

Virginia Province Approach to DO Criteria Setting

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Virginia Province Approach (VPA)

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- **Method for developing DO criteria that is similar to that used for developing toxics criteria**
 - Relies on Laboratory data: LC50 values (lethality) and selected NOEC/HOEC value endpoints (primarily growth)
 - Relies primarily on the 4 most sensitive species for which DO sensitivity data are available and the total number of genera with data available
 - Should (must?) have a frequency and duration (averaging period) components associated with criterion concentration (magnitude)

The VPA, like the toxics criteria methodology, does not yield site-specific DO criteria

United States
Environmental Protection
Agency

Office of Water
4304

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Ambient Aquatic Life Water Quality Criteria for Dissolved Oxygen (Saltwater): Cape Cod to Cape Hatteras

Site-Specific DO Criteria Using the VPA:

- Requires knowledge of species that could reasonably occur at the site and life stages that occur and when they occur
- Requires DO sensitivity data for each species **or for a taxonomically close surrogate.**
- Available species sensitivity data is a major limiting factor in developing site-specific DO criteria using the VPA. Other limiting factors include:
 - Information on effects other than lethality or growth (e.g., avoidance, spawning behavior, reproduction success)
 - Surrogates consider taxonomic similarity, not necessarily ecological similarity

Steps to Derive Criteria Using the VPA

- Develop list of species present in the waterbody or site of interest
 - Include fish, other vertebrates, and invertebrates
 - Include seasonal residents, anadromous species, and species that use the area for spawning or other life stages
- Identify reported lab sensitivity values; search literature for newly generated values if any. (*Often limited to about 30 species for acute values; fewer for chronic values*)
- Identify local species for which acute survival or chronic growth lab data are available
- Identify potential surrogate species to match DO data with local species
 - Genus level, family level
- Identify four most sensitive endpoints for acute and chronic sensitivity
- Calculate DO criteria (CMC, CCC, Larval Recruitment Curve)

Surrogate Selection

Species with
available DO data
AND
present in South San
Francisco Bay sloughs



Striped Bass, *Morone saxatilis*
Family: Moronidae

South San Francisco Bay species
(same genus as VPA species)



Green Sturgeon, *Acipenser medirostris*
Family: Acipenseridae

Species with available DO data
(not present in study area)



Atlantic Sturgeon, *Acipenser oxyrinchus oxyrinchus*
Family: Acipenseridae

South San Francisco Bay species
(same family as VPA species)



Pacific Herring, *Clupea pallasii*
Family: *Clupeidae*

Species with available DO data
(not present in study area)



Atlantic Menhaden, *Brevoortia tyrannus*
Family: *Clupeidae*

Species with available DO data that is not present in South San Francisco Bay sloughs for which a member of the same family or genus could not be found



American Lobster, *Homarus americanus*
Family: Nephropidae

Criteria Derived Using the VPA

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► Criterion Minimum Concentration (CMC)

- A value that describes the minimum acceptable DO value that is not expected to cause lethality in young/sensitive life stages of aquatic organisms - ***often based on juvenile or subadult stage***

► Criterion Continuous Concentration (CCC)

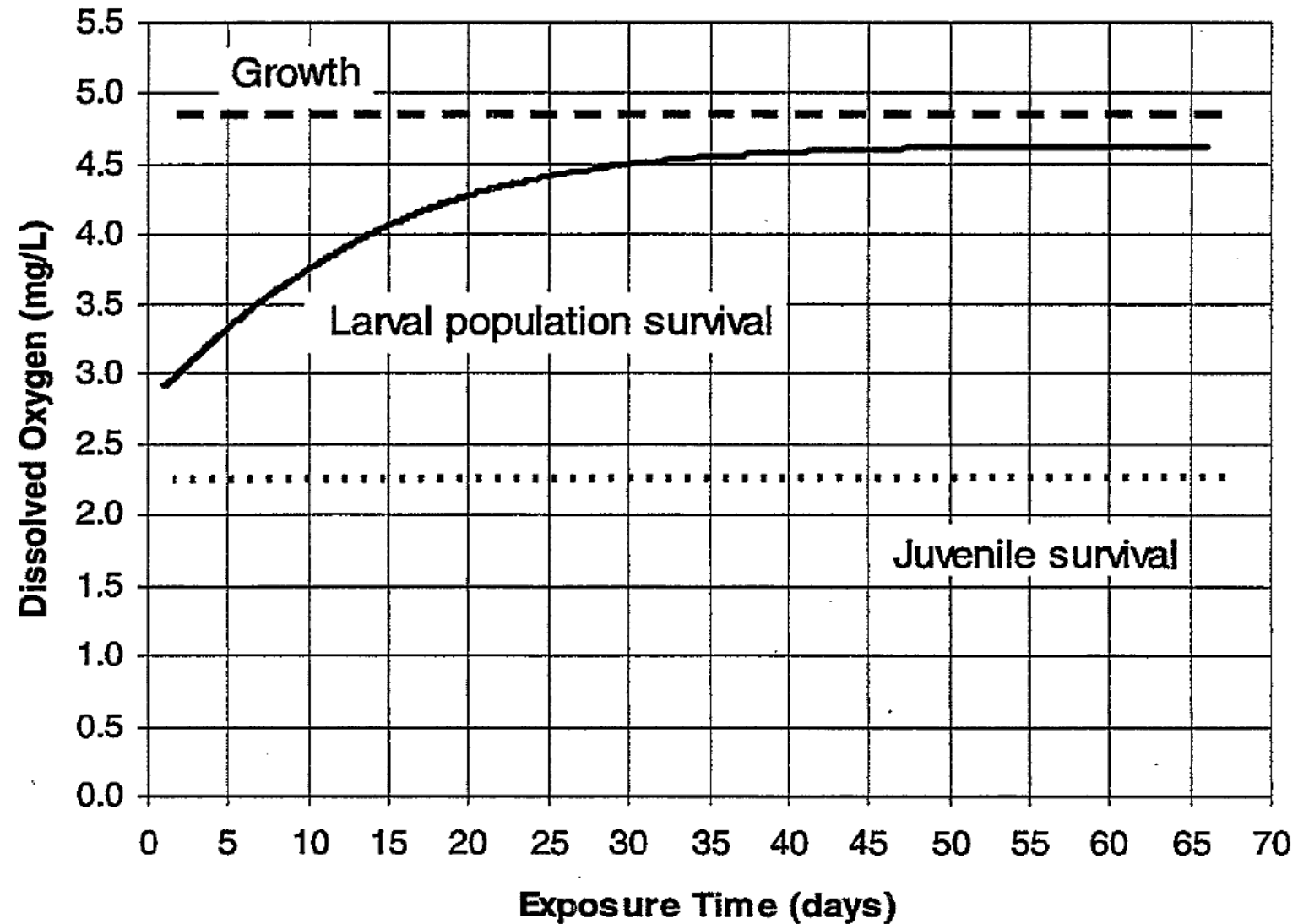
- A value that describes acceptable DO that occurs over an extended period of time and is not expected to cause chronic growth effects in aquatic organisms – ***generally based on larval or juvenile stage***

► Larval Recruitment Curve

- A value that describes concentration of DO that is expected to cause minimal lethality to larval populations.
- Results are time dependent; curve that allows the lowest DO concentrations for short durations and increased DO concentrations for longer durations

Example VPA DO Criteria

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	Common Name	Scientific Name	Genus Level	Family Level
Chronic Data Available	Atlantic Croaker	<i>Micropogonias undulatus</i>	Surrogate not found	
	Florida Flagfish	<i>Jordanella floridae</i>	Surrogate not found	
	Gulf Killifish	<i>Fundulus grandis</i>		✓
	Salmonids	<i>Oncorhynchus sp.</i>	✓	
	Spider Crab	<i>Libinia emarginata</i>		✓
	Southern Flounder	<i>Paralichthys lethostigma</i>	✓	
	Weakfish	<i>Micropogonias undulatus</i>		✓
Acute and Chronic	American Lobster	<i>Homarus americanus</i>	Surrogate not found	
	Atlantic Menhaden	<i>Brevoortia tyrannus</i>		✓
	Atlantic Rock Crab	<i>Cancer irroratus</i>		✓
	Atlantic Silverside	<i>Menidia menidia</i>	✓	
	Atlantic Sturgeon	<i>Acipenser oxyrinchus oxyrinchus</i>	✓	
	Blue Crab	<i>Callinectes sapidus</i>	Surrogate not found	
	Copepod	<i>Acartia tonsa</i>	✓	
	Daggerblade Grass Shrimp	<i>Palaemonetes pugio</i>		✓
	Eastern Oyster	<i>Crassostrea virginica</i>		✓
	Marsh Grass shrimp	<i>Palaemonetes vulgaris</i>		✓
	Mysid Shrimp	<i>Mysidae</i>		✓
	Northern White Shrimp	<i>Litopenaeus setiferus</i>	Surrogate not found	
	Quahog (Hard clam)	<i>Mercenaria mercenaria</i>		✓
	Say Mud Crab	<i>Dyspanopeus sayi</i>	Surrogate not found	
	Sheepshead Minnow	<i>Cyprinodon variegatus</i>	Surrogate not found	
	Shortnose sturgeon	<i>Acipenser oxyrinchus</i>	✓	
	Spot	<i>Micropogonias undulatus</i>	Surrogate not found	
	Striped Bass	<i>Morone saxatilis</i>	✓	
	Summer Flounder	<i>Paralichthys dentatus</i>	✓	
	Winter Flounder	<i>Pseudopleuronectes americanus</i>		✓

List of species with valid DO sensitivity data

- Yellow: Chronic Data (7 total)
- Orange: Both Chronic & Acute (20 total)

► If a species from this list does not occur at the site, a species of the same genus or family is substituted

Acute Data Available

Common Name	Scientific Name	Genus Level	Family Level
Atlantic Herring	<i>Clupea harengus</i>		✓
Atlantic Surfclam	<i>Spisula solidissima</i>	Surrogate not found	
Bay Anchovy	<i>Anchoa mitchilli</i>		✓
Burry's Octopus	<i>Octopus burryi</i>	Surrogate not found	
Flat mud crab	<i>Eurypanopeus despressus</i>	Surrogate not found	
Four-eye Amphipod	<i>Ampelisca abdita</i>	✓	
Fourspine Stickleback	<i>Apeltes quadracus</i>		✓
Green Crab	<i>Carcinus maenas</i>		✓
Harris Mud Crab	<i>Rithropanopeus harrisii</i>	✓	
Longfin Squid	<i>Loligo pealii</i>	Surrogate not found	
Inland silversides	<i>Menidia beryllina</i>	✓	
Mummichog	<i>Fundulus heteroclitus</i>		✓
Naked Goby	<i>Gobiosoma bosc</i>		✓
Northern Pipefish	<i>Syngnathus fuscus</i>	✓	
Northern Seabrook	<i>Prionotus carolinus</i>	Surrogate not found	
Pinfish	<i>Lagodon rhomboides</i>	Surrogate not found	
Pink Shrimp	<i>Farfantepenaeus duorarum</i>	Surrogate not found	
Pompano	<i>Trachinotus carolinus</i>		✓
Red Drum	<i>Sciaenops ocellatus</i>	Surrogate not found	
Sailfin Molly	<i>Poecilia latipinna</i>		✓
Sand Shrimp	<i>Crangon septemspinosa</i>	✓	
Scaled sardine	<i>Harengula jaguana</i>		✓
Scup	<i>Stenotomus chrysops</i>	Surrogate not found	
Skilletfish	<i>Gobiesox strumosus</i>	Surrogate not found	
Spotted Seatrout	<i>Cynoscion nebulosus</i>		✓
Striped Blenny	<i>Chasmodes bosquianus</i>	Surrogate not found	
Striped Mullet	<i>Mugil cephalus</i>	✓	
Tautog	<i>Tautog onitis</i>	Surrogate not found	
Windowpane	<i>Scophthalmus aquosus</i>	Surrogate not found	

Species with valid acute DO sensitivity data from VPA document and more current literature sources

Genus mean acute DO sensitivity values for species and genera relevant to the site

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South San Francisco Bay Species		Surrogate Species with Available DO Data		GMAV (DO, mg/L)	GMAV % sat
Common Name	Scientific Name	Common Name	Scientific Name		
Pacific Herring	<i>Clupea pallasii</i>	Atlantic Herring	<i>Clupea harengus</i>	2.80	34.5%
Western Mosquitofish	<i>Gambusia affinis</i>	Sailfin Molly	<i>Poecilia latipinna</i>	2.60	35.2%
Rainwater Killifish	<i>Lucania parva</i>	Mummichog	<i>Fundulus heteroclitus</i>	2.40	26.9%
White Sturgeon	<i>Acipenser transmontanus</i>	Atlantic Sturgeon	<i>Acipenser oxyrinchus oxyrinchus</i>	2.37	29.5%
Green Sturgeon	<i>Acipenser medirostris</i>	Shortnose Sturgeon	<i>Acipenser brevirostrum</i>		
American Shad	<i>Alosa sapidissima</i>	Scaled sardine	<i>Harengula jaguana</i>	2.17	28.1%
Threadfin Shad	<i>Dorosoma petenense</i>				
Dungeness Crab	<i>Engraulis mordax</i>	Atlantic Rock Crab	<i>Cancer irroratus</i>	2.15	24.3%
Northern Anchovy	<i>Metacarcinus magister</i>	Bay Anchovy	<i>Anchoa mitchilli</i>	2.11	15.4%
Striped Mullet	<i>Mugil cephalus</i>	Striped Mullet	<i>Mugil cephalus</i>	2.10	26.7%
White Croaker	<i>Genyonemus lineatus</i>	Spotted Seatrout	<i>Cynoscion nebulosus</i>	1.89	24.6%
Pacific Jack Mackerel	<i>Trachurus symmetricus</i>	Pompano	<i>Trachinotus carolinus</i>	1.74	21.8%
Mississippi Silverside	<i>Menidia audens</i>	Atlantic Silverside	<i>Menidia menidia</i>	1.64	20.1%
		Inland Silversides	<i>Menidia beryllina</i>		
Bay Pipefish	<i>Syngnathus leptorhynchus</i>	Northern Pipefish	<i>Syngnathus fuscus</i>	1.63	17.9%
Striped Bass	<i>Morone saxatilis</i>	Striped Bass	<i>Morone saxatilis</i>	1.58	18.3%

Genus mean acute DO sensitivity values (continued)

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		Surrogate Species with Available DO Data		GMAV (DO, mg/L)	GMAV % sat
Common Name	Scientific Name	Common Name	Scientific Name		
Diamond Turbot	<i>Hypsopsetta guttulata</i>	Winter Flounder	<i>Pseudopleuronectes americanus</i>	1.38	15.7%
English Sole	<i>Parophrys vetulus</i>				
Starry Flounder	<i>Platichthys stellatus</i>				
Sand Sole	<i>Psettichthys melanostictus</i>				
California Halibut	<i>Paralichthys californicus</i>	Summer Flounder	<i>Paralichthys dentatus</i>	1.37	16.2%
Yellowfin Goby	<i>Acanthogobius flavimanus</i>	Naked Goby	<i>Gobiosoma bosc</i>	1.33	16.1%
Opposum Shrimp	<i>Neomysis mercedis</i>	Mysid Shrimp	<i>Mysidae sp.</i>	1.27	16.0%
Olympia Oyster	<i>Ostrea lurida</i>	Eastern Oyster	<i>Crassostrea virginica</i>	1.15	15.6%
American Shad	<i>Alosa sapidissima</i>	Atlantic Menhaden	<i>Brevoortia tyrannus</i>	1.12	13.4%
Threadfin Shad	<i>Dorosoma petenense</i>				
Native Bay Shrimp	<i>Crangon franciscorum</i>	Sand Shrimp	<i>Crangon septiemspinosa</i>	0.97	10.9%
Threespine Stickleback	<i>Gasterosteus aculeatus</i>	Fourspine Stickleback	<i>Apeltes quadracus</i>	0.91	10.1%
Four-eye Amphipod	<i>Ampelisca abdita</i>	Four-eye Amphipod	<i>Ampelisca abdita</i>	0.9	10.2%
Korean Prawn	<i>Palaemon macrodactylus</i>	Marsh Grass Shrimp	<i>Palaemonetes vulgaris</i>	0.79	9.2%
Siberian Prawn	<i>Exopalaemon modestus</i>	Daggerblade Grass Shrimp	<i>Palaemonetes pugio</i>		
Japanese Little Neck Clam	<i>Venerupis philippinarum</i>	Quahog (Hard Clam)	<i>Mercenaria mercenaria</i>	0.71	8.5%
Harris Mud Crab	<i>Rithropanopeus harrisi</i>	Harris Mud Crab	<i>Rithropanopeus harrisi</i>	0.51	4.6%
Green Crab	<i>Carcinus maenas</i>	Green Crab	<i>Carcinus maenas</i>	0.34	3.8%
Acartia sp	<i>Acartia sp</i>	Copepod	<i>Acartia tonsa</i>	0.19	2.1%

Ranked genus mean acute toxicity values

Common	Scientific Name	GMAV	Rank
Atlantic Herring	<i>Clupea harengus</i>	2.80	27
Sailfin Molly	<i>Poecilia latipinna</i>	2.6	26
Mummichog	<i>Fundulus heteroclitus</i>	2.4	25
Atlantic/Shortnose Sturgeon	<i>Acipenser oxyrinchus oxyrinchus/ brevirostrum</i>	2.37	24
Scaled sardine	<i>Harengula jaguana</i>	2.17	23
Atlantic Rock Crab	<i>Cancer irroratus</i>	2.15	22
Bay Anchovy	<i>Anchoa mitchilli</i>	2.11	21
Striped Mullet	<i>Mugil cephalus</i>	2.10	20
Spotted Seatrout	<i>Cynoscion nebulosus</i>	1.89	19
Pompano	<i>Trachinotus carolinus</i>	1.74	18
Atlantic/Inland Silverside	<i>Menidia menidia /beryllina</i>	1.64	17
Northern Pipefish	<i>Syngnathus fuscus</i>	1.63	16
Striped Bass	<i>Morone saxatilis</i>	1.58	15
Winter Flounder	<i>Pseudopleuronectes americanus</i>	1.38	14
Summer Flounder	<i>Paralichthys dentatus</i>	1.37	13
Naked Goby	<i>Gobiosoma bosc</i>	1.33	12
Mysid Shrimp	<i>Mysidae sp.</i>	1.27	11
Eastern Oyster	<i>Crassostrea virginica</i>	1.15	10
Atlantic Menhaden	<i>Brevoortia tyrannus</i>	1.12	9
Sand Shrimp	<i>Crangon septiemspinosa</i>	0.97	8
Fourspine Stickleback	<i>Apeltes quadracus</i>	0.91	7
Four-eye Amphipod	<i>Ampelisca abdita</i>	0.90	6
Marsh/Daggerblade Grass Shrimp	<i>Paleomonetes vulgaris/ pugio</i>	0.79	5
Quahog (Hard clam)	<i>Mercenaria mercenaria</i>	0.71	4
Harris Mud Crab	<i>Rithropanopeus harrisii</i>	0.51	3
Green Crab	<i>Carcinus maenas</i>	0.34	2
Copepod	<i>Acartia tonsa</i>	0.19	1

Components used in calculations of CCC and CMC

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Rank	Genus	GMAV	1/GMAV	LN GMAV	(LN GMAV) ²	P=R/(N+1)	sqrt P
24	Acipenser	2.37	0.46	0.8629	0.7446	0.857	0.926
25	Fundulus	2.40	0.42	0.8755	0.7664	0.893	0.945
26	Poecilia	2.60	0.38	0.9555	0.9130	0.929	0.964
27	Clupea	2.80	0.36	1.0296	1.0601	0.964	0.982
			Sum	3.72	3.48	3.64	3.82

P = cumulative probability N = sample size R = rank

$$S^2 = \frac{\sum((\ln GMAV)^2) - ((\sum(\ln GMAV))^2 / 4)}{\sum(P) - ((\sum\sqrt{P}))^2 / 4)}$$

$$S = \sqrt{S^2} \quad P = R/(n + 1)$$

$$L = (\sum(\ln GMAV) - S(\sum(\sqrt{P}))) / 4$$

$$A = S(\sqrt{0.95}) + L$$

$$FAV = e^A$$

Where:

R = rank of sensitivity

GMAV = Genus mean acute value

FAV = Final Acute Value

FAV= 2.710067

Ratio= 1.38 (EPA, 2000)

CMC= 3.74 mg/l

VPA Acute Criterion (CMC) Results

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- Total of 27 relevant genera
- Top 4 most sensitive
 - Pacific Herring
 - Western Mosquitofish
 - Rainwater Killifish
 - White/Green Sturgeon

Criterion	Value (DO mg/L)	% saturation
CMC	3.7	45.6% *

* Based on salinity and temperature of the lab tests

Chronic DO sensitivity values for species relevant to the site

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Site Species		Surrogate Species with Available DO Data		GMCV (DO, mg/L)	GMCV % sat
Common Name	Scientific Name	Common Name	Scientific Name		
Steelhead	<i>Oncorhynchus mykiss</i>	Salmonids	<i>Oncorhynchus</i> sp.	5-6*	61.6%
Chinook salmon	<i>Oncorhynchus tshawytscha</i>				
Majidae sp.	<i>Majidae</i> sp.	Spider Crab	<i>Libinia emarginata</i>	4.67	64.9%
White Sturgeon	<i>Acipenser transmontanus</i>	Shortnose sturgeon	<i>Acipenser brevirostrum</i>	4.26	51.5%
Green Sturgeon	<i>Acipenser medirostris</i>	Atlantic Sturgeon	<i>Acipenser oxyrinchus oxyrinchus</i>		
California Halibut	<i>Paralichthys californicus</i>	Summer Flounder	<i>Paralichthys dentatus</i>	3.33	38.7%
		Southern Flounder	<i>Paralichthys lethostigma</i>		
Mississippi Silverside	<i>Menidia audens</i>	Atlantic Silverside	<i>Menidia menidia</i>	3.30	38.2%
Japanese Little Neck Clam	<i>Venerupis philippinarum</i>	Quahog (Hard clam)	<i>Mercenaria mercenaria</i>	3.17	42.0%
Dungeness Crab	<i>Metacarcinus magister</i>	Atlantic Rock Crab	<i>Cancer irroratus</i>	2.87	32.2%
Pacific Herring	<i>Clupea pallasii</i>	Atlantic Menhaden	<i>Brevoortia tyrannus</i>	2.83	36.5%
Threadfin Shad	<i>Dorosoma petenense</i>				
American Shad	<i>Alosa sapidissima</i>				
Striped Bass	<i>Morone saxatilis</i>	Striped Bass	<i>Morone saxatilis</i>	2.8	38.3%
Opposum Shrimp	<i>Neomysis mercedis</i>	Mysid Shrimp	<i>Mysidae</i> sp.	2.67	33.6%
Diamond Turbot	<i>Hypsopsetta guttulata</i>	Winter Flounder	<i>Pseudopleuronectes americanus</i>	2.2	24.8%
English Sole	<i>Parophrys vetulus</i>				
Starry Flounder	<i>Platichthys stellatus</i>				
Sand Sole	<i>Psettichthys melanostictus</i>				

Chronic DO sensitivity values (continued)

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Site Species		Surrogate Species with Available DO Data		GMCV (DO, mg/L)	GMCV % sat
Common Name	Scientific Name	Common Name	Scientific Name		
Korean Prawn	<i>Palaemon macrodactylus</i>	Marsh Grass Shrimp	<i>Palaemonetes vulgaris</i>	2.17	27.4%
Siberian Prawn	<i>Exopalaemon modestus</i>	Daggerblade Grass Shrimp	<i>Palaemonetes pugio</i>		
Acartia sp.	<i>Acartia sp.</i>	Copepod	<i>Acartia tonsa</i>	2.14	26.4%
White Croaker	<i>Genyonemus lineatus</i>	Weakfish	<i>Cynoscion regalis</i>	2.0	24.6%
Olympia Oyster	<i>Ostrea lurida</i>	Eastern Oyster	<i>Crassostrea virginica</i>	1.5	18.5%
Rainwater Killifish	<i>Lucania parva</i>	Gulf Killifish	<i>Fundulus grandis</i>	1.34	17.1%

Ranked genus mean chronic sensitivity values

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Common	Scientific Name	GMAV	Rank
Salmonids	<i>Oncorhynchus sp.</i>	5-6	16
Spider Crab	<i>Libinia emarginata</i>	4.67	15
Atlantic/Shortnose Sturgeon	<i>Acipenser oxyrinchus oxyrinchus/ brevirostrum</i>	4.26	14
Summer/Southern Flounder	<i>Paralichthys dentatus/lethostigma</i>	3.33	13
Atlantic Silverside	<i>Menidia menidia</i>	3.30	12
Quahog (Hard clam)	<i>Mercenaria mercenaria</i>	3.17	11
Atlantic Rock Crab	<i>Mercenaria mercenaria</i>	2.87	10
Atlantic Menhaden	<i>Brevoortia tyrannus</i>	2.83	9
Striped Bass	<i>Morone saxatilis</i>	2.80	8
Mysid Shrimp	<i>Mysidae sp.</i>	2.67	7
Winter Flounder	<i>Pseudopleuronectes americanus</i>	2.20	6
Marsh/Daggerblade Grass Shrimp	<i>Paleomonetes vulgaris/pugio</i>	2.17	5
Copepod	<i>Acartia tonsa</i>	2.14	4
Weakfish	<i>Cynoscion regalis</i>	2.00	3
Eastern Oyster	<i>Crassostrea virginica</i>	1.50	2
Gulf Killifish	<i>Fundulus grandis</i>	1.34	1

How many significant digits when expressing DO criteria?

EPA Criteria Methodology (Stephan et al 1985) says:

Data reported by original investigators should not be rounded off.
Results of all intermediate calculations should be rounded to four significant digits.

AND

Round both the Criterion Maximum Concentration and the Criterion Continuous Concentration **to two significant digits.**

VPA DO Criteria Document (2000) says:

“Many programs that monitor coastal DO with electronic equipment cannot measure DO to better than 0.5 mg/L due to limitations of instrument accuracy and resolution (e.g., Strobel et al., 1995; Strobel and Heltse, 1999) or sampling design (Summers et al., 1997). Attempts to refine the limits presented here or to apply these limits in assessing field DO conditions should take this into account.”

But there's been much improvement in sensor technology since 2000

Chronic criterion (CCC) using VPA

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- 16 relevant genera
- Most sensitive genera:
 - Salmonids
 - Spider crab
 - White/Green Sturgeon
 - California Halibut

Criterion	Value (DO mg/L)	% saturation
CCC	5.3	65.3% *

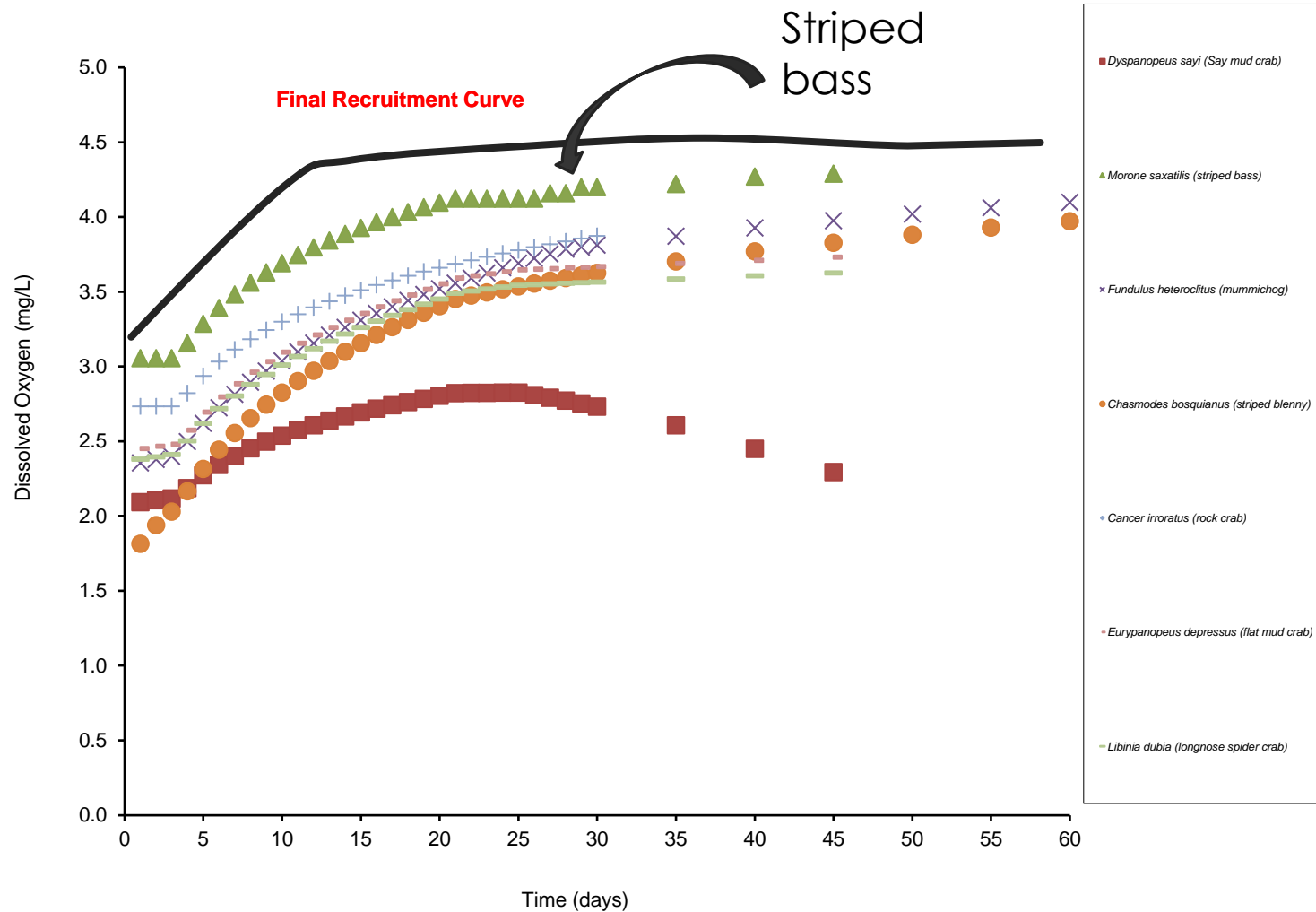
* Based on salinity and temperature in lab tests

Larval Recruitment Results

From USEPA 2000 (VPA)

Surrogate Species	Larval Stage duration (days)	Larval LC50 (mg/L)	Salinity (ppt)	Temp (°C)
Morone saxitalis	35-50	2.42	4-7	18-19
Palaemonetes vulgaris	3 – 6	1.9	29-31	20-20
Dyspanopeus sayi	20	1.98	30-32	19-26
Menidia menidia	21 – 42	1.44	30-32	20-23

Larval Recruitment Results



- **Morone (Striped bass) most sensitive**
- A DO concentration ≥ 4.3 mg/L would be protective of larval recruitment at the site

Virginia Province Calculations with and without salmonids and/or sturgeon

Criterion	Value (DO mg/L)	% saturation
CMC (with Sturgeon)	3.7	45.6%
CMC (without Sturgeon)	3.8	46.8%
CCC (with Salmonids and Sturgeon)	5.3	65.3%
CCC (without Salmonids)	4.3	52.9%
CCC (without Sturgeon)	5.3	65.5%
CCC(without Salmonids and Sturgeon)	4.5	55.4%

Criteria Expressed as Percent Saturation

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Criterion	Value (DO mg/L)	Percent saturation summer	Percent saturation winter
CMC (with Sturgeon)	3.7	43.7%	35.7%
CMC (without Sturgeon)	3.8	44.8%	36.7%
CCC (with Salmonids and Sturgeon)	5.3	62.5%	51.1%
CCC (without Salmonids)	4.3	50.7%	41.5%
CCC (without Sturgeon)	5.3	67.2%	55.0%
CCC(without Salmonids and Sturgeon)	4.5	53.1%	43.4%

Projected percent saturation during winter and summer was determined using the CCC and CMC thresholds and mean temperatures and salinities collected at all sites.

What is a scientifically defensible averaging period?

An instantaneous DO acute criterion (CMC) does not necessarily represent actual potential for harm to aquatic life

- Duration of acute tests used to develop the CMC are between 1-4 days (24-96 hours).
- Some field studies have shown that many species can tolerate low DO levels (< 24 h LC50) for short periods of time (e.g., 1 day). EPA reported 24-h LC50s similar to 48-h LC50s.
- Fish mortality can occur rapidly (< 12 h) to low DO levels for some species. A 24-h averaging period may be under protective in those cases
- Duration of DO levels $< \text{CMC}$ during a 24-h period and across multiple days may need to be considered.

Chronic DO criterion should not be expressed as an instantaneous value.

- Duration of chronic tests used to develop the CCC are between 7-30 days. Generally expressed as a weekly or monthly rolling average.

How can continuous monitoring data help?

Continuous DO monitoring can inform duration and frequency of low DO events:

- Data could be used in conjunction with time-to-death lab data for some sensitive species to evaluate protectiveness of a 24-h average for the CMC.
- Monitoring during summer and maybe other seasons could inform whether different CMCs or averaging periods may be warranted.
- Data could help develop a maximum allowable exceedance rate of the 24-hour average

Example of Criteria Exceedence Thresholds Suisun Marsh

- CMC should be exceeded in no more than 4% of daily average values (15 times per year)
- CCC as 7-day average values should be exceeded no more than 16% of the time (8 times per year).
- The 30-day average value should not fall below the CCC
- The 1-day and 7-day exceedances may occur multiple times in a month, as long as the 30-day CCC is maintained.

Summary of VPA for Criteria Setting

Pros

- Methodology similar to the way aquatic life toxics criteria derived
- Relies on standard lab test data
- Method has been applied and accepted in several locations

Cons

- Does not consider what is achievable naturally
- Toxicity data derived under standard lab conditions – data may be based on life stages or water quality conditions not relevant to a site
- Does not consider potential mitigating factors (e.g., avoidance, prey availability)
- Lab toxicity data available for certain species only; data not available for many resident species of interest

DO Concentration vs. Percent Saturation

- The Virginia Province guidance presents DO data as concentration (mg/L)
 - lab tests across species not substantially different in temp or salinity so percent saturation less of an issue using the VPA approach
- Chesapeake Bay DO criteria expressed as mg/L but did cross check with % saturation for sensitive species – factored in habitat differences and naturally low DO saturation in deep water habitat
- Florida DEP (2013) uses percent saturation DO criteria because it accounts for known seasonal (*i.e.*, temperature) effects on expected DO levels in natural waterbodies
 - Salinity effects not as much an issue for coastal Florida waters where the DO criteria apply

DO Concentration vs. Percent Saturation in Criteria Setting

- Many states choose not to use percent saturation because it requires paired temp, salinity, and DO measurements
 - may be logistically challenging for some programs
- DO criteria expressed as concentration presumes a minimal allowable DO level throughout the year regardless of water temperature and salinity
 - may not be realistic and possibly overprotective for certain sites and seasons