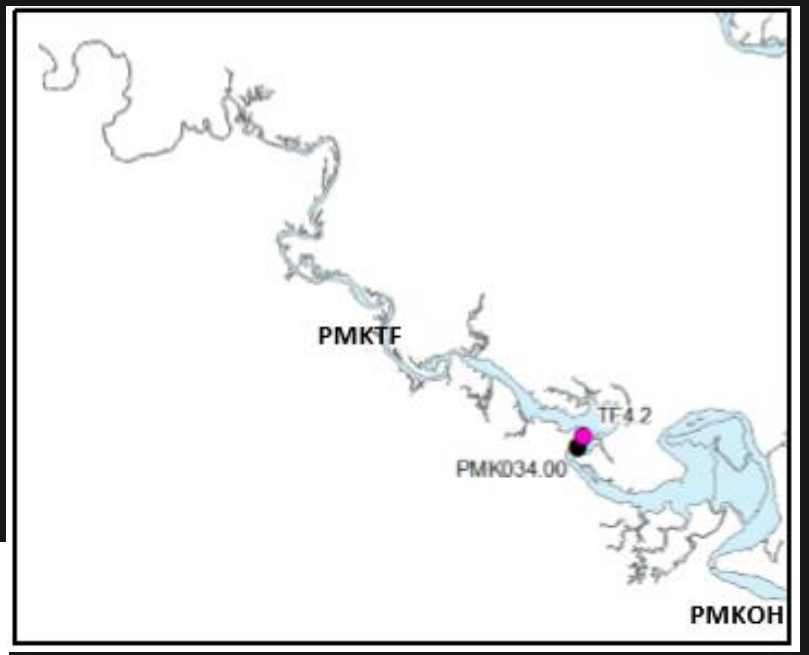


I paired nine ConMons with nearest midchannel stations



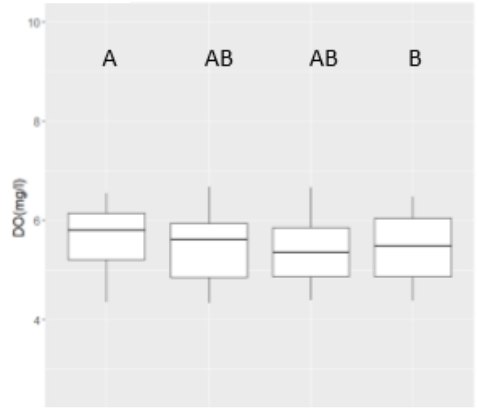
ConMon station

Mid-channel station



Summer samples from PMK034.00 matched within 15 minutes of samples taken at TF4.2(n=19) at the surface (1-m), middle (3-m) and bottom (6-m) of the Open Water habitat. Letters represent statistically similar groups ($p \geq 0.05$, Nemenyi post hoc test). Data represent the summer seasons of the 2013-2018 period.

TF4.2



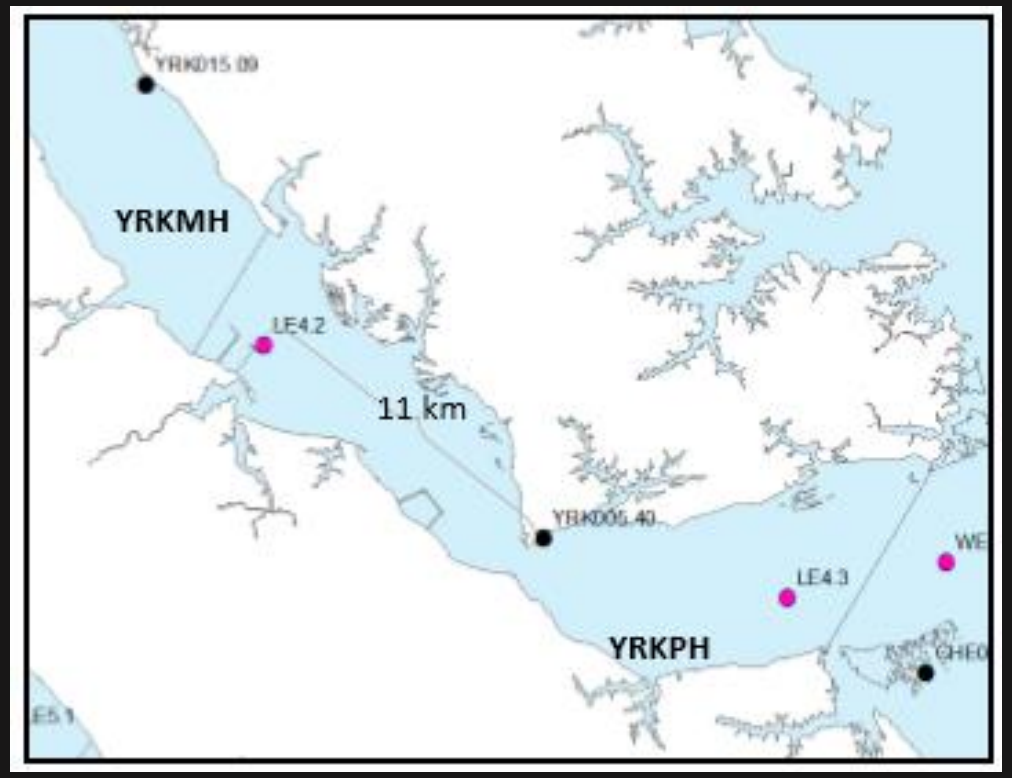
Lots of similarity between ConMon and mid-channel data

Correlation matrix for time-matched samples taken at ConMon station PMK034.00 and at different depth intervals at stations TF4.2. (Spearman's correlation coefficients, $p<0.05$ shown in bold).

TF4.2 (n=19)

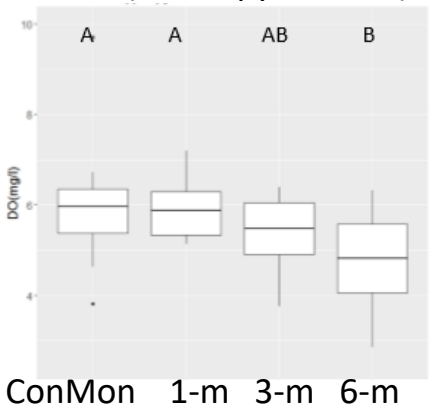
	ConMon	1-m	3-m	6-m
ConMon		**0.86**	**0.89**	**0.82**
1-m	**0.86**		**0.95**	**0.92**
3-m	**0.89**	**0.95**		**0.92**
6-m	**0.82**	**0.92**	**0.92**	

Strong correlation between ConMon and mid-channel data

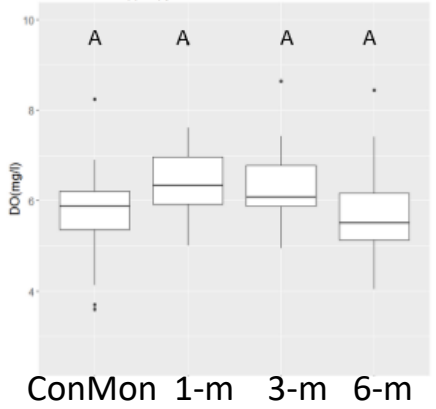


Summer samples from YRK005.40 matched within 15 minutes of samples taken at LE4.2 (n=21) and LE4.3 (n=20) at the surface (1-m), middle (6-m and 3-m, respectively) and bottom (12-m and 4-m, respectively) of the Open Water habitat. Letters represent statistically similar groups ($p \geq 0.05$, Nemenyi post hoc test). Average monthly pycnocline depths (based on 2006-2008 interpolations) were used to delineate Open Water from Deep Water uses. Data represent the summer seasons of the 2013-2018 period.

LE4.2 (above pycnocline)



LE4.3 (above pycnocline)



Lots of similarity between ConMon and SOME mid-channel data

Correlation matrix for time-matched samples taken at ConMon station YRK005.40 and at different depth intervals at stations LE4.2 and LE4.3. (Spearman's correlation coefficients, $p<0.05$ shown in bold).

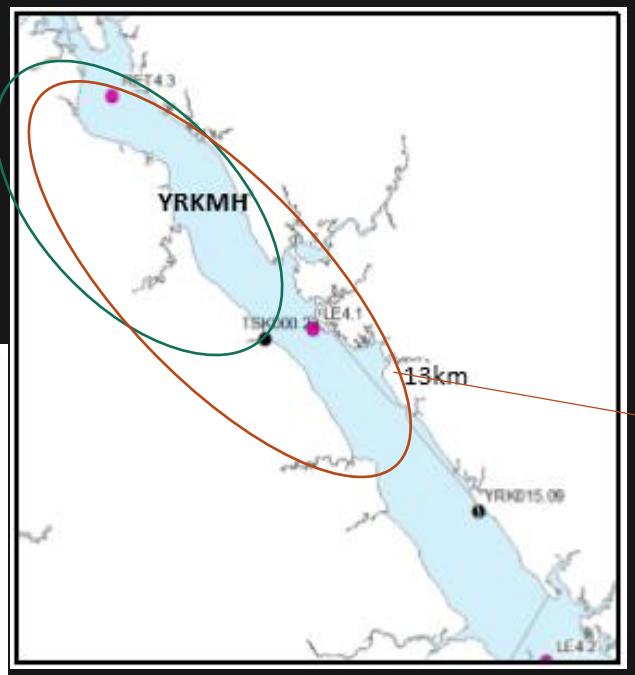
LE4.2 (n=21)

	ConMon	1-m	3-m	6-m
ConMon		0.07	**0.52**	0.21
1-m	0.07		**0.45**	0.23
3-m	**0.52**	**0.45**		**0.61**
6-m	0.21	0.23	**0.61**	

LE4.3 (n=20)

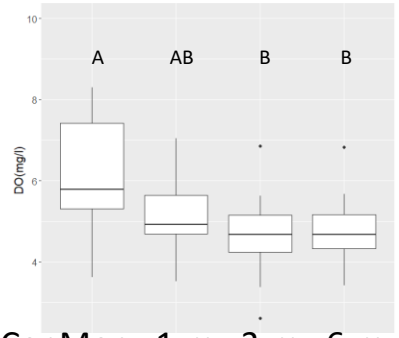
	ConMon	1-m	3-m	6-m
ConMon		**0.56**	**0.53**	**0.54**
1-m	**0.56**		**0.75**	**0.48**
3-m	**0.53**	**0.75**		**0.66**
6-m	**0.54**	**0.48**	**0.66**	

Moderate correlation between ConMon and SOME mid-channel data

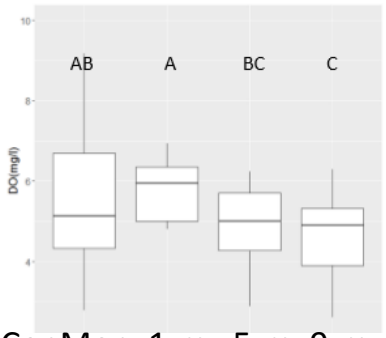


Summer samples from TSK000.23 matched within 15 minutes of samples taken at RET4.3 (n=19) and LE4.1 (n=20) at the surface (1-m), middle (3-m and 5-m, respectively) and bottom (6-m and 9-m, respectively) of the Open Water habitat. Letters represent statistically similar groups (p≥0.05, Nemenyi post hoc test). Data represent the summer seasons of the 2013-2018 period.

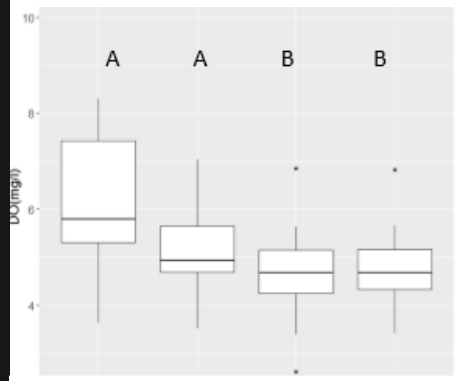
RET4.3



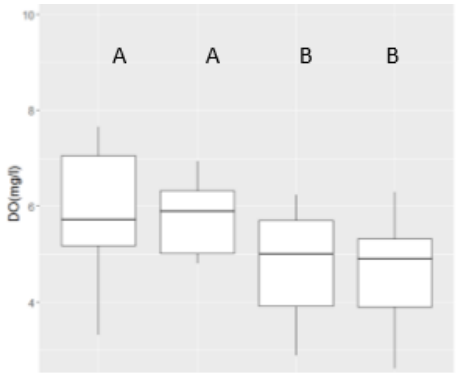
LE4.1



RET4.3



LE4.1



Correlation matrix for time-matched samples taken at ConMon station TSK000.23 and at different depth intervals at stations RET4.3 and LE4.1. (Spearman's correlation coefficients, p<0.05 shown in bold).

RET4.3 (n=19)

	ConMon	1-m	3-m	6-m
ConMon		0.14	0.24	0.17
1-m	0.14		**0.75**	**0.69**
3-m	0.24	**0.75**		**0.98**
6-m	0.17	**0.69**	**0.98**	

LE4.1 (n=20)

	ConMon	1-m	5-m	9-m
ConMon		0.26	0.27	0.30
1-m	0.58		0.20	0.15
5-m	0.26	0.20		**0.98**
9-m	0.20	0.15	**0.98**	

Correlation matrix for time-matched samples taken at ConMon station YRK015.40 and at different depth intervals at stations RET4.3 and LE4.1. (Spearman's correlation coefficients, p<0.05 shown in bold).

RET4.3 (n=21)

	ConMon	1-m	3-m	6-m
ConMon		-0.08	-0.10	-0.07
1-m	-0.08		**0.68**	**0.63**
3-m	-0.10	**0.68**		**0.97**
6-m	-0.07	**0.63**	**0.97**	

LE4.1 (n=21)

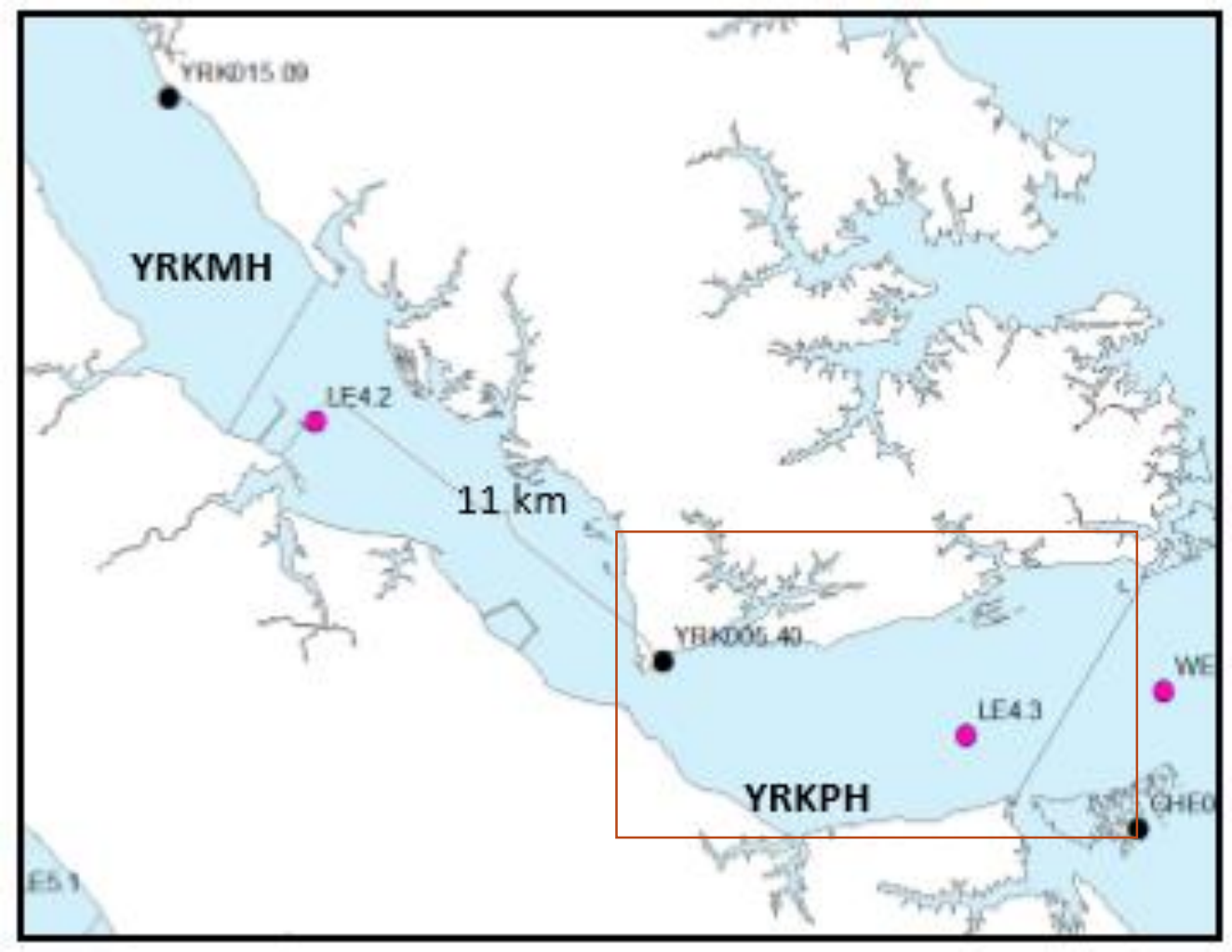
	ConMon	1-m	5-m	9-m
ConMon		**0.58**	0.12	0.08
1-m	**0.58**		0.24	0.18
5-m	0.12	0.24		**0.98**
9-m	0.08	0.18	**0.98**	

Little similarity between ConMon and mid-channel data

No correlation between ConMon and mid-channel data

PMKTF and PMKOH show the most promise as segments that could be fully assessed with respect to short-duration criteria using ConMon.

YRKPH, CB7PH, and MOBPH might be good candidates for a subsegmentation approach.



Perhaps the short-duration criteria for the lower portion of YRKPH could be assessed using ConMon data @ YRK005.40?

Another

We should consider a weight-of-(no) evidence approach to short-duration criteria

"If an assessment dataset for a segment shows….

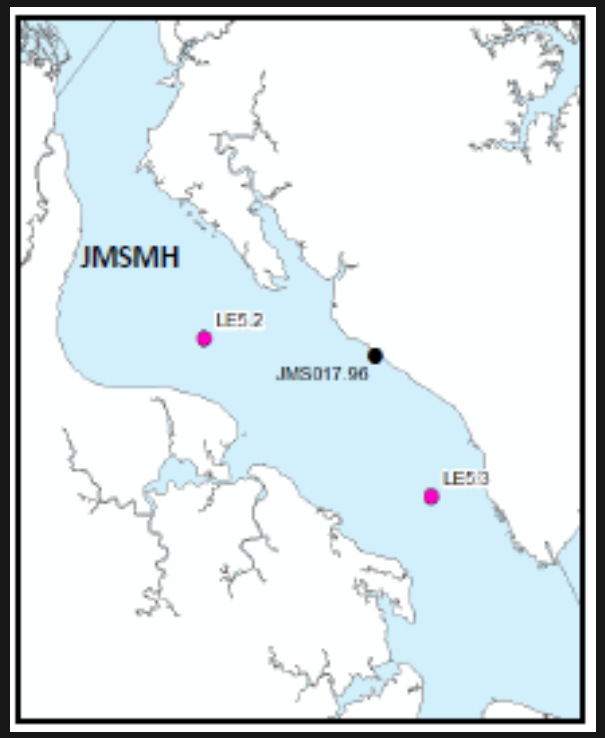
- no exceedances of any of the applicable short-duration criteria in a ConMon dataset spanning all three summers of the assessment period

AND

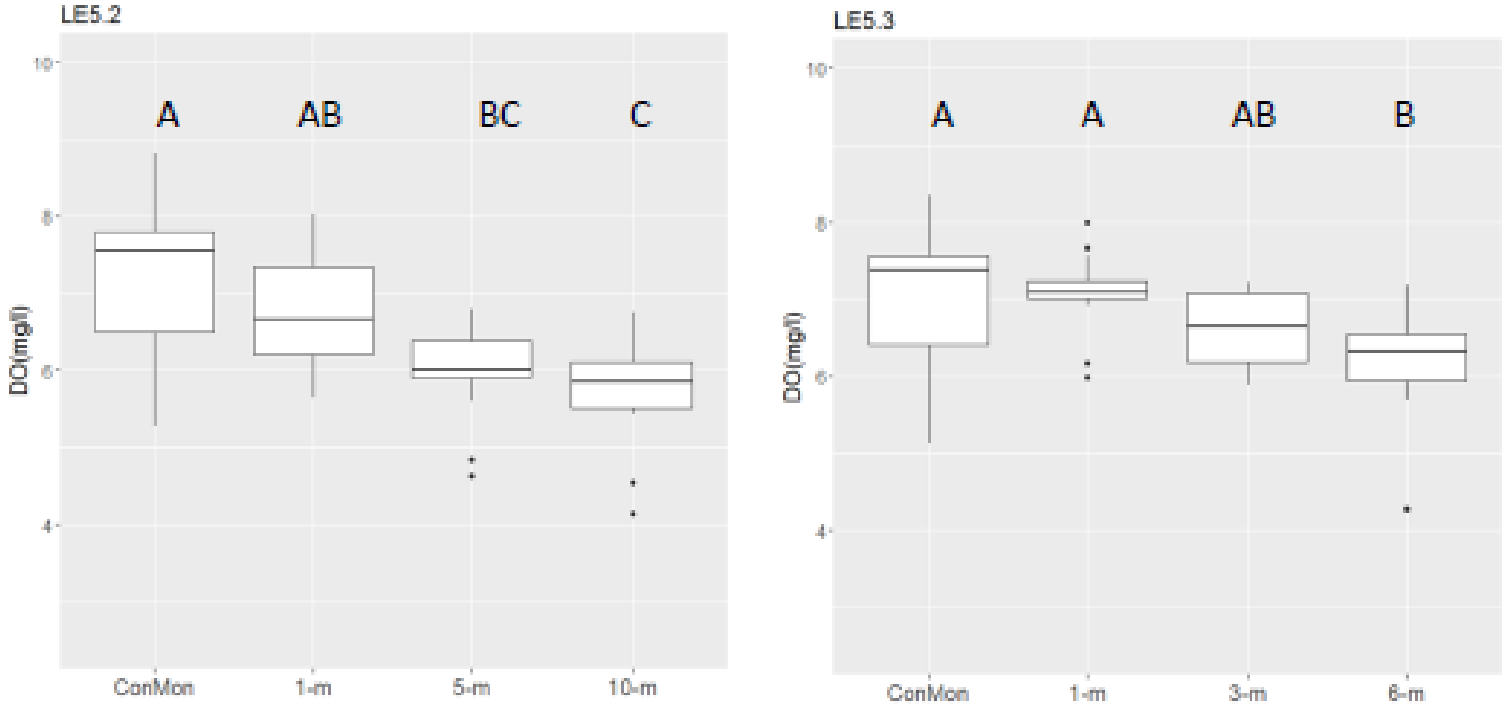
- no observations of low DO* in all other data covering the same time span,

then attainment of the applicable short-duration criteria can be assumed."

* Values lower than 3.2 mg/l (@ non-high temp) and 4.3 mg/l (@ high temp)



Summer samples from JMS017.96 matched within 15 minutes of samples taken at LE5.2 (n=16) and LE4.3(n=15) at the surface (1-m), middle (4-m and 3-m, respectively) and bottom (6-m and 4-m, respectively) of the Open Water habitat. Letters represent statistically similar groups ($p \geq 0.05$, Nemenyi post hoc test). Data represent the summer seasons of the 2013-2017 period.



No low DO observed by the ConMon or at midchannel stations in this segment

Let’s get as much information as we can out of ConMon data!

Please use me!
☺