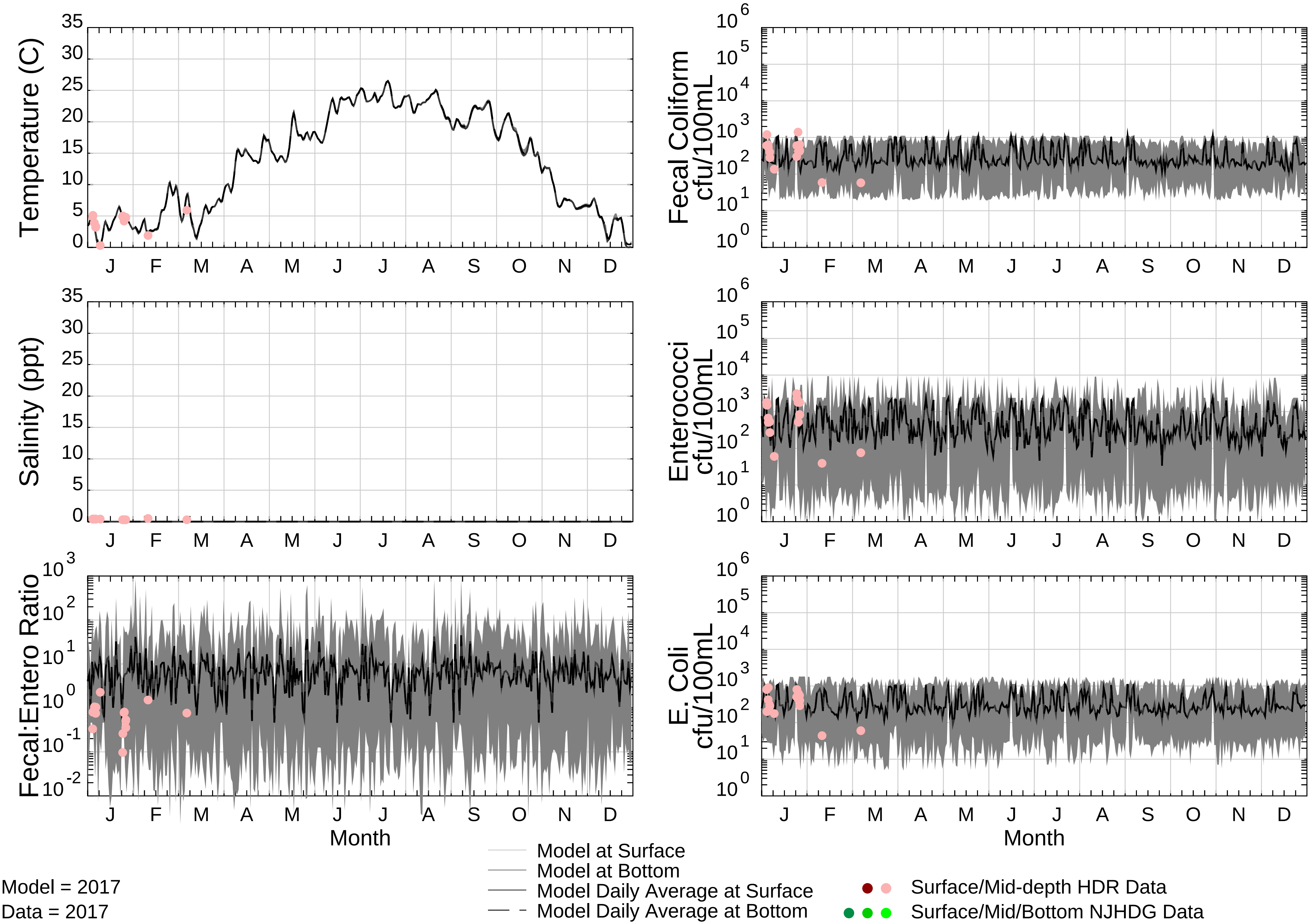
Appendix F

Additional Water Quality Model Validation Figures

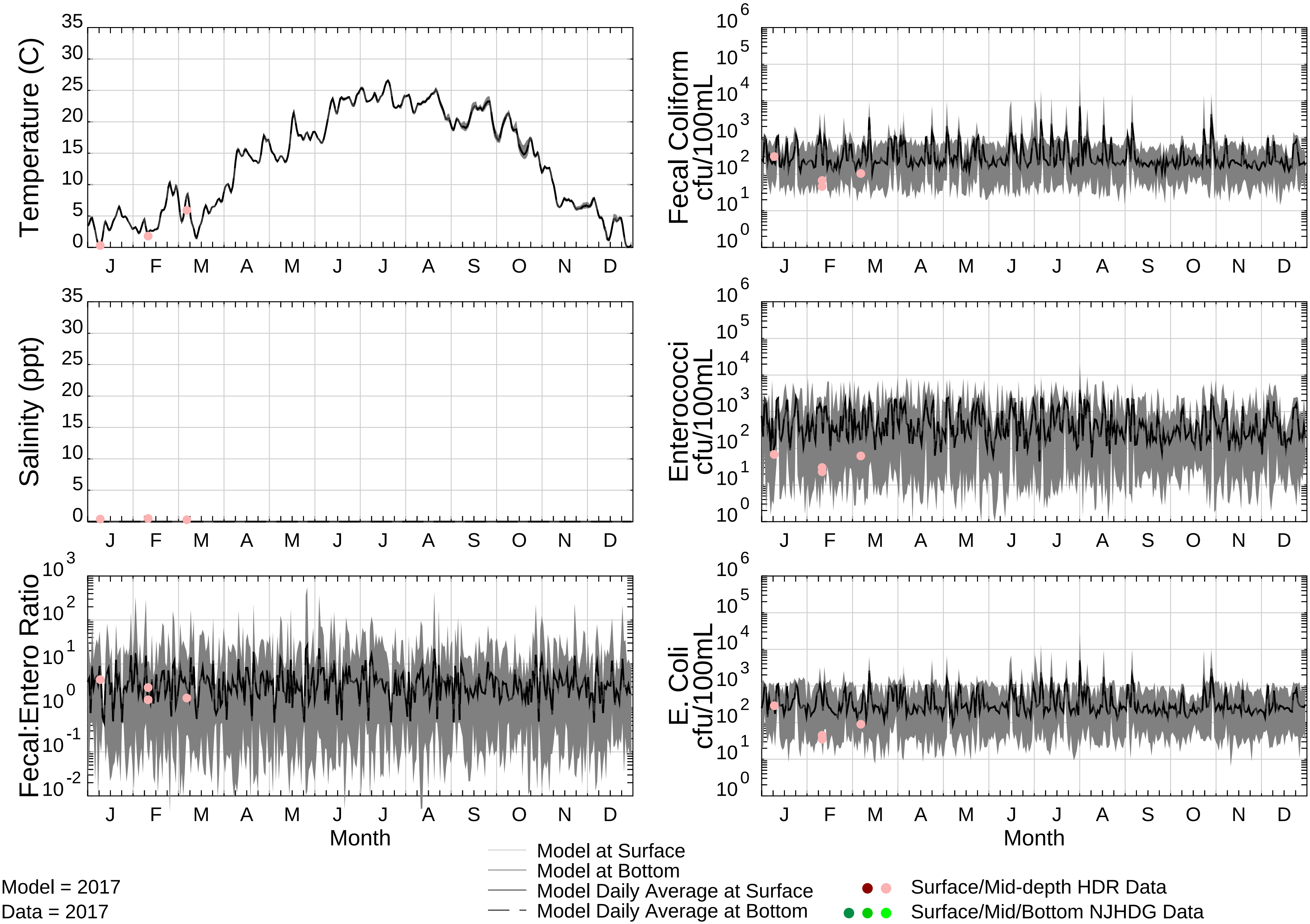
Appendix F-1

Additional Validation Annual Time-Series Figures

Station: B24

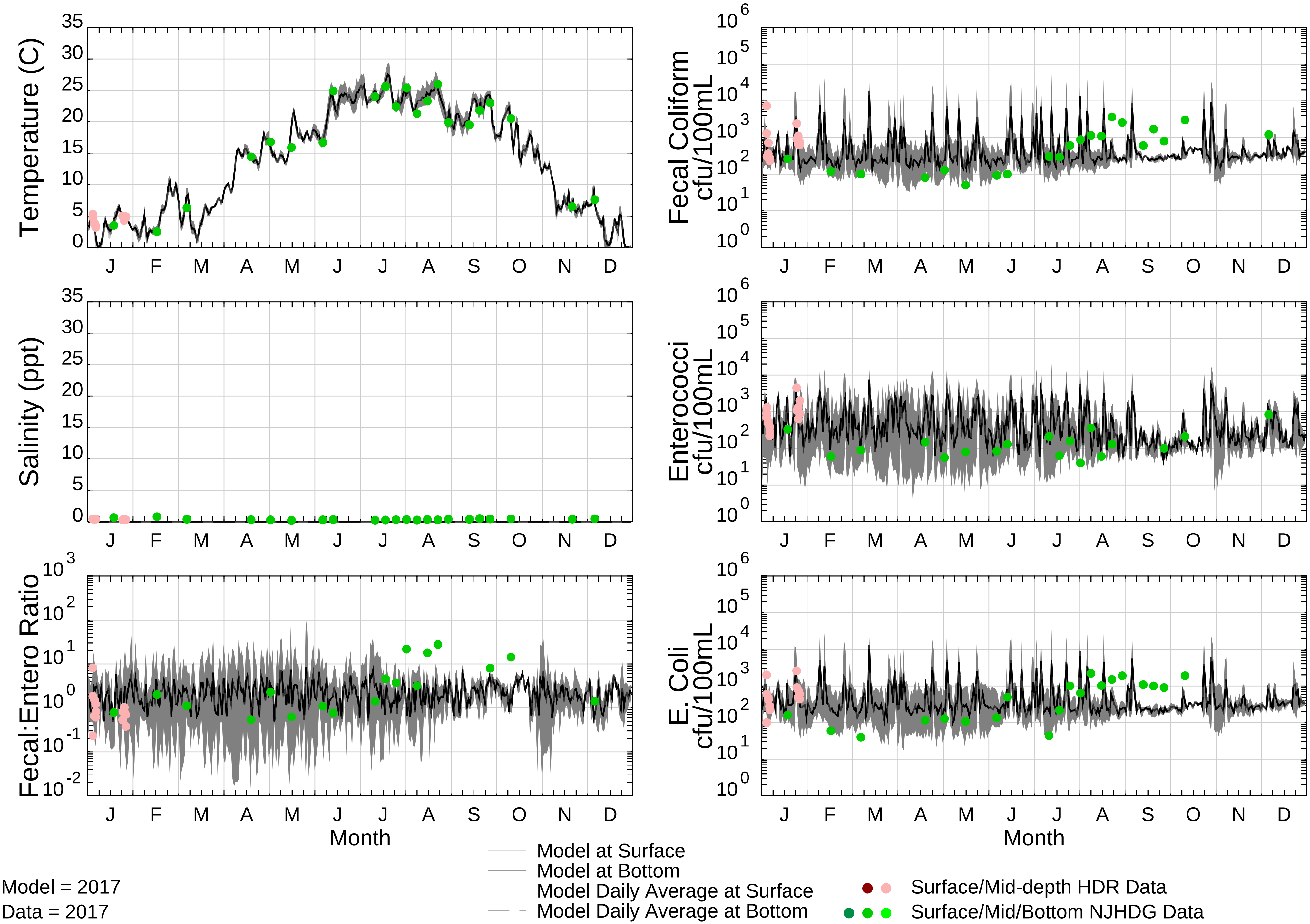

Temperature (C)
Salinity (ppt)
Fecal:Entero Ratio
Fecal Coliform cfu/100mL
Enterococci cfu/100mL
E. Coli cfu/100mL
J F M A M J J A S O N D
Month
Model at Surface
Model at Bottom
Model Daily Average at Surface
Model Daily Average at Bottom
Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data
Model = 2017
Data = 2017

Station: 2

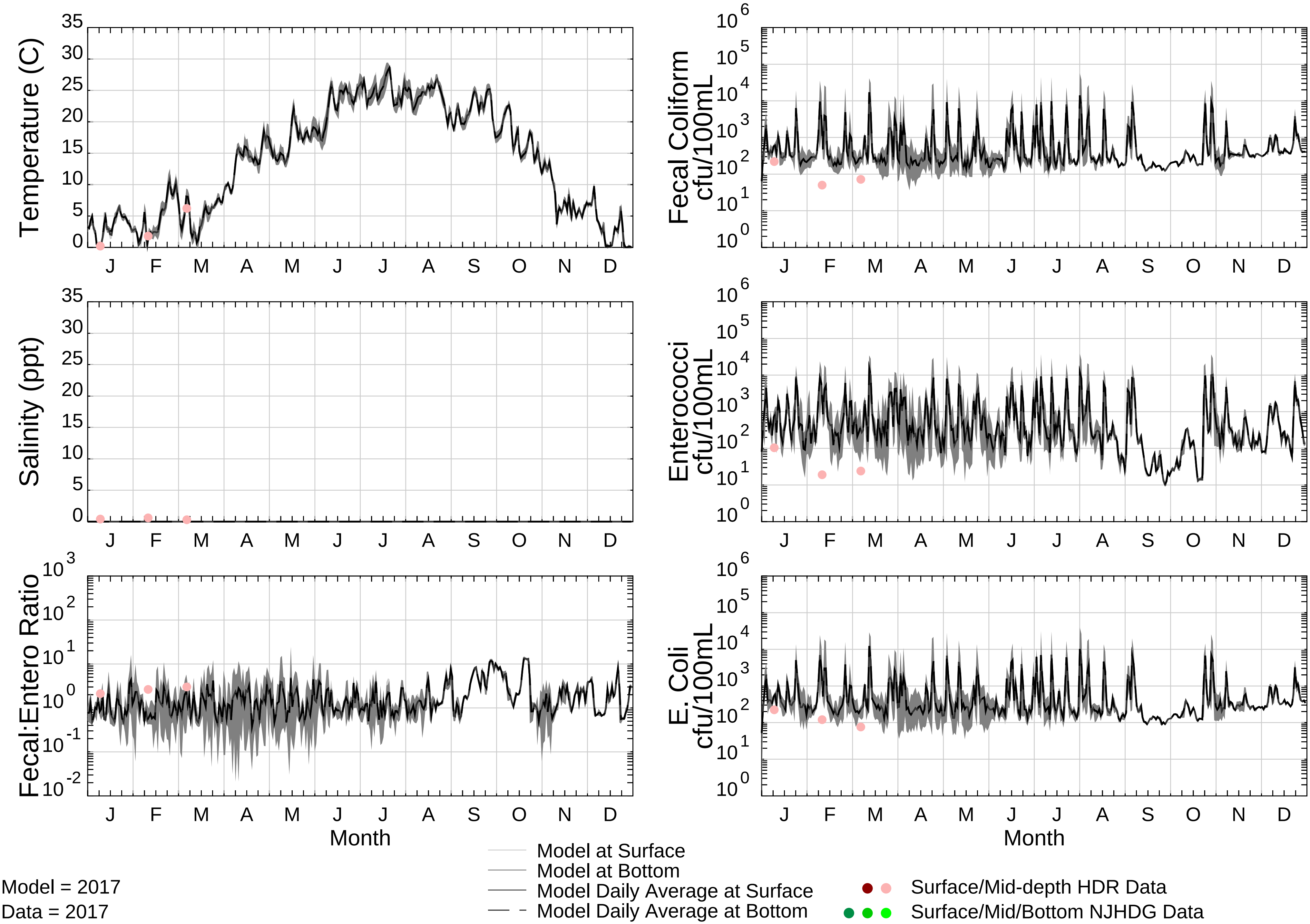


Model = 2017
Data = 2017

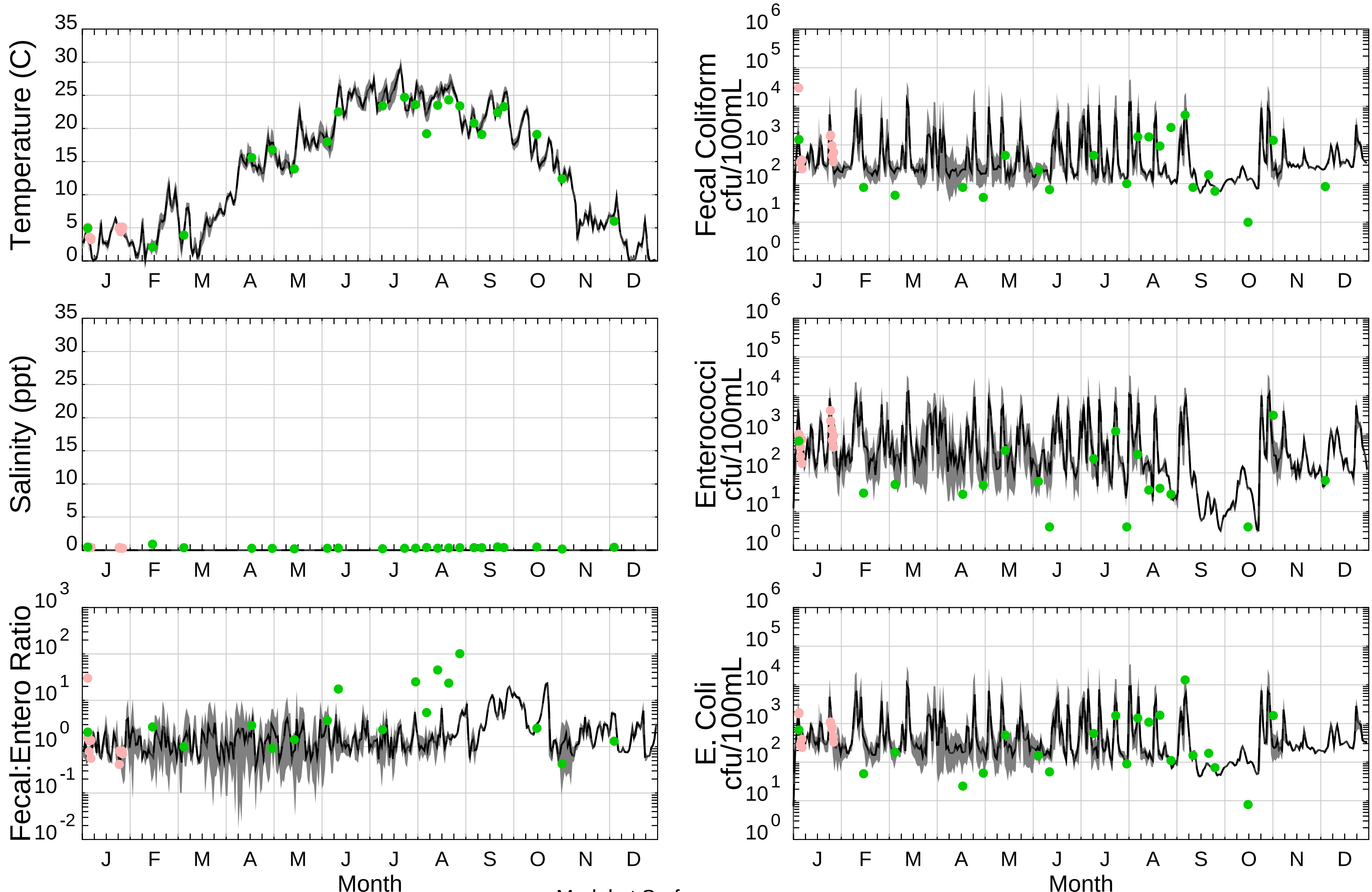
Station: 3


Temperature (C)
Salinity (ppt)
Fecal:Entero Ratio
Fecal Coliform cfu/100mL
Enterococci cfu/100mL
E. Coli cfu/100mL
J F M A M J J A S O N D
Month
Model at Surface
Model at Bottom
Model Daily Average at Surface
Model Daily Average at Bottom
Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data
Model = 2017
Data = 2017

Station: B22


Temperature (C)
Salinity (ppt)
Fecal:Entero Ratio
Fecal Coliform cfu/100mL
Enterococci cfu/100mL
E. Coli cfu/100mL
J F M A M J J A S O N D
Month
Model at Surface
Model at Bottom
Model Daily Average at Surface
Model Daily Average at Bottom
Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data
Model = 2017
Data = 2017

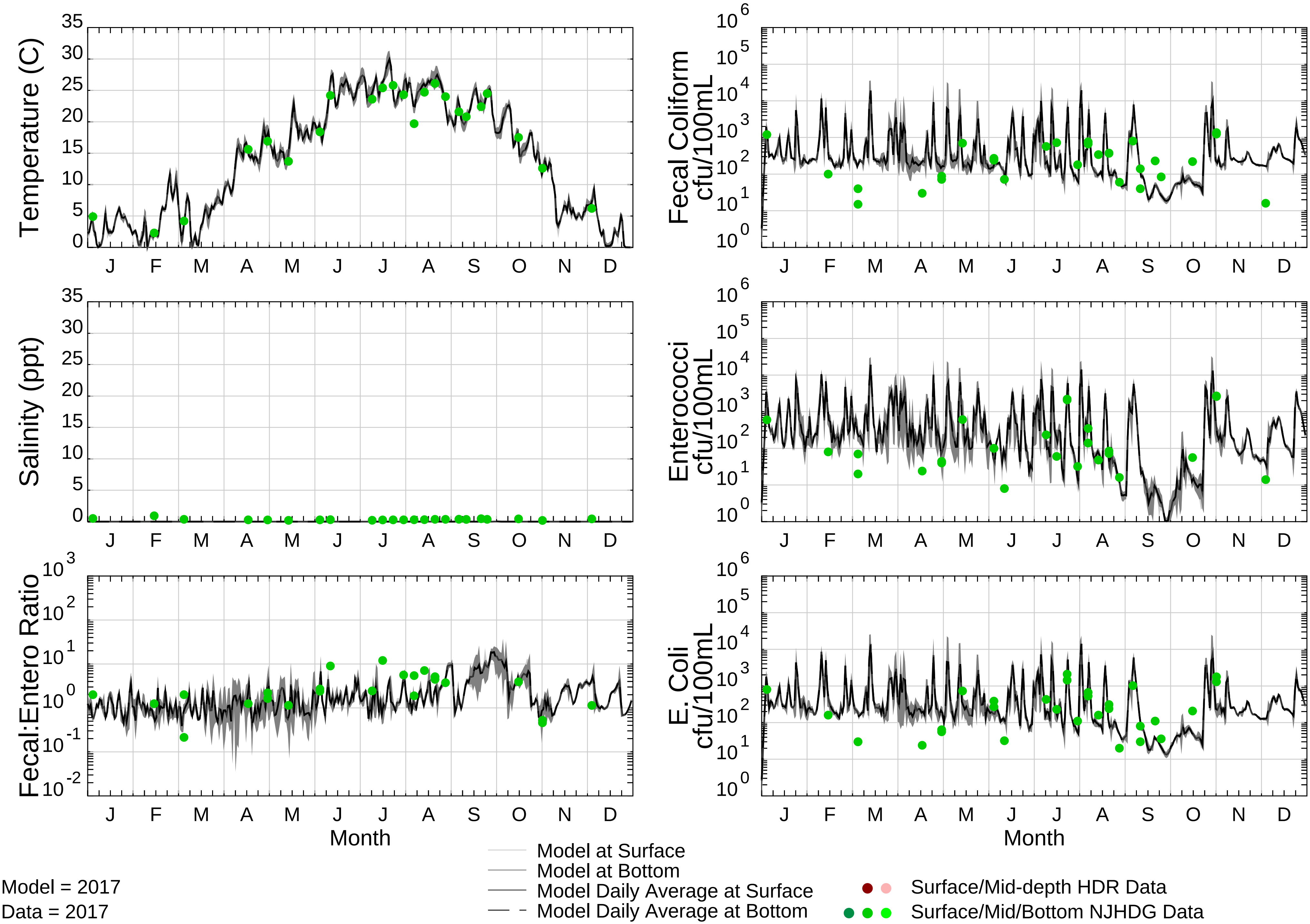
Station: 4



Model at Surface
Model at Bottom
Model Daily Average at Surface
Model Daily Average at Bottom
Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

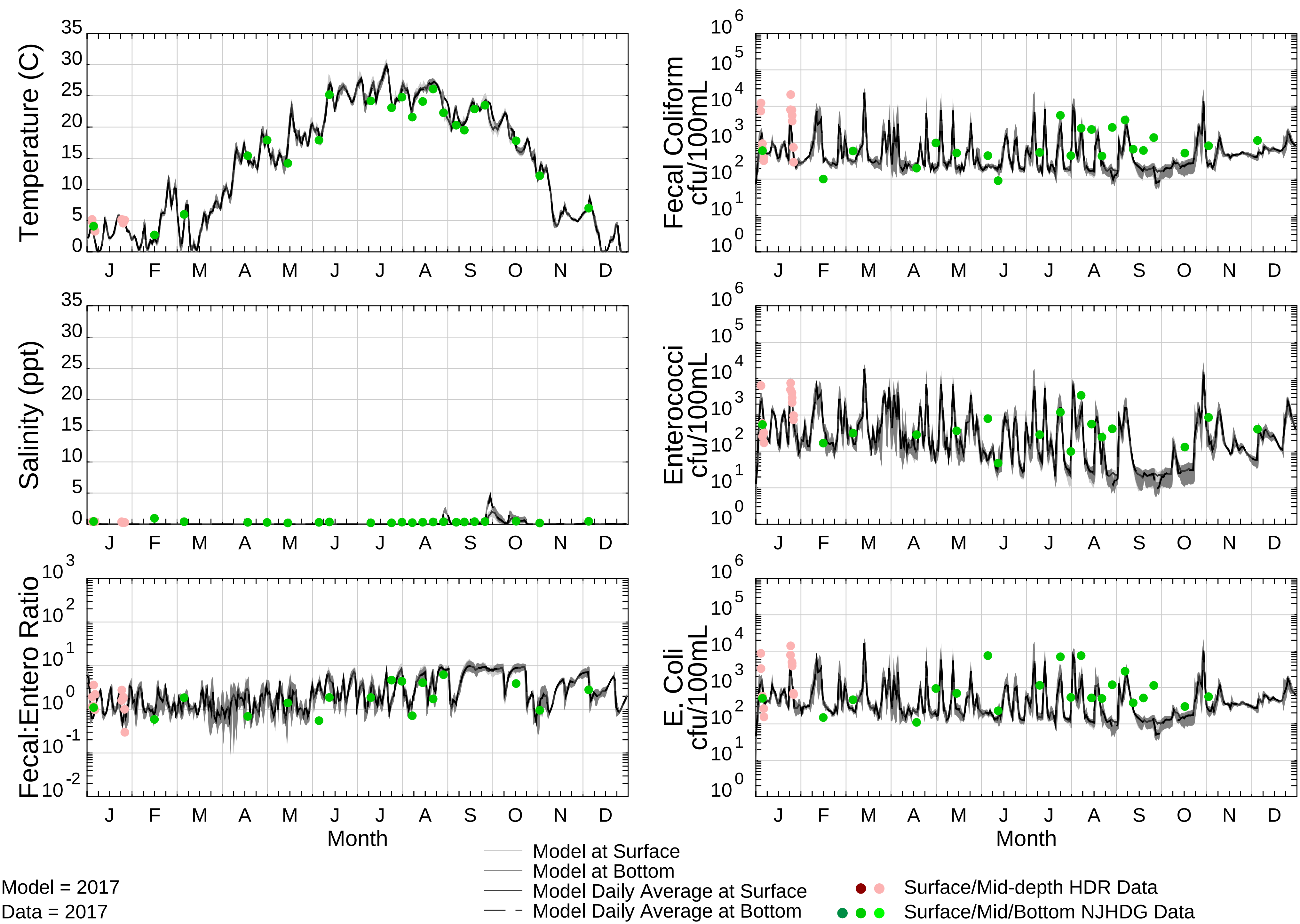
Model = 2017
Data = 2017

Station: 5



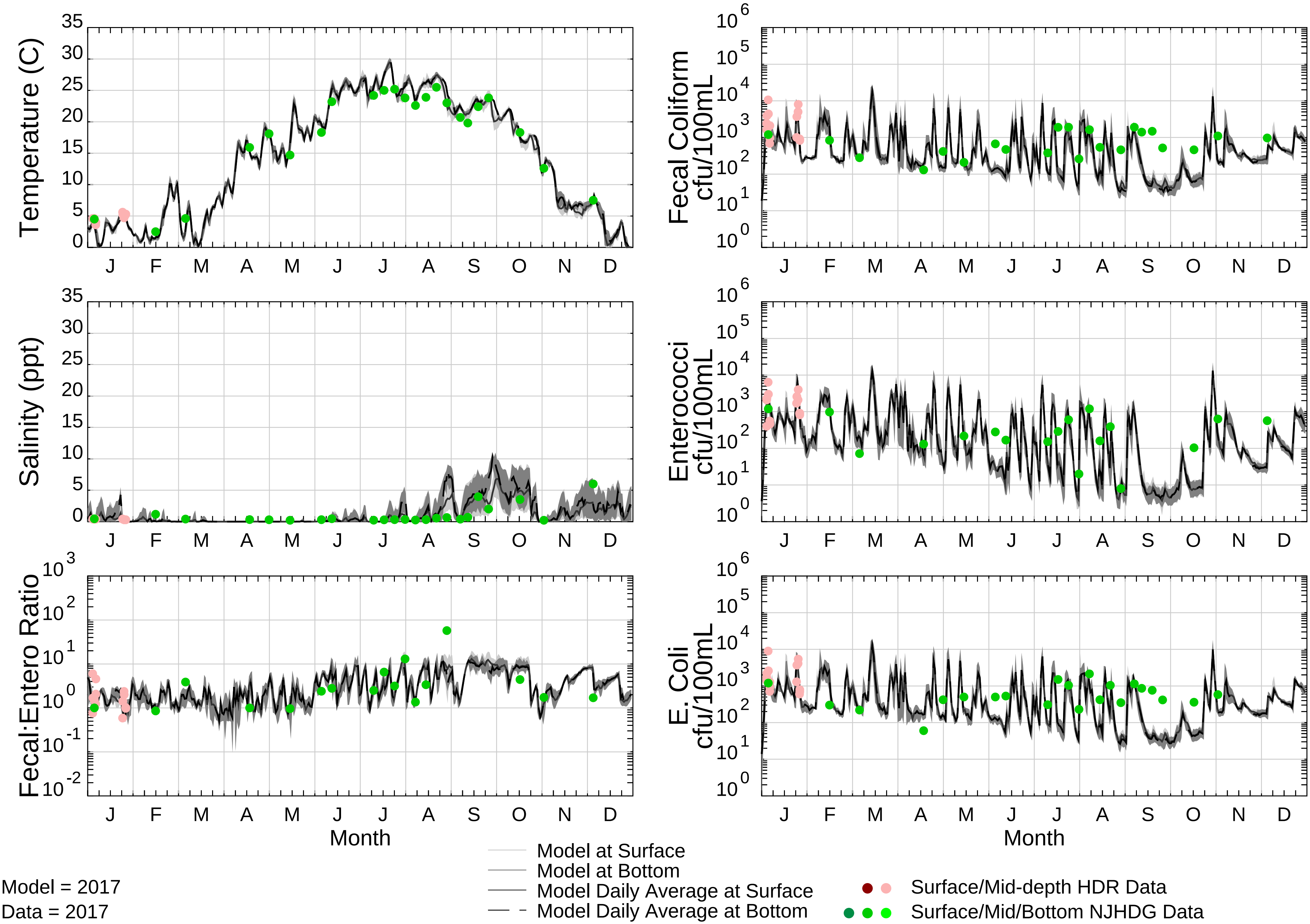
Model = 2017
Data = 2017

Station: 7



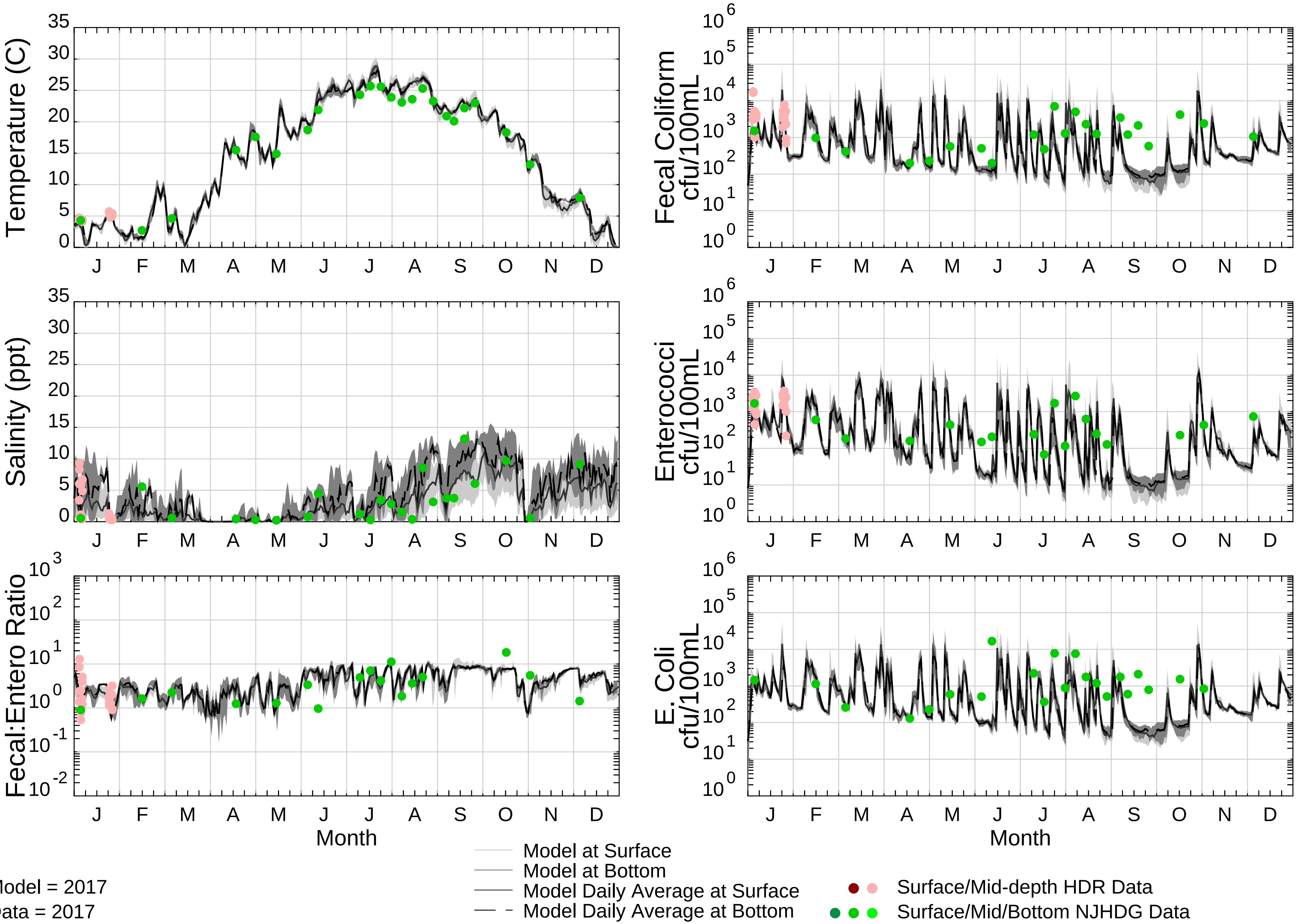
Model = 2017
Data = 2017

Station: 8



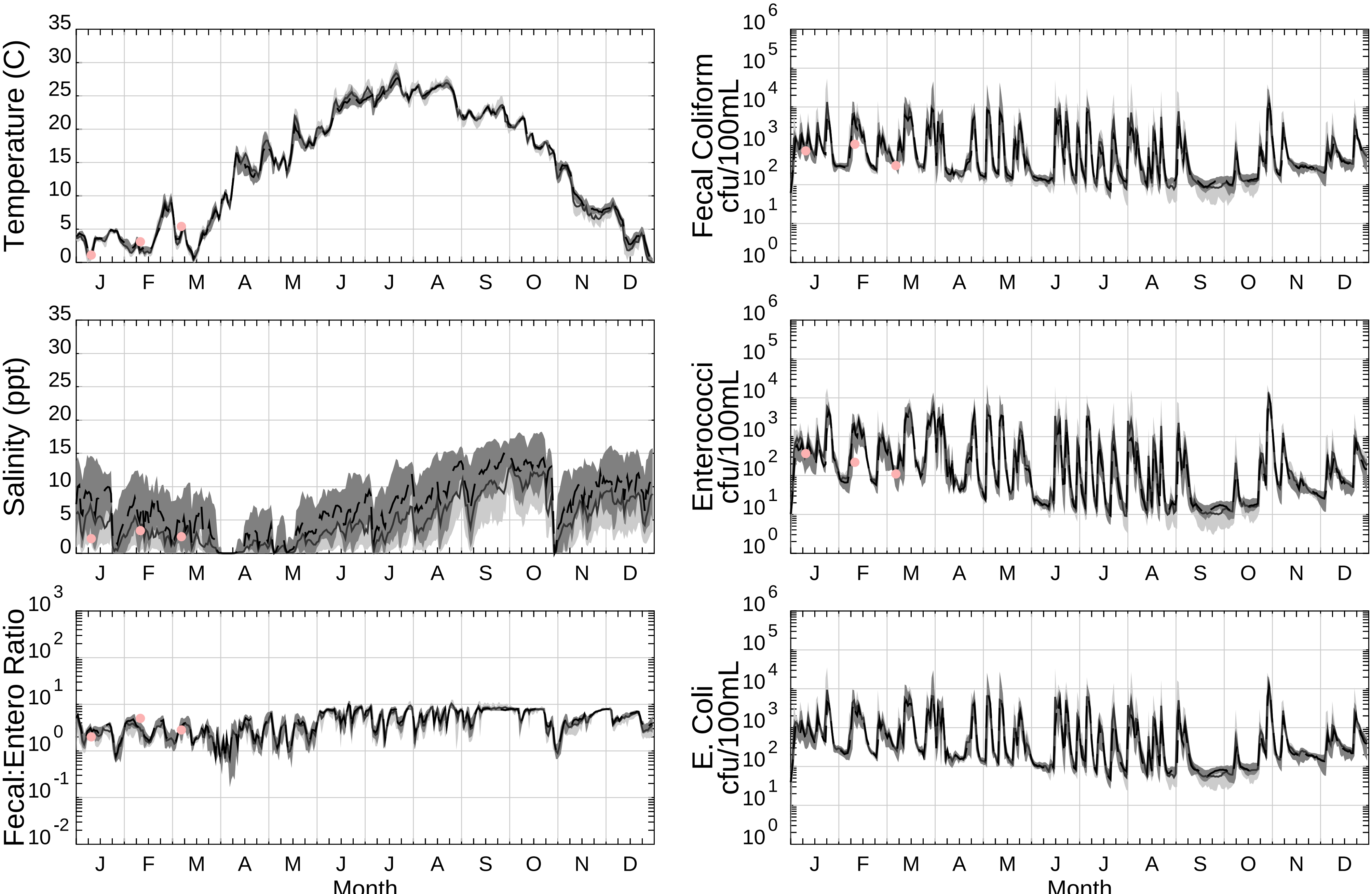
Model = 2017
Data = 2017

Station: 10



Model = 2017
Data = 2017

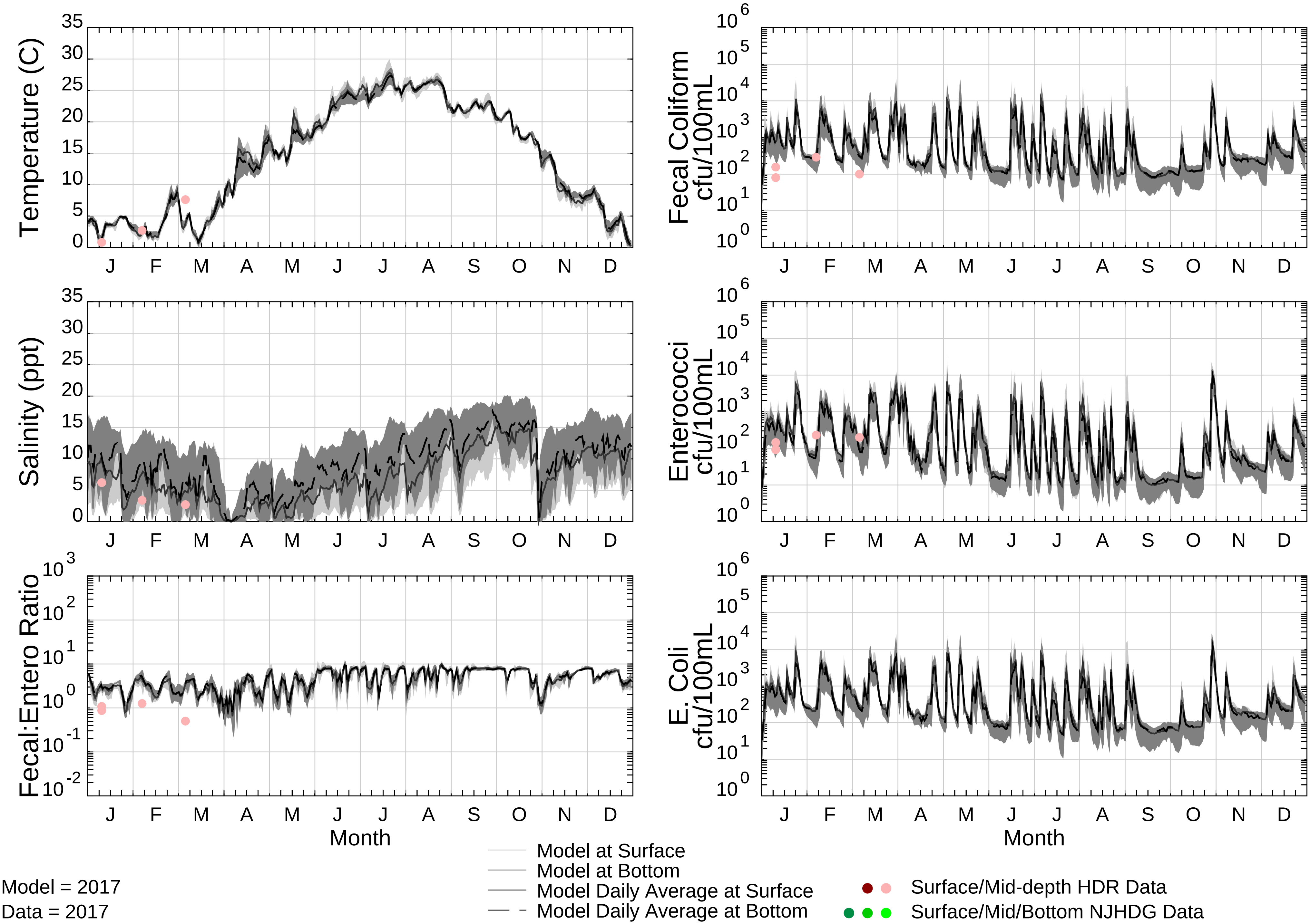
Station: 11



Model at Surface
Model at Bottom
Model Daily Average at Surface
Model Daily Average at Bottom
Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

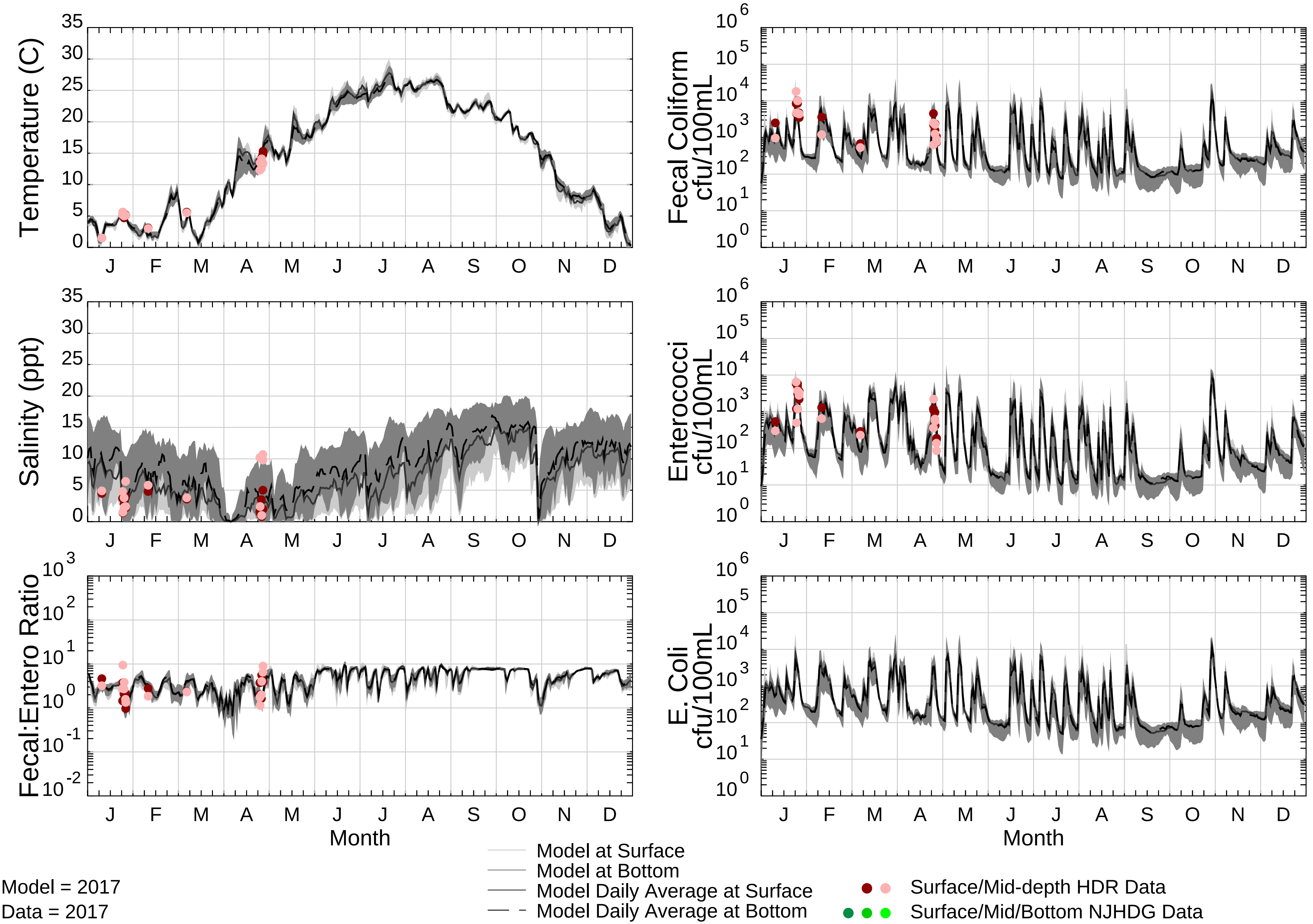
Model = 2017
Data = 2017

Station: B8



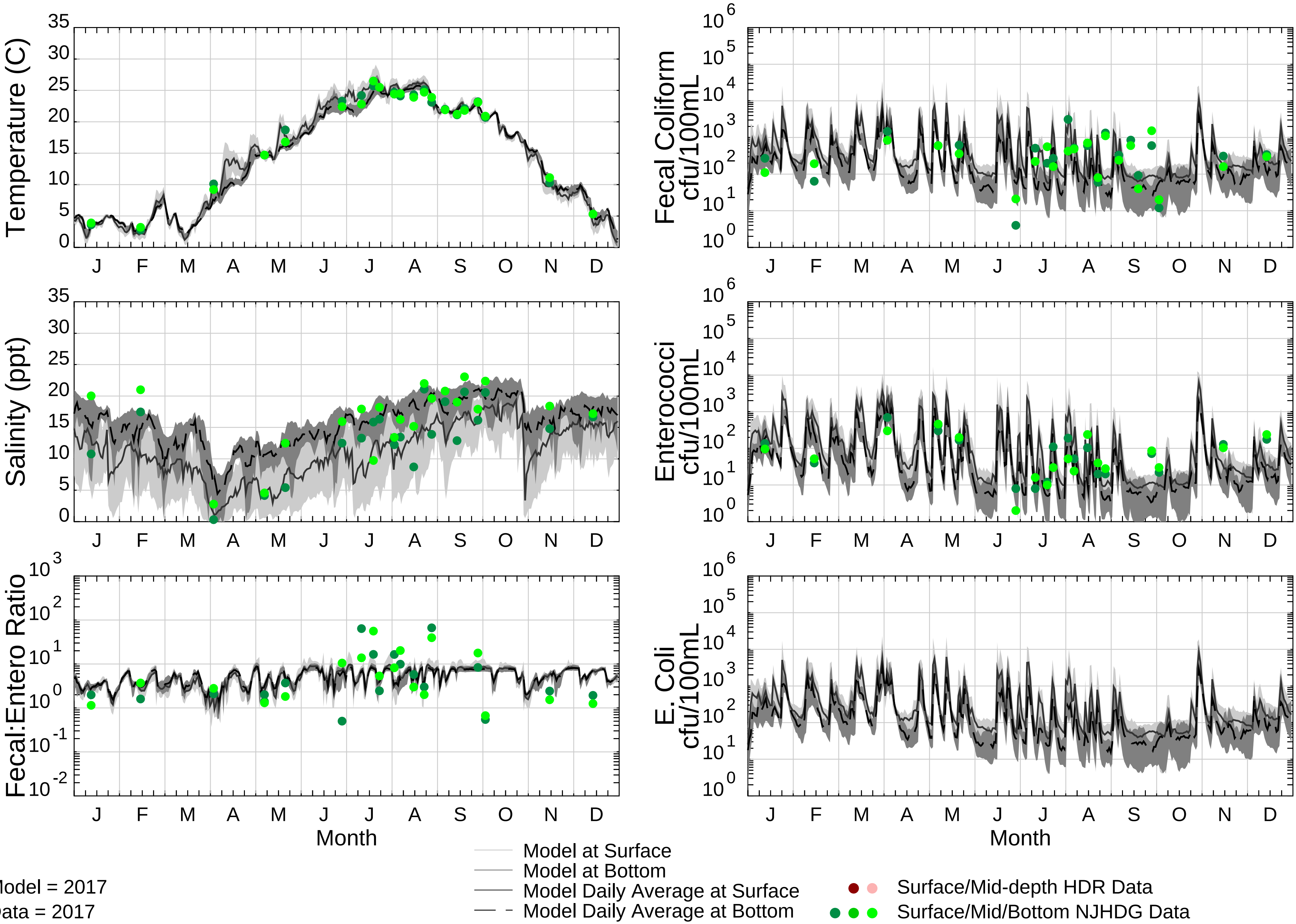
Model = 2017
Data = 2017

Station: B6



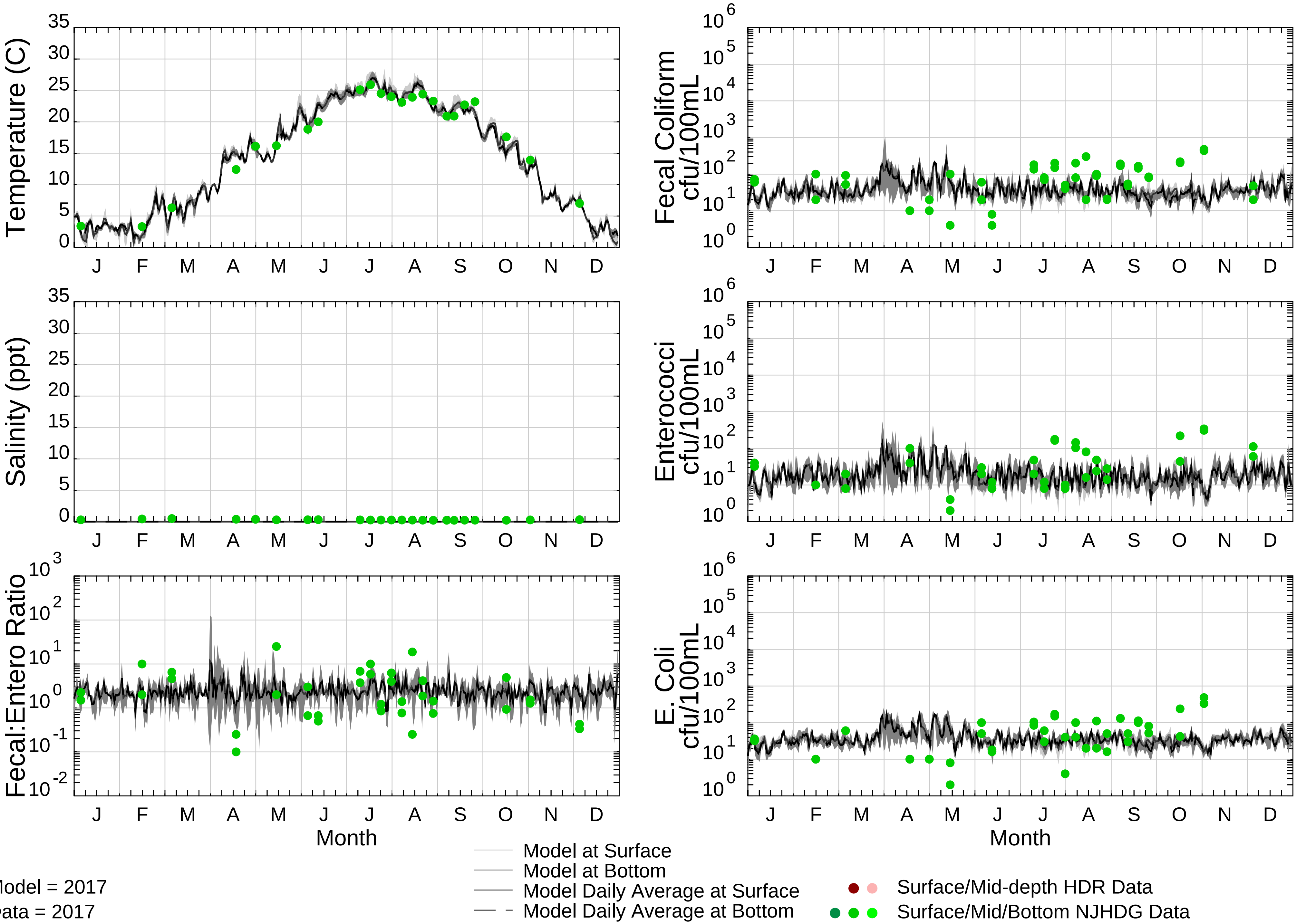
Model = 2017
Data = 2017

Station: 12



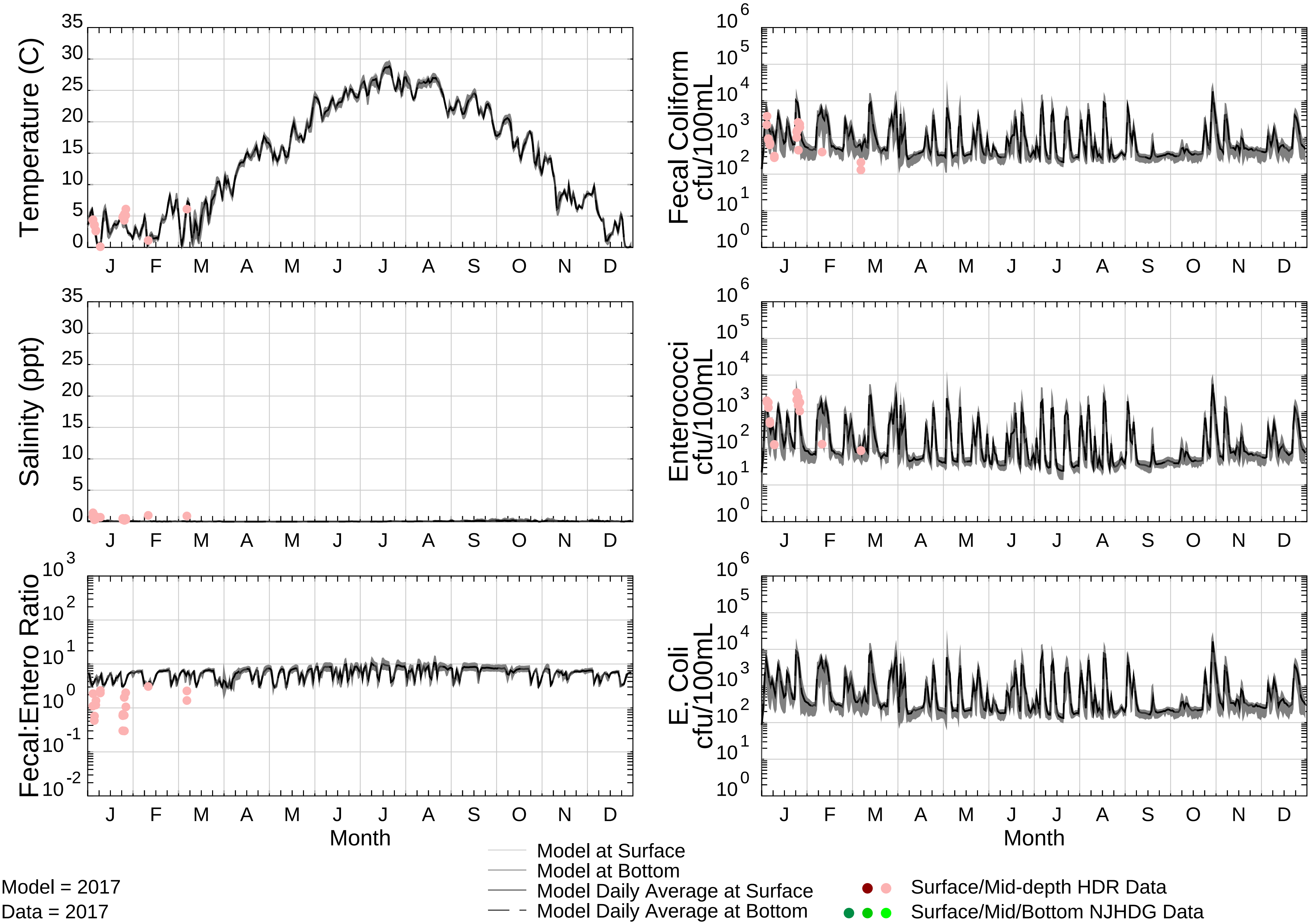
Model = 2017
Data = 2017

Station: 13



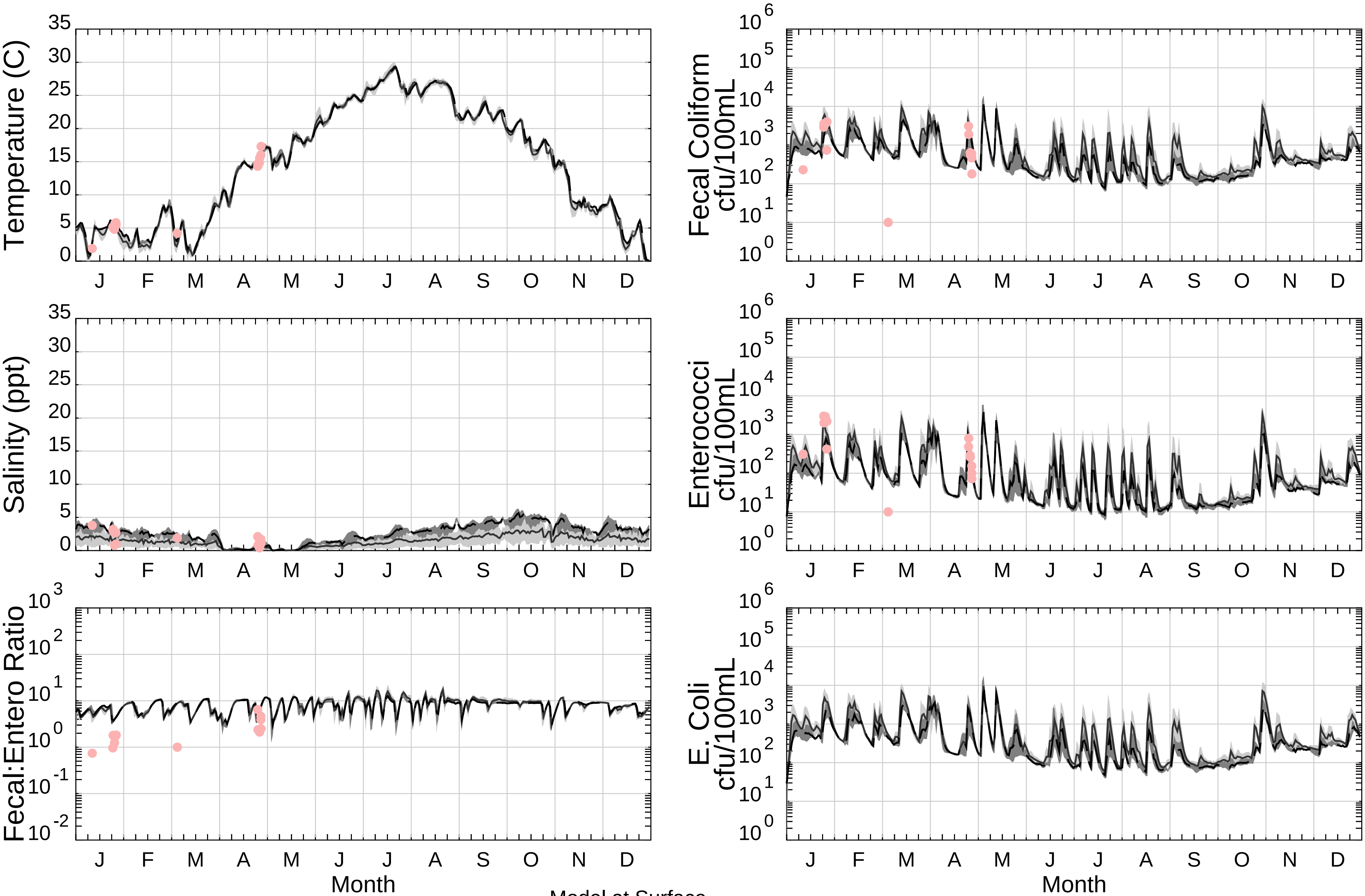
Model = 2017
Data = 2017

Station: B1



Model = 2017
Data = 2017

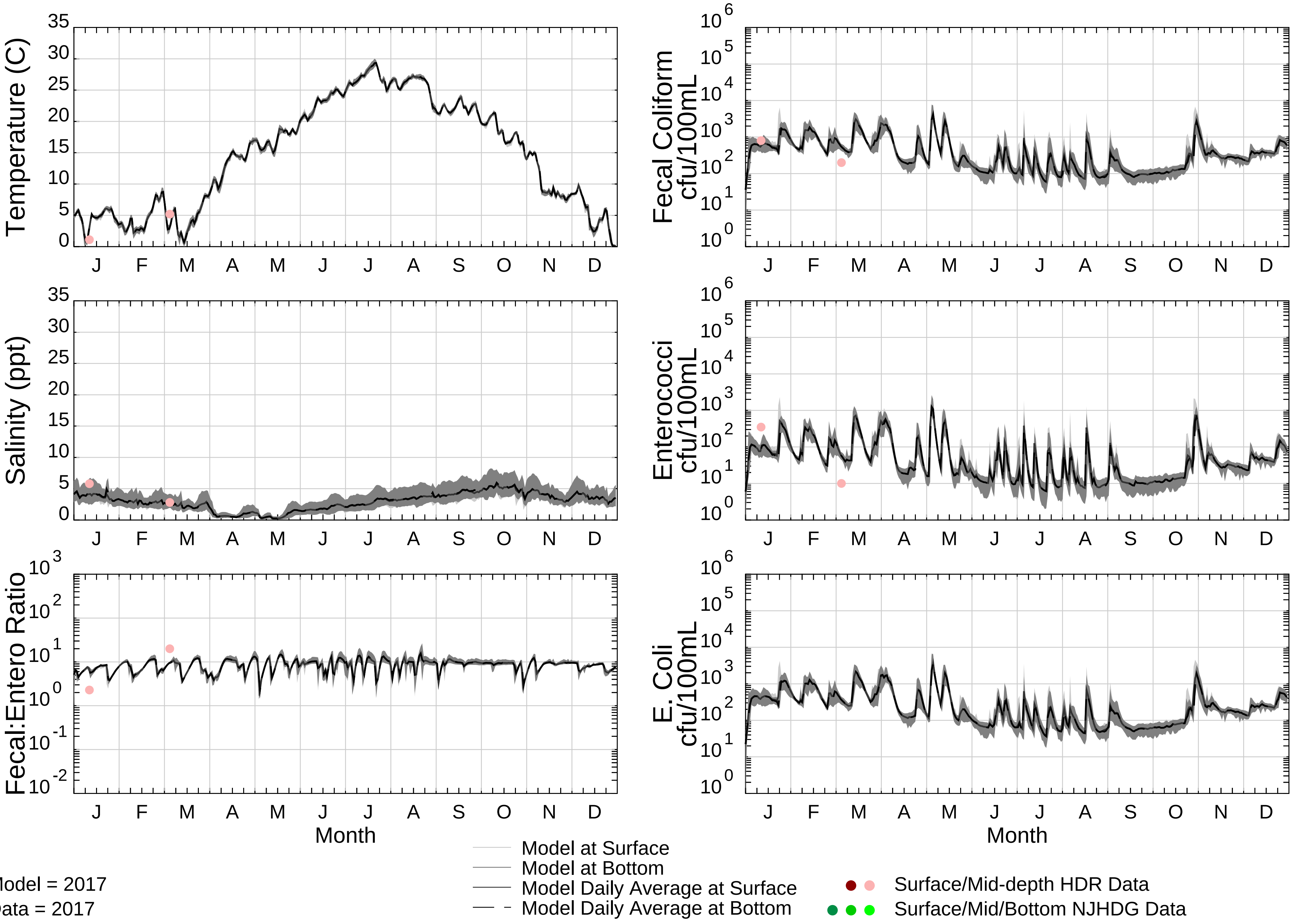
Station: B2



Model at Surface
Model at Bottom
Model Daily Average at Surface
Model Daily Average at Bottom
Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

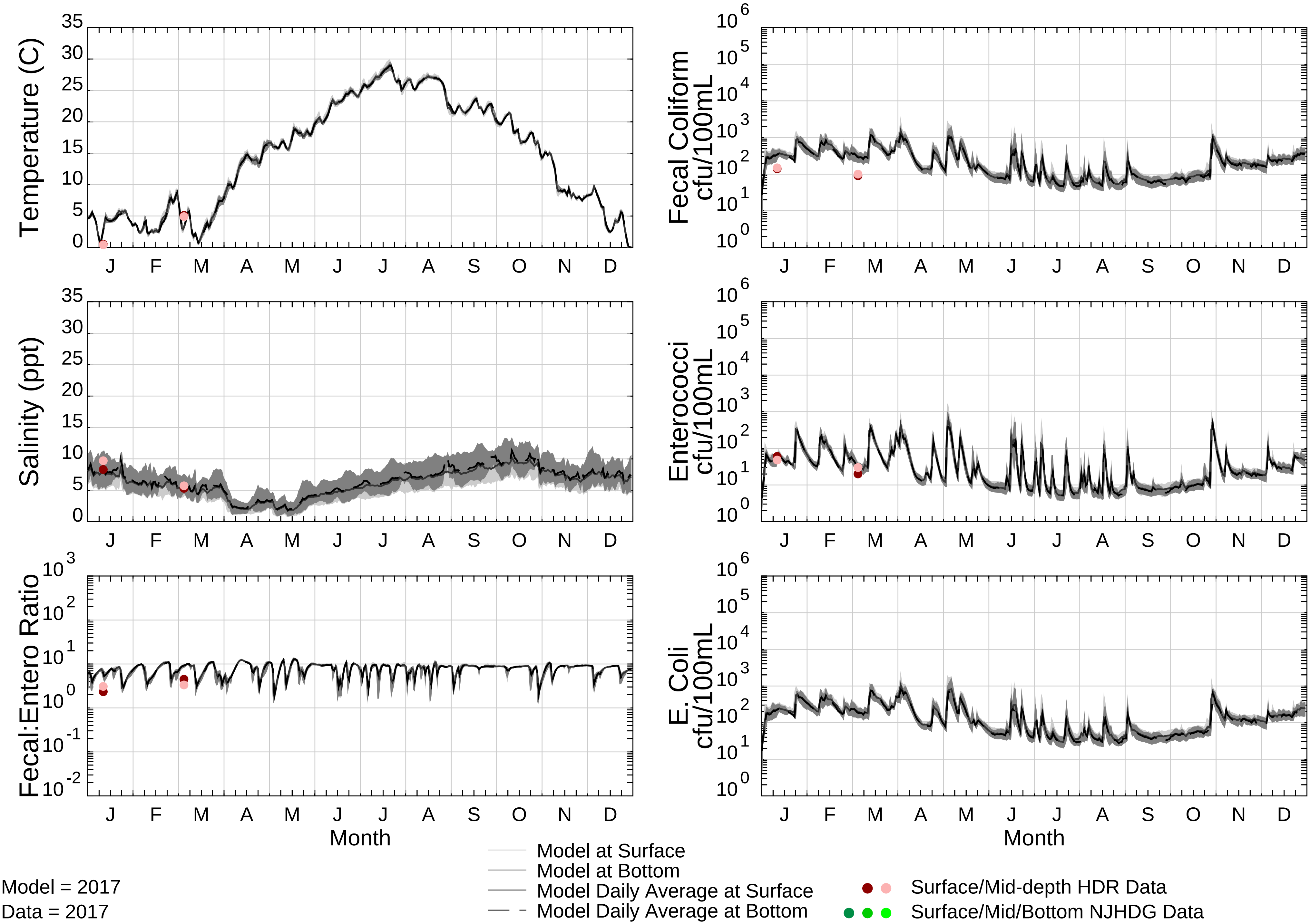
Model = 2017
Data = 2017

Station: B11



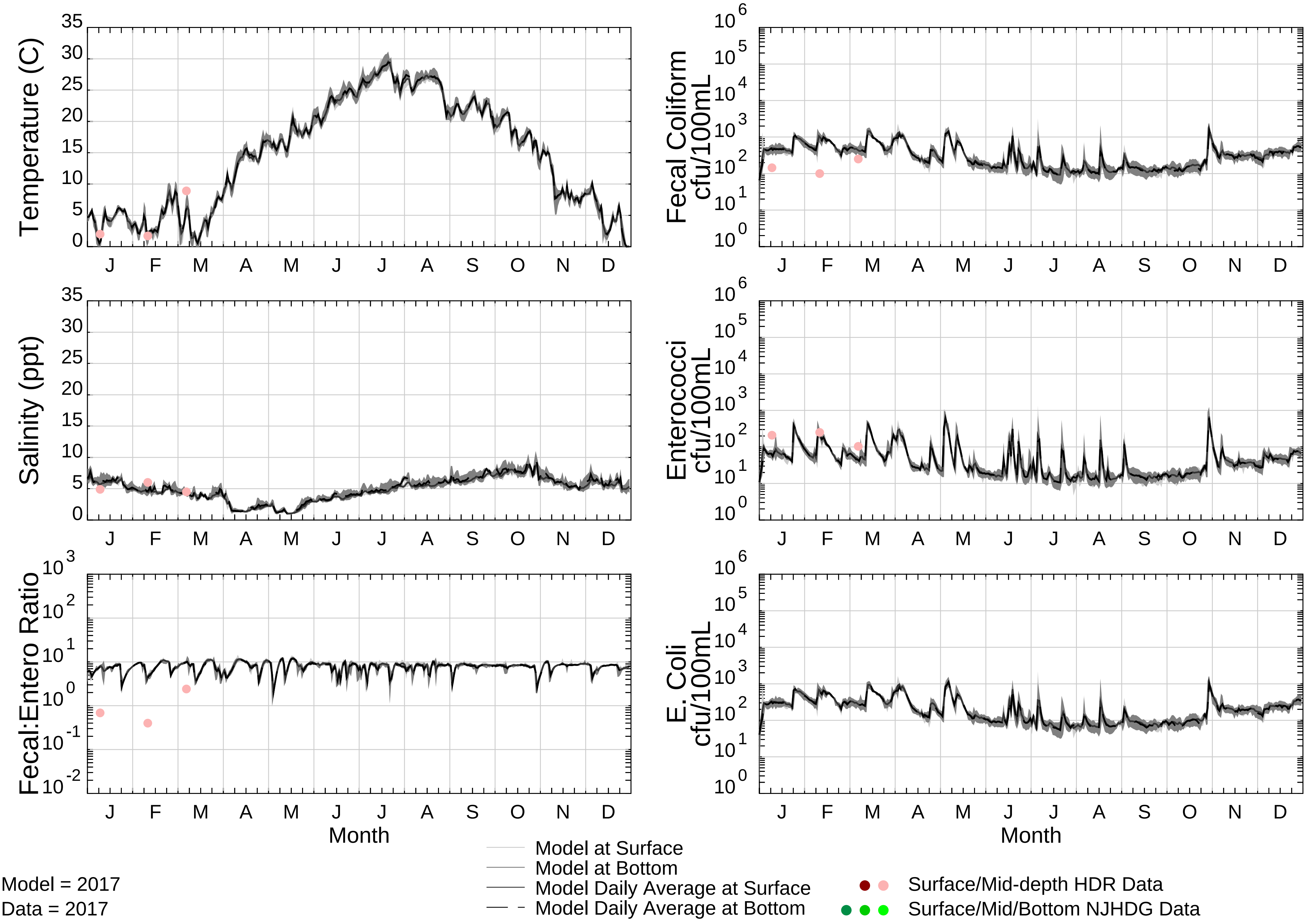
Model = 2017
Data = 2017

Station: B3



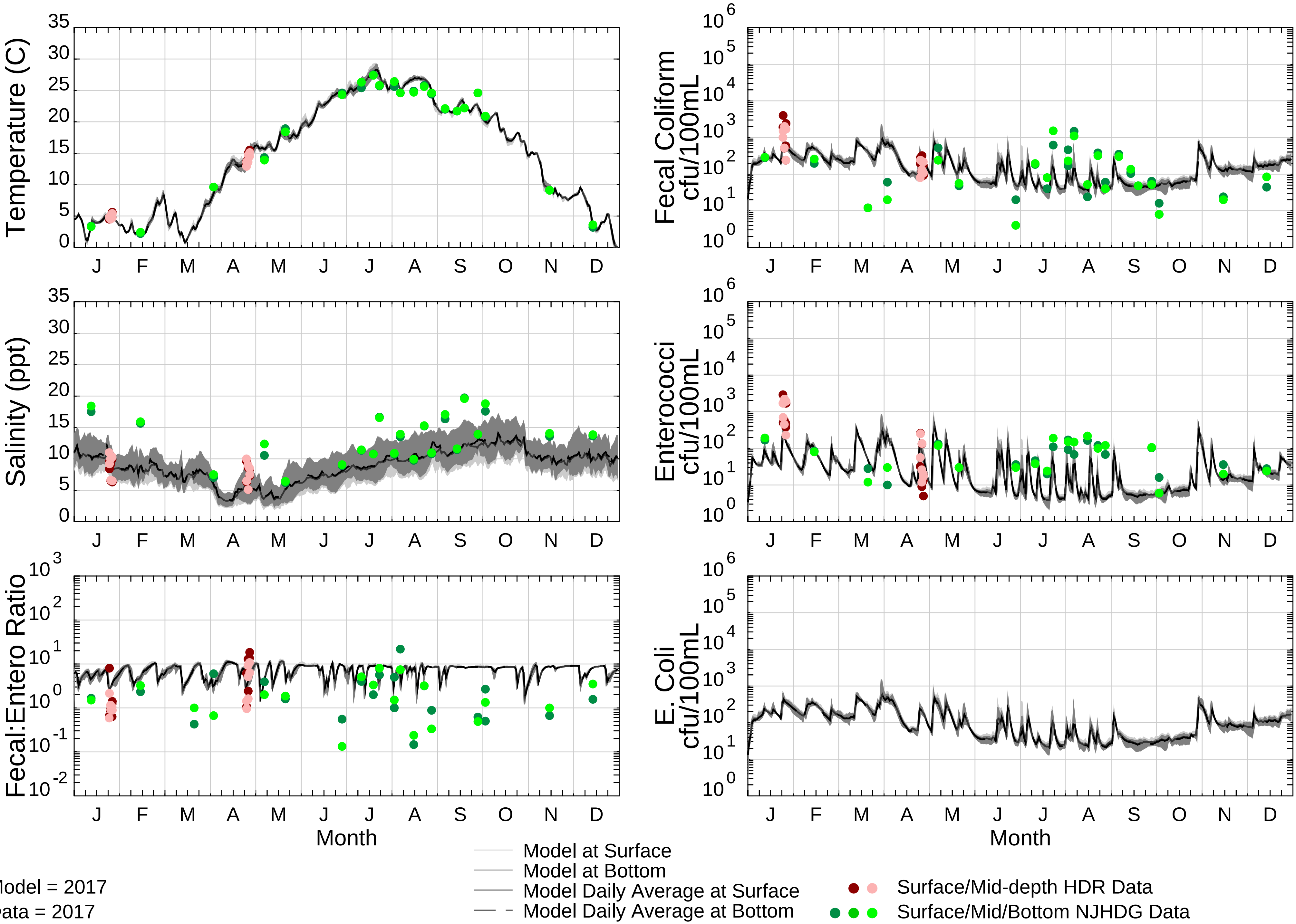
Model = 2017
Data = 2017

Station: B4

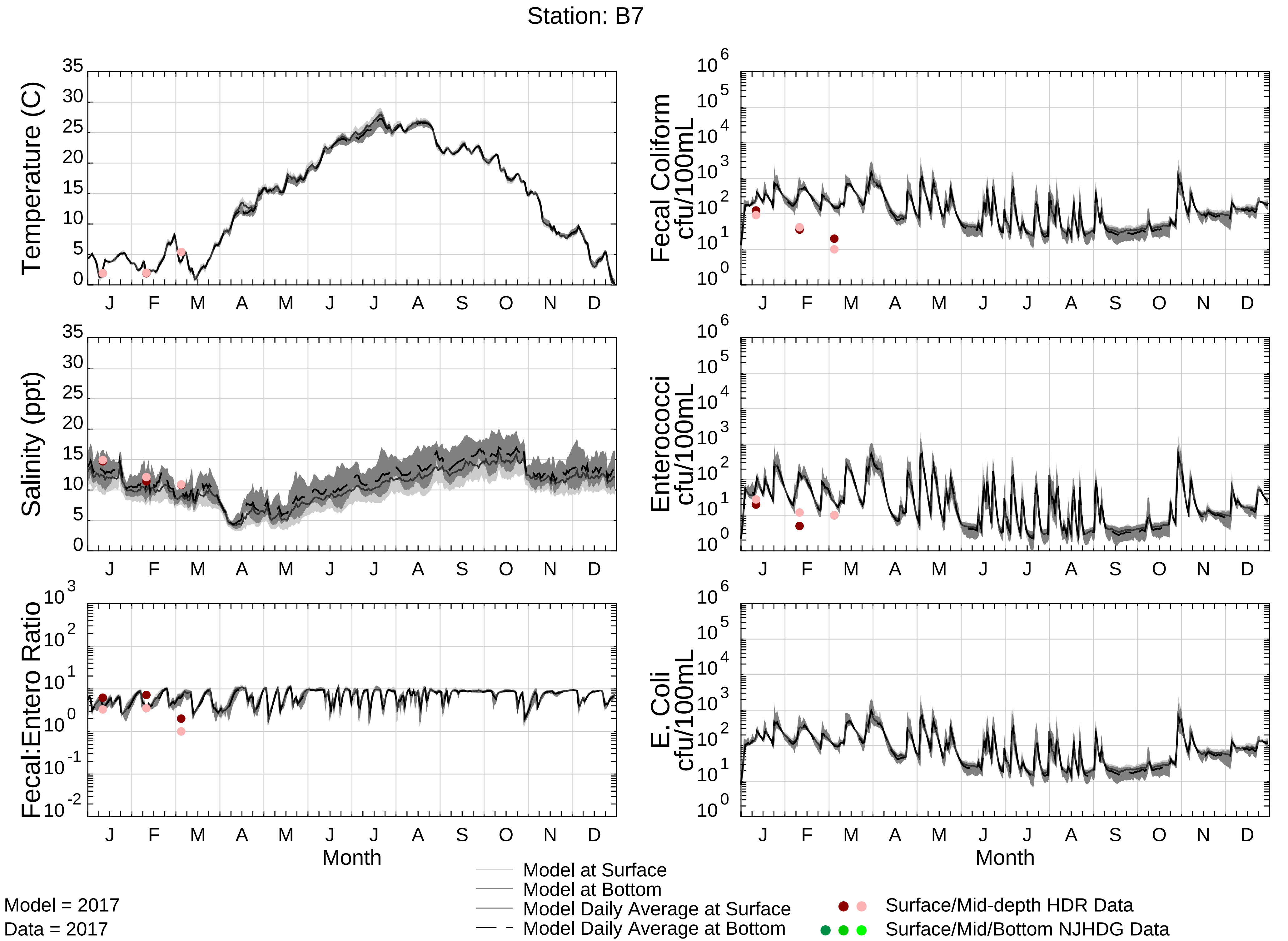


Model = 2017
Data = 2017

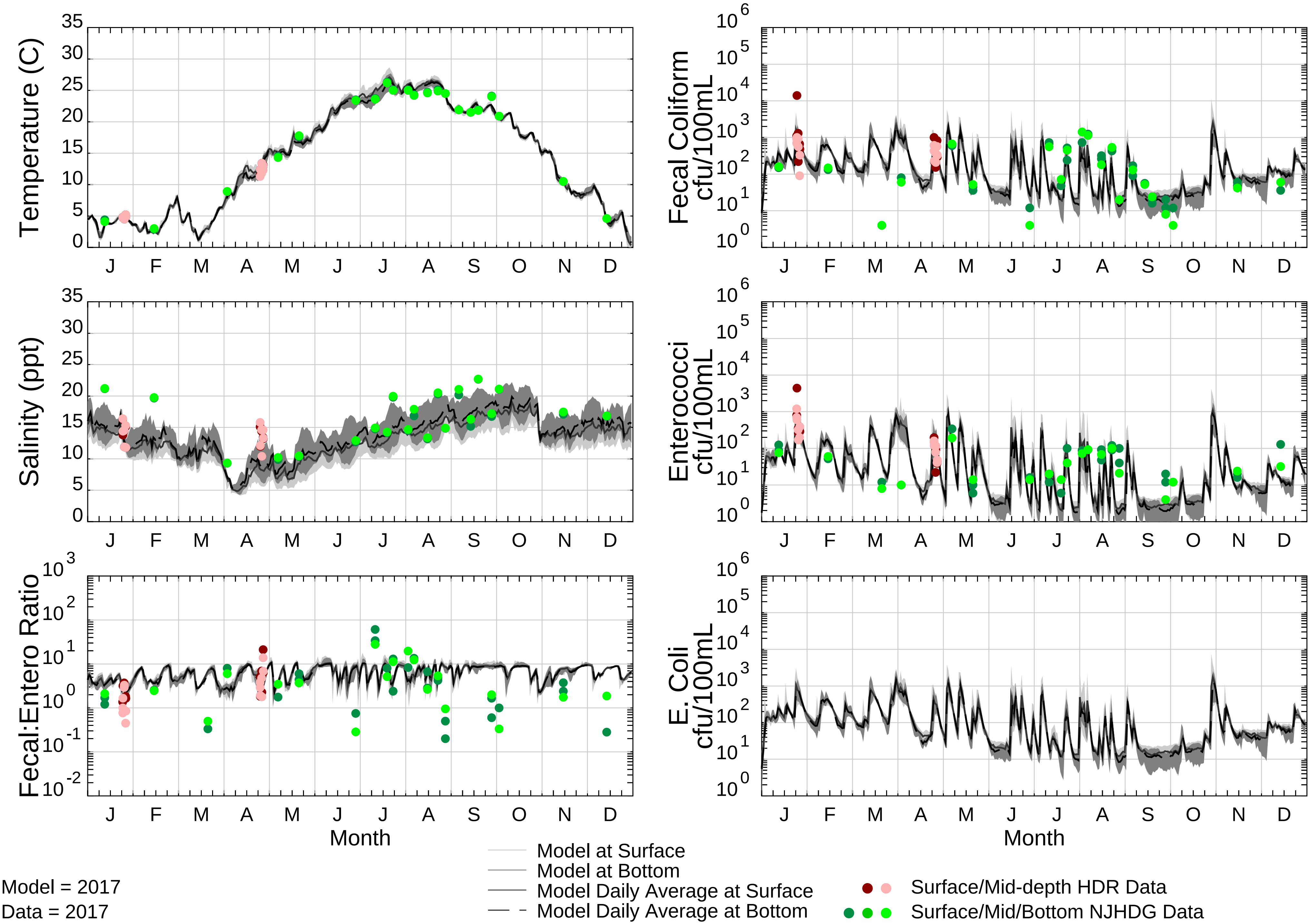
Station: 14



Model = 2017
Data = 2017

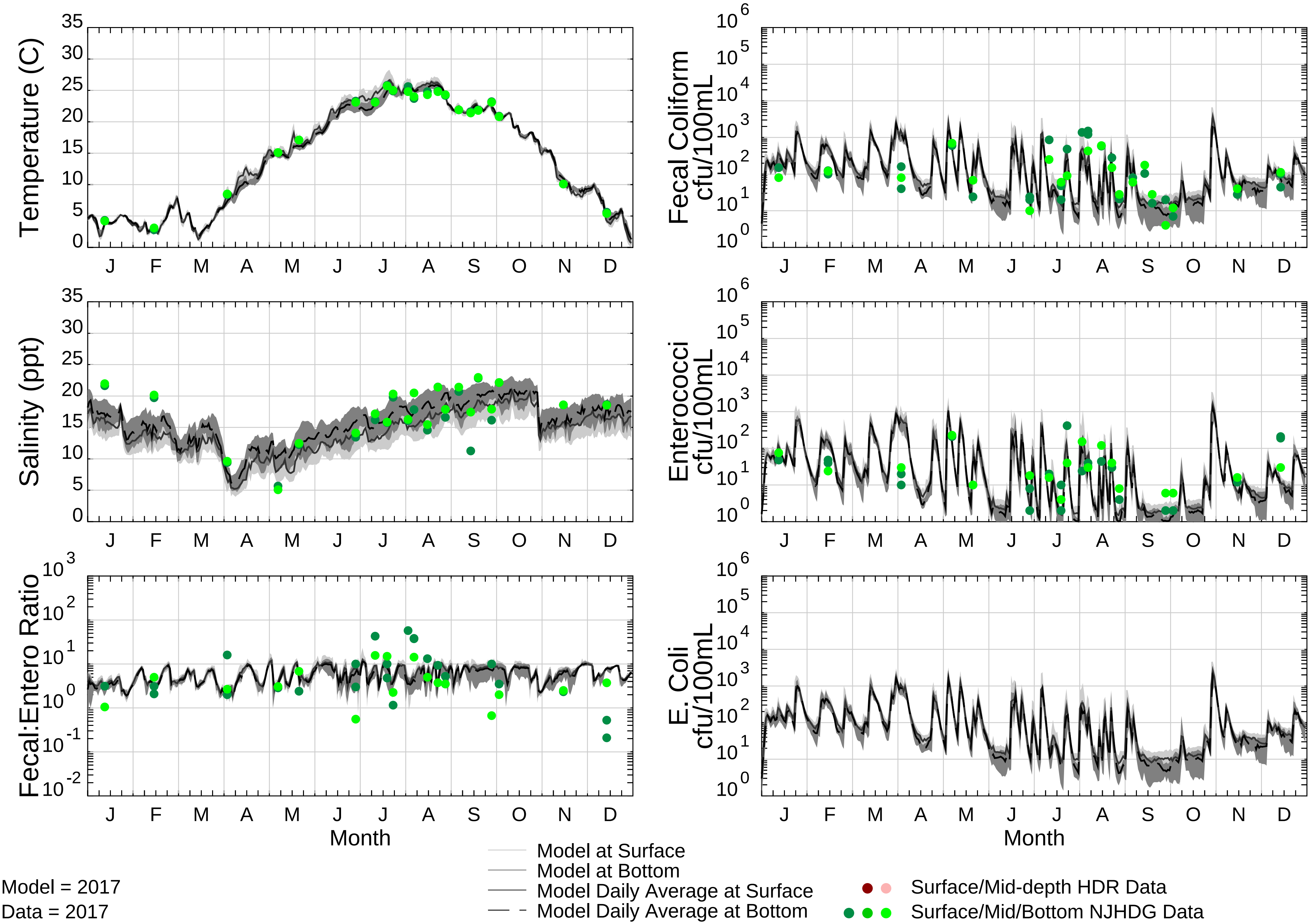

Station: B7
Temperature (C)
Salinity (ppt)
Fecal:Entero Ratio
Fecal Coliform cfu/100mL
Enterococci cfu/100mL
E. Coli cfu/100mL
J F M A M J J A S O N D
Month
Model at Surface
Model at Bottom
Model Daily Average at Surface
Model Daily Average at Bottom
Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data
Model = 2017
Data = 2017

Station: 15



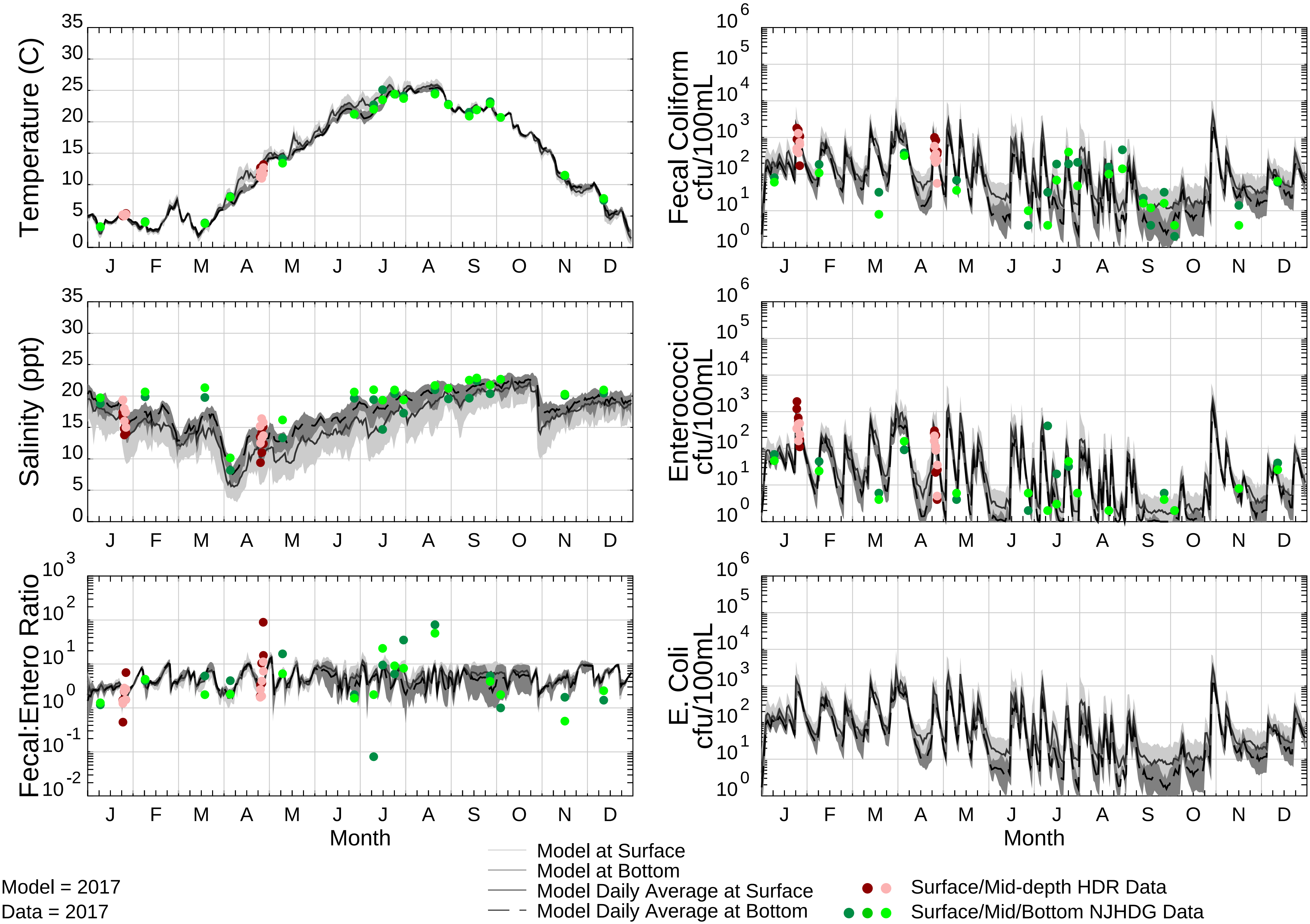
Model = 2017
Data = 2017

Station: 16



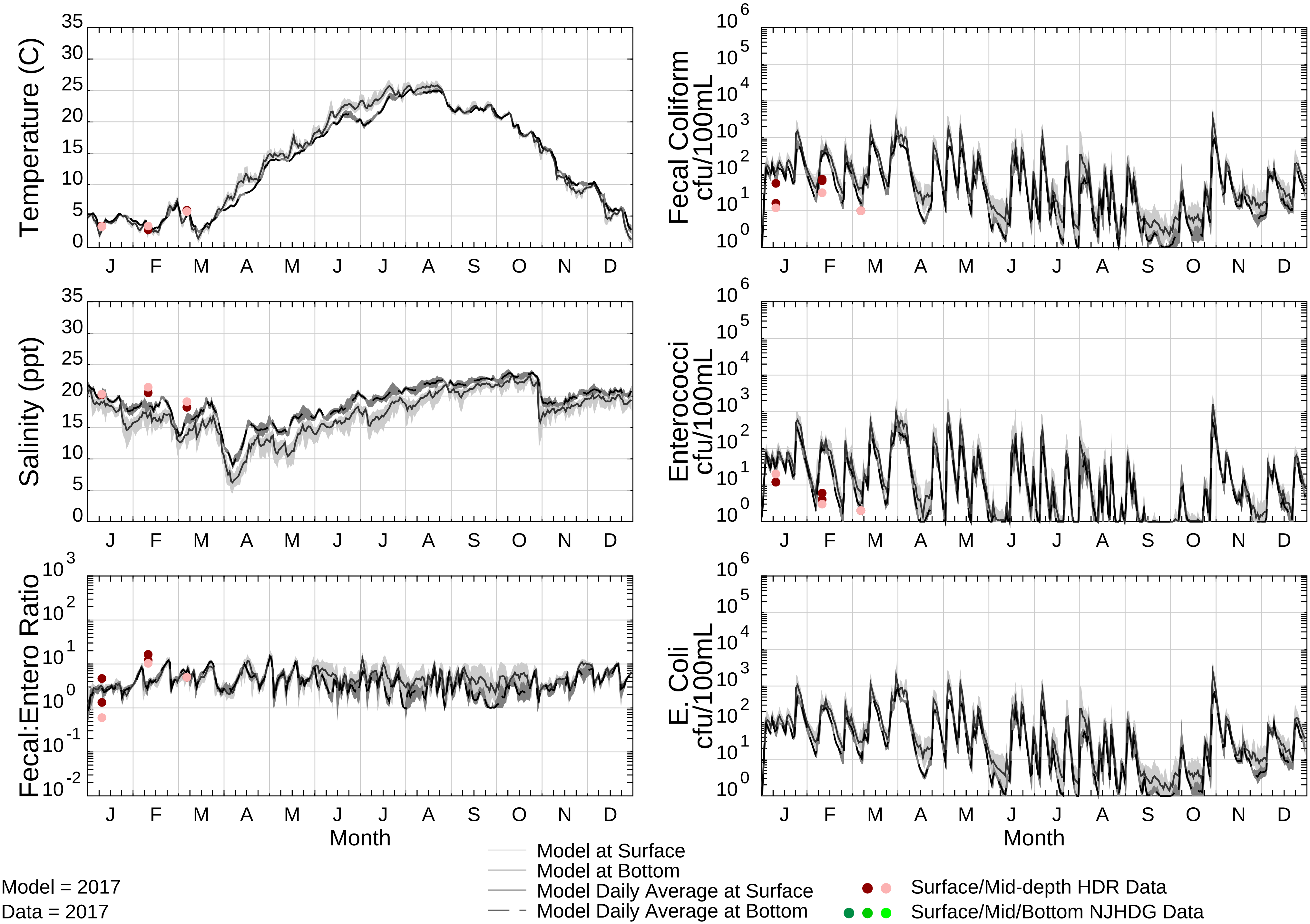
Model = 2017
Data = 2017

Station: 17



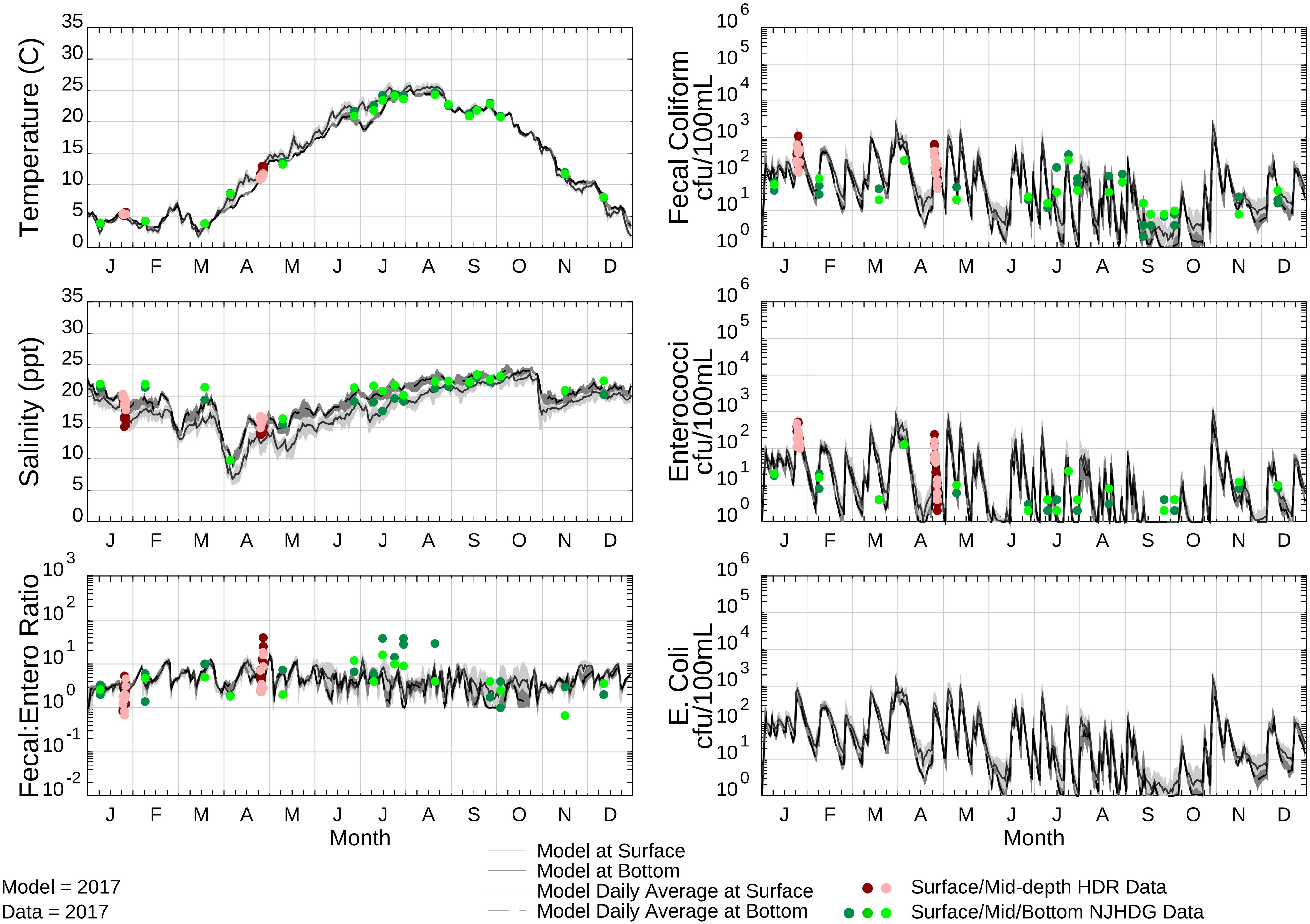
Model = 2017
Data = 2017

Station: B10



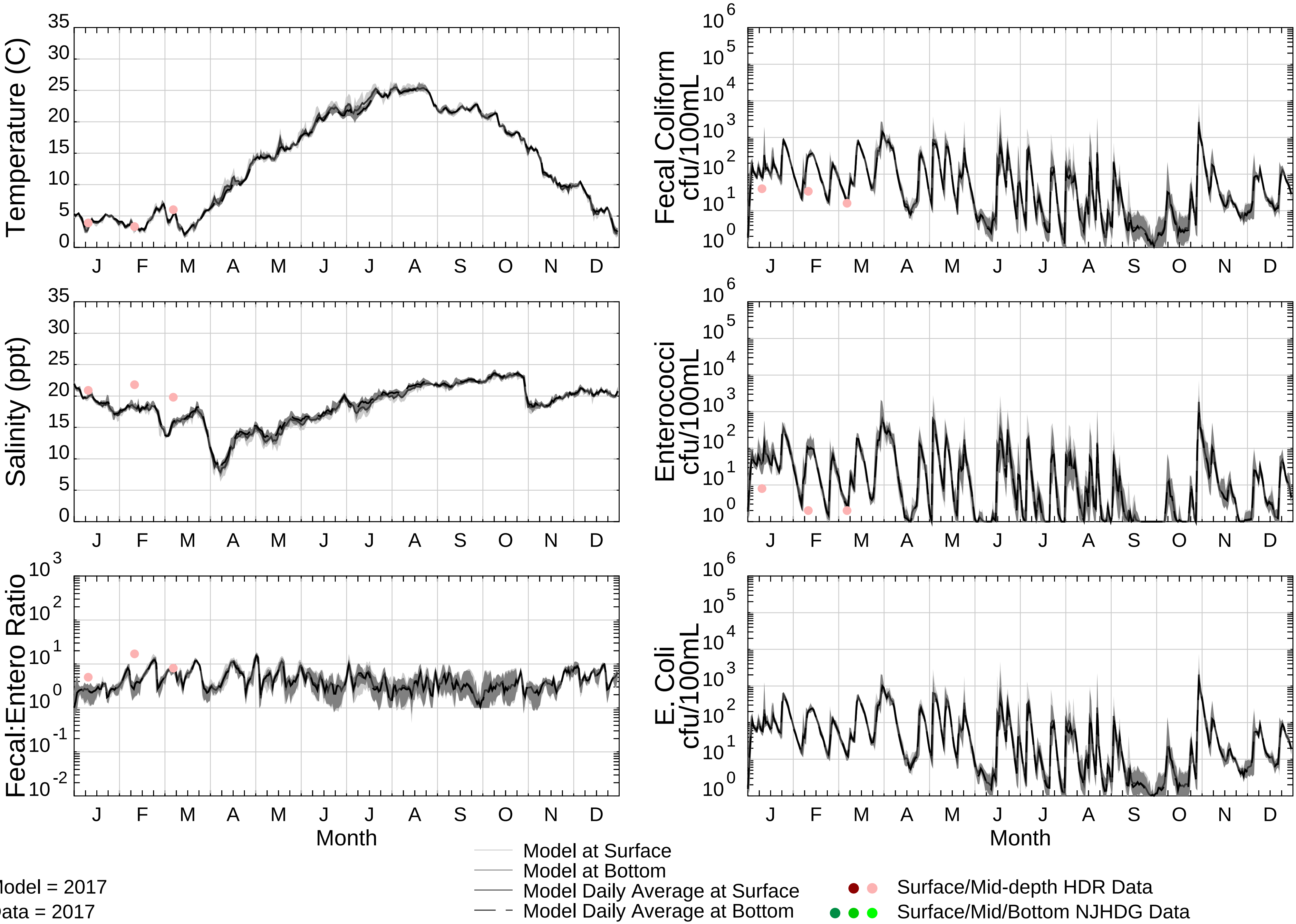
Model = 2017
Data = 2017

Station: 18



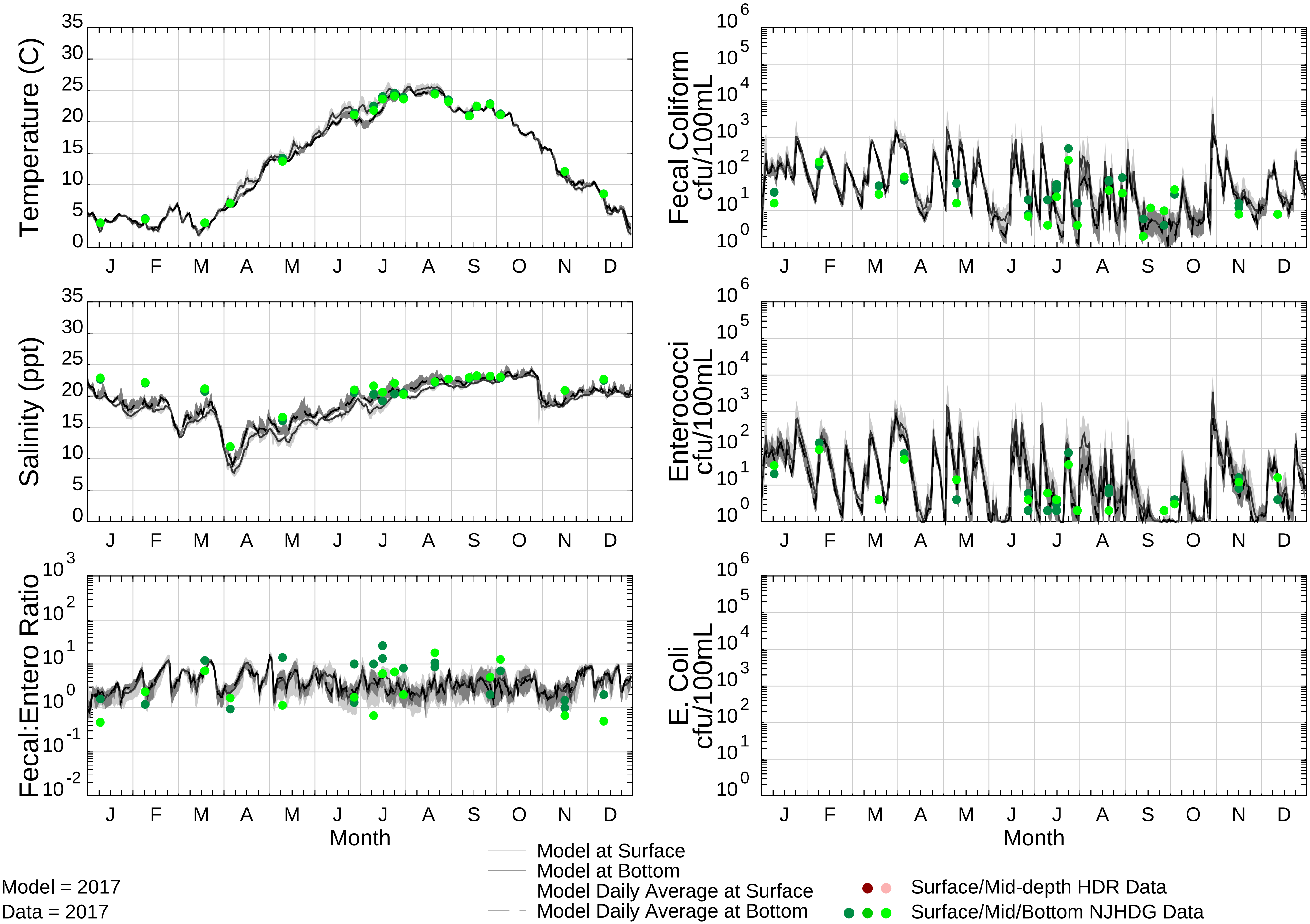
Model = 2017
Data = 2017

Station: B17



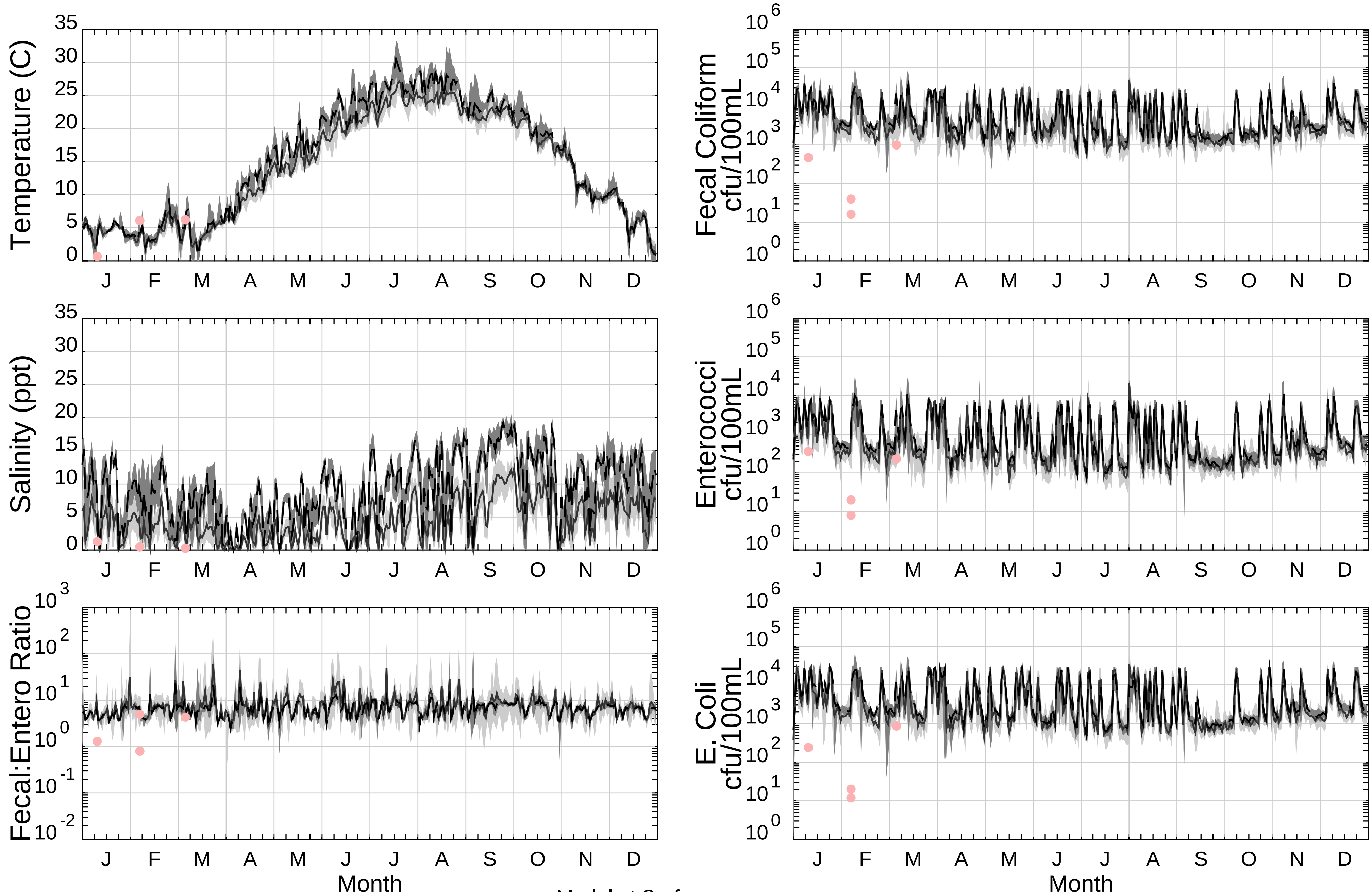
Model = 2017
Data = 2017

Station: 19



Model = 2017
Data = 2017

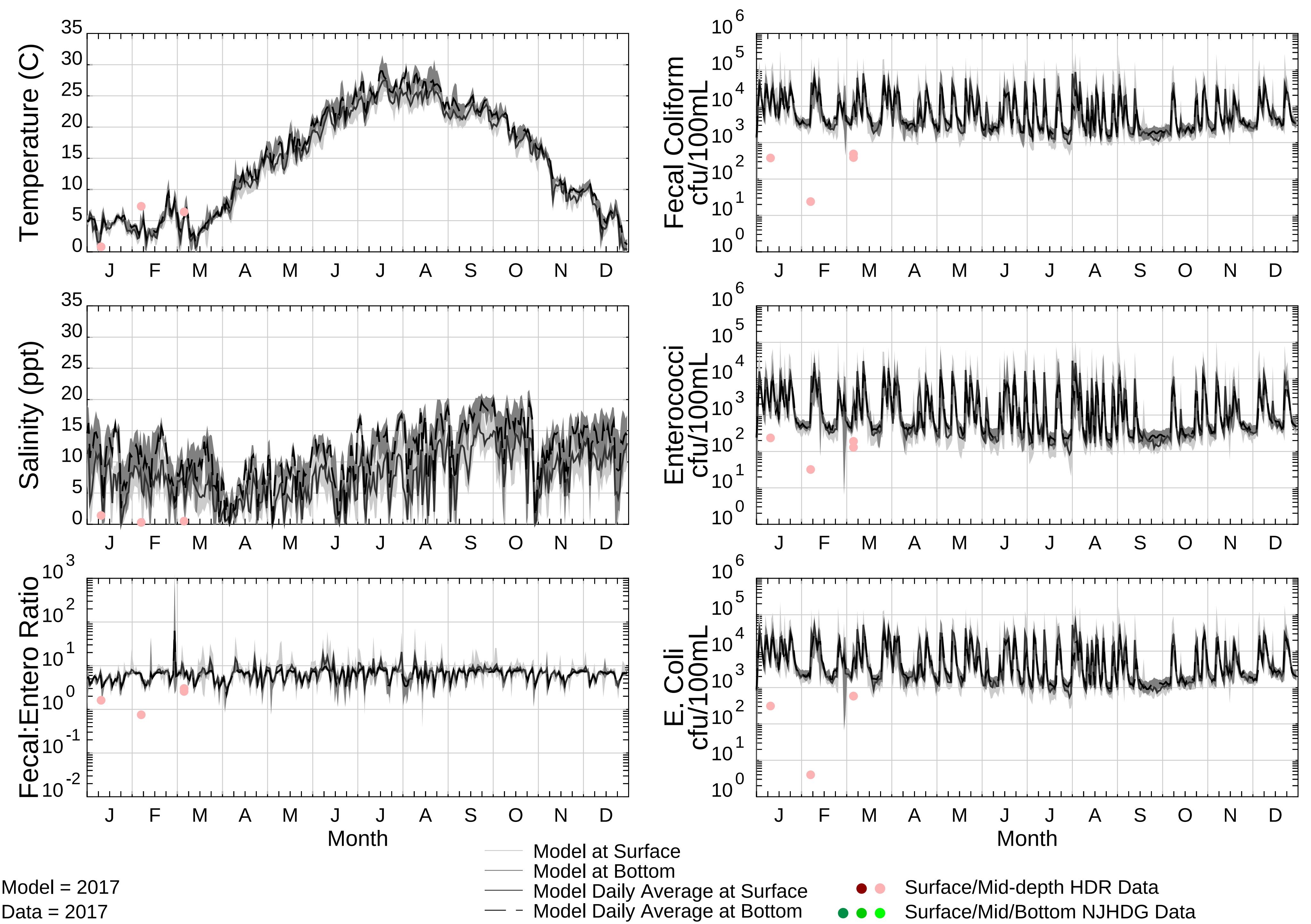
Station: B16



Model at Surface
Model at Bottom
Model Daily Average at Surface
Model Daily Average at Bottom
Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

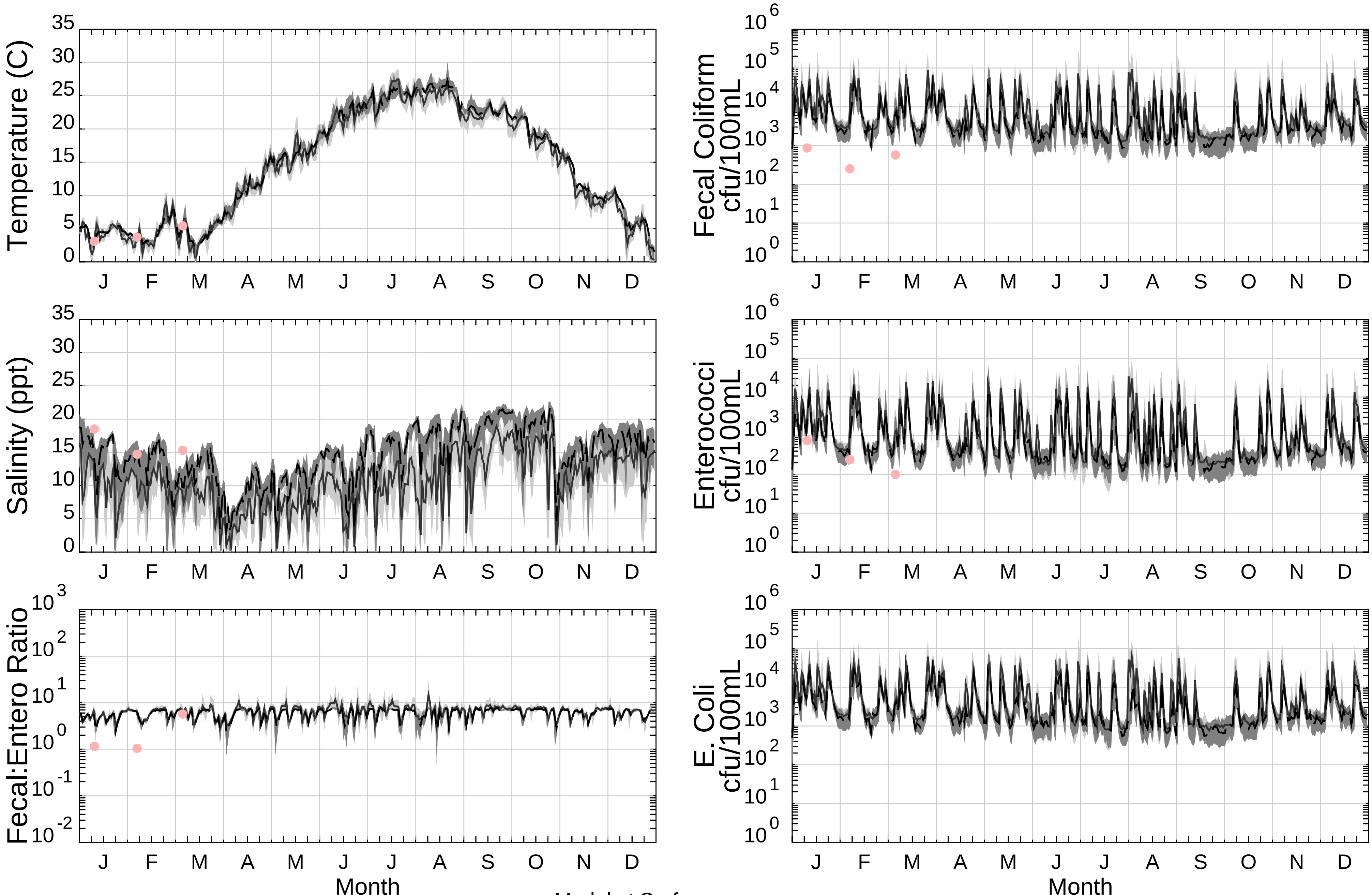
Model = 2017
Data = 2017

Station: B14



Model = 2017
Data = 2017

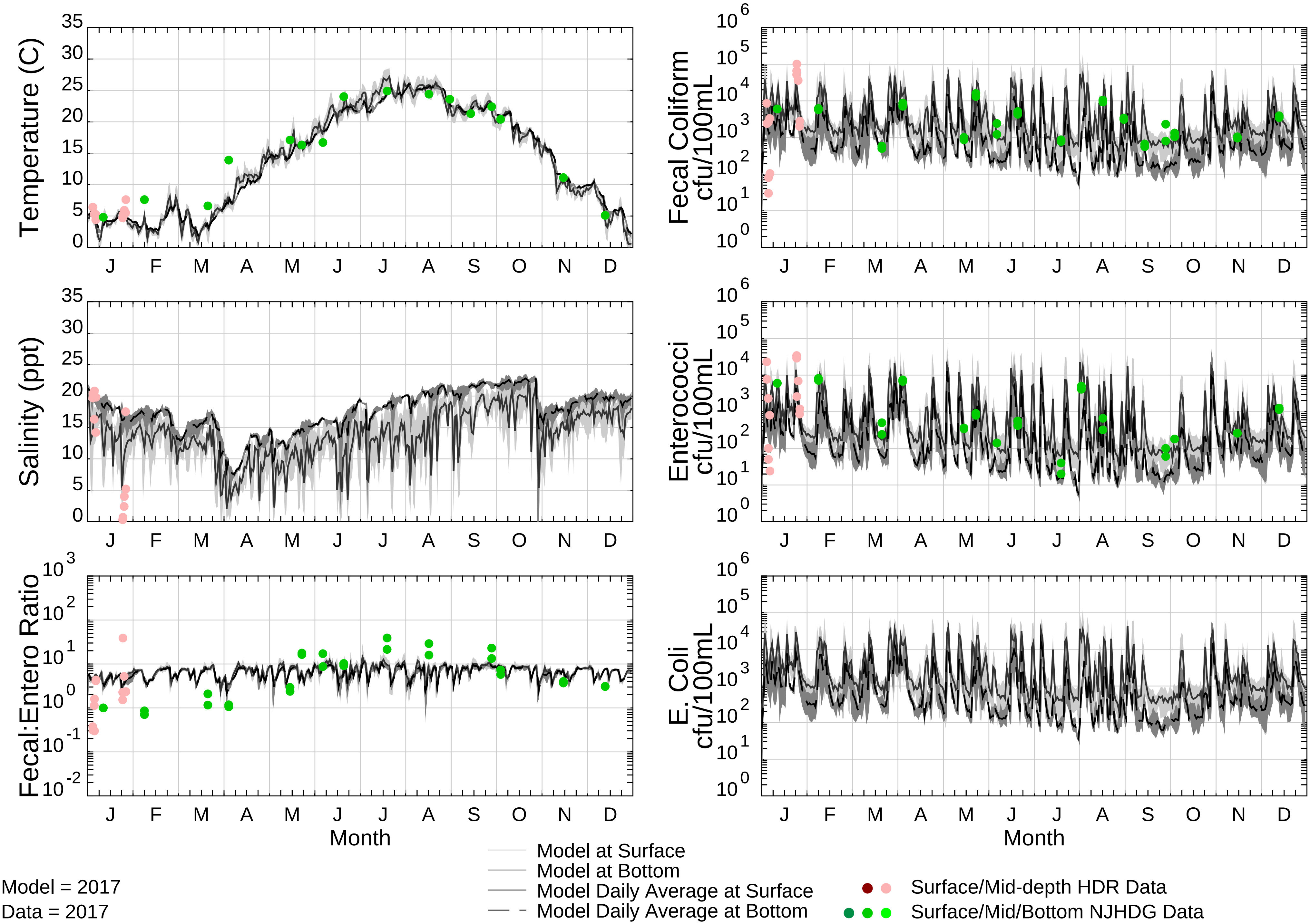
Station: B13



Model at Surface
Model at Bottom
Model Daily Average at Surface
Model Daily Average at Bottom
Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

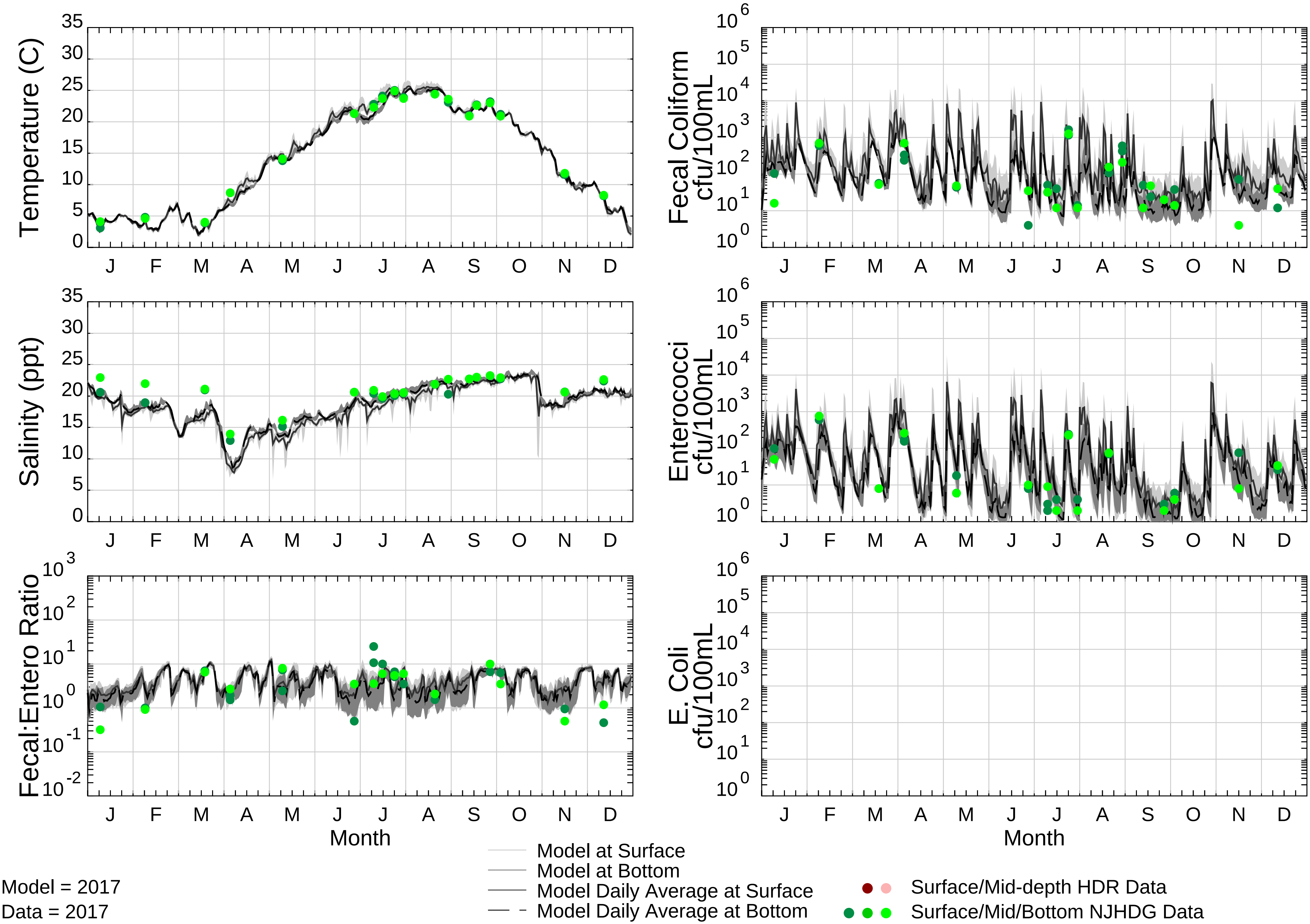
Model = 2017
Data = 2017

Station: 20

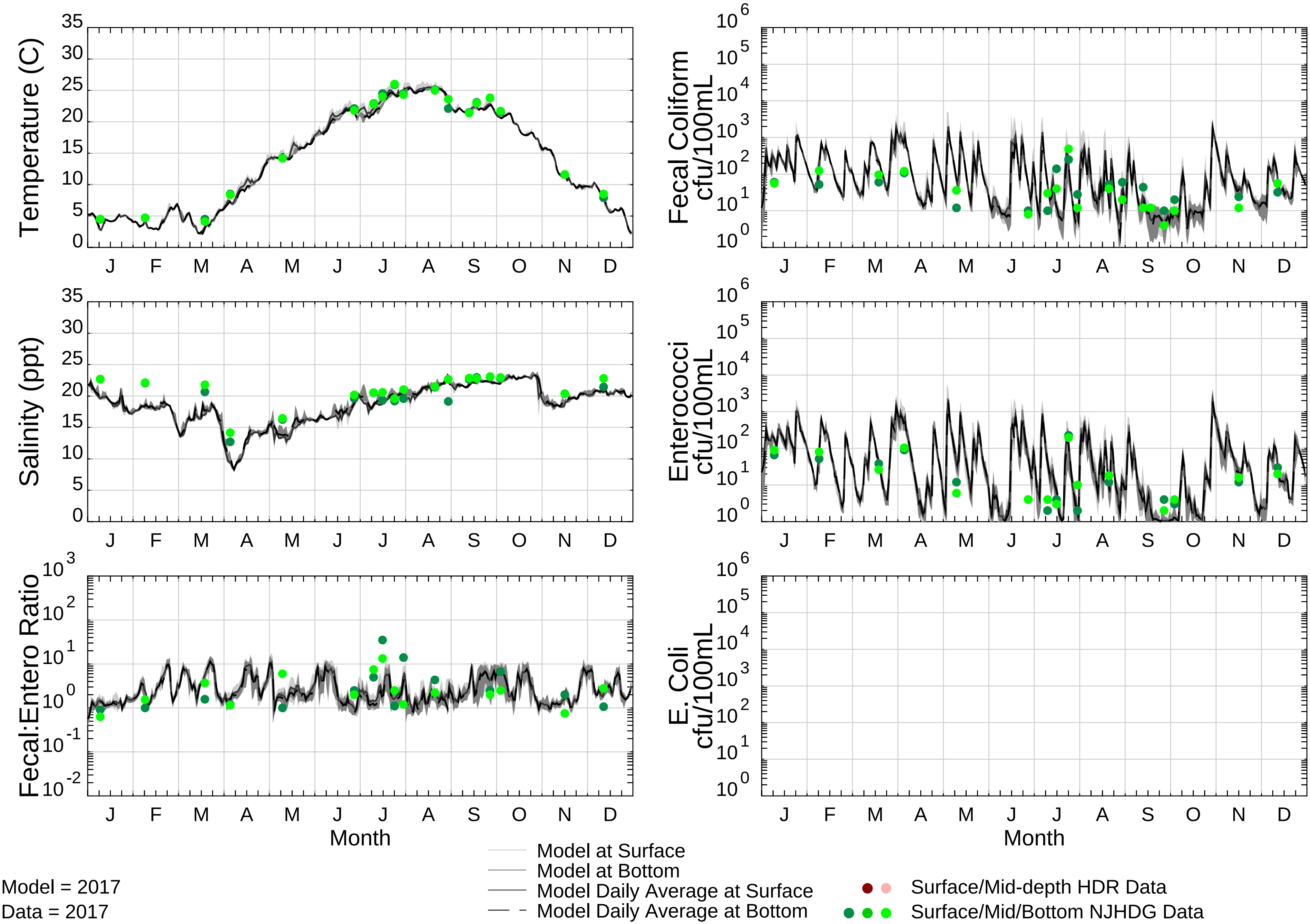


Model = 2017
Data = 2017

Station: 21

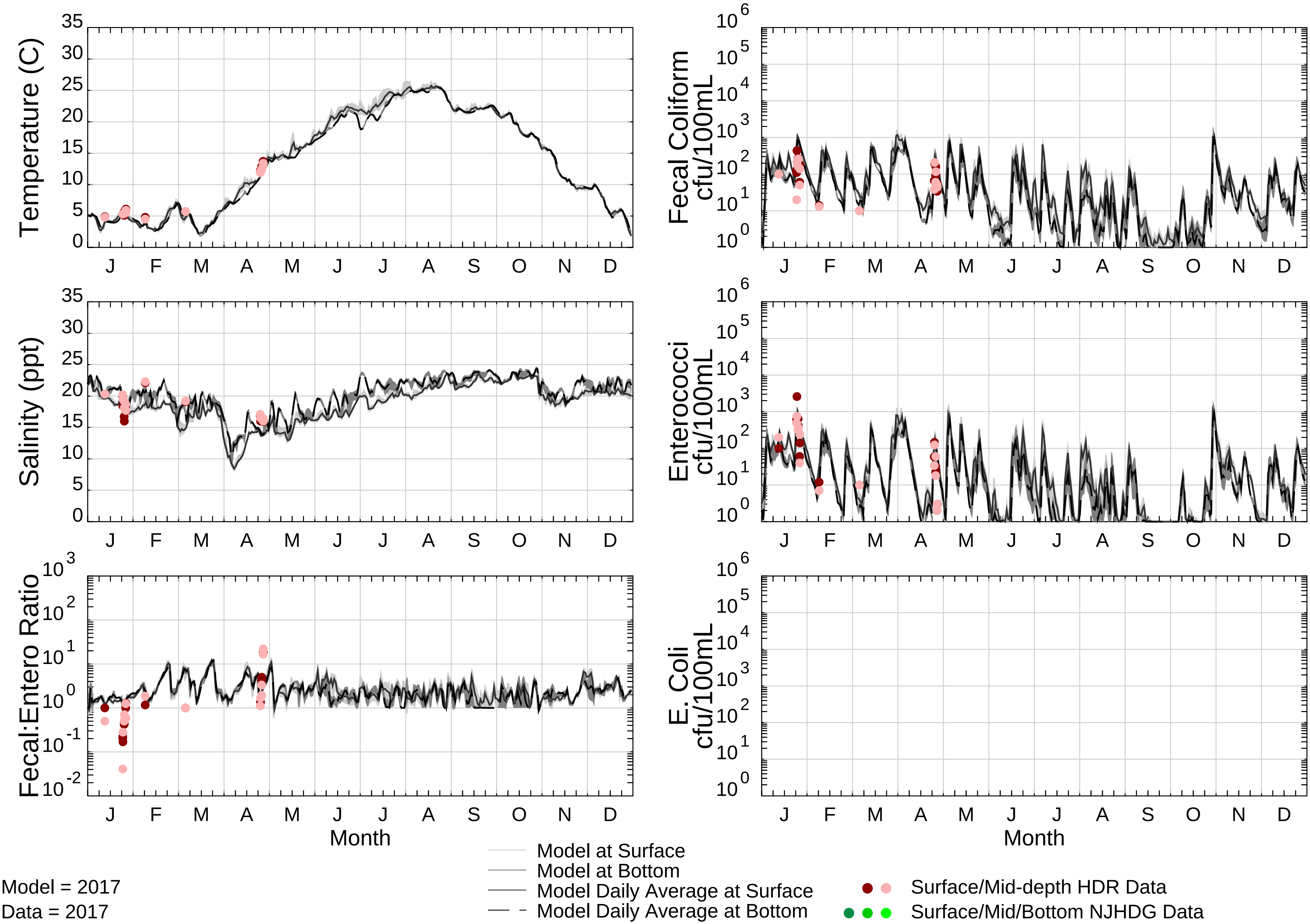

Temperature (C)
Salinity (ppt)
Fecal:Entero Ratio
Fecal Coliform cfu/100mL
Enterococci cfu/100mL
E. Coli cfu/100mL
J F M A M J J A S O N D
Month
Model at Surface
Model at Bottom
Model Daily Average at Surface
Model Daily Average at Bottom
Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data
Model = 2017
Data = 2017

Station: 23



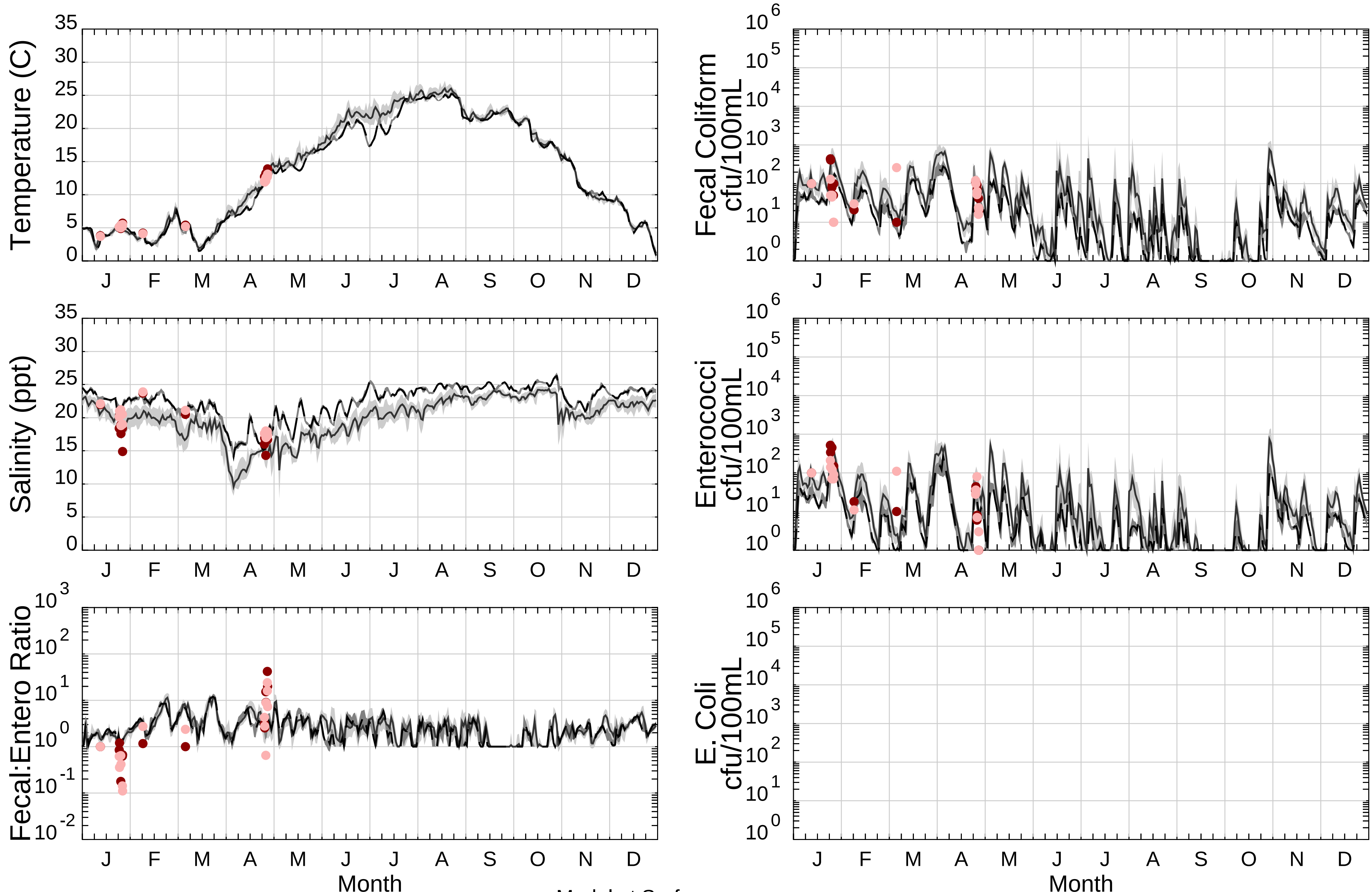
Model = 2017
Data = 2017

Station: 24



Model = 2017
Data = 2017

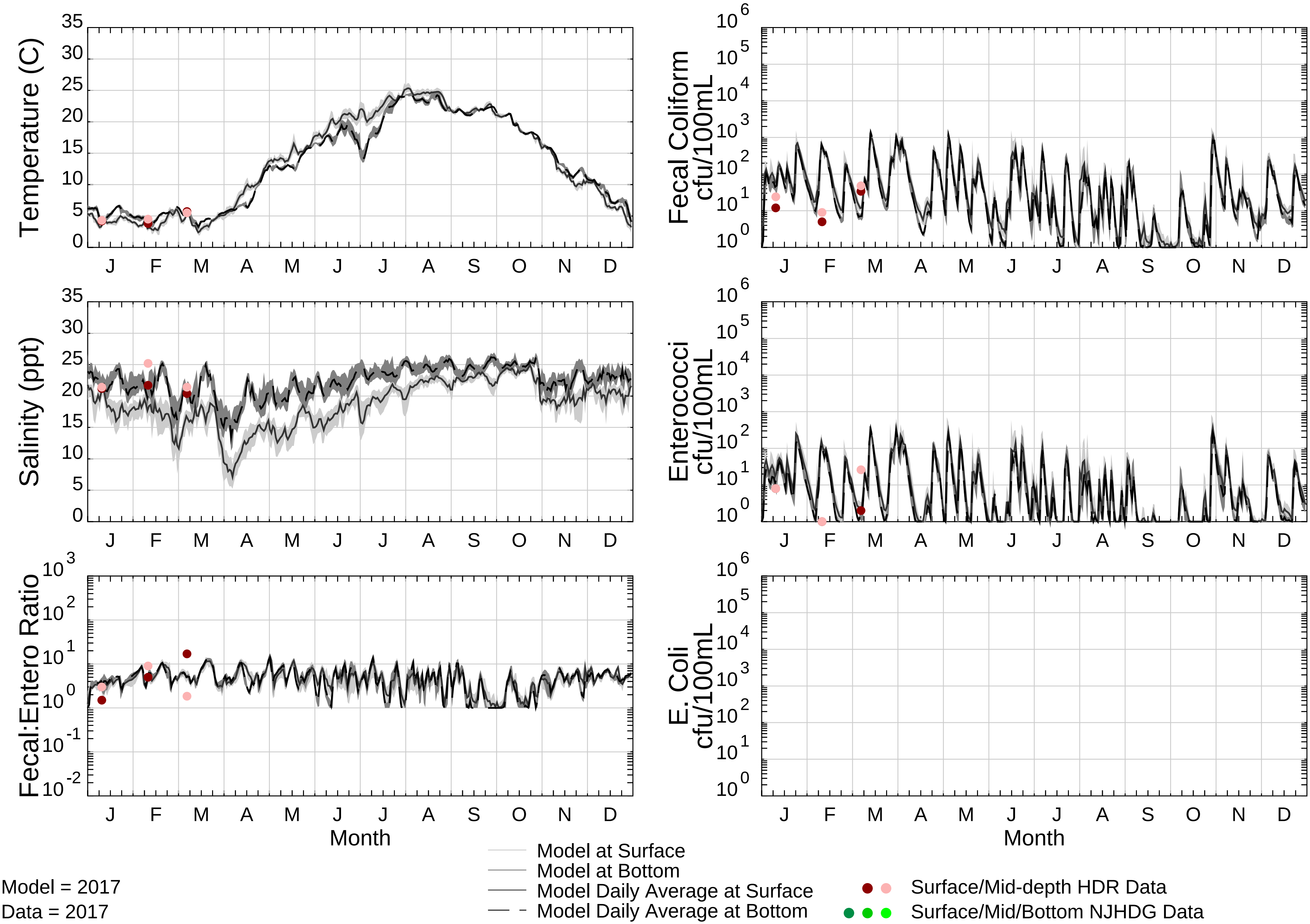
Station: B15



Model at Surface
Model at Bottom
Model Daily Average at Surface
Model Daily Average at Bottom
Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

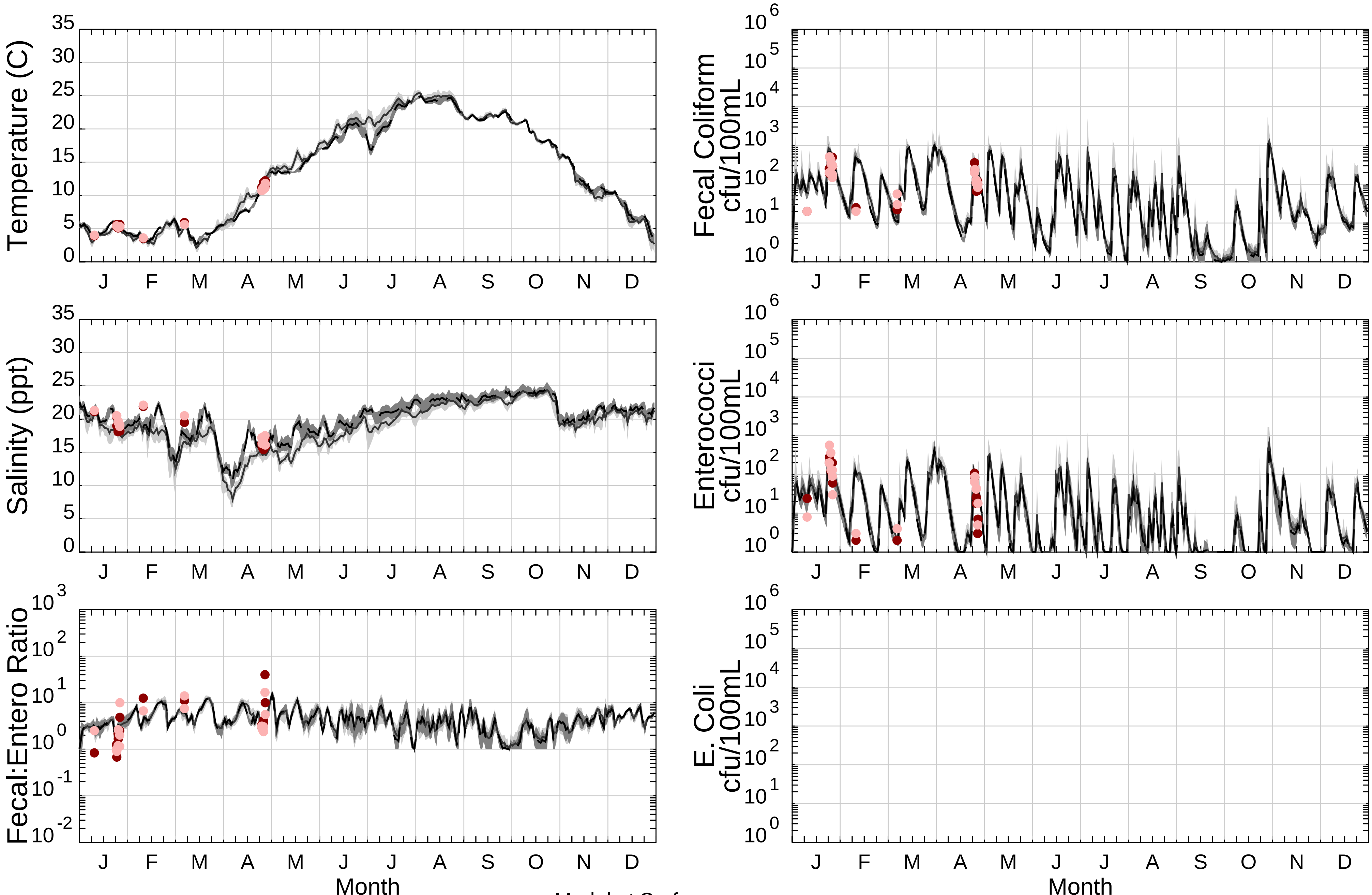
Model = 2017
Data = 2017

Station: B20



Model = 2017
Data = 2017

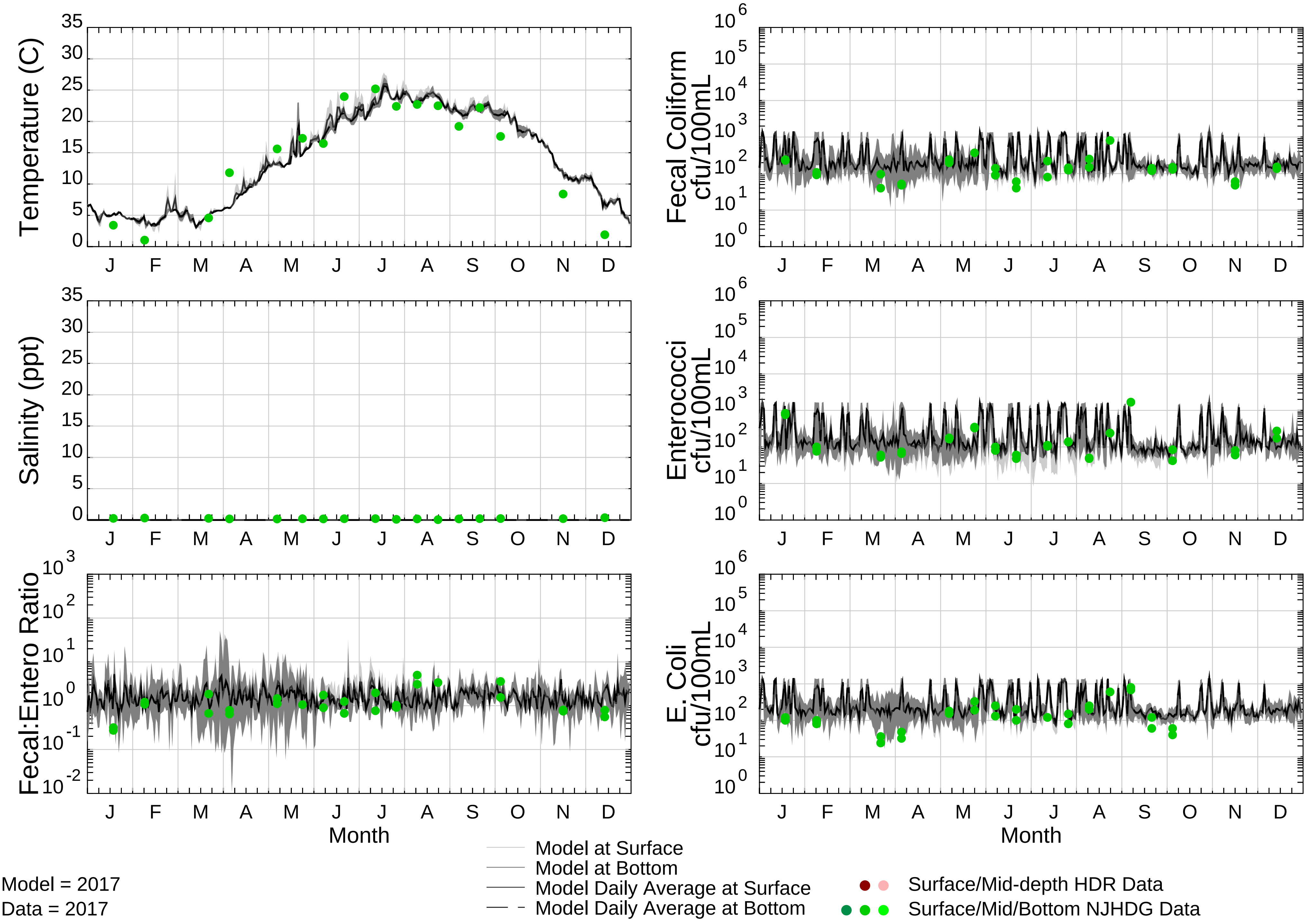
Station: B12



Model at Surface
Model at Bottom
Model Daily Average at Surface
Model Daily Average at Bottom
Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

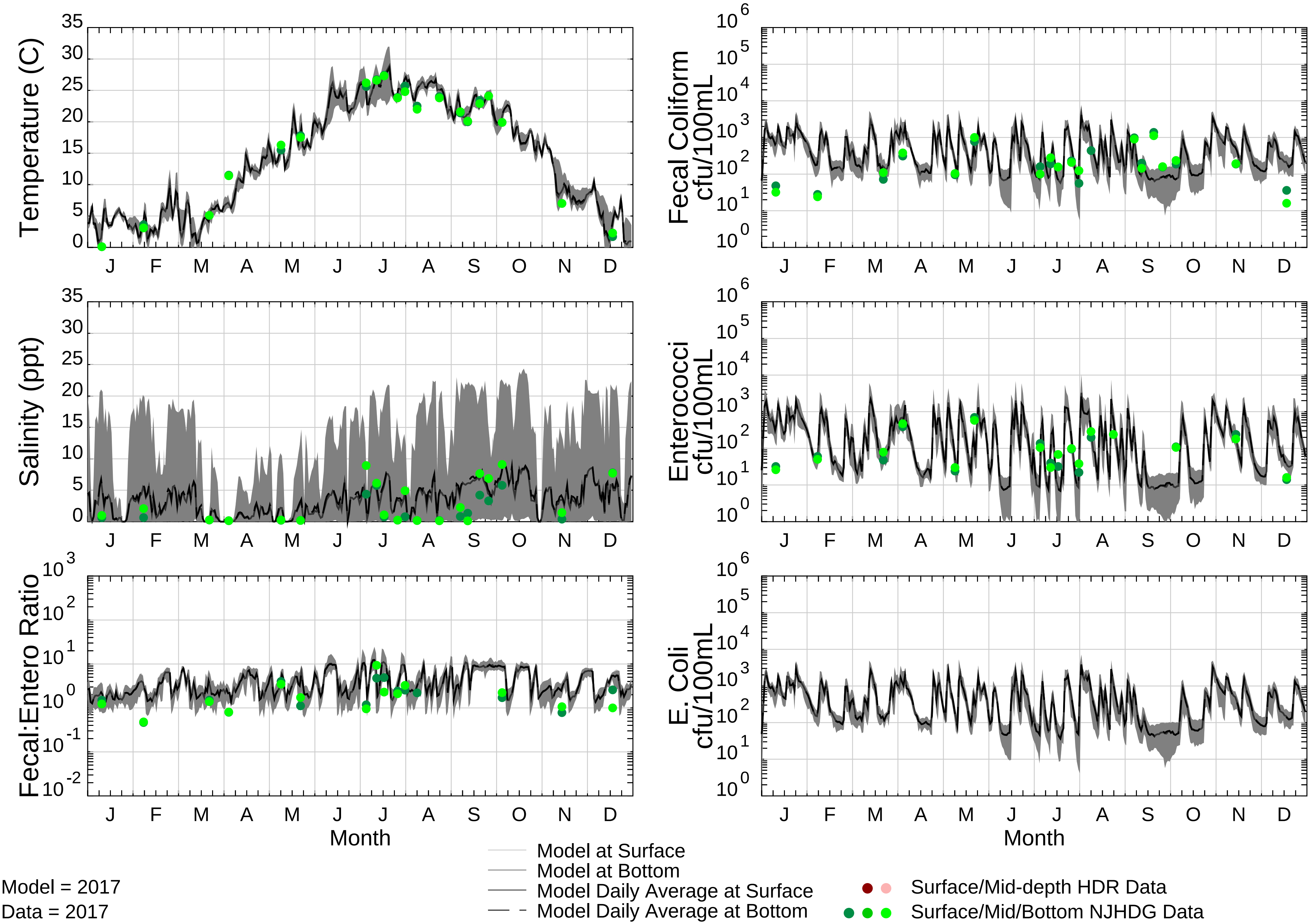
Model = 2017
Data = 2017

Station: 25



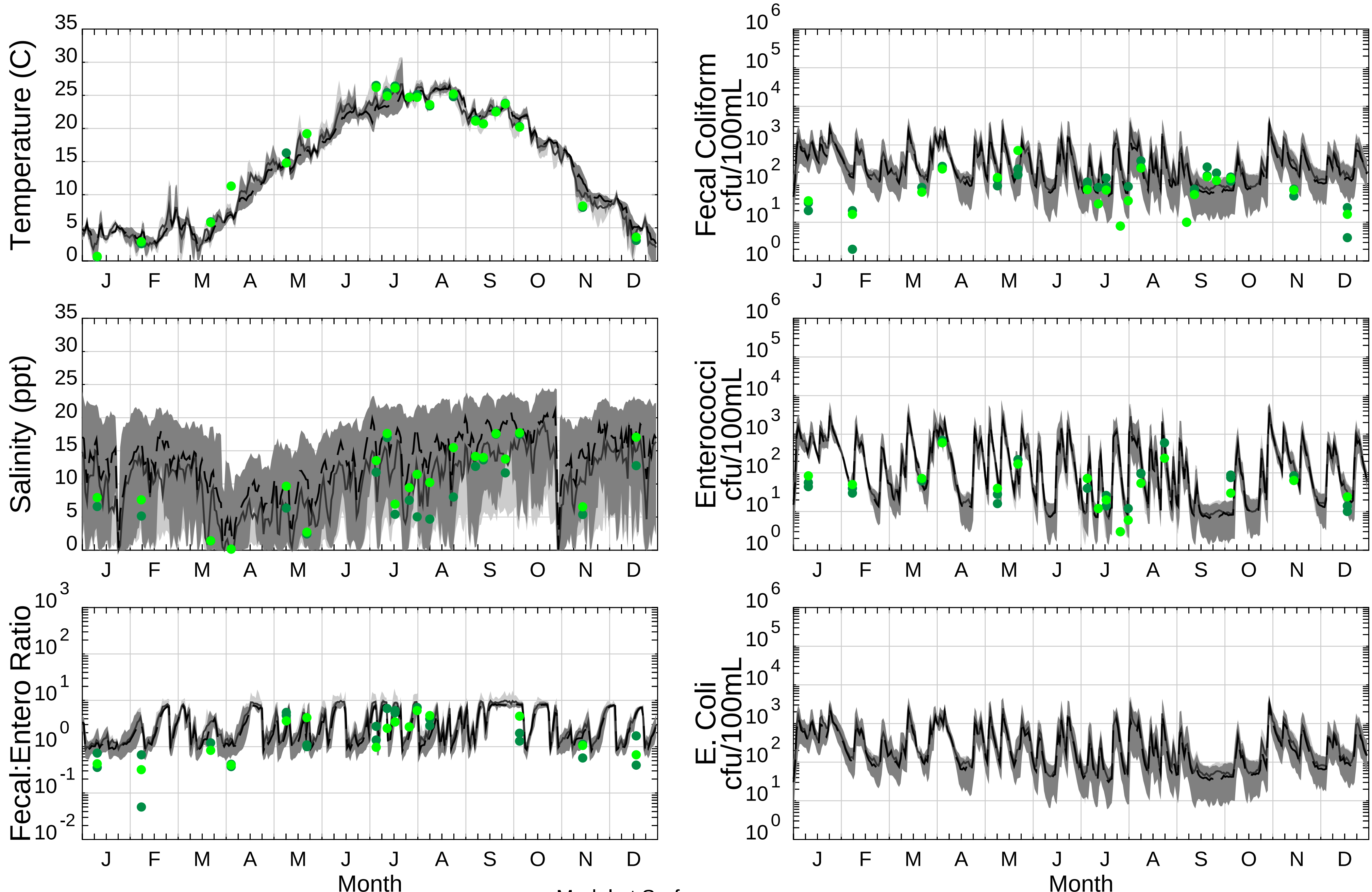
Model = 2017
Data = 2017

Station: 26



Model = 2017
Data = 2017

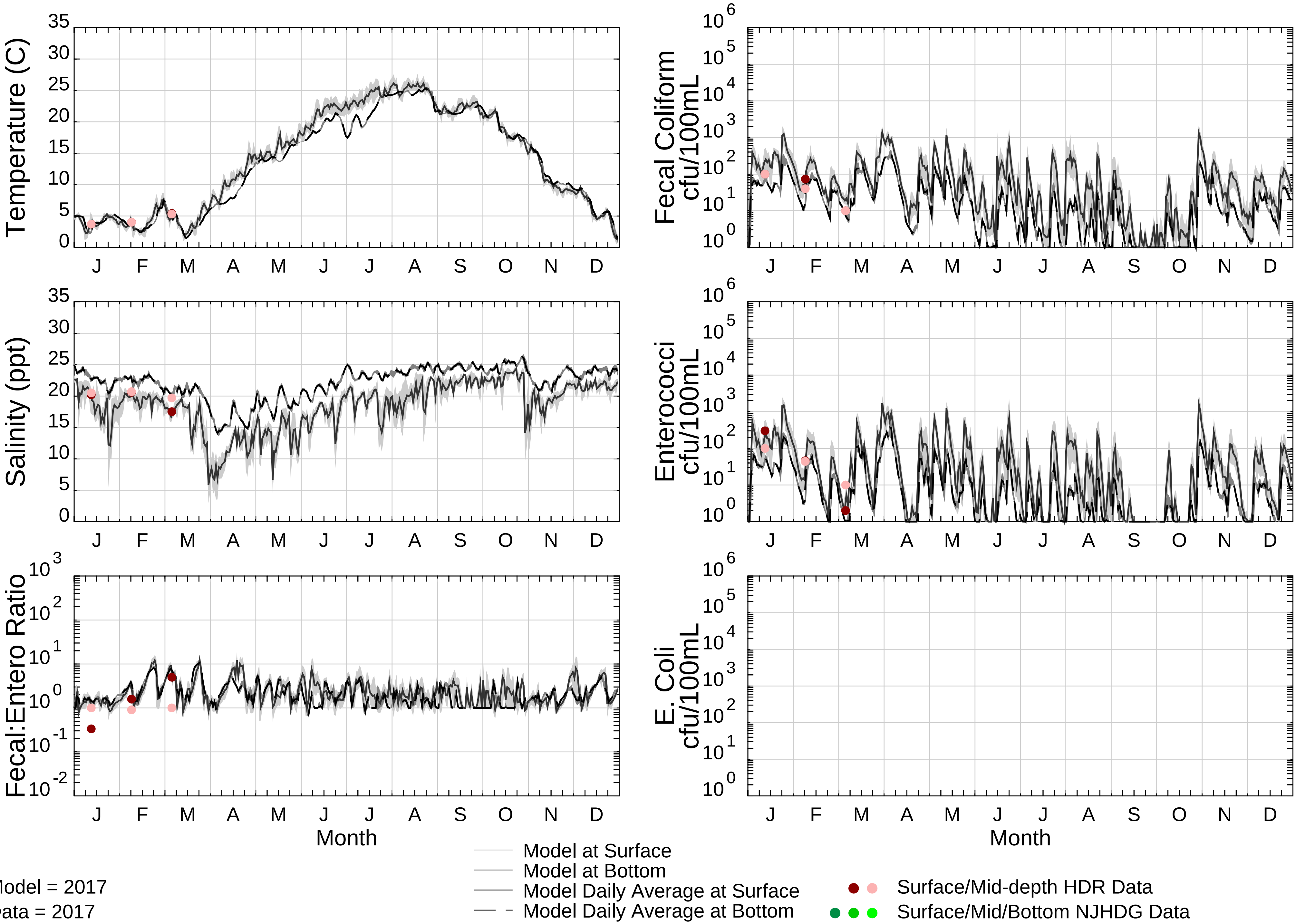
Station: 27



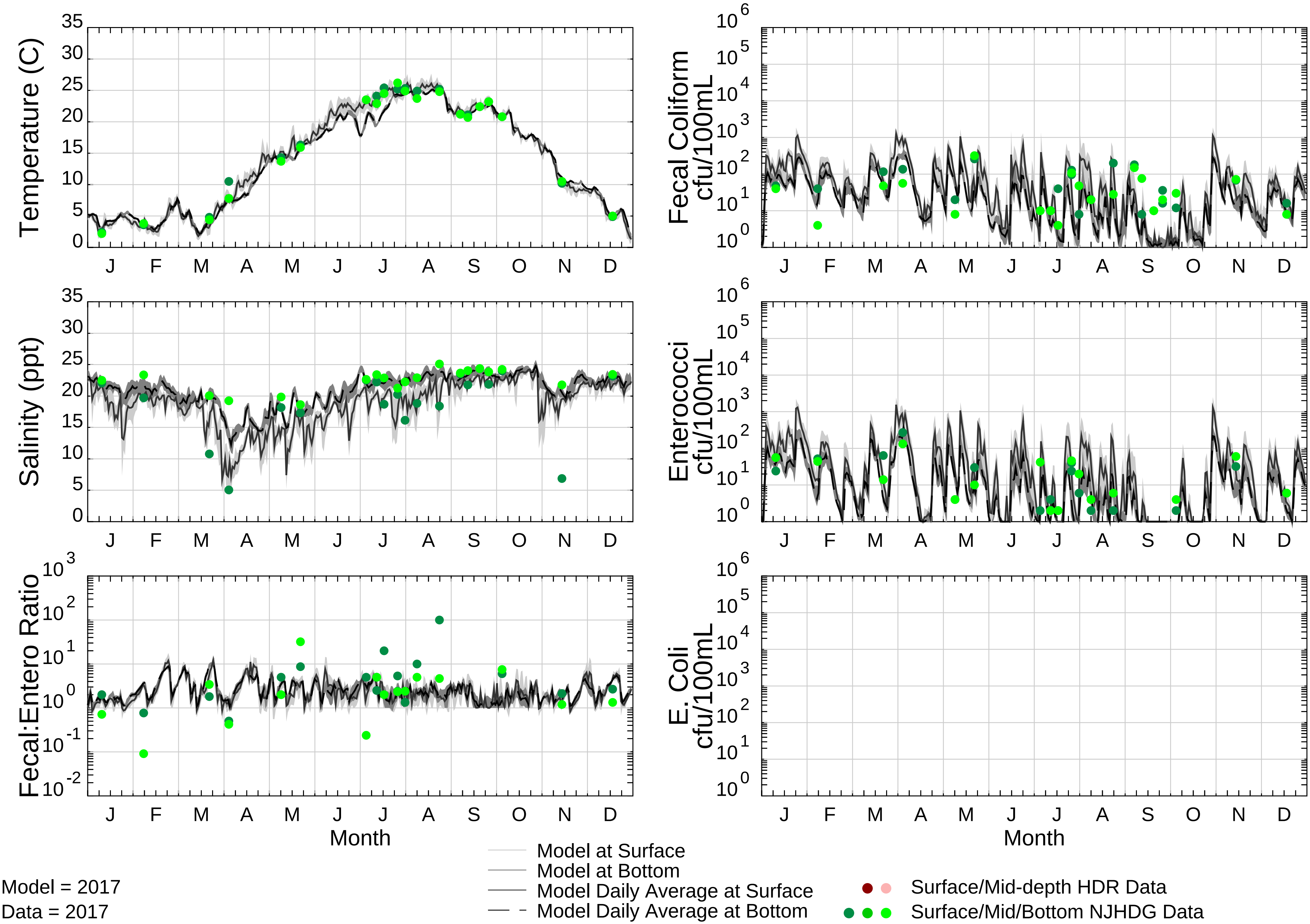
Model at Surface
Model at Bottom
Model Daily Average at Surface
Model Daily Average at Bottom
Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

Model = 2017
Data = 2017

Station: B19

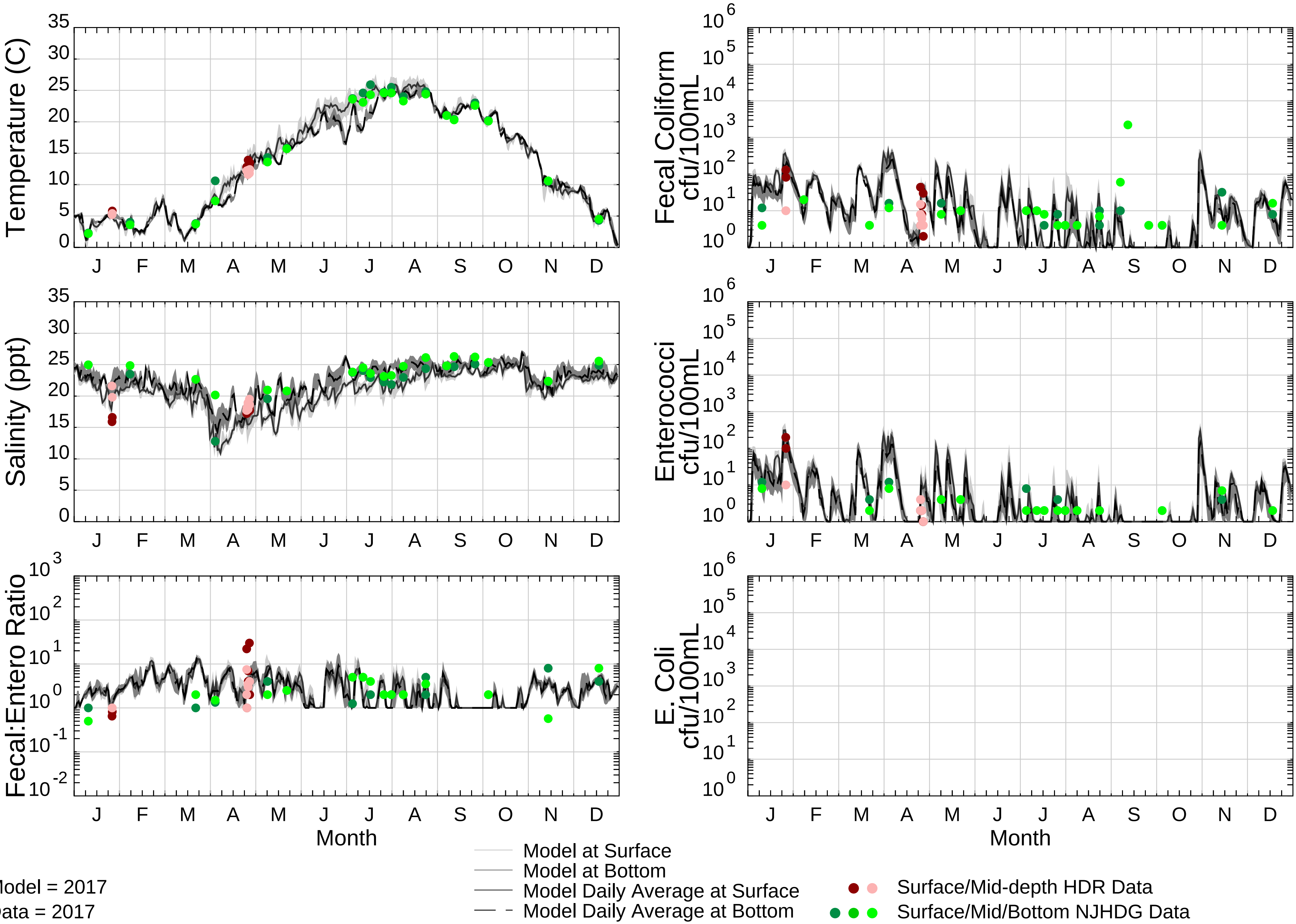

Temperature (C)
Salinity (ppt)
Fecal:Entero Ratio
Fecal Coliform cfu/100mL
Enterococci cfu/100mL
E. Coli cfu/100mL
J F M A M J J A S O N D
Month
Model at Surface
Model at Bottom
Model Daily Average at Surface
Model Daily Average at Bottom
Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data
Model = 2017
Data = 2017

Station: 28



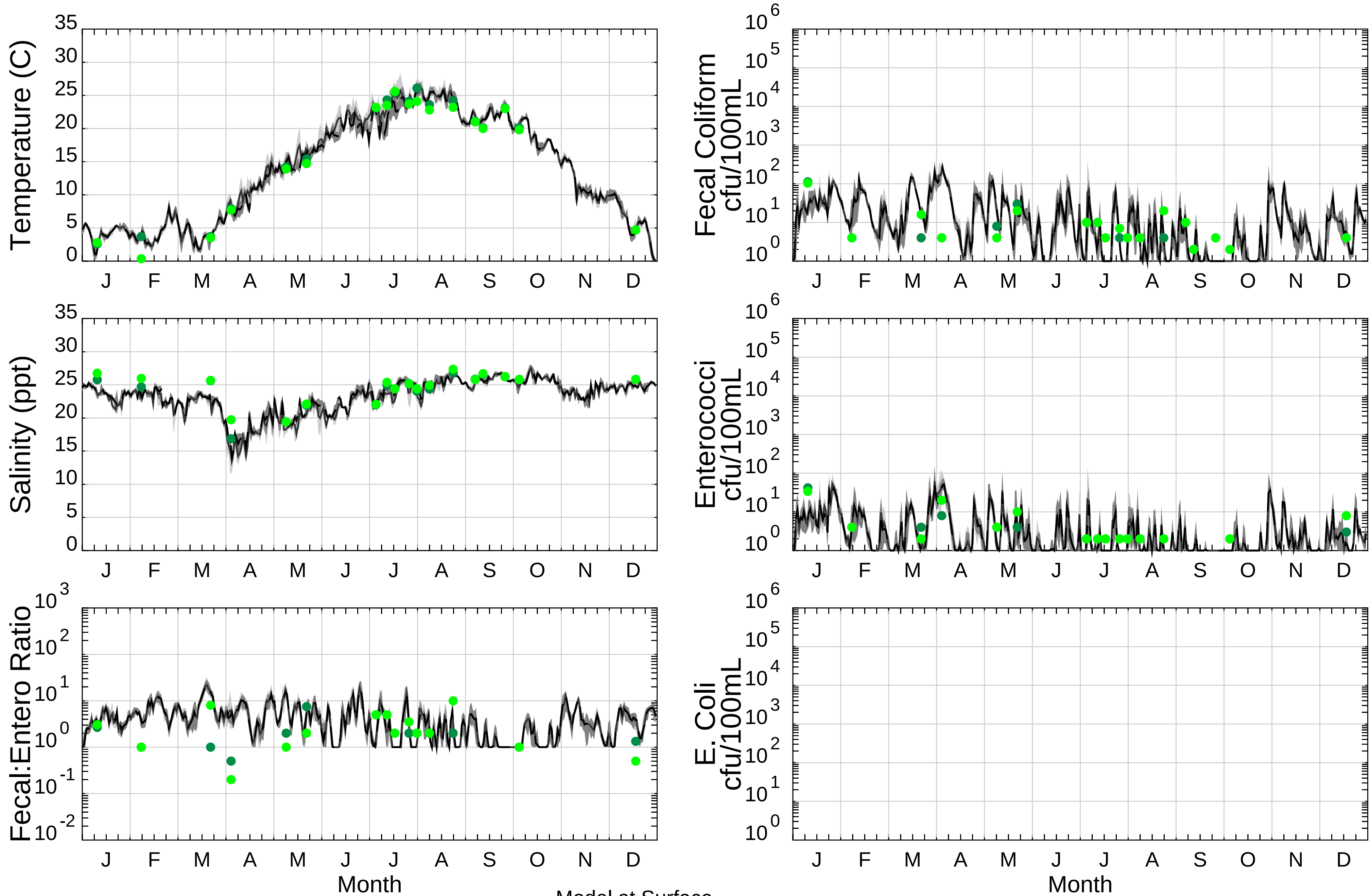
Model = 2017
Data = 2017

Station: 29



Model = 2017
Data = 2017

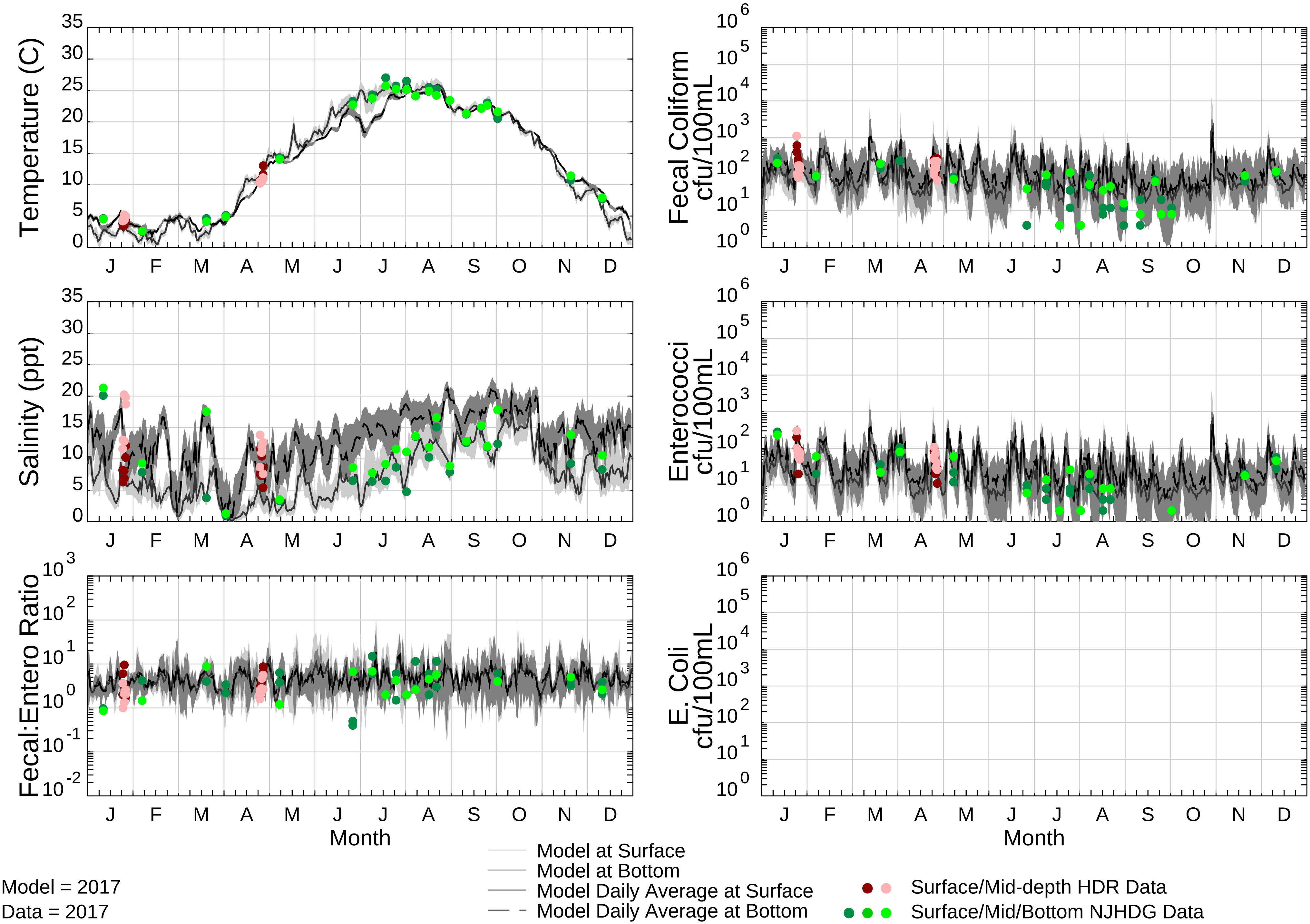
Station: 30



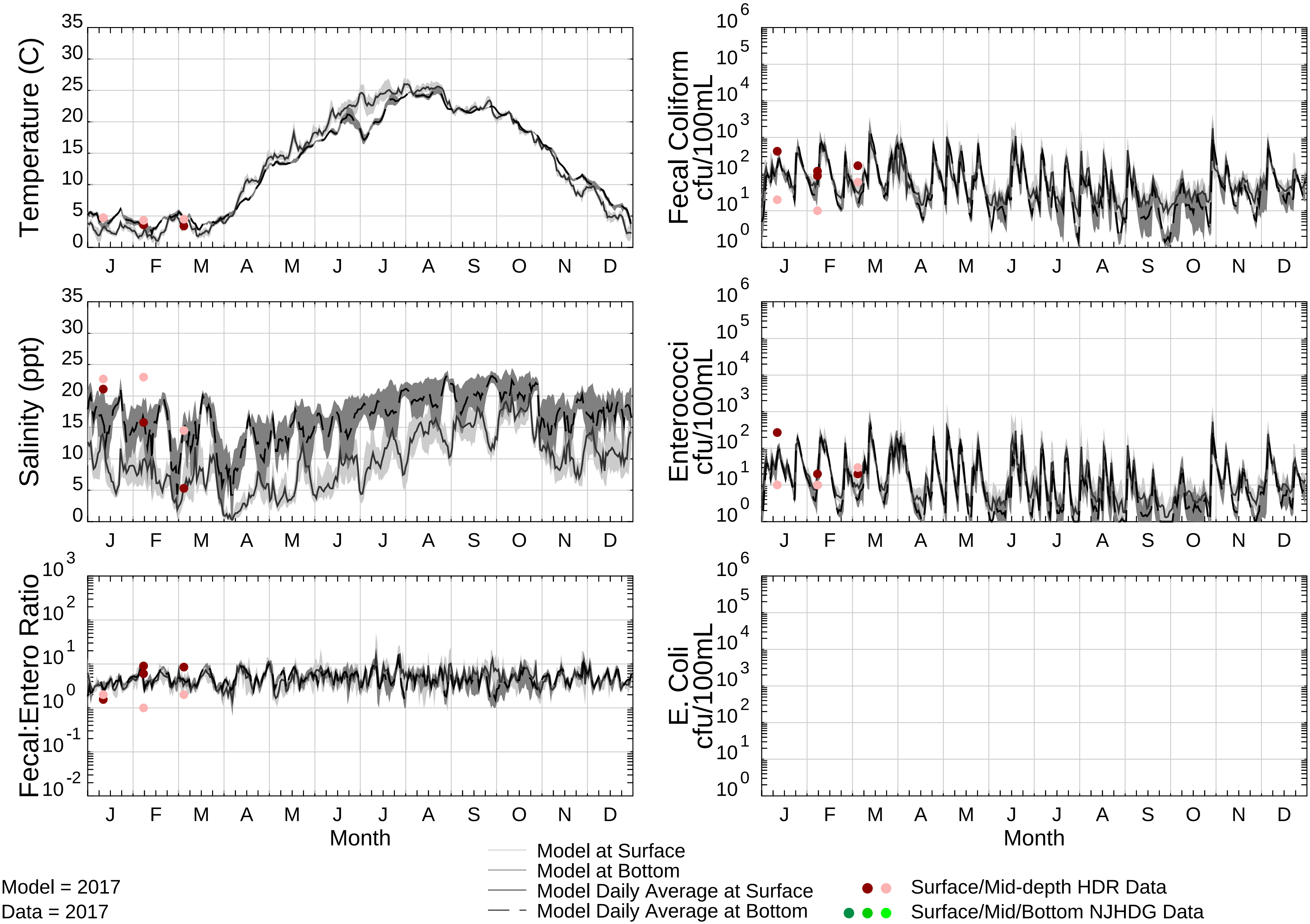
Model at Surface
Model at Bottom
Model Daily Average at Surface
Model Daily Average at Bottom
Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

Model = 2017
Data = 2017

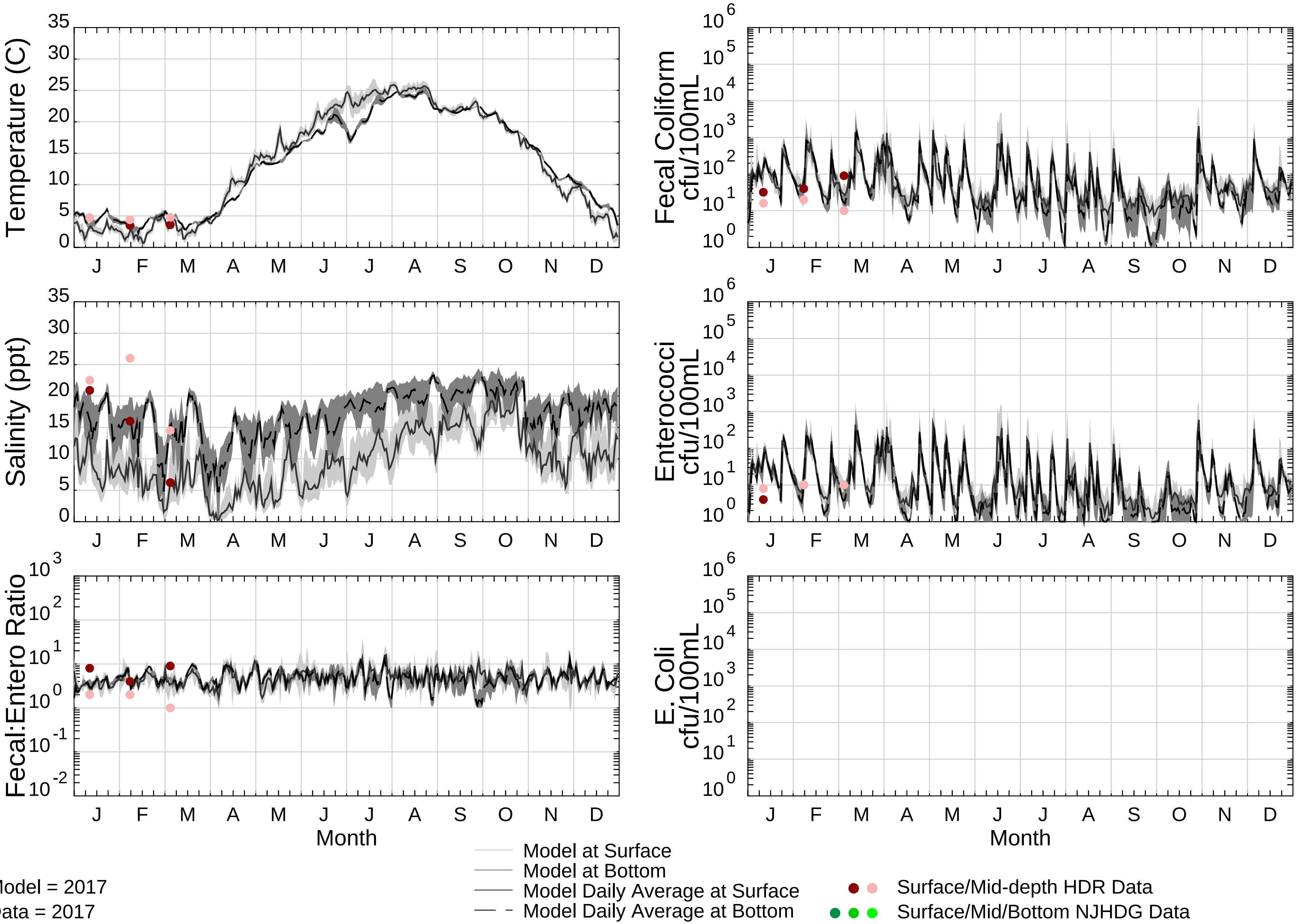
Station: 31


Temperature (C)
Salinity (ppt)
Fecal:Entero Ratio
Fecal Coliform cfu/100mL
Enterococci cfu/100mL
E. Coli cfu/100mL
J F M A M J J A S O N D
Month
Model at Surface
Model at Bottom
Model Daily Average at Surface
Model Daily Average at Bottom
Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data
Model = 2017
Data = 2017

Station: B5A

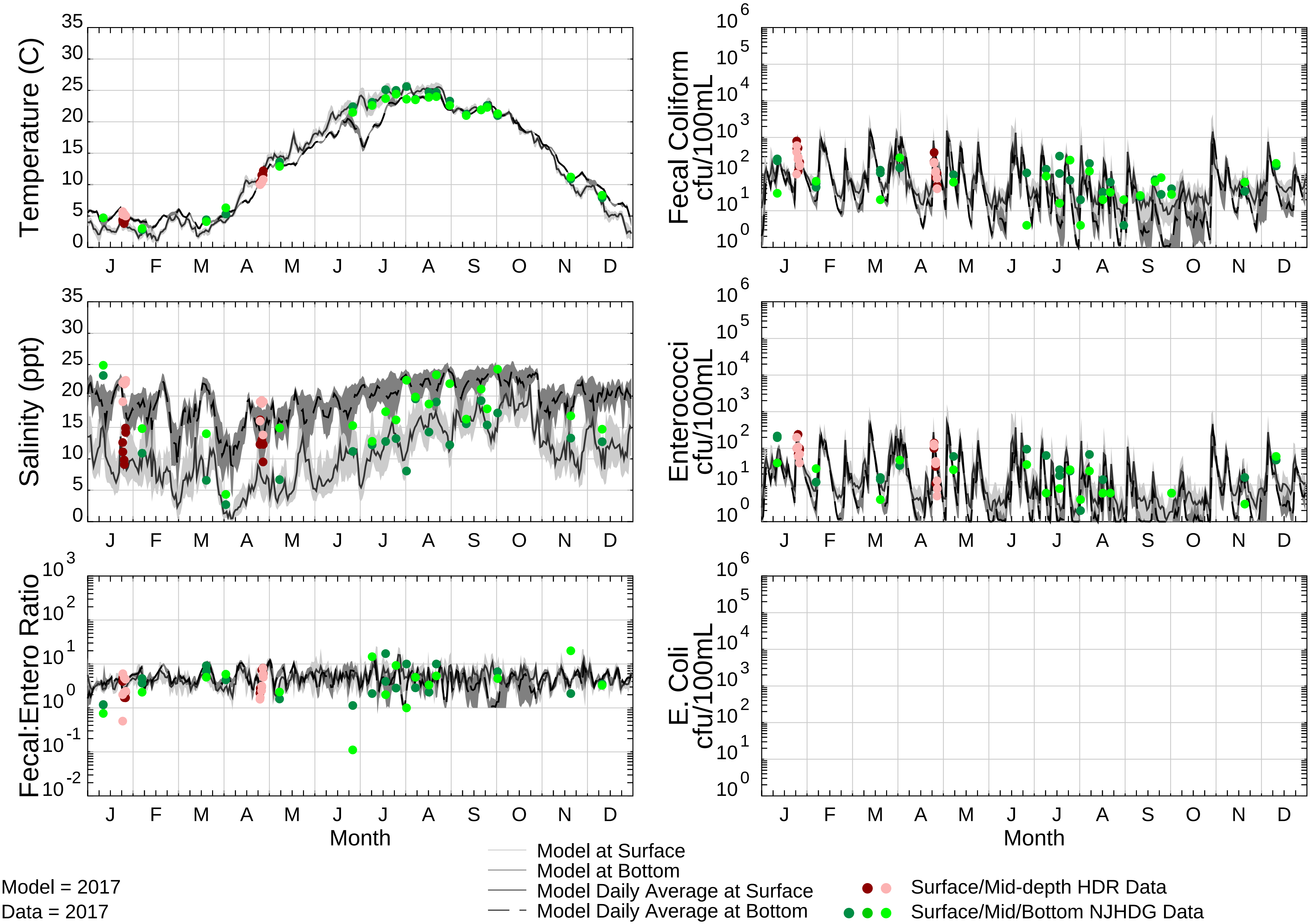

Temperature (C)
Salinity (ppt)
Fecal:Entero Ratio
Fecal Coliform cfu/100mL
Enterococci cfu/100mL
E. Coli cfu/100mL
J F M A M J J A S O N D
Month
Model at Surface
Model at Bottom
Model Daily Average at Surface
Model Daily Average at Bottom
Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data
Model = 2017
Data = 2017

Station: B5B



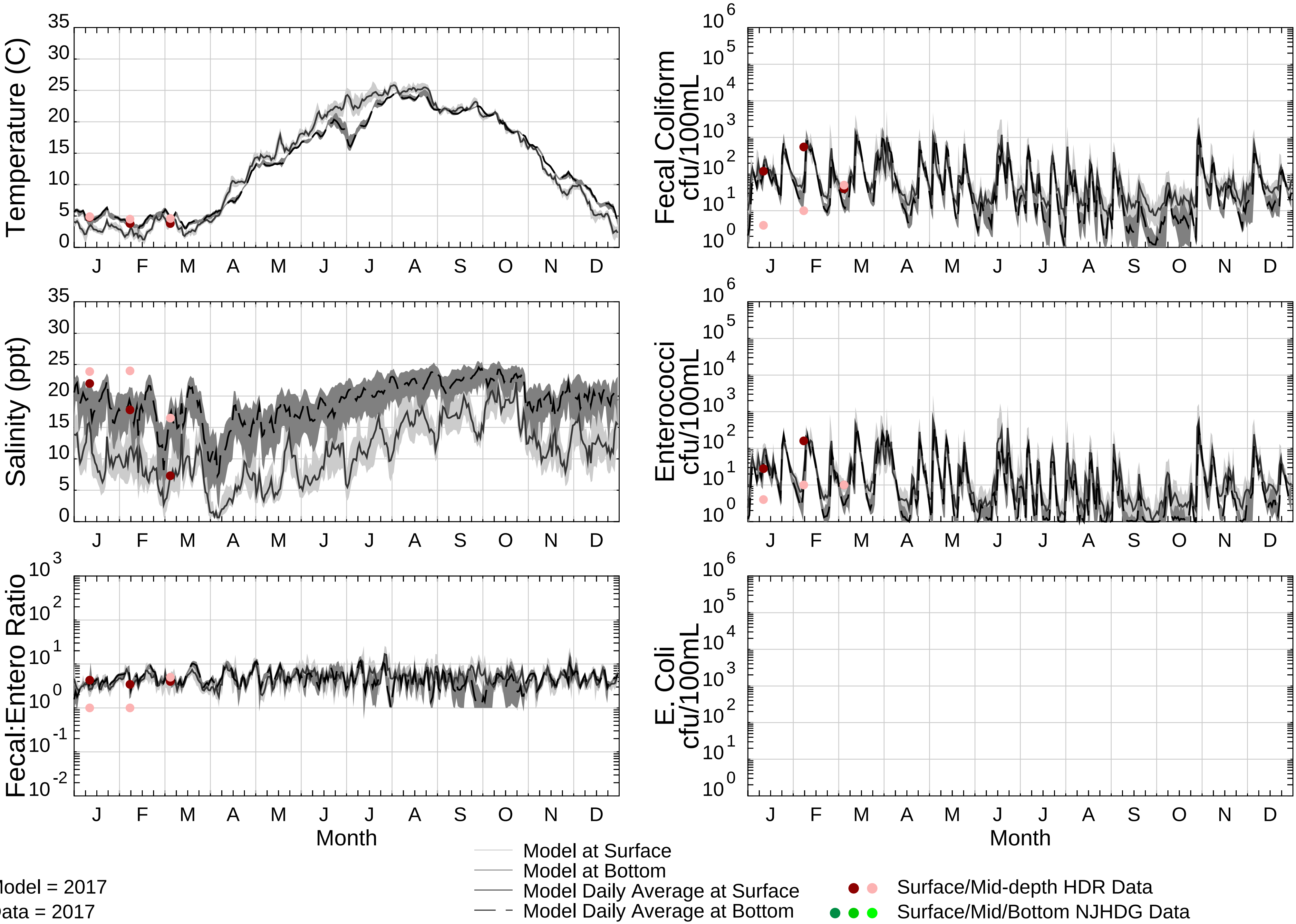
Model = 2017
Data = 2017

Station: 32



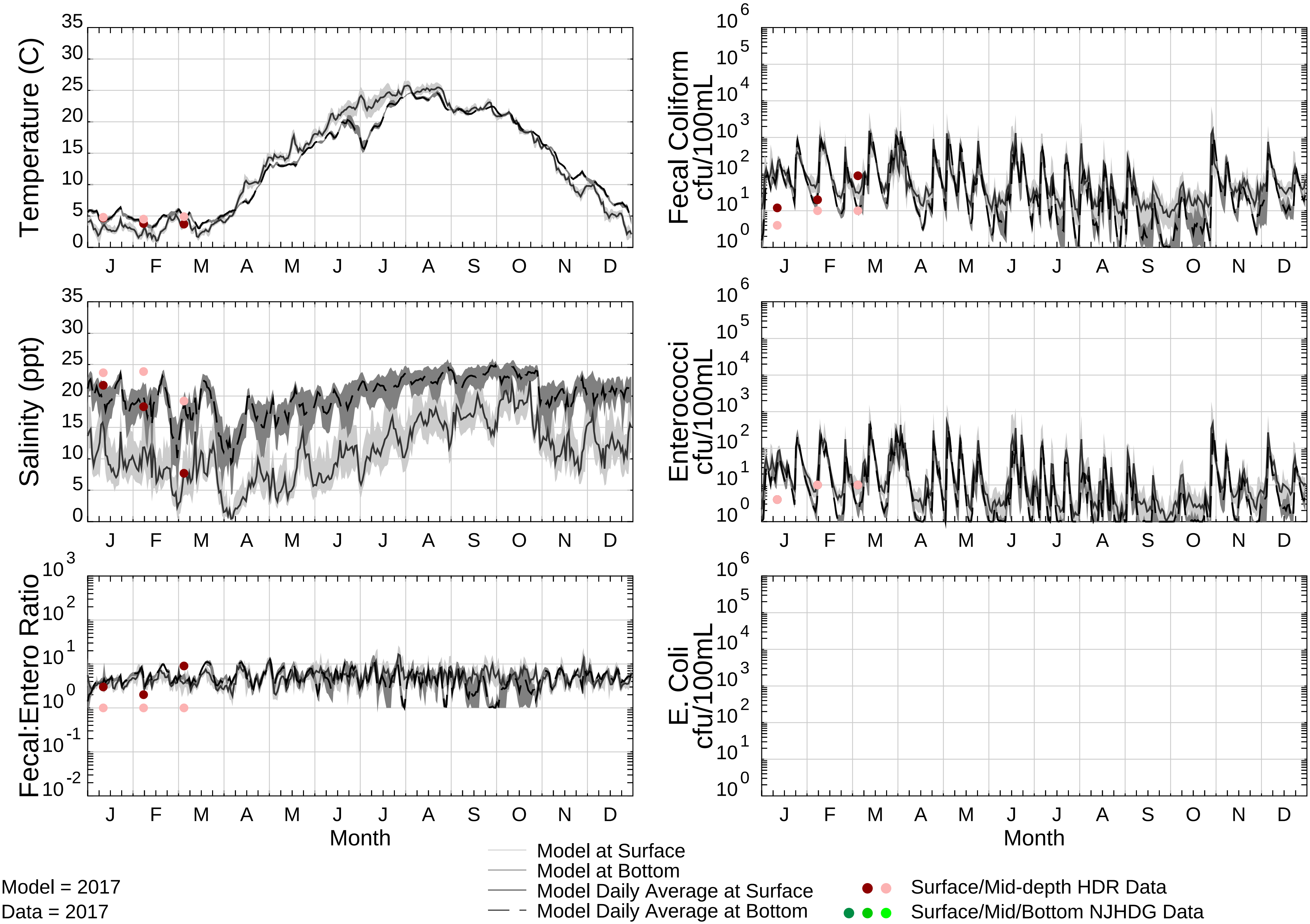
Model = 2017
Data = 2017

Station: B18A



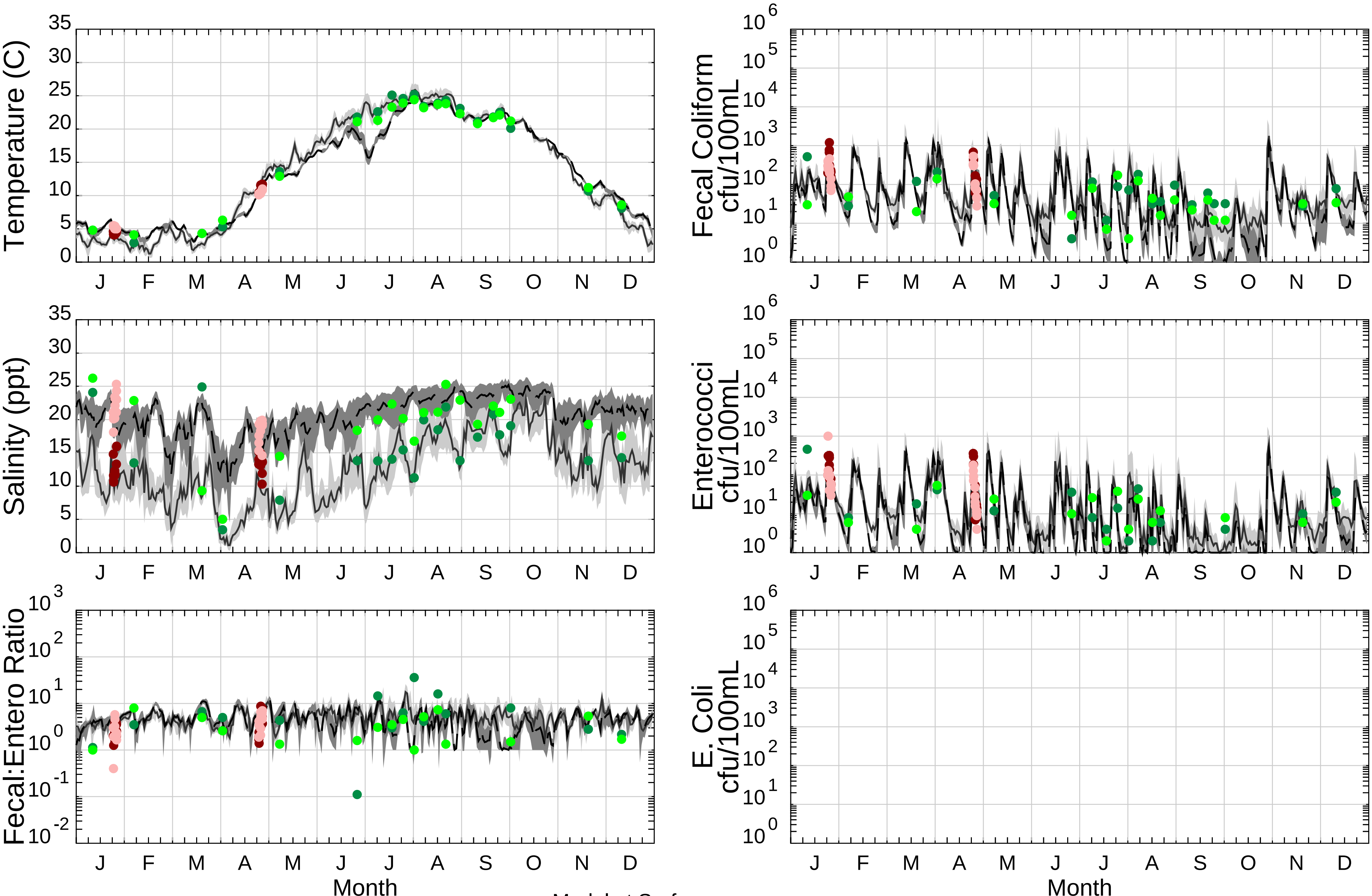
Model = 2017
Data = 2017

Station: B18B



Model = 2017
Data = 2017

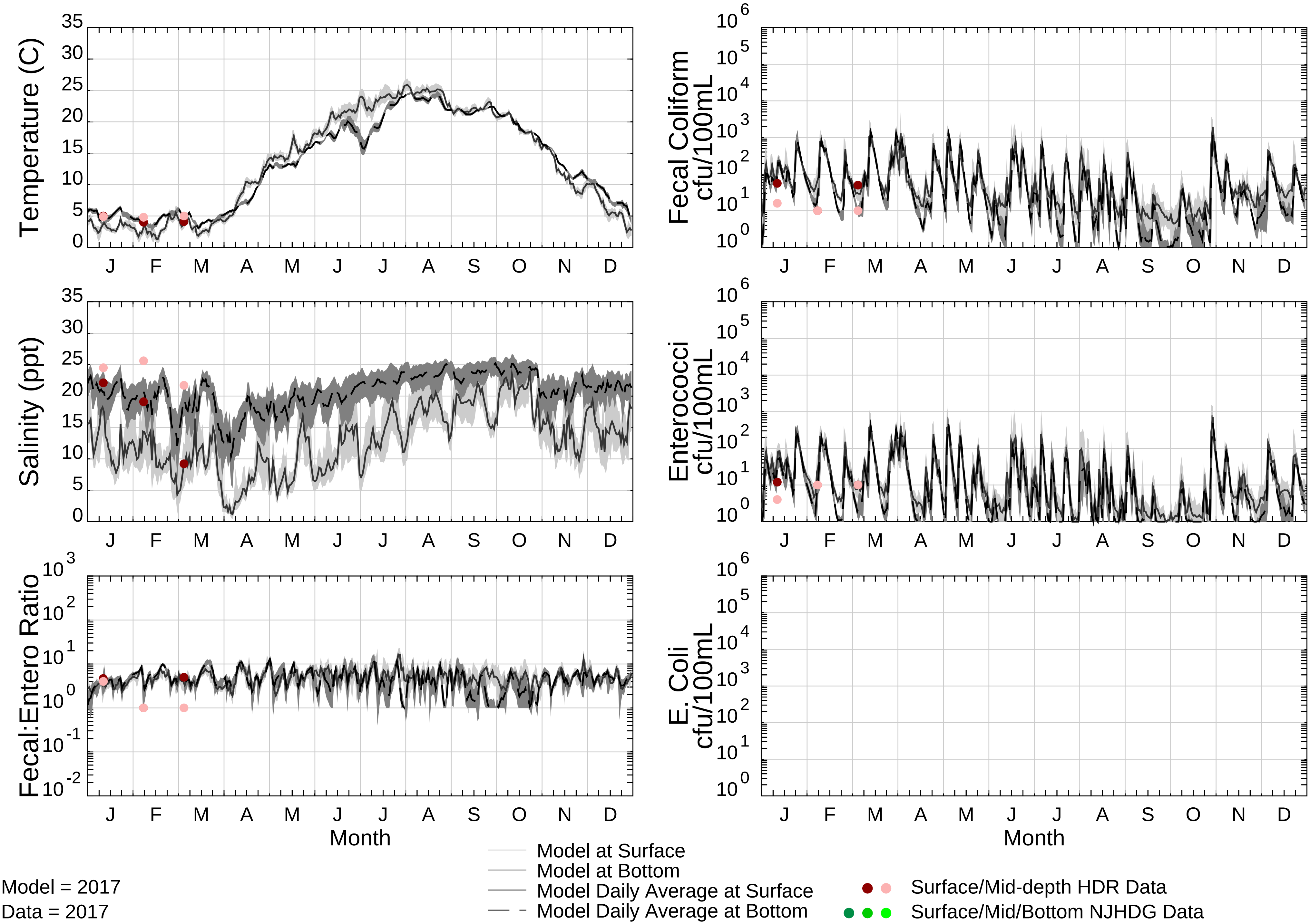
Station: 33



Model at Surface
Model at Bottom
Model Daily Average at Surface
Model Daily Average at Bottom
Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

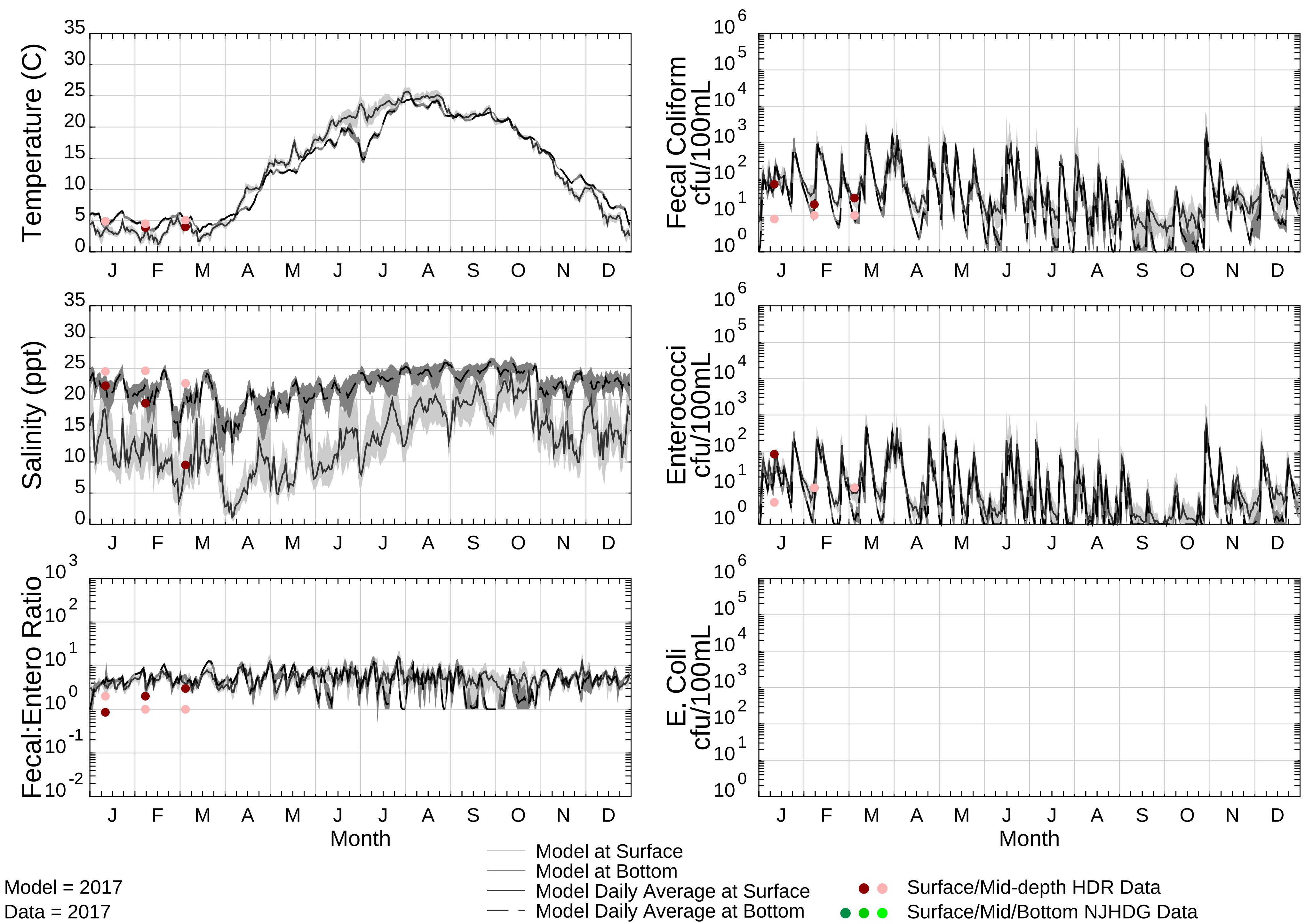
Model = 2017
Data = 2017

Station: B23A



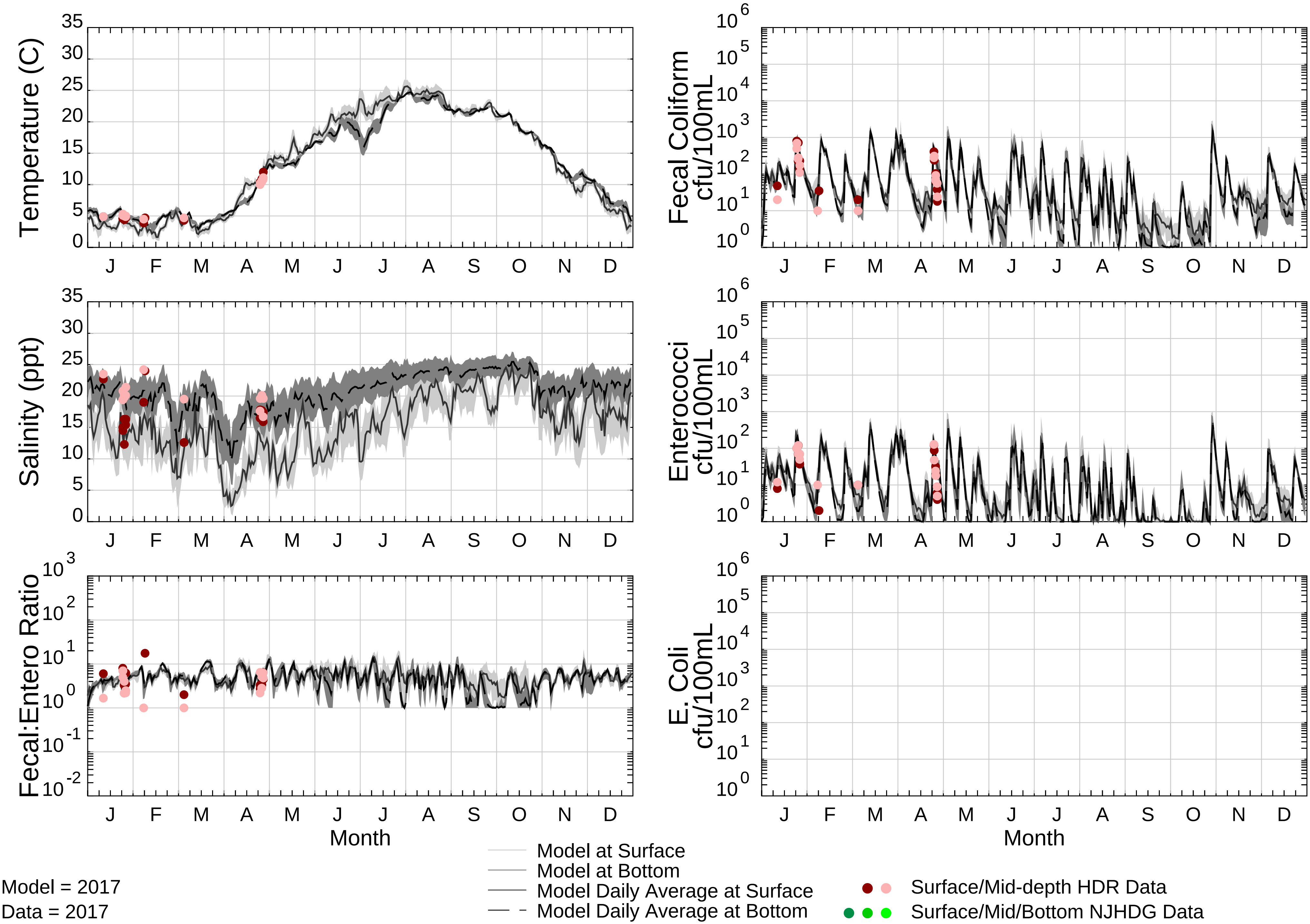
Model = 2017
Data = 2017

Station: B23B

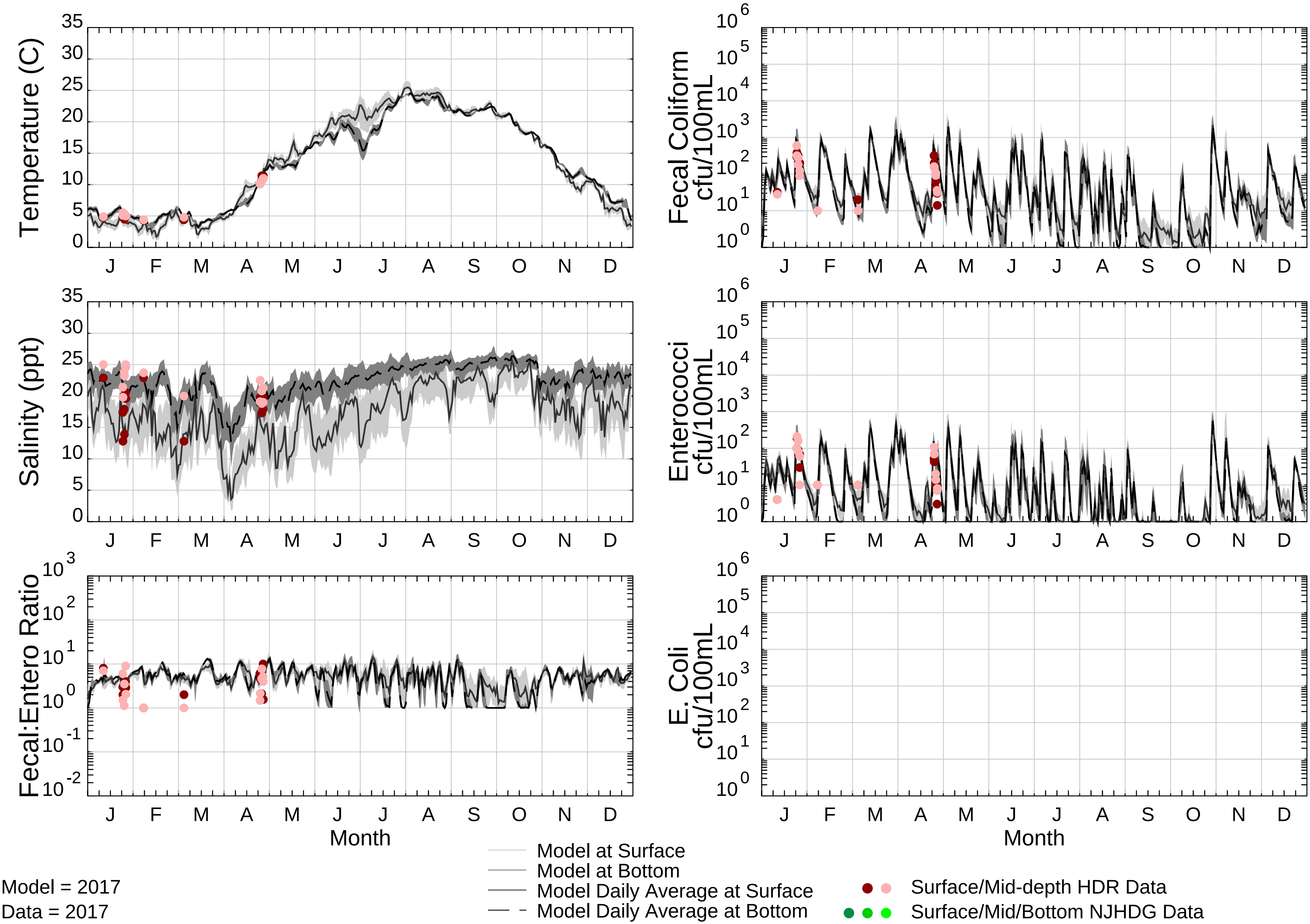


Model = 2017
Data = 2017

Station: B26

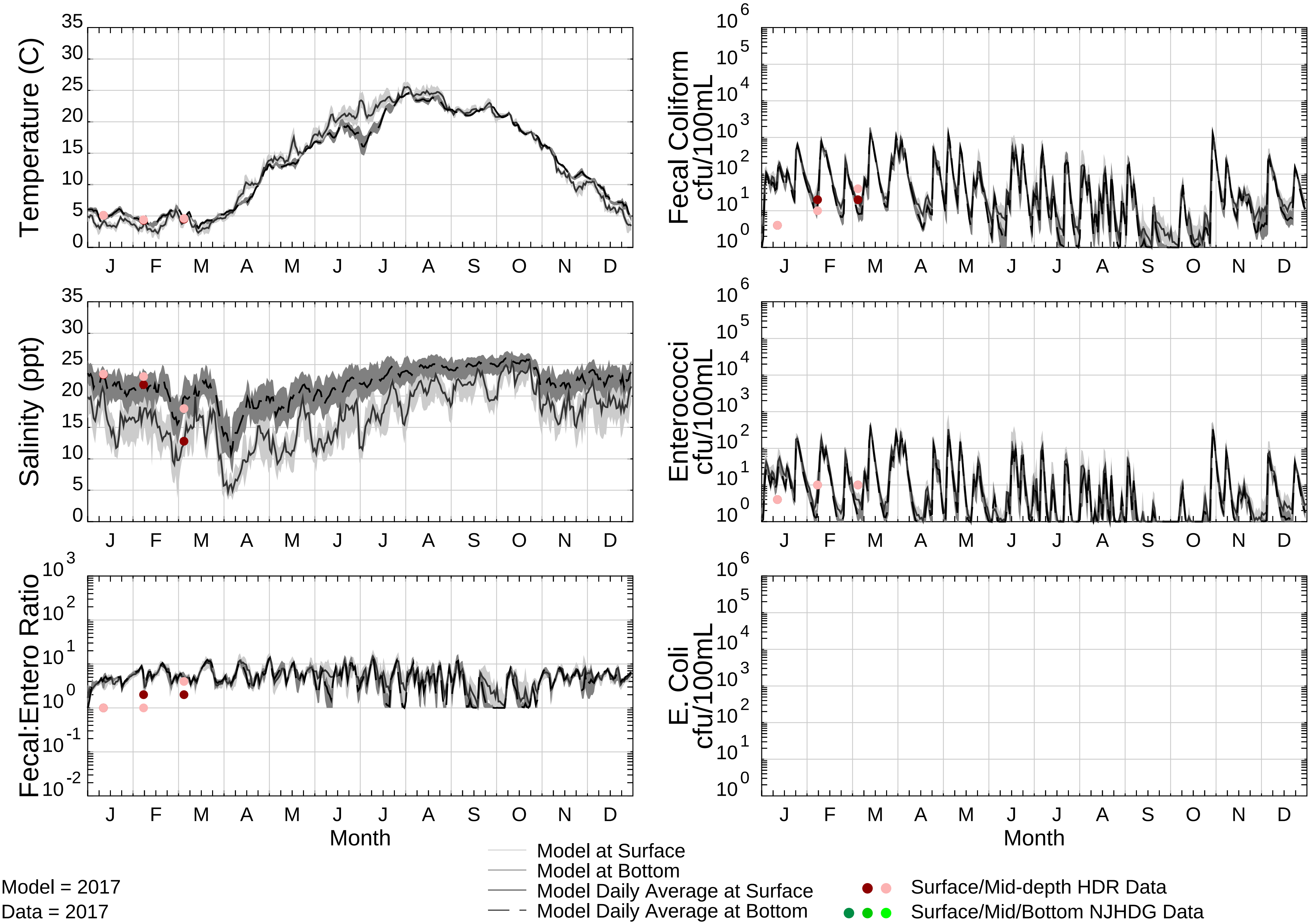

Temperature (C)
Fecal Coliform cfu/100mL
Salinity (ppt)
Enterococci cfu/100mL
Fecal:Entero Ratio
E. Coli cfu/100mL
J F M A M J J A S O N D
Month
Model at Surface
Model at Bottom
Model Daily Average at Surface
Model Daily Average at Bottom
Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data
Model = 2017
Data = 2017

Station: B27



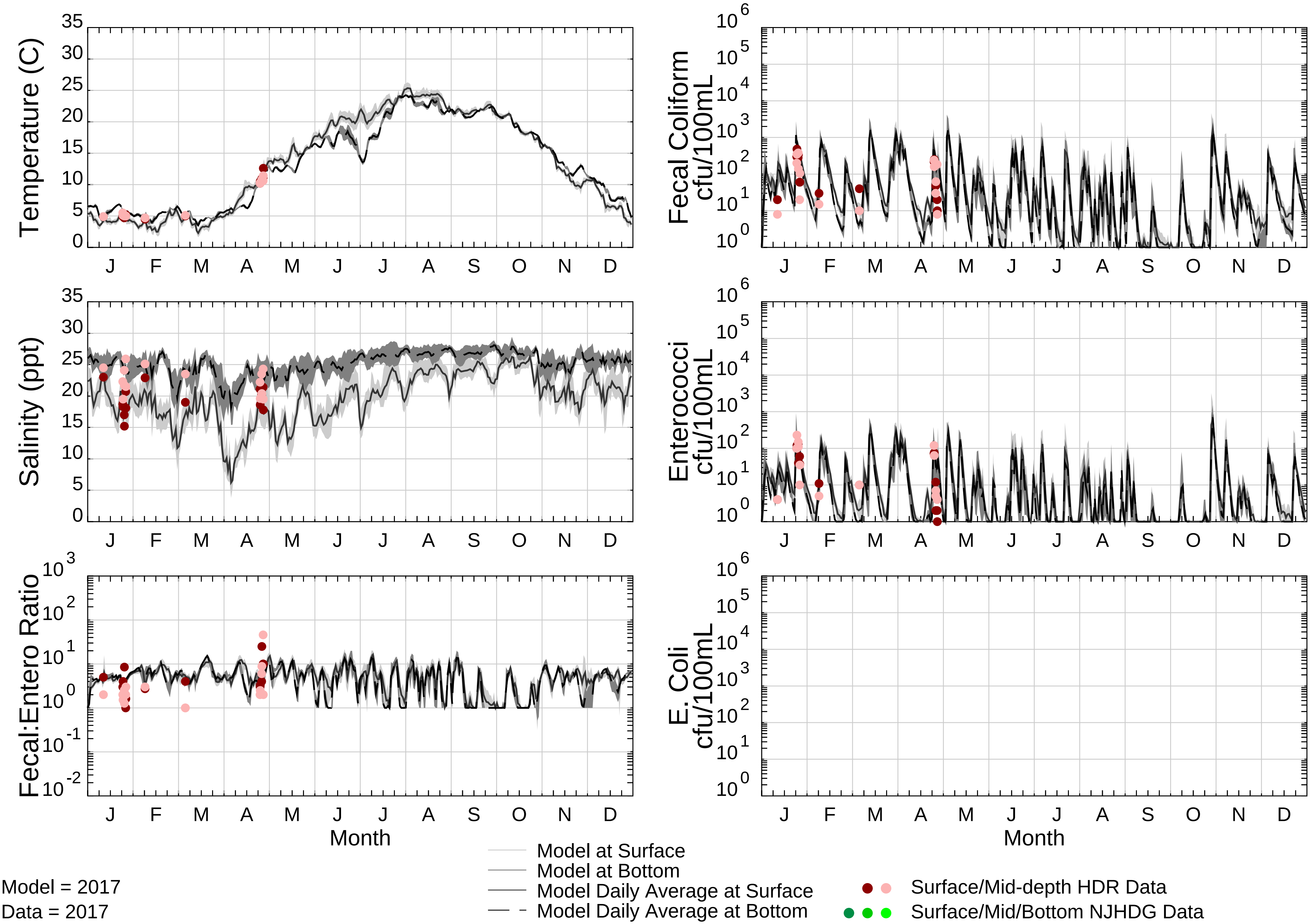
Model = 2017
Data = 2017

Station: B9



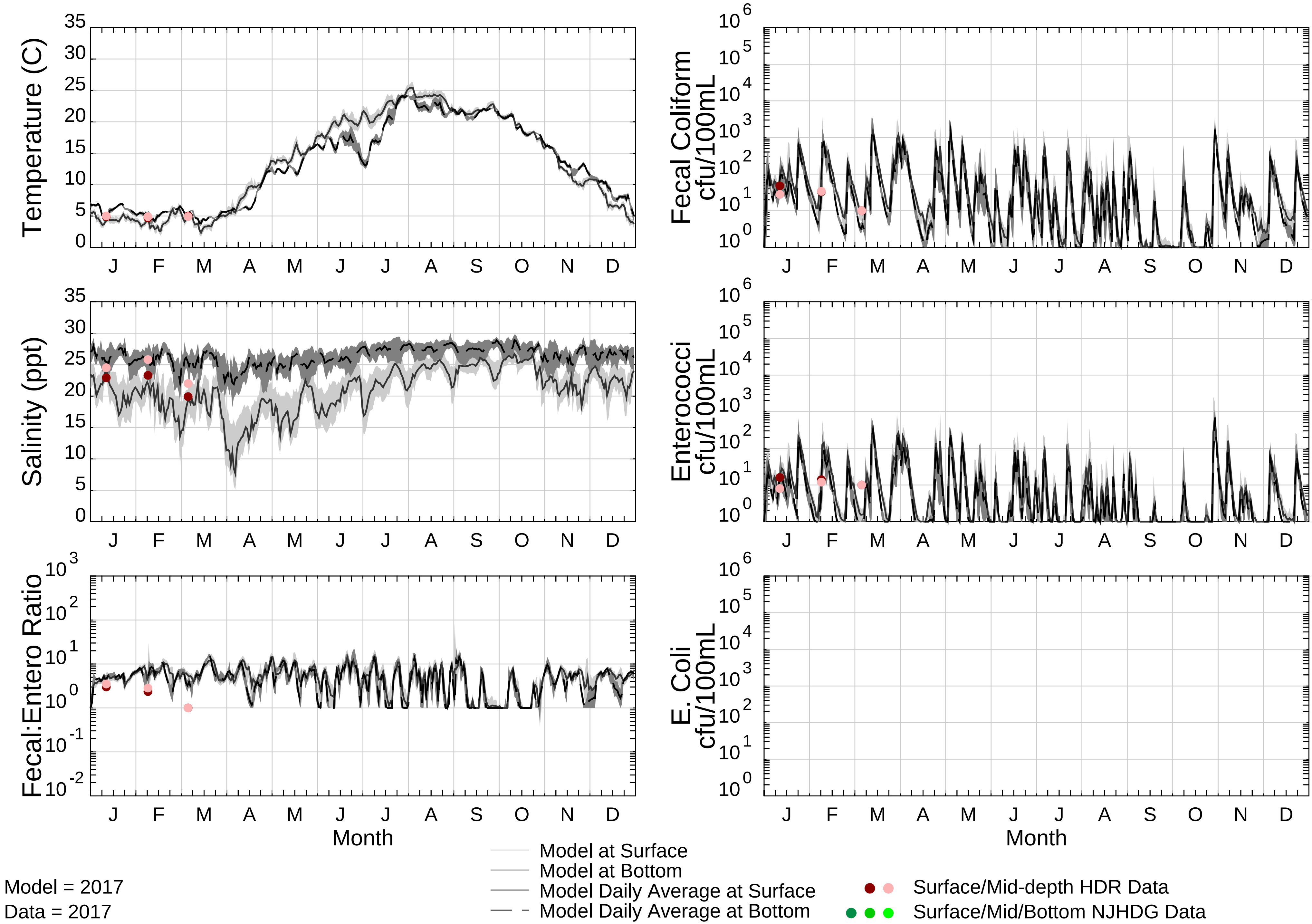
Model = 2017
Data = 2017

Station: B28

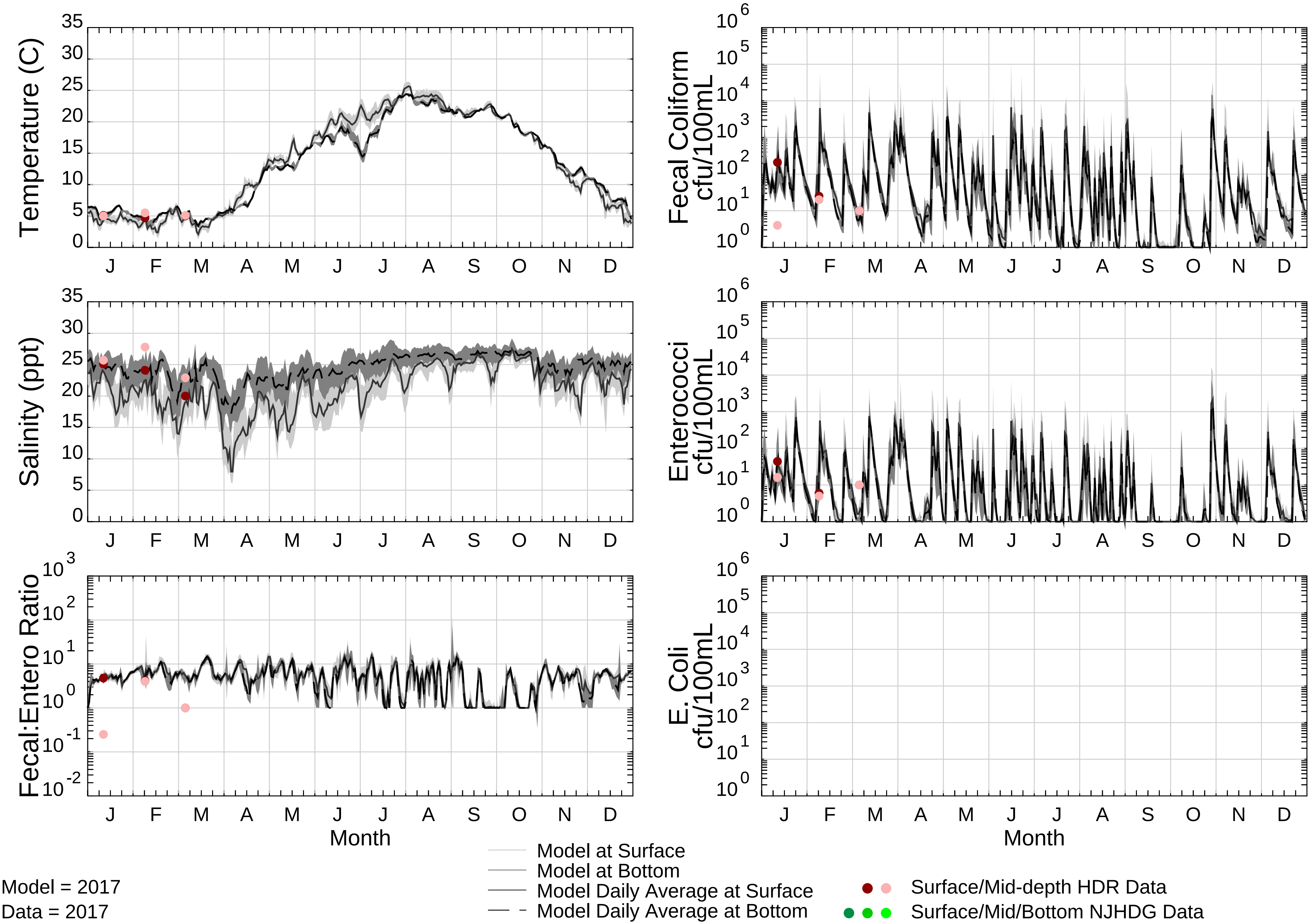


Model = 2017
Data = 2017

Station: B21A



Station: B21B



Model = 2017
Data = 2017

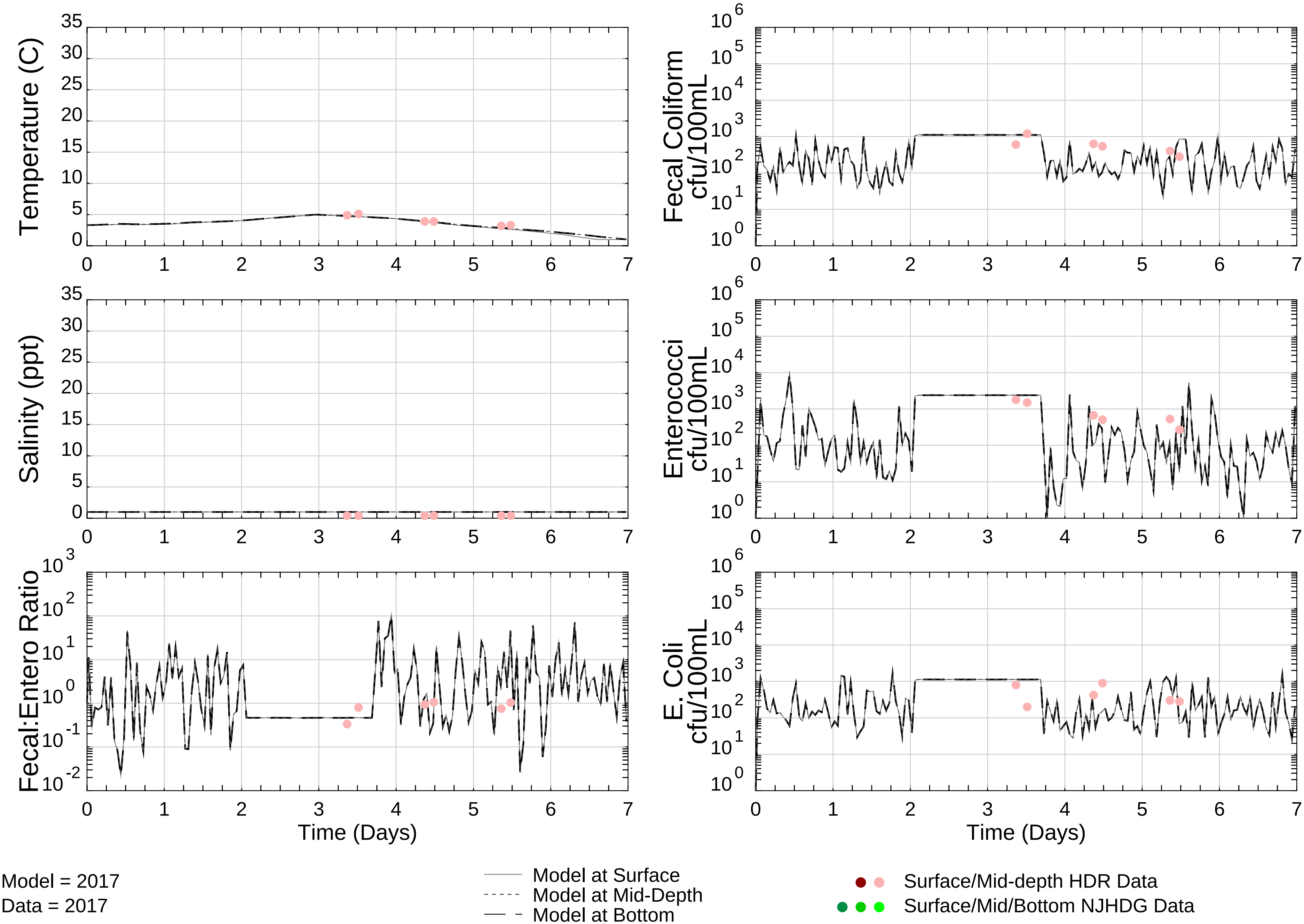
Appendix F-2

Additional Validation Wet-Weather Time-Series Figures

Passaic River & Tributaries
Passaic River

FW2

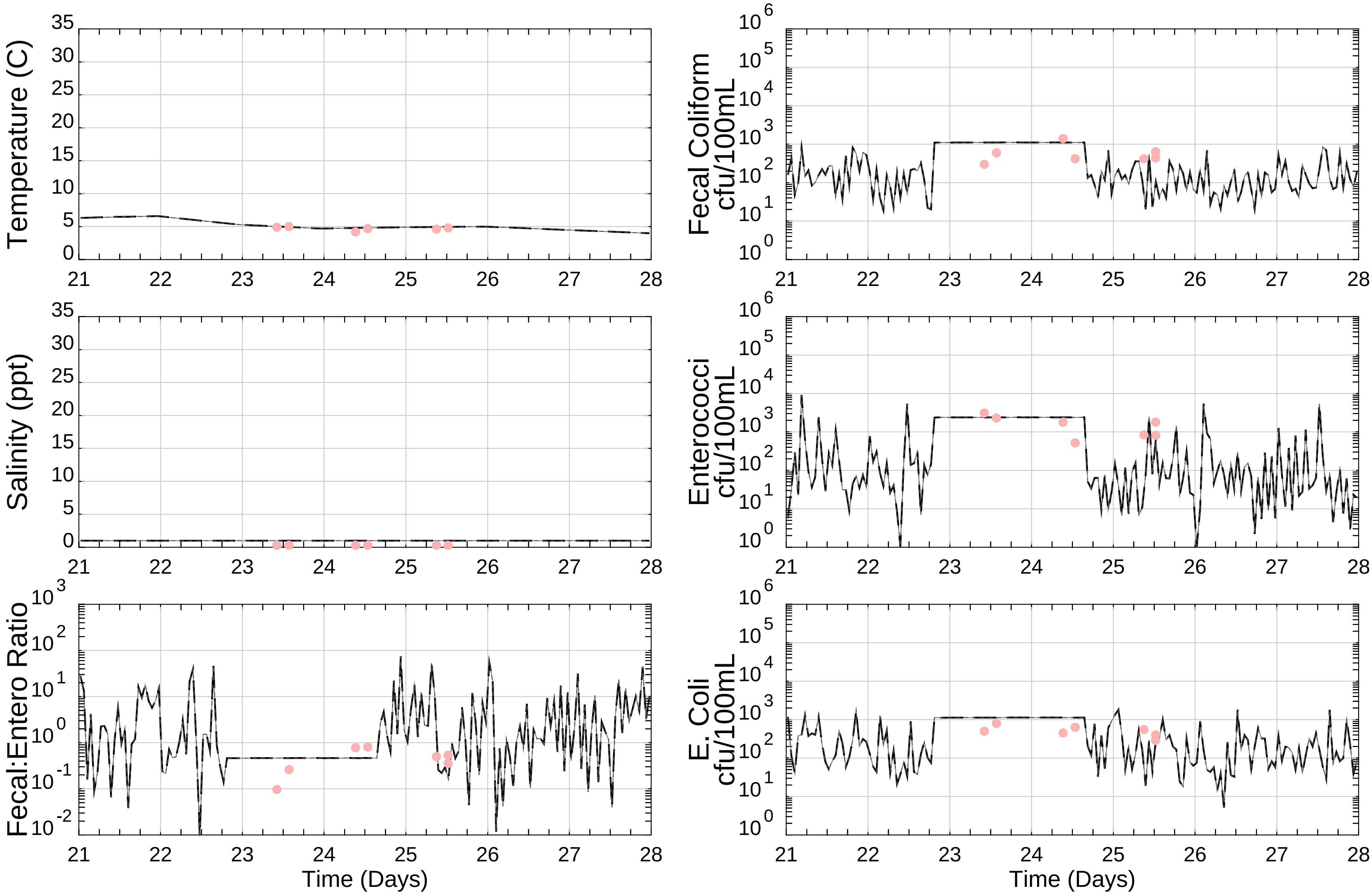
Station: B24 Event 1 (Jan 1-7)



Model = 2017
Data = 2017

Passaic River & Tributaries
Passaic River

Station: B24 Event 2 (Jan 21-28)



Model = 2017
Data = 2017

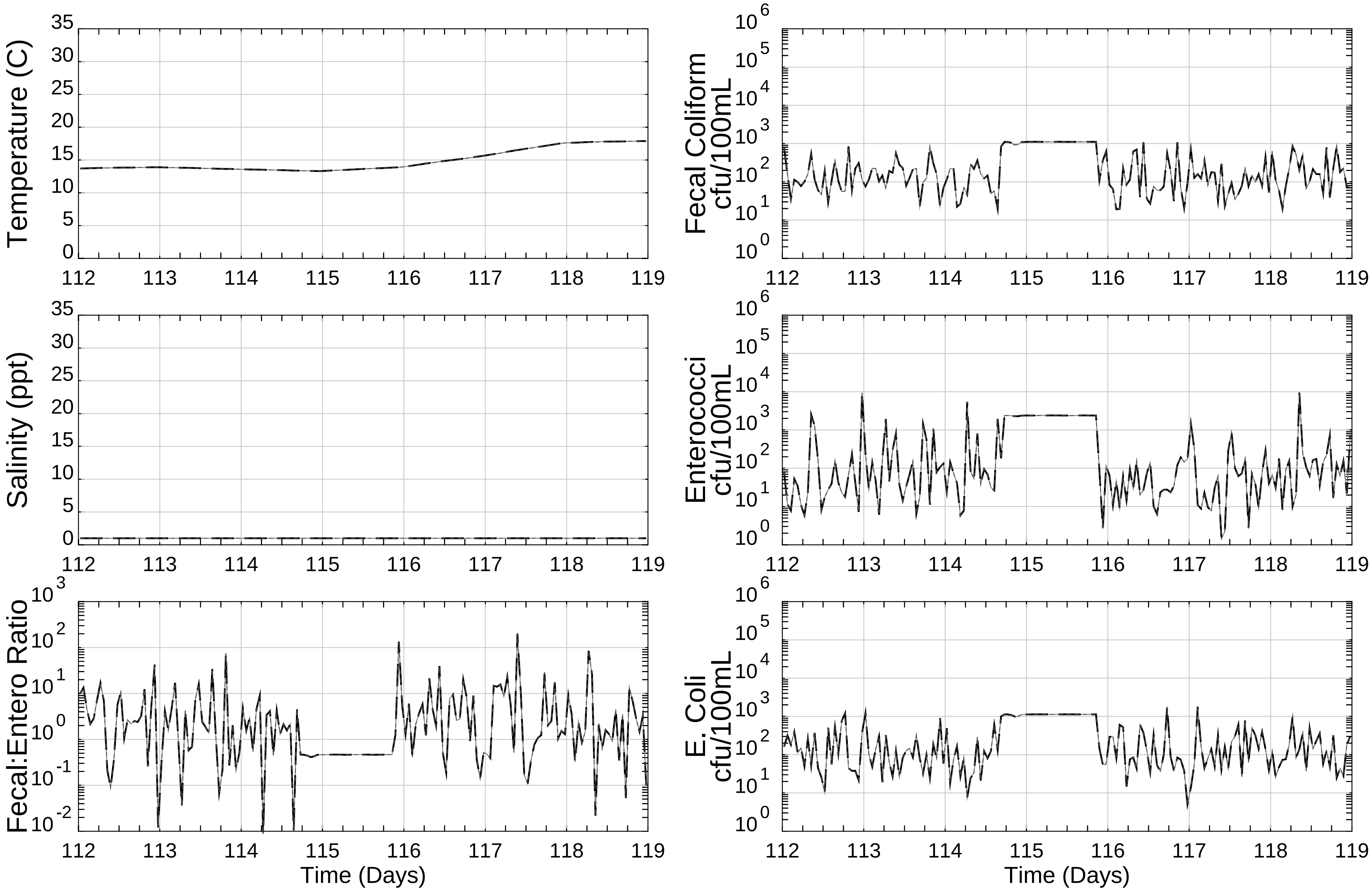
Model at Surface
Model at Mid-Depth
Model at Bottom

Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

Passaic River & Tributaries
Passaic River

FW2

Station: B24 Event 3 (Apr 23-29)

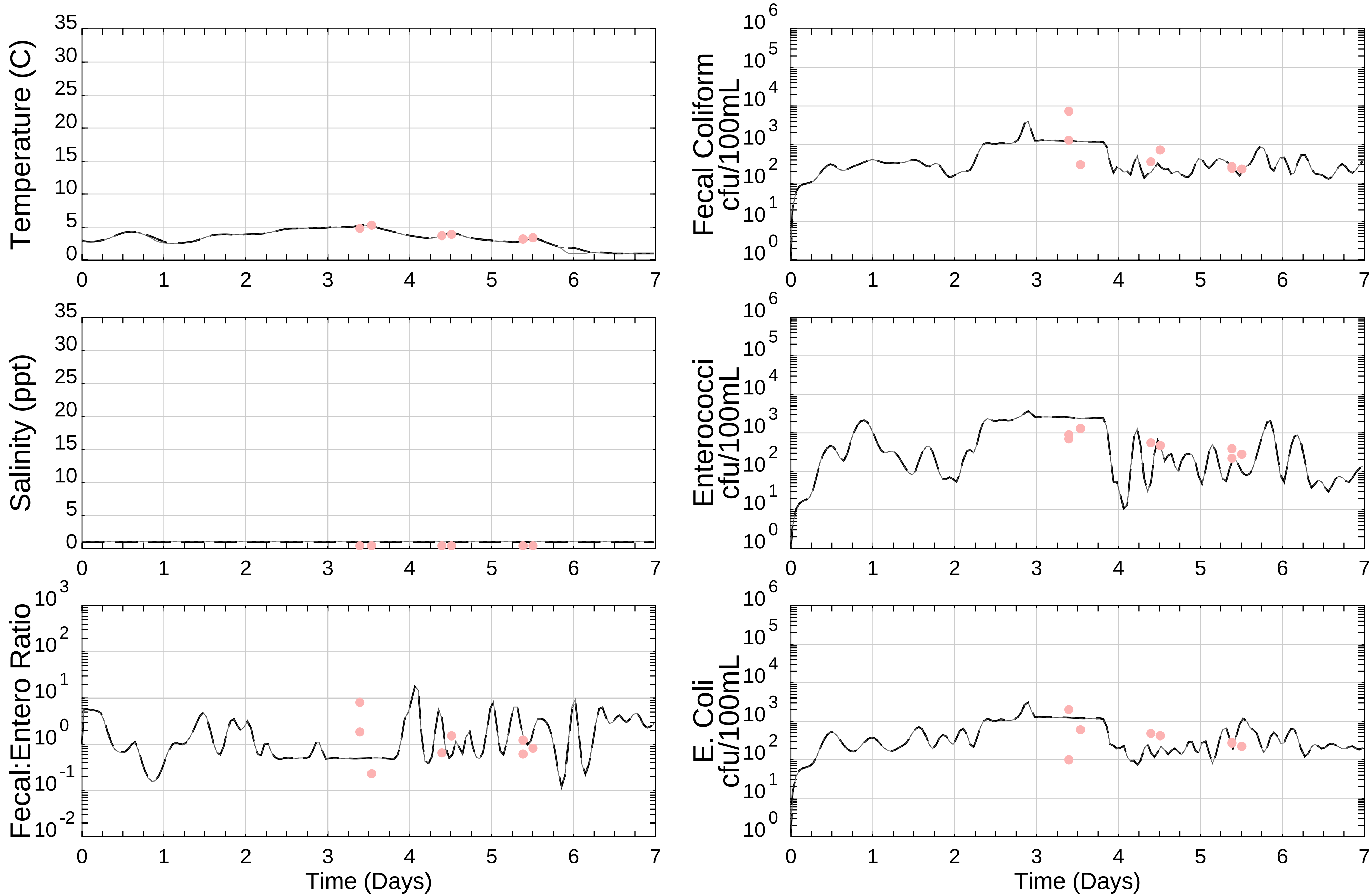


Model = 2017
Data = 2017

Passaic River & Tributaries
Passaic River

FW2

Station: 3 Event 1 (Jan 1-7)



Model = 2017
Data = 2017

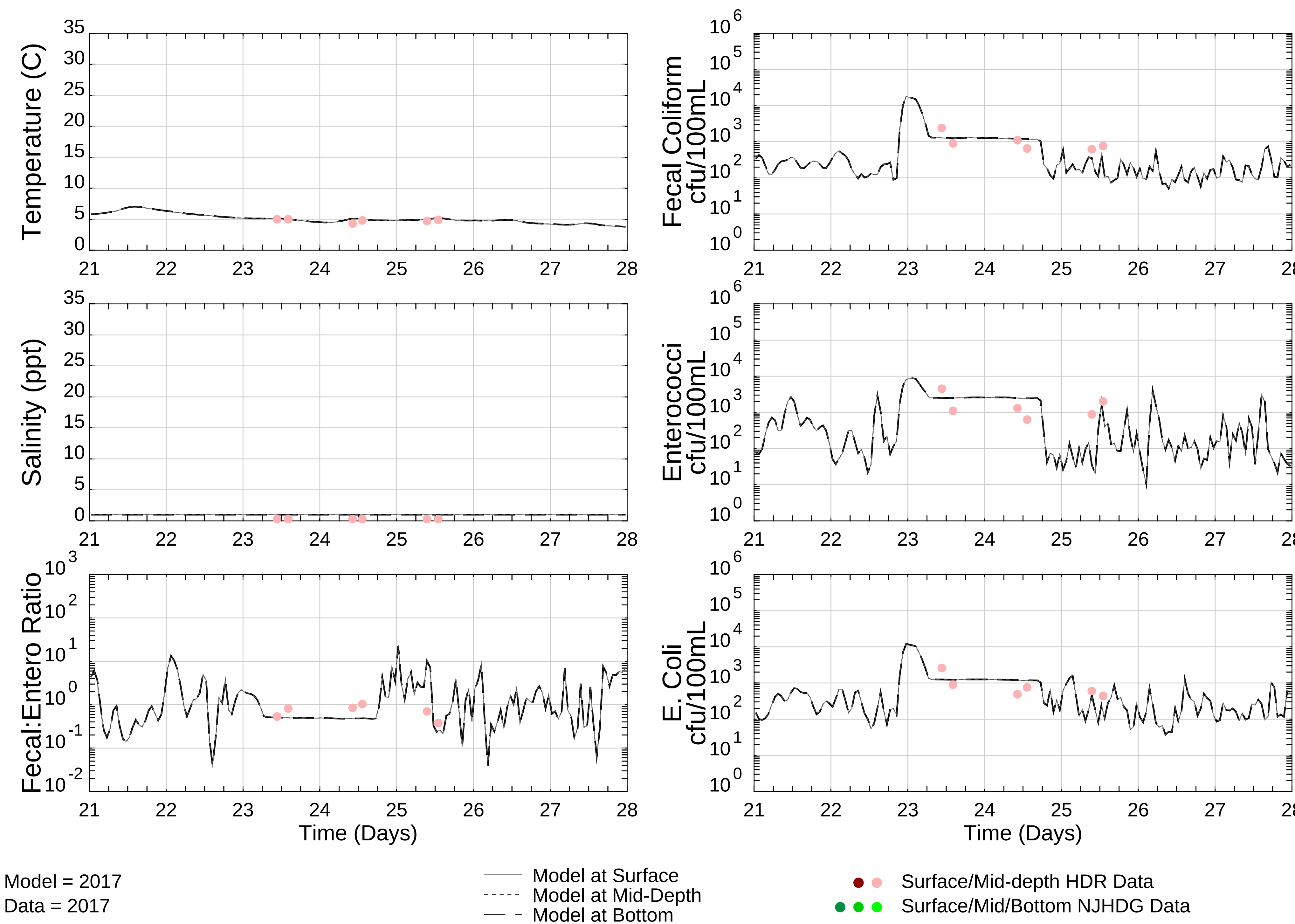
Model at Surface
Model at Mid-Depth
Model at Bottom

Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

Passaic River & Tributaries
Passaic River

FW2

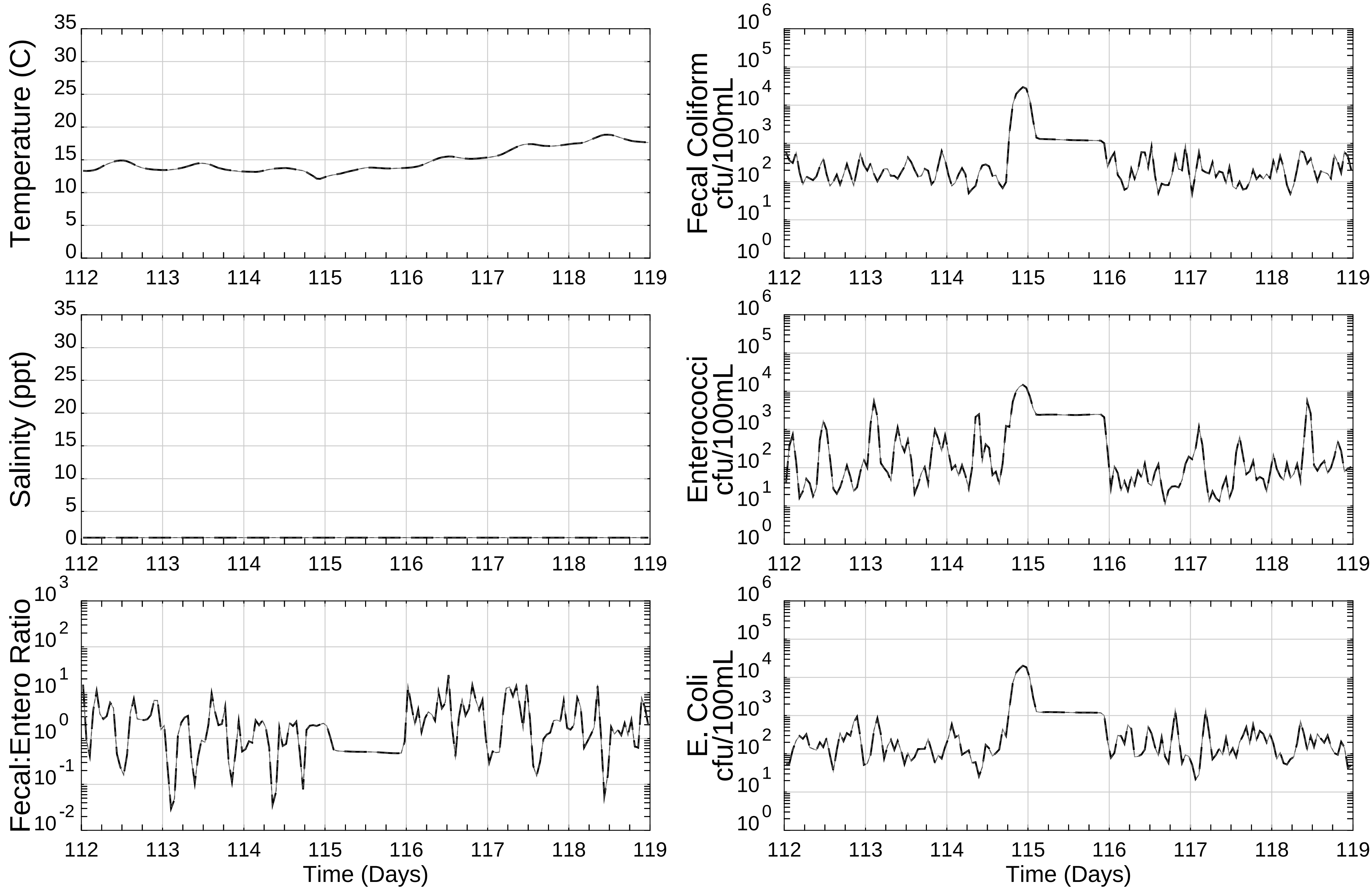
Station: 3 Event 2 (Jan 21-28)



Passaic River & Tributaries
Passaic River

FW2

Station: 3 Event 3 (Apr 23-29)



Model = 2017
Data = 2017

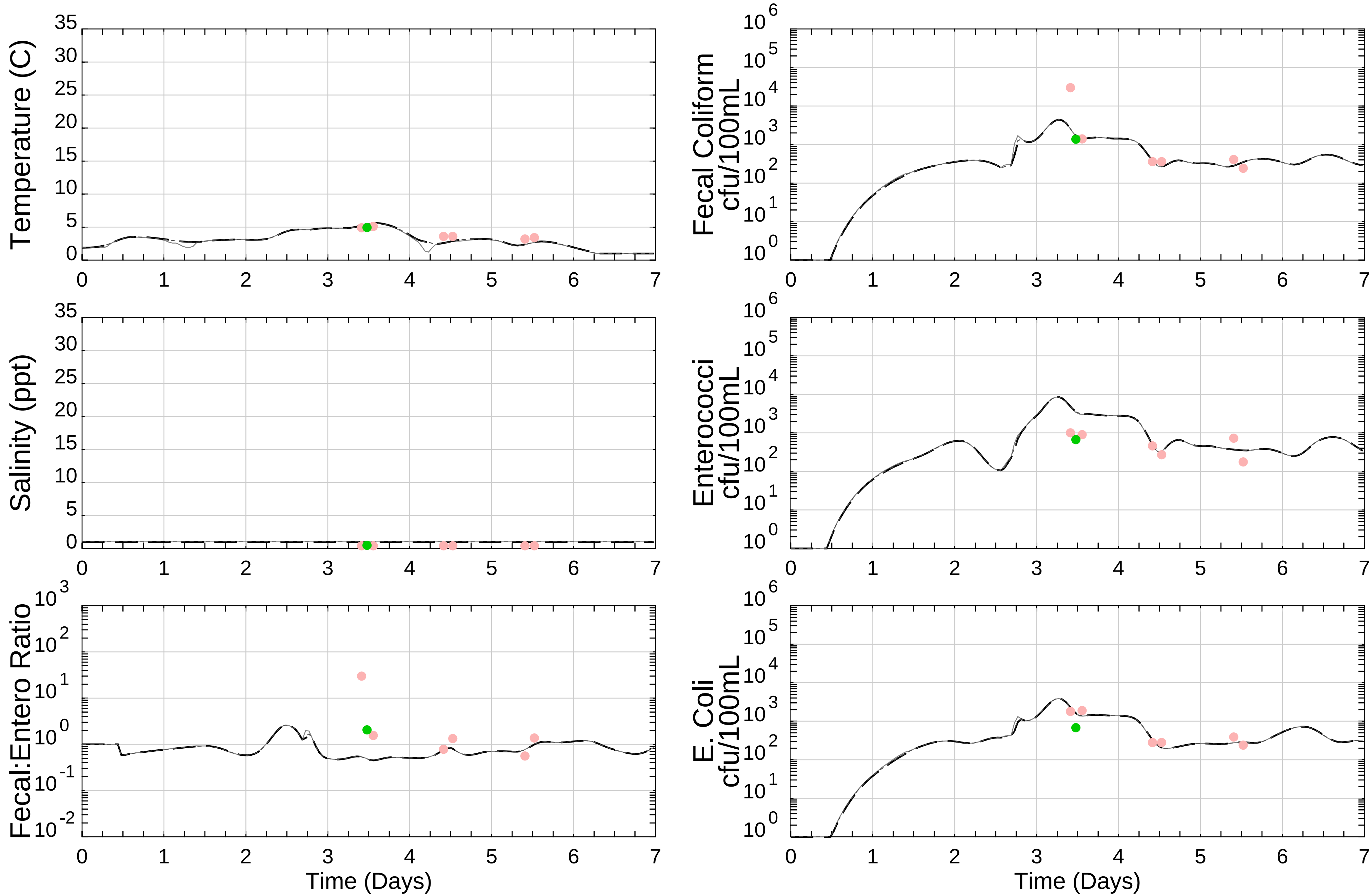
Model at Surface
Model at Mid-Depth
Model at Bottom

Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

Passaic River & Tributaries
Passaic River

FW2

Station: 4 Event 1 (Jan 1-7)



Model = 2017
Data = 2017

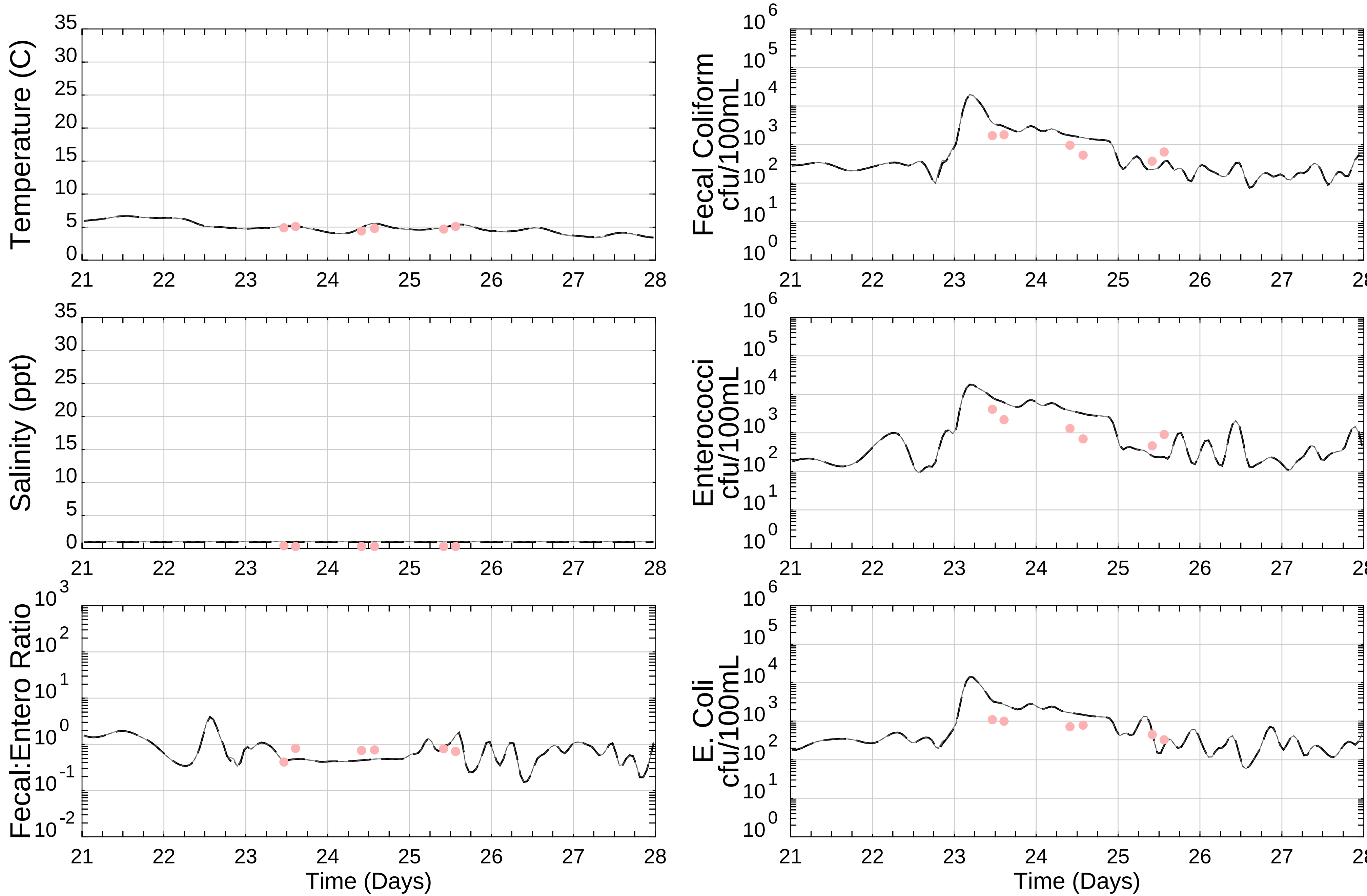
Model at Surface
Model at Mid-Depth
Model at Bottom

Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

Passaic River & Tributaries
Passaic River

FW2

Station: 4 Event 2 (Jan 21-28)



Model = 2017
Data = 2017

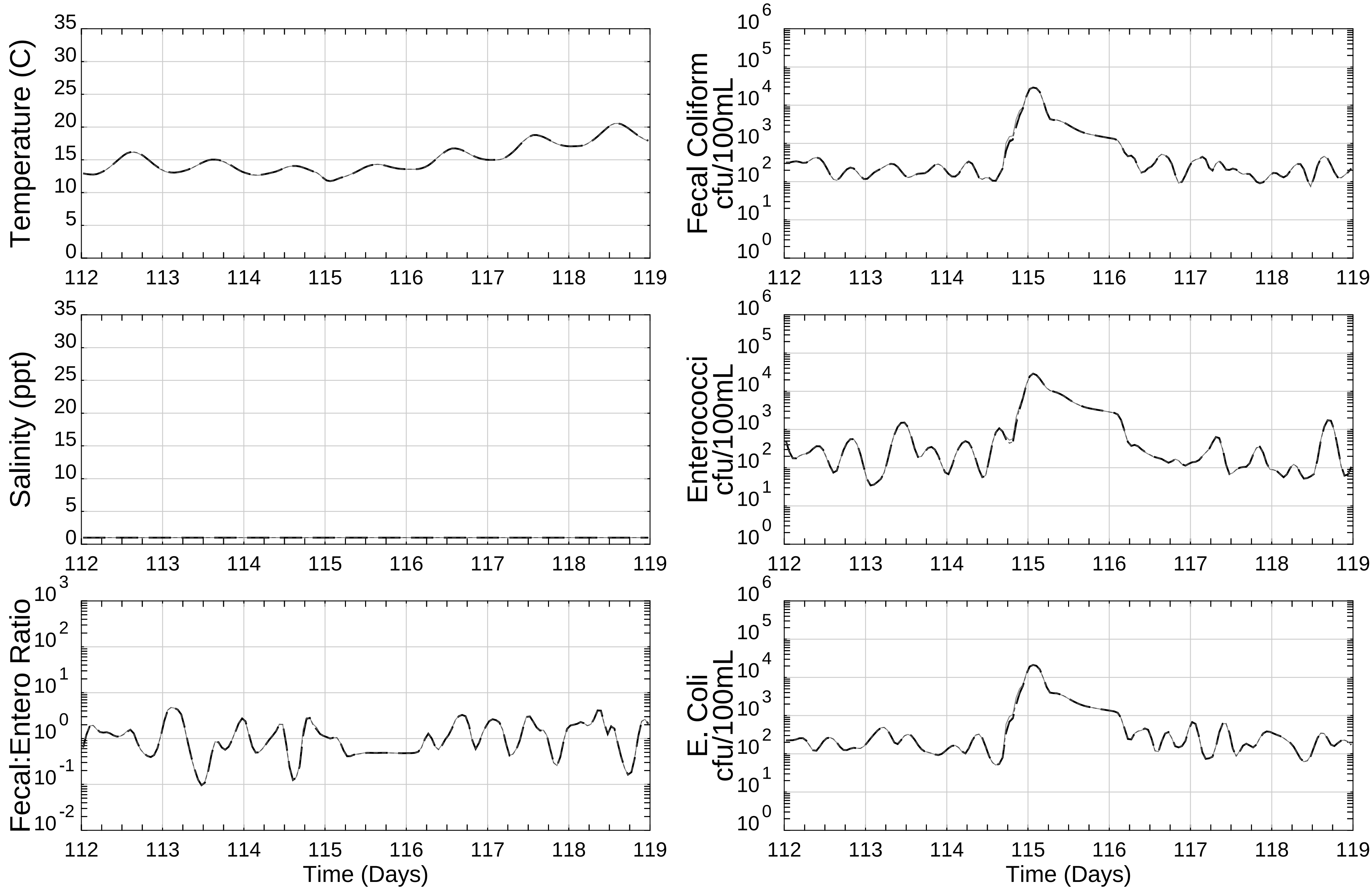
Model at Surface
Model at Mid-Depth
Model at Bottom

Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

Passaic River & Tributaries
Passaic River

FW2

Station: 4 Event 3 (Apr 23-29)



Model = 2017
Data = 2017

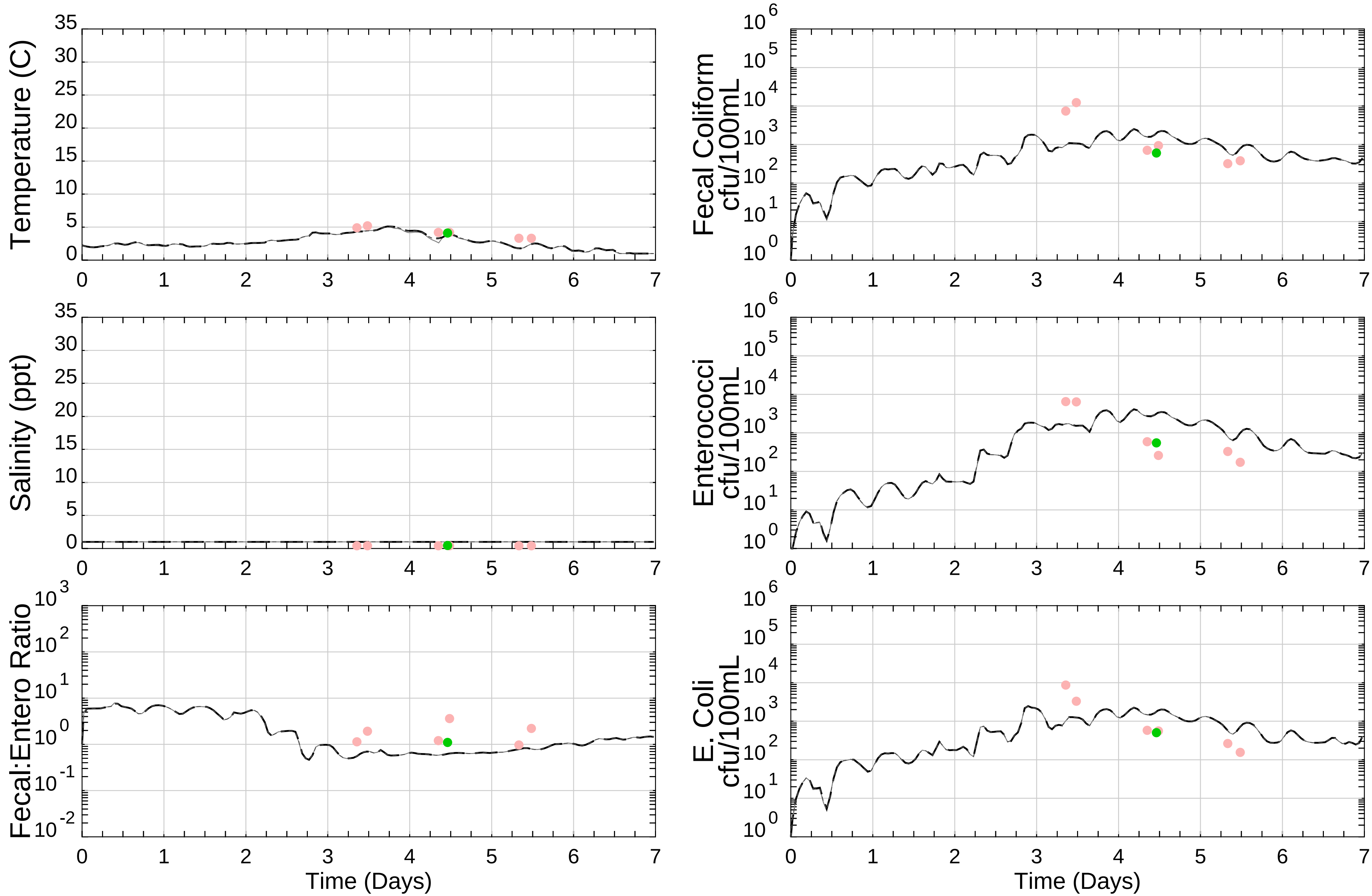
Model at Surface
Model at Mid-Depth
Model at Bottom

Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

Passaic River & Tributaries
Passaic River

FW2/SE2

Station: 7 Event 1 (Jan 1-7)

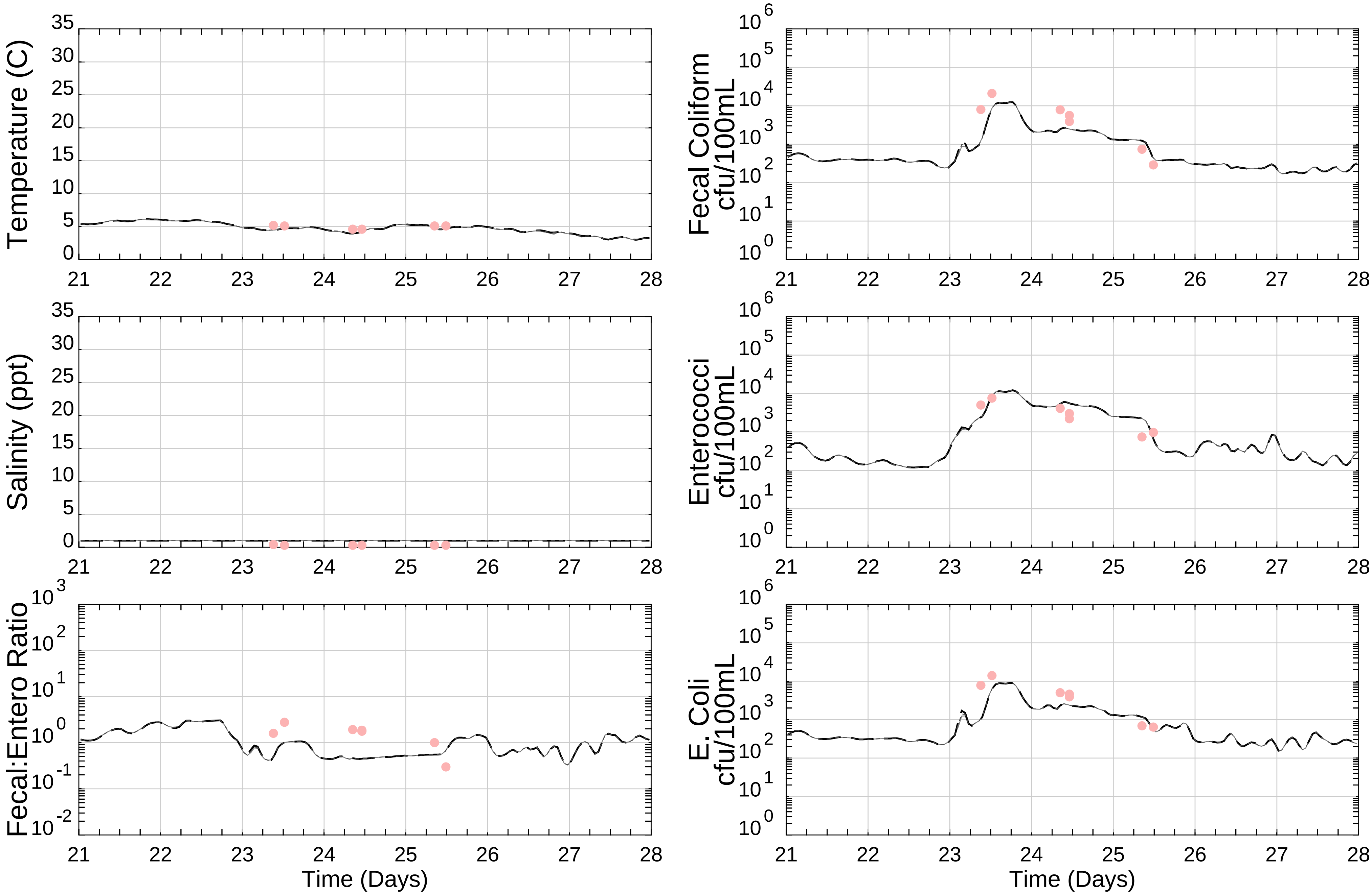


Model = 2017
Data = 2017

Model at Surface
Model at Mid-Depth
Model at Bottom

Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

Station: 7 Event 2 (Jan 21-28)



Model = 2017
Data = 2017

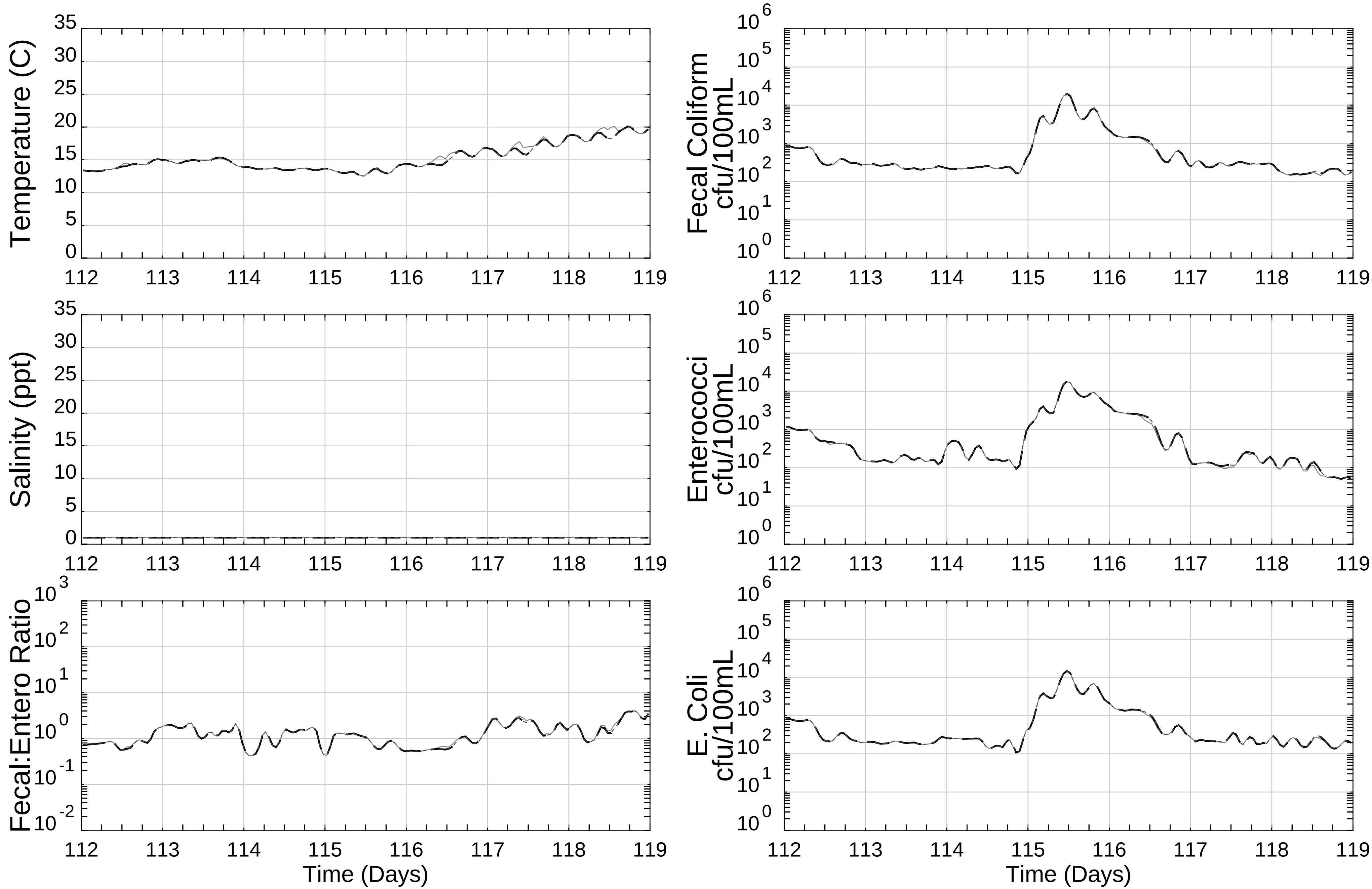
Model at Surface
Model at Mid-Depth
Model at Bottom

Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

Passaic River & Tributaries
Passaic River

FW2/SE2

Station: 7 Event 3 (Apr 23-29)

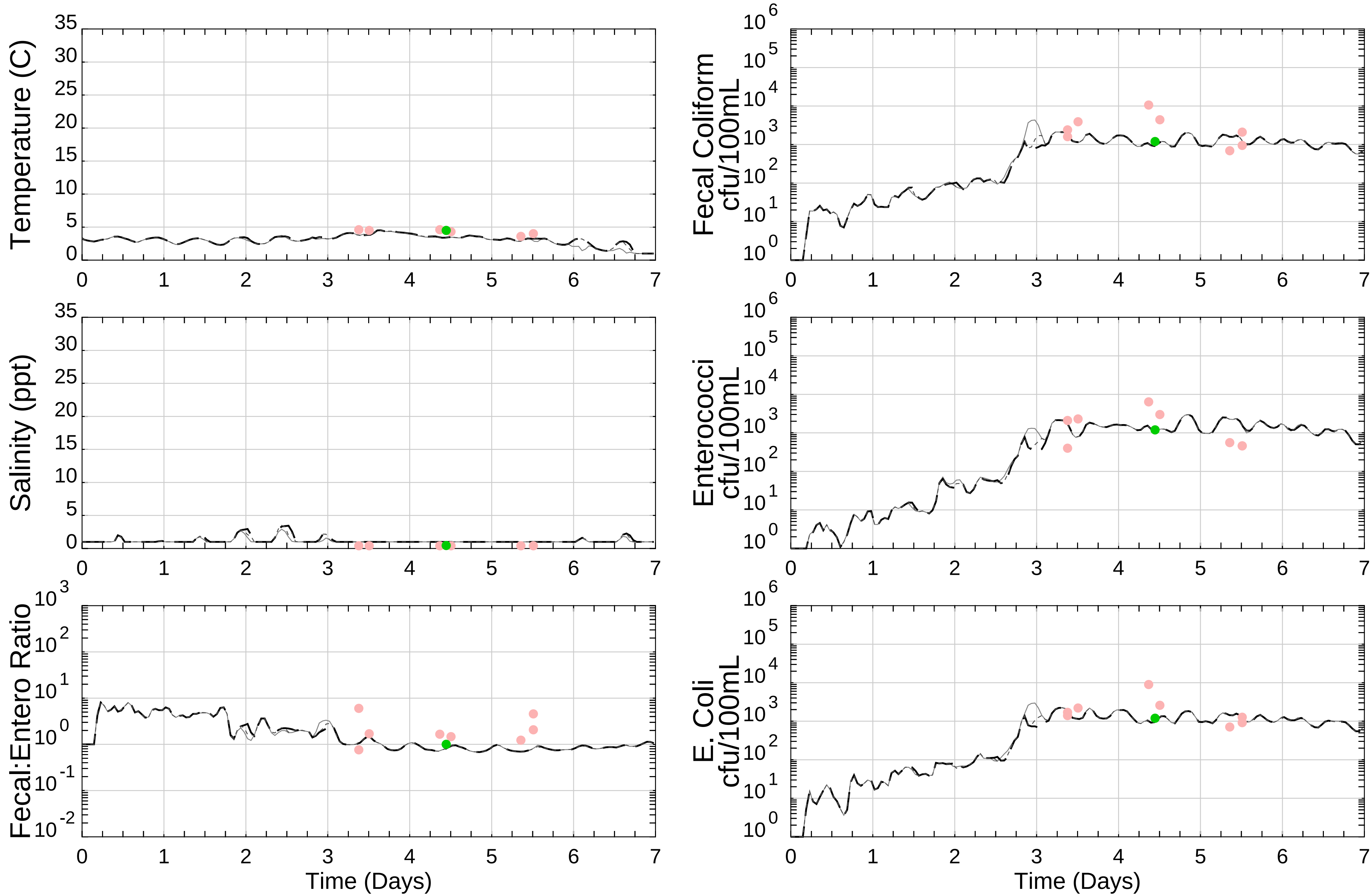


Model = 2017
Data = 2017

Passaic River & Tributaries
Passaic River

FW2/SE2

Station: 8 Event 1 (Jan 1-7)



Model = 2017
Data = 2017

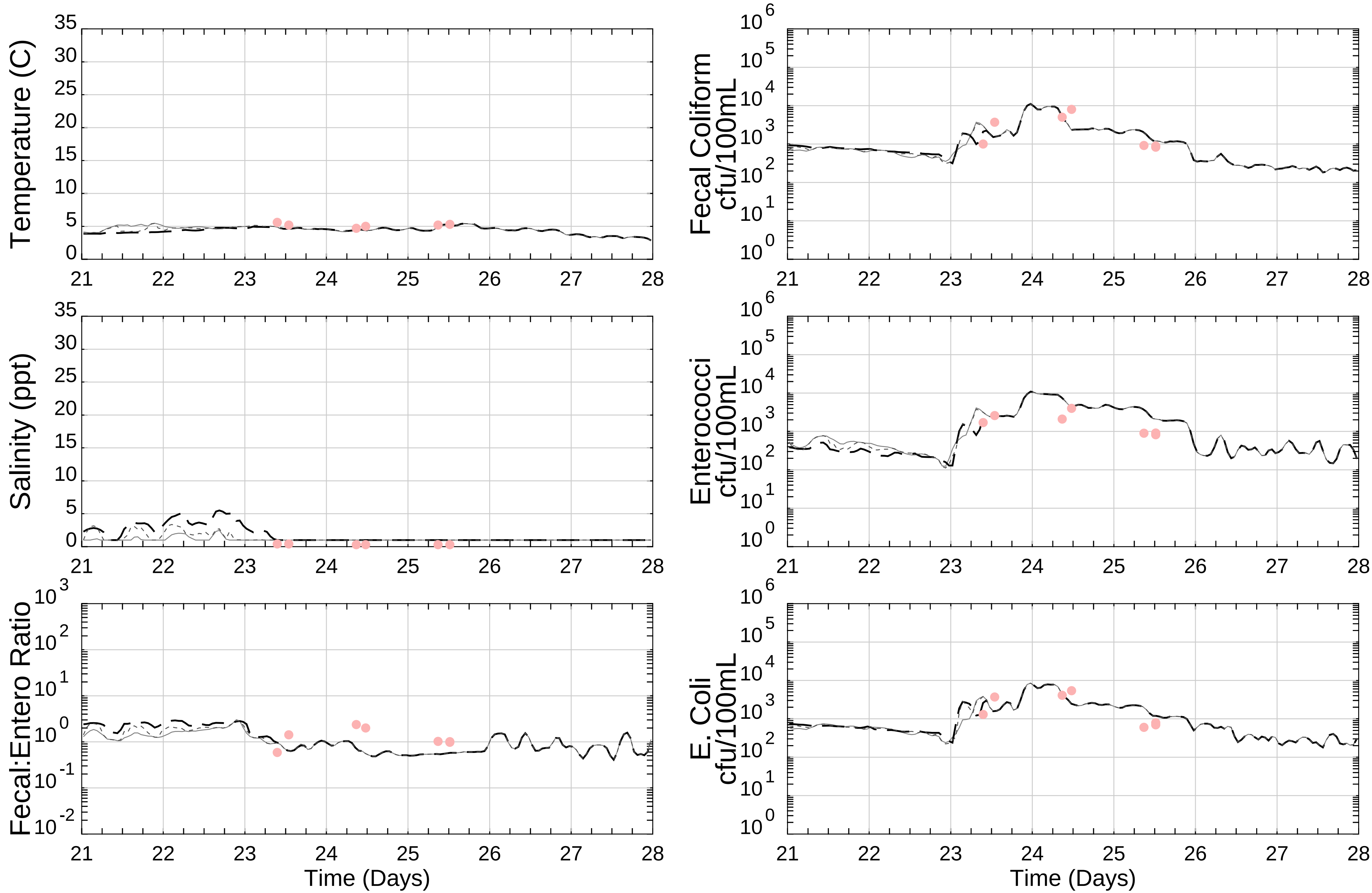
Model at Surface
Model at Mid-Depth
Model at Bottom

Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

Passaic River & Tributaries
Passaic River

FW2/SE2

Station: 8 Event 2 (Jan 21-28)



Model = 2017
Data = 2017

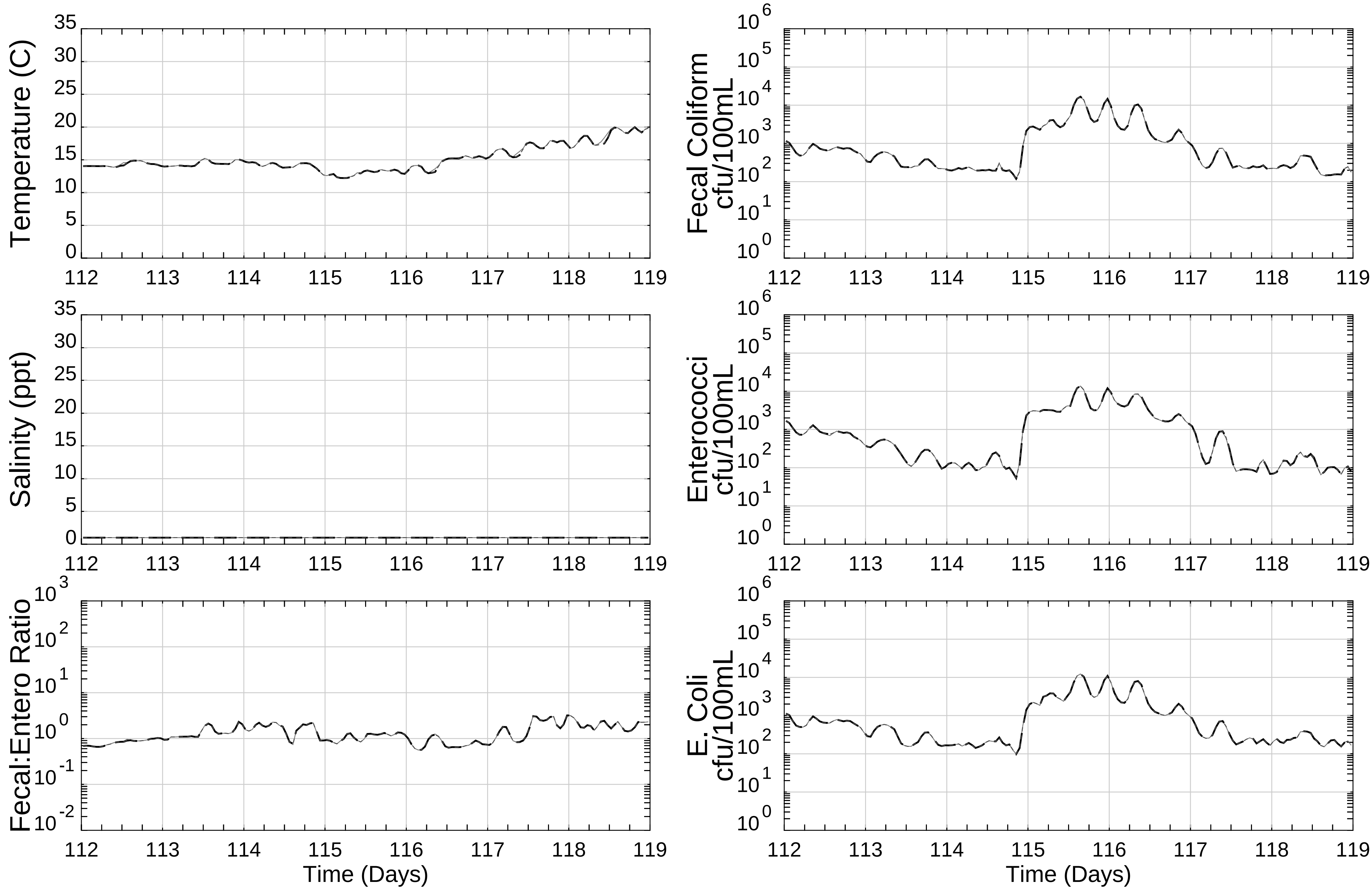
Model at Surface
Model at Mid-Depth
Model at Bottom

Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

Passaic River & Tributaries
Passaic River

FW2/SE2

Station: 8 Event 3 (Apr 23-29)



Model = 2017
Data = 2017

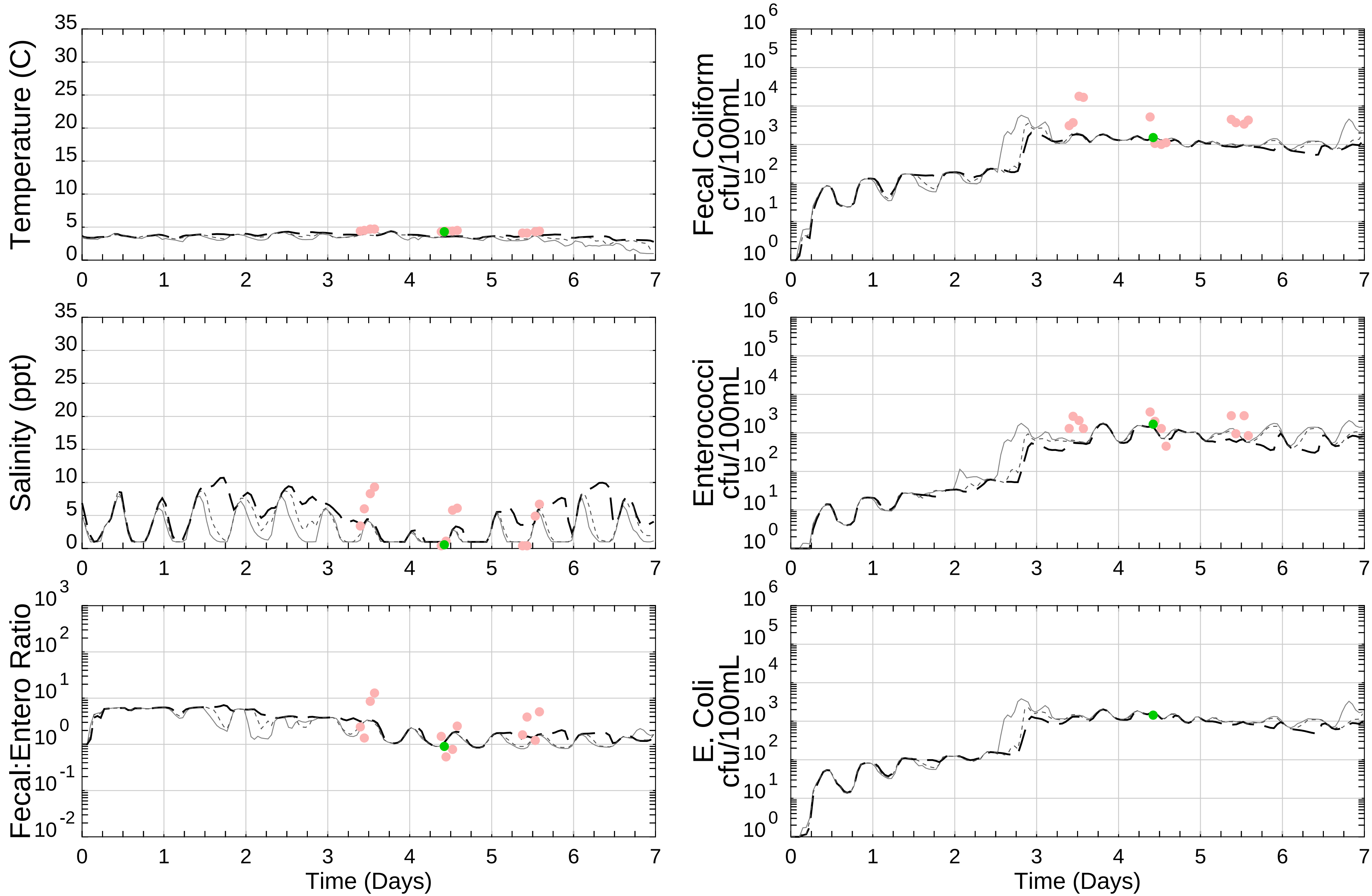
Model at Surface
Model at Mid-Depth
Model at Bottom

Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

Passaic River & Tributaries
Passaic River

SE3

Station: 10 Event 1 (Jan 1-7)



Model = 2017
Data = 2017

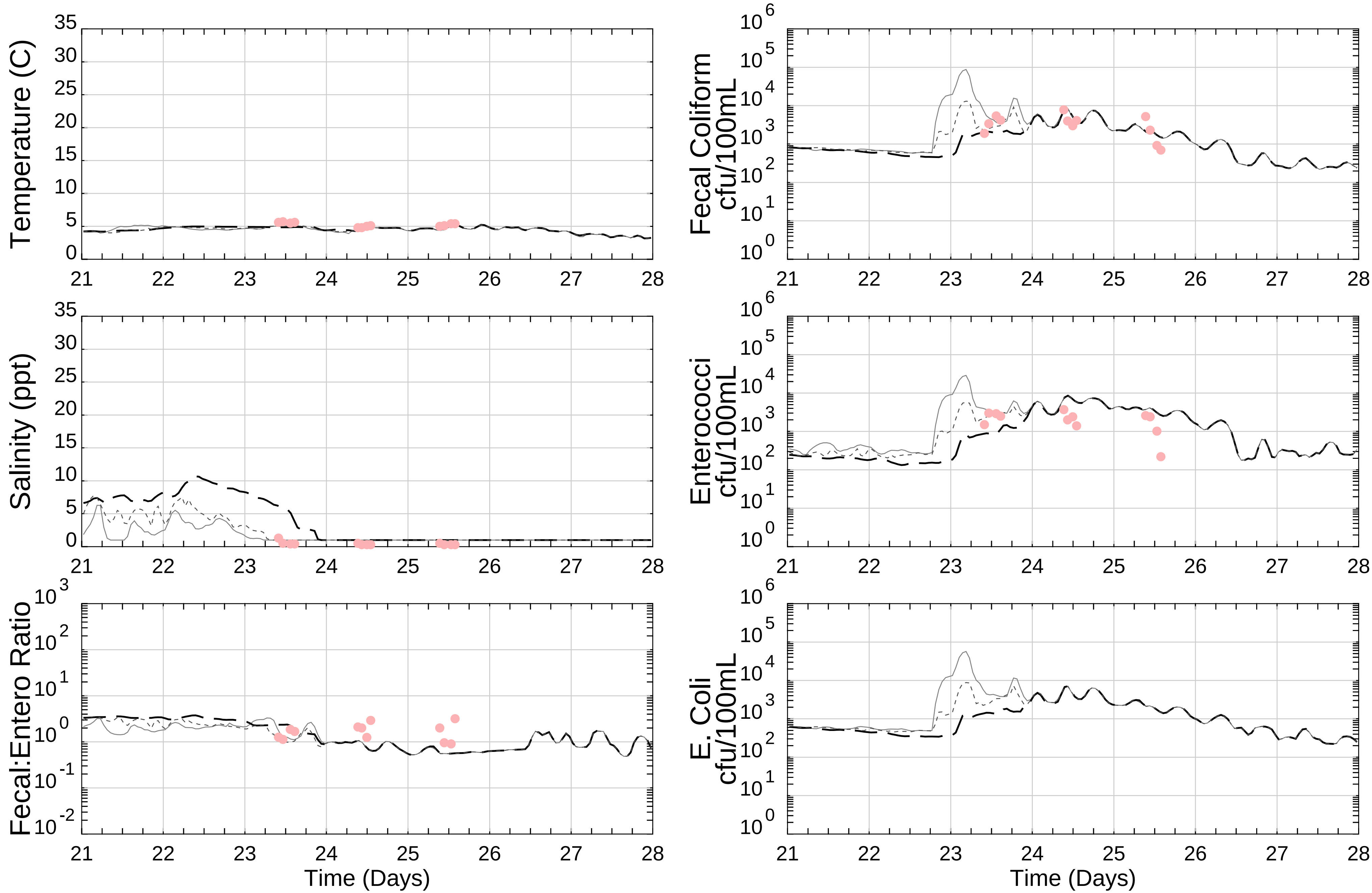
Model at Surface
Model at Mid-Depth
Model at Bottom

Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

Passaic River & Tributaries
Passaic River

SE3

Station: 10 Event 2 (Jan 21-28)



Model = 2017
Data = 2017

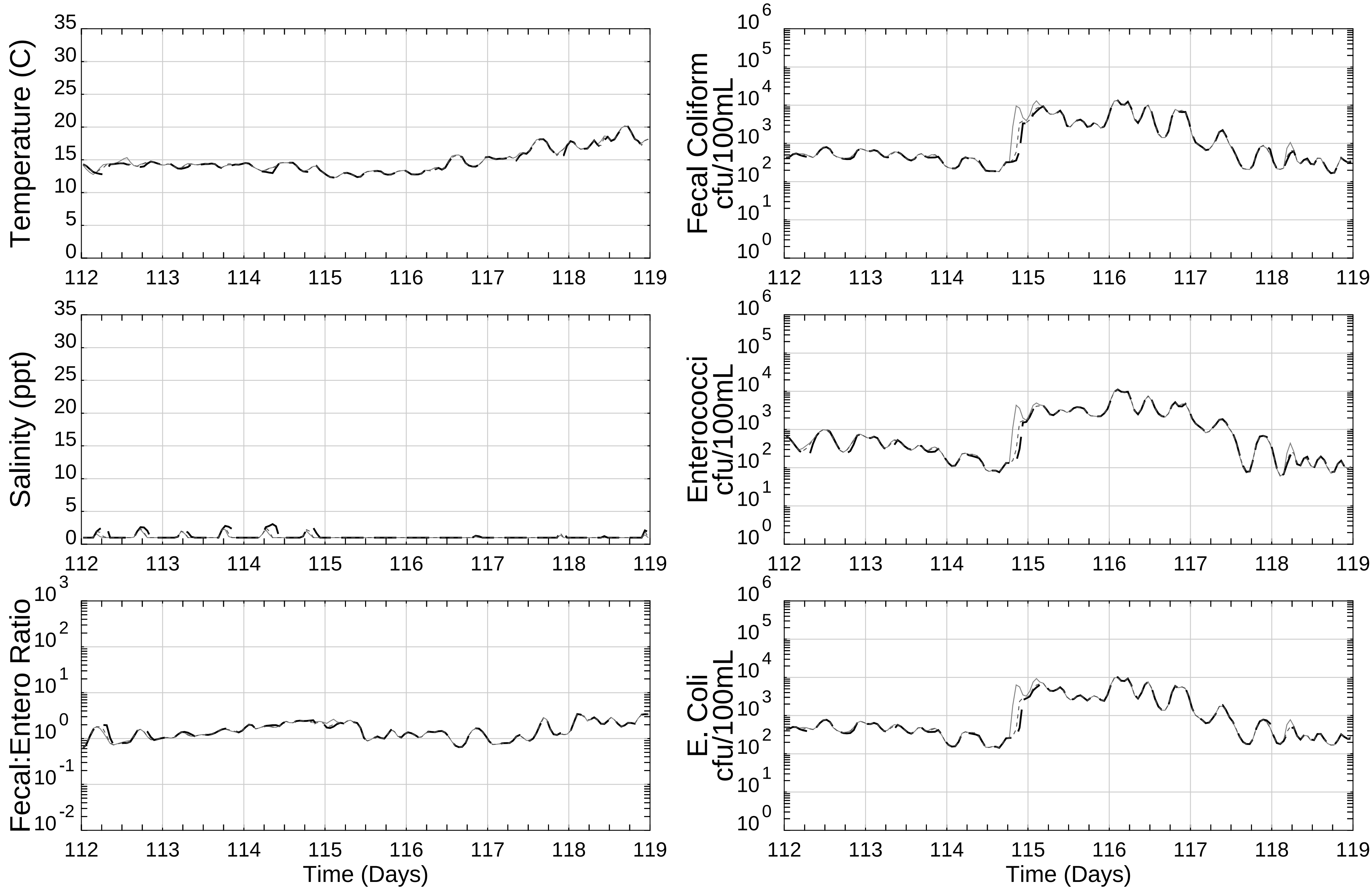
Model at Surface
Model at Mid-Depth
Model at Bottom

Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

Passaic River & Tributaries
Passaic River

SE3

Station: 10 Event 3 (Apr 23-29)

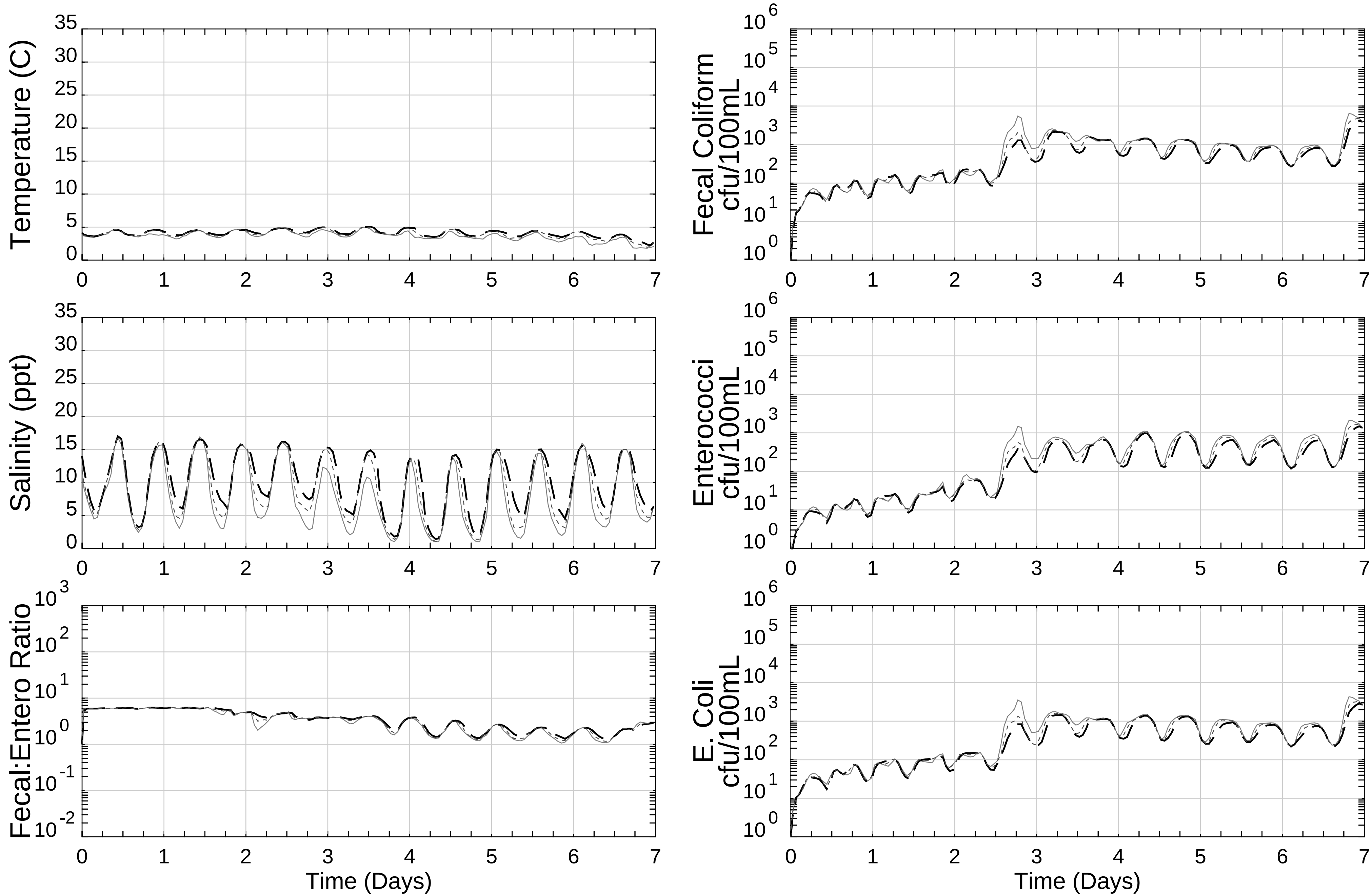


Model = 2017
Data = 2017

Model at Surface
Model at Mid-Depth
Model at Bottom

Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

Station: B6 Event 1 (Jan 1-7)



Model = 2017
Data = 2017

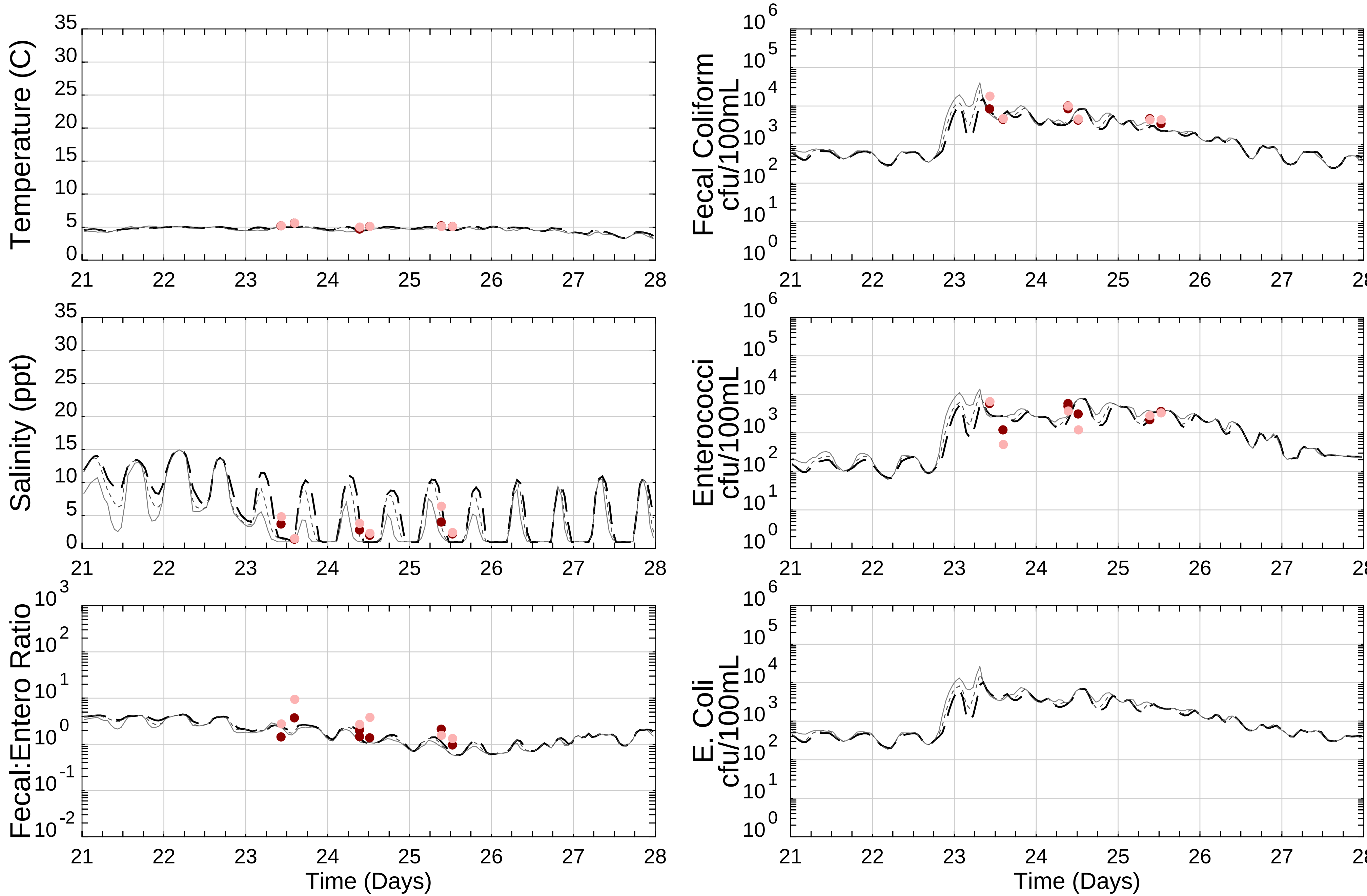
Model at Surface
Model at Mid-Depth
Model at Bottom

Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

Passaic River & Tributaries
Passaic River

SE3

Station: B6 Event 2 (Jan 21-28)



Model = 2017
Data = 2017

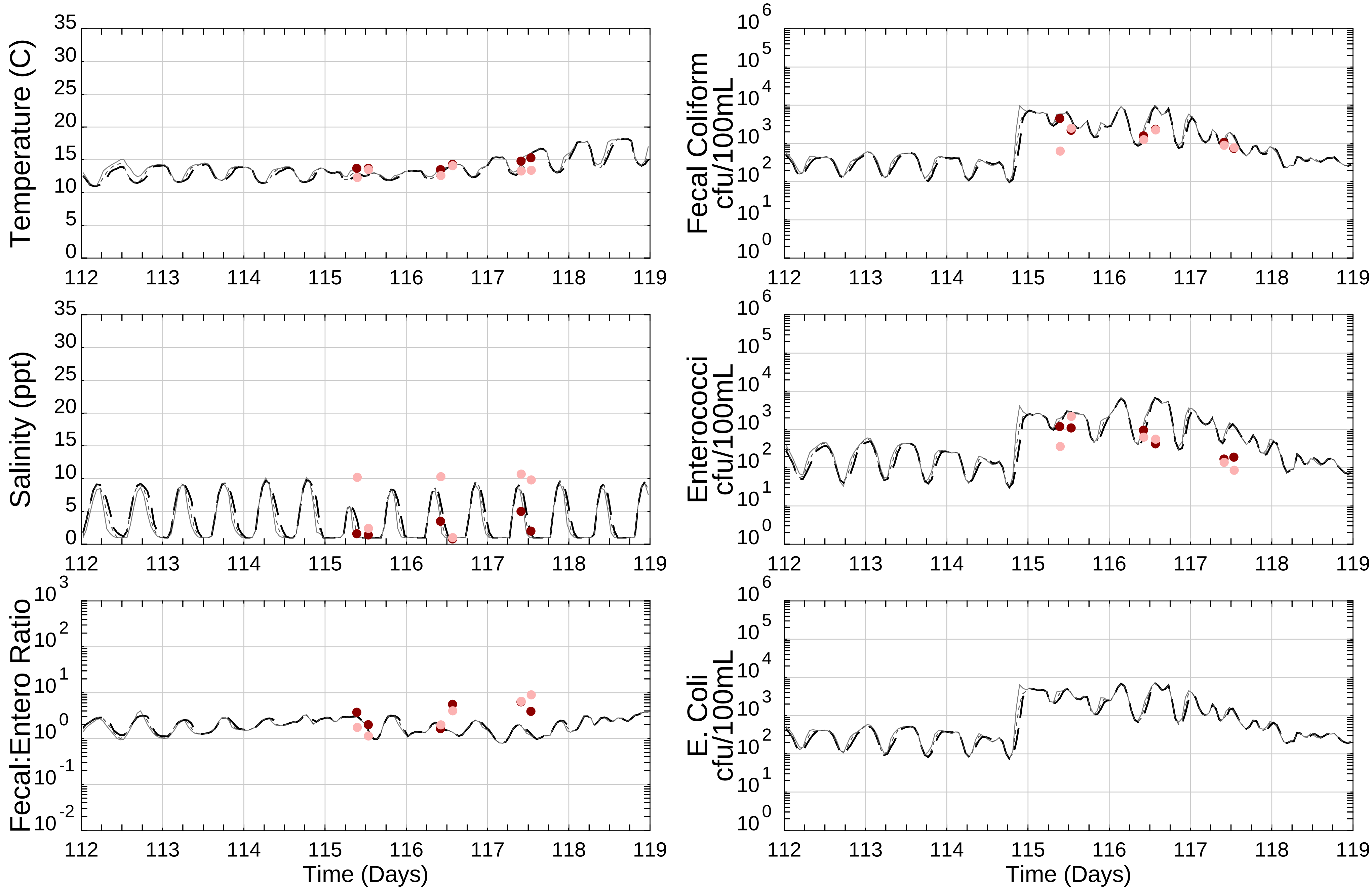
Model at Surface
Model at Mid-Depth
Model at Bottom

Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

Passaic River & Tributaries
Passaic River

SE3

Station: B6 Event 3 (Apr 23-29)



Model = 2017
Data = 2017

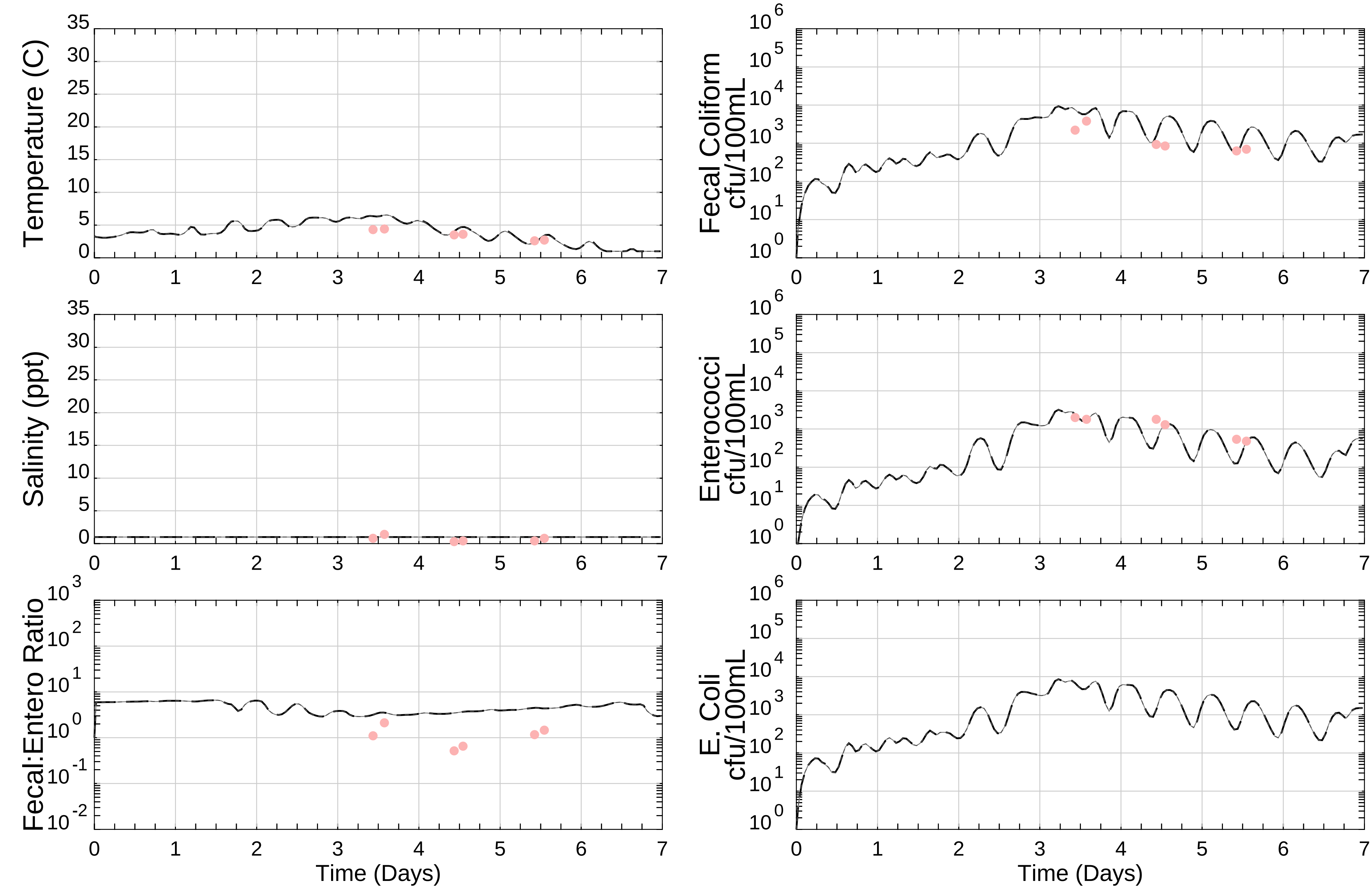
Model at Surface
Model at Mid-Depth
Model at Bottom

Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

Hackensack River & Tributaries
Hackensack River

SE1

Station: B1 Event 1 (Jan 1-7)



Model = 2017
Data = 2017

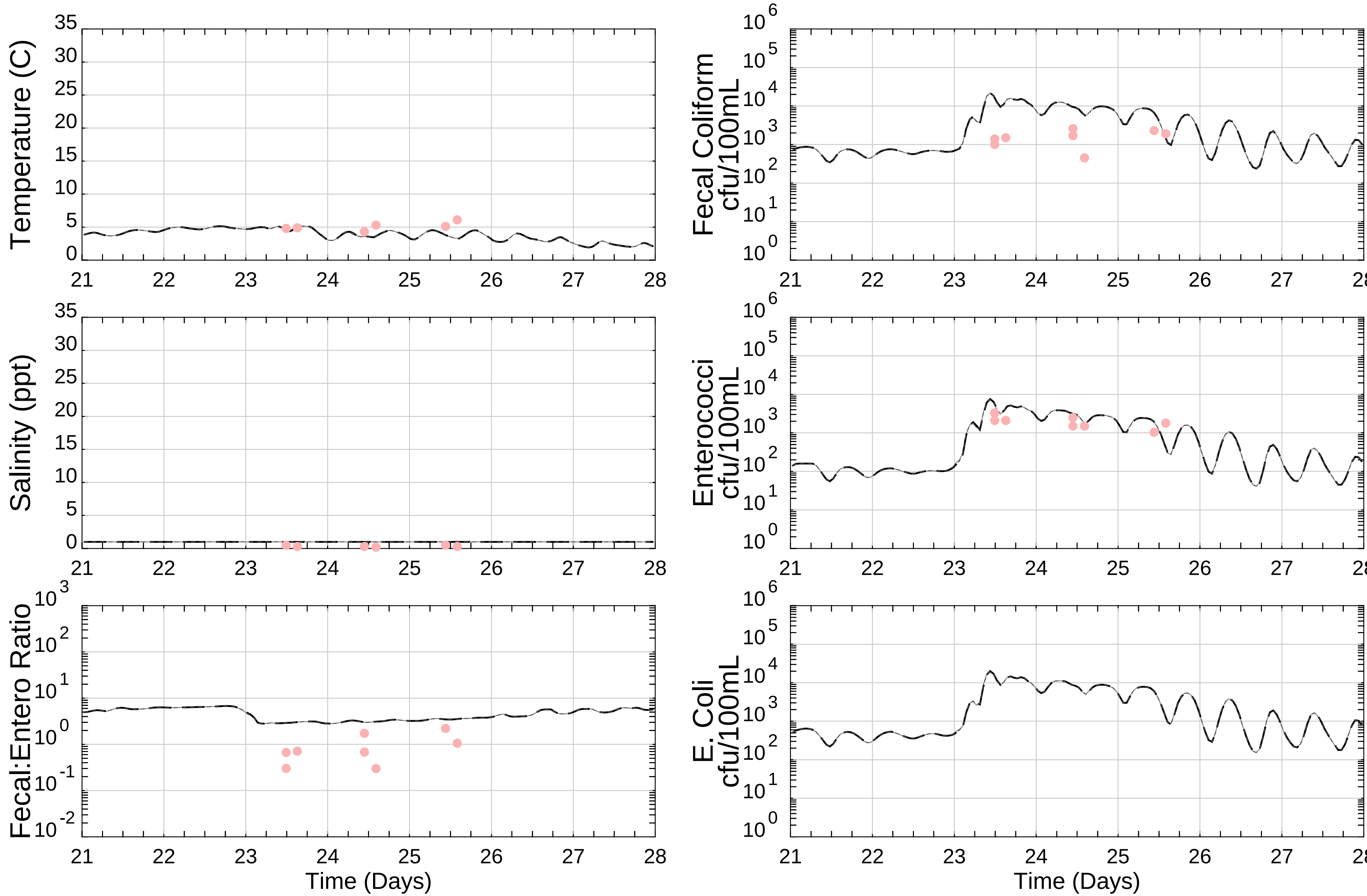
Model at Surface
Model at Mid-Depth
Model at Bottom

Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

Hackensack River & Tributaries
Hackensack River

SE1

Station: B1 Event 2 (Jan 21-28)



Model = 2017
Data = 2017

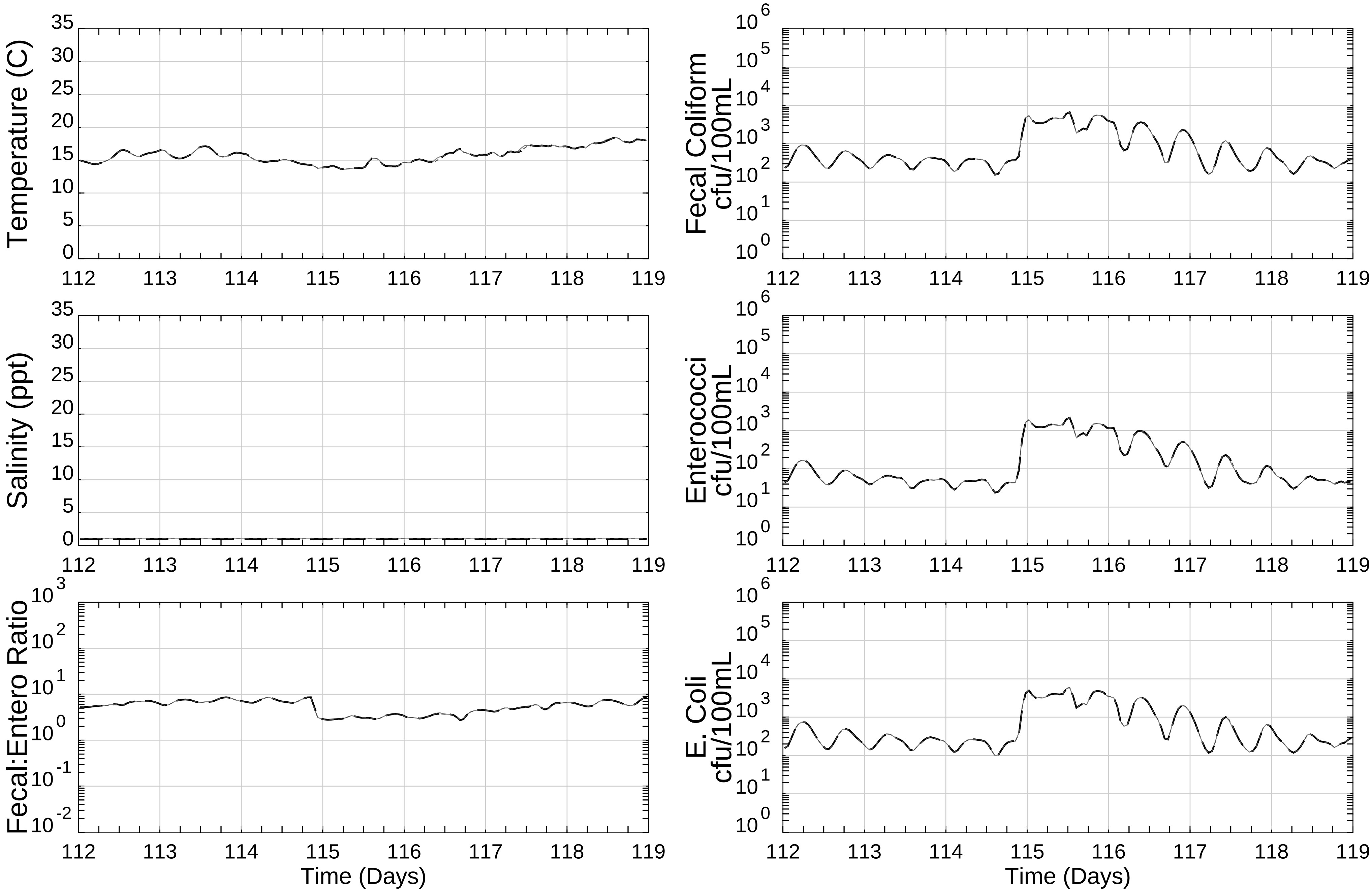
Model at Surface
Model at Mid-Depth
Model at Bottom

Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

Hackensack River & Tributaries
Hackensack River

SE1

Station: B1 Event 3 (Apr 23-29)



Model = 2017
Data = 2017

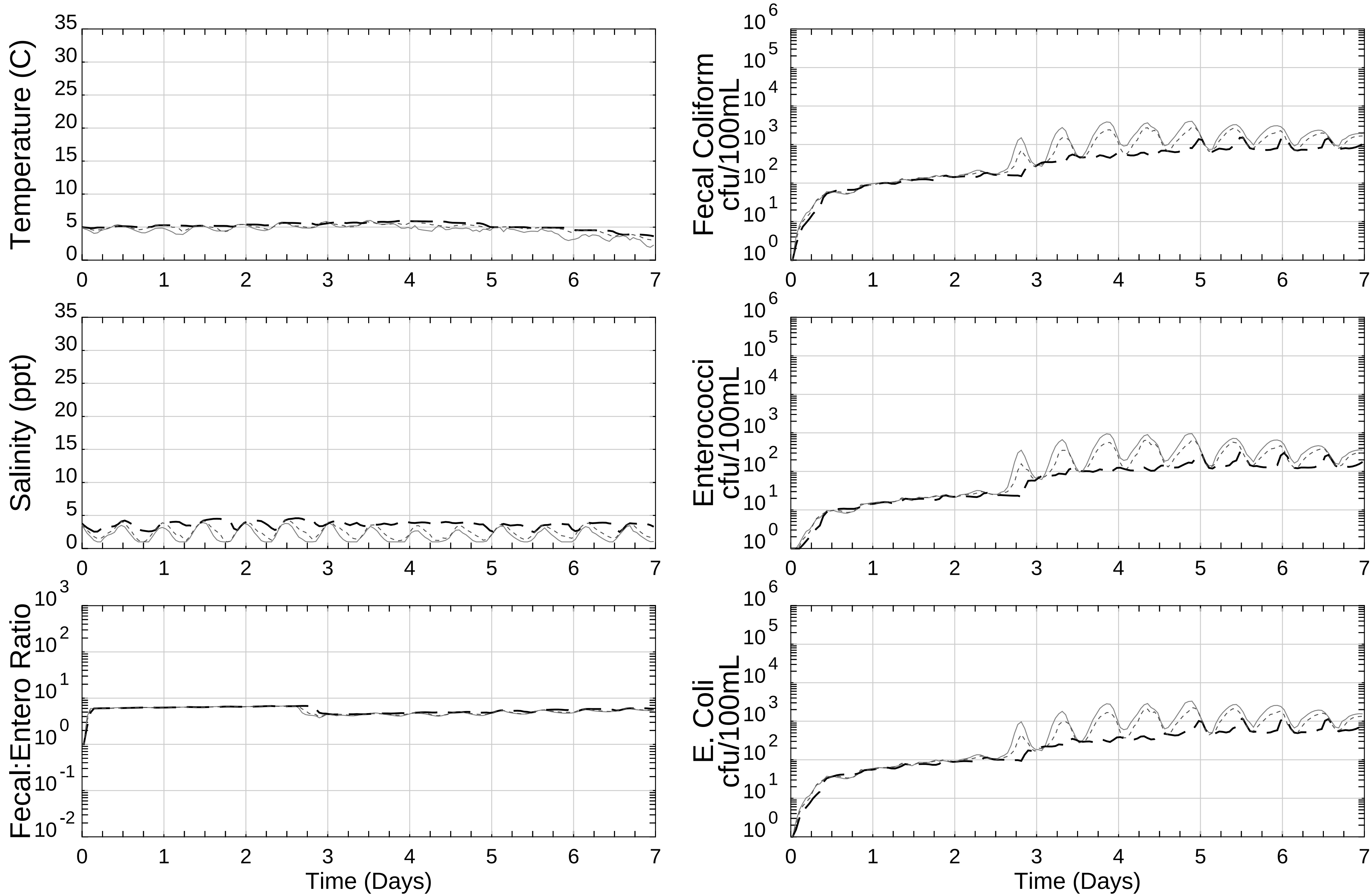
Model at Surface
Model at Mid-Depth
Model at Bottom

Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

Hackensack River & Tributaries
Hackensack River

SE1

Station: B2 Event 1 (Jan 1-7)



Model = 2017
Data = 2017

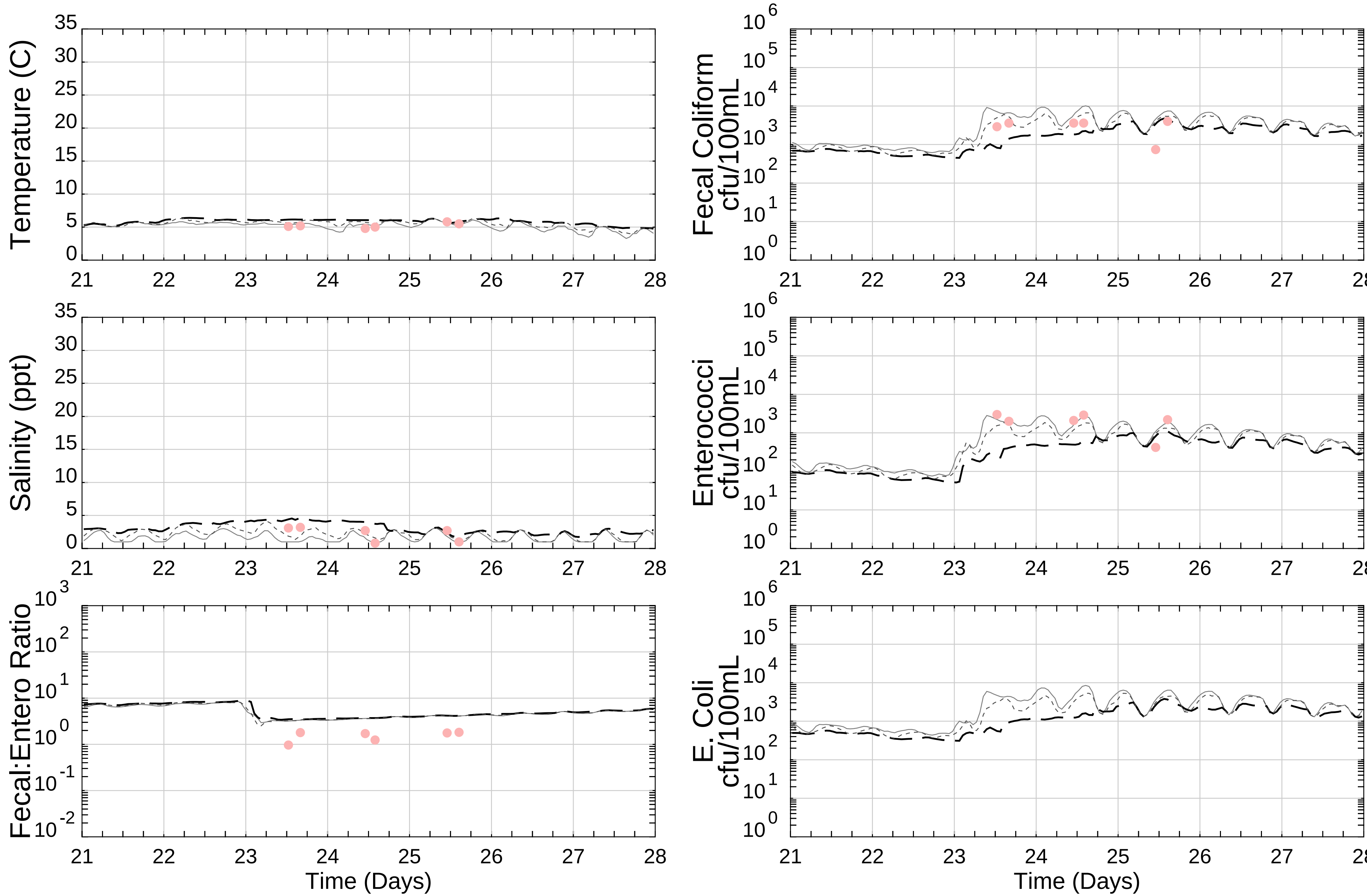
Model at Surface
Model at Mid-Depth
Model at Bottom

Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

Hackensack River & Tributaries
Hackensack River

SE1

Station: B2 Event 2 (Jan 21-28)



Model = 2017
Data = 2017

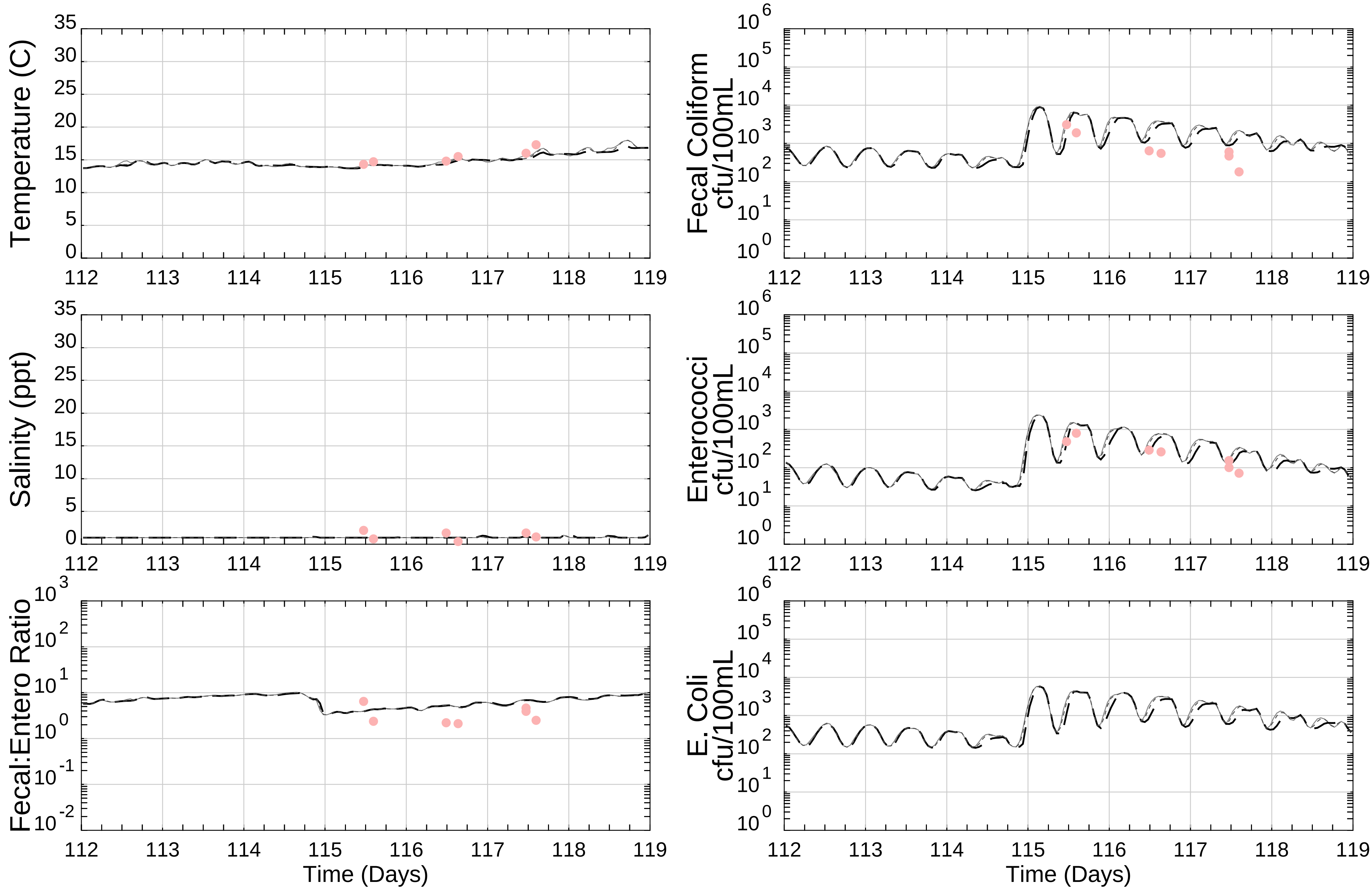
Model at Surface
Model at Mid-Depth
Model at Bottom

Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

Hackensack River & Tributaries
Hackensack River

SE1

Station: B2 Event 3 (Apr 23-29)



Model = 2017
Data = 2017

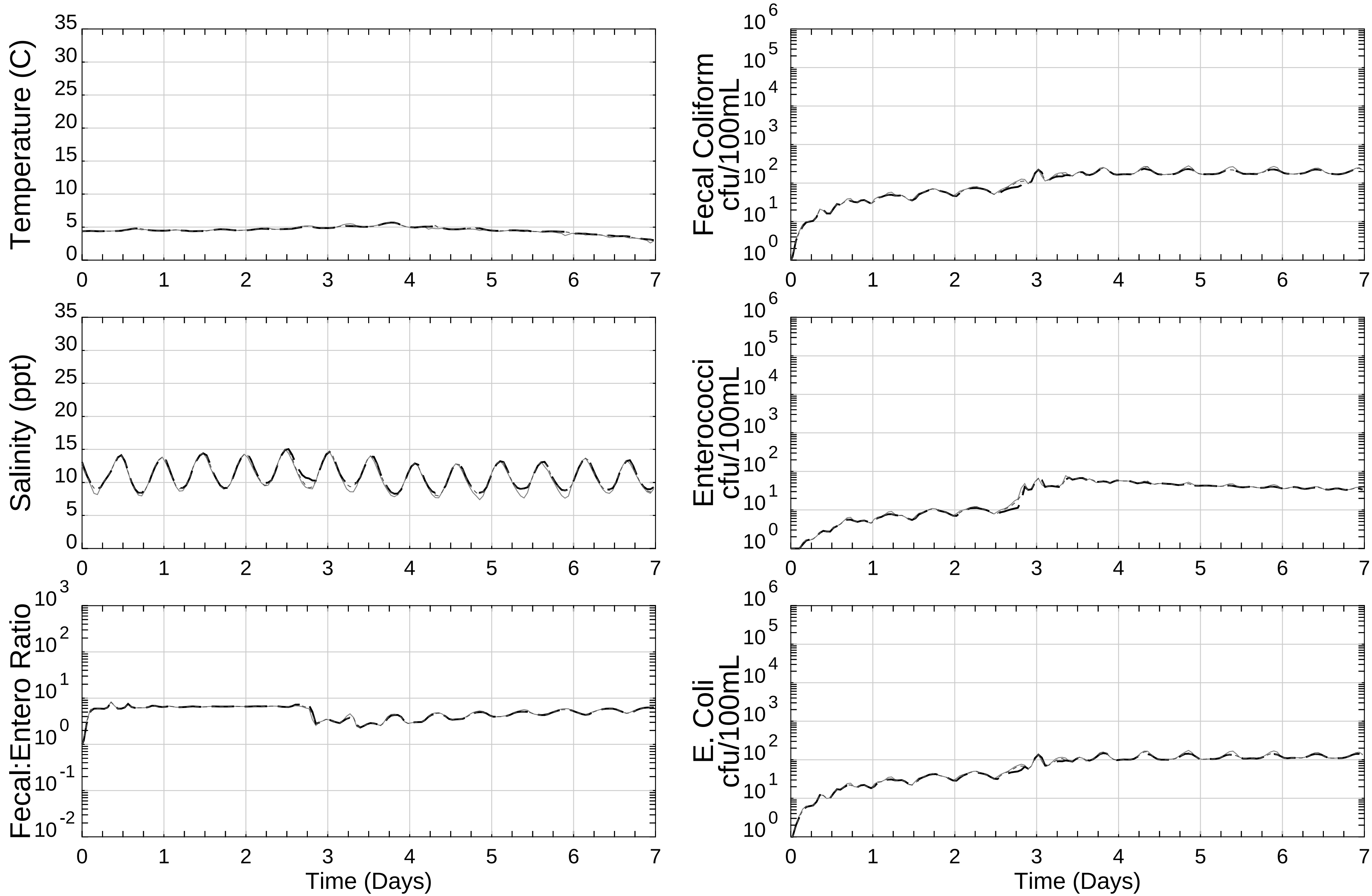
Model at Surface
Model at Mid-Depth
Model at Bottom

Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

Hackensack River & Tributaries
Hackensack River

SE2

Station: 14 Event 1 (Jan 1-7)

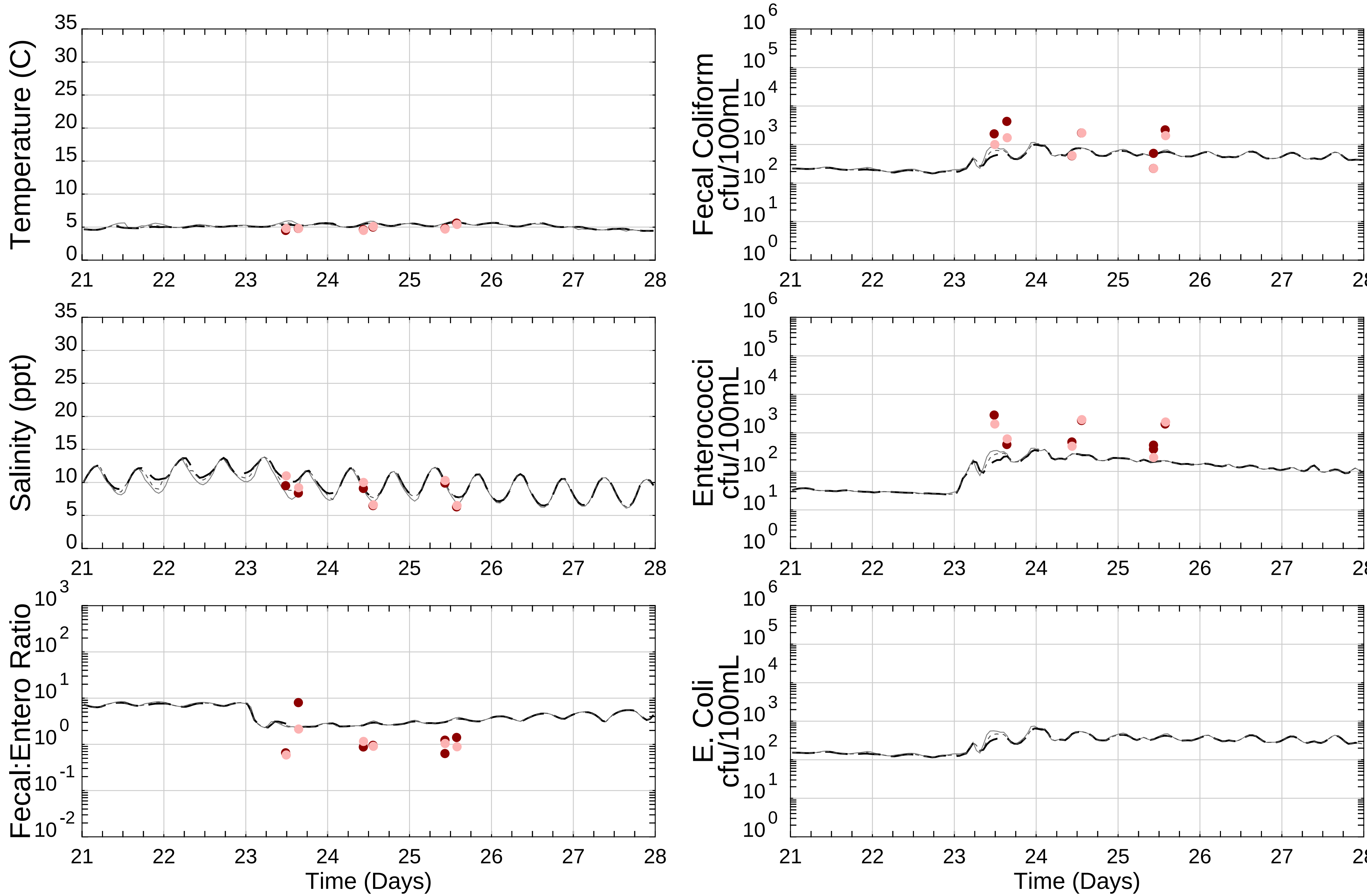


Model = 2017
Data = 2017

Hackensack River & Tributaries
Hackensack River

SE2

Station: 14 Event 2 (Jan 21-28)



Model = 2017
Data = 2017

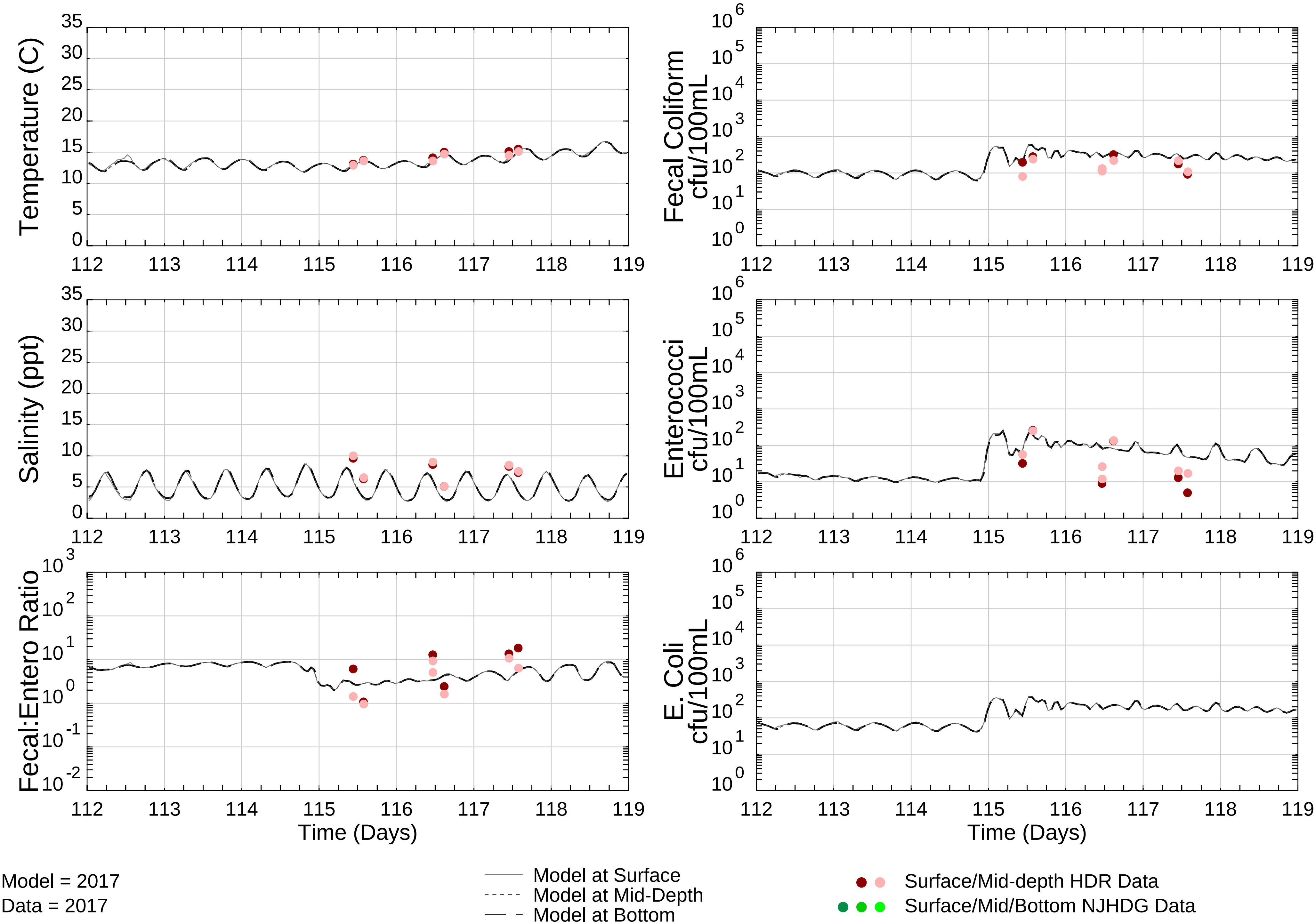
Model at Surface
Model at Mid-Depth
Model at Bottom

Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

Hackensack River & Tributaries
Hackensack River

SE2

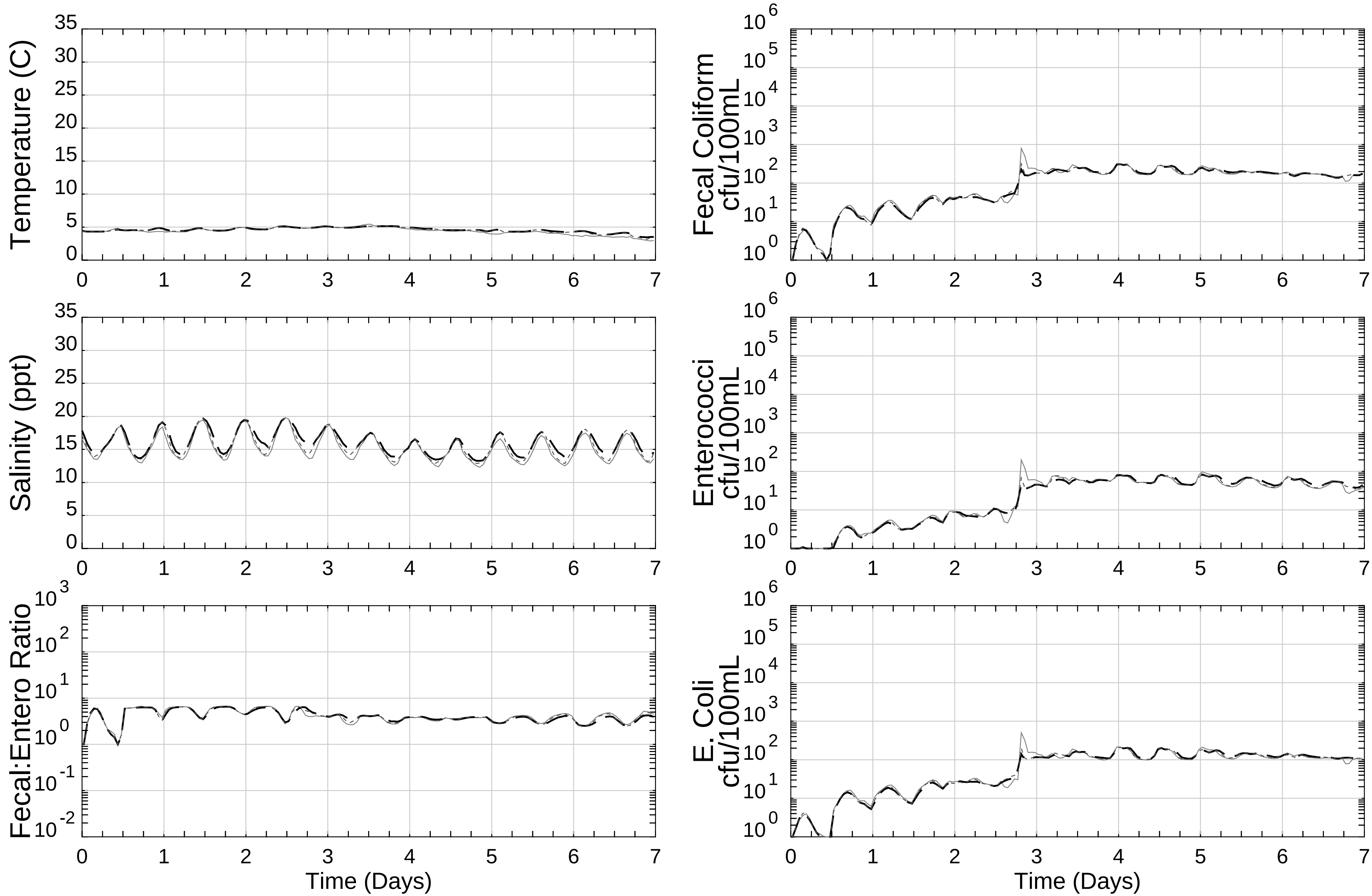
Station: 14 Event 3 (Apr 23-29)



Hackensack River & Tributaries
Hackensack River

SE2

Station: 15 Event 1 (Jan 1-7)



Model = 2017
Data = 2017

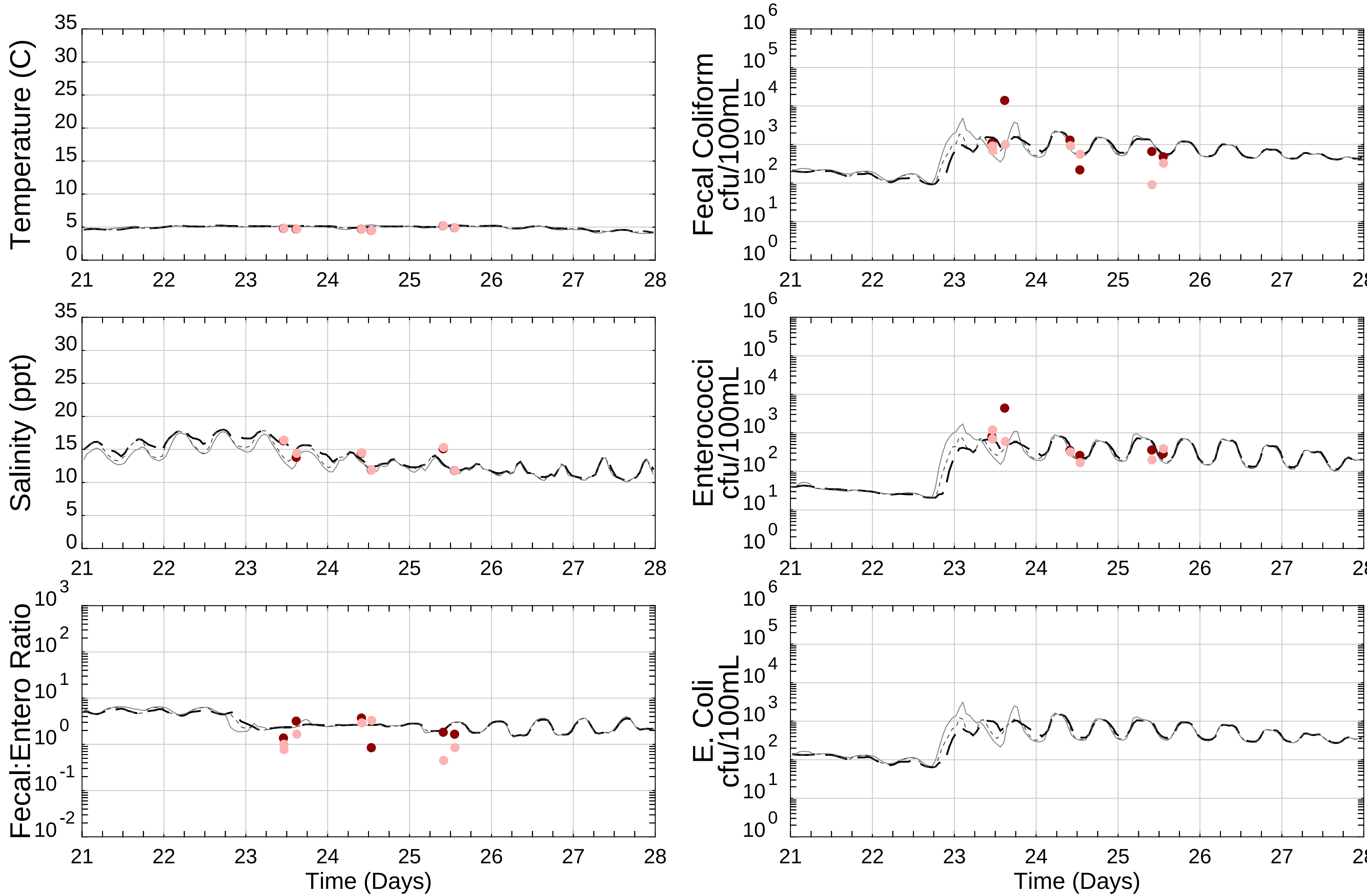
Model at Surface
Model at Mid-Depth
Model at Bottom

Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

Hackensack River & Tributaries
Hackensack River

SE2

Station: 15 Event 2 (Jan 21-28)



Model = 2017
Data = 2017

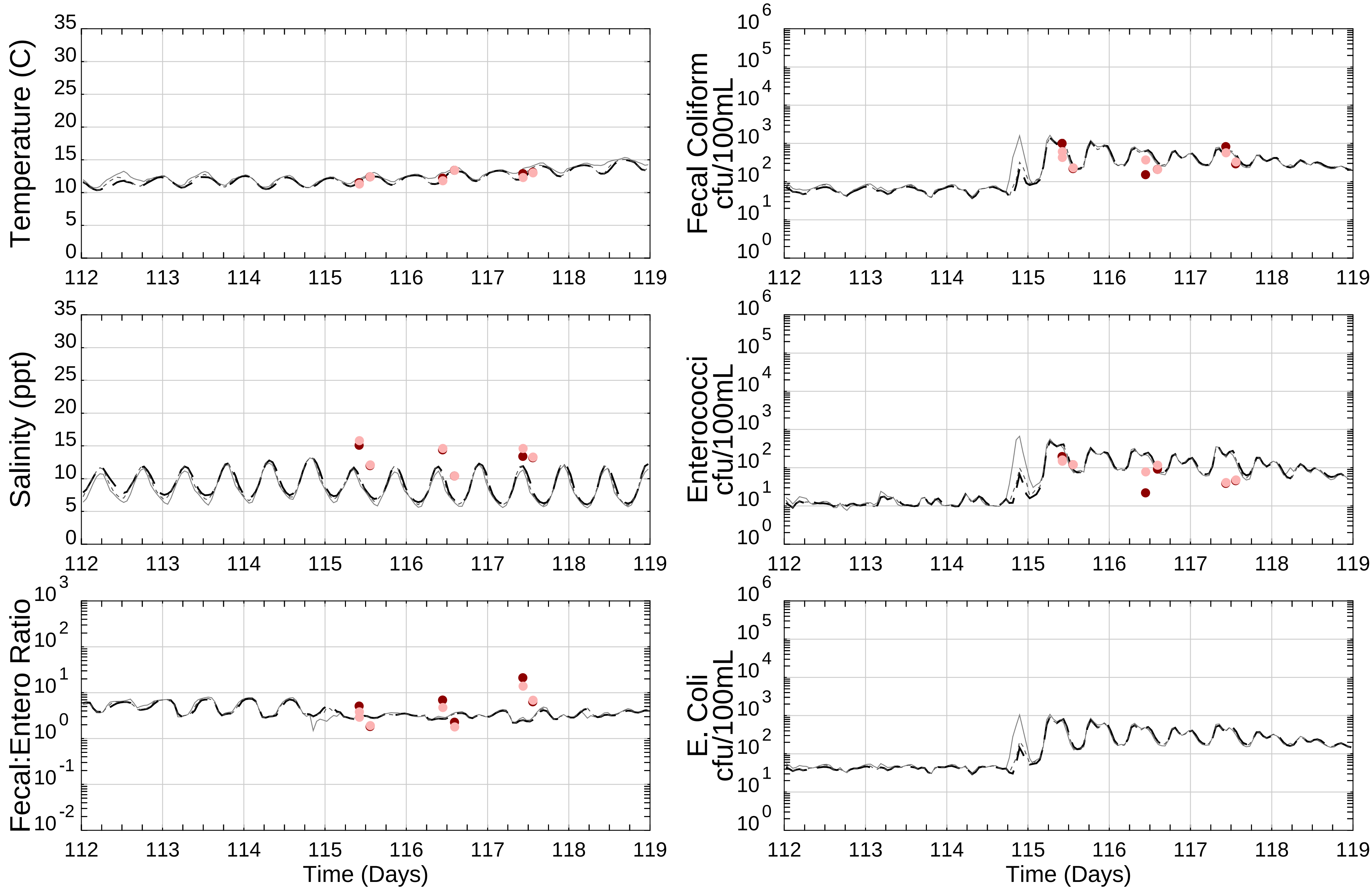
Model at Surface
Model at Mid-Depth
Model at Bottom

Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

Hackensack River & Tributaries
Hackensack River

SE2

Station: 15 Event 3 (Apr 23-29)



Model = 2017
Data = 2017

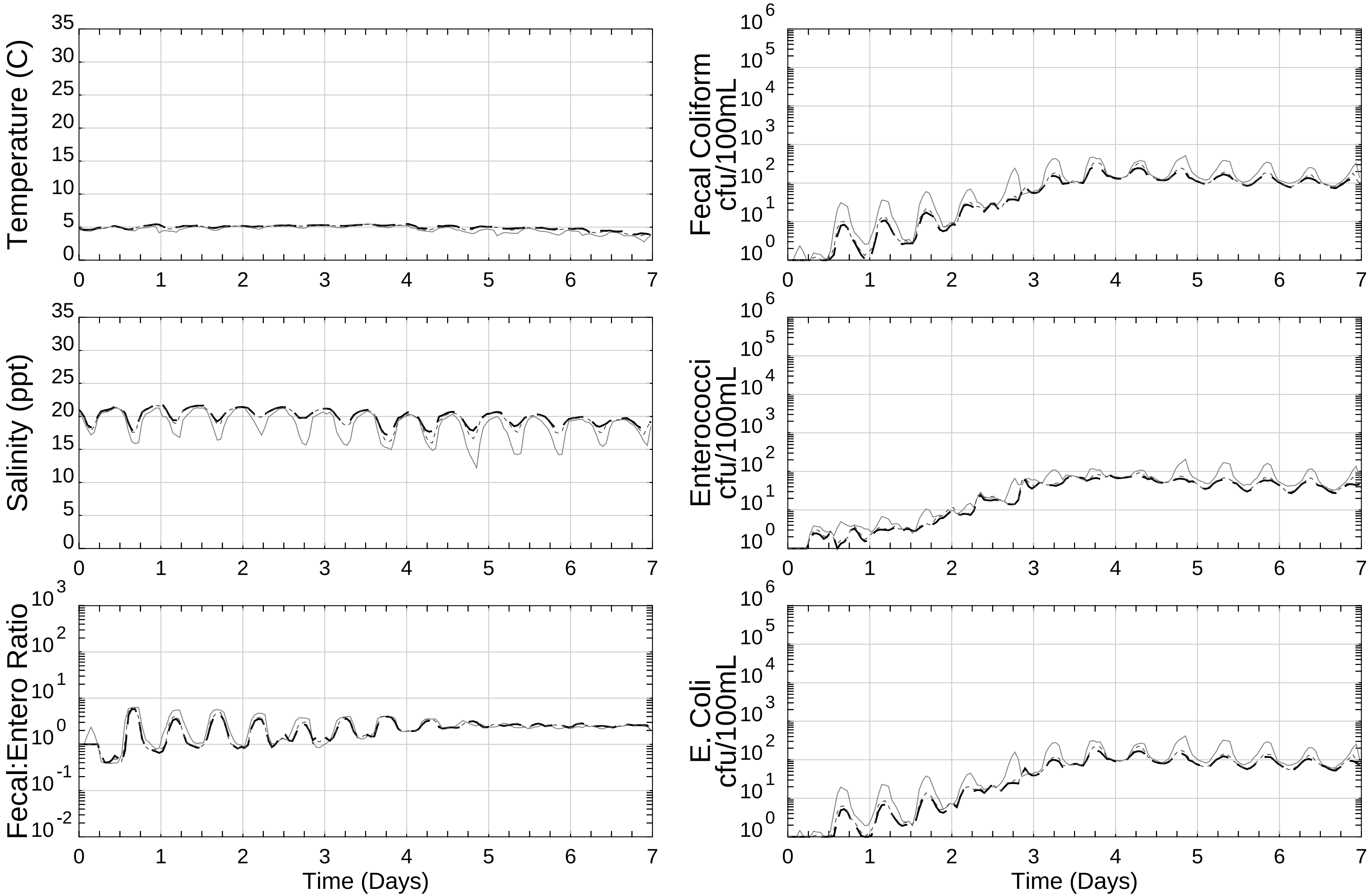
Model at Surface
Model at Mid-Depth
Model at Bottom

Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

Newark Bay & Tributaries
Newark Bay

SE3

Station: 17 Event 1 (Jan 1-7)



Model = 2017
Data = 2017

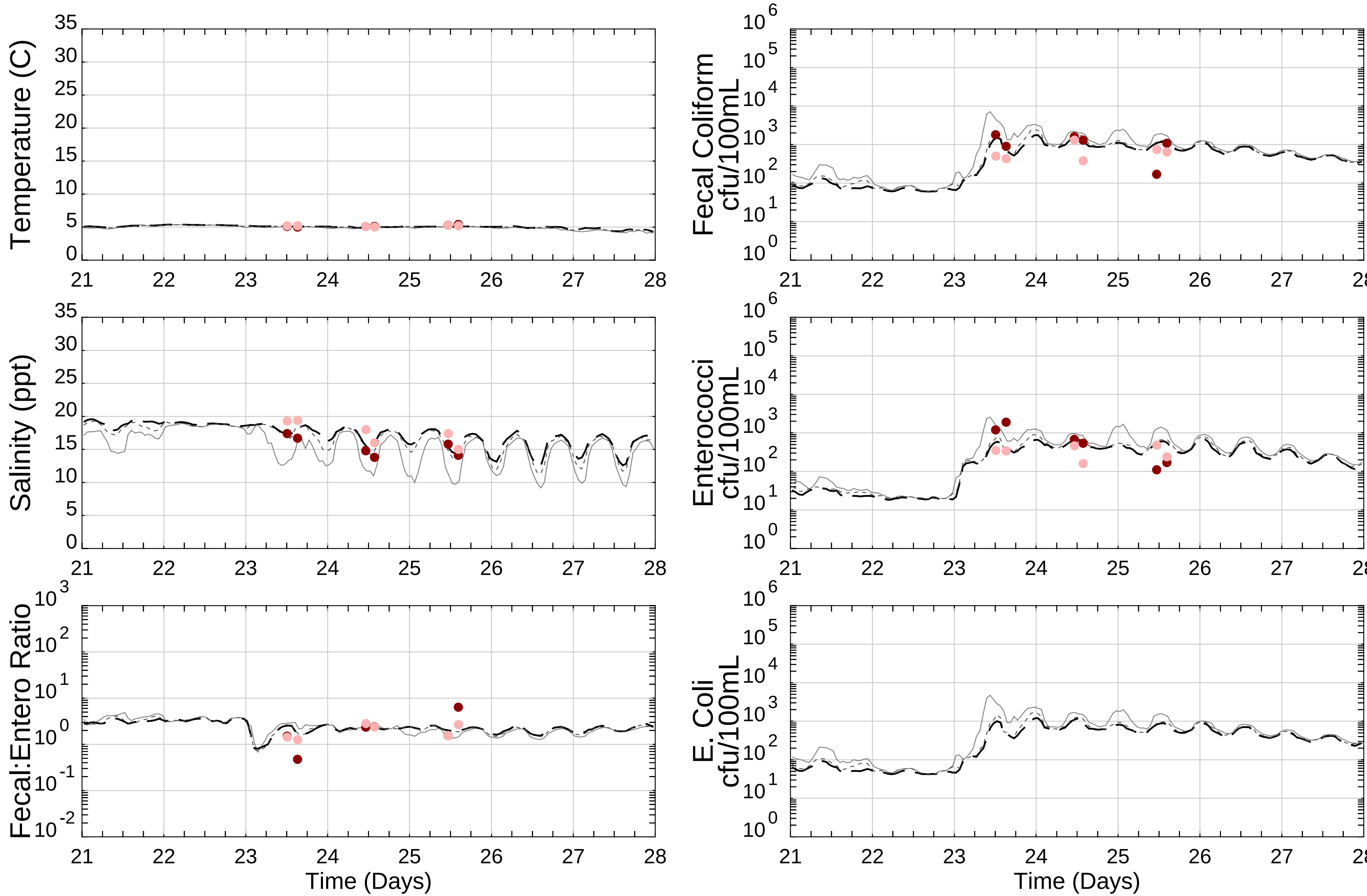
Model at Surface
Model at Mid-Depth
Model at Bottom

Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

Newark Bay & Tributaries
Newark Bay

SE3

Station: 17 Event 2 (Jan 21-28)



Model = 2017
Data = 2017

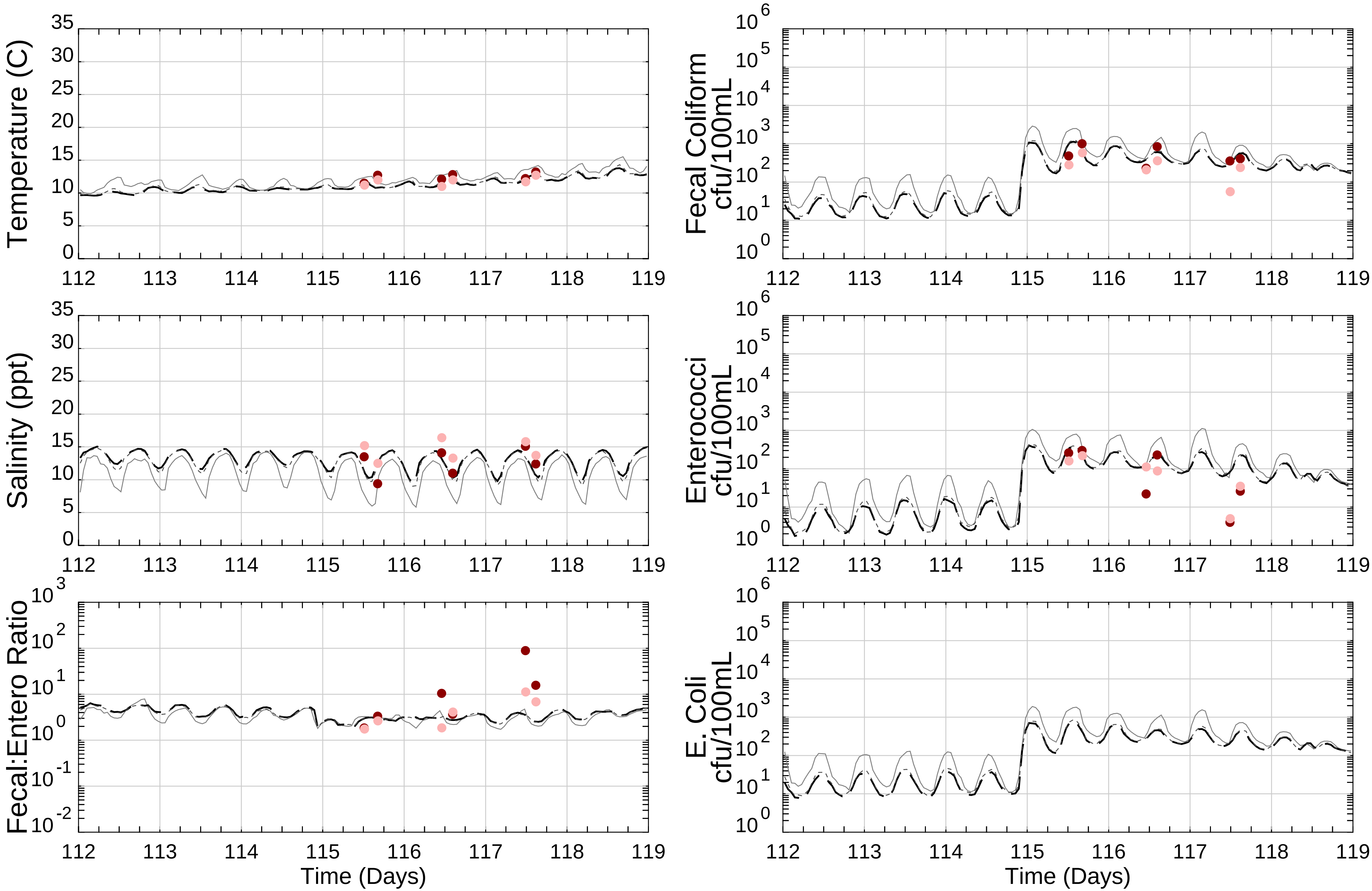
Model at Surface
Model at Mid-Depth
Model at Bottom

Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

Newark Bay & Tributaries
Newark Bay

SE3

Station: 17 Event 3 (Apr 23-29)



Model = 2017
Data = 2017

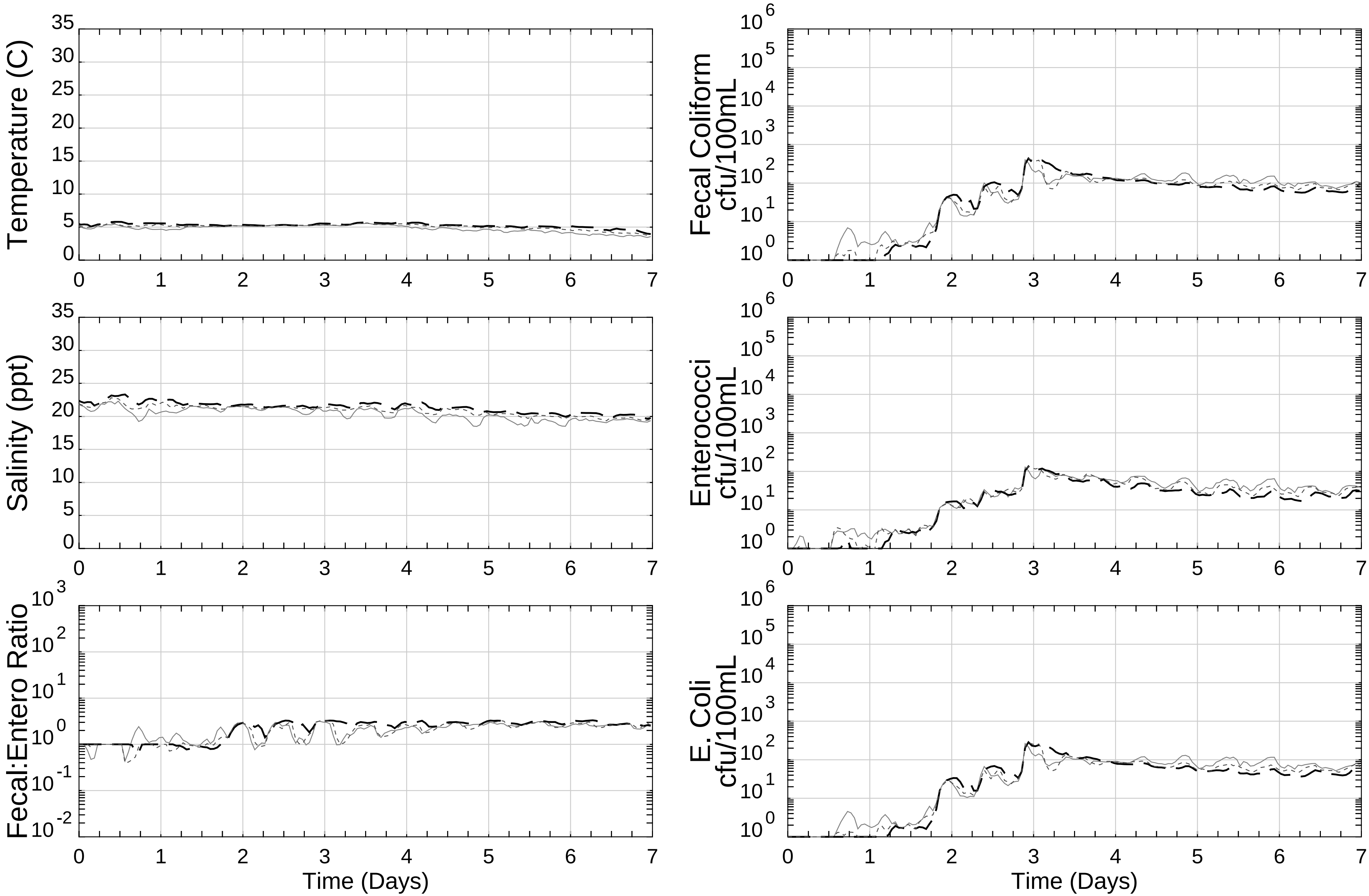
Model at Surface
Model at Mid-Depth
Model at Bottom

Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

Newark Bay & Tributaries
Newark Bay

SE3

Station: 18 Event 1 (Jan 1-7)

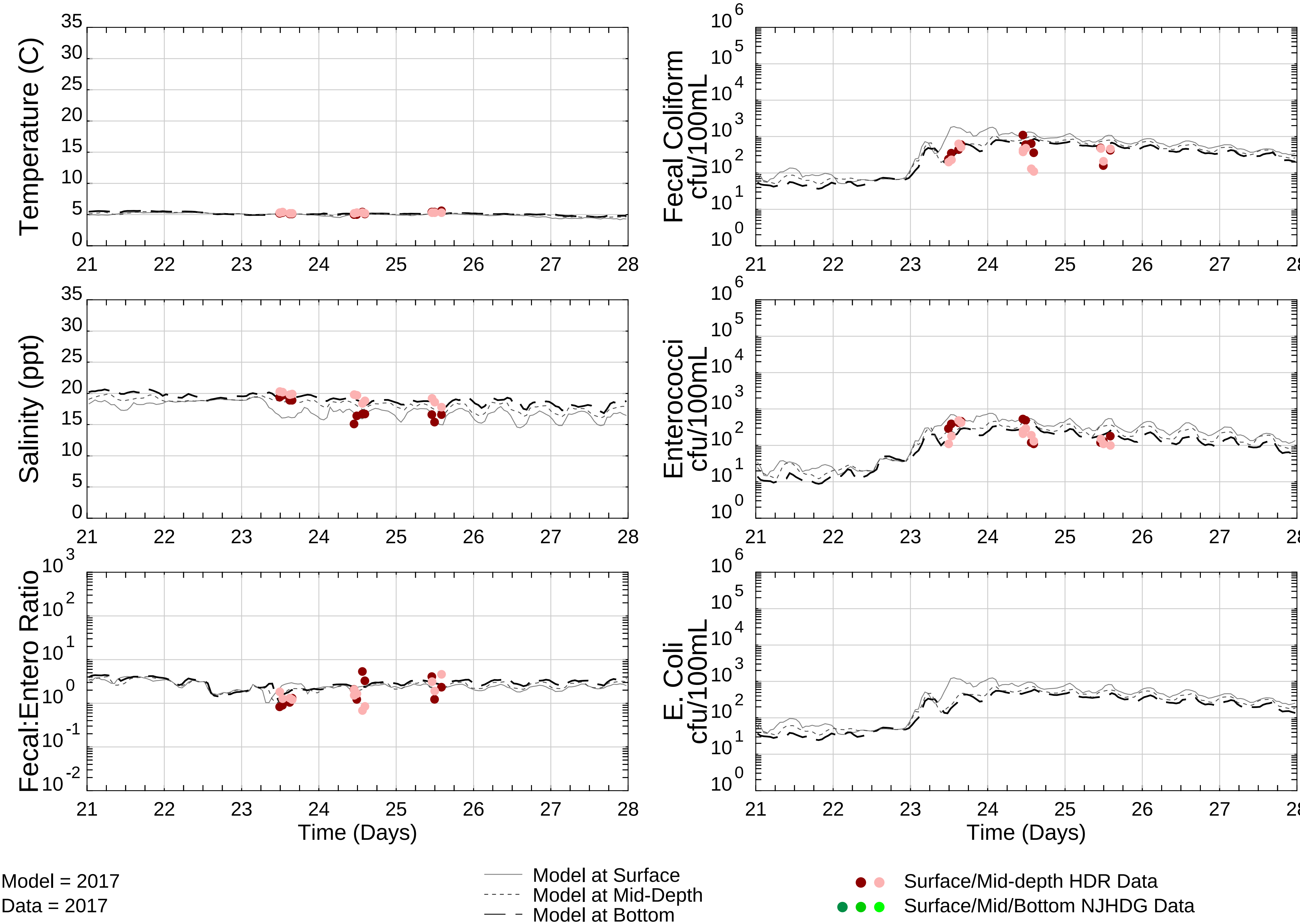


Model = 2017
Data = 2017

Model at Surface
Model at Mid-Depth
Model at Bottom

Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

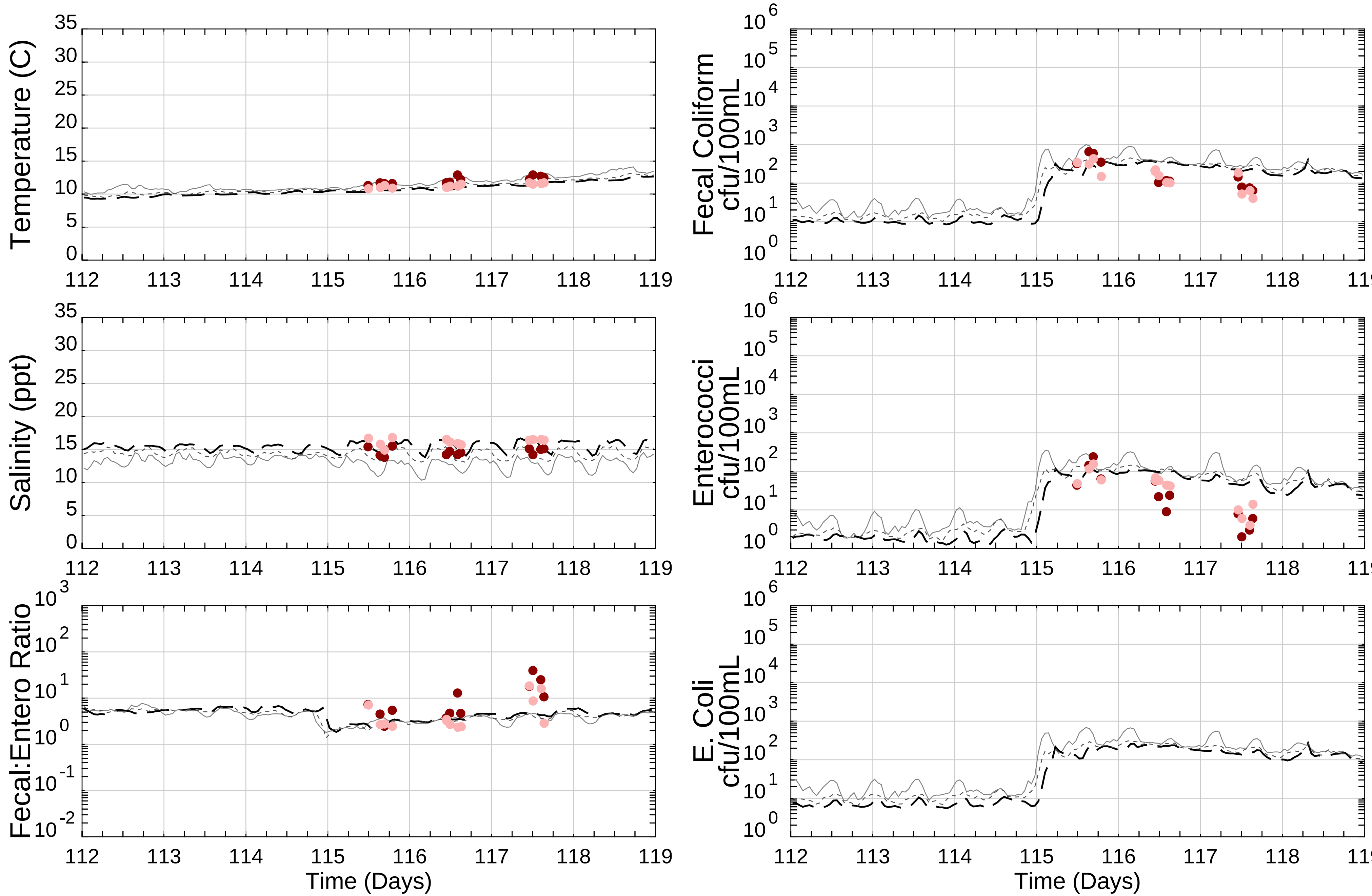
Station: 18 Event 2 (Jan 21-28)



Newark Bay & Tributaries
Newark Bay

SE3

Station: 18 Event 3 (Apr 23-29)



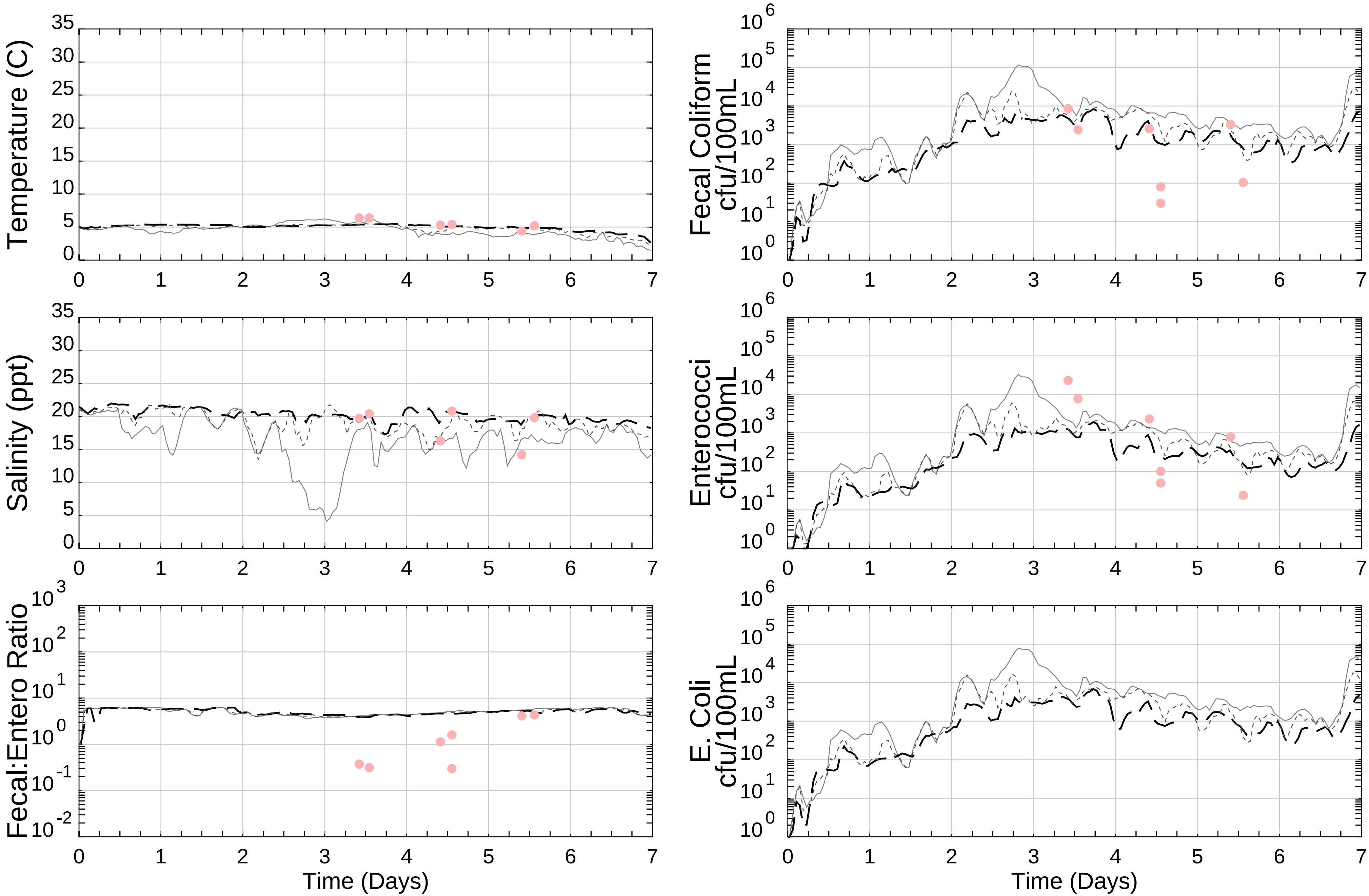
Model = 2017
Data = 2017

Model at Surface
Model at Mid-Depth
Model at Bottom

Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

Newark Bay & Tributaries
Elizabeth River

Station: 20 Event 1 (Jan 1-7)



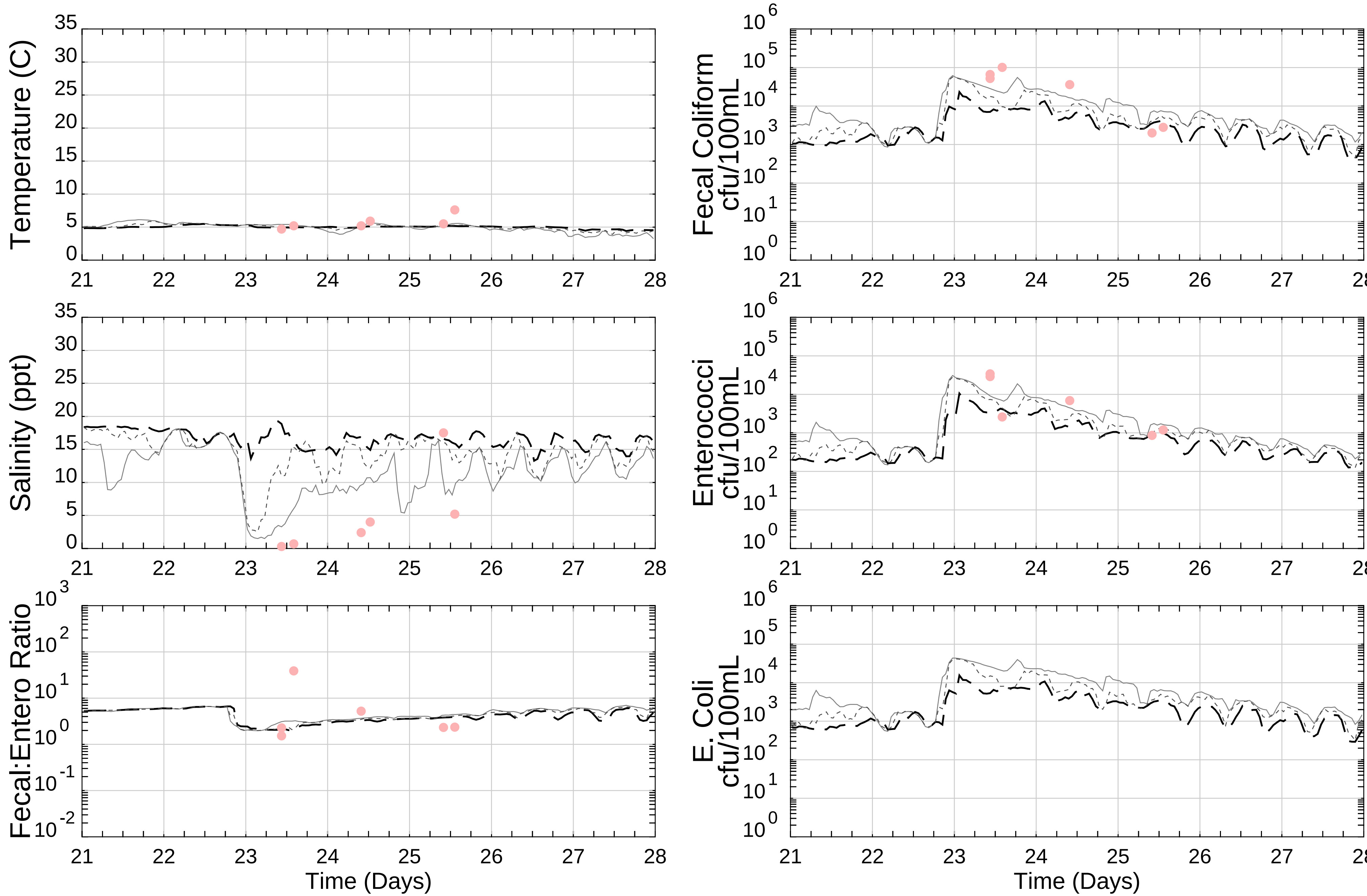
Model = 2017
Data = 2017

Model at Surface
Model at Mid-Depth
Model at Bottom

Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

Newark Bay & Tributaries
Elizabeth River

Station: 20 Event 2 (Jan 21-28)



Model = 2017
Data = 2017

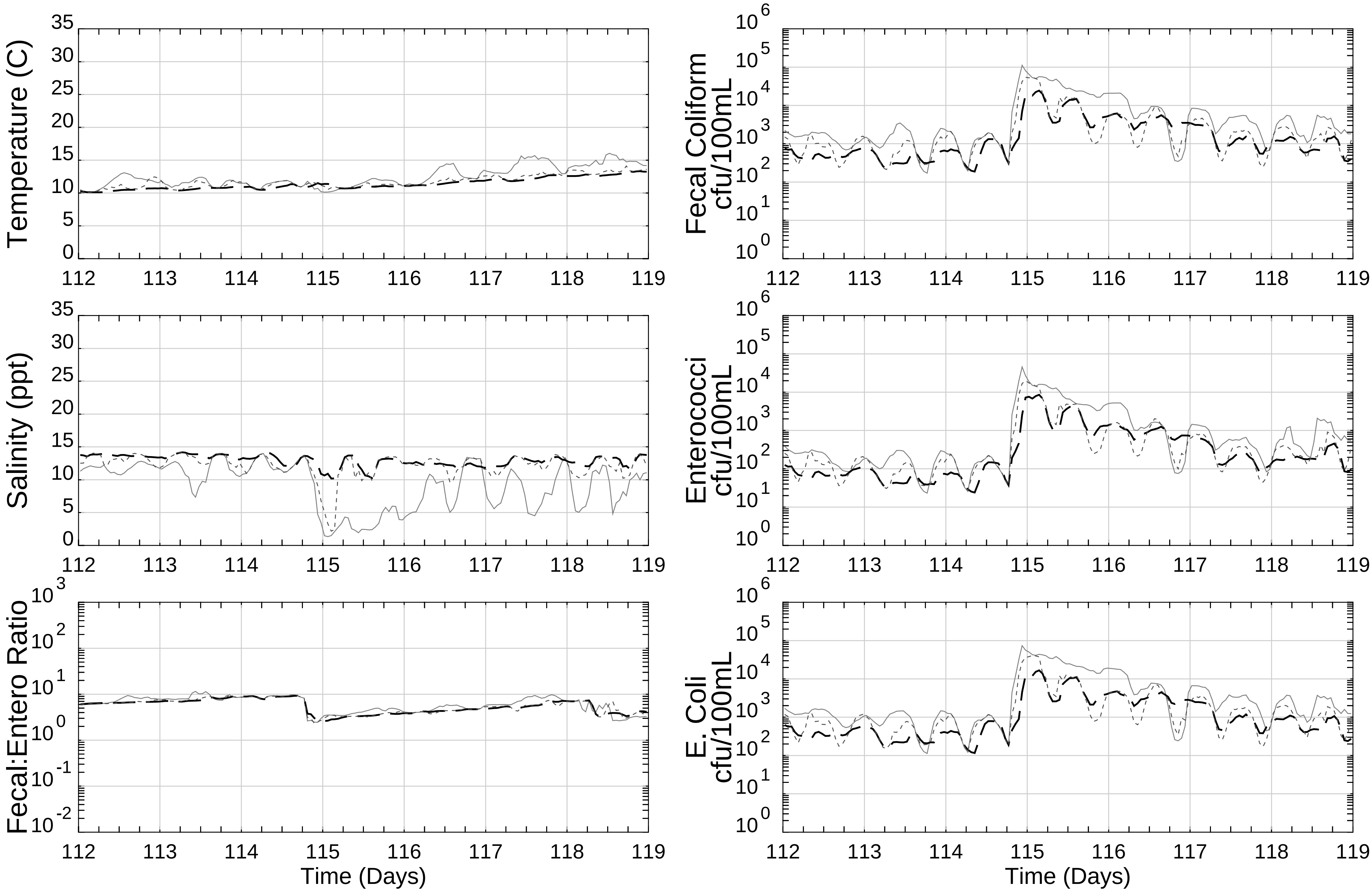
Model at Surface
Model at Mid-Depth
Model at Bottom

Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

Newark Bay & Tributaries
Elizabeth River

SE3

Station: 20 Event 3 (Apr 23-29)



Model = 2017
Data = 2017

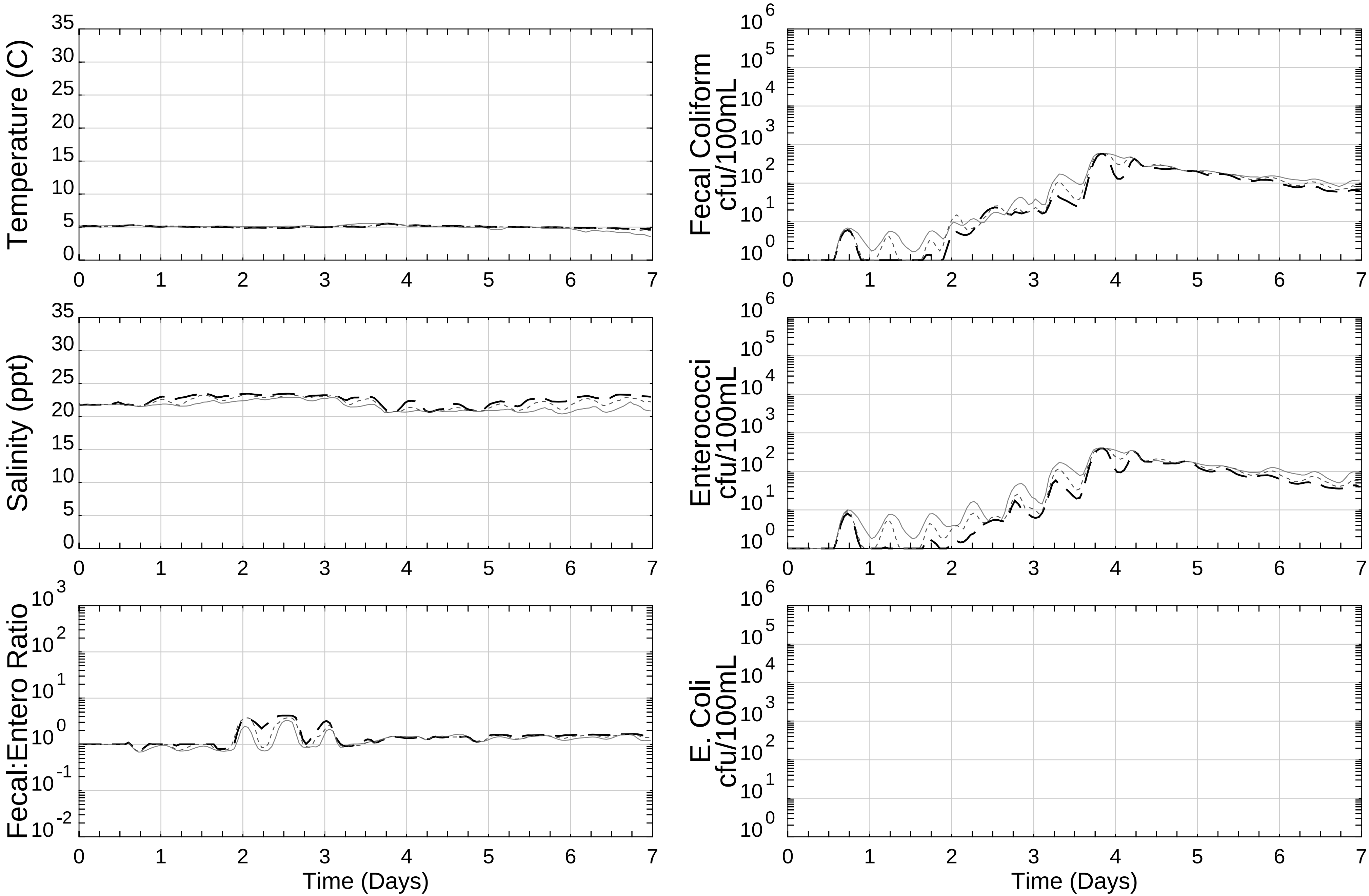
Model at Surface
Model at Mid-Depth
Model at Bottom

Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

Arthur Kill, Raritan River/Bay & Tributaries
Arthur Kill

SE3

Station: 24 Event 1 (Jan 1-7)



Model = 2017
Data = 2017

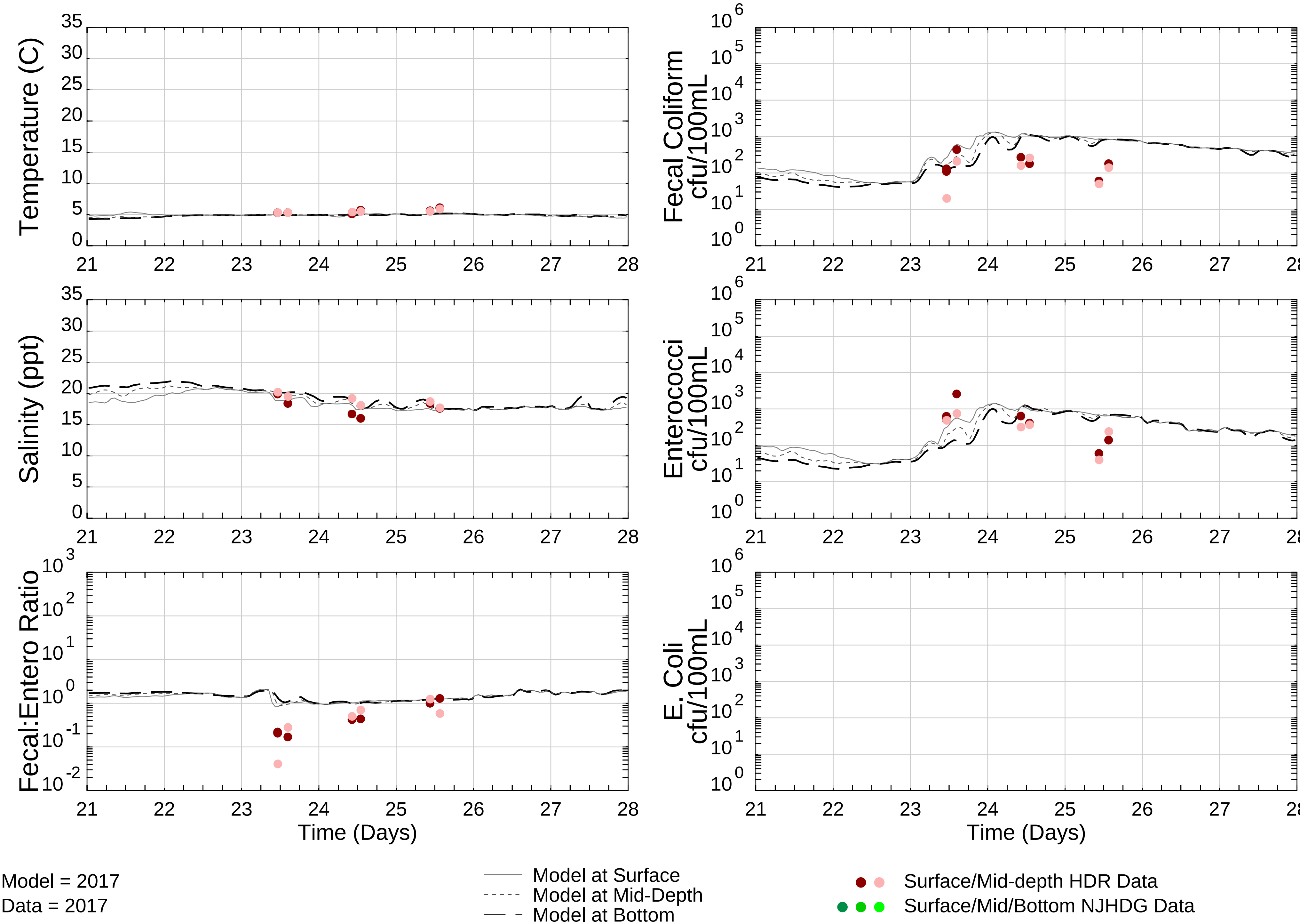
Model at Surface
Model at Mid-Depth
Model at Bottom

Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

Arthur Kill, Raritan River/Bay & Tributaries
Arthur Kill

SE3

Station: 24 Event 2 (Jan 21-28)

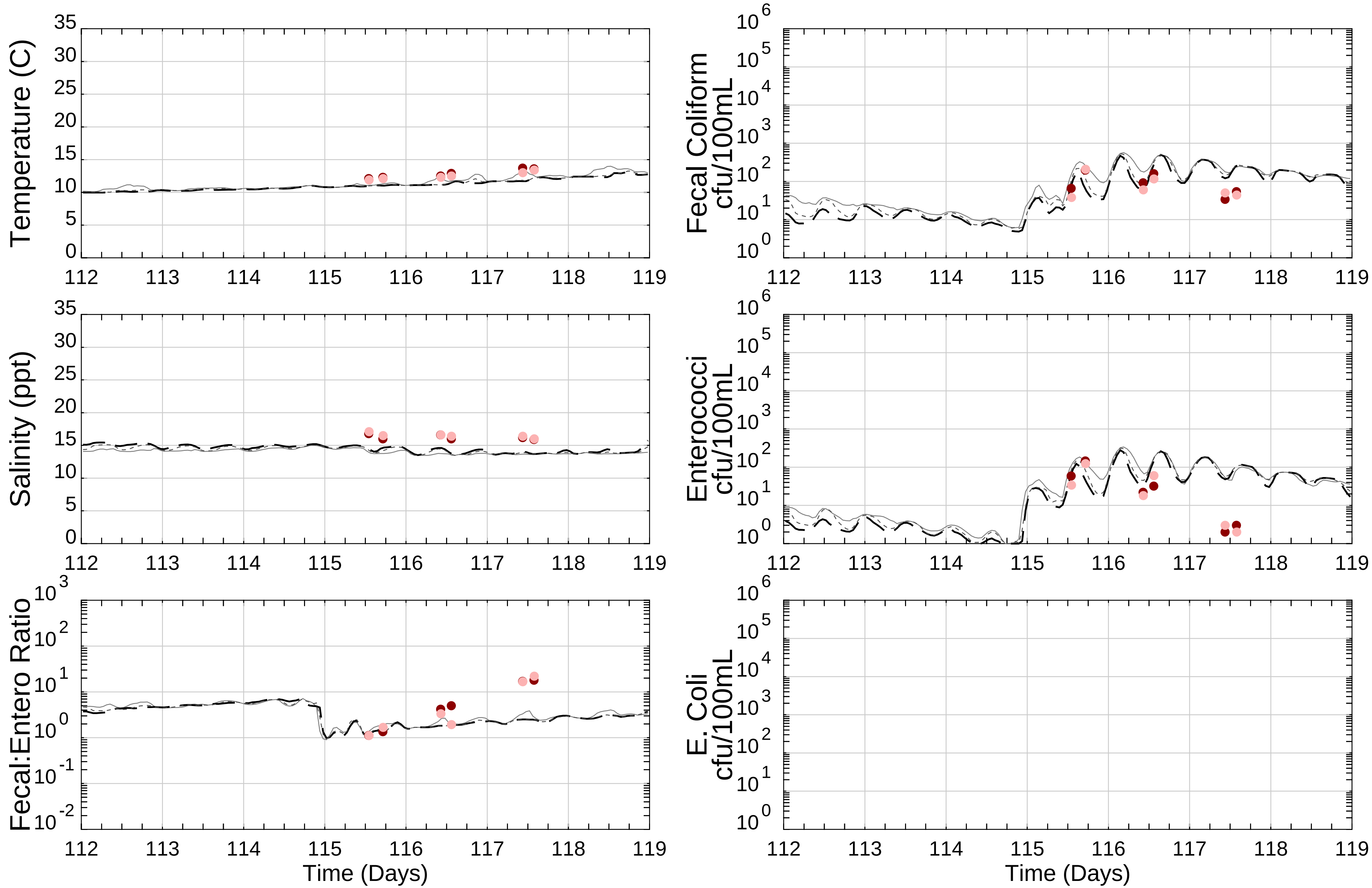


Model = 2017
Data = 2017

Arthur Kill, Raritan River/Bay & Tributaries
Arthur Kill

SE3

Station: 24 Event 3 (Apr 23-29)



Model = 2017
Data = 2017

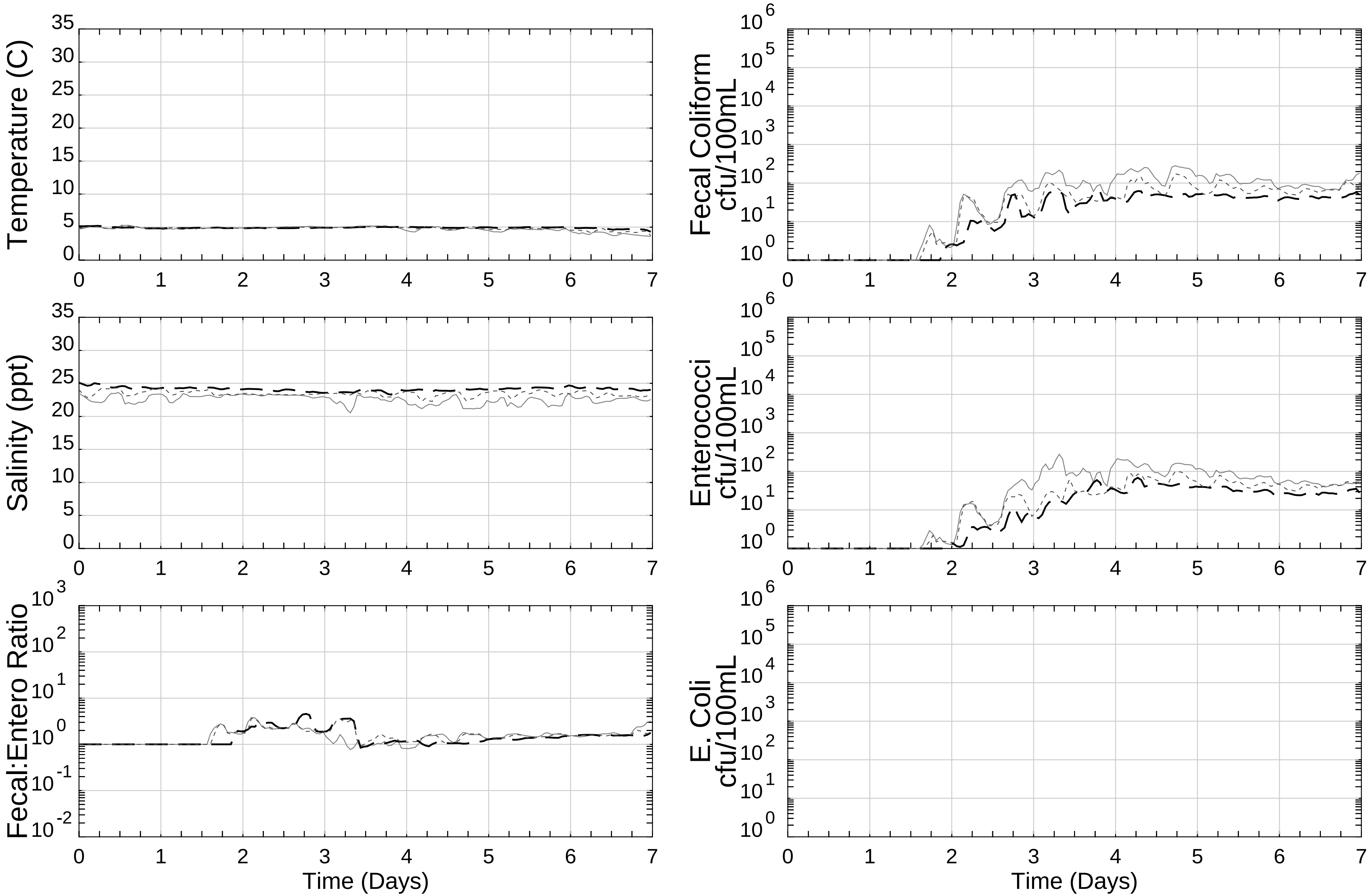
Model at Surface
Model at Mid-Depth
Model at Bottom

Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

Arthur Kill, Raritan River/Bay & Tributaries
Arthur Kill

SE2

Station: B15 Event 1 (Jan 1-7)



Model = 2017
Data = 2017

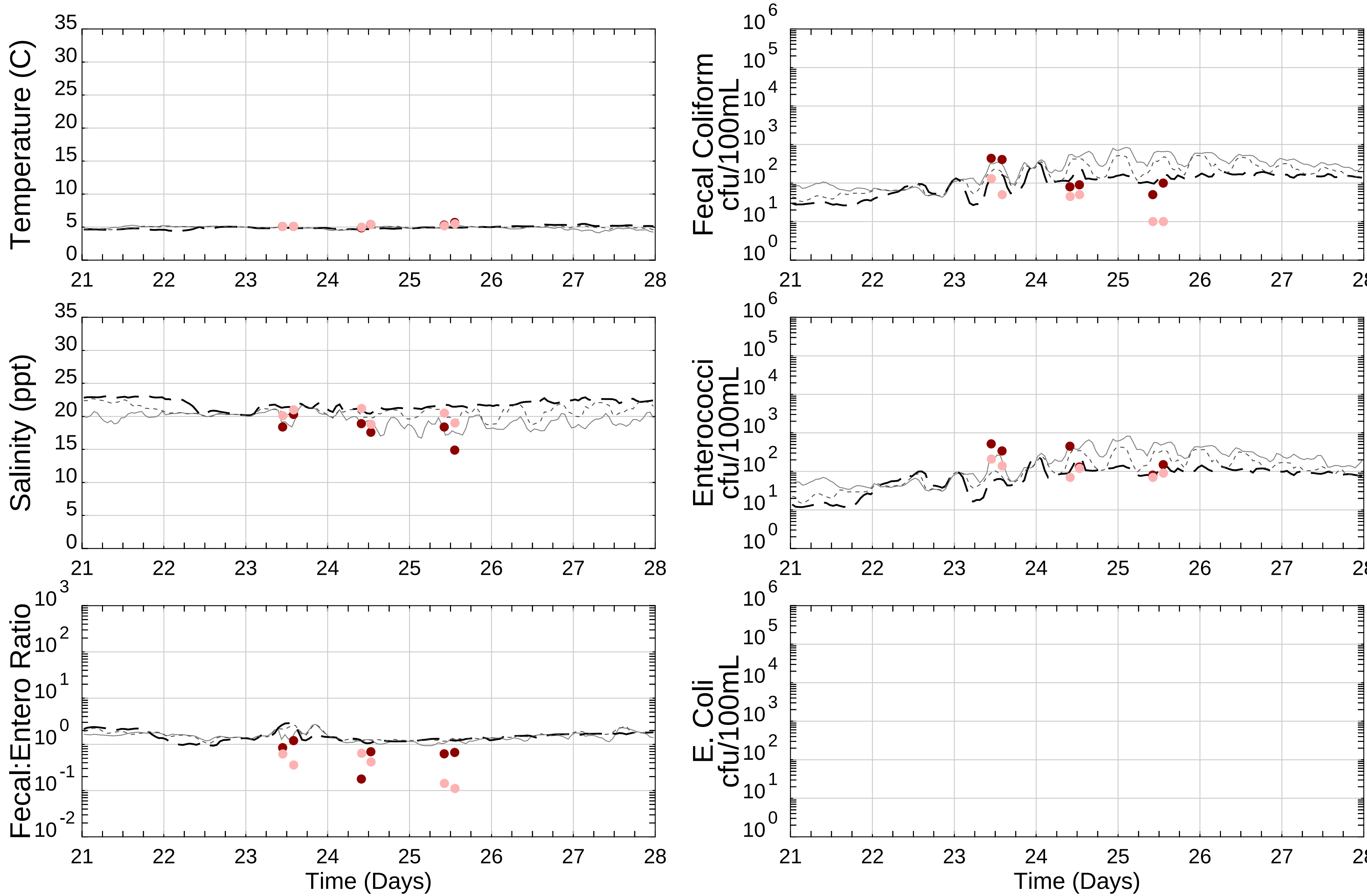
Model at Surface
Model at Mid-Depth
Model at Bottom

Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

Arthur Kill, Raritan River/Bay & Tributaries
Arthur Kill

SE2

Station: B15 Event 2 (Jan 21-28)



Model = 2017
Data = 2017

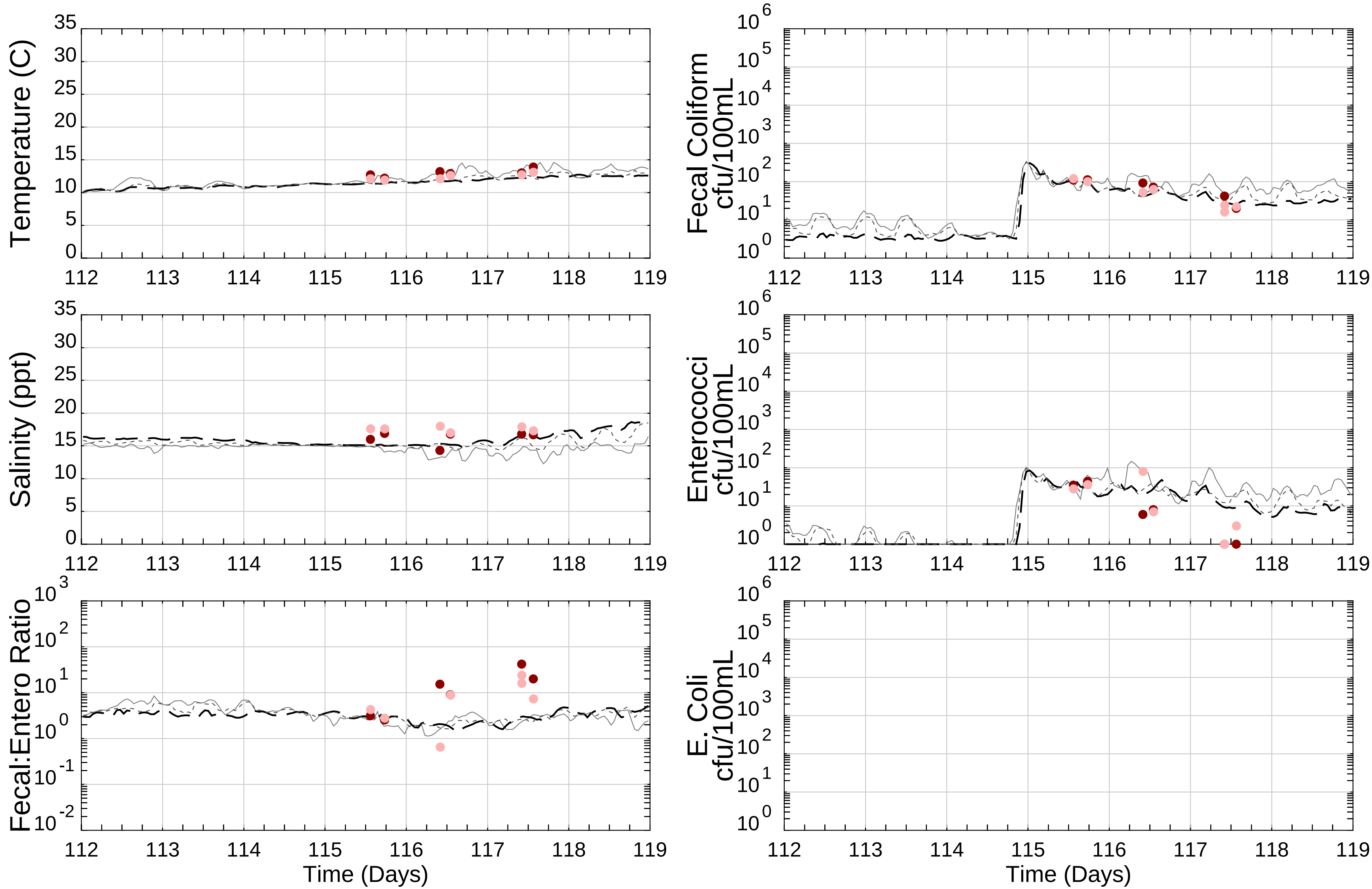
Model at Surface
Model at Mid-Depth
Model at Bottom

Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

Arthur Kill, Raritan River/Bay & Tributaries
Arthur Kill

SE2

Station: B15 Event 3 (Apr 23-29)



Model = 2017
Data = 2017

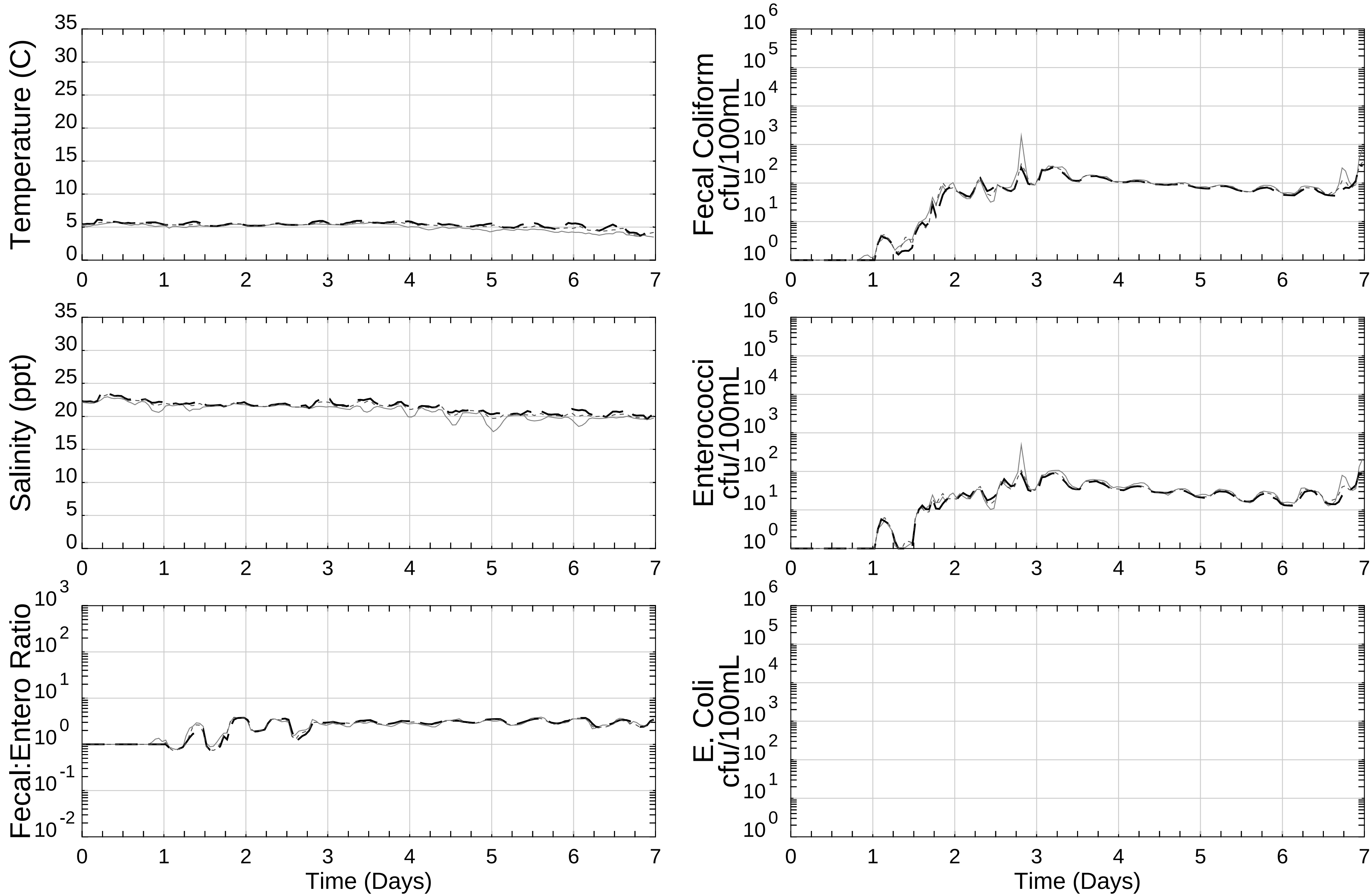
Model at Surface
Model at Mid-Depth
Model at Bottom

Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

Hudson River, Upper Bay
Kill Van Kull

SE3

Station: B12 Event 1 (Jan 1-7)



Model = 2017
Data = 2017

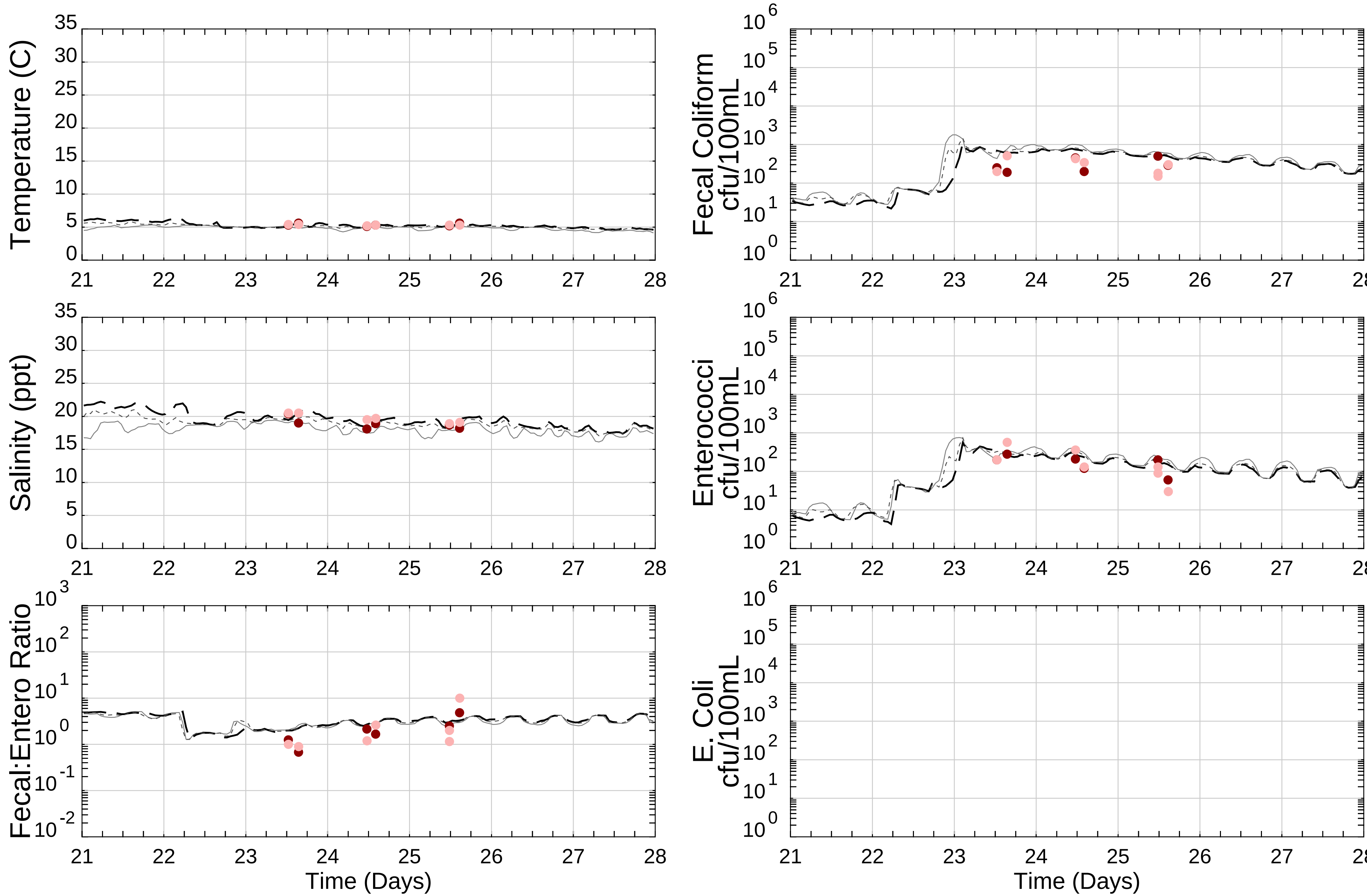
Model at Surface
Model at Mid-Depth
Model at Bottom

Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

Hudson River, Upper Bay
Kill Van Kull

SE3

Station: B12 Event 2 (Jan 21-28)



Model = 2017
Data = 2017

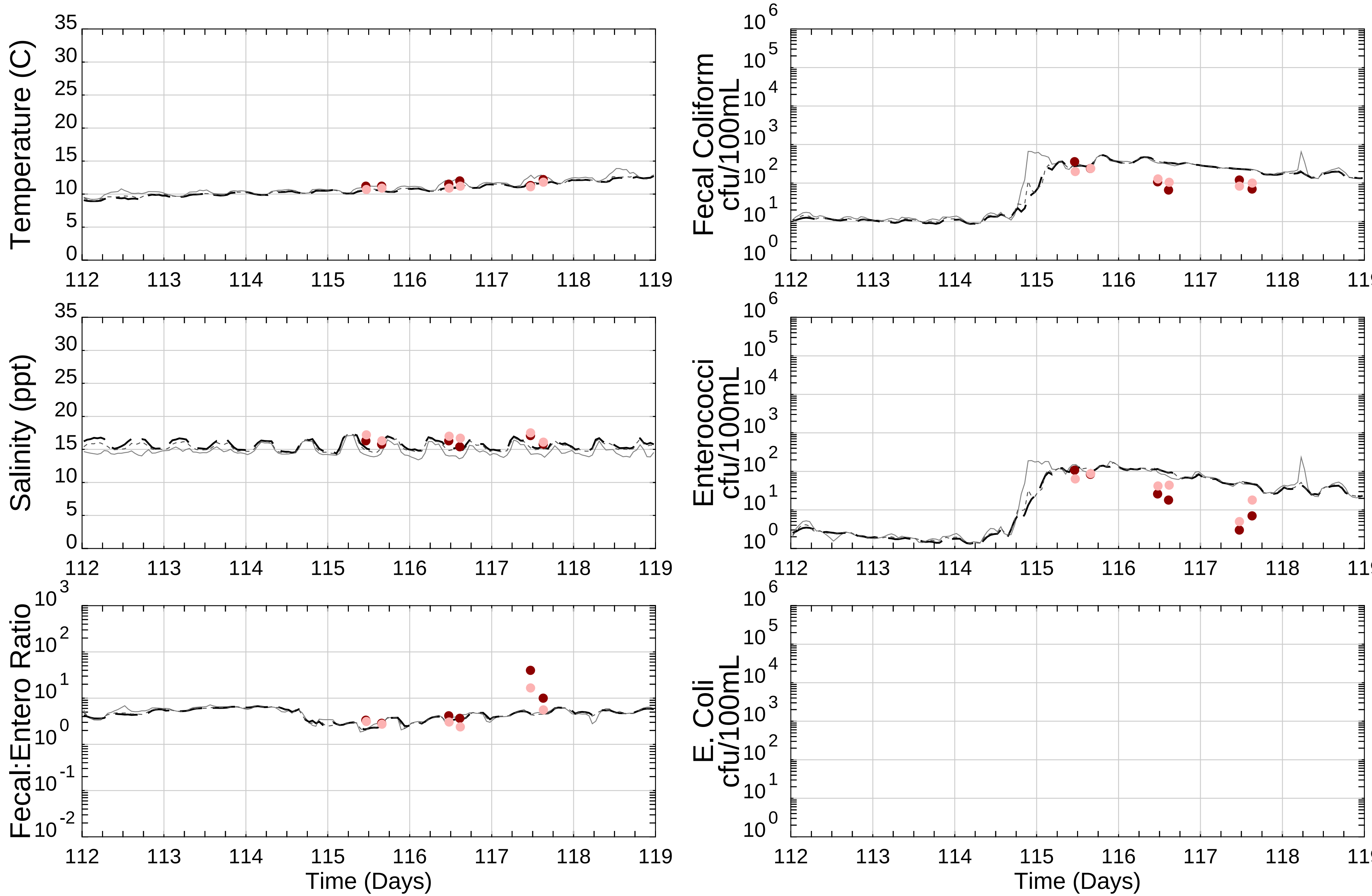
Model at Surface
Model at Mid-Depth
Model at Bottom

Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

Hudson River, Upper Bay
Kill Van Kull

SE3

Station: B12 Event 3 (Apr 23-29)



Model = 2017
Data = 2017

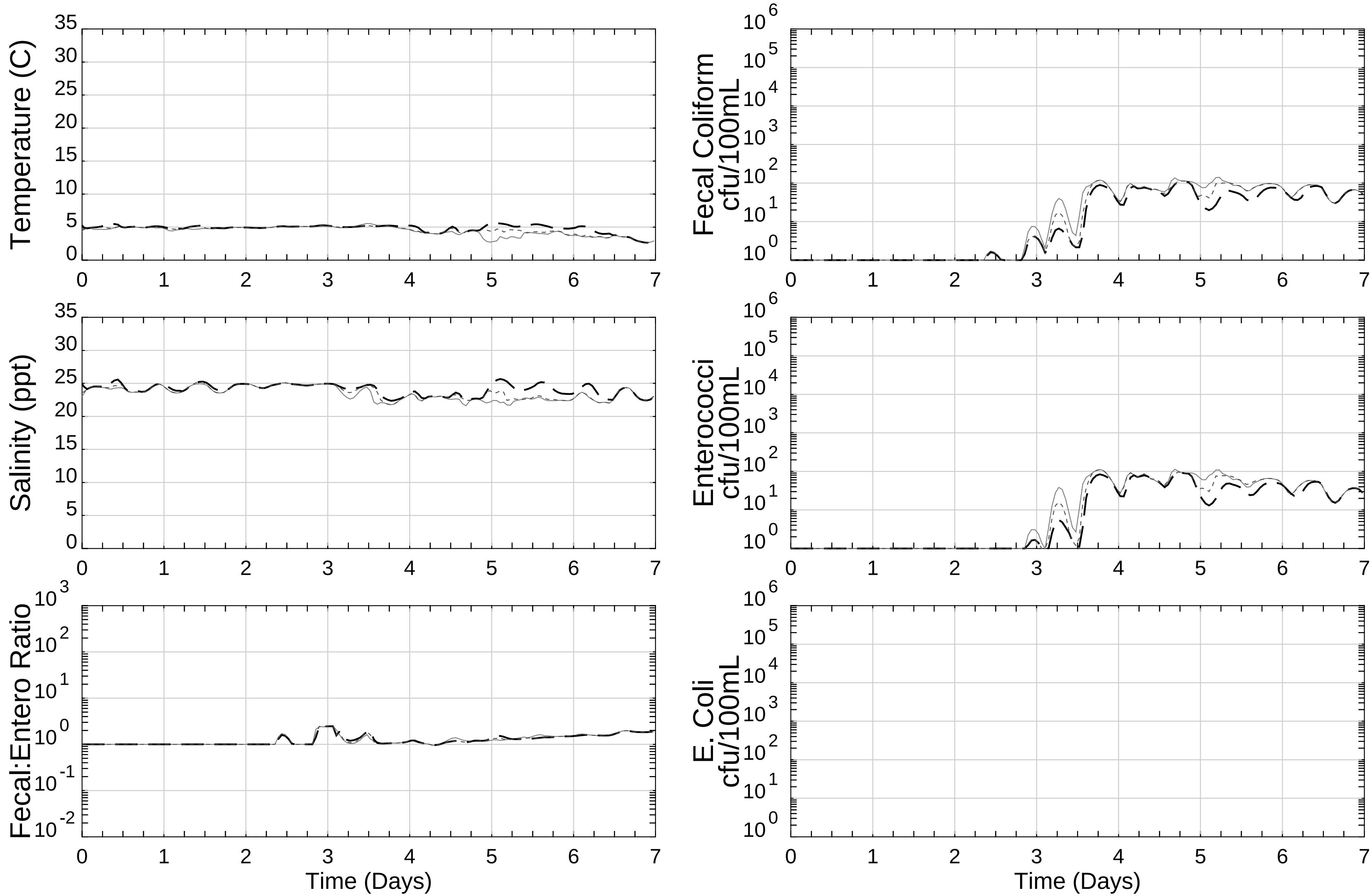
Model at Surface
Model at Mid-Depth
Model at Bottom

Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

Arthur Kill, Raritan River/Bay & Tributaries
Raritan Bay

SE1

Station: 29 Event 1 (Jan 1-7)

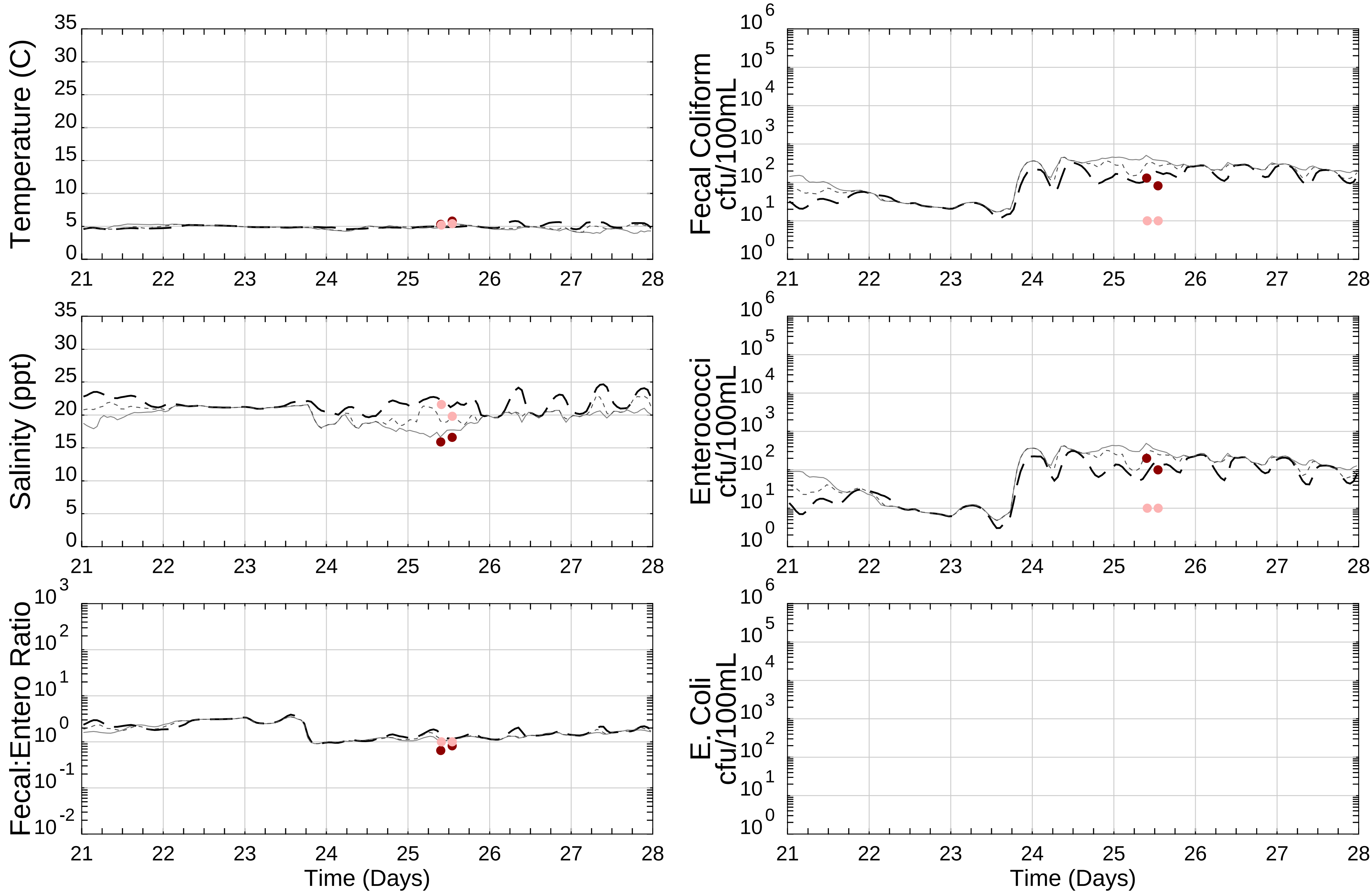


Model = 2017
Data = 2017

Model at Surface
Model at Mid-Depth
Model at Bottom

Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

Arthur Kill, Raritan River/Bay & Tributaries
Raritan Bay
SE1
Station: 29 Event 2 (Jan 21-28)



Model = 2017
Data = 2017

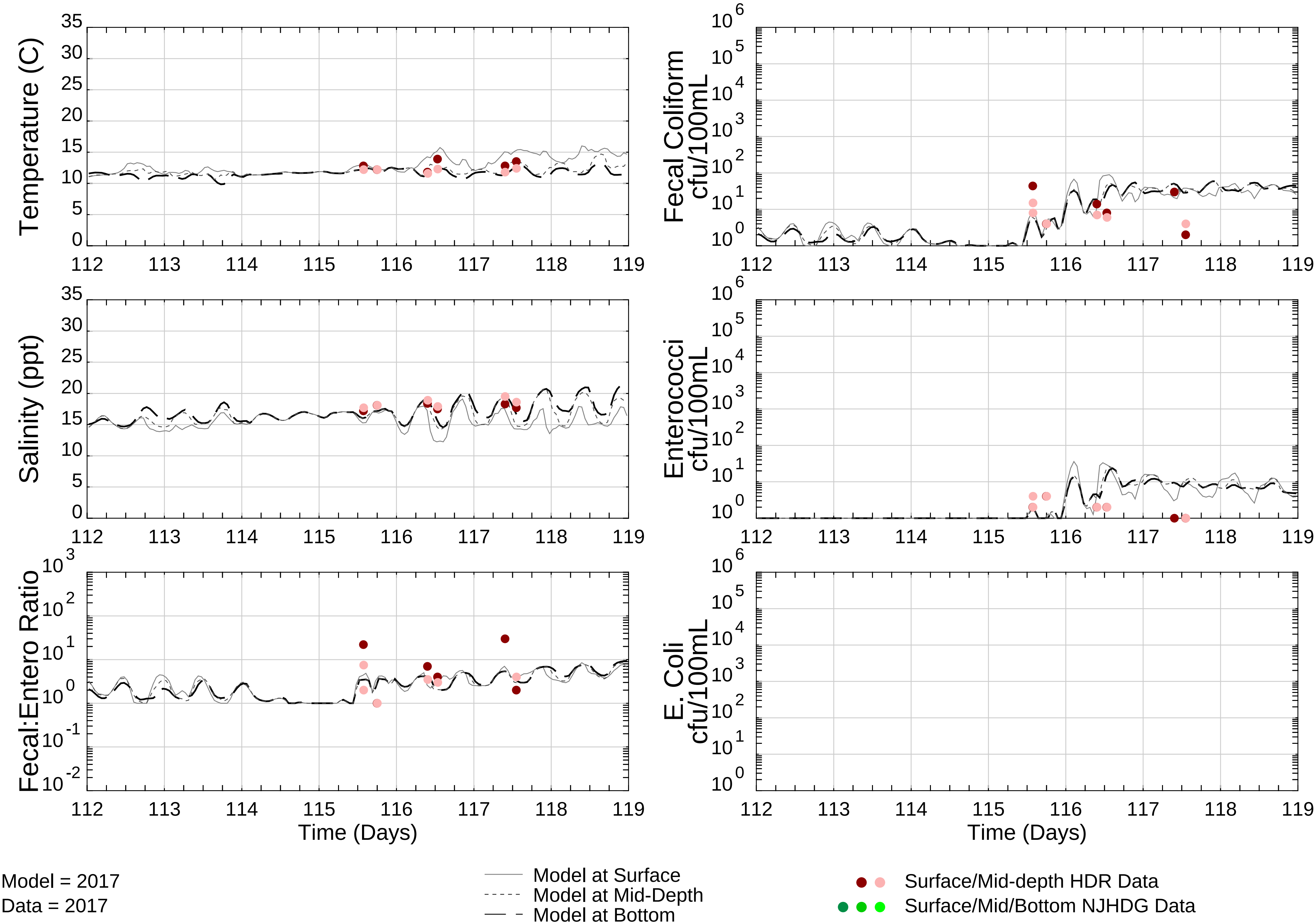
Model at Surface
Model at Mid-Depth
Model at Bottom

Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

Arthur Kill, Raritan River/Bay & Tributaries
Raritan Bay

SE1

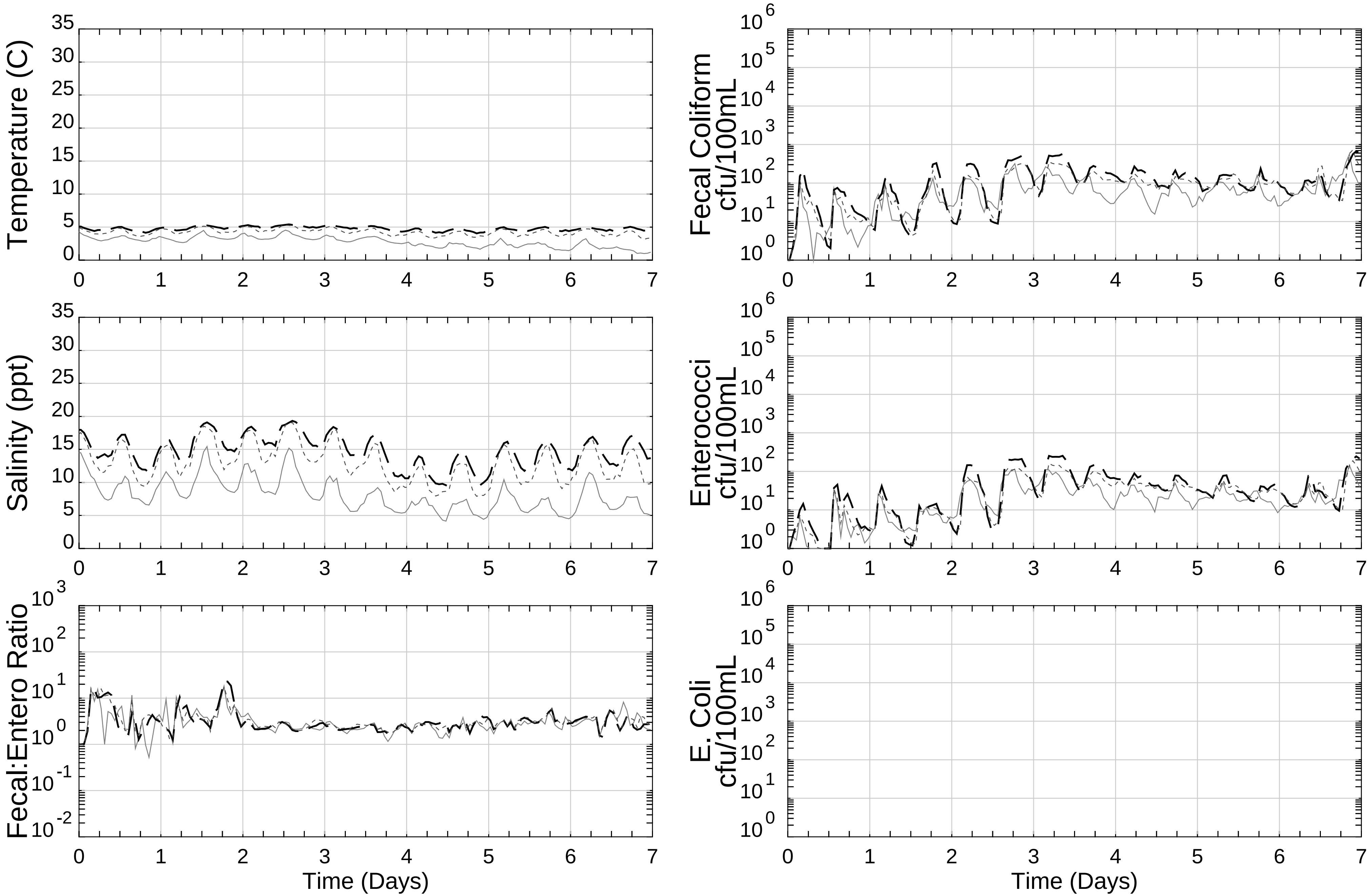
Station: 29 Event 3 (Apr 23-29)



Hudson River, Upper Bay
Hudson River

SE2

Station: 31 Event 1 (Jan 1-7)



Model = 2017
Data = 2017

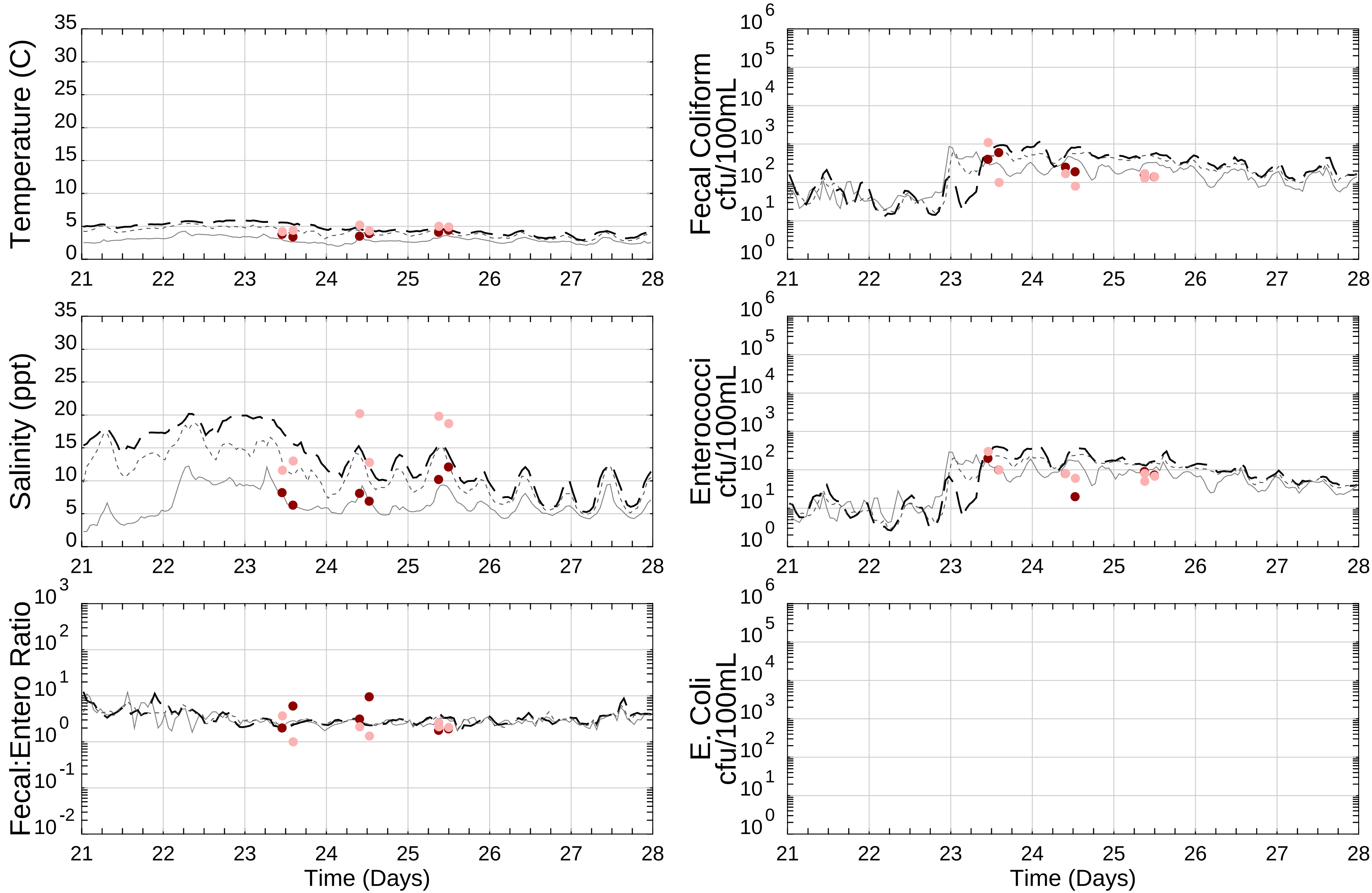
Model at Surface
Model at Mid-Depth
Model at Bottom

Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

Hudson River, Upper Bay
Hudson River

SE2

Station: 31 Event 2 (Jan 21-28)



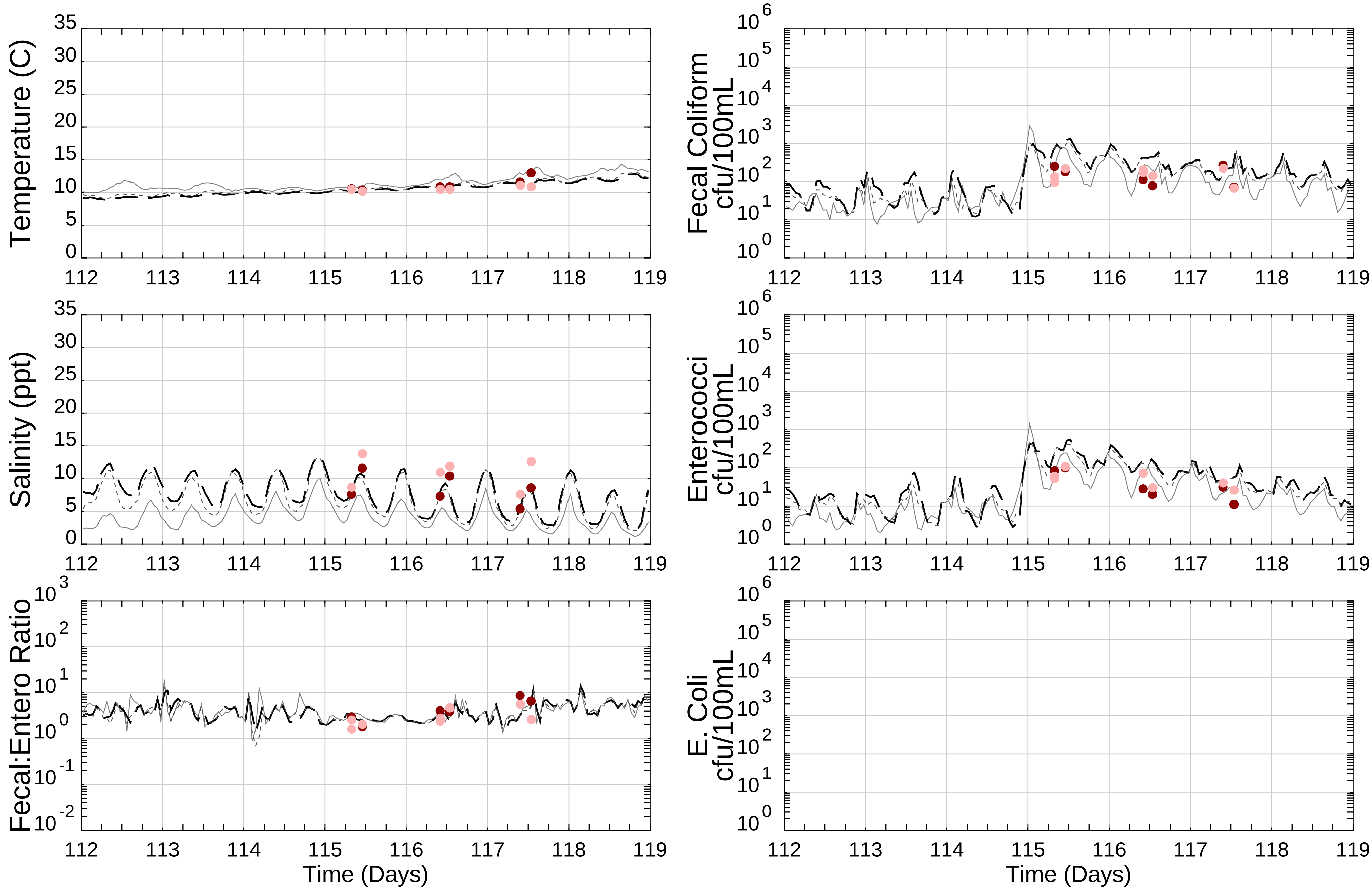
Model = 2017
Data = 2017

Model at Surface
Model at Mid-Depth
Model at Bottom

Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

Hudson River, Upper Bay
Hudson River

Station: 31 Event 3 (Apr 23-29)



Model = 2017
Data = 2017

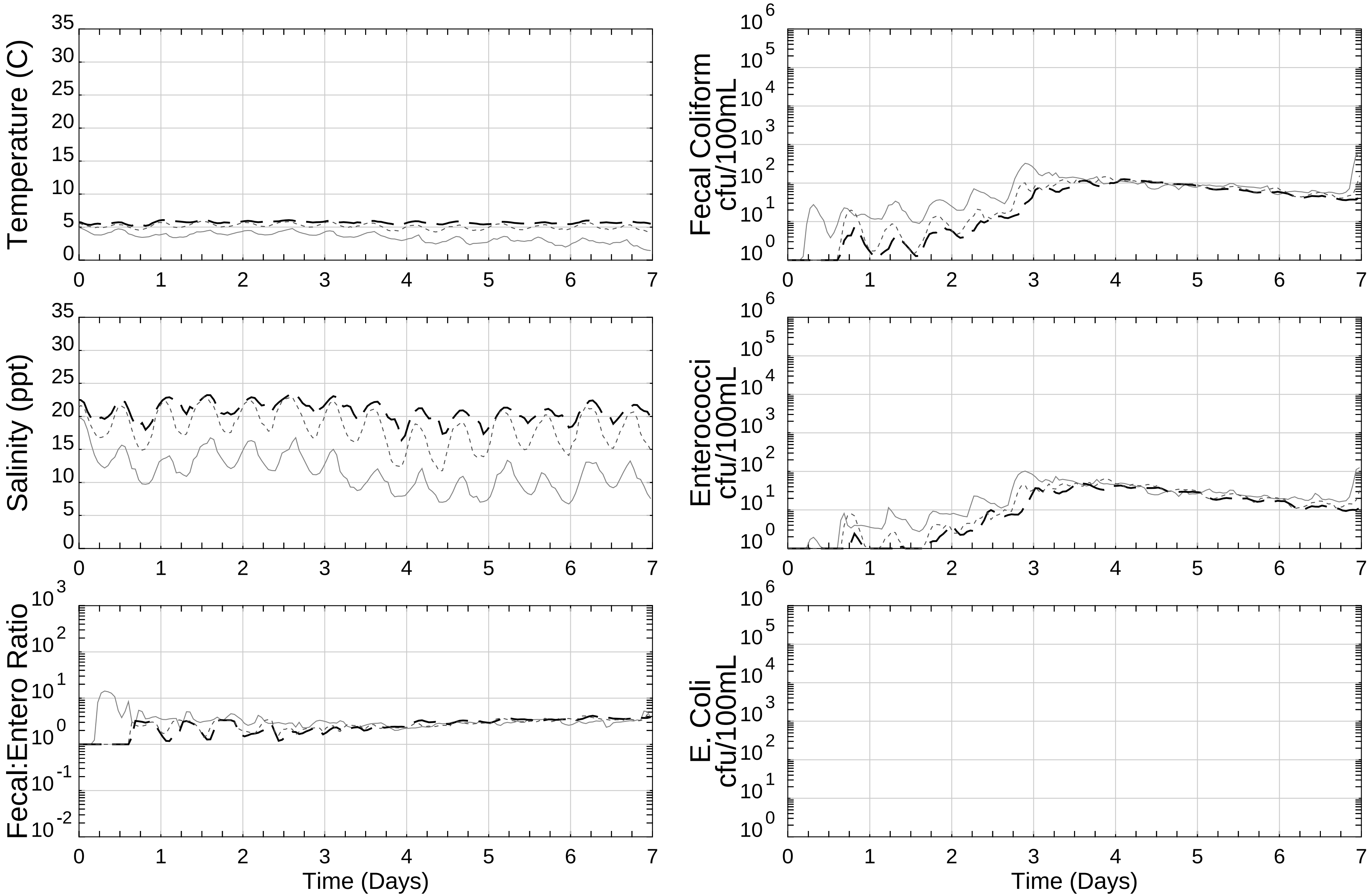
Model at Surface
Model at Mid-Depth
Model at Bottom

Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

Hudson River, Upper Bay
Hudson River

SE2

Station: 32 Event 1 (Jan 1-7)



Model = 2017
Data = 2017

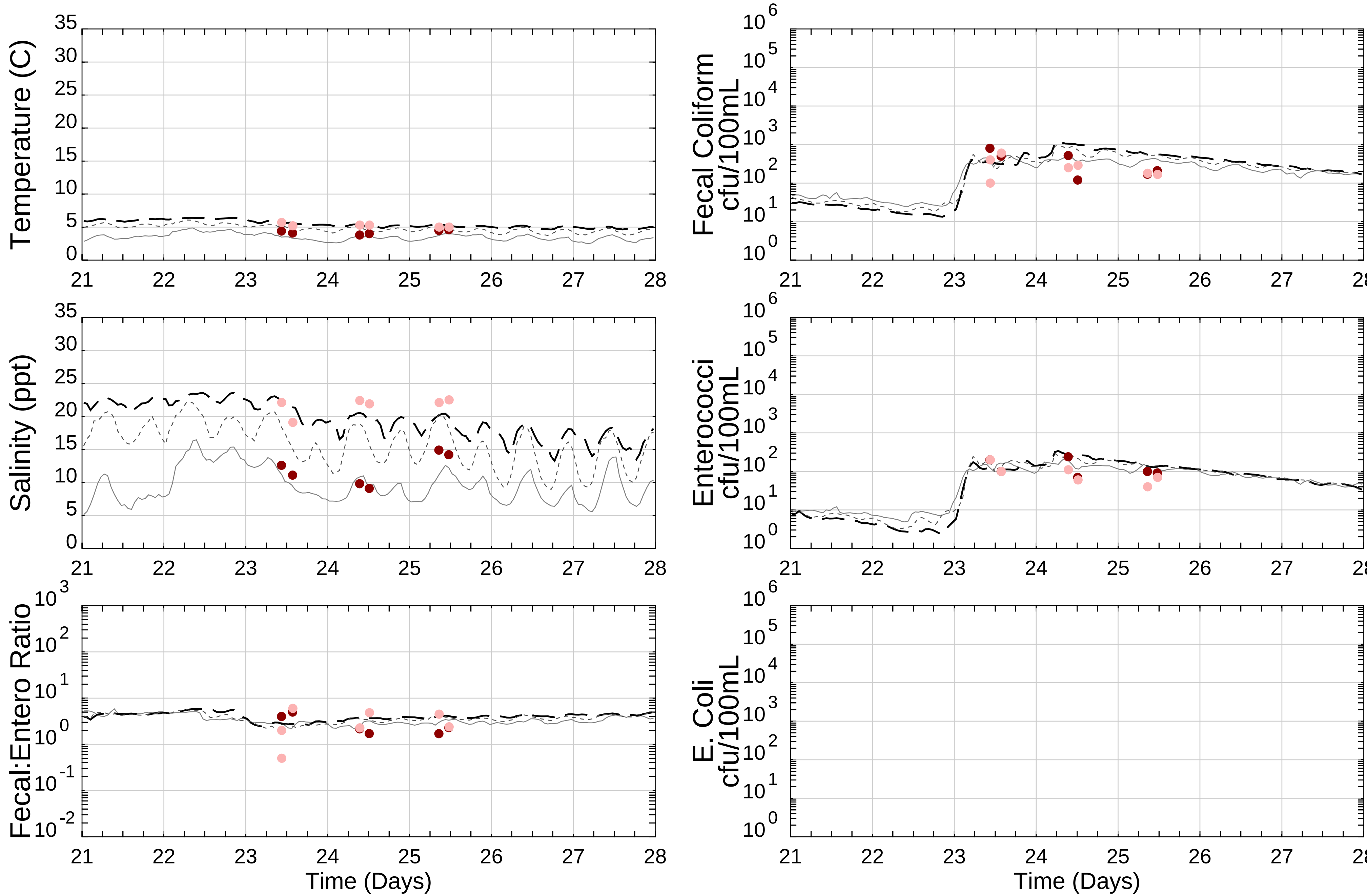
Model at Surface
Model at Mid-Depth
Model at Bottom

Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

Hudson River, Upper Bay
Hudson River

SE2

Station: 32 Event 2 (Jan 21-28)



Model = 2017
Data = 2017

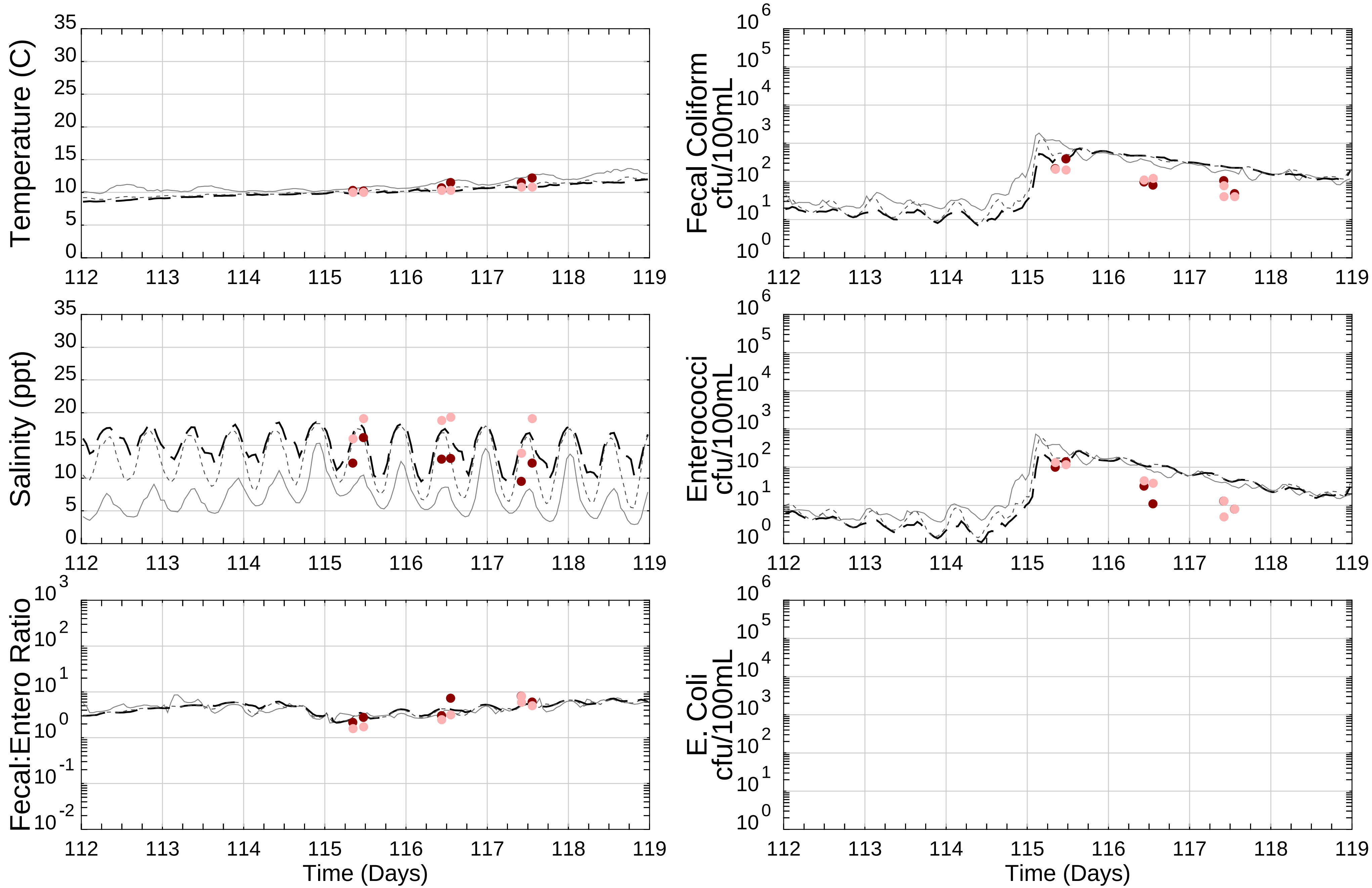
Model at Surface
Model at Mid-Depth
Model at Bottom

Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

Hudson River, Upper Bay
Hudson River

SE2

Station: 32 Event 3 (Apr 23-29)



Model = 2017
Data = 2017

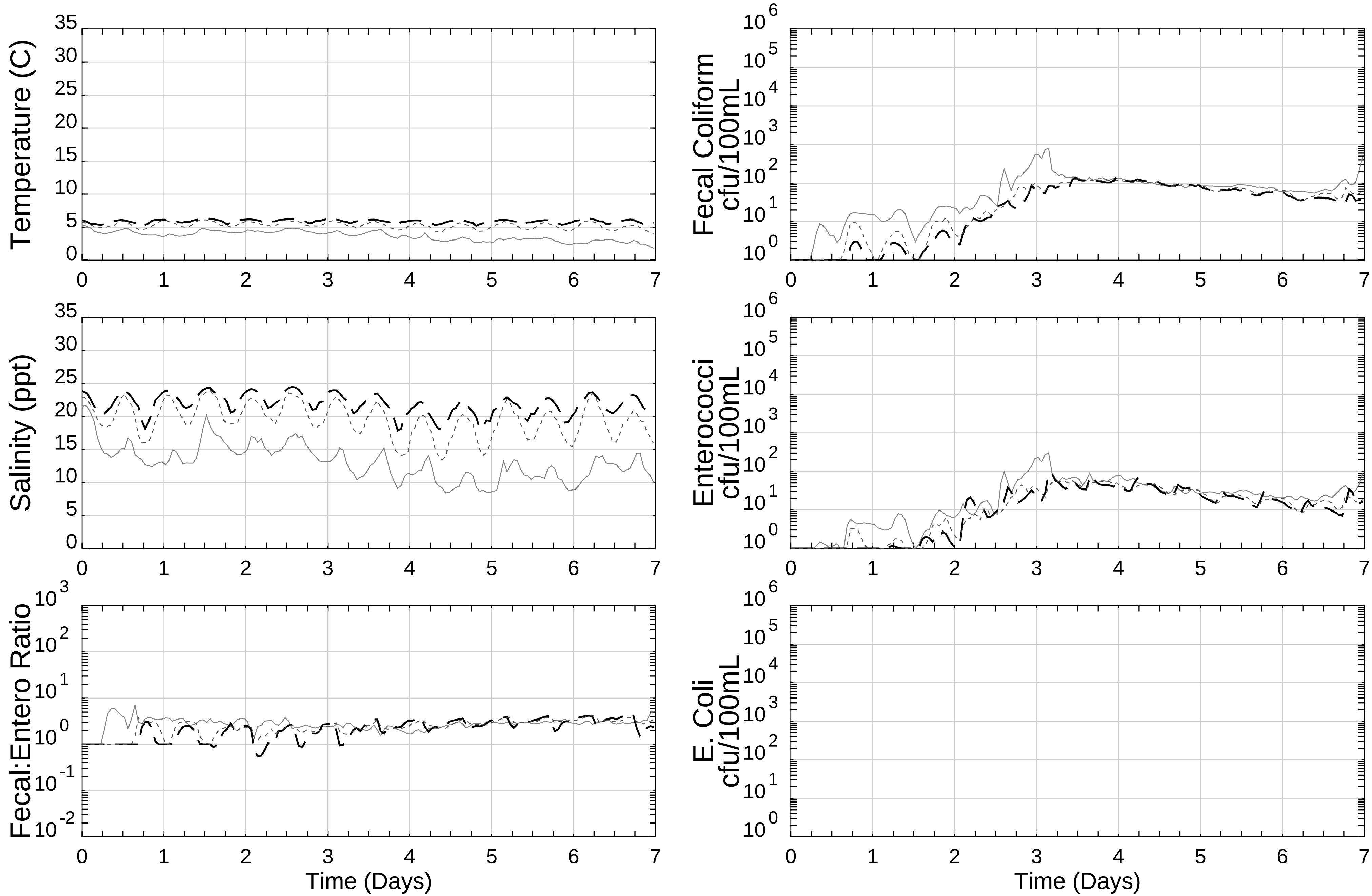
Model at Surface
Model at Mid-Depth
Model at Bottom

Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

Hudson River, Upper Bay
Hudson River

SE2

Station: 33 Event 1 (Jan 1-7)



Model = 2017
Data = 2017

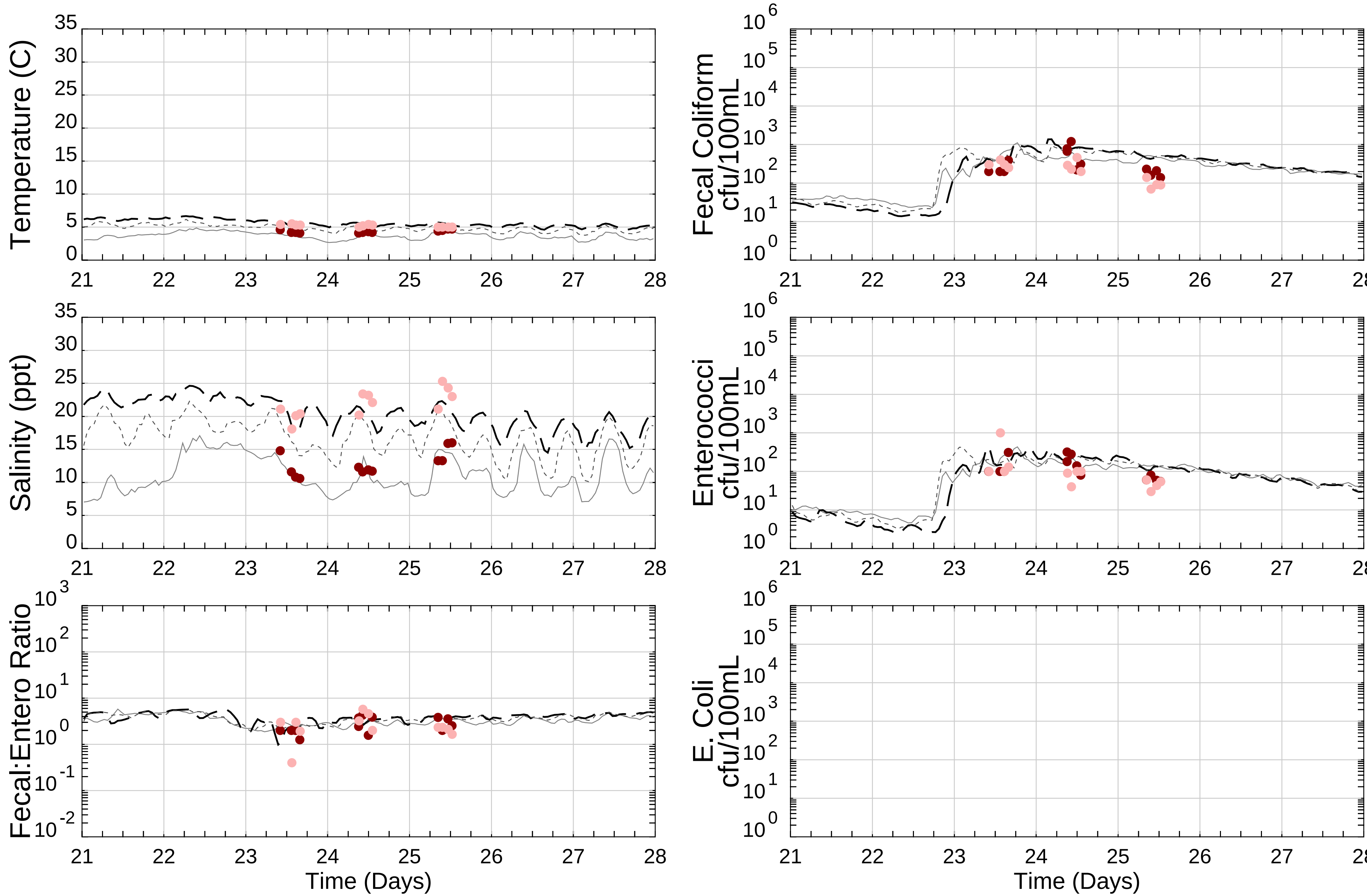
Model at Surface
Model at Mid-Depth
Model at Bottom

Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

Hudson River, Upper Bay
Hudson River

SE2

Station: 33 Event 2 (Jan 21-28)



Model = 2017
Data = 2017

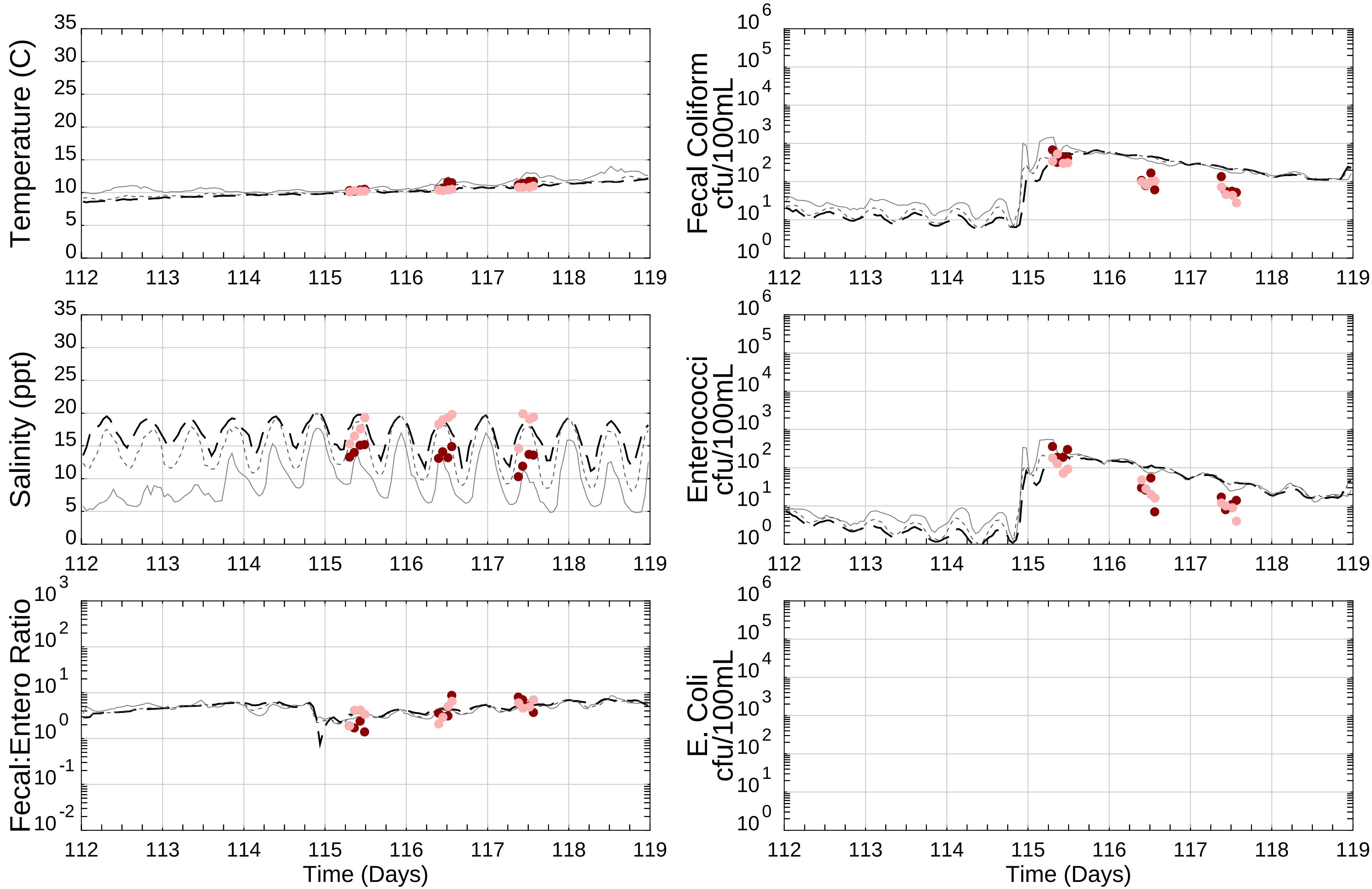
Model at Surface
Model at Mid-Depth
Model at Bottom

Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

Hudson River, Upper Bay
Hudson River

SE2

Station: 33 Event 3 (Apr 23-29)



Model = 2017
Data = 2017

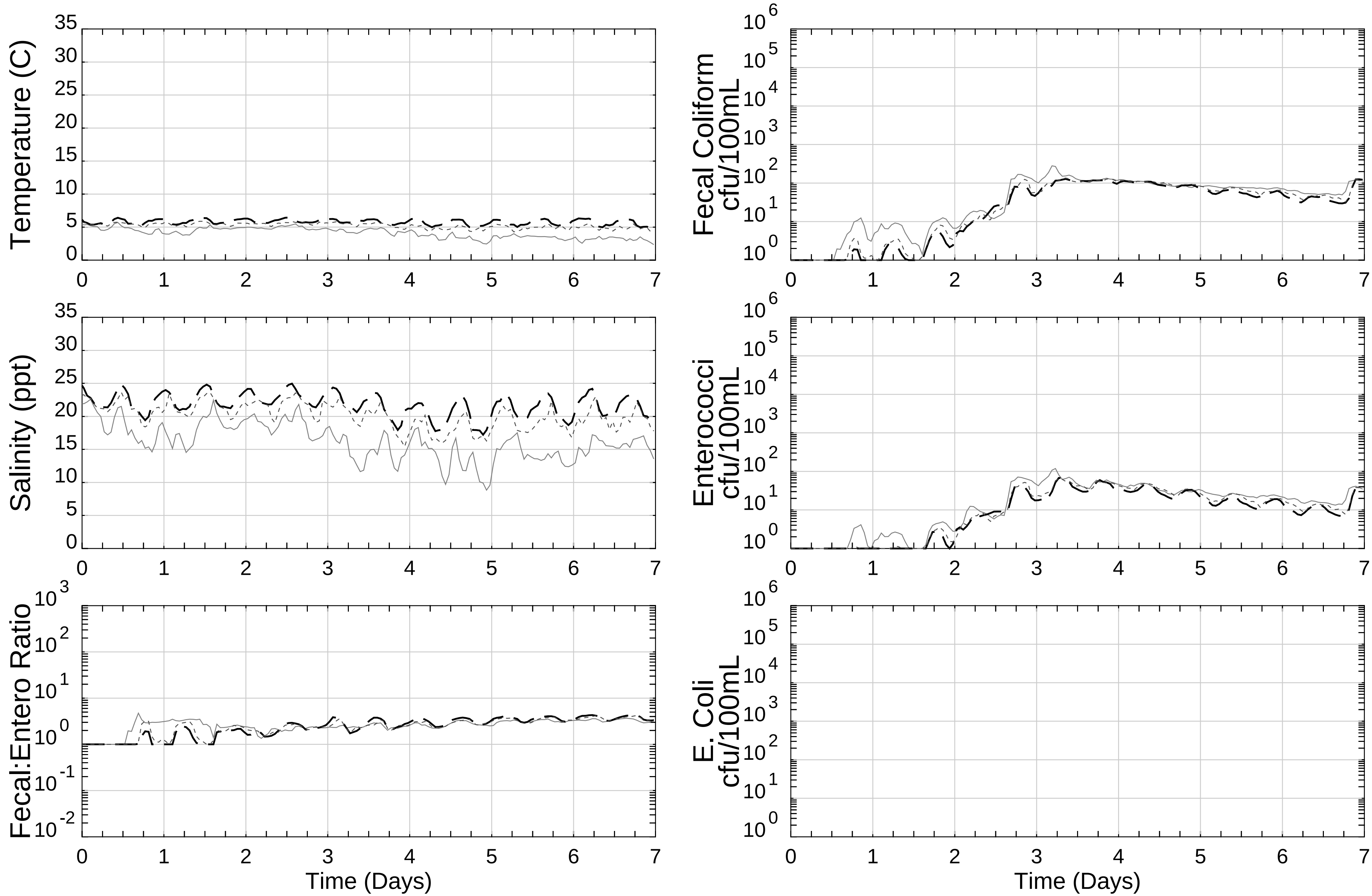
Model at Surface
Model at Mid-Depth
Model at Bottom

Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

Hudson River, Upper Bay
Upper Bay

SE2

Station: B26 Event 1 (Jan 1-7)



Model = 2017
Data = 2017

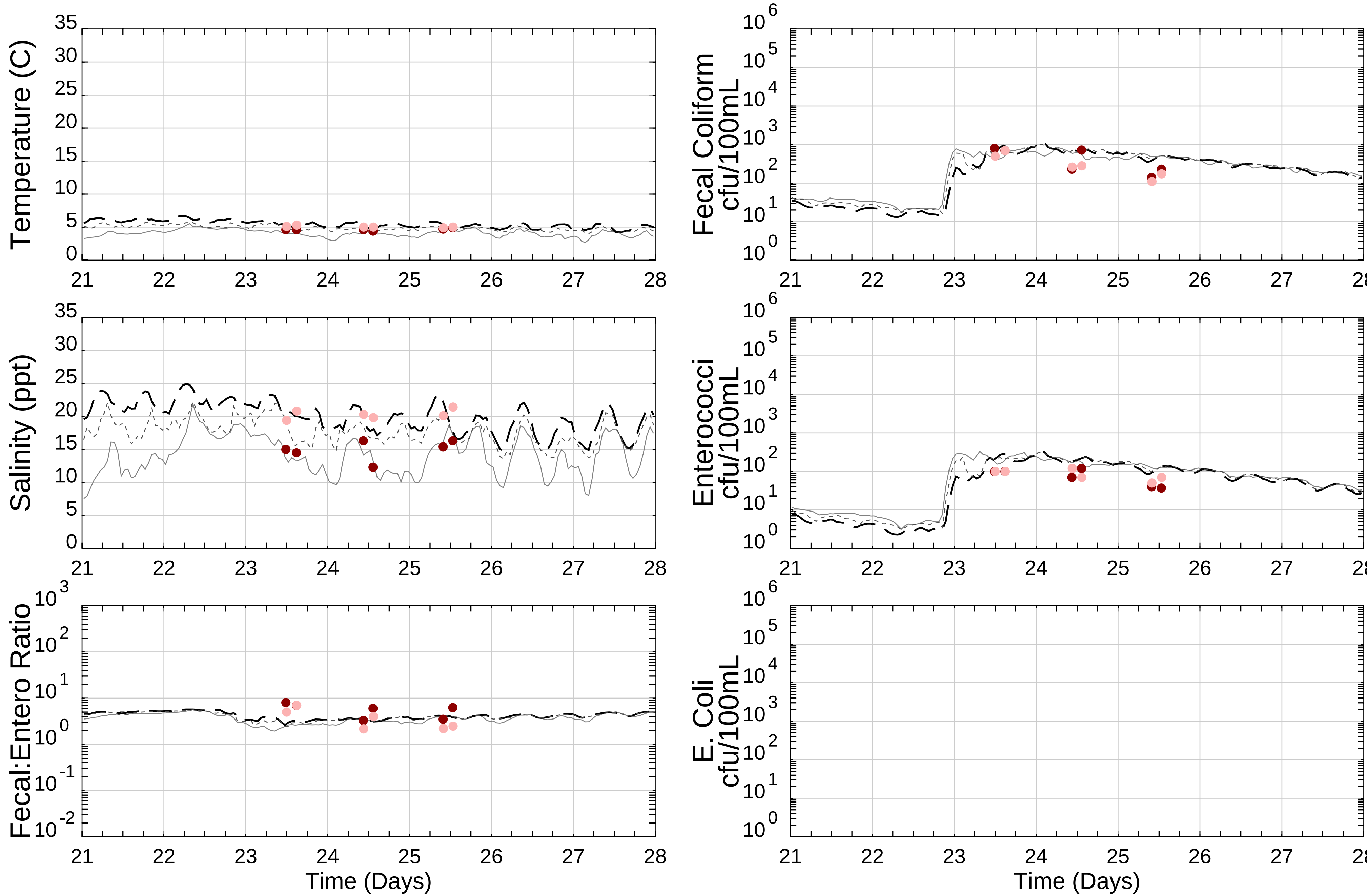
Model at Surface
Model at Mid-Depth
Model at Bottom

Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

Hudson River, Upper Bay
Upper Bay

SE2

Station: B26 Event 2 (Jan 21-28)



Model = 2017
Data = 2017

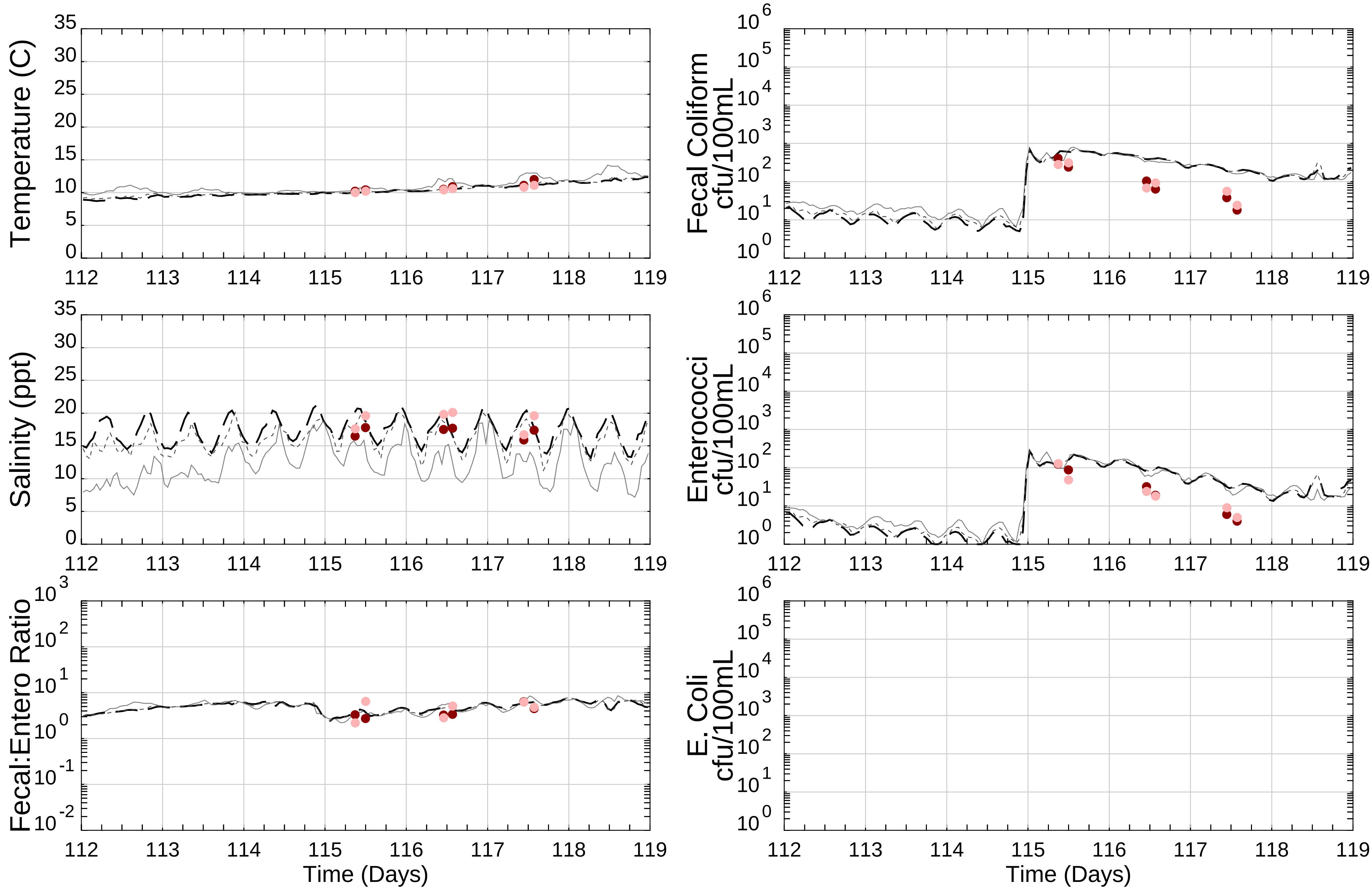
Model at Surface
Model at Mid-Depth
Model at Bottom

Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

Hudson River, Upper Bay
Upper Bay

SE2

Station: B26 Event 3 (Apr 23-29)



Model = 2017
Data = 2017

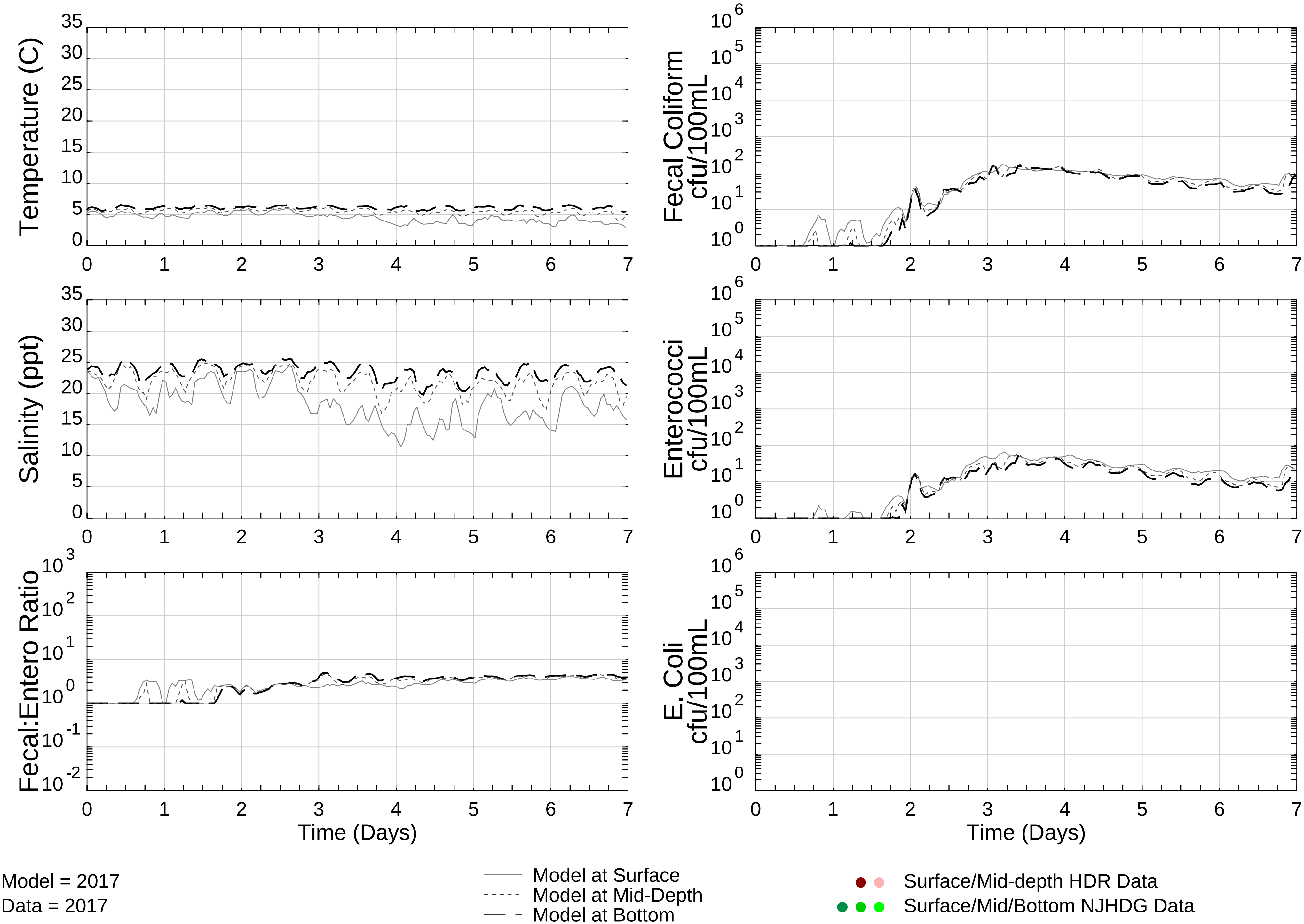
Model at Surface
Model at Mid-Depth
Model at Bottom

Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

Hudson River, Upper Bay
Upper Bay

SE2

Station: B27 Event 1 (Jan 1-7)

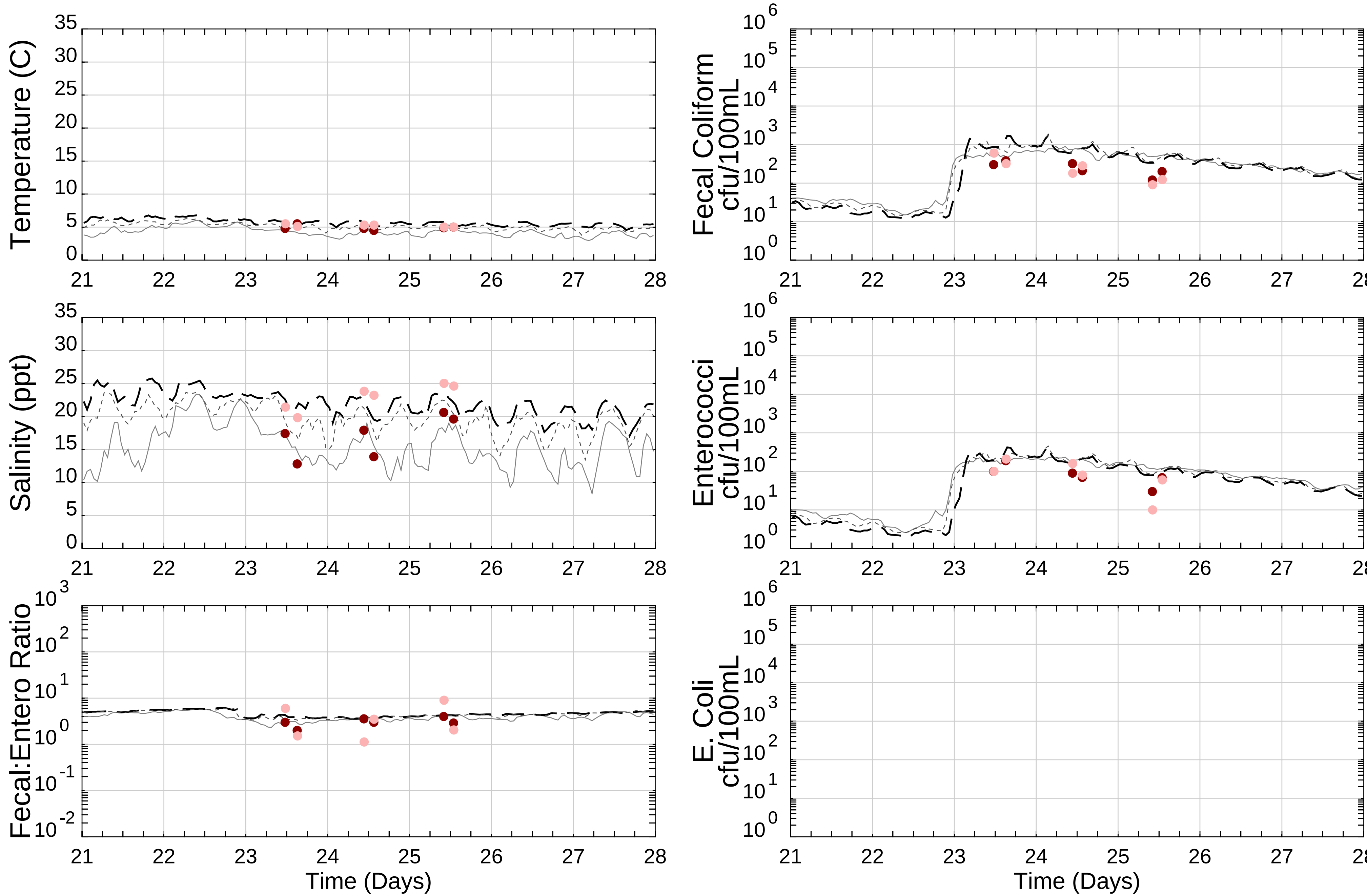


Model = 2017
Data = 2017

Hudson River, Upper Bay
Upper Bay

SE2

Station: B27 Event 2 (Jan 21-28)



Model = 2017
Data = 2017

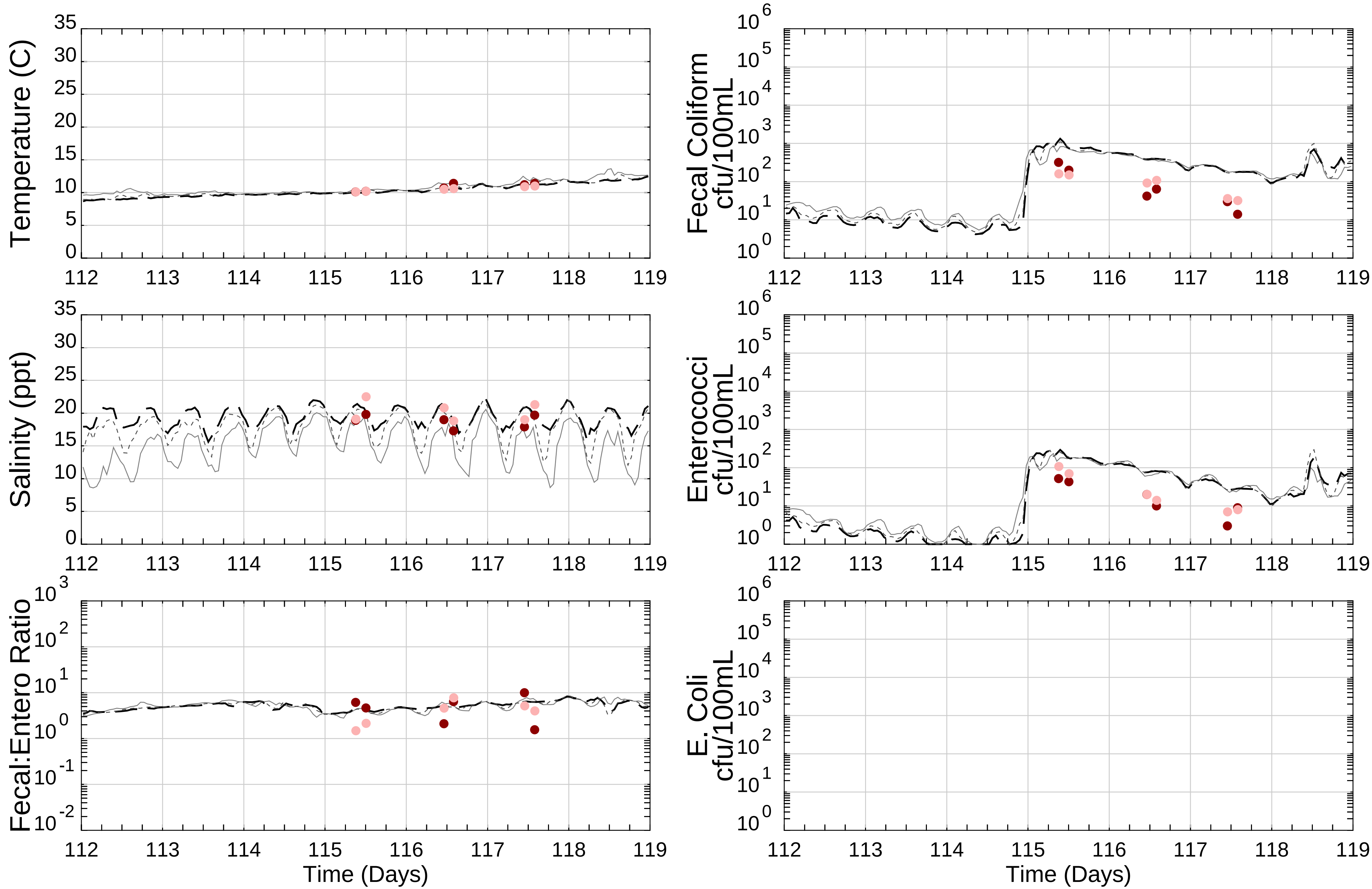
Model at Surface
Model at Mid-Depth
Model at Bottom

Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

Hudson River, Upper Bay
Upper Bay

SE2

Station: B27 Event 3 (Apr 23-29)



Model = 2017
Data = 2017

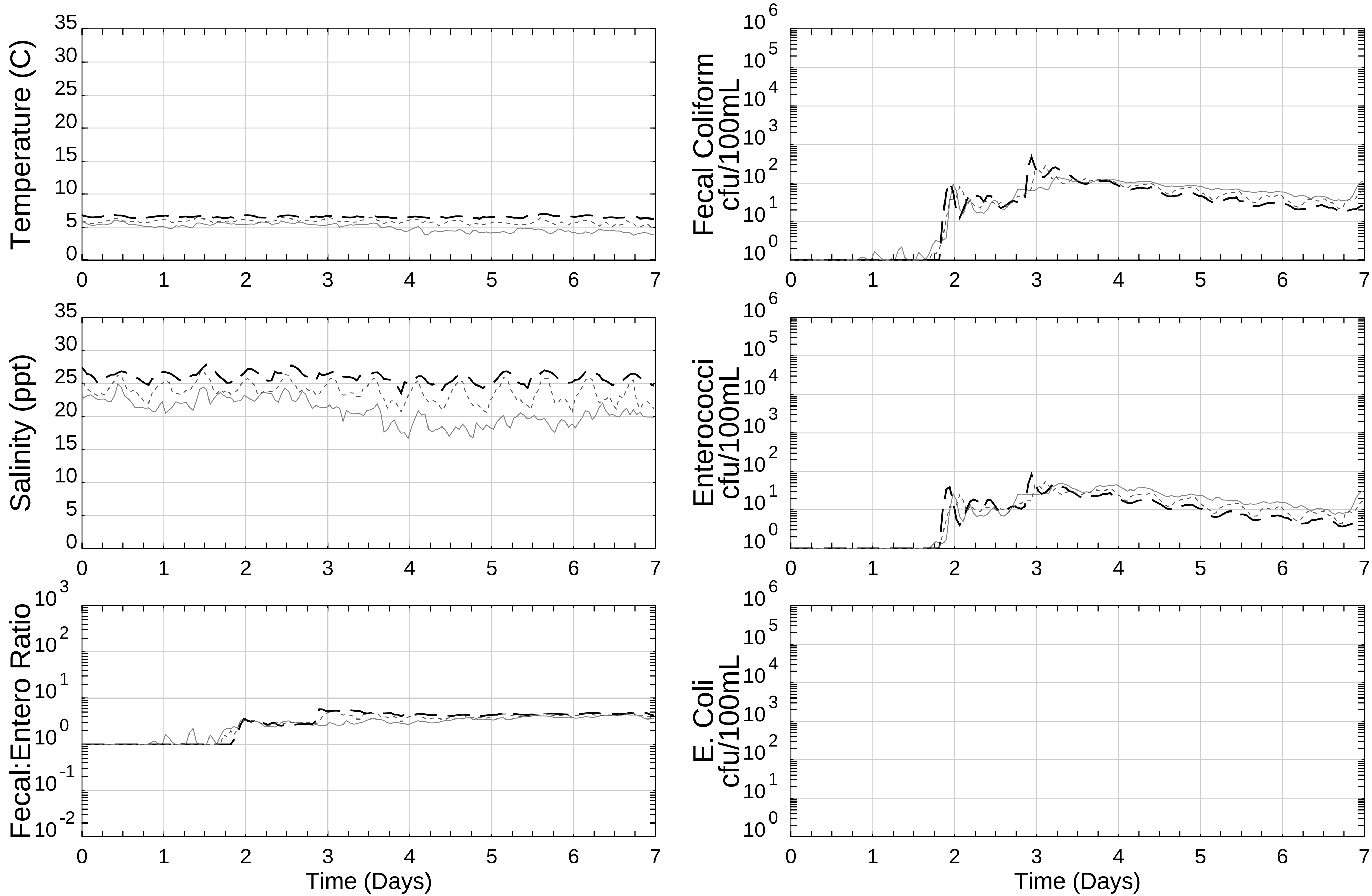
Model at Surface
Model at Mid-Depth
Model at Bottom

Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

Hudson River, Upper Bay
Upper Bay

SE2

Station: B28 Event 1 (Jan 1-7)



Model = 2017
Data = 2017

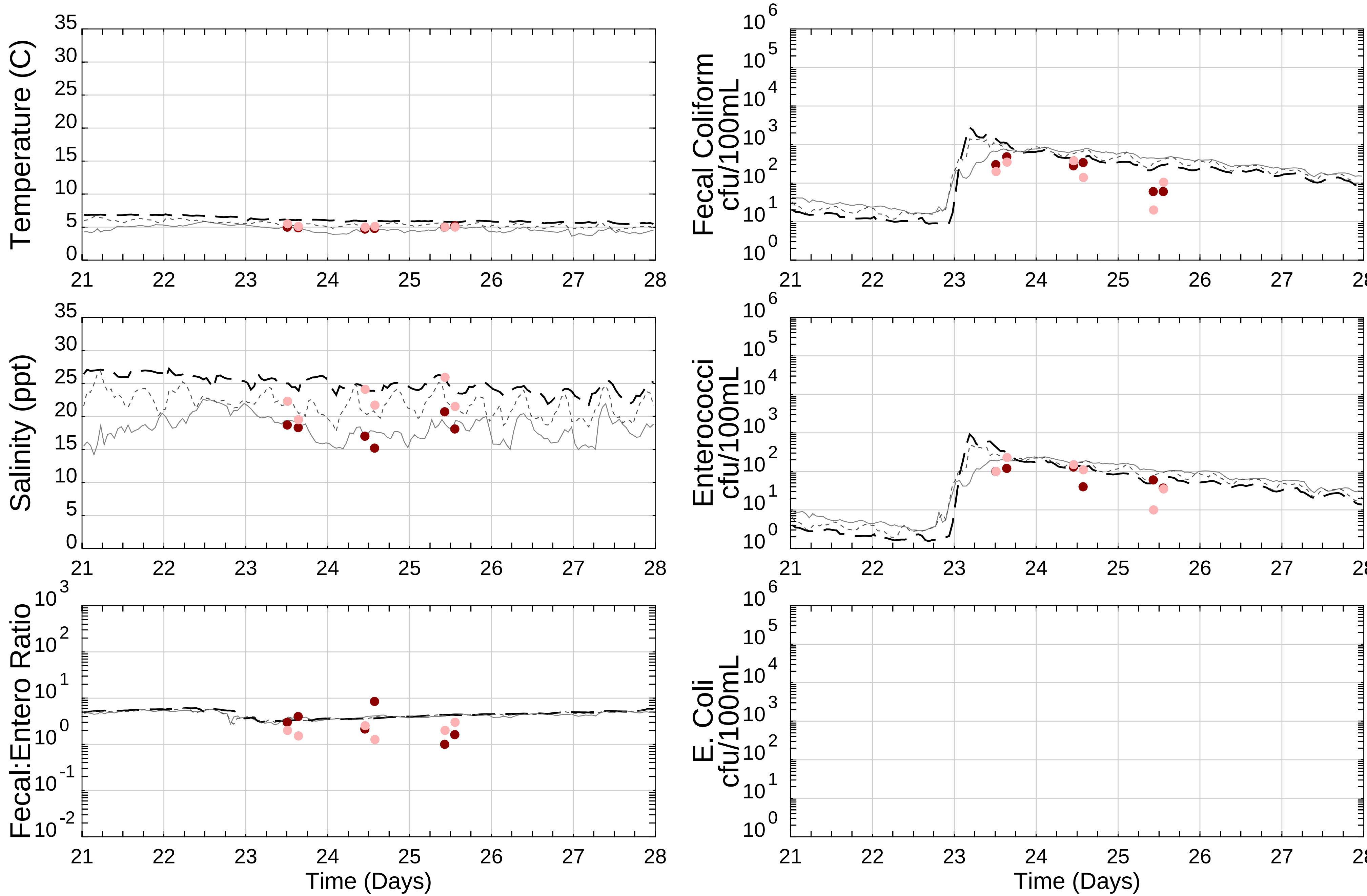
Model at Surface
Model at Mid-Depth
Model at Bottom

Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

Hudson River, Upper Bay
Upper Bay

SE2

Station: B28 Event 2 (Jan 21-28)



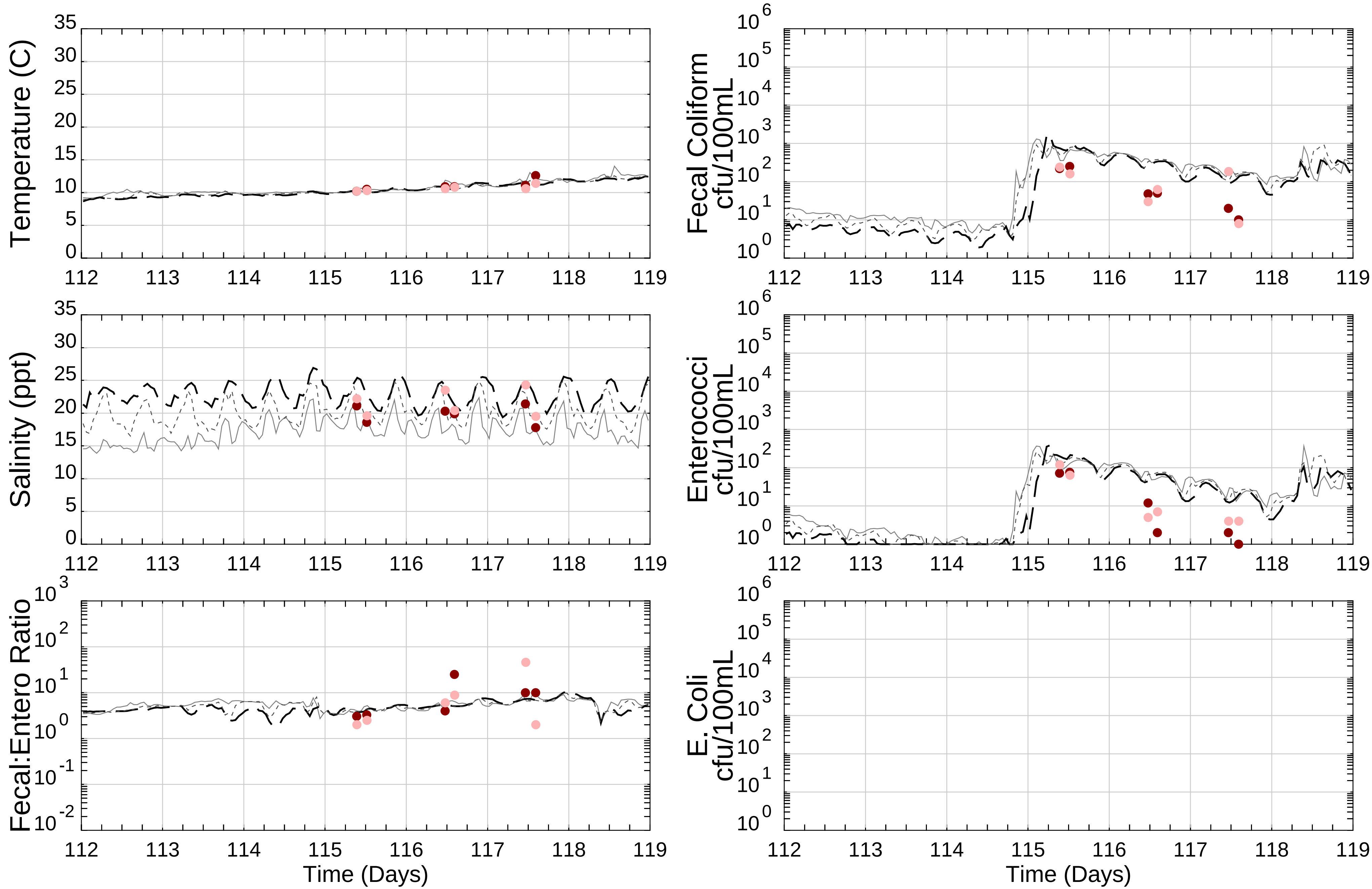
Model = 2017
Data = 2017

Model at Surface
Model at Mid-Depth
Model at Bottom

Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

Hudson River, Upper Bay
Upper Bay

Station: B28 Event 3 (Apr 23-29)



Model = 2017
Data = 2017

Model at Surface
Model at Mid-Depth
Model at Bottom

Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

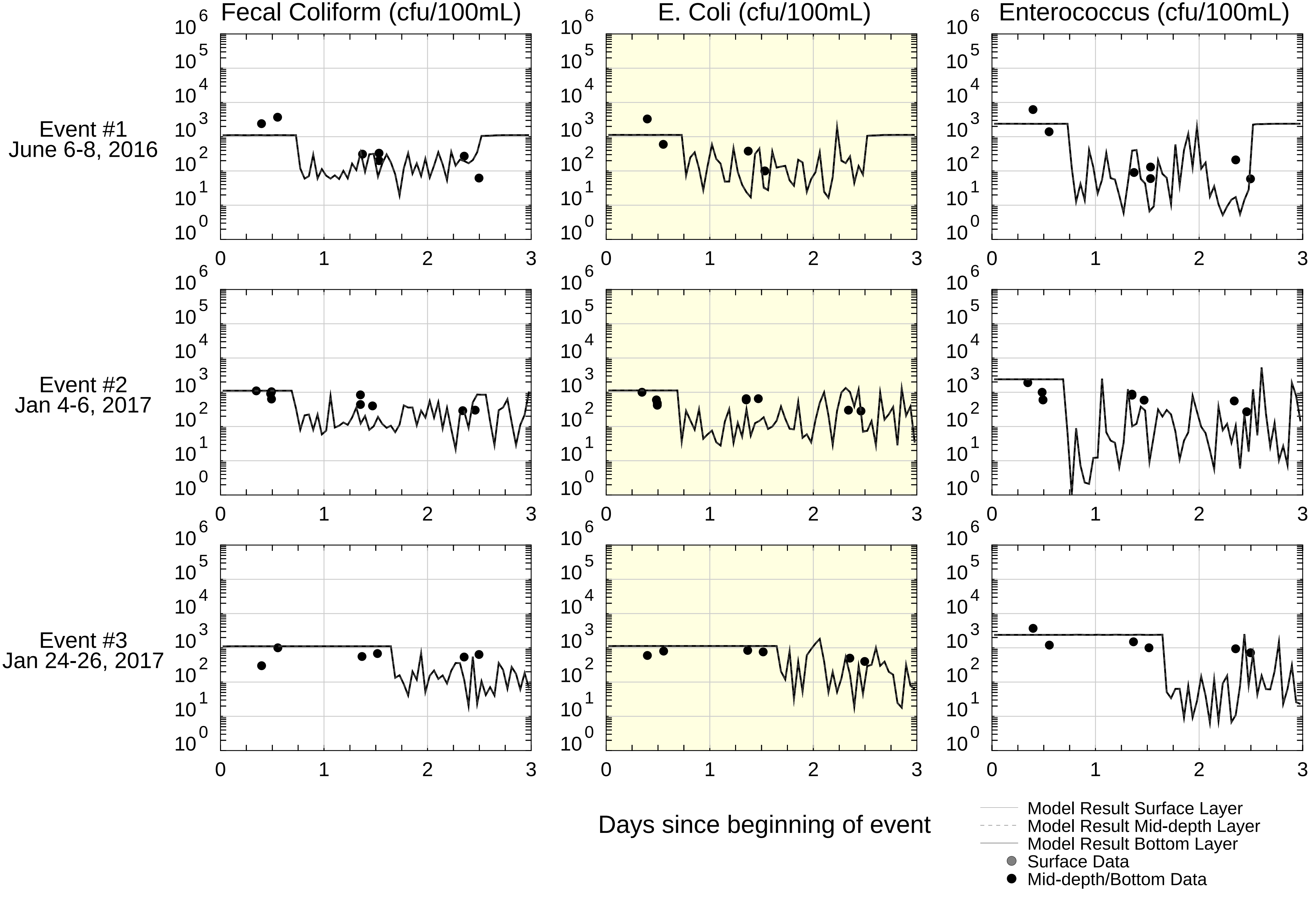
Appendix F-3

Additional Wet-Weather Time Series Figures

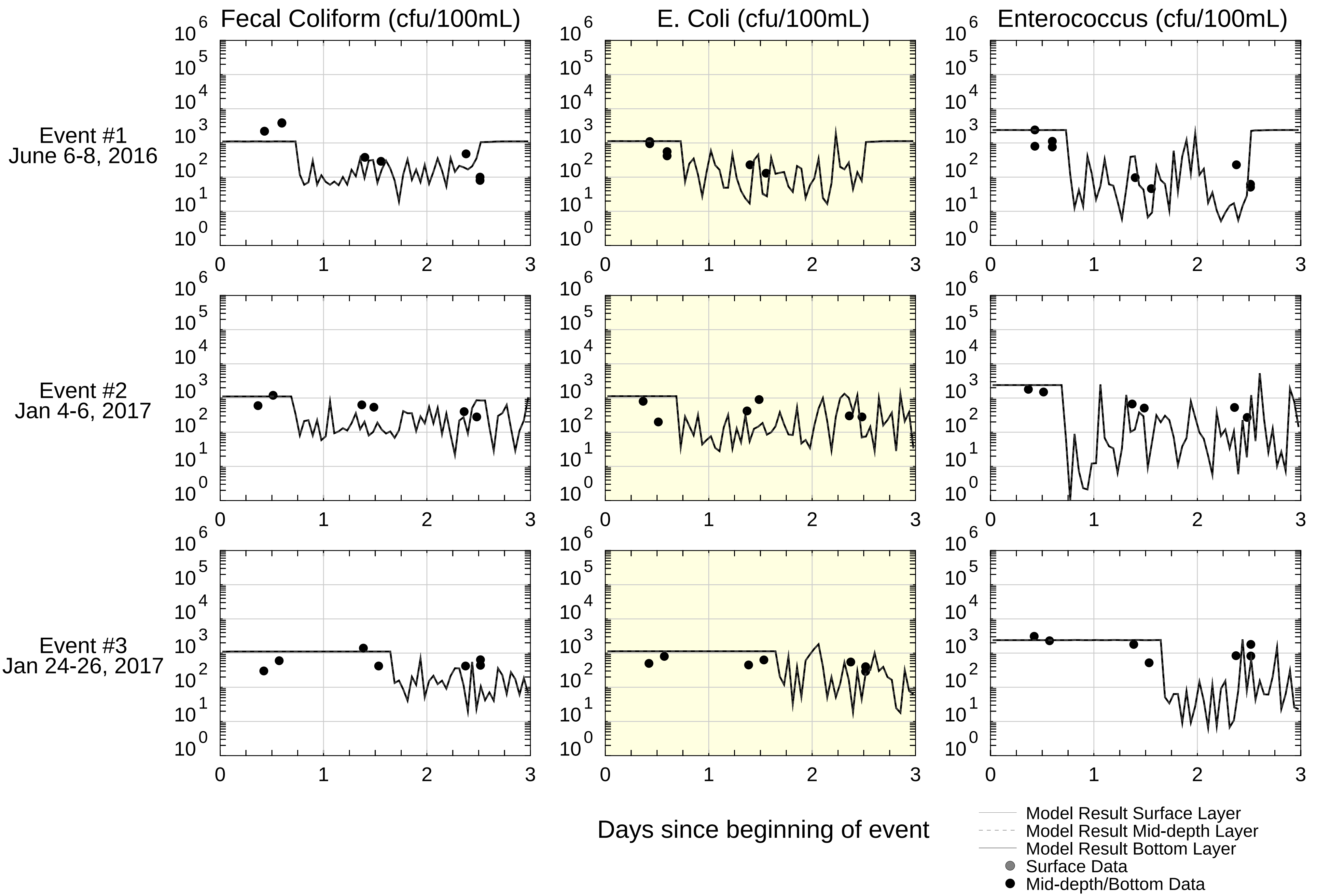
Passaic River & Tributaries
Passaic River

FW2

Station: 1



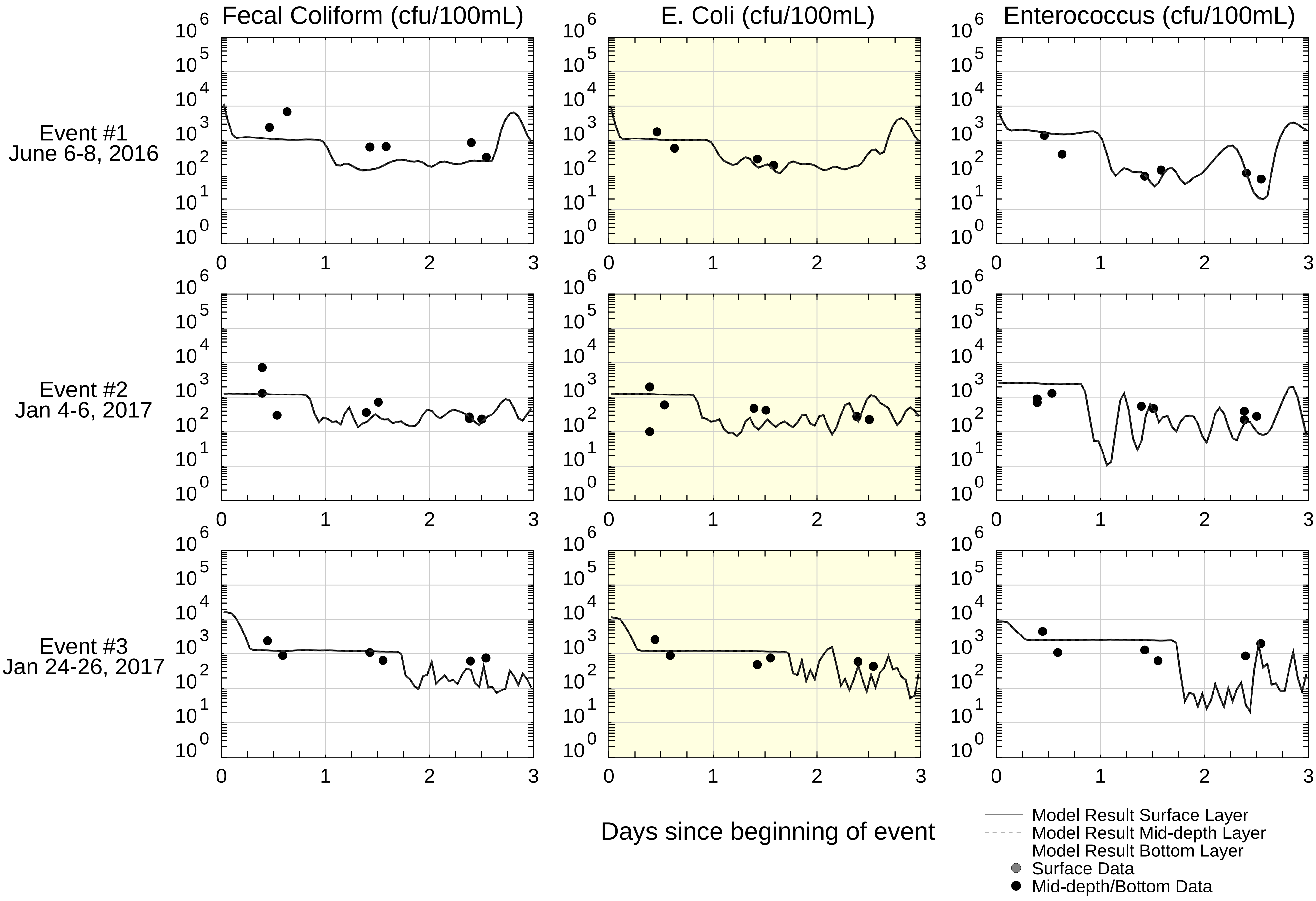
Station: B24


Fecal Coliform (cfu/100mL)
E. Coli (cfu/100mL)
Enterococcus (cfu/100mL)
Event #1
June 6-8, 2016
Event #2
Jan 4-6, 2017
Event #3
Jan 24-26, 2017
10^0
10^1
10^2
10^3
10^4
10^5
10^6
0
1
2
3
Days since beginning of event
Model Result Surface Layer
Model Result Mid-depth Layer
Model Result Bottom Layer
Surface Data
Mid-depth/Bottom Data

Passaic River & Tributaries
Passaic River

FW2

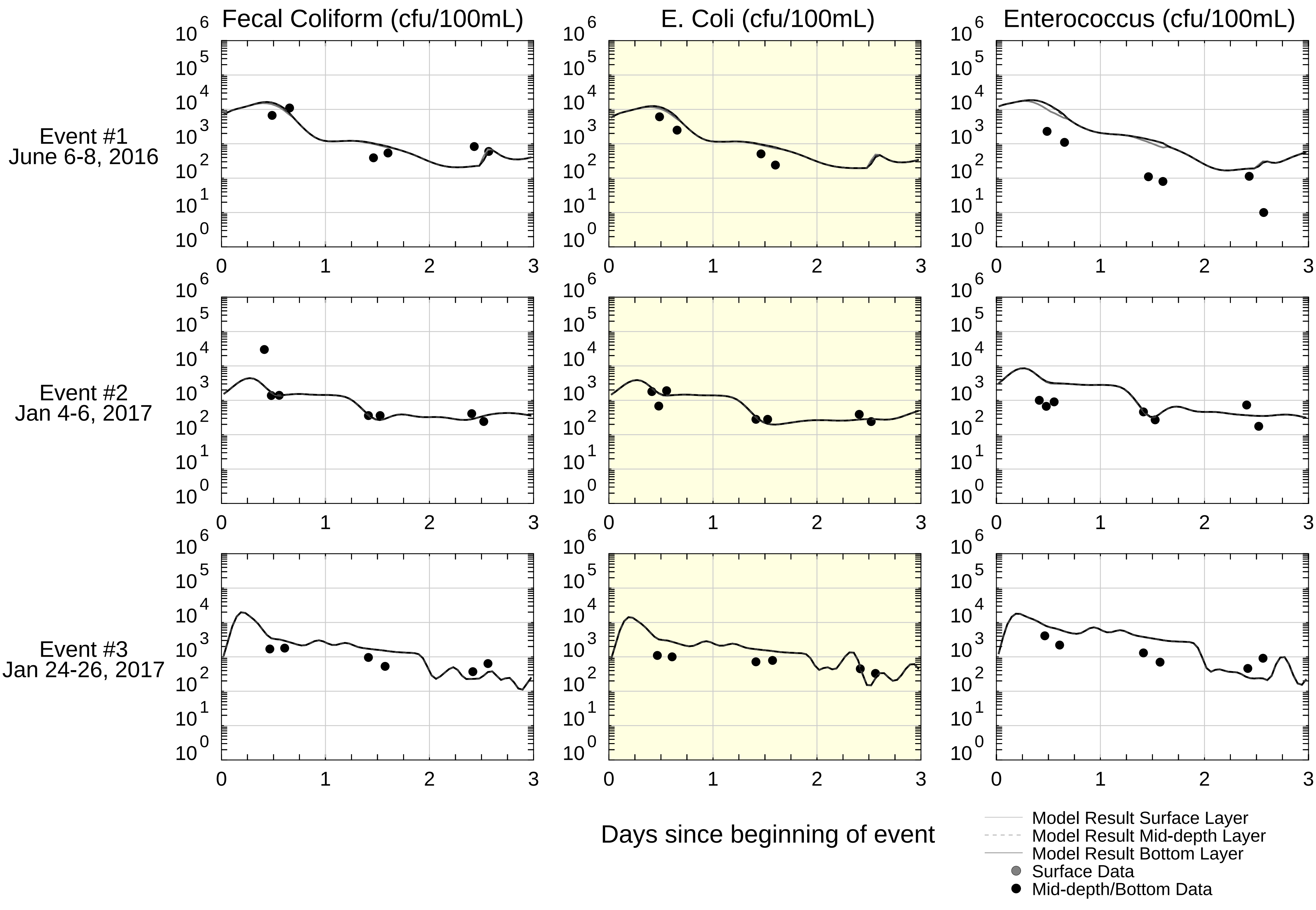
Station: 3



Passaic River & Tributaries
Passaic River

FW2

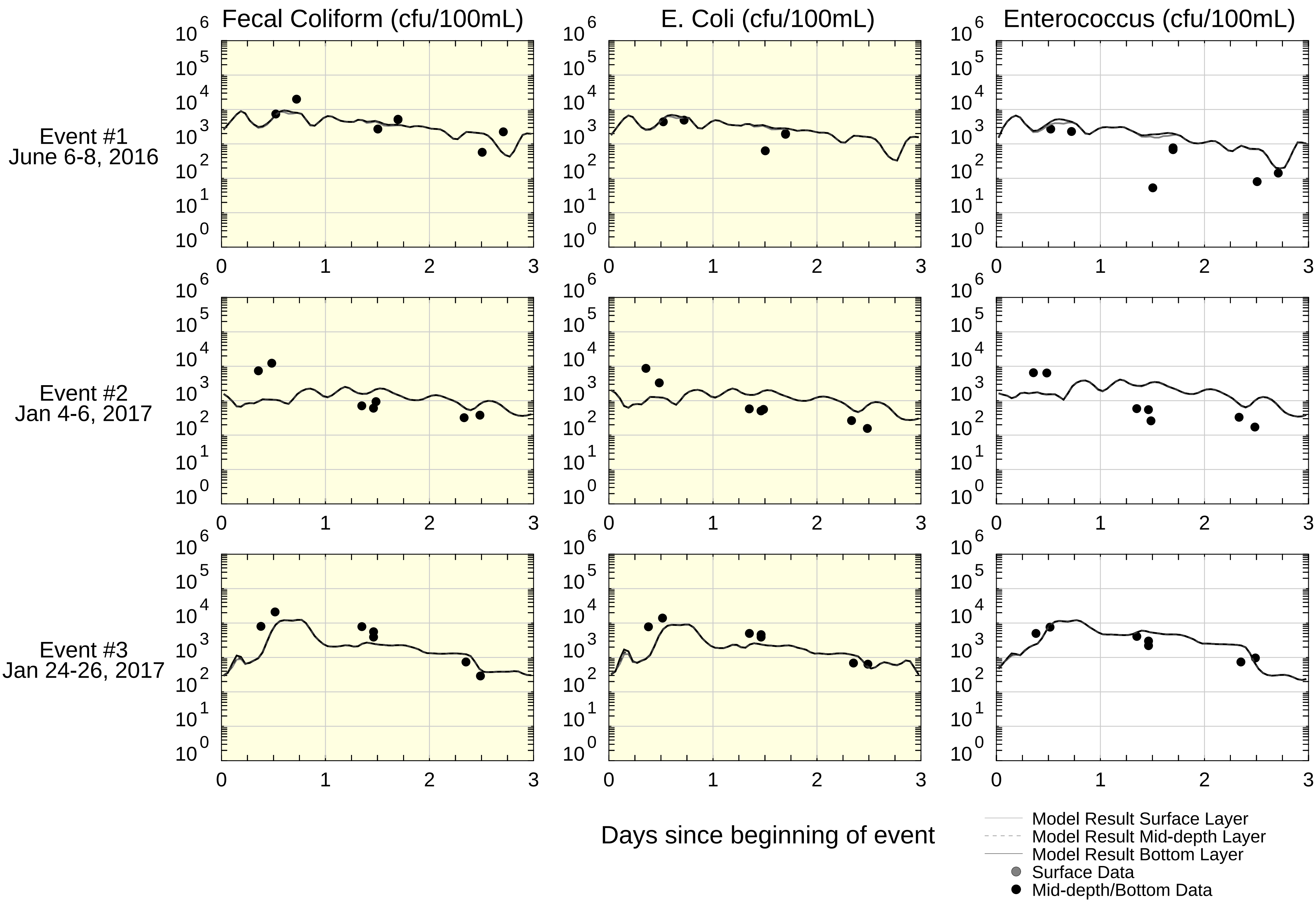
Station: 4



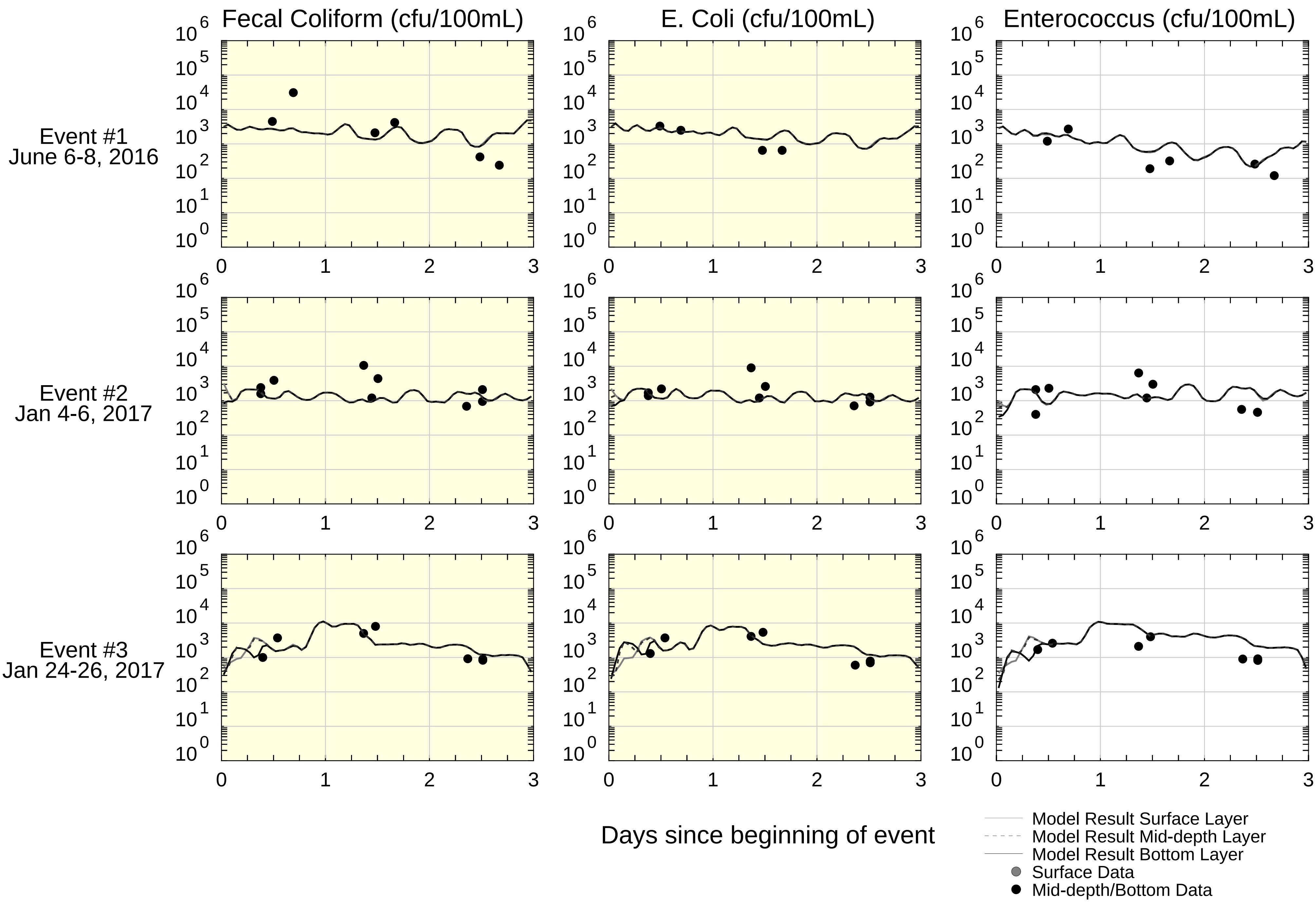
Passaic River & Tributaries
Passaic River

FW2/SE2

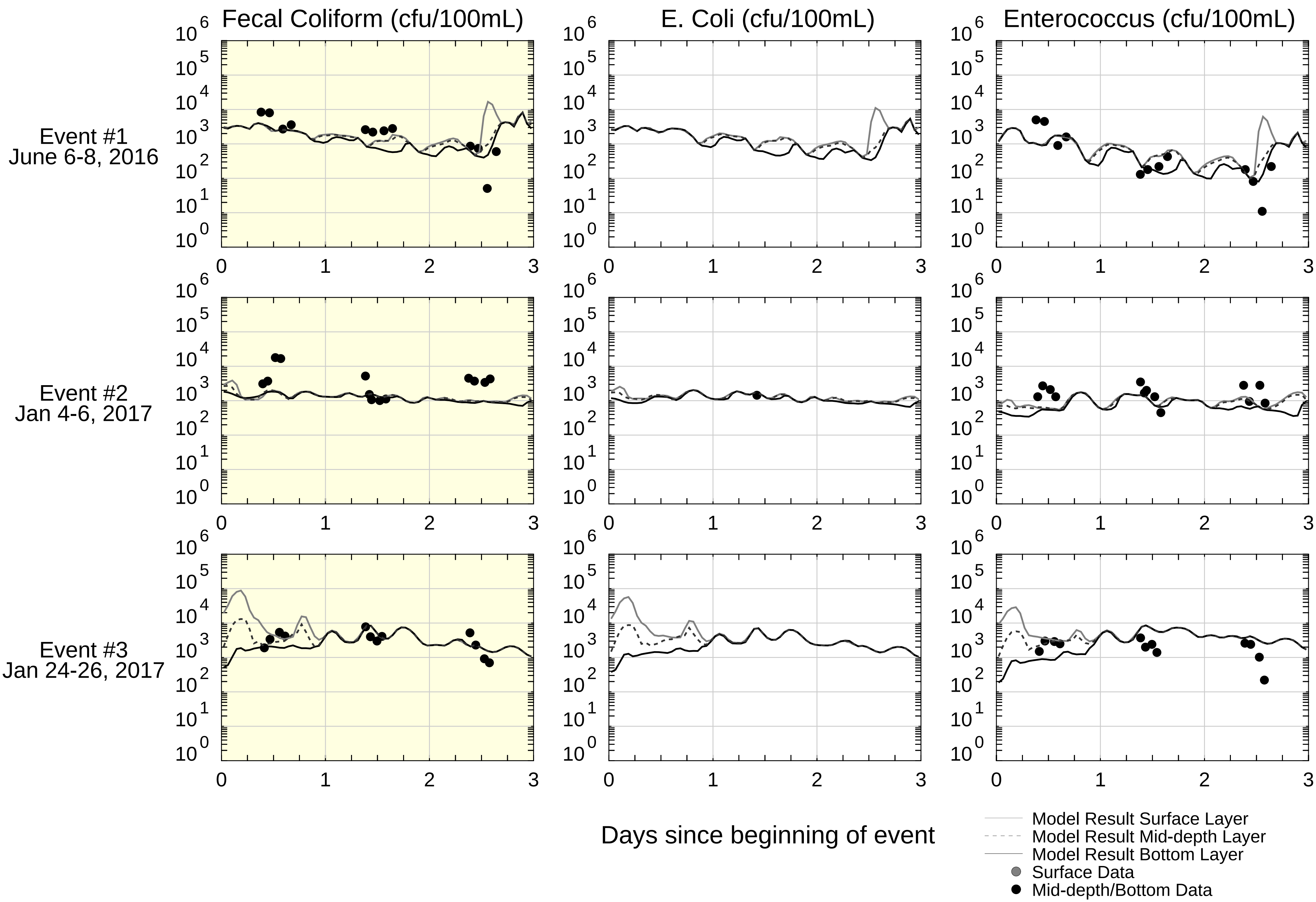
Station: 7



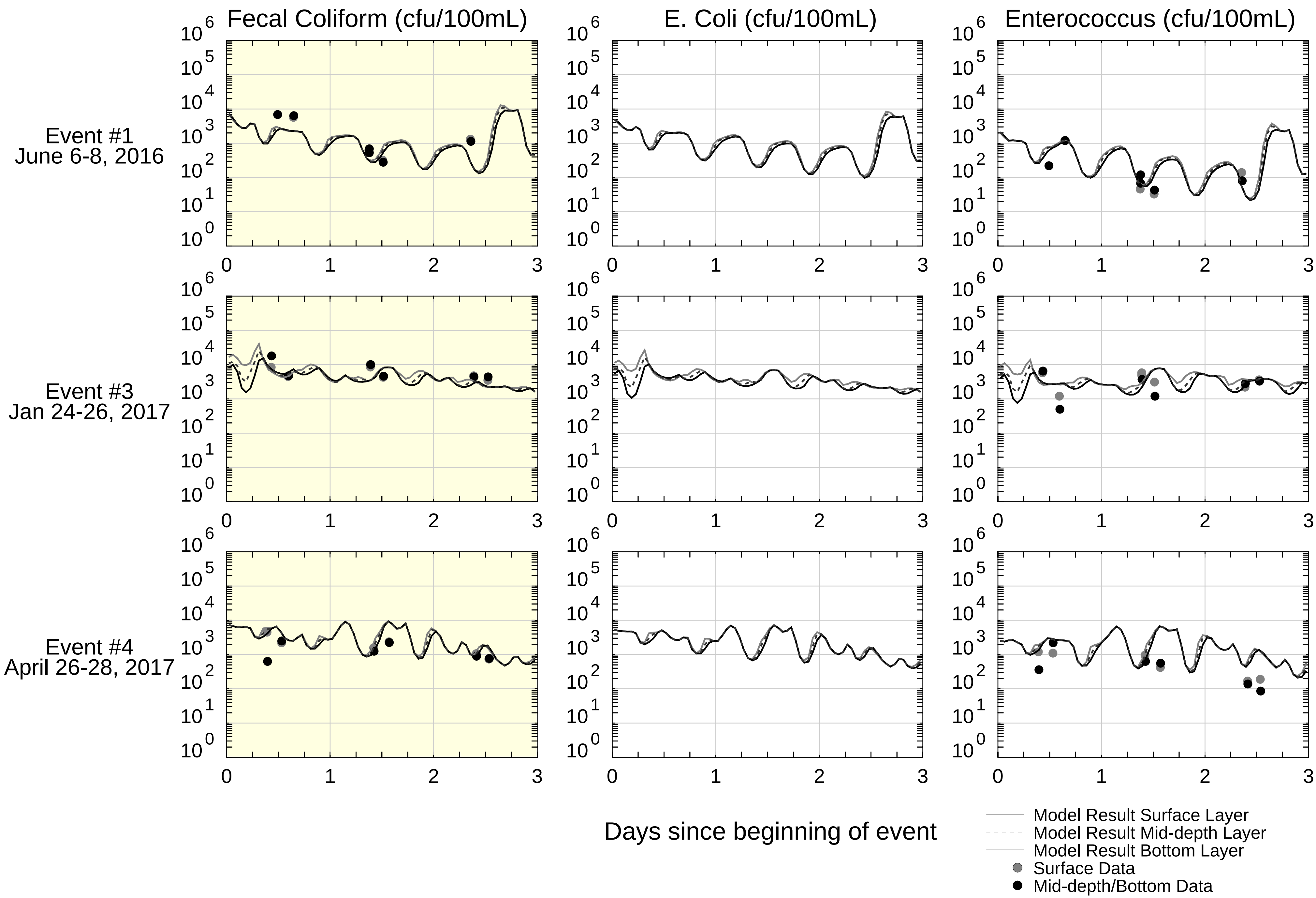
Station: 8


Fecal Coliform (cfu/100mL)
E. Coli (cfu/100mL)
Enterococcus (cfu/100mL)
Event #1
June 6-8, 2016
Event #2
Jan 4-6, 2017
Event #3
Jan 24-26, 2017
10^6
10^5
10^4
10^3
10^2
10^1
10^0
0
1
2
3
Days since beginning of event
Model Result Surface Layer
Model Result Mid-depth Layer
Model Result Bottom Layer
Surface Data
Mid-depth/Bottom Data

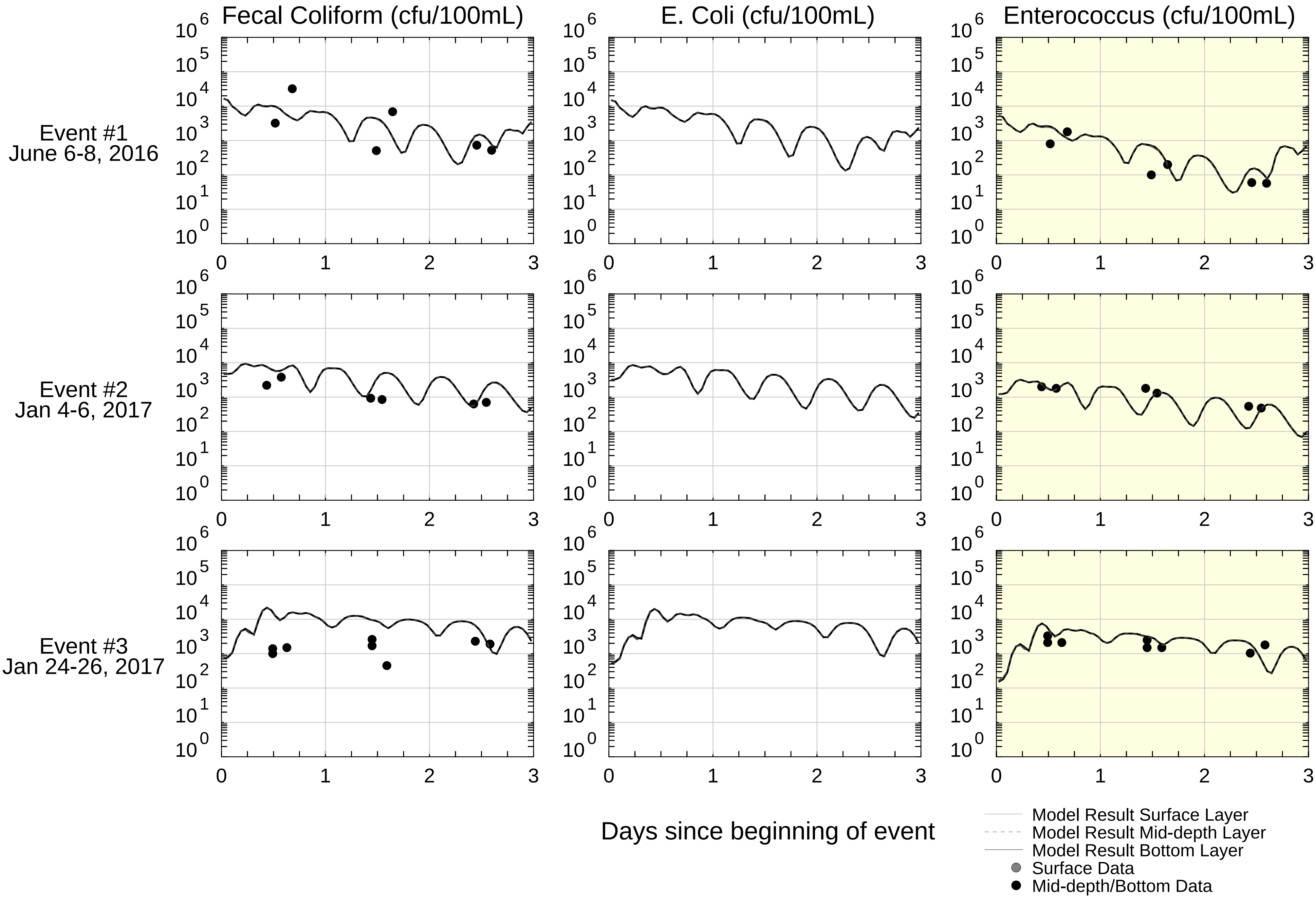
Station: 10


Fecal Coliform (cfu/100mL)
E. Coli (cfu/100mL)
Enterococcus (cfu/100mL)
Event #1
June 6-8, 2016
Event #2
Jan 4-6, 2017
Event #3
Jan 24-26, 2017
10^0
10^1
10^2
10^3
10^4
10^5
10^6
0
1
2
3
Days since beginning of event
Model Result Surface Layer
Model Result Mid-depth Layer
Model Result Bottom Layer
Surface Data
Mid-depth/Bottom Data

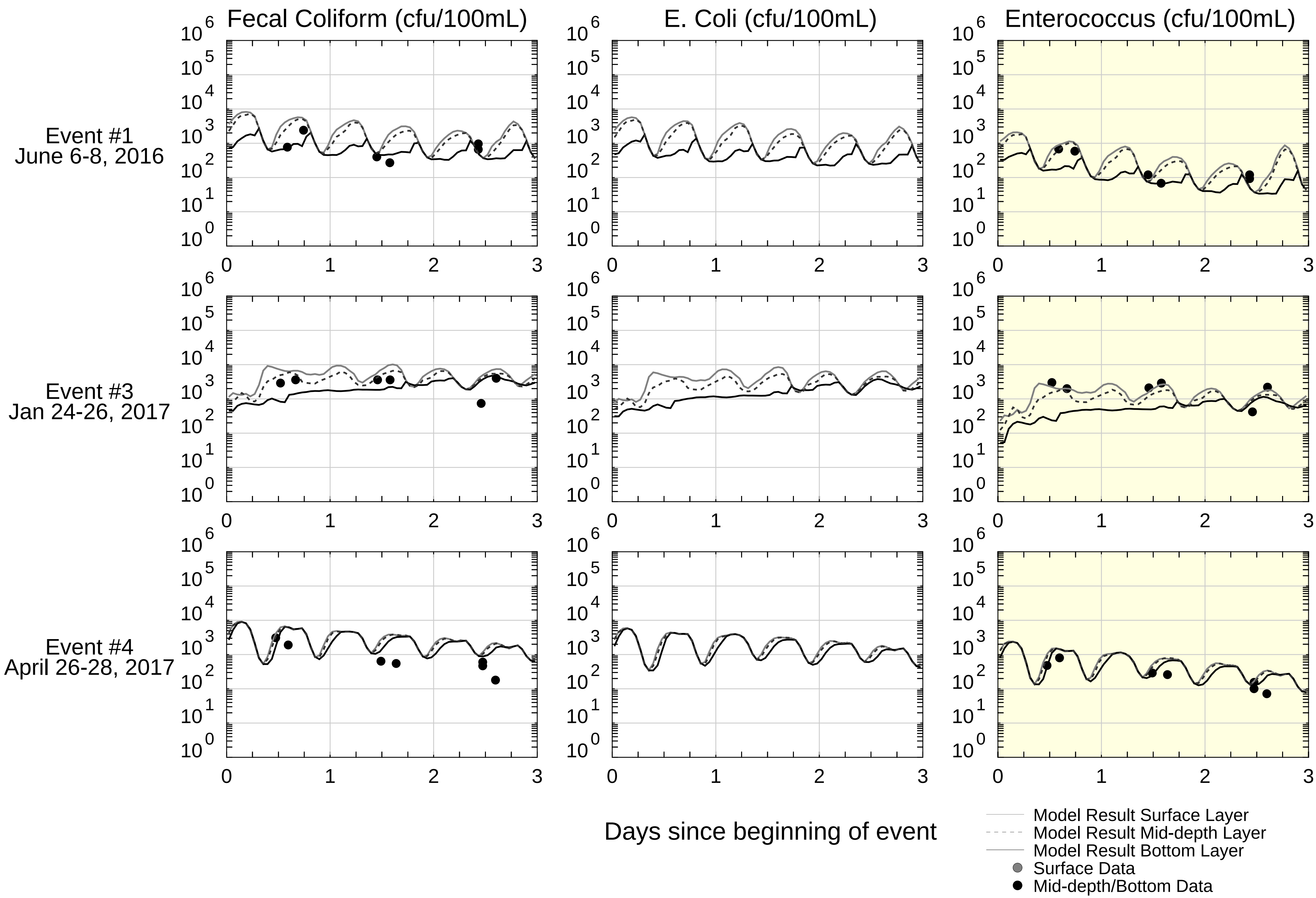
Station: B6


Fecal Coliform (cfu/100mL)
E. Coli (cfu/100mL)
Enterococcus (cfu/100mL)
Event #1
June 6-8, 2016
Event #3
Jan 24-26, 2017
Event #4
April 26-28, 2017
10^6
10^5
10^4
10^3
10^2
10^1
10^0
0
1
2
3
Days since beginning of event
Model Result Surface Layer
Model Result Mid-depth Layer
Model Result Bottom Layer
Surface Data
Mid-depth/Bottom Data

Station: B1


Fecal Coliform (cfu/100mL)
E. Coli (cfu/100mL)
Enterococcus (cfu/100mL)
Event #1
June 6-8, 2016
Event #2
Jan 4-6, 2017
Event #3
Jan 24-26, 2017
10^6
10^5
10^4
10^3
10^2
10^1
10^0
0
1
2
3
Days since beginning of event
Model Result Surface Layer
Model Result Mid-depth Layer
Model Result Bottom Layer
Surface Data
Mid-depth/Bottom Data

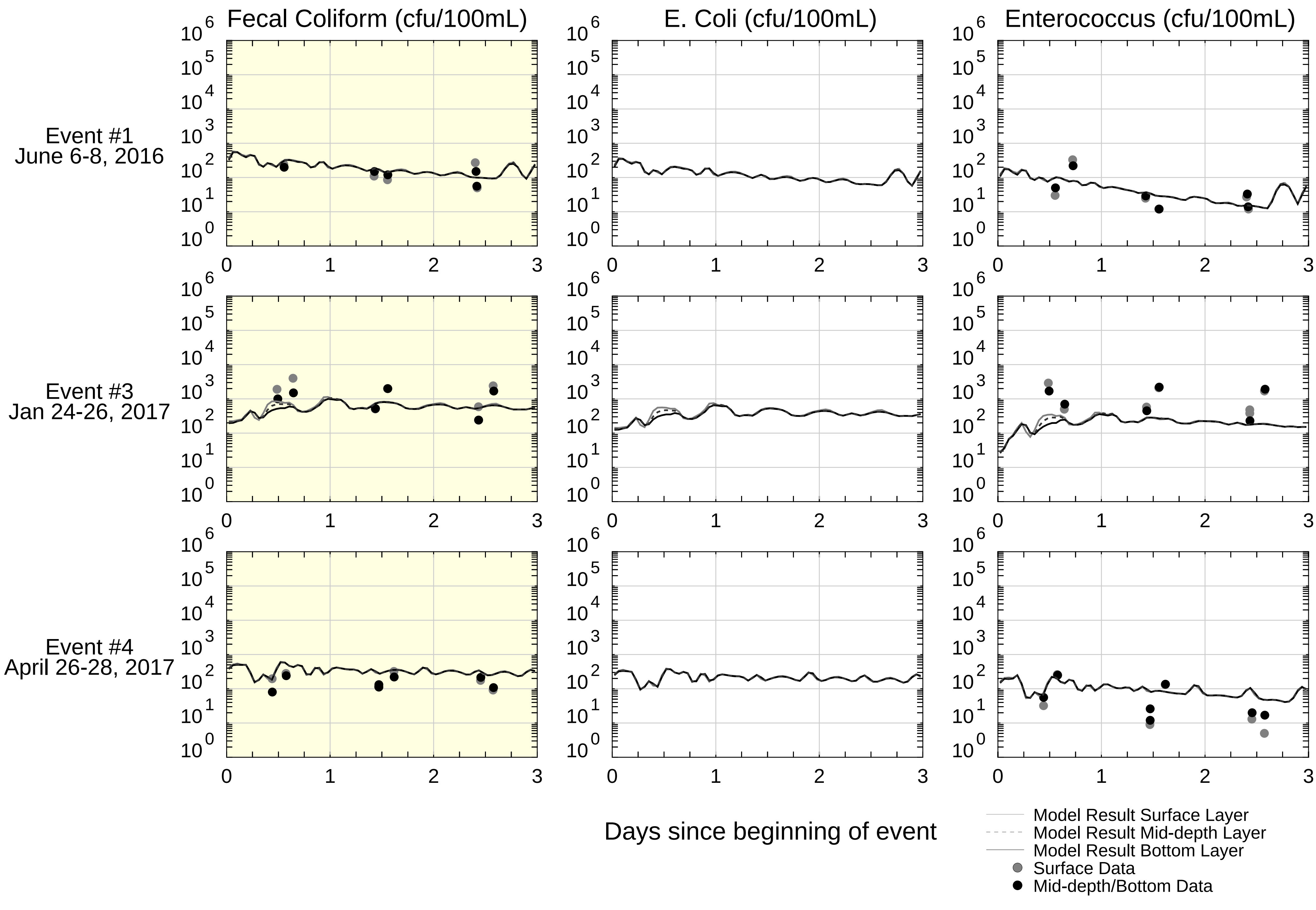
Station: B2


Fecal Coliform (cfu/100mL)
E. Coli (cfu/100mL)
Enterococcus (cfu/100mL)
Event #1
June 6-8, 2016
Event #3
Jan 24-26, 2017
Event #4
April 26-28, 2017
10^0
10^1
10^2
10^3
10^4
10^5
10^6
0
1
2
3
Days since beginning of event
Model Result Surface Layer
Model Result Mid-depth Layer
Model Result Bottom Layer
Surface Data
Mid-depth/Bottom Data

Hackensack River & Tributaries
Hackensack River

SE2

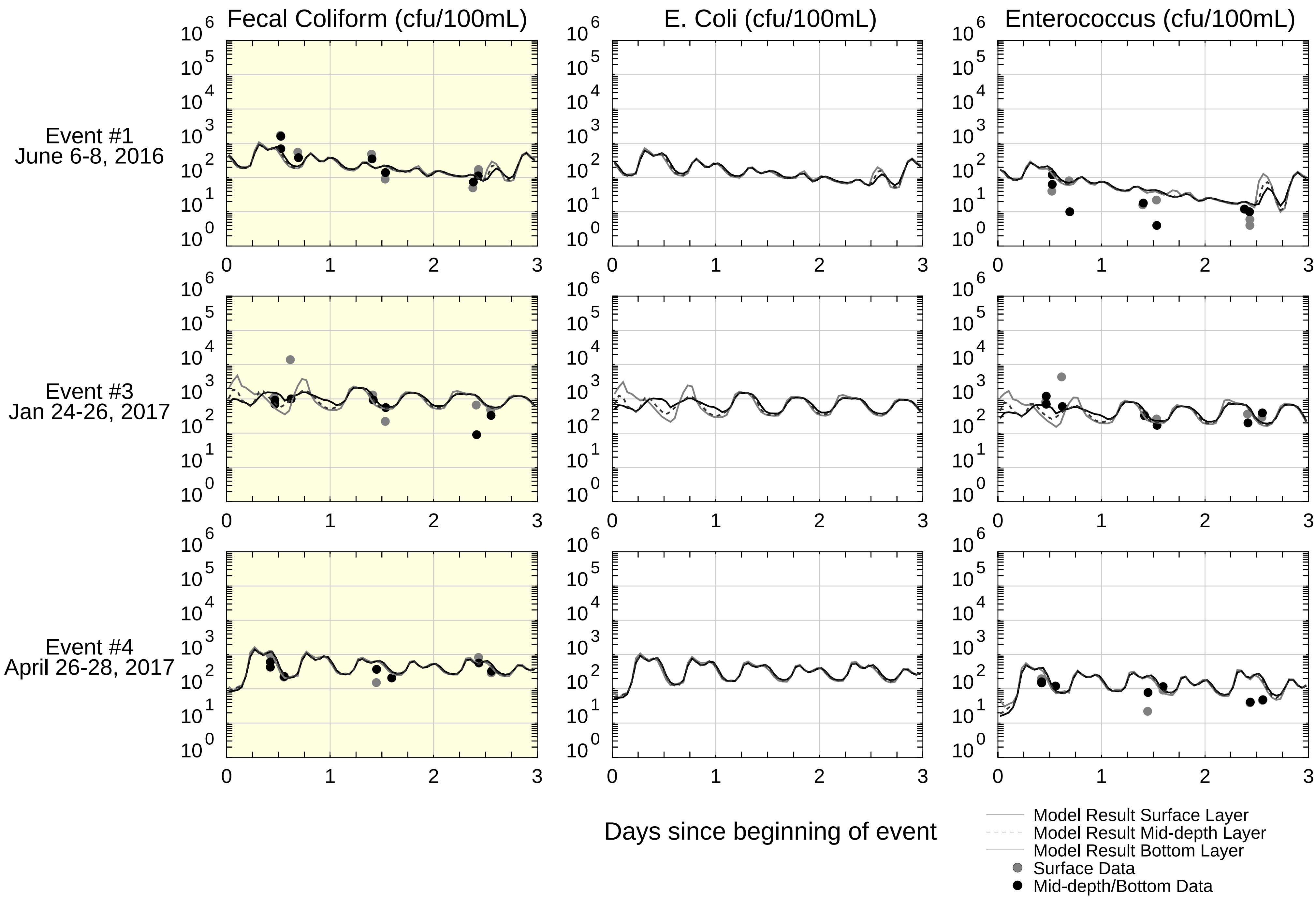
Station: 14



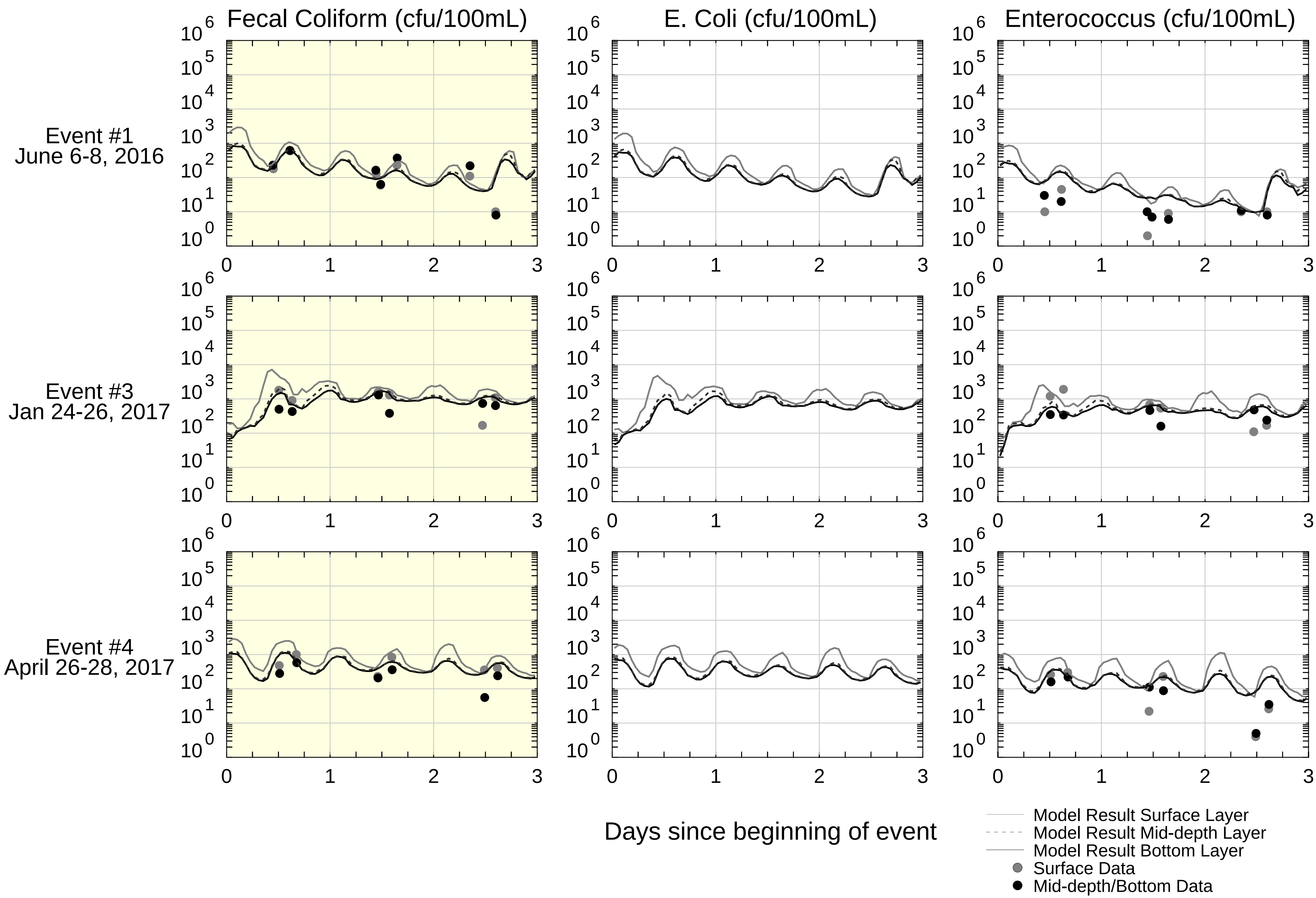
Hackensack River & Tributaries
Hackensack River

SE2

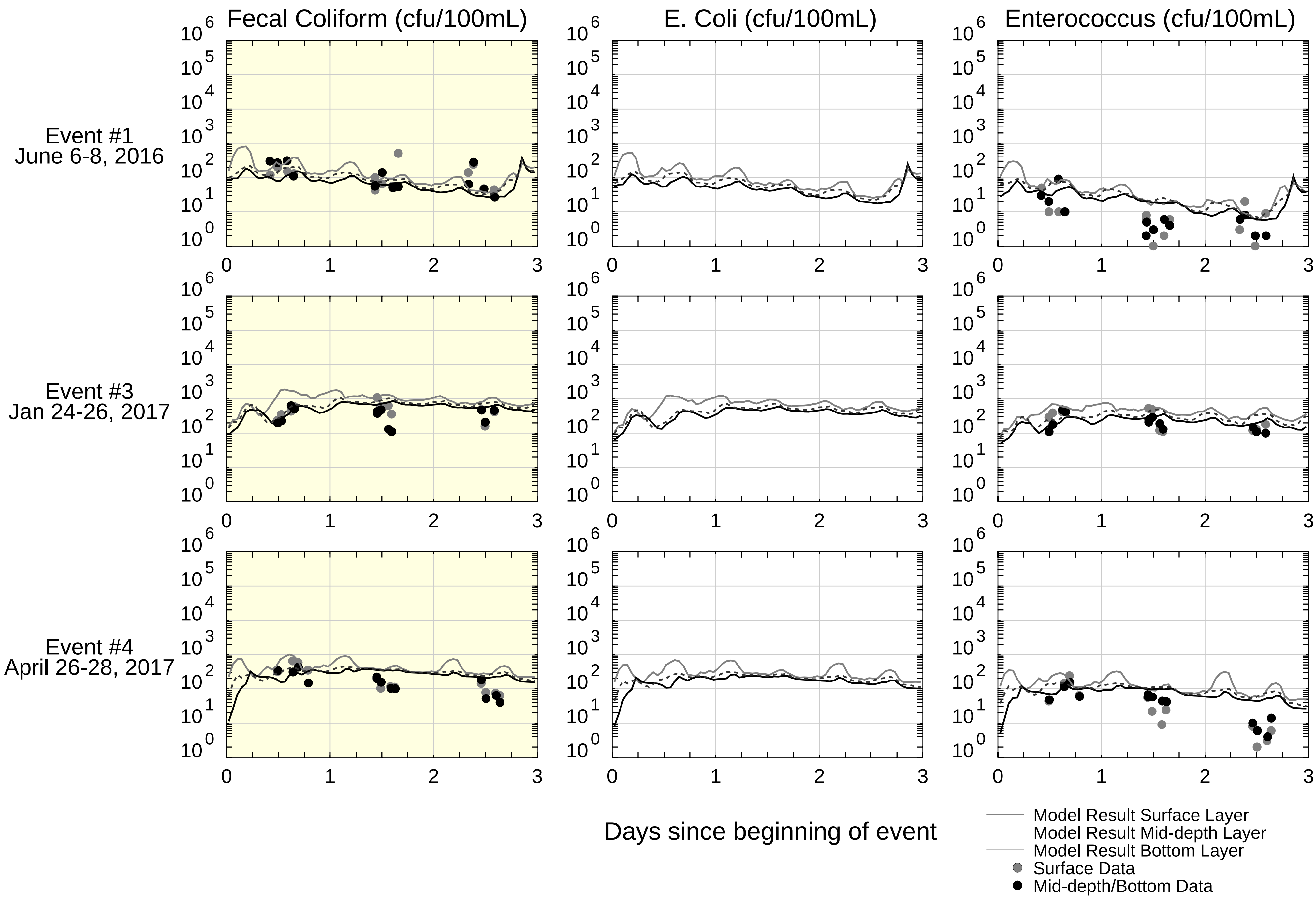
Station: 15



Station: 17


Fecal Coliform (cfu/100mL)
E. Coli (cfu/100mL)
Enterococcus (cfu/100mL)
Event #1
June 6-8, 2016
Event #3
Jan 24-26, 2017
Event #4
April 26-28, 2017
10^0
10^1
10^2
10^3
10^4
10^5
10^6
0
1
2
3
Days since beginning of event
Model Result Surface Layer
Model Result Mid-depth Layer
Model Result Bottom Layer
Surface Data
Mid-depth/Bottom Data

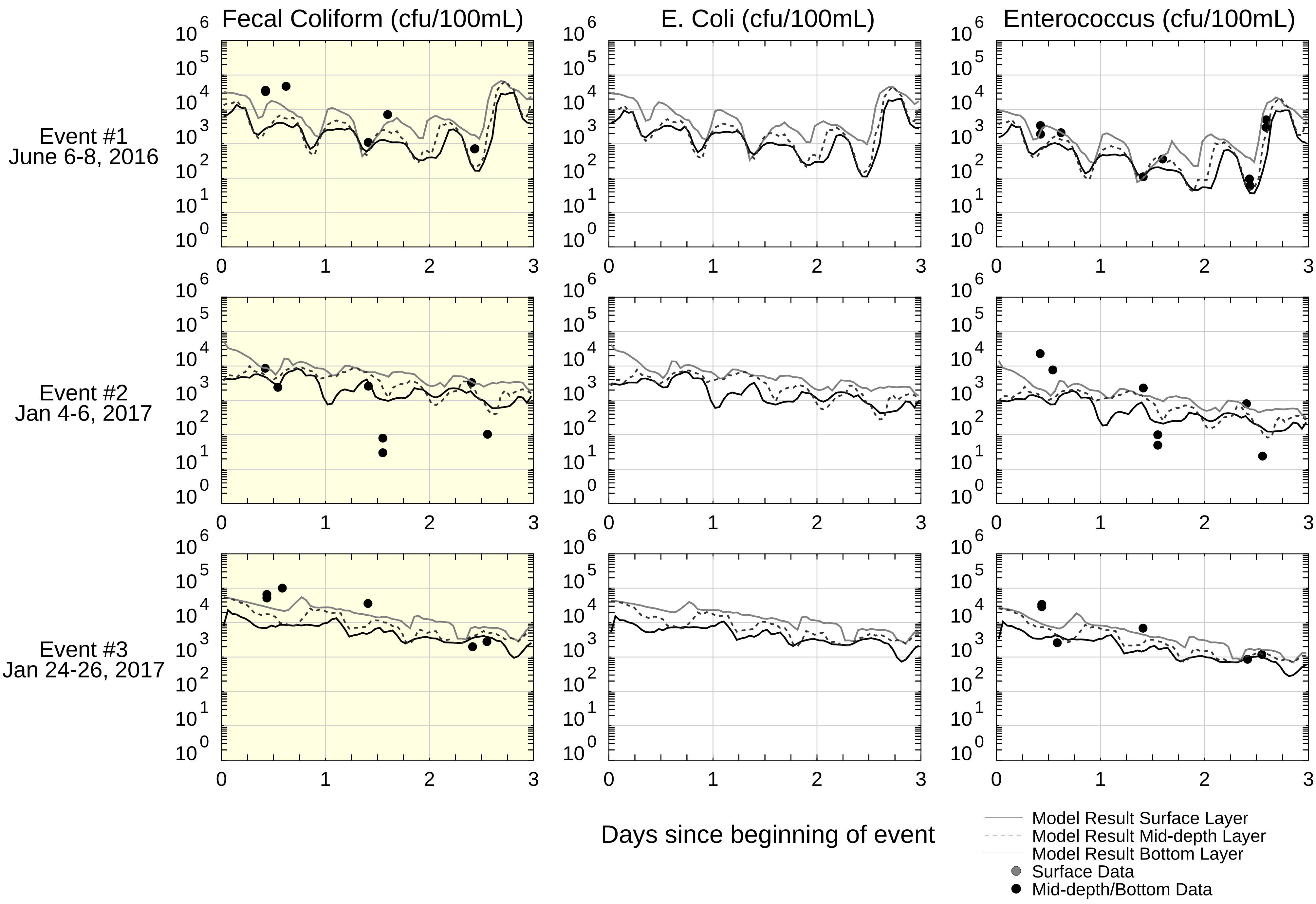
Station: 18


Fecal Coliform (cfu/100mL)
E. Coli (cfu/100mL)
Enterococcus (cfu/100mL)
Event #1
June 6-8, 2016
Event #3
Jan 24-26, 2017
Event #4
April 26-28, 2017
10^6
10^5
10^4
10^3
10^2
10^1
10^0
0
1
2
3
Days since beginning of event
Model Result Surface Layer
Model Result Mid-depth Layer
Model Result Bottom Layer
Surface Data
Mid-depth/Bottom Data

Newark Bay & Tributaries
Elizabeth River

SE3

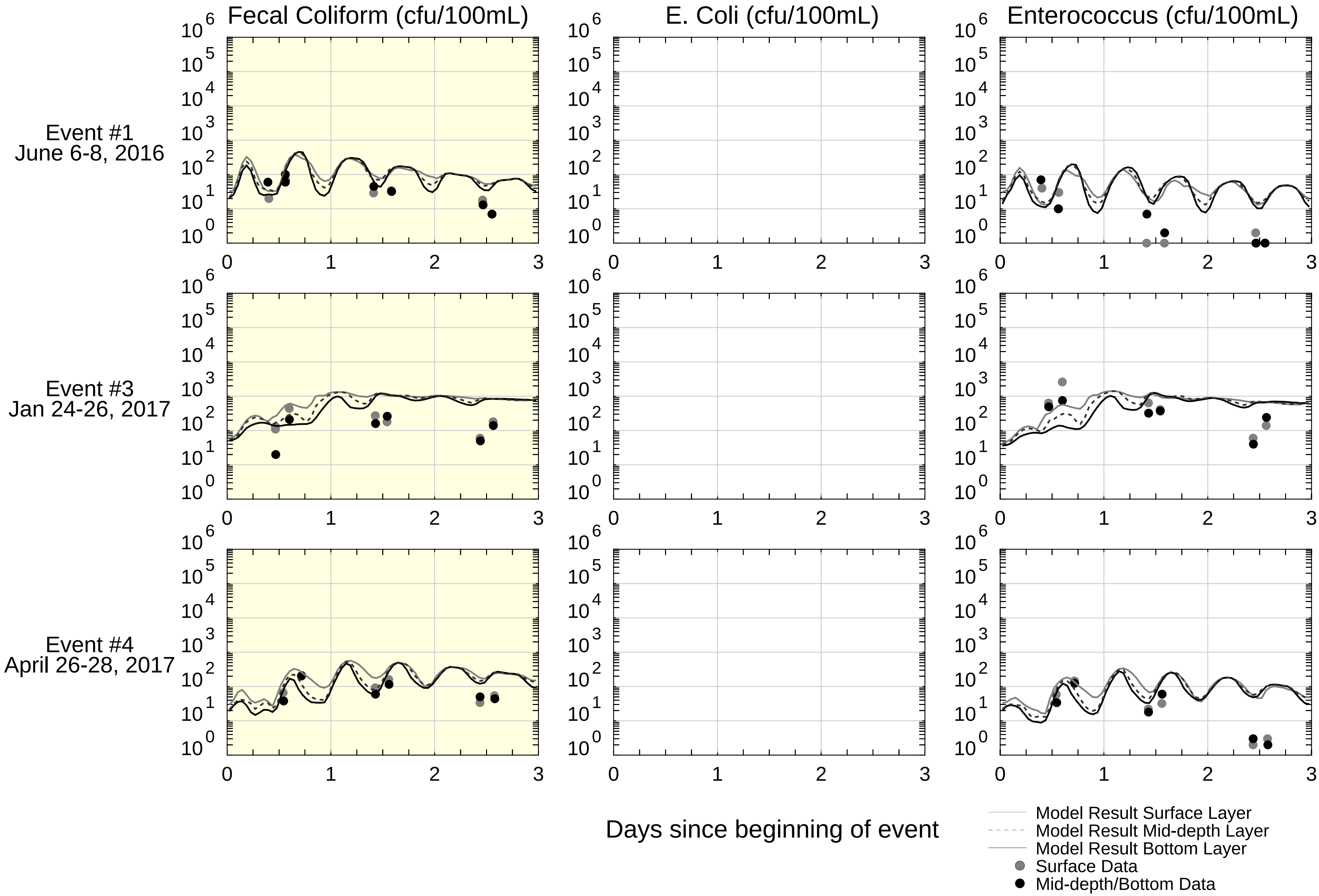
Station: 20



Arthur Kill, Raritan River/Bay & Tributaries
Arthur Kill

SE3

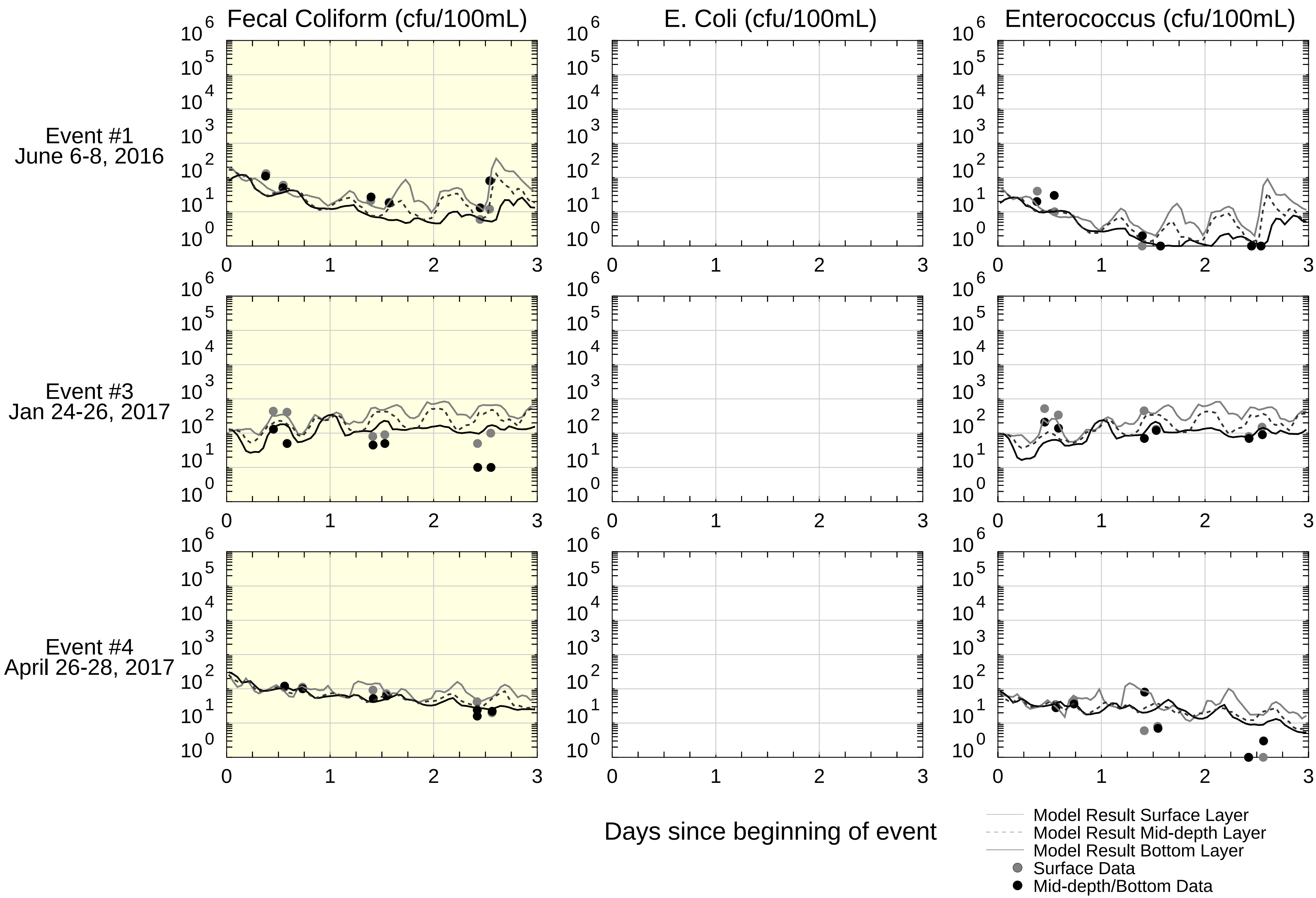
Station: 24



Arthur Kill, Raritan River/Bay & Tributaries
Arthur Kill

SE2

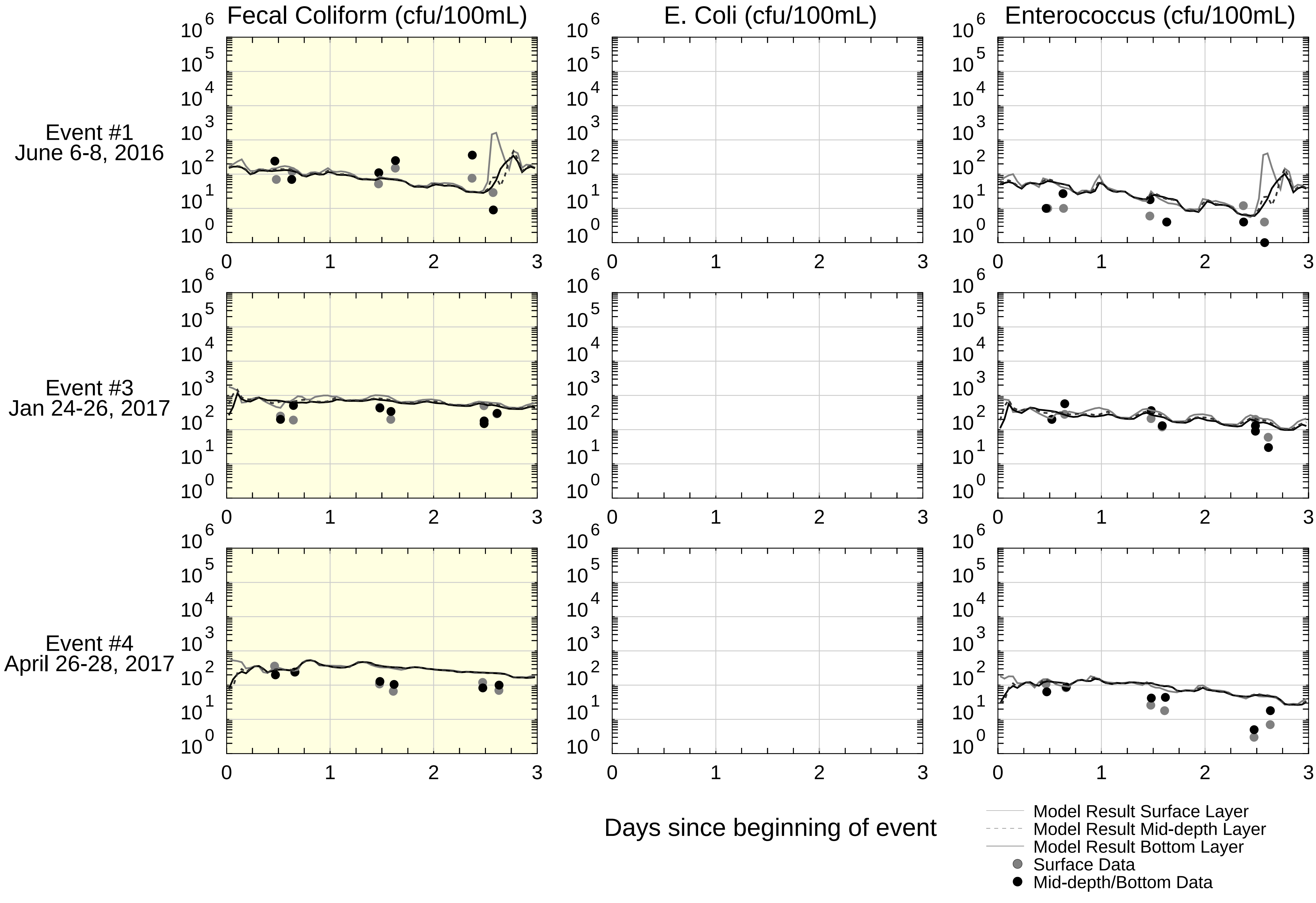
Station: B15



Hudson River, Upper Bay
Kill Van Kull

SE3

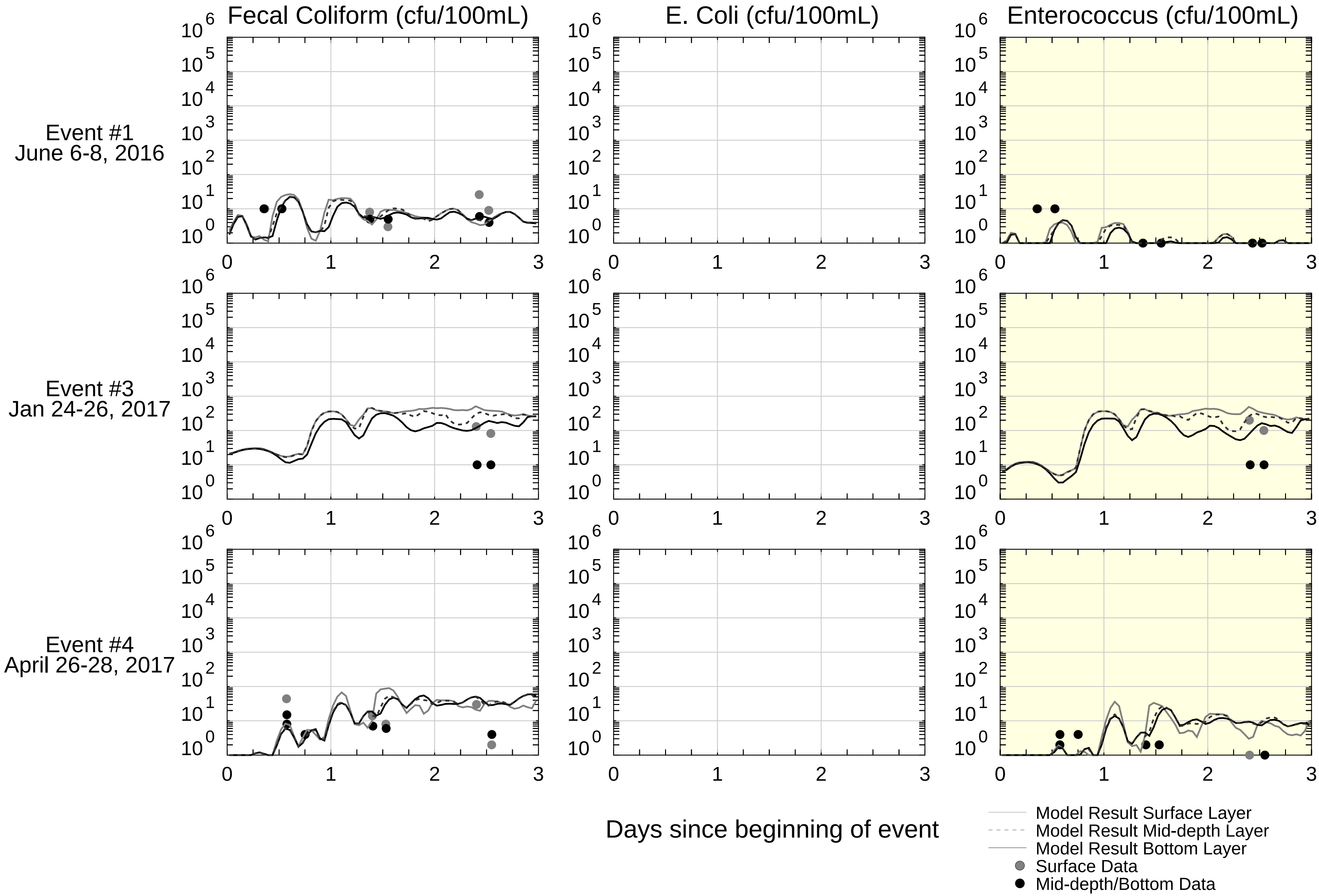
Station: B12



Arthur Kill, Raritan River/Bay & Tributaries
Raritan Bay

SE1

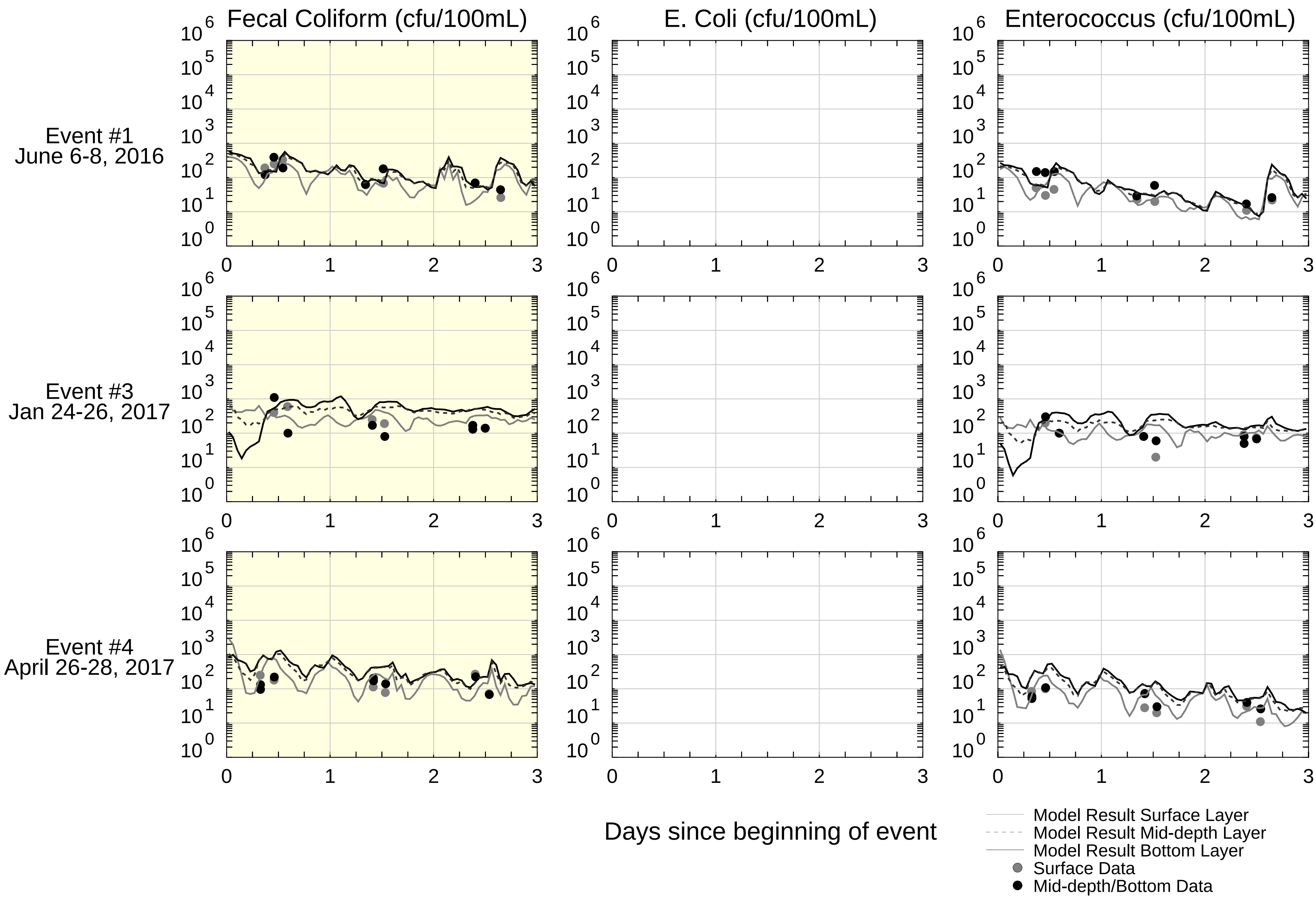
Station: 29



Hudson River, Upper Bay
Hudson River

SE2

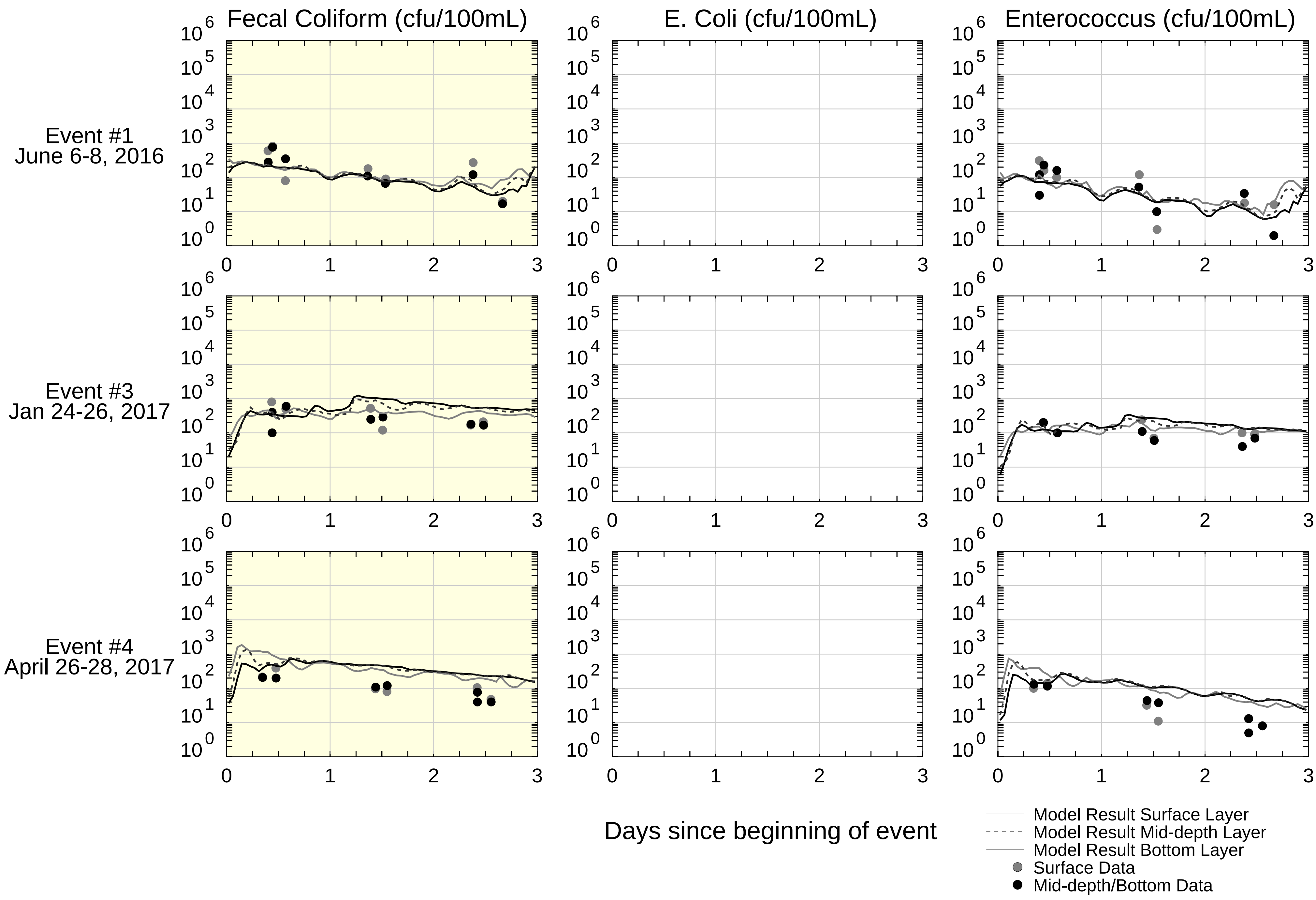
Station: 31



Hudson River, Upper Bay
Hudson River

SE2

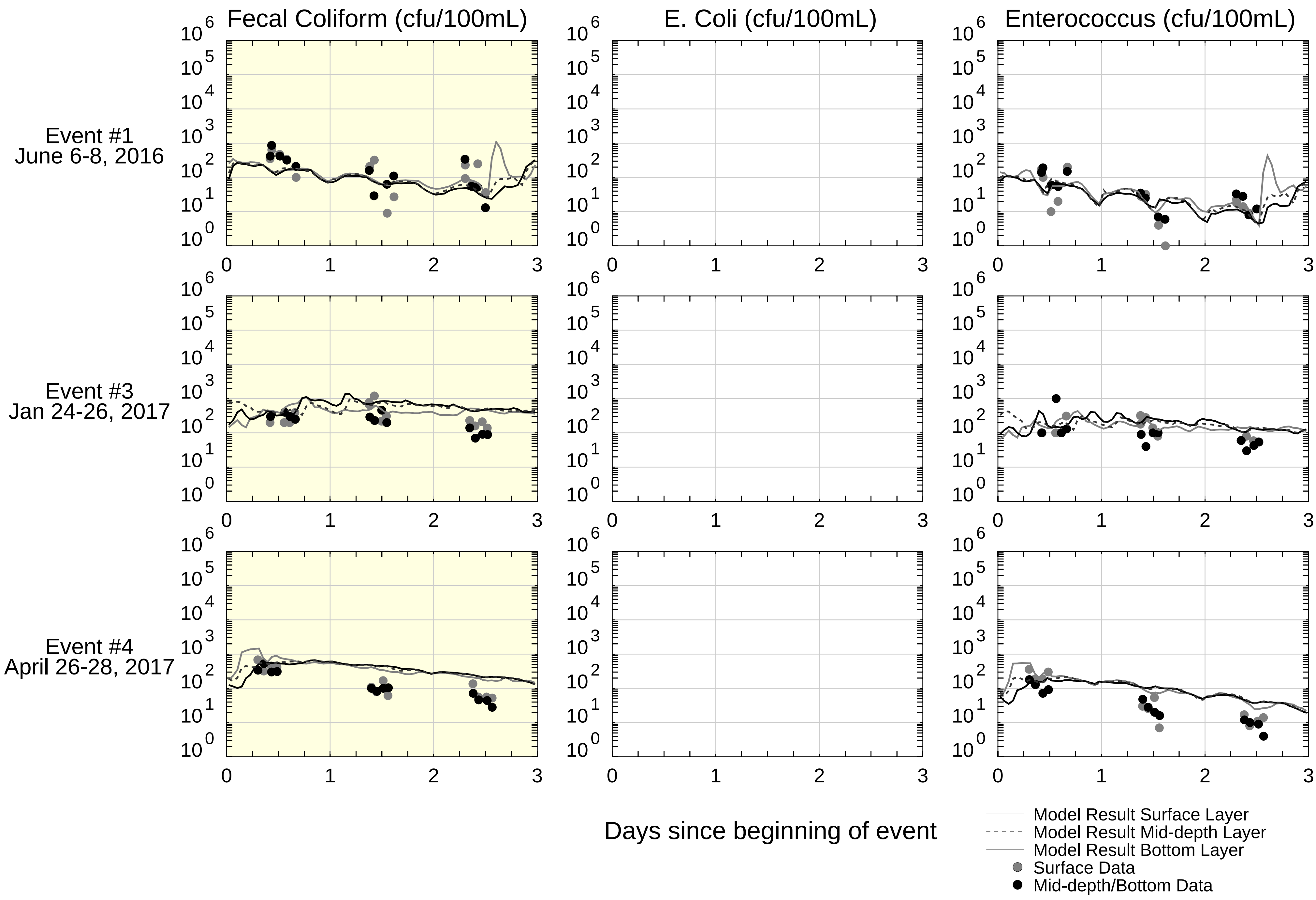
Station: 32



Hudson River, Upper Bay
Hudson River

SE2

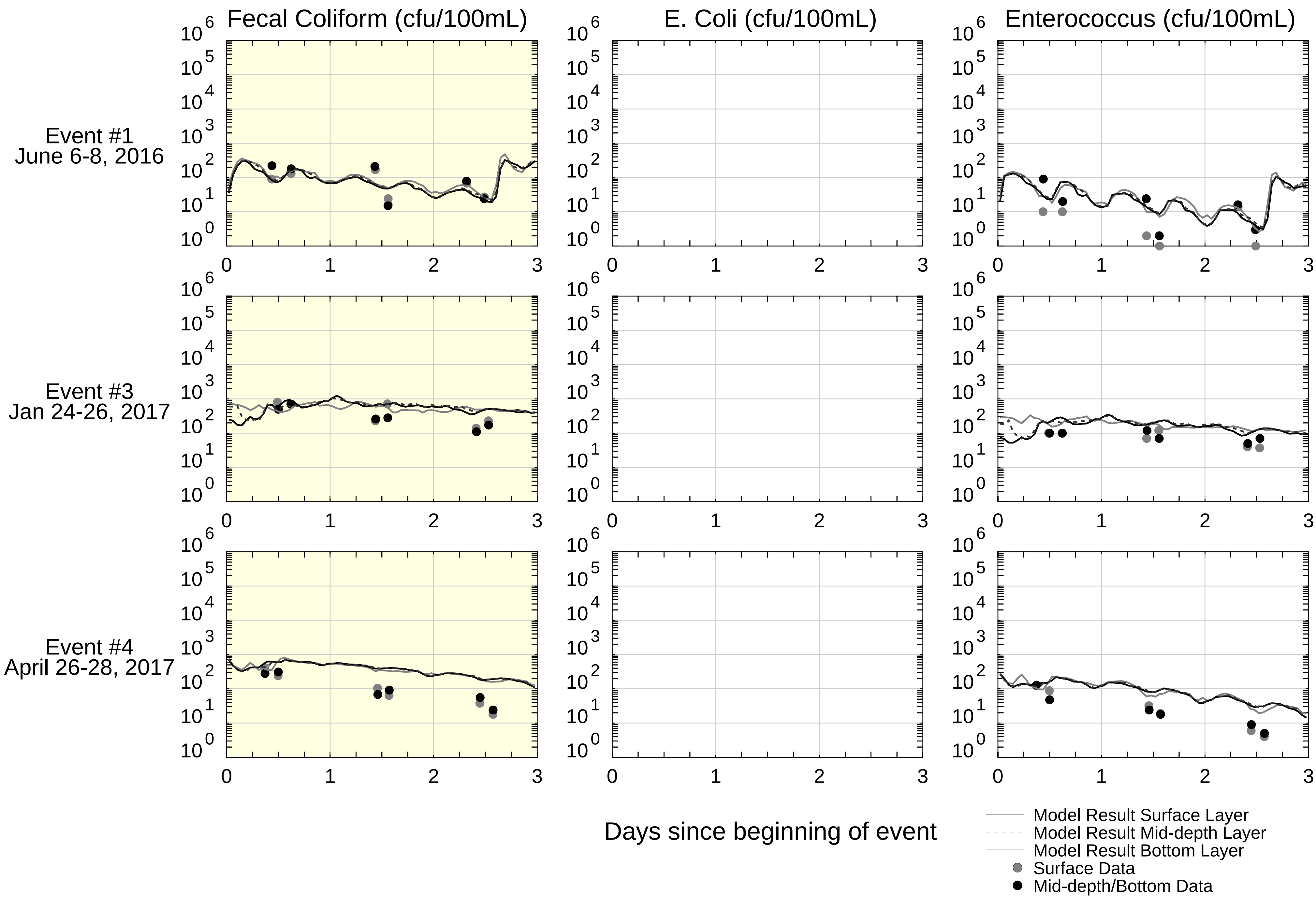
Station: 33



Hudson River, Upper Bay
Upper Bay

SE2

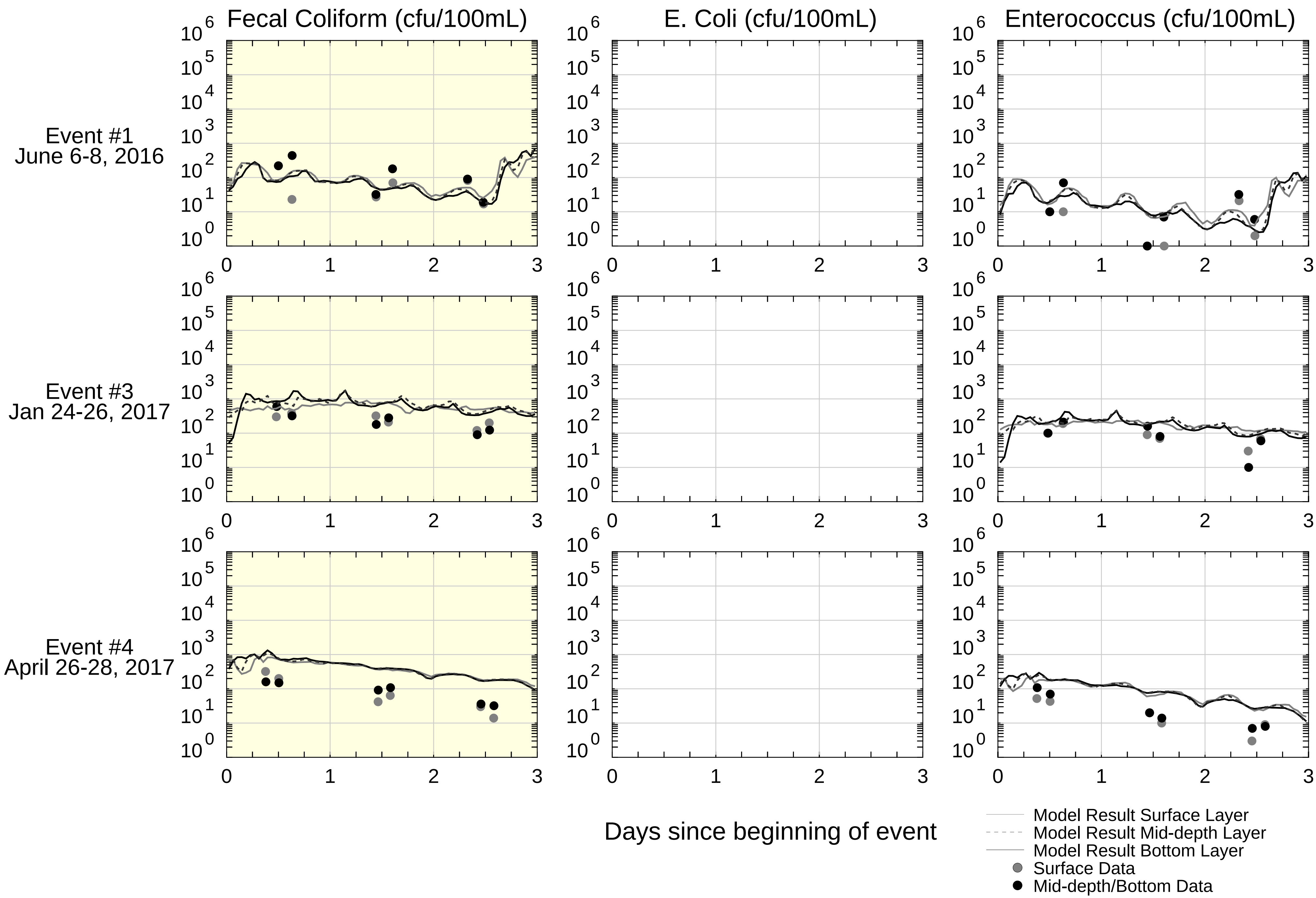
Station: B26



Hudson River, Upper Bay
Upper Bay

SE2

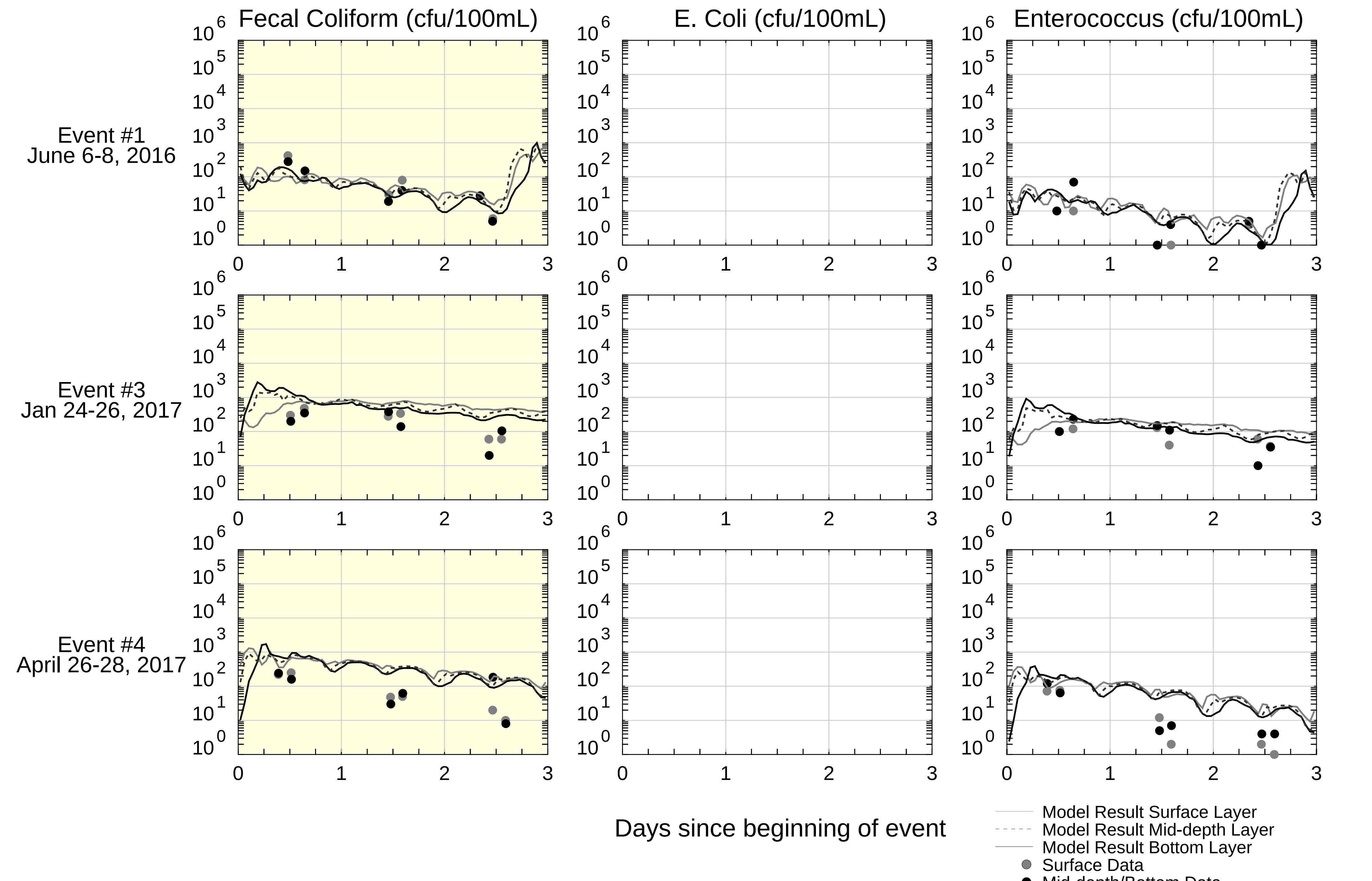
Station: B27



Hudson River, Upper Bay
Upper Bay

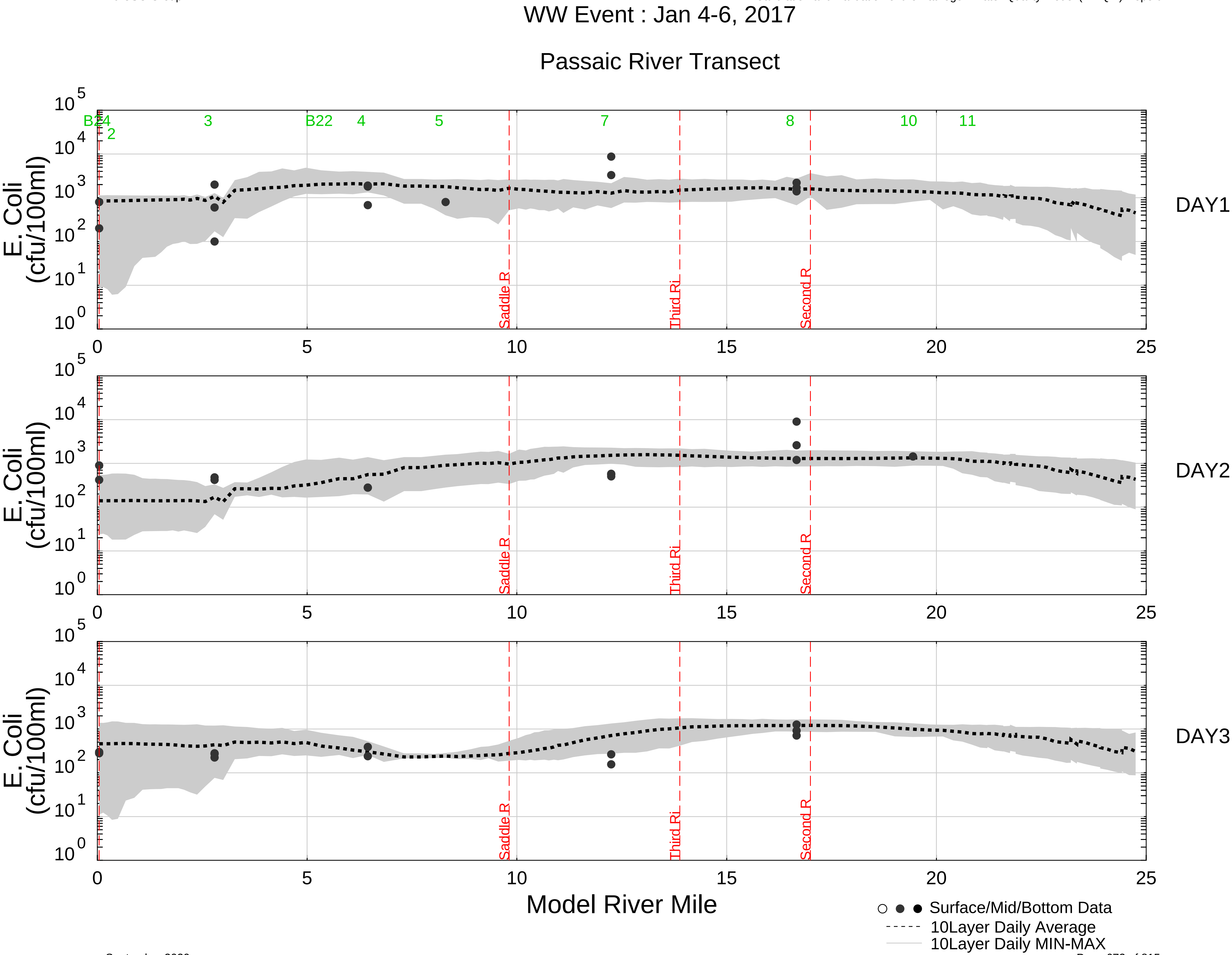
SE2

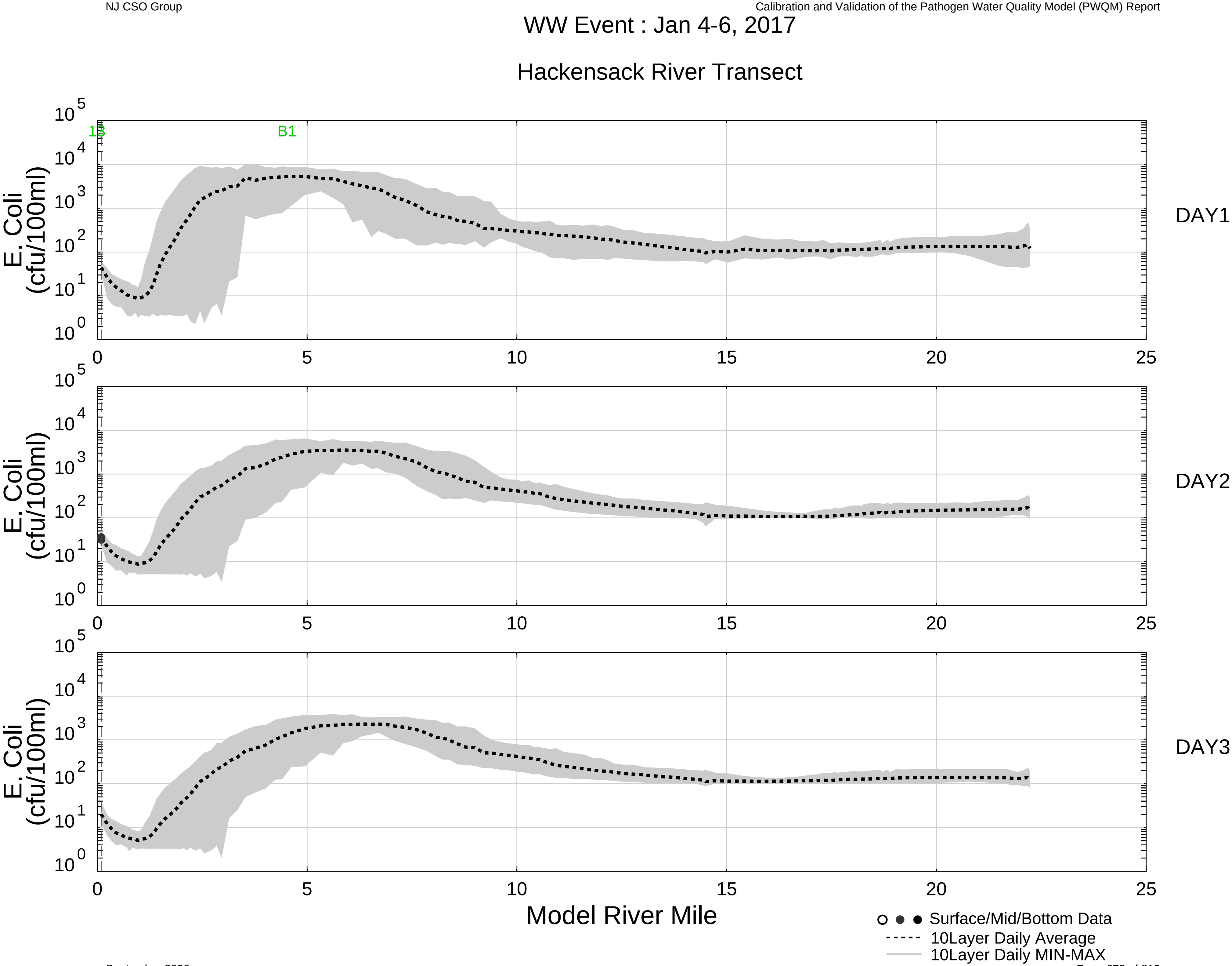
Station: B28



Appendix F-4

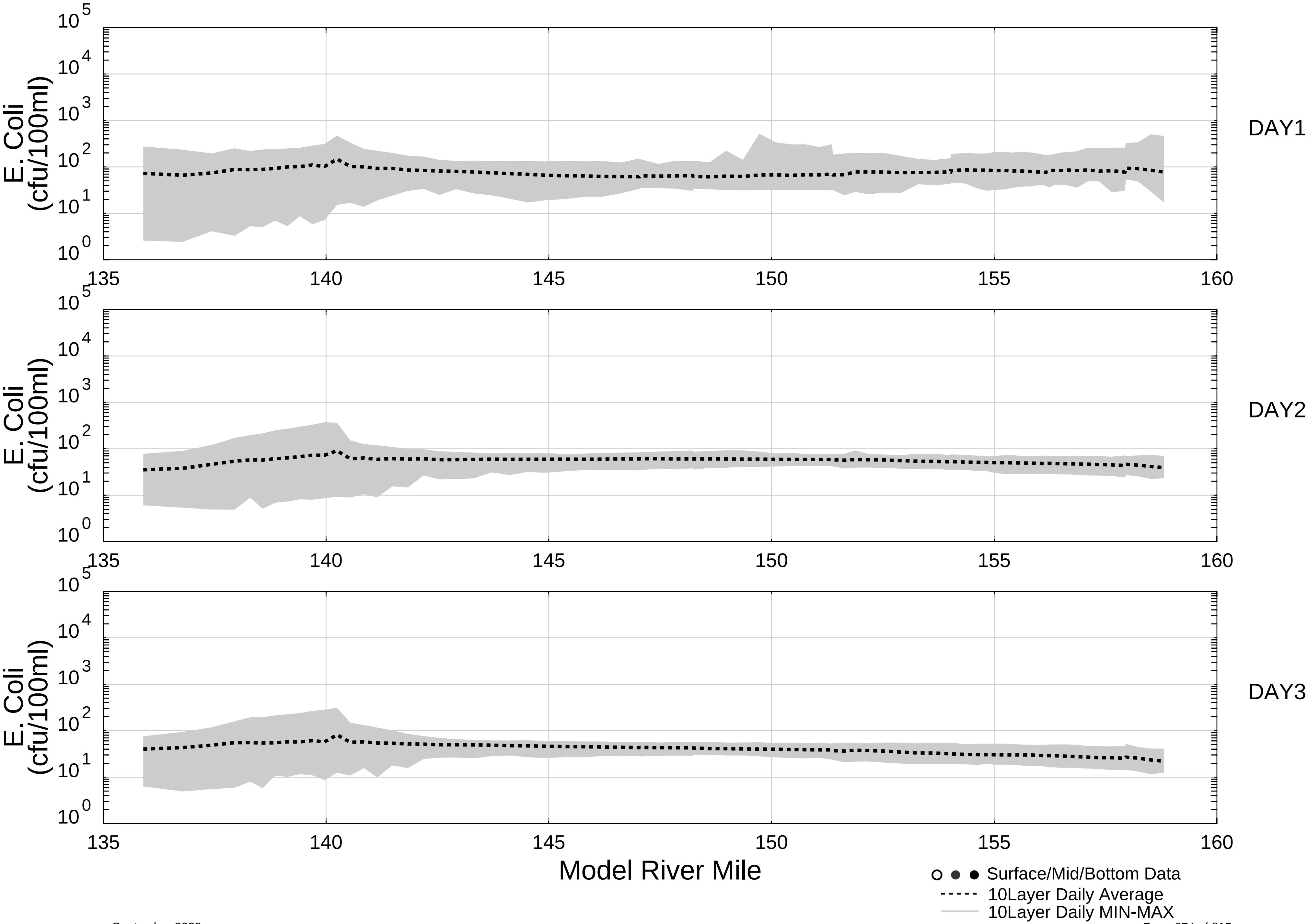
Additional Validation E. Coli Transect Figures


WW Event : Jan 4-6, 2017
Passaic River Transect
E. Coli (cfu/100ml)
B24
2
3
B22
4
5
7
8
10
11
Saddle R
Third Ri
Second R
DAY1
DAY2
DAY3
Model River Mile
Surface/Mid/Bottom Data
10Layer Daily Average
10Layer Daily MIN-MAX


WW Event : Jan 4-6, 2017
Hackensack River Transect
13
B1
E. Coli (cfu/100ml)
10^0
10^1
10^2
10^3
10^4
10^5
0
5
10
15
20
25
DAY1
DAY2
DAY3
Model River Mile
Surface/Mid/Bottom Data
10Layer Daily Average
10Layer Daily MIN-MAX

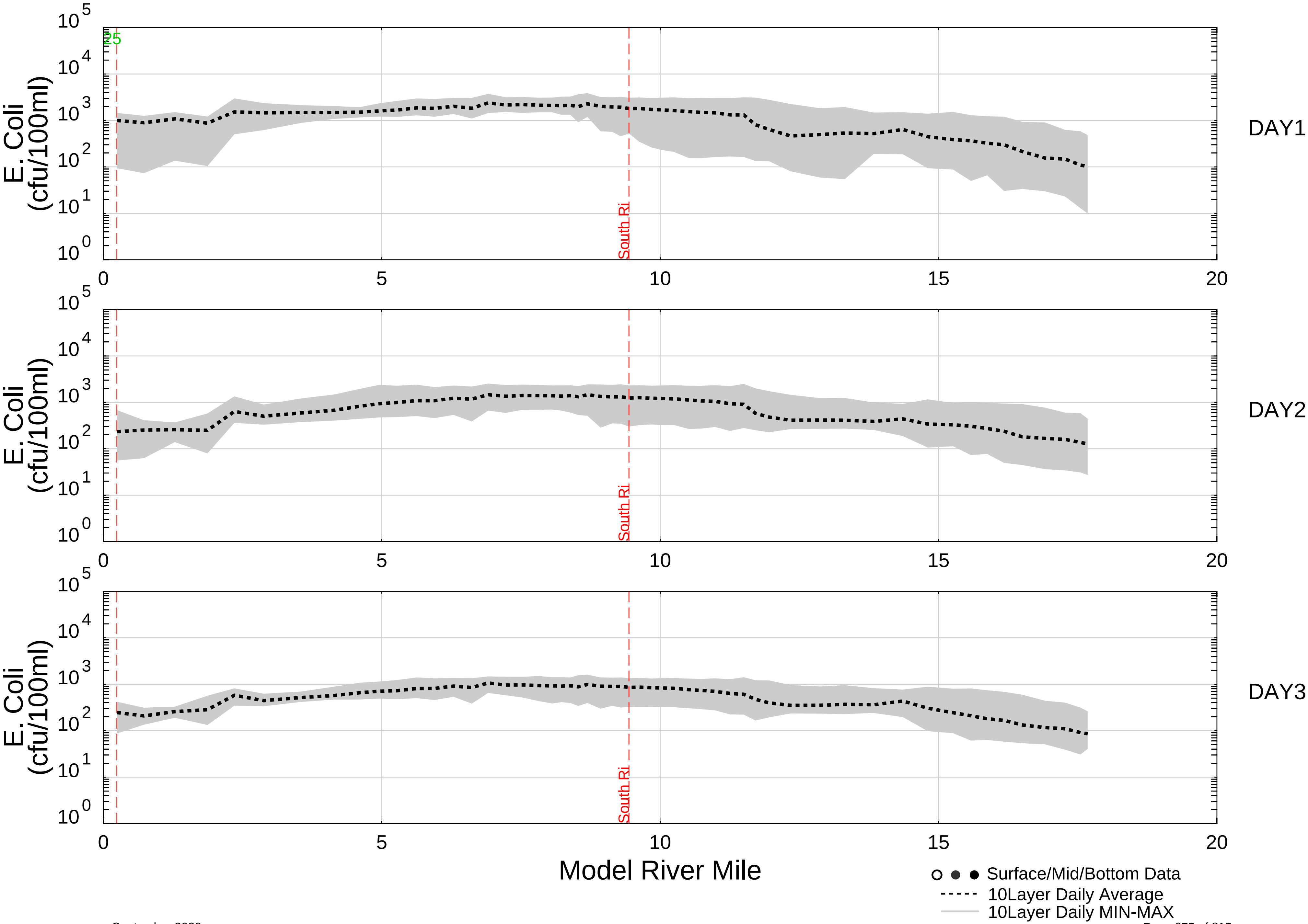
WW Event : Jan 4-6, 2017

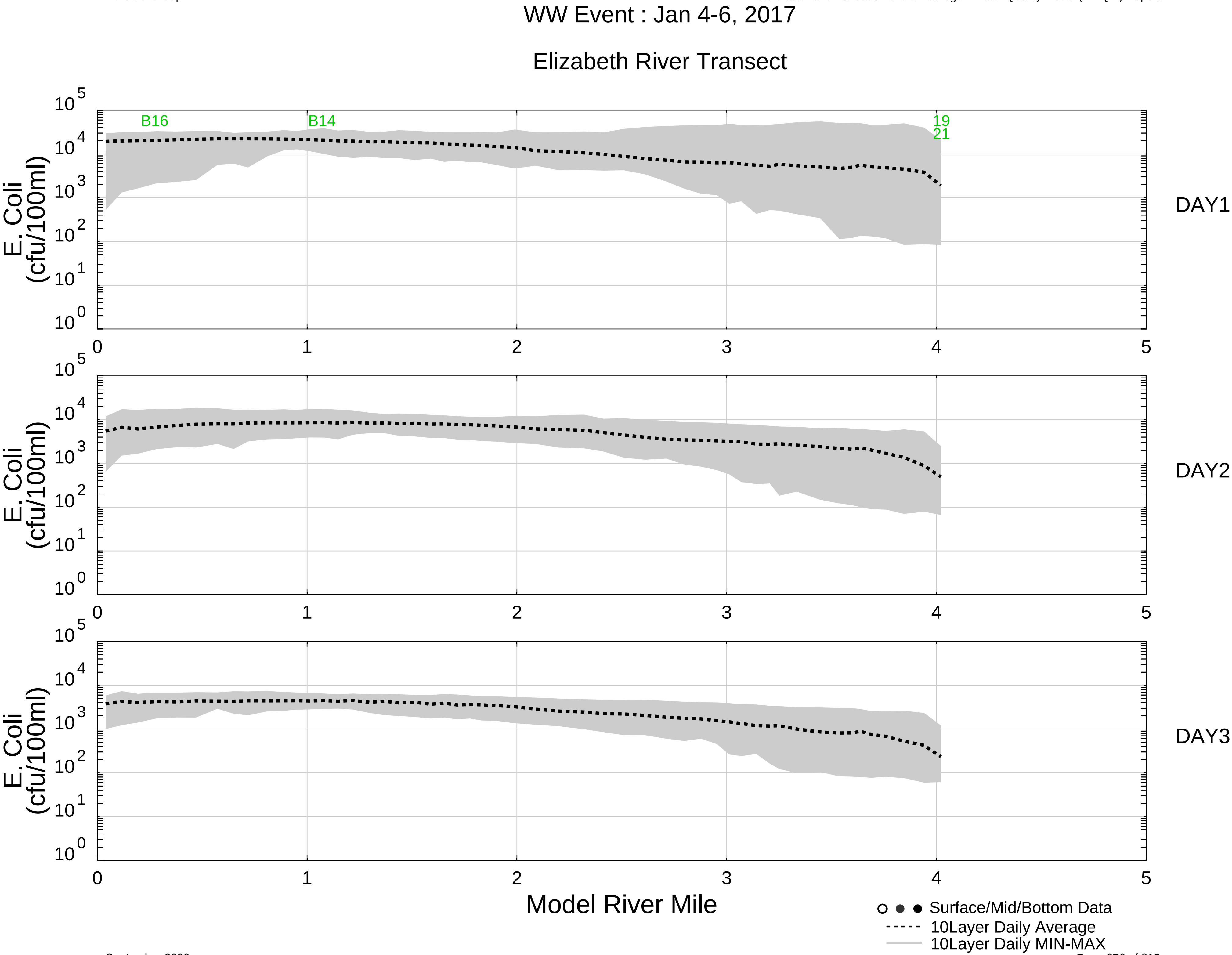
Hudson River Transect

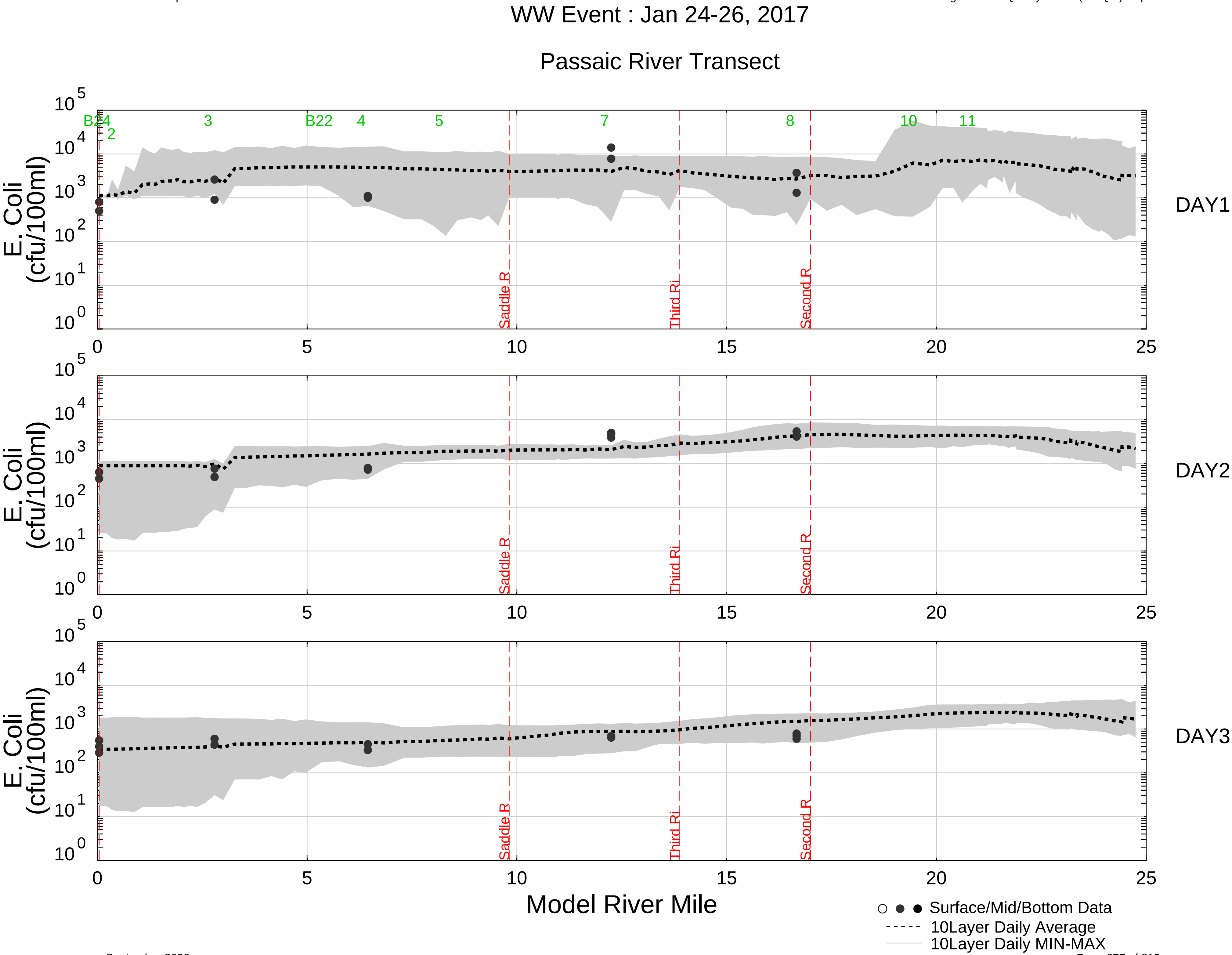


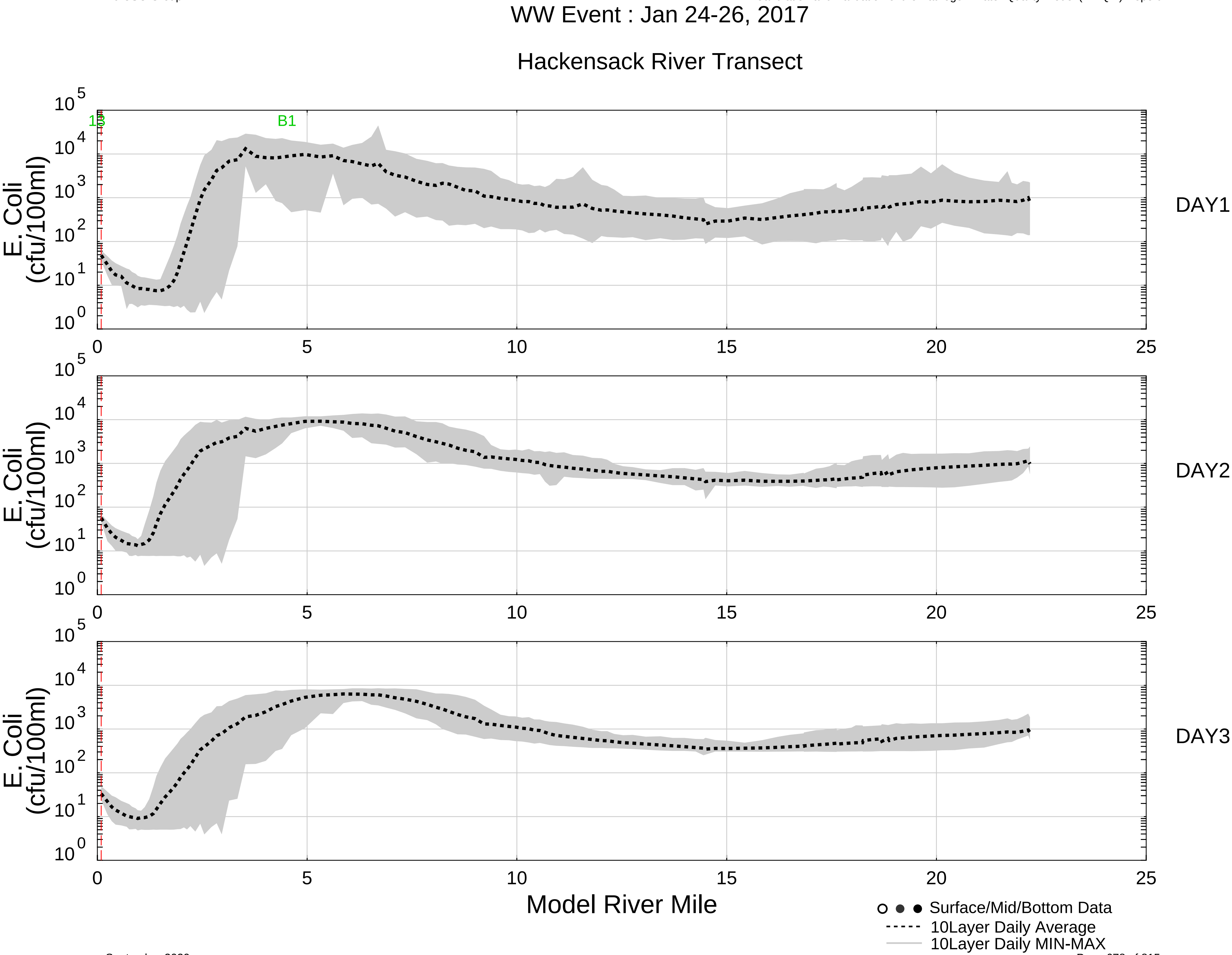
WW Event : Jan 4-6, 2017

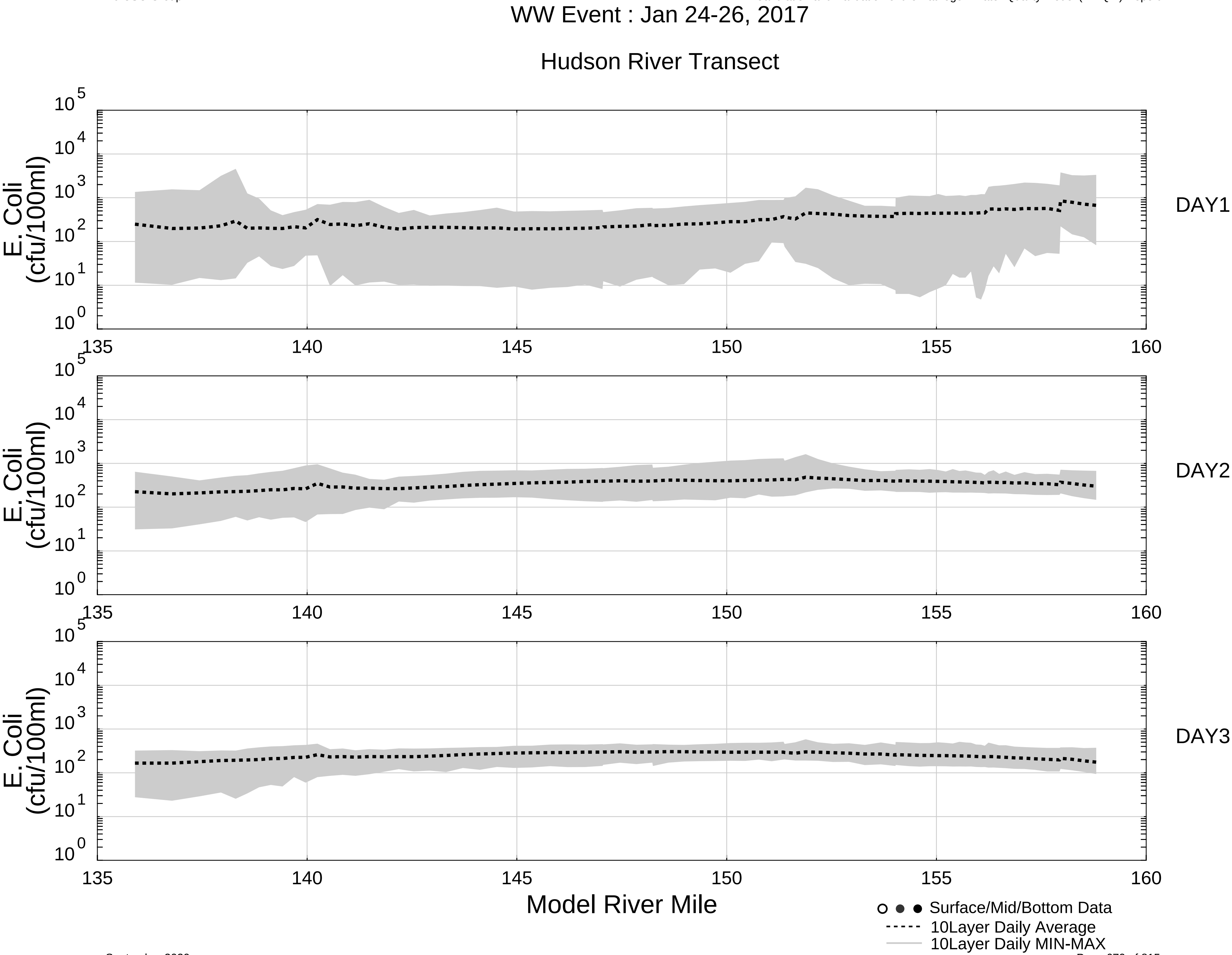
Raritan River Transect




WW Event : Jan 4-6, 2017
Elizabeth River Transect
B16
B14
19
21
E. Coli (cfu/100ml)
DAY1
DAY2
DAY3
Model River Mile
Surface/Mid/Bottom Data
10Layer Daily Average
10Layer Daily MIN-MAX

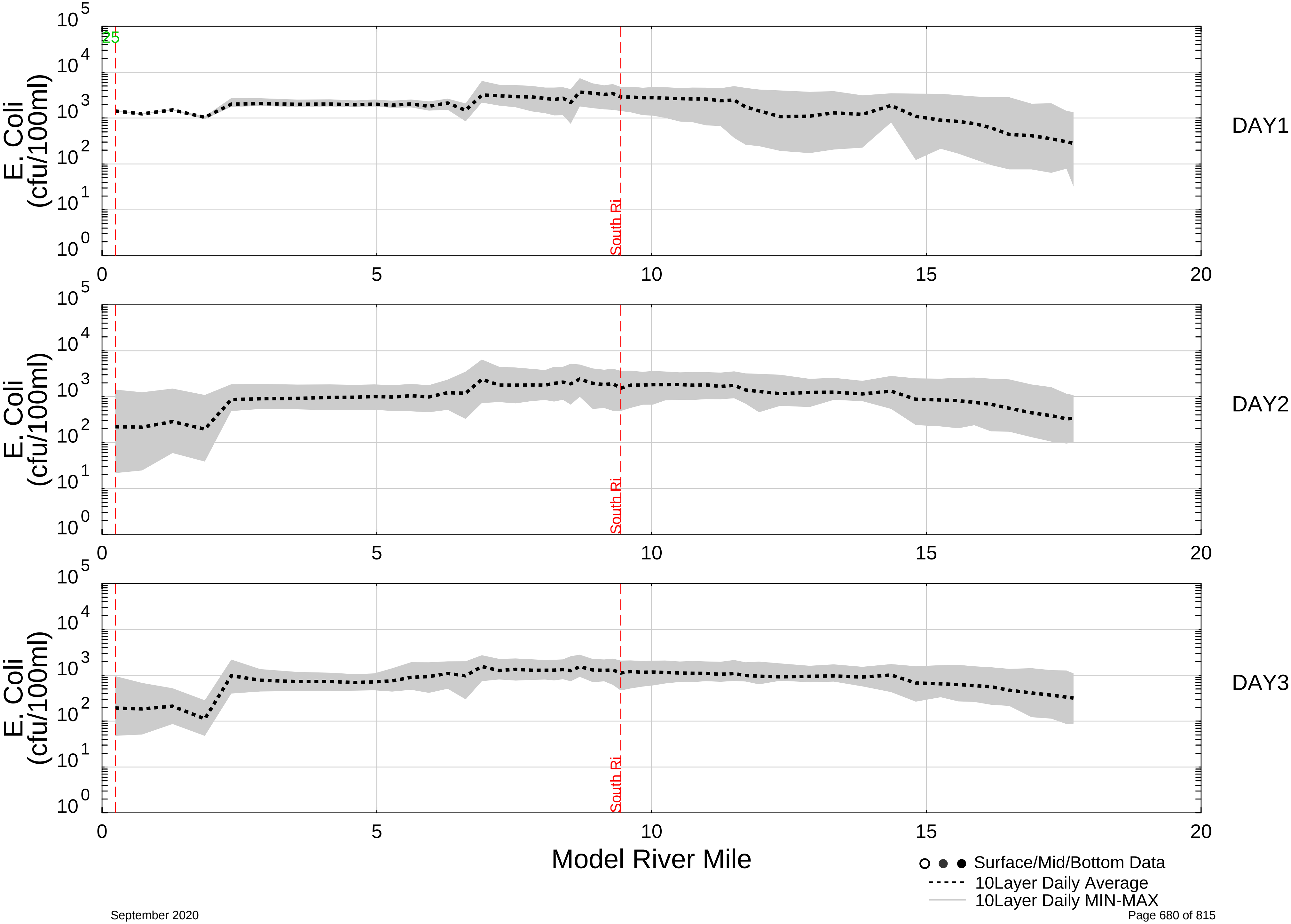

WW Event : Jan 24-26, 2017
Passaic River Transect
E. Coli (cfu/100ml)
B24
2
3
B22
4
5
7
8
10
11
Saddle R
Third Ri
Second R
DAY1
DAY2
DAY3
Model River Mile
Surface/Mid/Bottom Data
10Layer Daily Average
10Layer Daily MIN-MAX

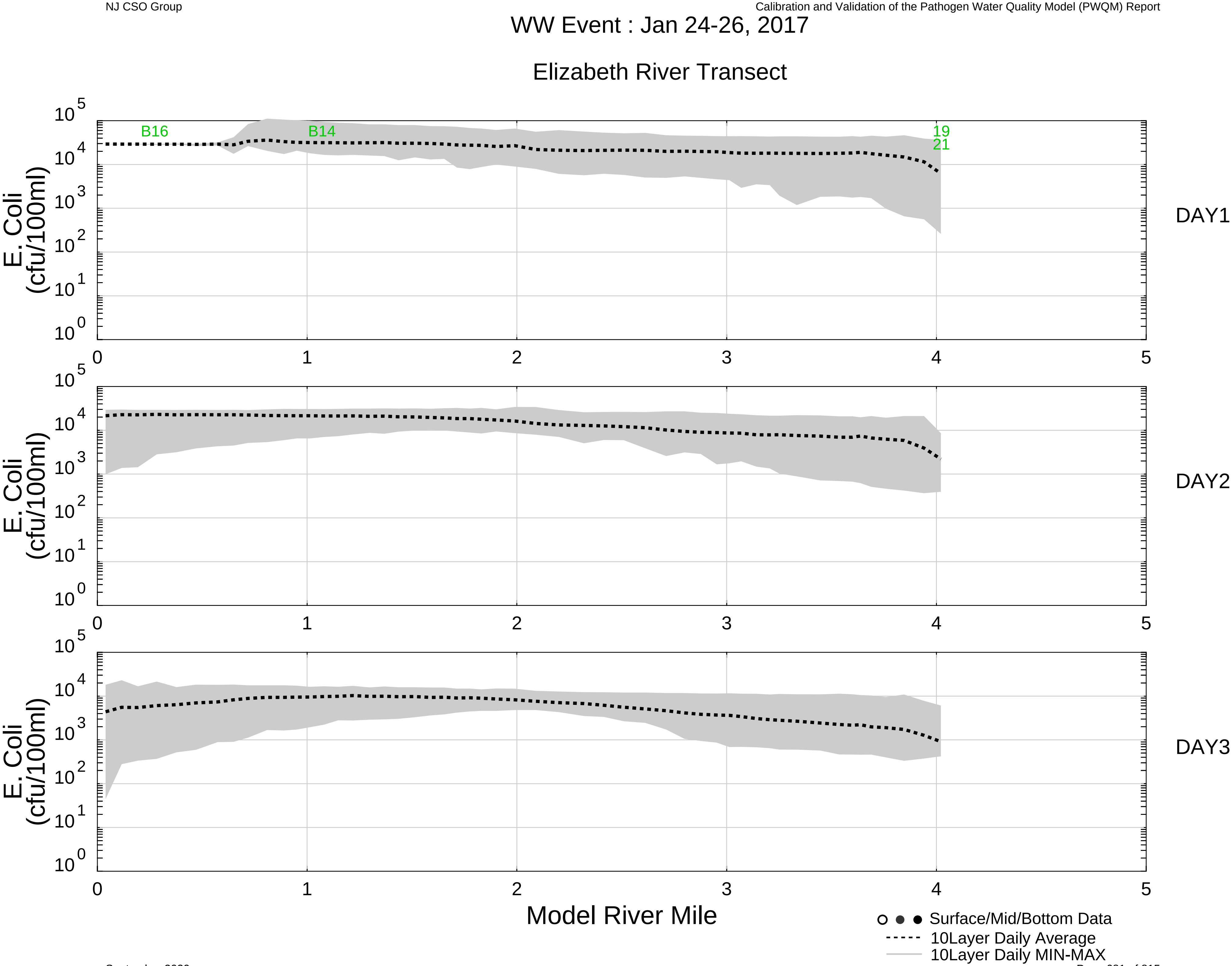

WW Event : Jan 24-26, 2017
Hackensack River Transect
E. Coli (cfu/100ml)
13
B1
DAY1
DAY2
DAY3
Model River Mile
Surface/Mid/Bottom Data
10Layer Daily Average
10Layer Daily MIN-MAX

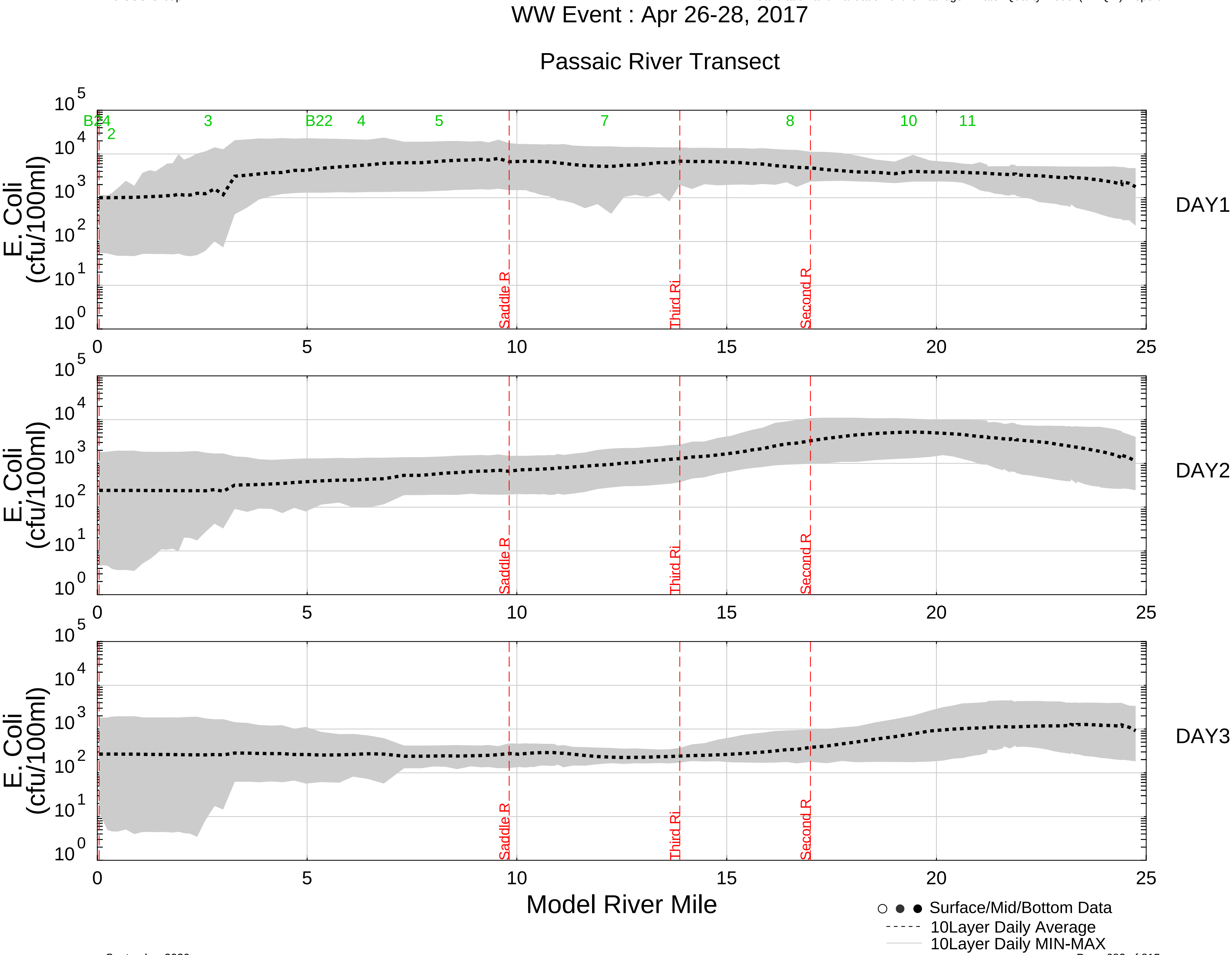

WW Event : Jan 24-26, 2017
Hudson River Transect
E. Coli (cfu/100ml)
10^5
10^4
10^3
10^2
10^1
10^0
135
140
145
150
155
160
DAY1
DAY2
DAY3
Model River Mile
Surface/Mid/Bottom Data
10Layer Daily Average
10Layer Daily MIN-MAX

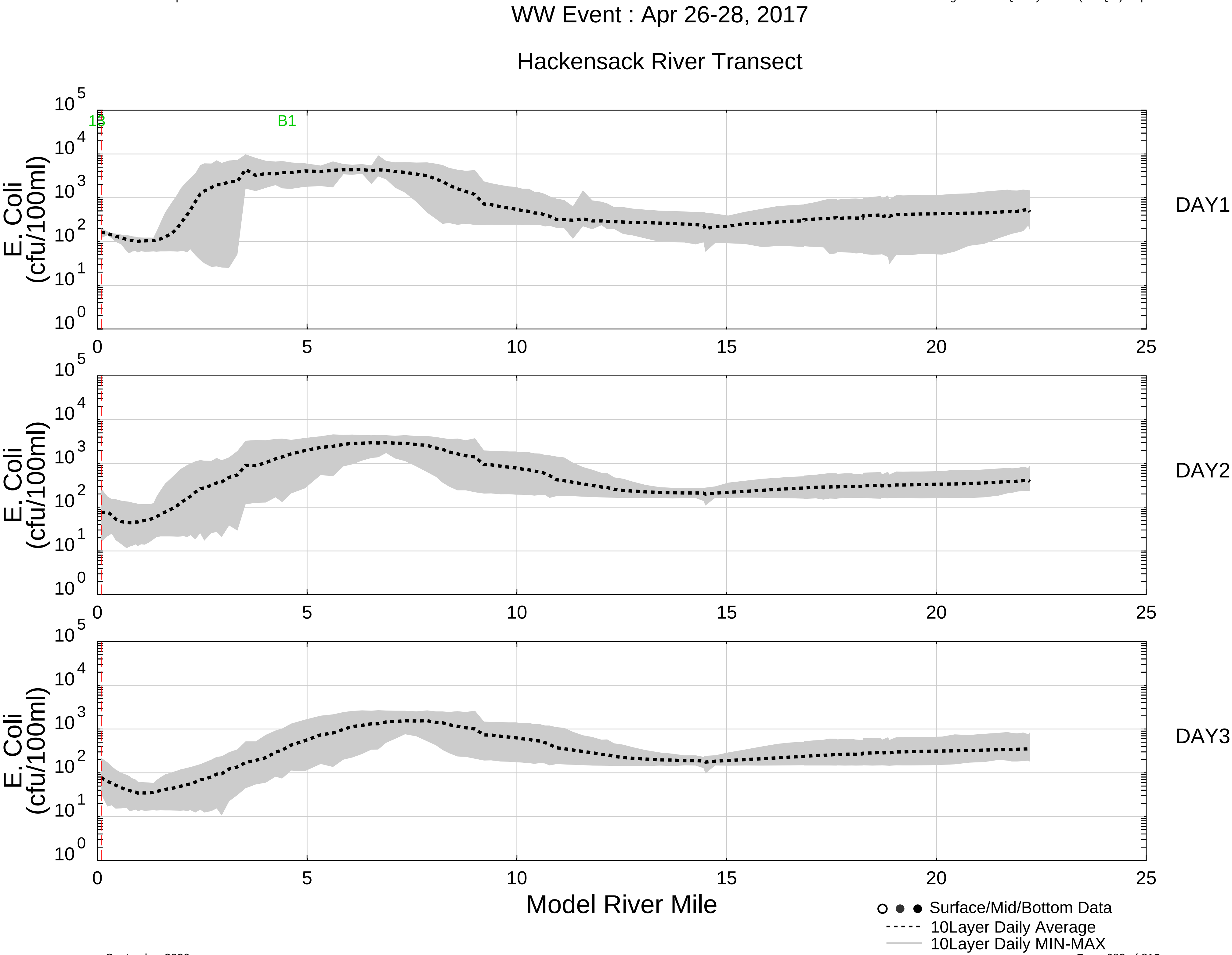
WW Event : Jan 24-26, 2017

Raritan River Transect



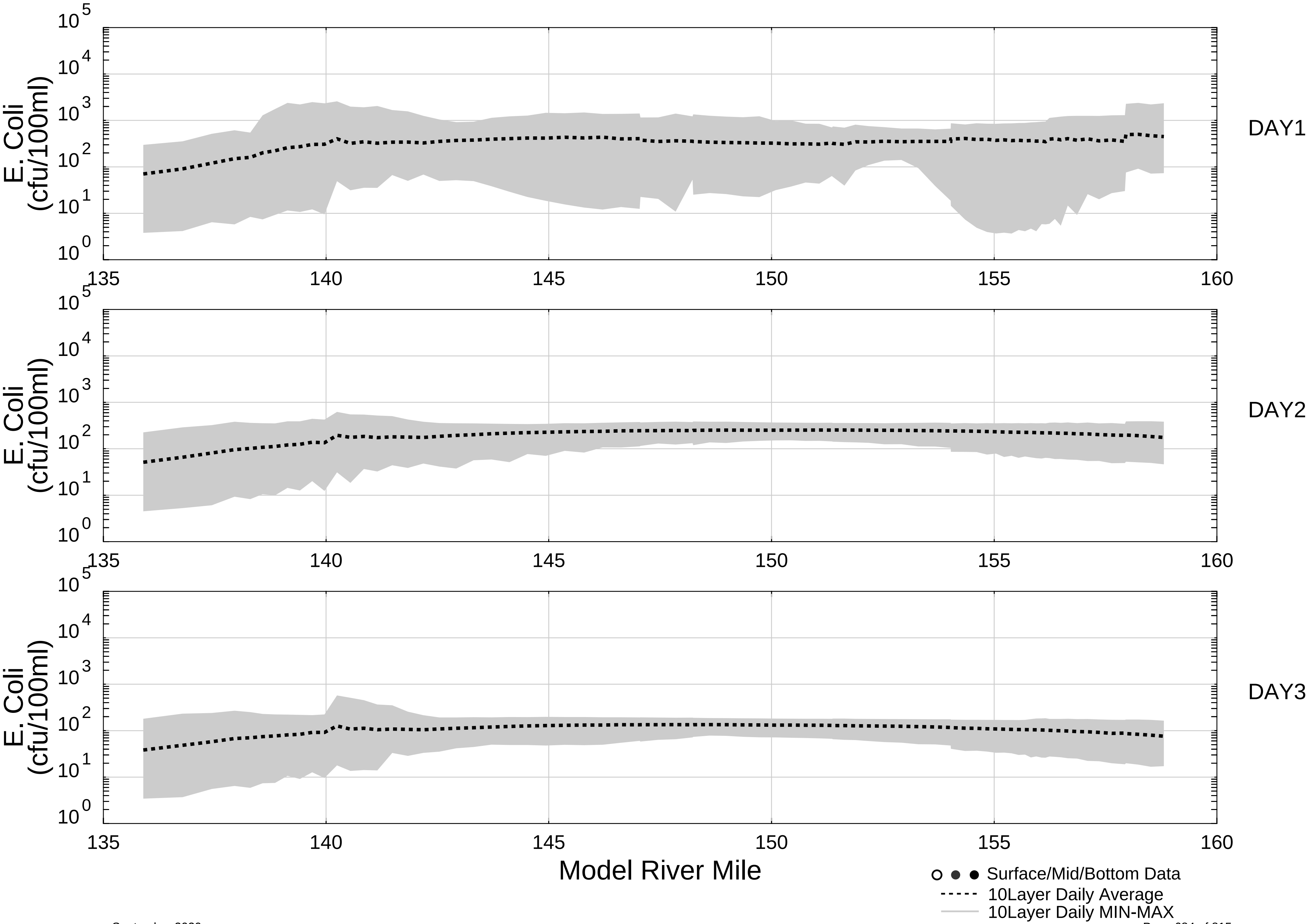

WW Event : Jan 24-26, 2017
Elizabeth River Transect
E. Coli (cfu/100ml)
10^0
10^1
10^2
10^3
10^4
10^5
B16
B14
19
21
DAY1
DAY2
DAY3
0
1
2
3
4
5
Model River Mile
Surface/Mid/Bottom Data
10Layer Daily Average
10Layer Daily MIN-MAX


WW Event : Apr 26-28, 2017
Passaic River Transect
E. Coli (cfu/100ml)
B24
2
3
B22
4
5
7
8
10
11
Saddle R
Third Ri
Second R
DAY1
DAY2
DAY3
Model River Mile
Surface/Mid/Bottom Data
10Layer Daily Average
10Layer Daily MIN-MAX


WW Event : Apr 26-28, 2017
Hackensack River Transect
E. Coli (cfu/100ml)
10^0
10^1
10^2
10^3
10^4
10^5
13
B1
DAY1
DAY2
DAY3
0
5
10
15
20
25
Model River Mile
Surface/Mid/Bottom Data
10Layer Daily Average
10Layer Daily MIN-MAX

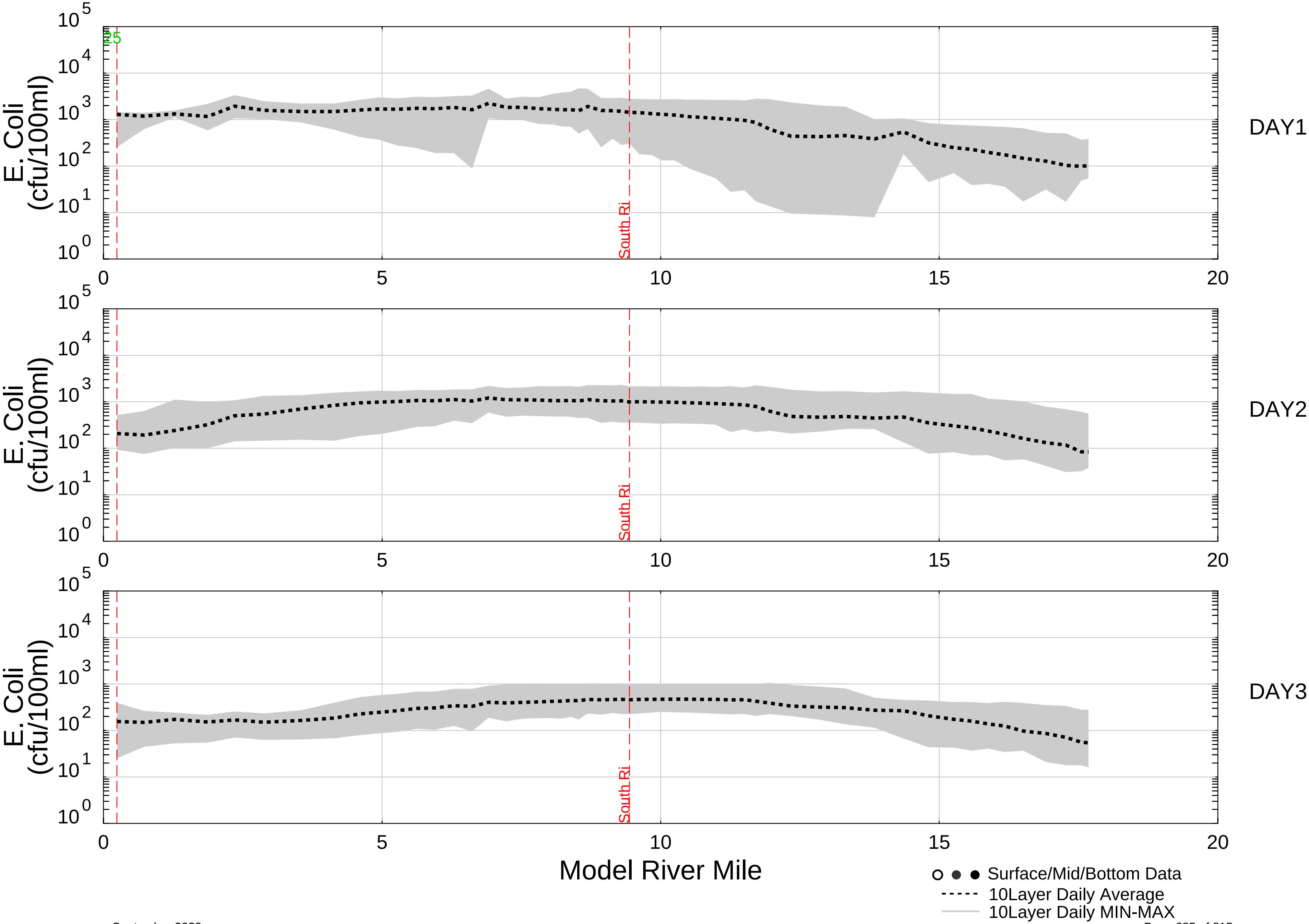
WW Event : Apr 26-28, 2017

Hudson River Transect



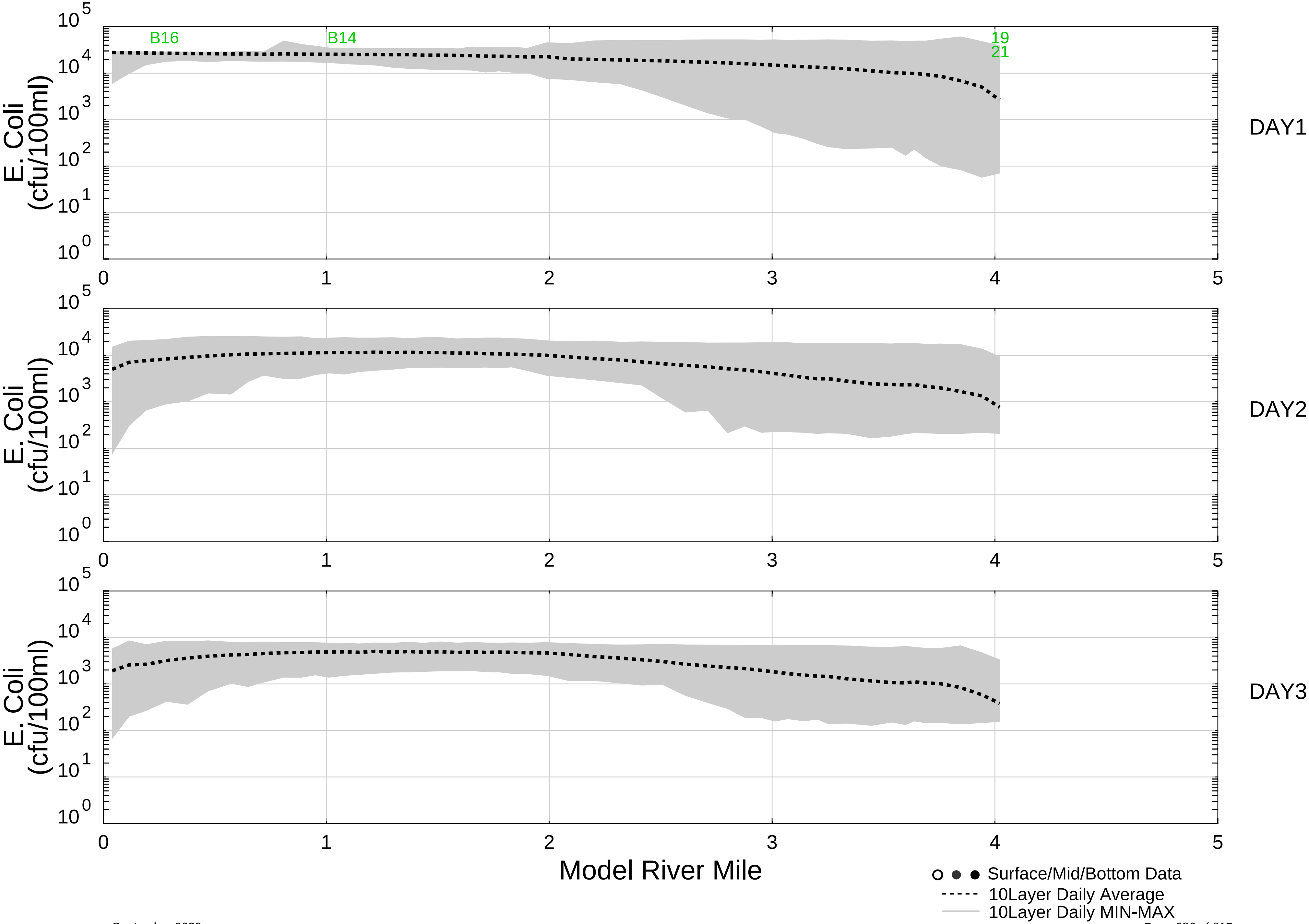
WW Event : Apr 26-28, 2017

Raritan River Transect



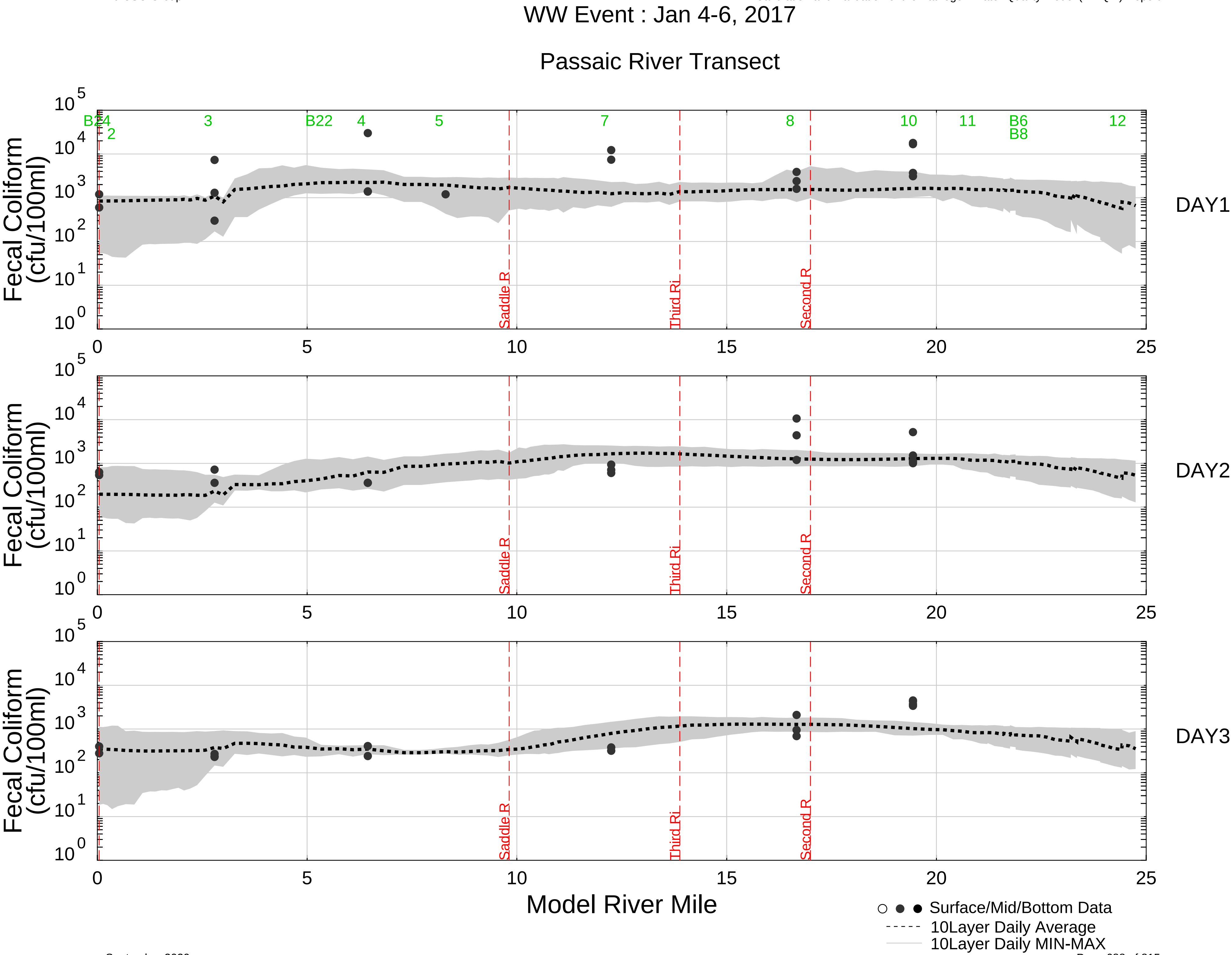
WW Event : Apr 26-28, 2017

Elizabeth River Transect



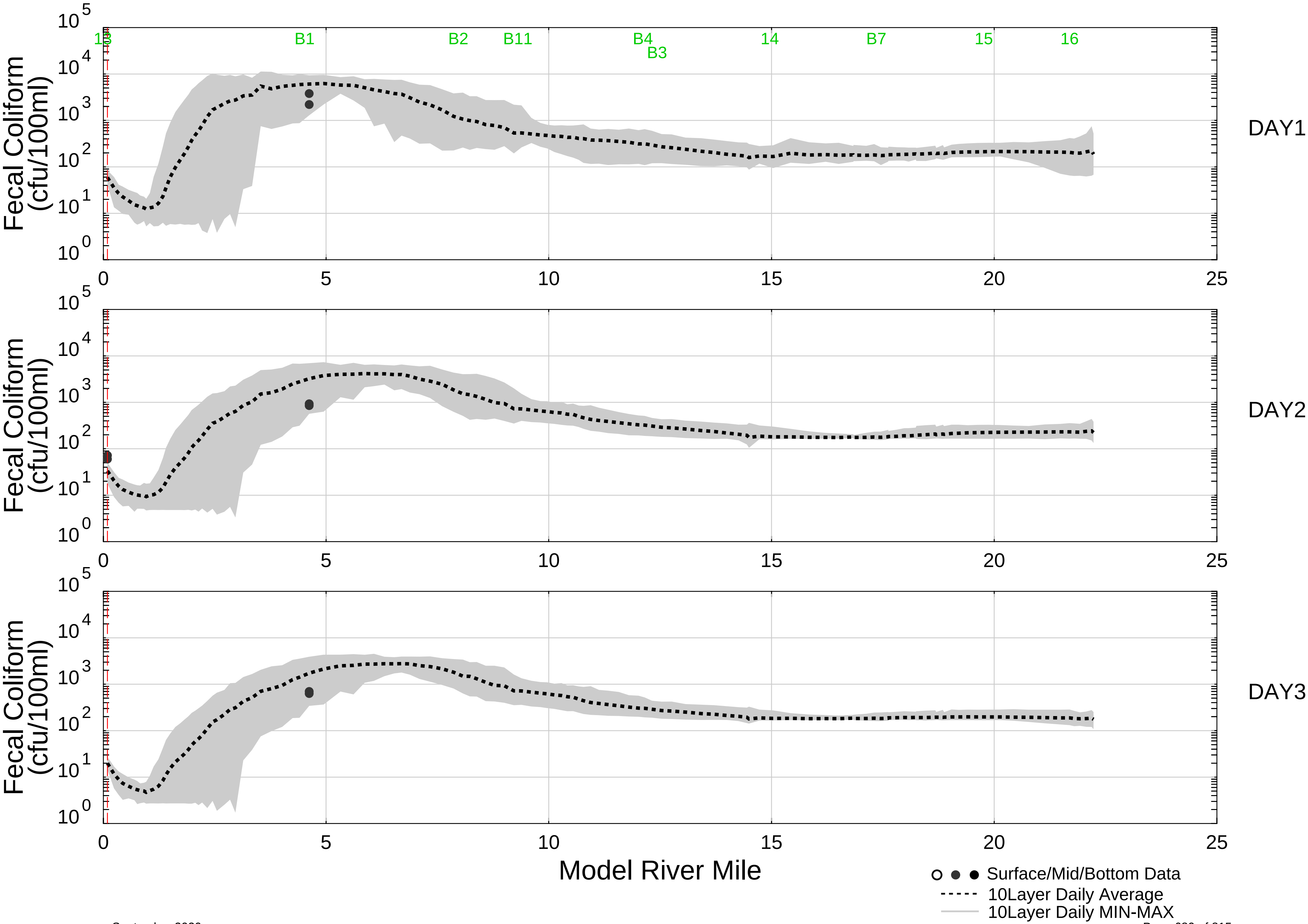
Appendix F-5

Additional Validation Fecal Coliform Transect Figures


WW Event : Jan 4-6, 2017
Passaic River Transect
Fecal Coliform (cfu/100ml)
DAY1
DAY2
DAY3
B24
2
3
B22
4
5
7
8
10
11
B6
B8
12
Saddle R
Third Ri
Second R
Model River Mile
Surface/Mid/Bottom Data
10Layer Daily Average
10Layer Daily MIN-MAX

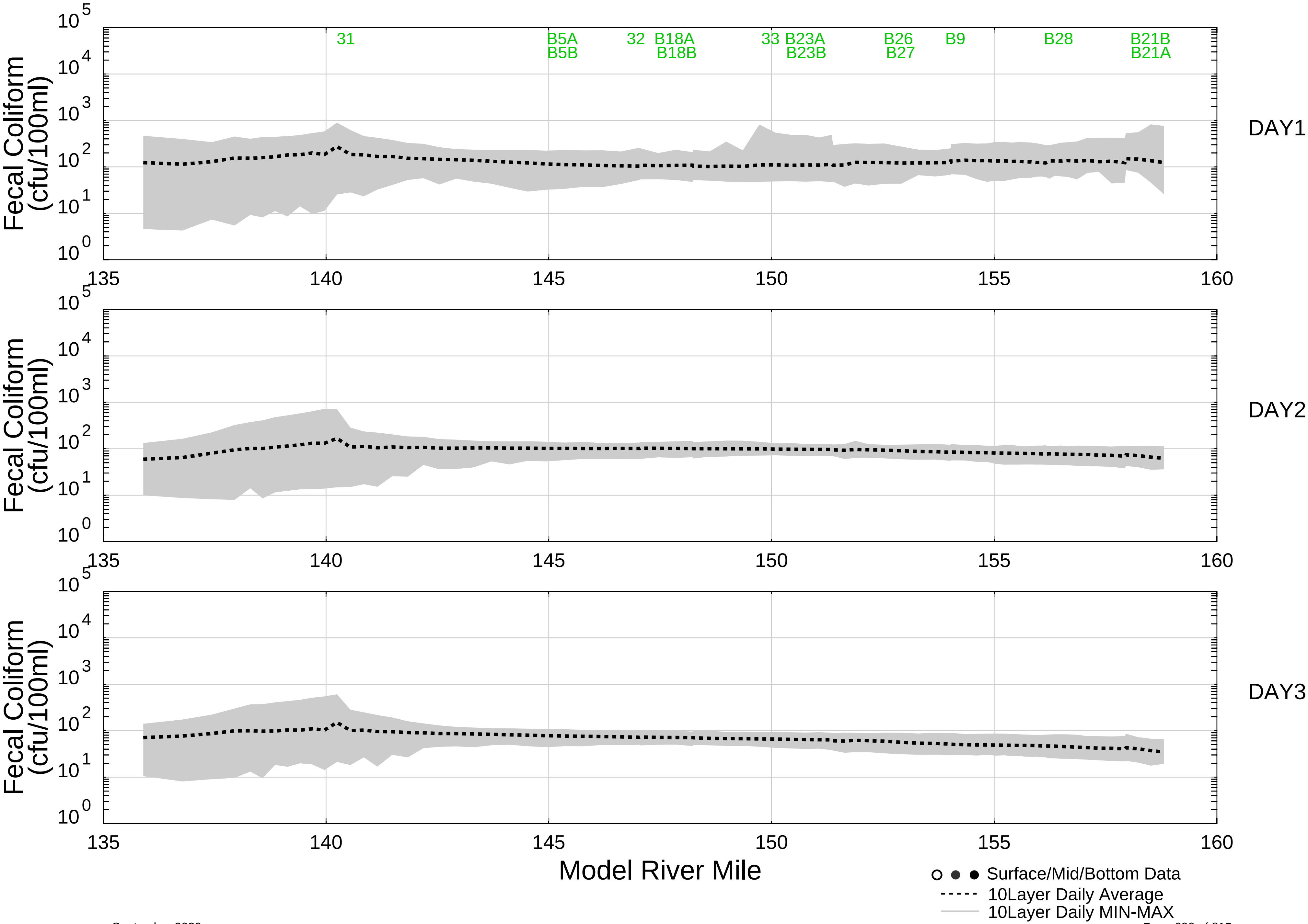
WW Event : Jan 4-6, 2017

Hackensack River Transect



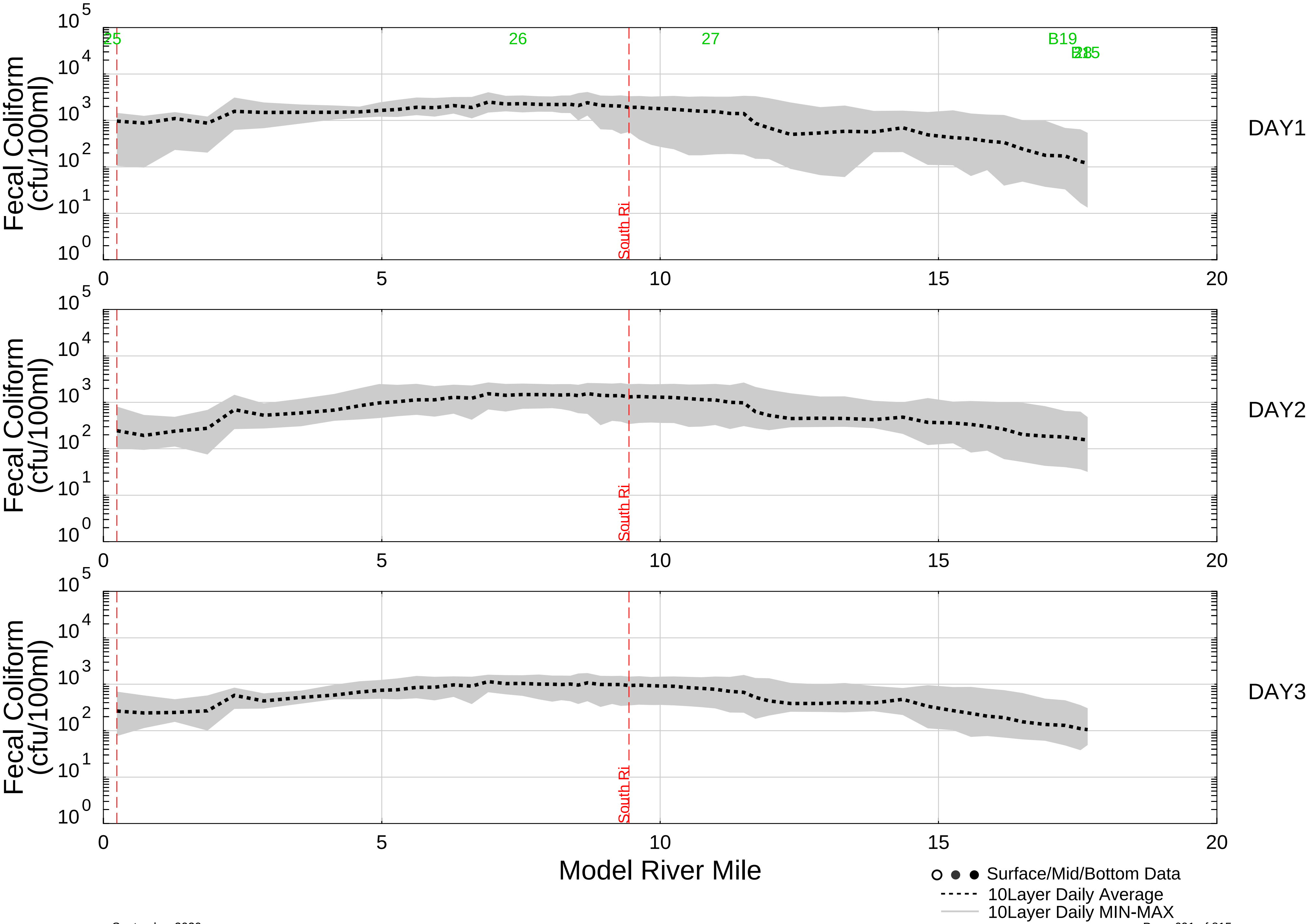
WW Event : Jan 4-6, 2017

Hudson River Transect



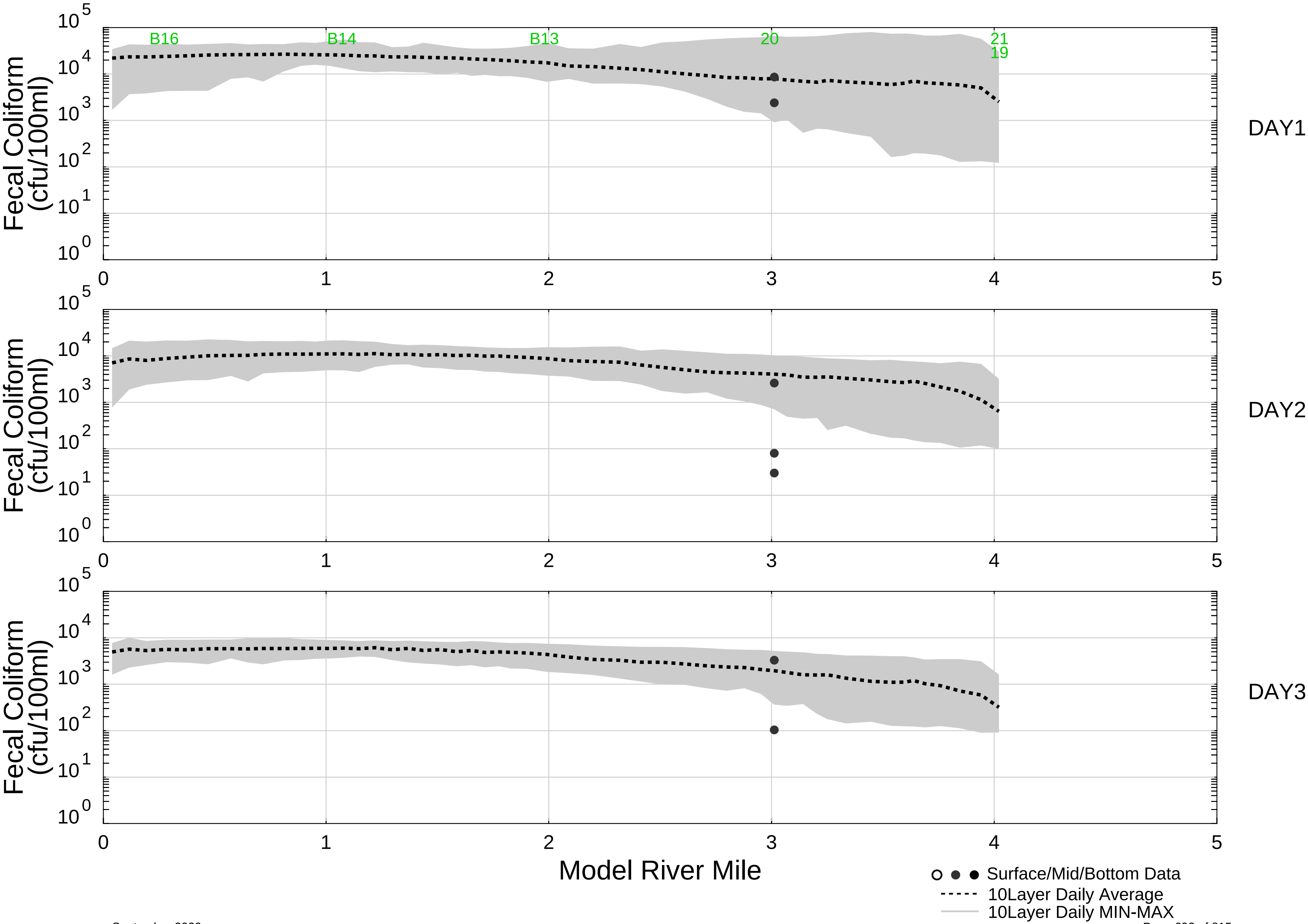
WW Event : Jan 4-6, 2017

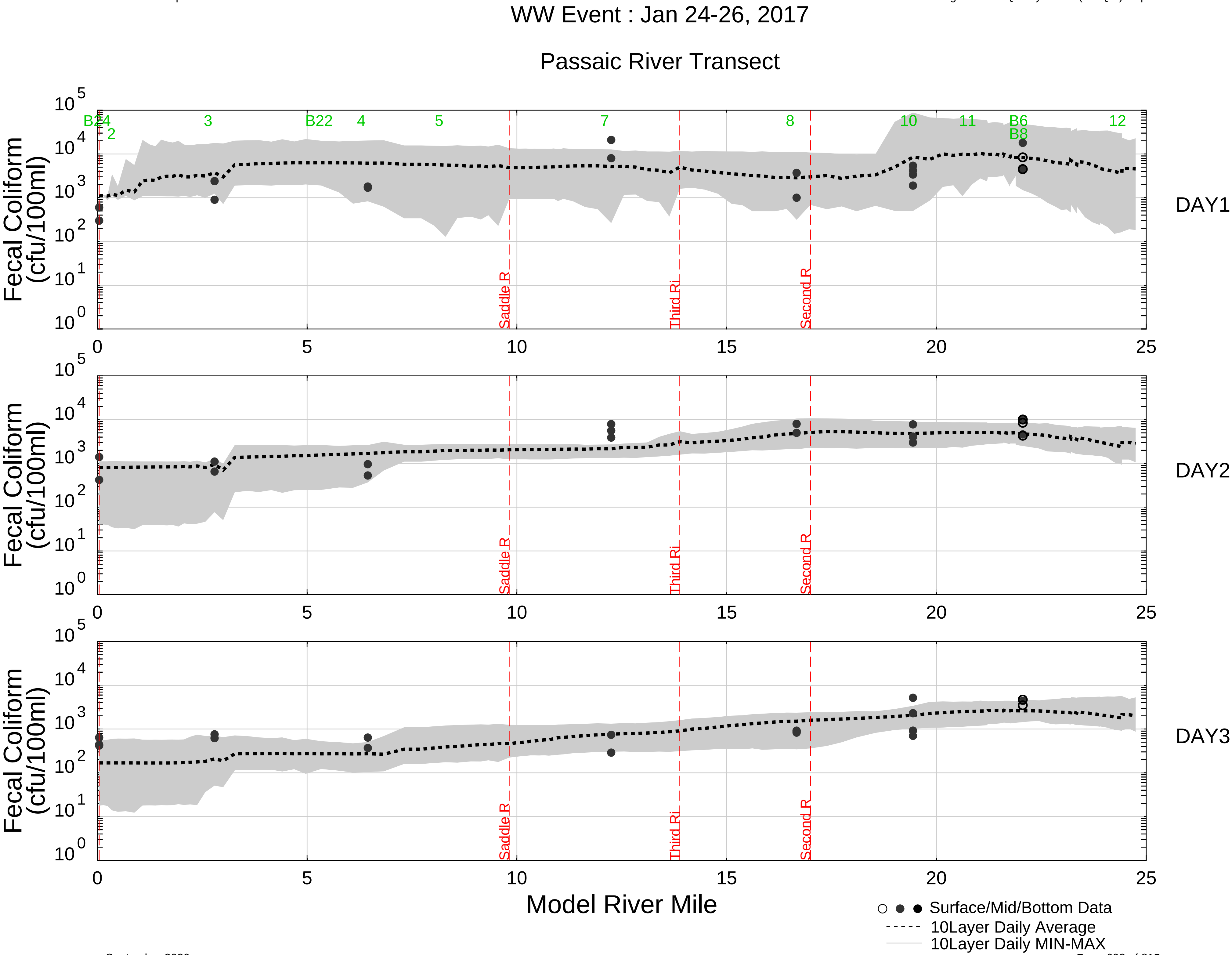
Raritan River Transect



WW Event : Jan 4-6, 2017

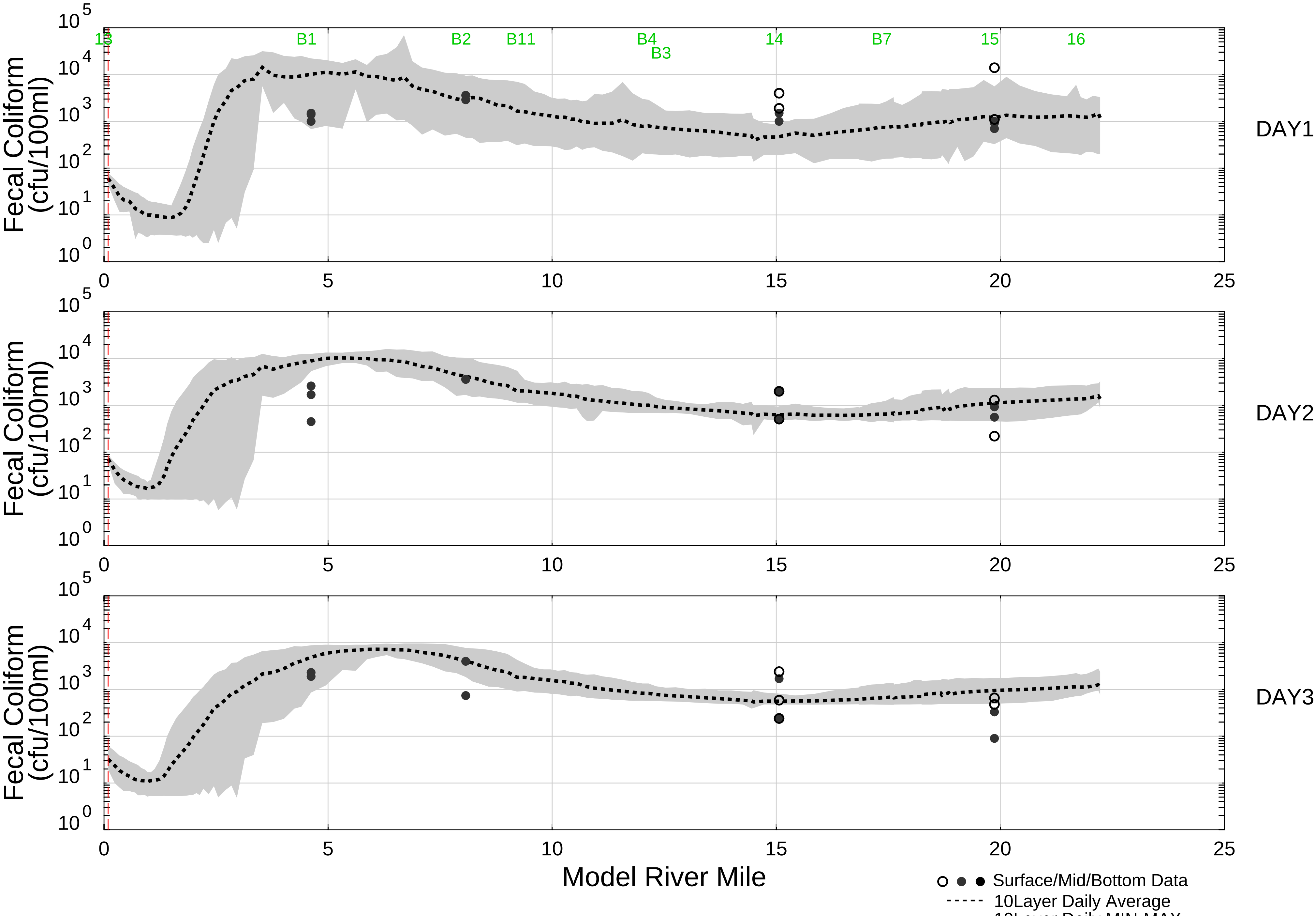
Elizabeth River Transect




WW Event : Jan 24-26, 2017
Passaic River Transect
B24
2
3
B22
4
5
7
8
10
11
B6
B8
12
Saddle R
Third Ri
Second R
Fecal Coliform (cfu/100ml)
DAY1
DAY2
DAY3
Model River Mile
Surface/Mid/Bottom Data
10Layer Daily Average
10Layer Daily MIN-MAX

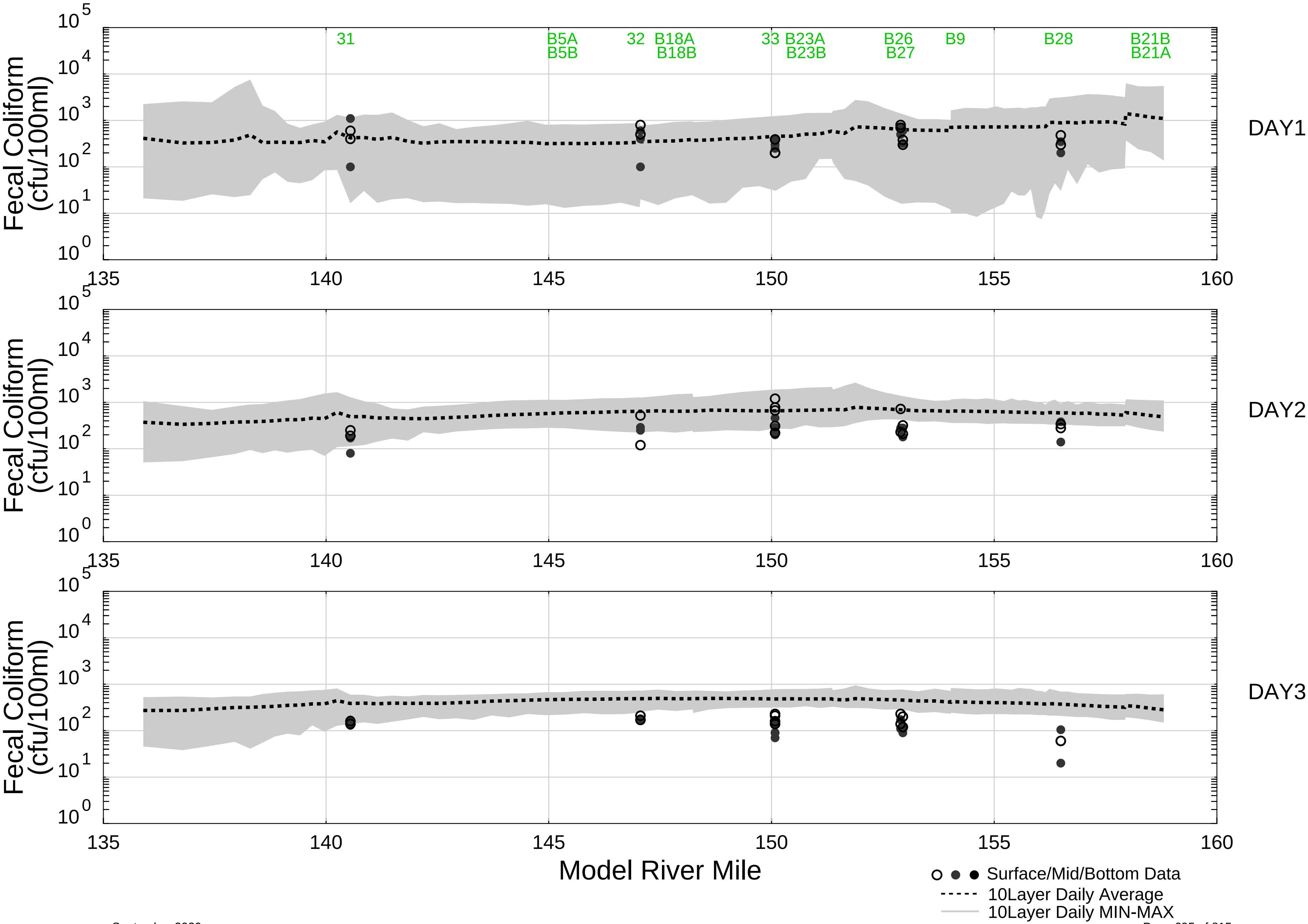
WW Event : Jan 24-26, 2017

Hackensack River Transect



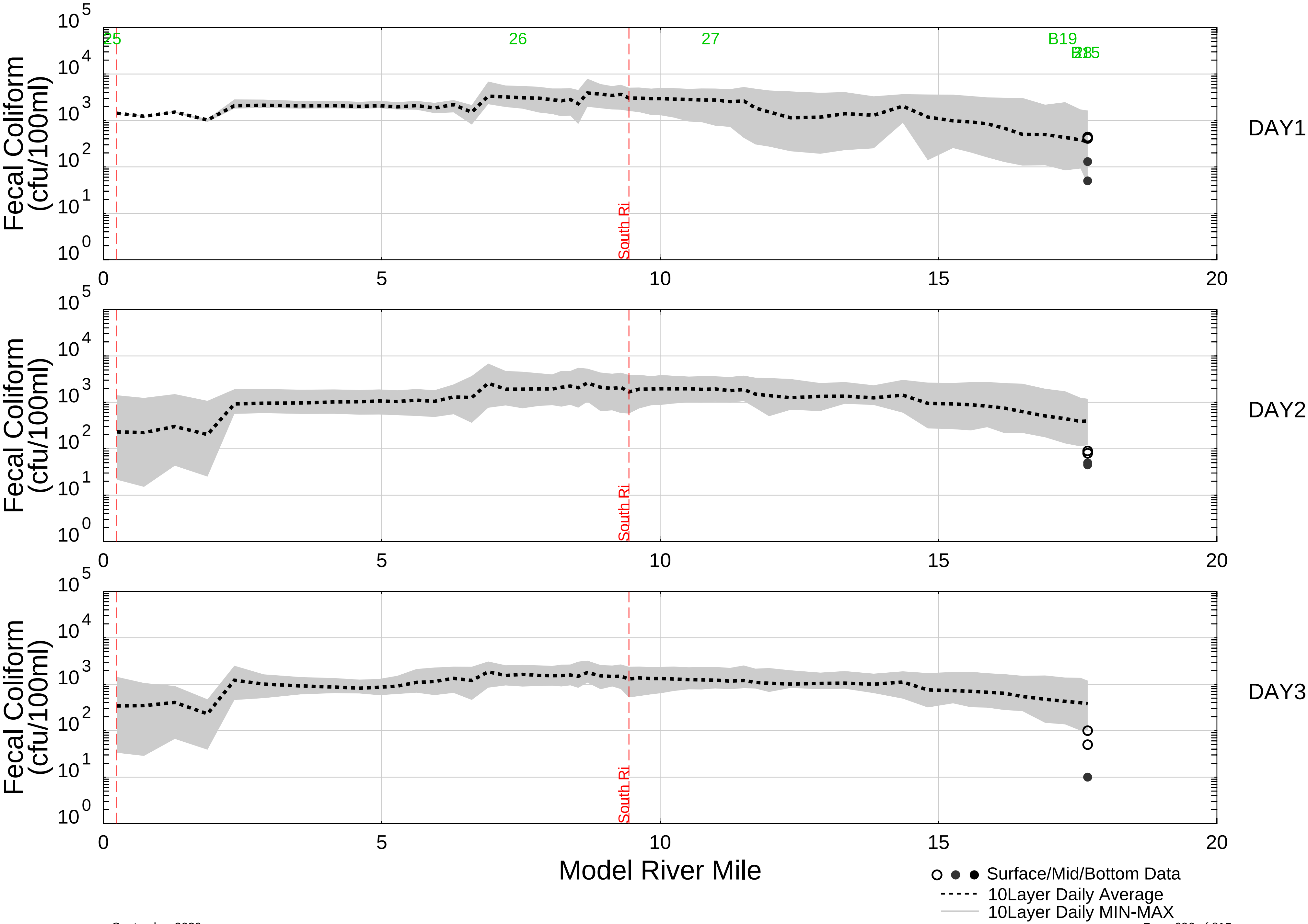
WW Event : Jan 24-26, 2017

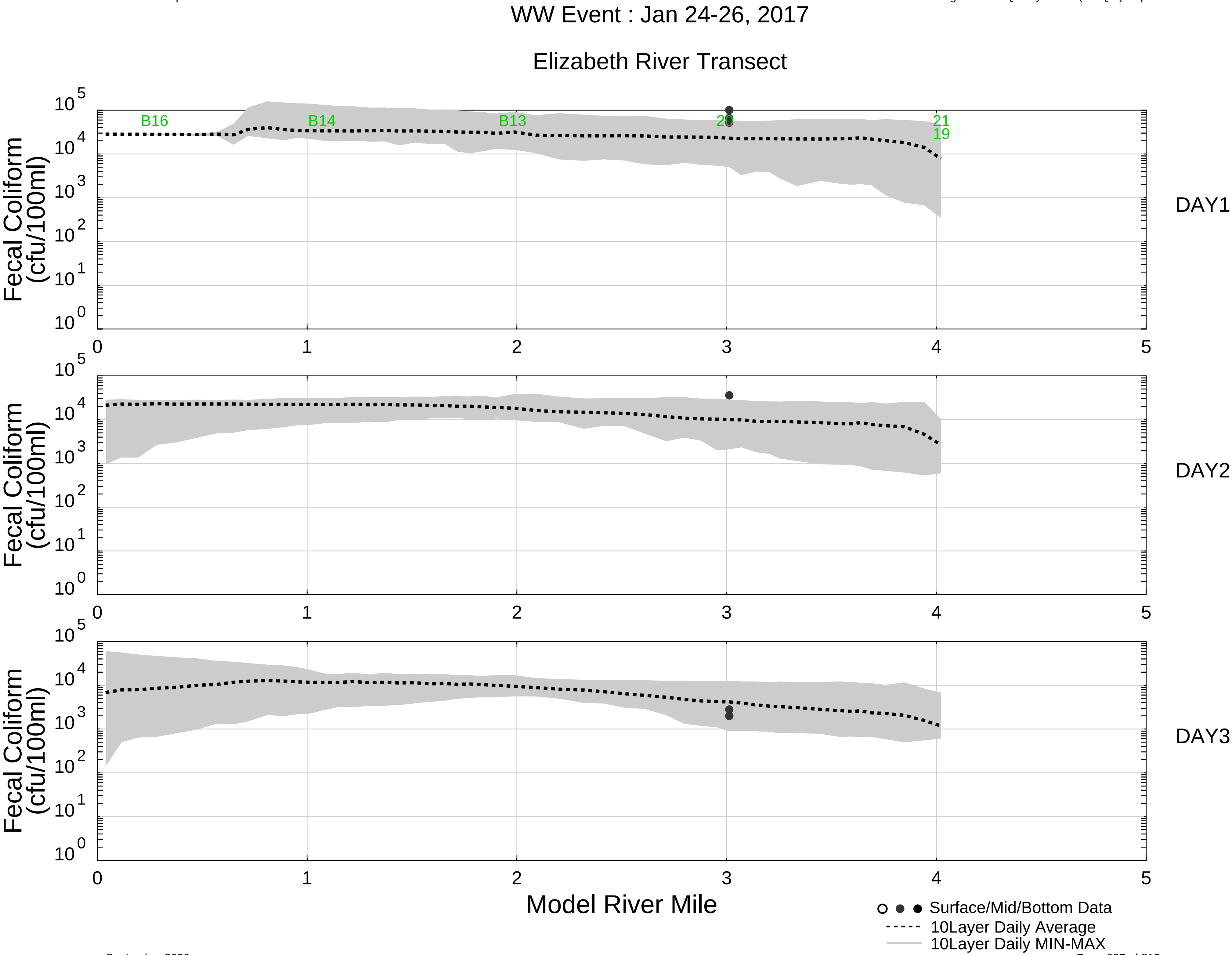
Hudson River Transect



WW Event : Jan 24-26, 2017

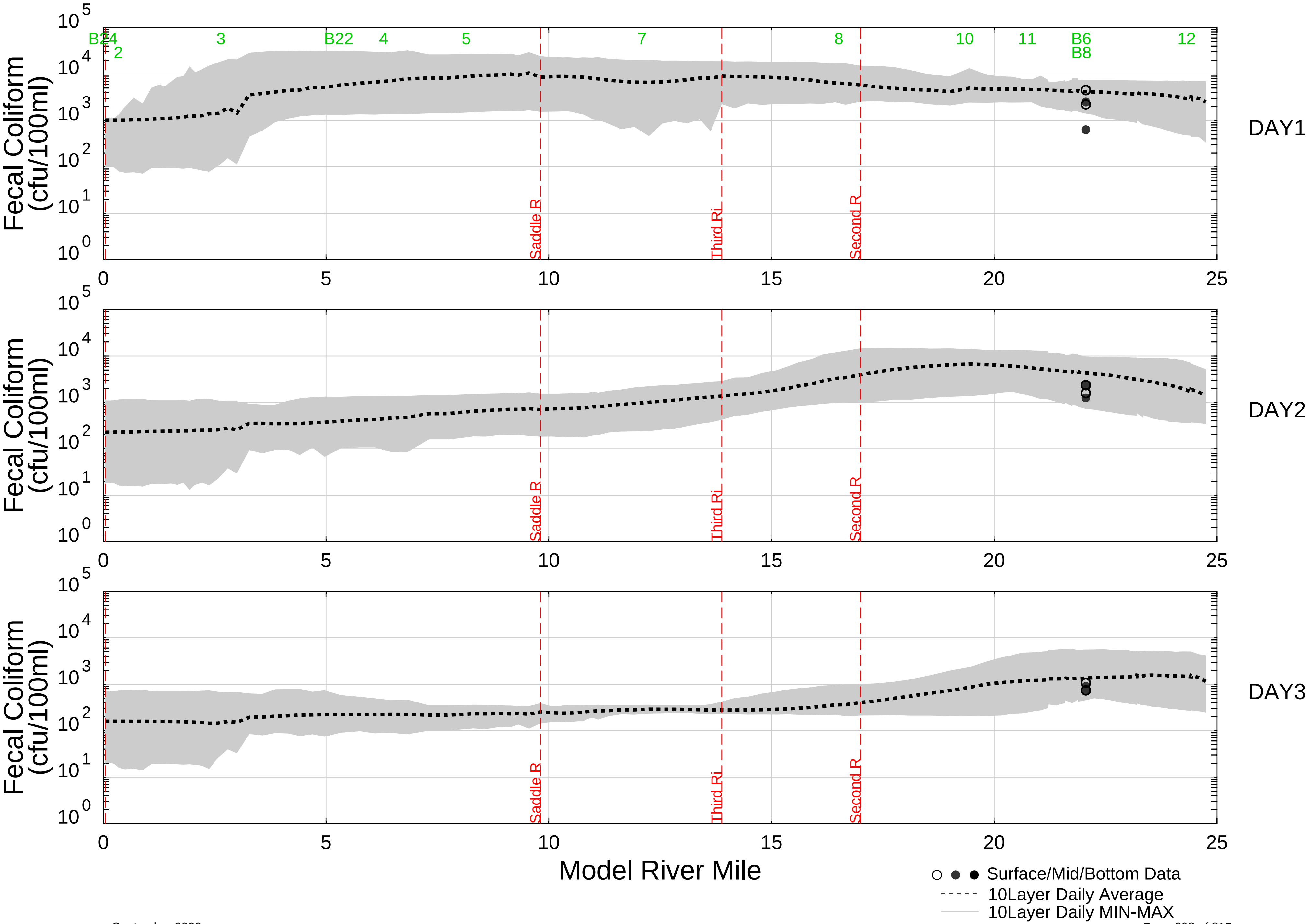
Raritan River Transect




WW Event : Jan 24-26, 2017
Elizabeth River Transect
B16
B14
B13
20
21
19
DAY1
DAY2
DAY3
Fecal Coliform (cfu/100ml)
Model River Mile
Surface/Mid/Bottom Data
10Layer Daily Average
10Layer Daily MIN-MAX

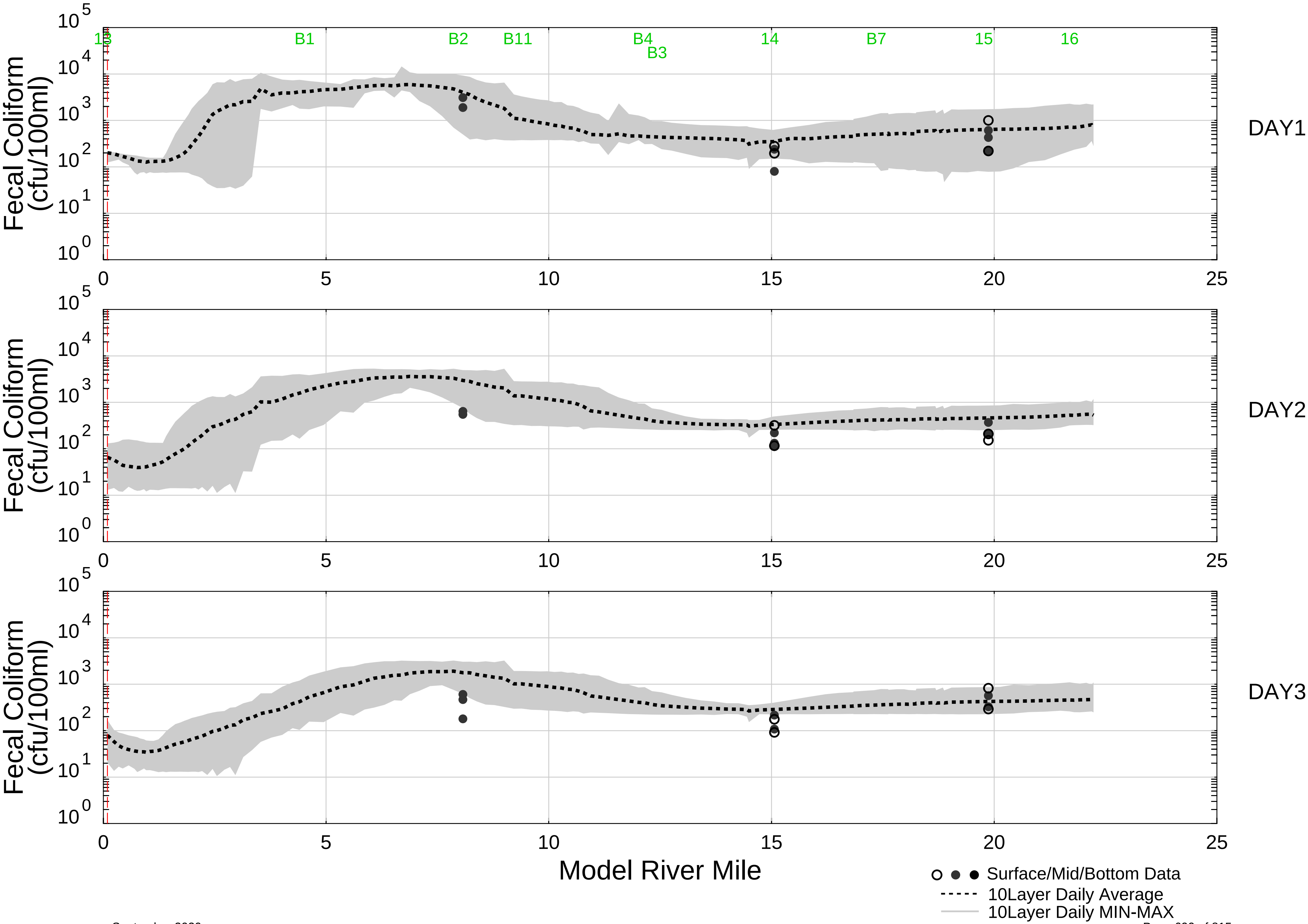
WW Event : Apr 26-28, 2017

Passaic River Transect



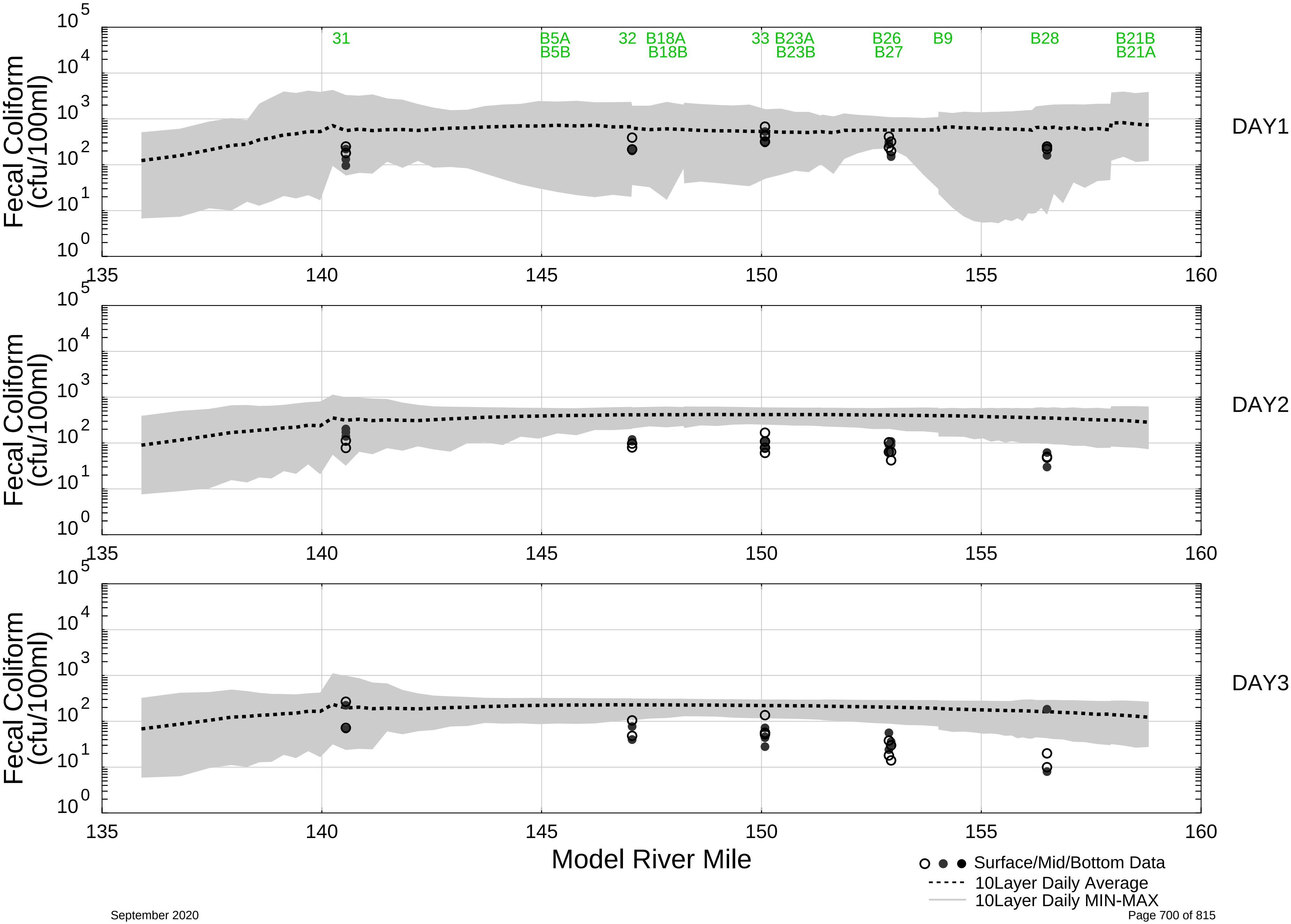
WW Event : Apr 26-28, 2017

Hackensack River Transect



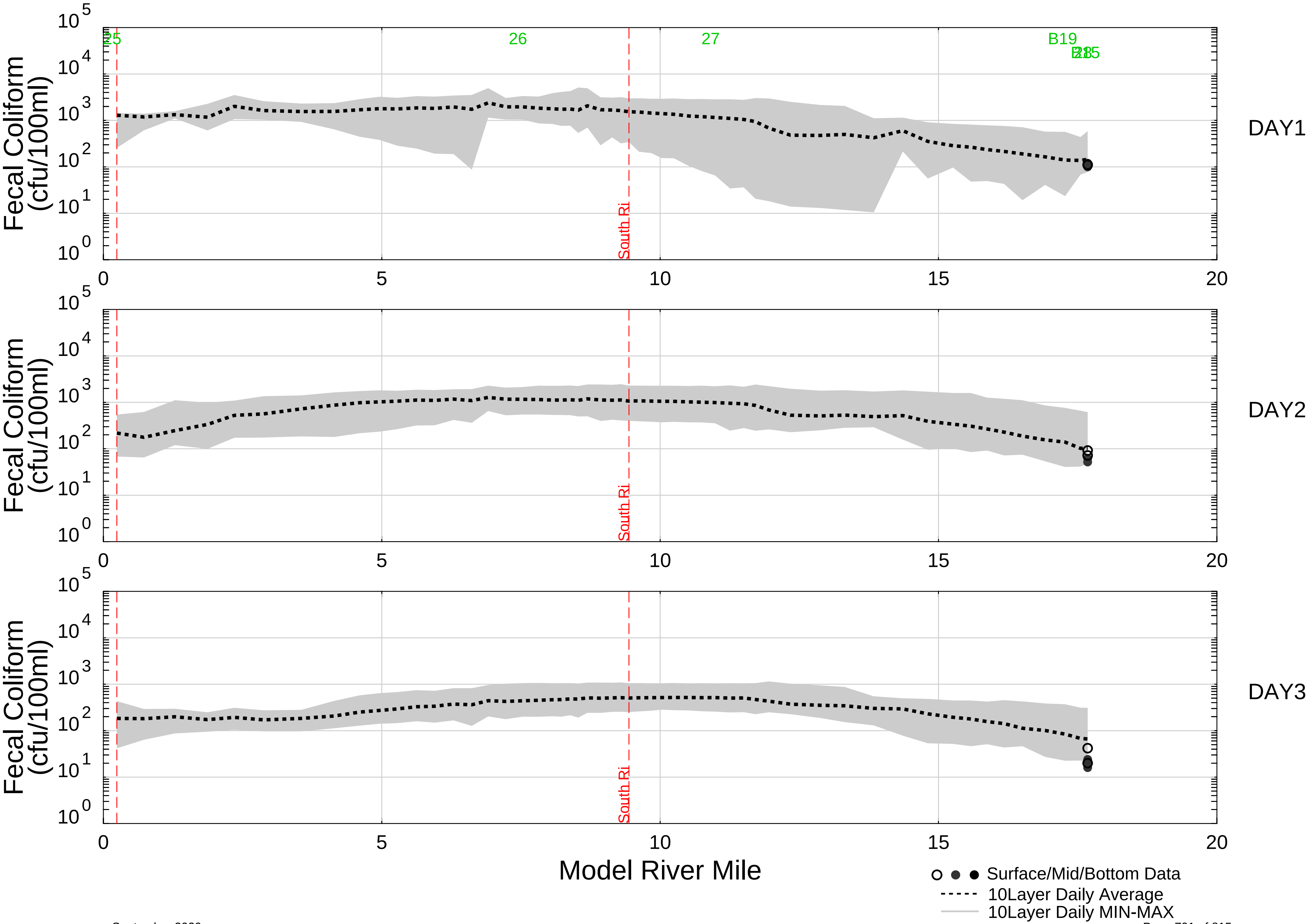
WW Event : Apr 26-28, 2017

Hudson River Transect



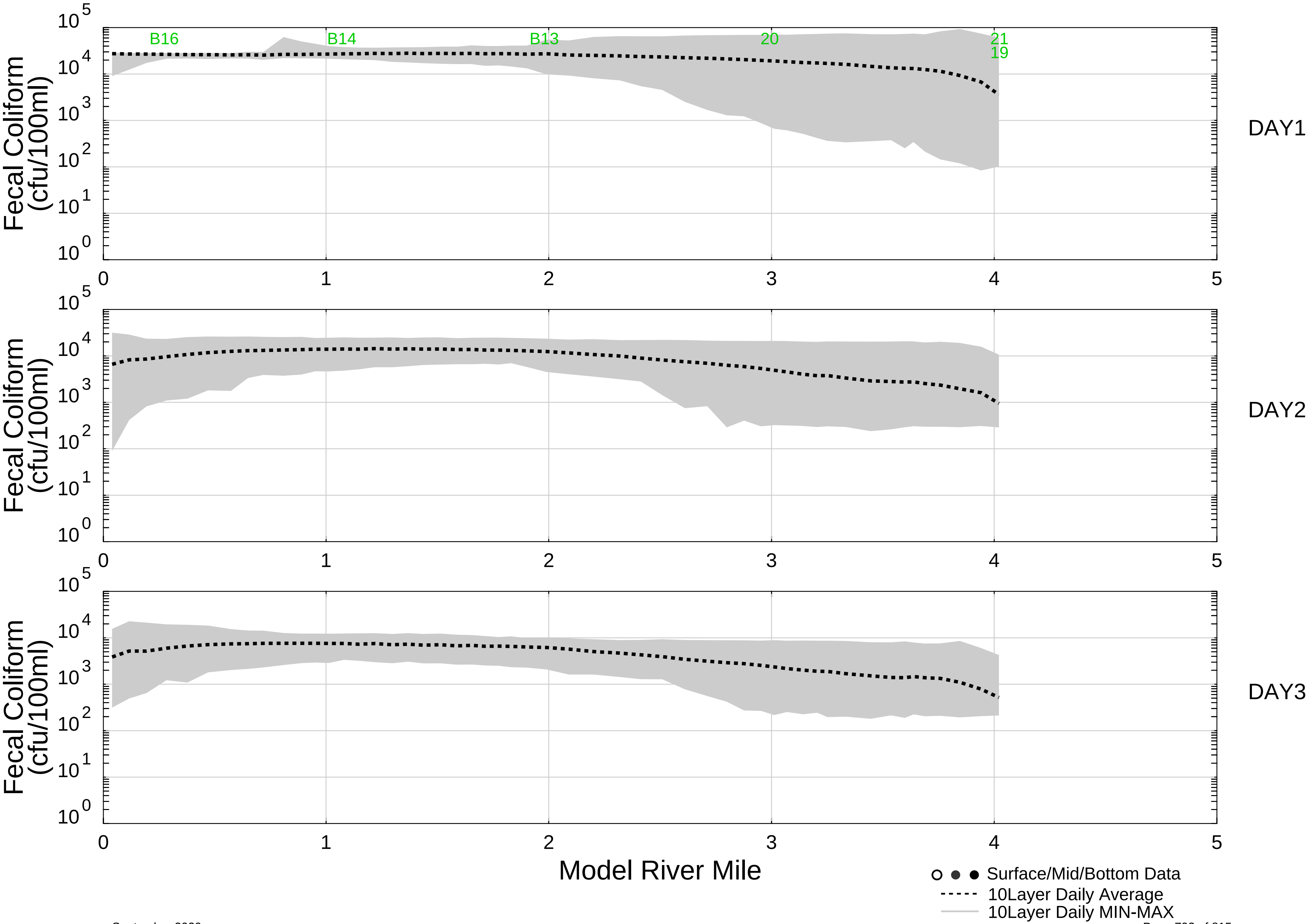
WW Event : Apr 26-28, 2017

Raritan River Transect



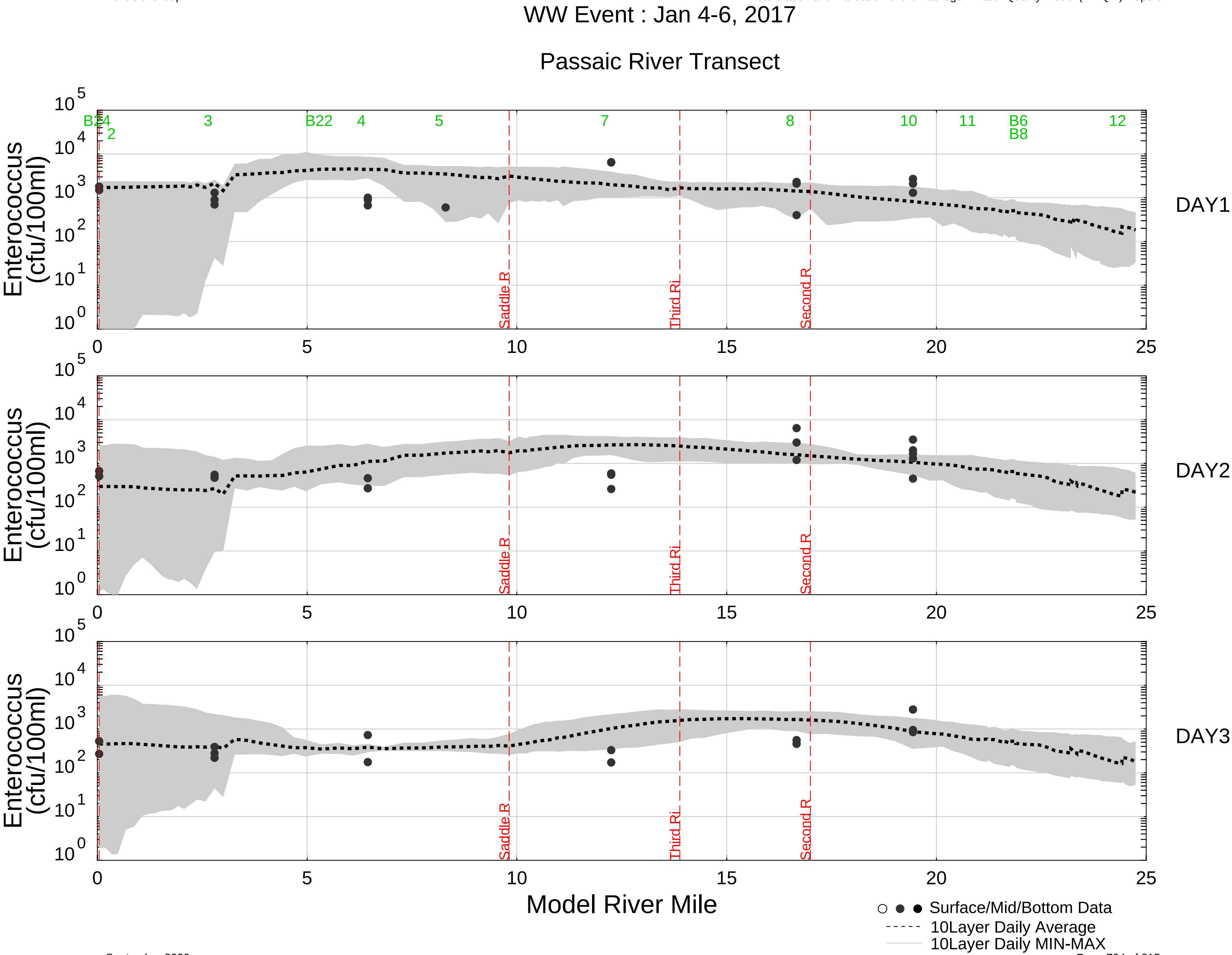
WW Event : Apr 26-28, 2017

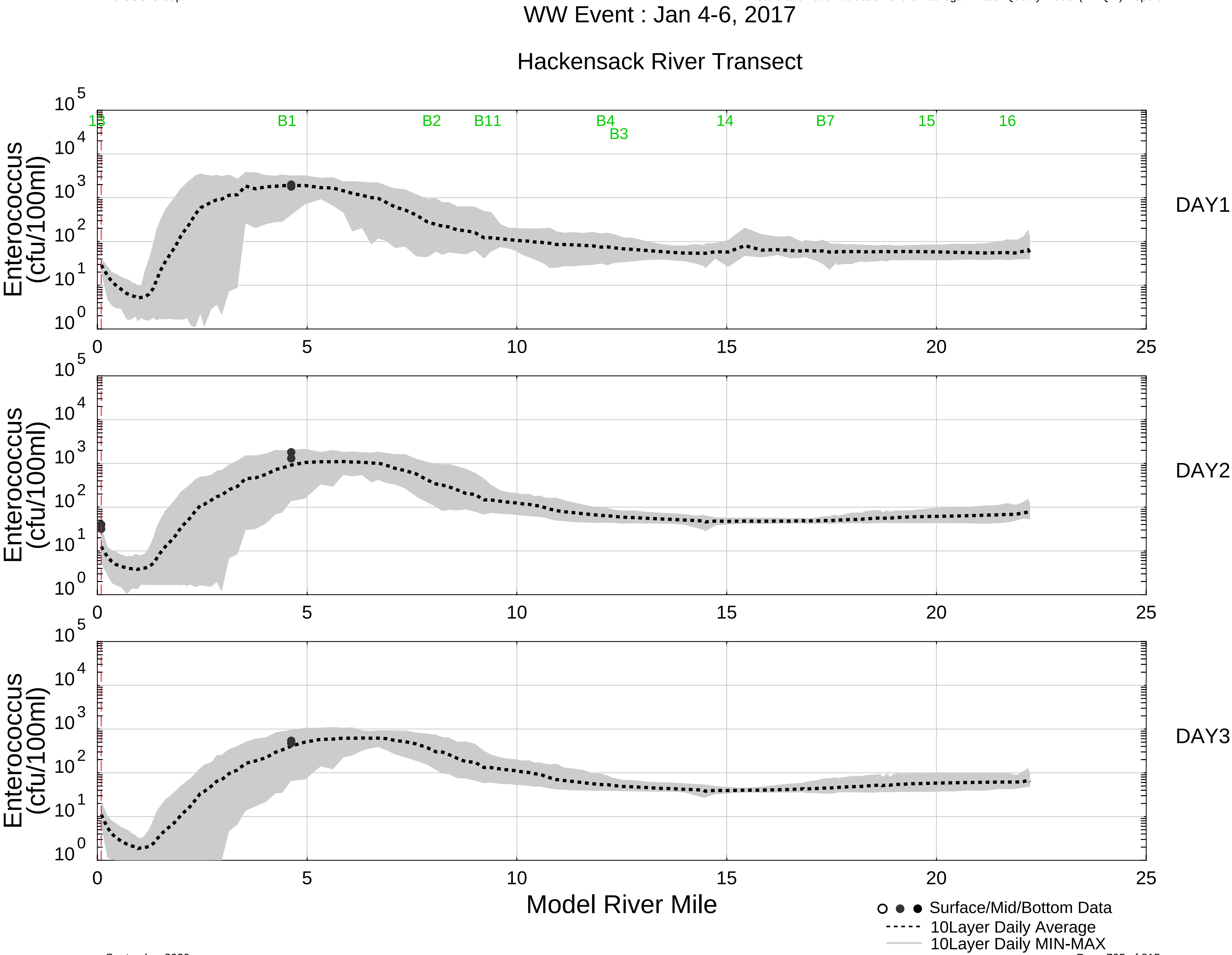
Elizabeth River Transect

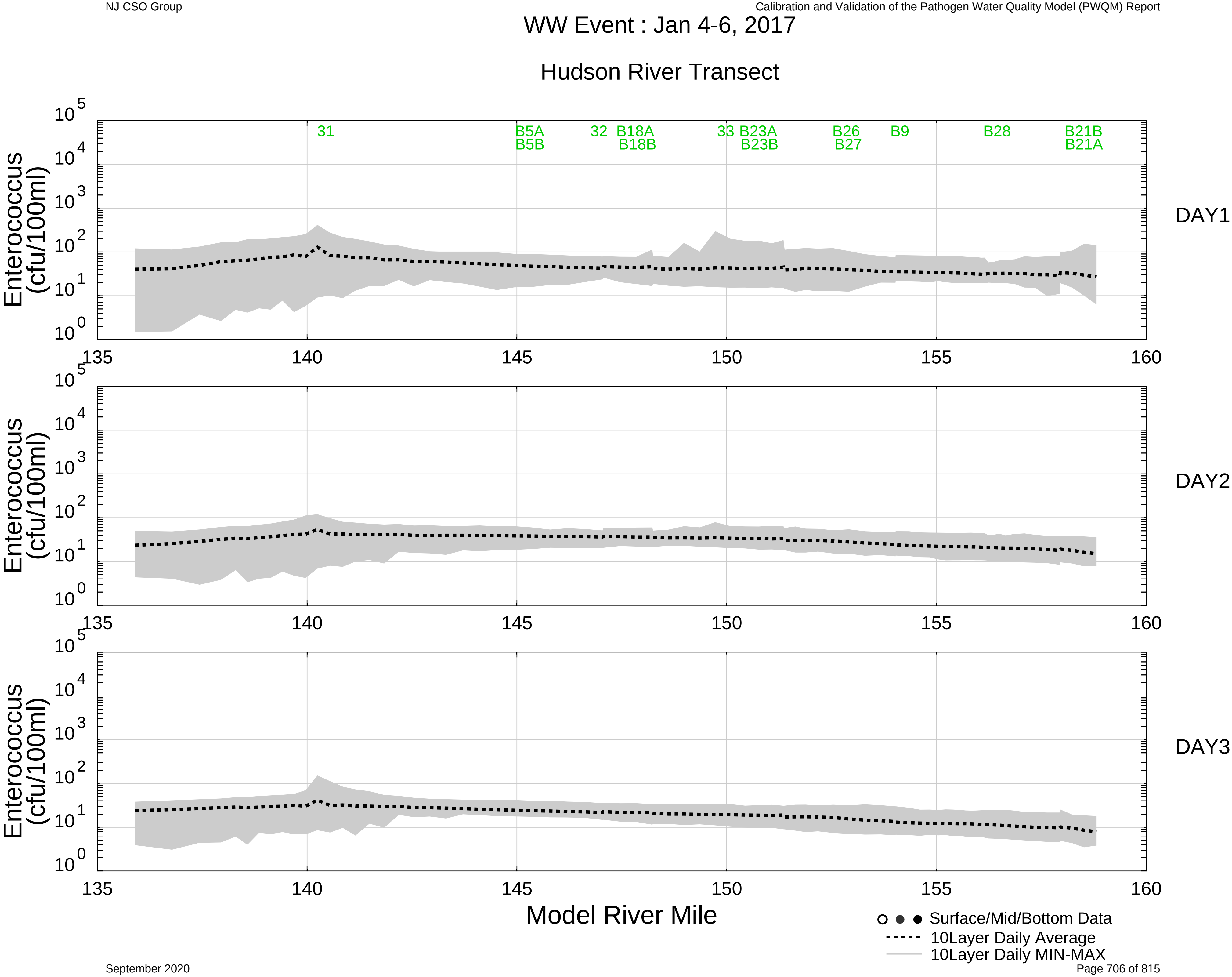


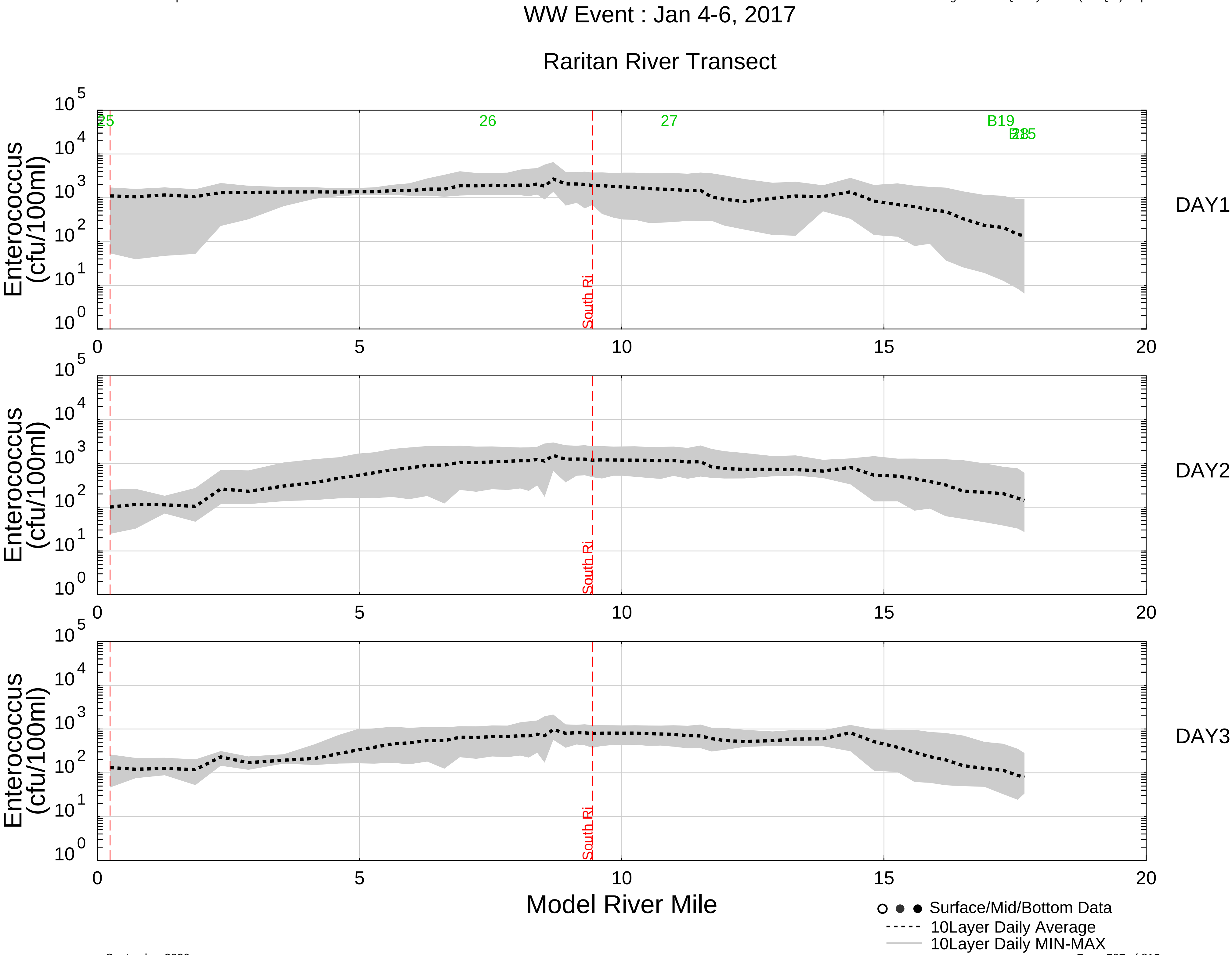
Appendix F-6

Additional Validation Enterococci Transect Figures


WW Event : Jan 4-6, 2017
Passaic River Transect
B24
2
3
B22
4
5
7
8
10
11
B6
B8
12
Saddle R
Third Ri
Second R
Enterococcus (cfu/100ml)
DAY1
DAY2
DAY3
Model River Mile
Surface/Mid/Bottom Data
10Layer Daily Average
10Layer Daily MIN-MAX

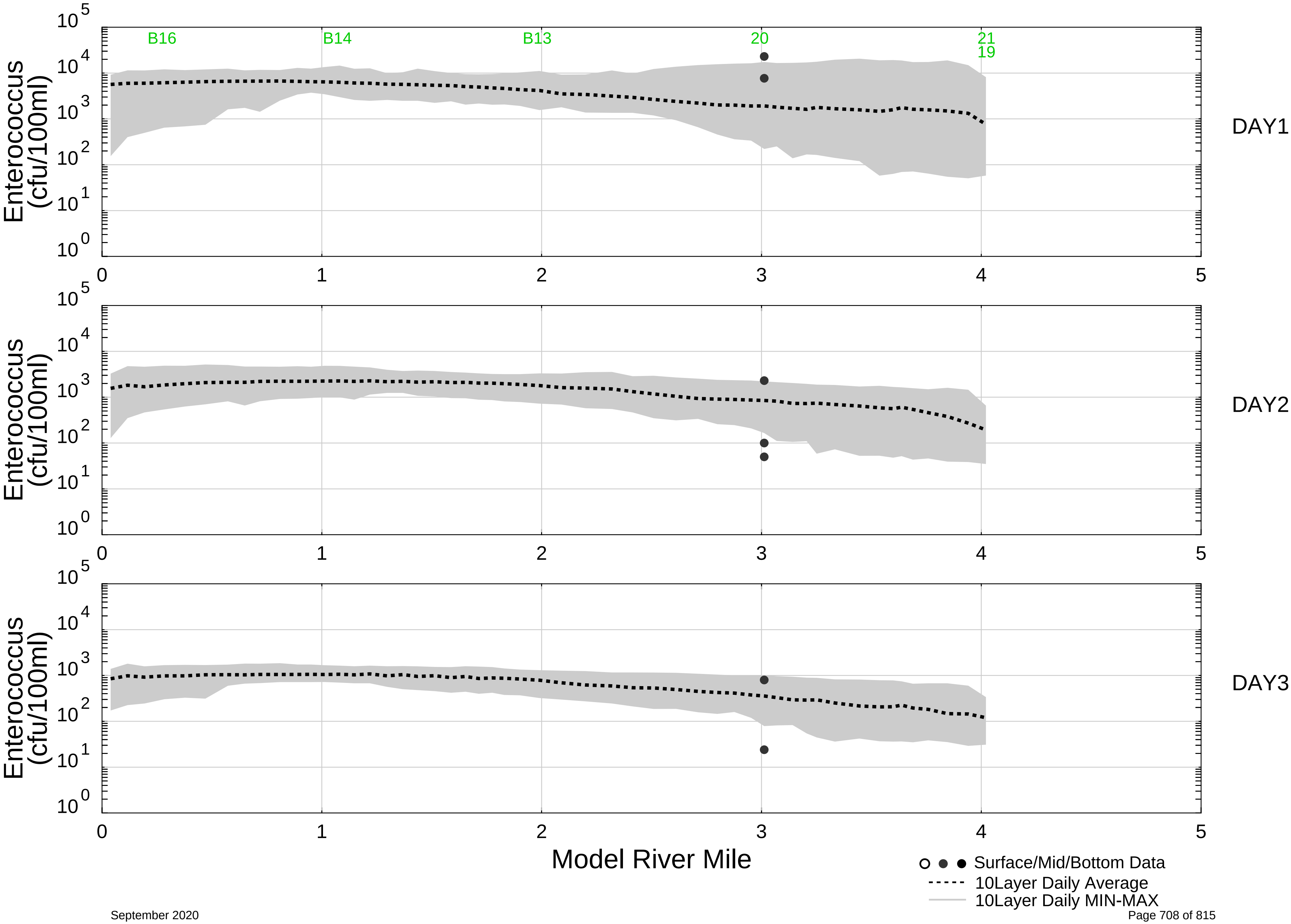

WW Event : Jan 4-6, 2017
Hackensack River Transect
13
B1
B2
B11
B4
B3
14
B7
15
16
DAY1
DAY2
DAY3
Enterococcus (cfu/100ml)
10^0
10^1
10^2
10^3
10^4
10^5
0
5
10
15
20
25
Model River Mile
Surface/Mid/Bottom Data
10Layer Daily Average
10Layer Daily MIN-MAX

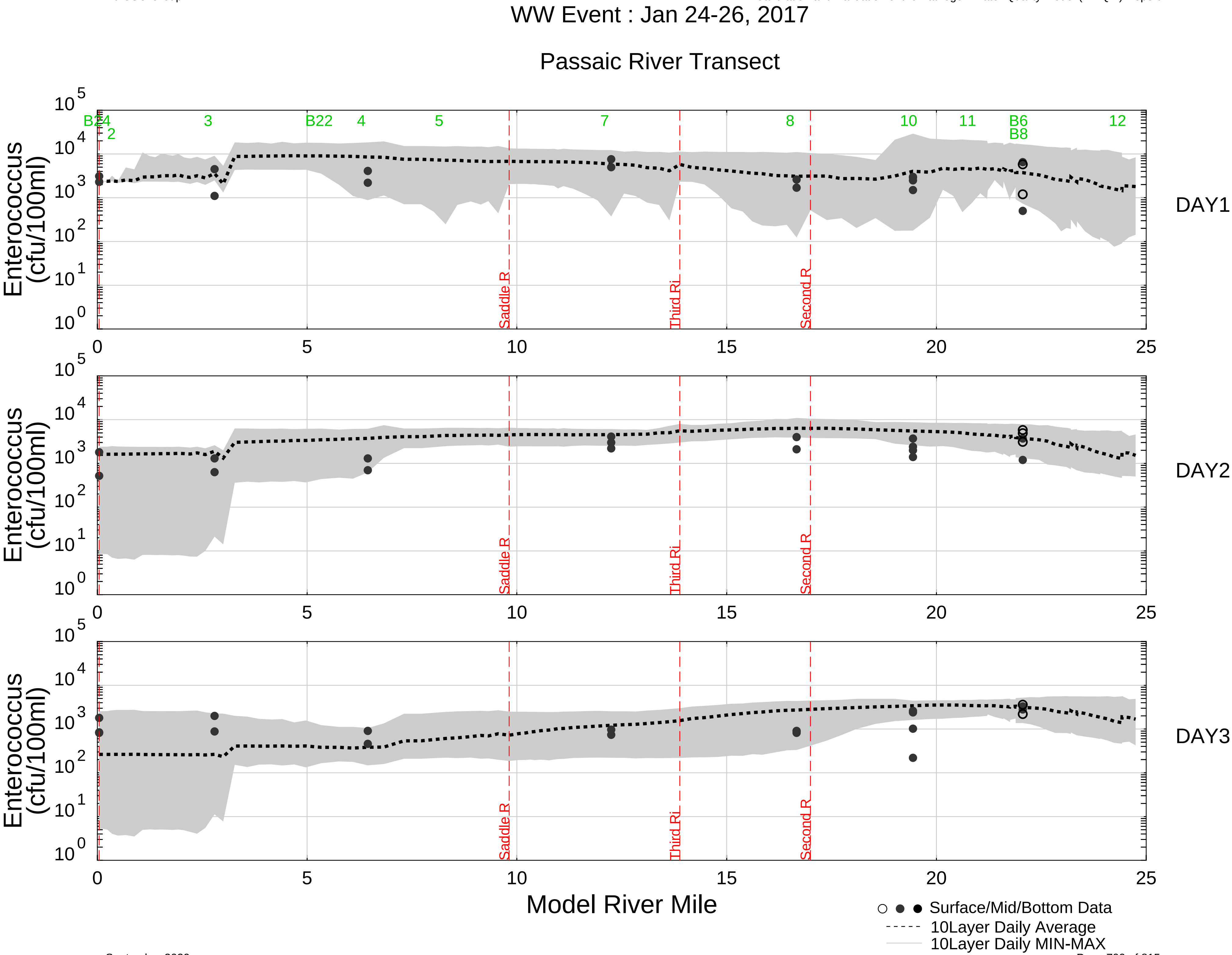

WW Event : Jan 4-6, 2017
Hudson River Transect
31
B5A
B5B
32
B18A
B18B
33
B23A
B23B
B26
B27
B9
B28
B21B
B21A
DAY1
DAY2
DAY3
Enterococcus (cfu/100ml)
10^0
10^1
10^2
10^3
10^4
10^5
135
140
145
150
155
160
Model River Mile
Surface/Mid/Bottom Data
10Layer Daily Average
10Layer Daily MIN-MAX


WW Event : Jan 4-6, 2017
Raritan River Transect
Enterococcus (cfu/100ml)
25
26
27
B19
B18
B15
South Ri
DAY1
DAY2
DAY3
0
5
10
15
20
10^0
10^1
10^2
10^3
10^4
10^5
Model River Mile
Surface/Mid/Bottom Data
10Layer Daily Average
10Layer Daily MIN-MAX

WW Event : Jan 4-6, 2017

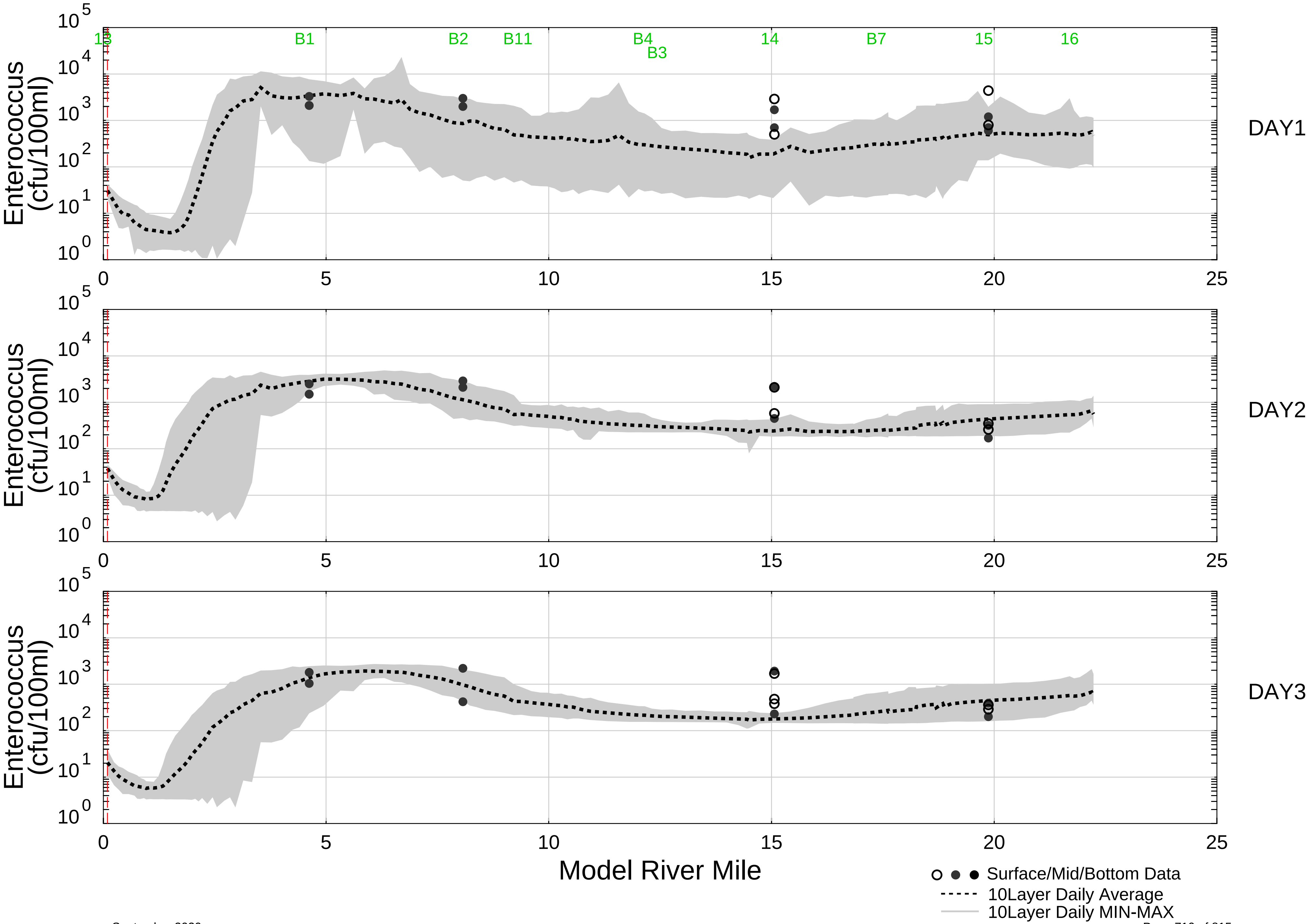
Elizabeth River Transect




WW Event : Jan 24-26, 2017
Passaic River Transect
Enterococcus (cfu/100ml)
B24
2
3
B22
4
5
7
8
10
11
B6
B8
12
Saddle R
Third Ri
Second R
DAY1
DAY2
DAY3
Model River Mile
Surface/Mid/Bottom Data
10Layer Daily Average
10Layer Daily MIN-MAX

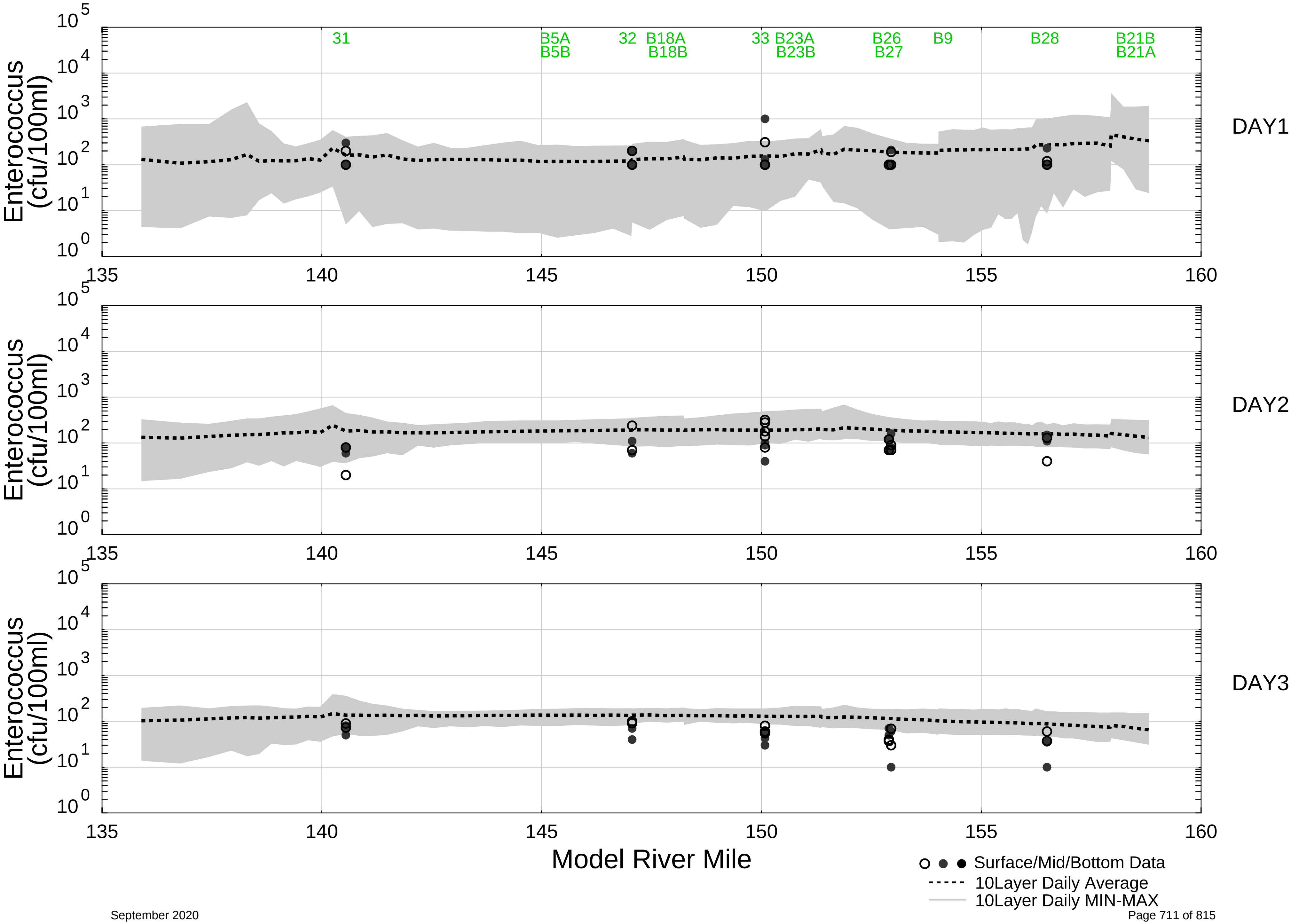
WW Event : Jan 24-26, 2017

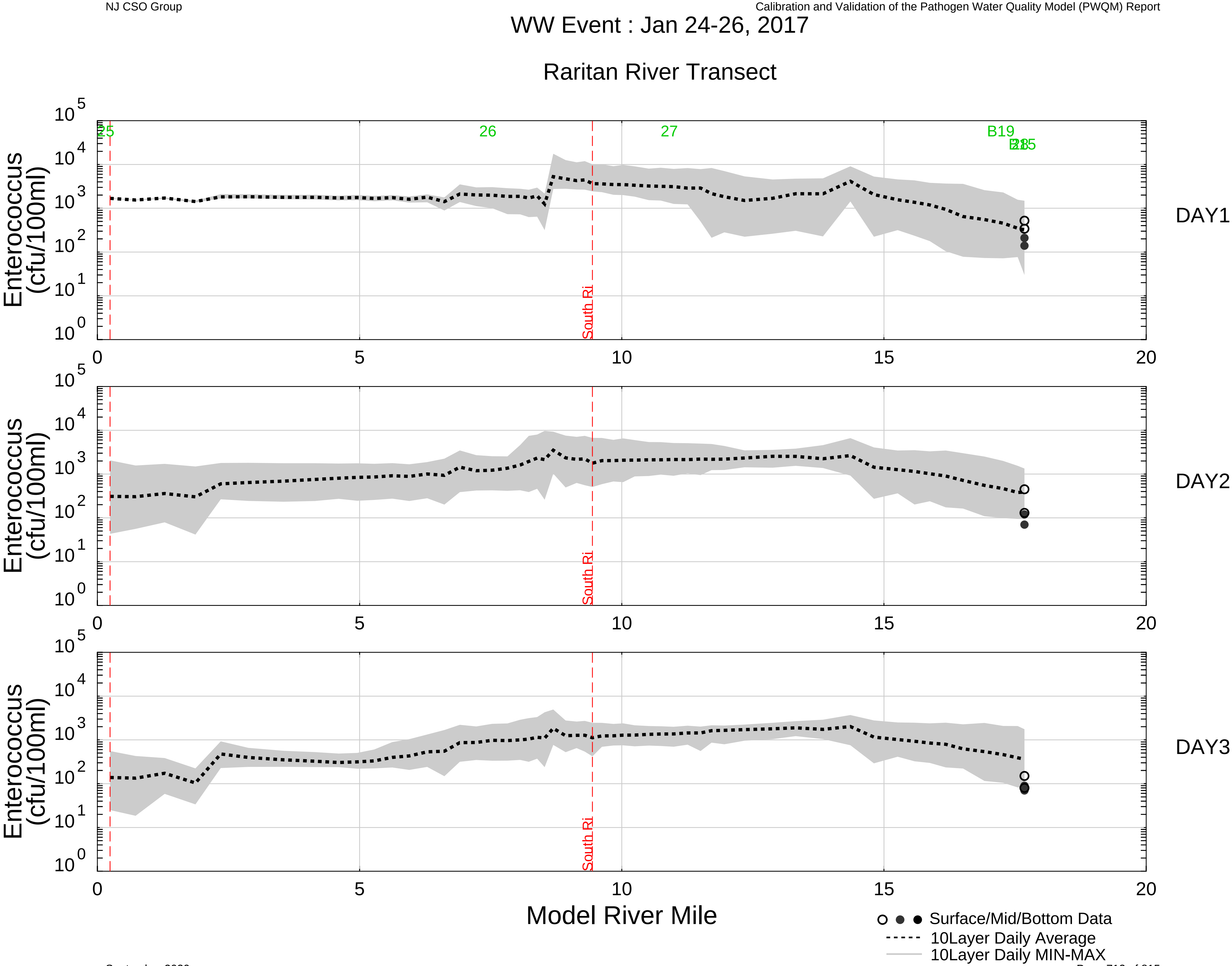
Hackensack River Transect

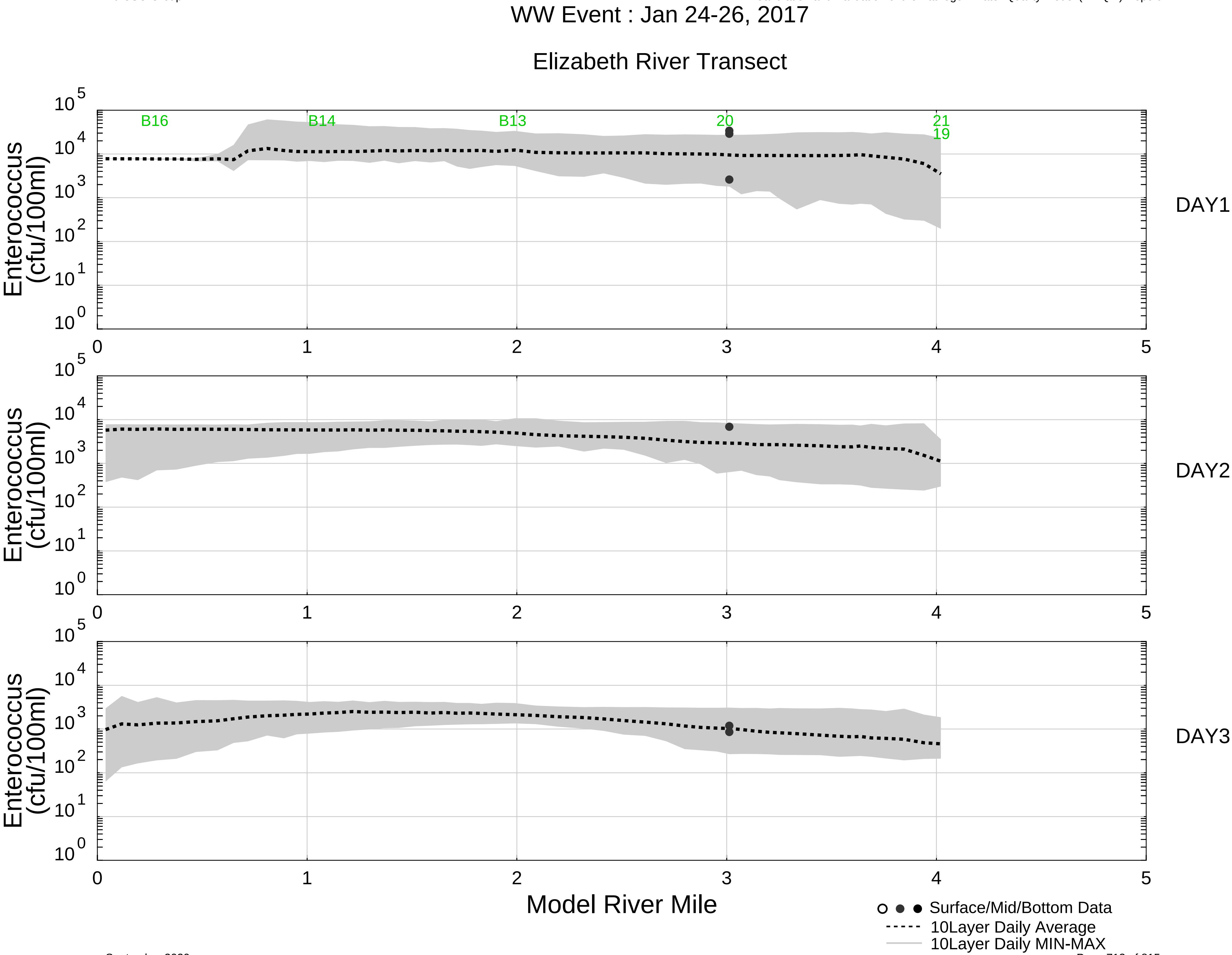


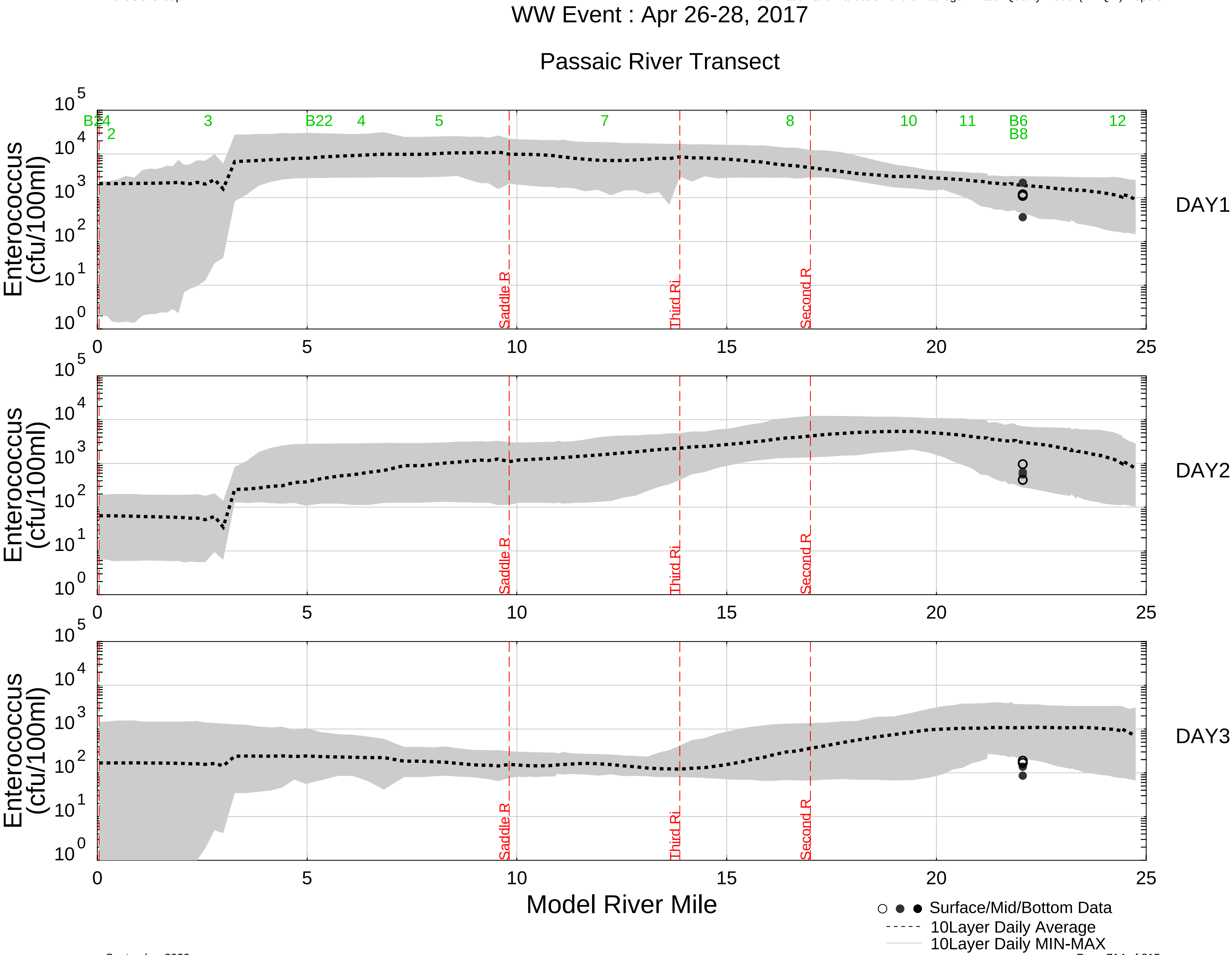
WW Event : Jan 24-26, 2017

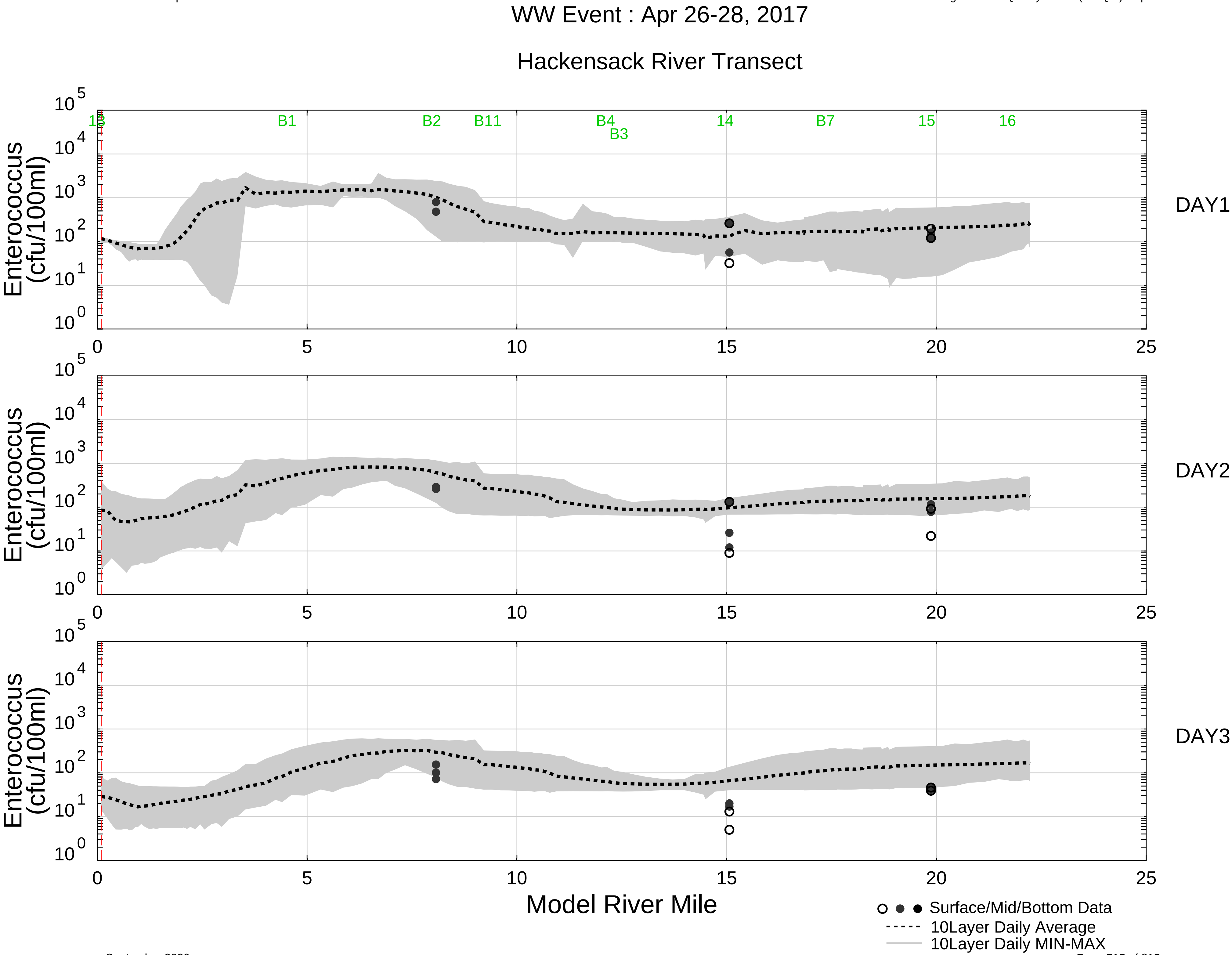
Hudson River Transect

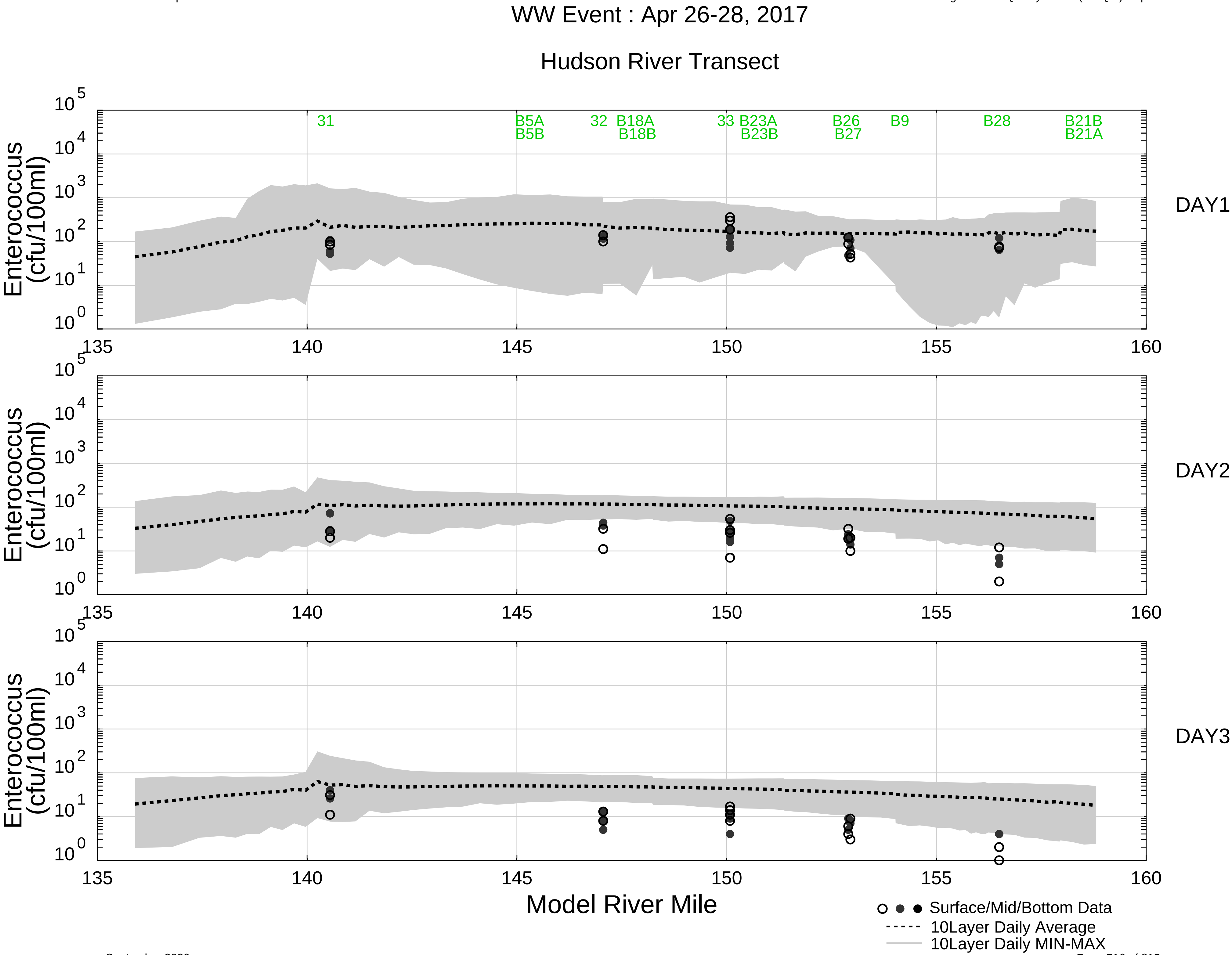


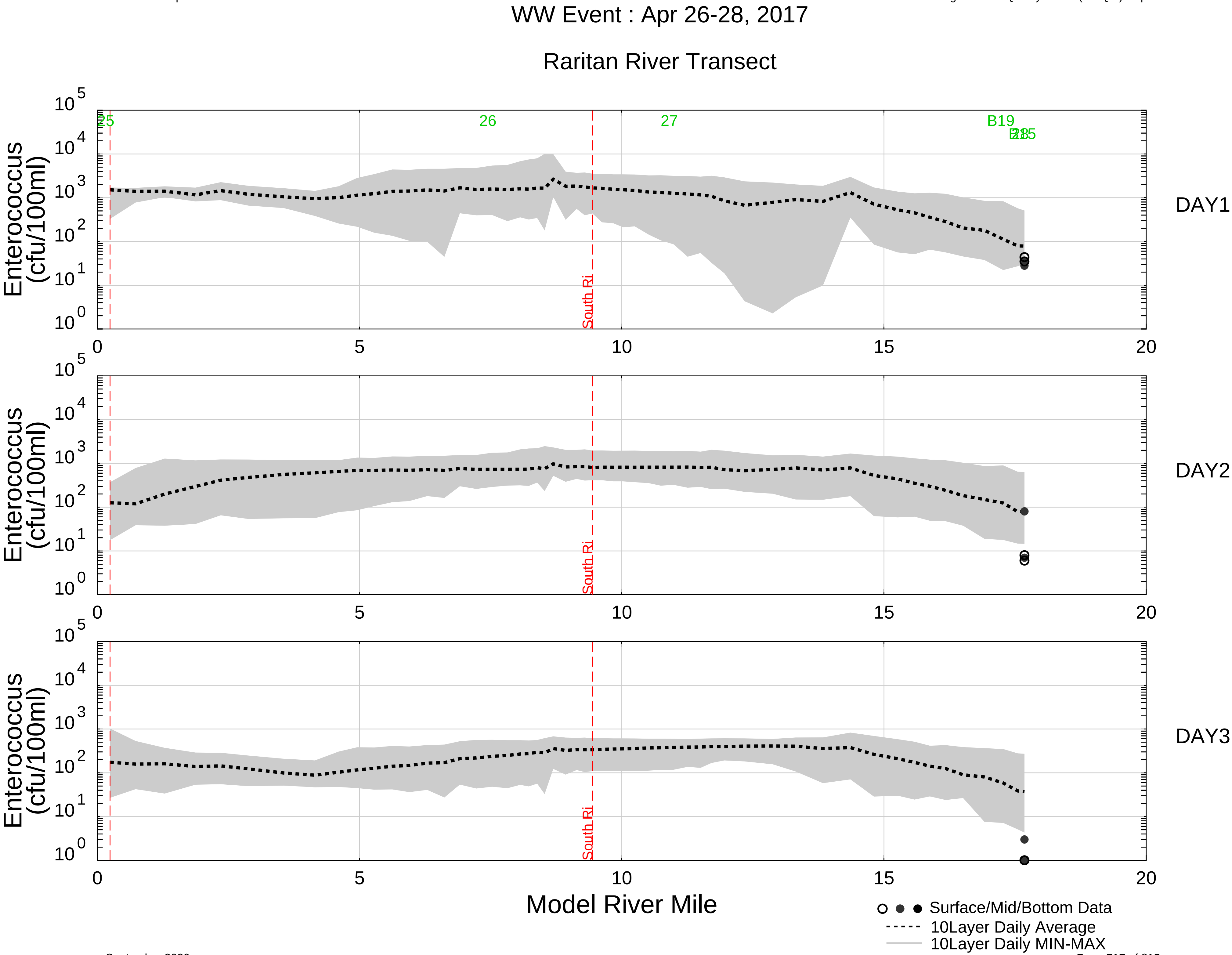

WW Event : Jan 24-26, 2017
Raritan River Transect
25
26
27
B19
B18
B15
South Ri
DAY1
DAY2
DAY3
Enterococcus (cfu/100ml)
10^0
10^1
10^2
10^3
10^4
10^5
0
5
10
15
20
Model River Mile
Surface/Mid/Bottom Data
10Layer Daily Average
10Layer Daily MIN-MAX


WW Event : Jan 24-26, 2017
Elizabeth River Transect
B16
B14
B13
20
21
19
Enterococcus (cfu/100ml)
DAY1
DAY2
DAY3
Model River Mile
Surface/Mid/Bottom Data
10Layer Daily Average
10Layer Daily MIN-MAX


WW Event : Apr 26-28, 2017
Passaic River Transect
Enterococcus (cfu/100ml)
B24
2
3
B22
4
5
7
8
10
11
B6
B8
12
Saddle R
Third Ri
Second R
DAY1
DAY2
DAY3
Model River Mile
Surface/Mid/Bottom Data
10Layer Daily Average
10Layer Daily MIN-MAX

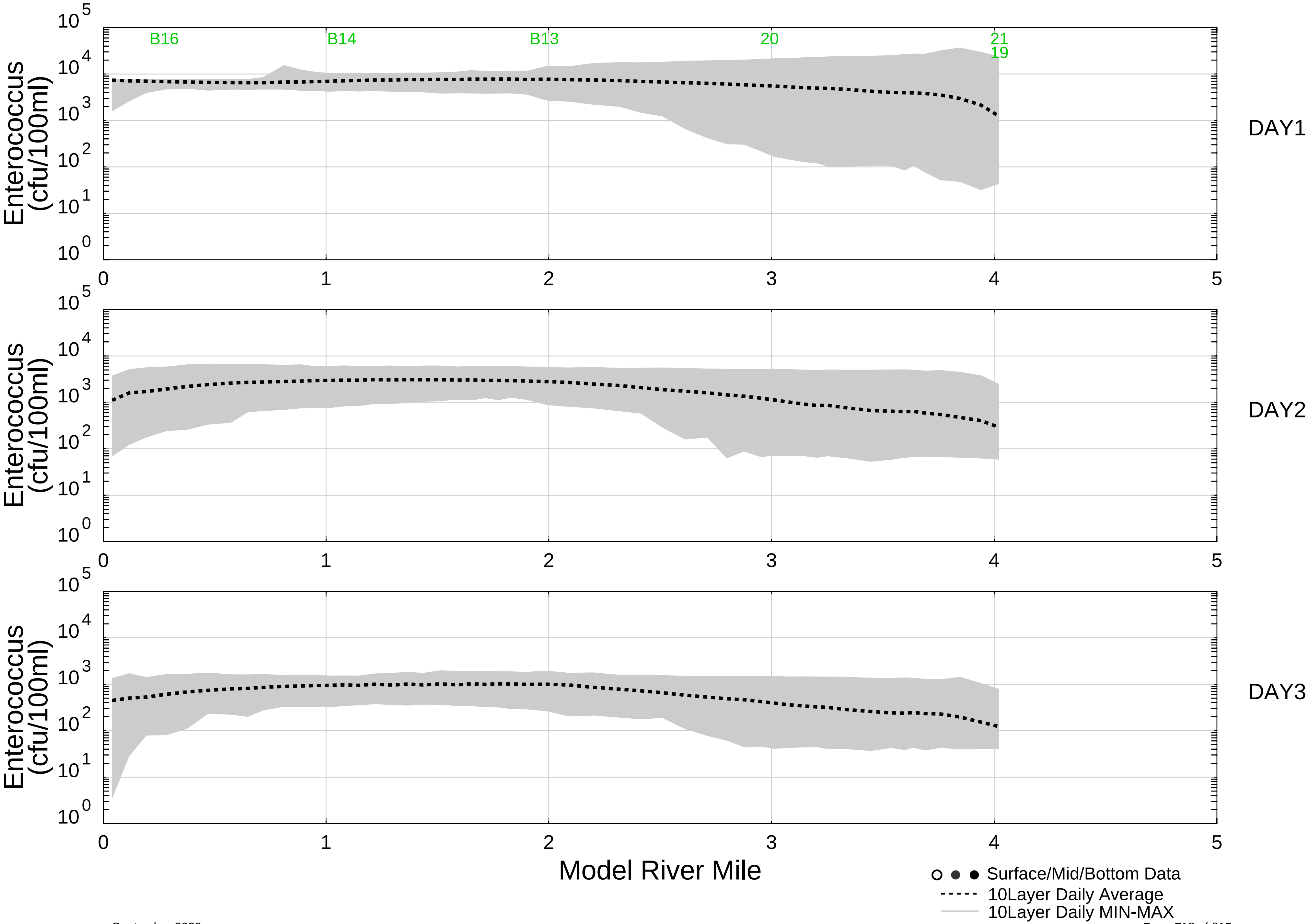

WW Event : Apr 26-28, 2017
Hackensack River Transect
13
B1
B2
B11
B4
B3
14
B7
15
16
Enterococcus (cfu/100ml)
10^0
10^1
10^2
10^3
10^4
10^5
0
5
10
15
20
25
DAY1
DAY2
DAY3
Model River Mile
Surface/Mid/Bottom Data
10Layer Daily Average
10Layer Daily MIN-MAX


WW Event : Apr 26-28, 2017
Hudson River Transect
Enterococcus (cfu/100ml)
31
B5A
B5B
32
B18A
B18B
33
B23A
B23B
B26
B27
B9
B28
B21B
B21A
DAY1
DAY2
DAY3
135
140
145
150
155
160
Model River Mile
Surface/Mid/Bottom Data
10Layer Daily Average
10Layer Daily MIN-MAX


WW Event : Apr 26-28, 2017
Raritan River Transect
25
26
27
B19
B18
B15
South Ri
Enterococcus (cfu/100ml)
DAY1
DAY2
DAY3
Model River Mile
Surface/Mid/Bottom Data
10Layer Daily Average
10Layer Daily MIN-MAX

WW Event : Apr 26-28, 2017

Elizabeth River Transect



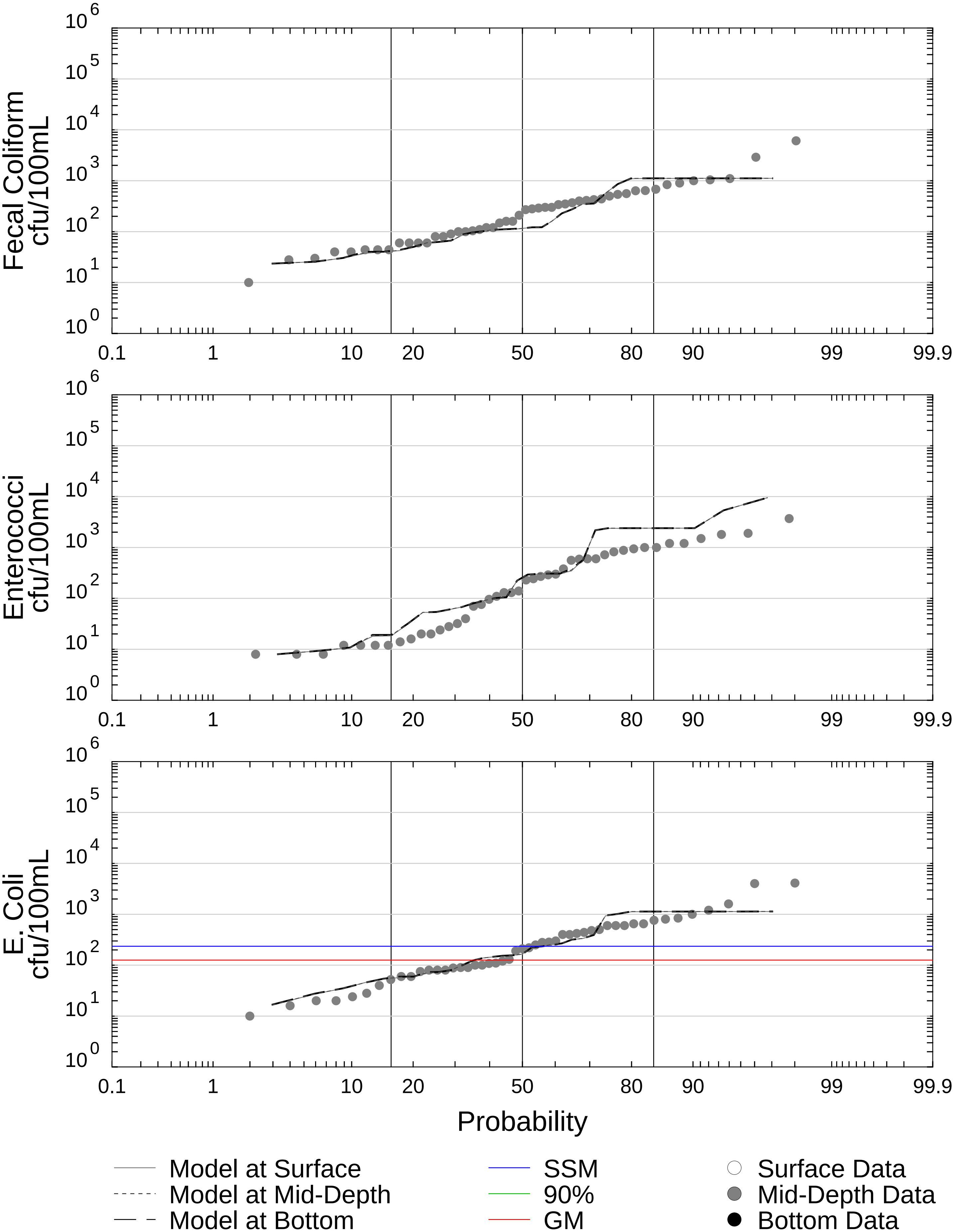
Appendix F-7

Additional Validation Probability Figures

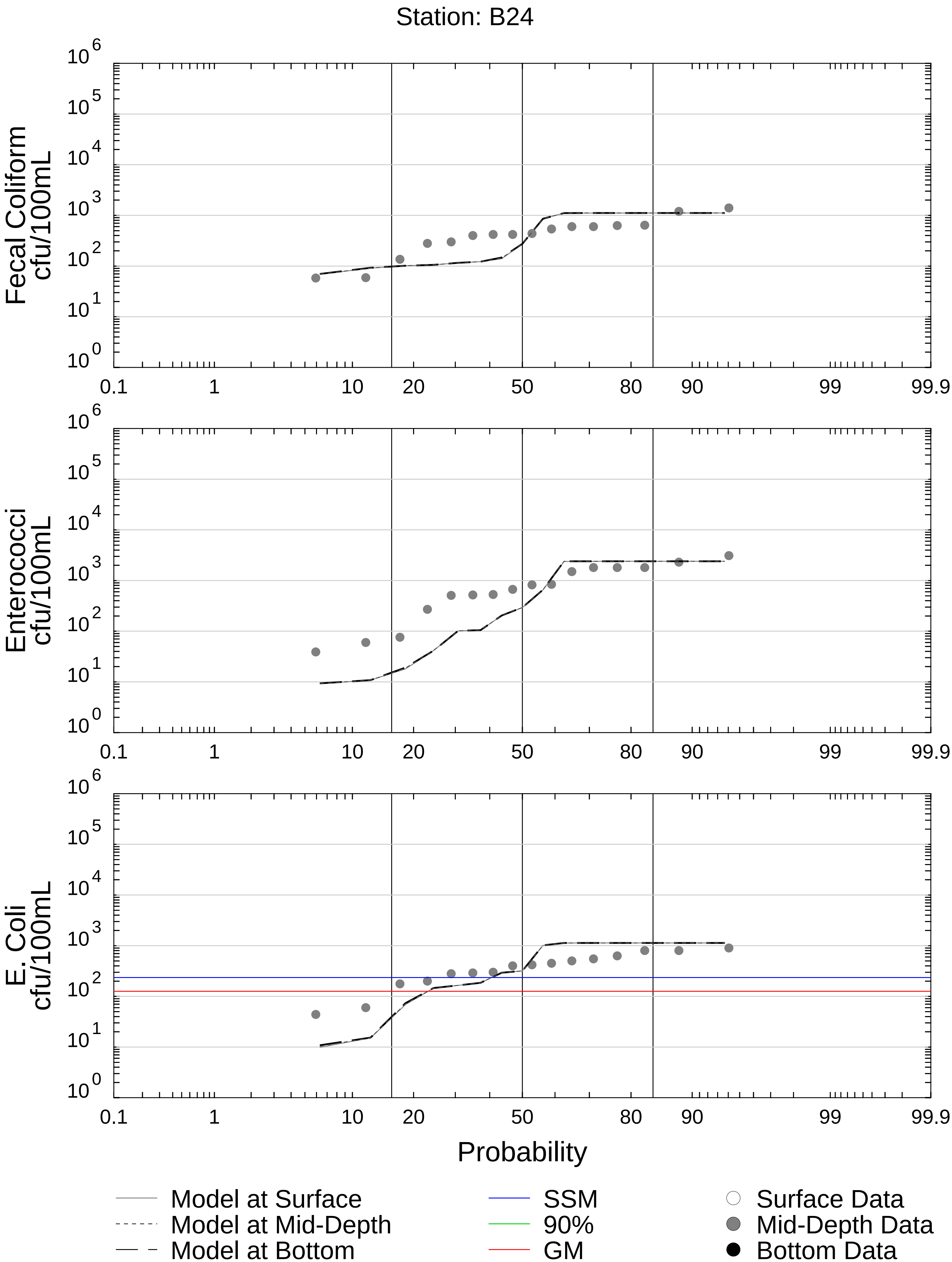
PASSAIC RIVER

FW2

Station: 1

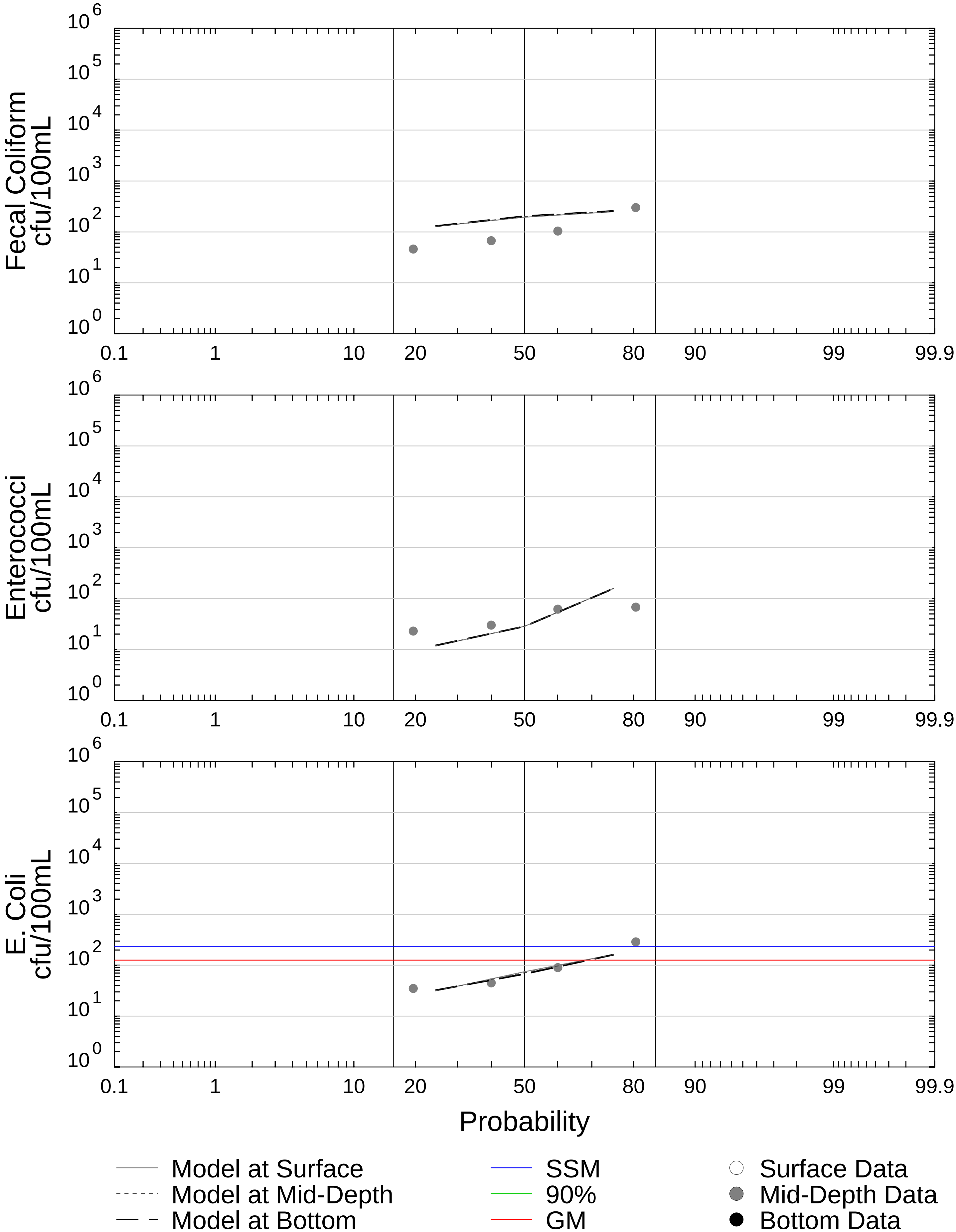


Model Results during data sampling hours only



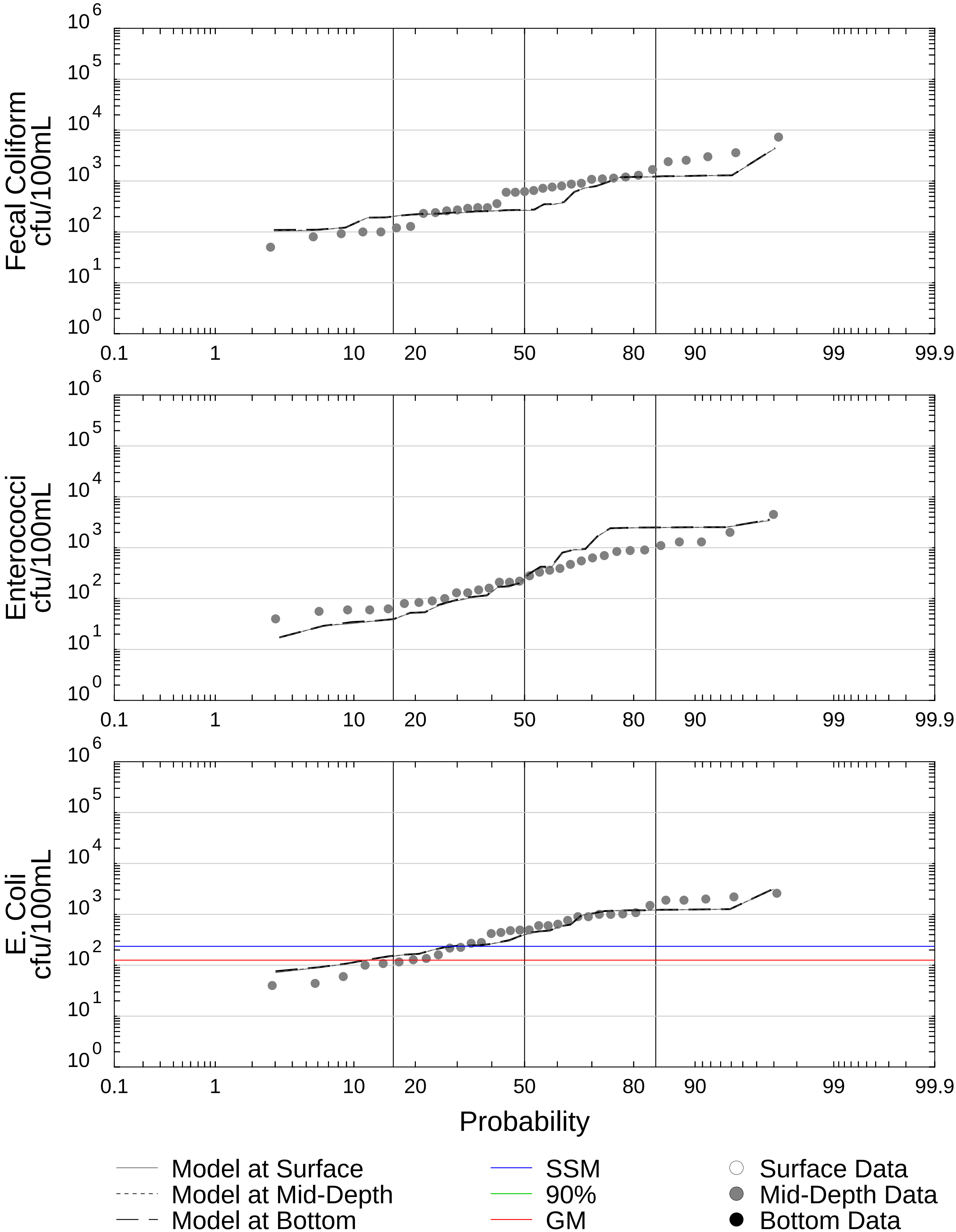
Model Results during data sampling hours only

Station: 2



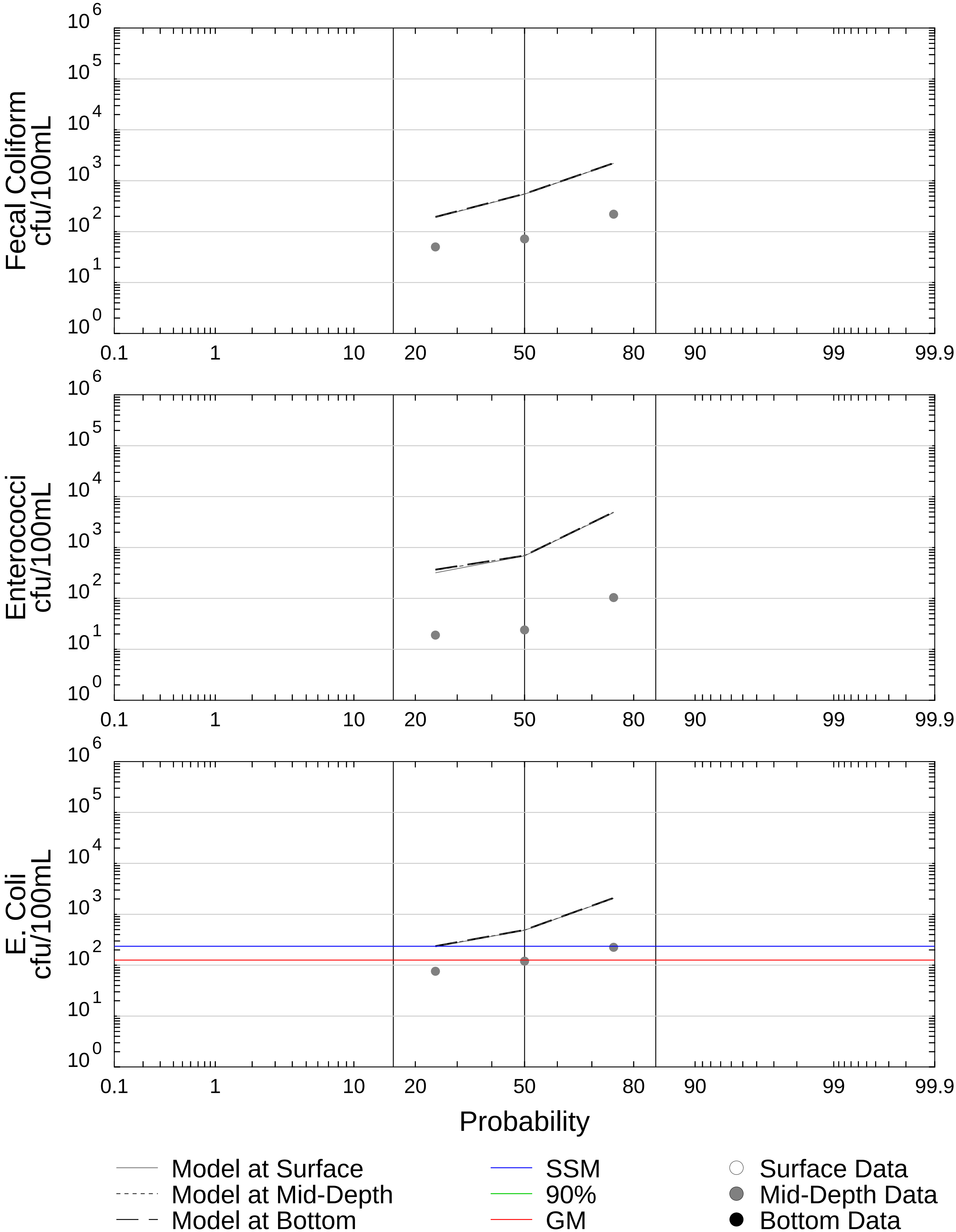
Model Results during data sampling hours only

Station: 3



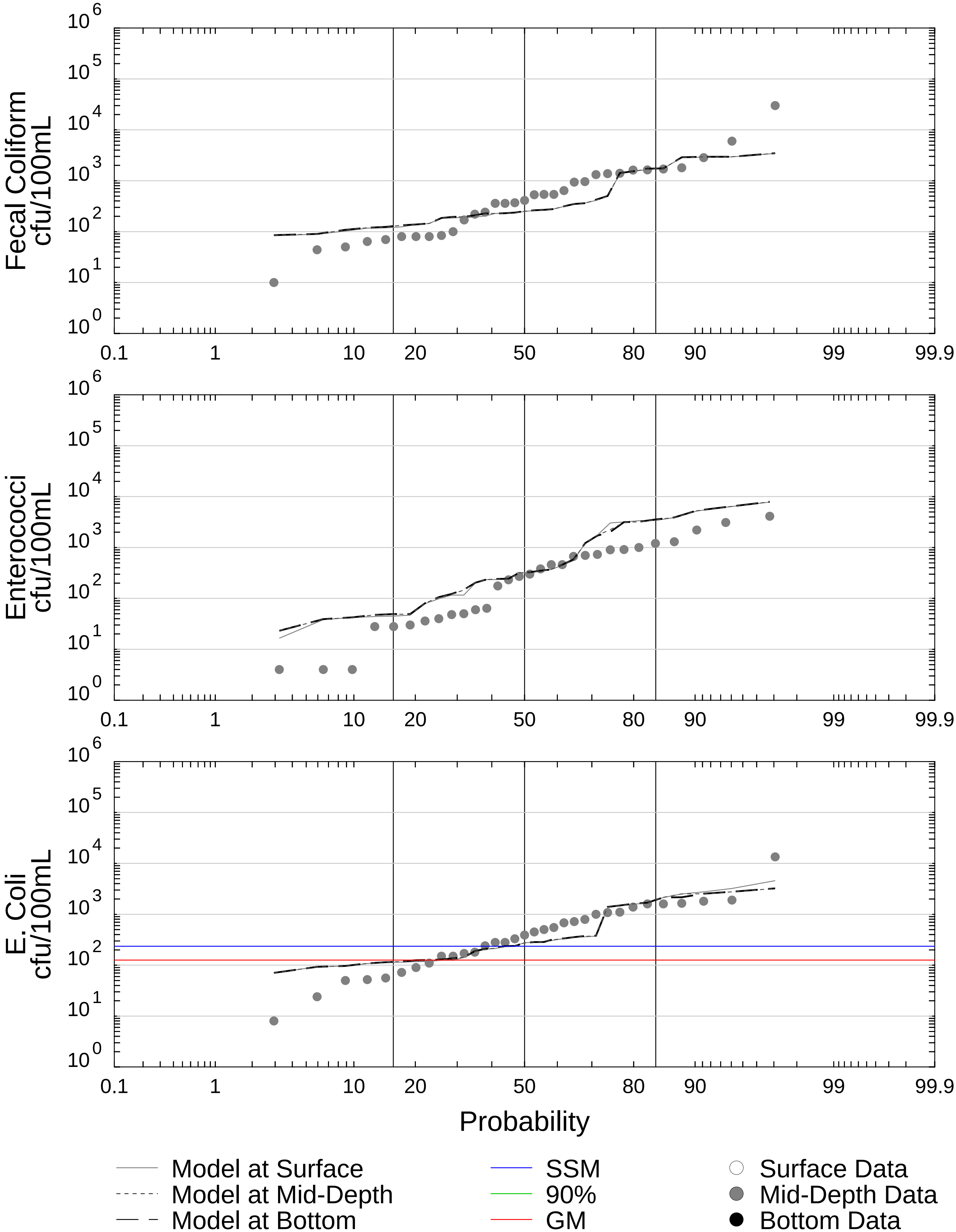
Model Results during data sampling hours only

Station: B22



Model Results during data sampling hours only

Station: 4

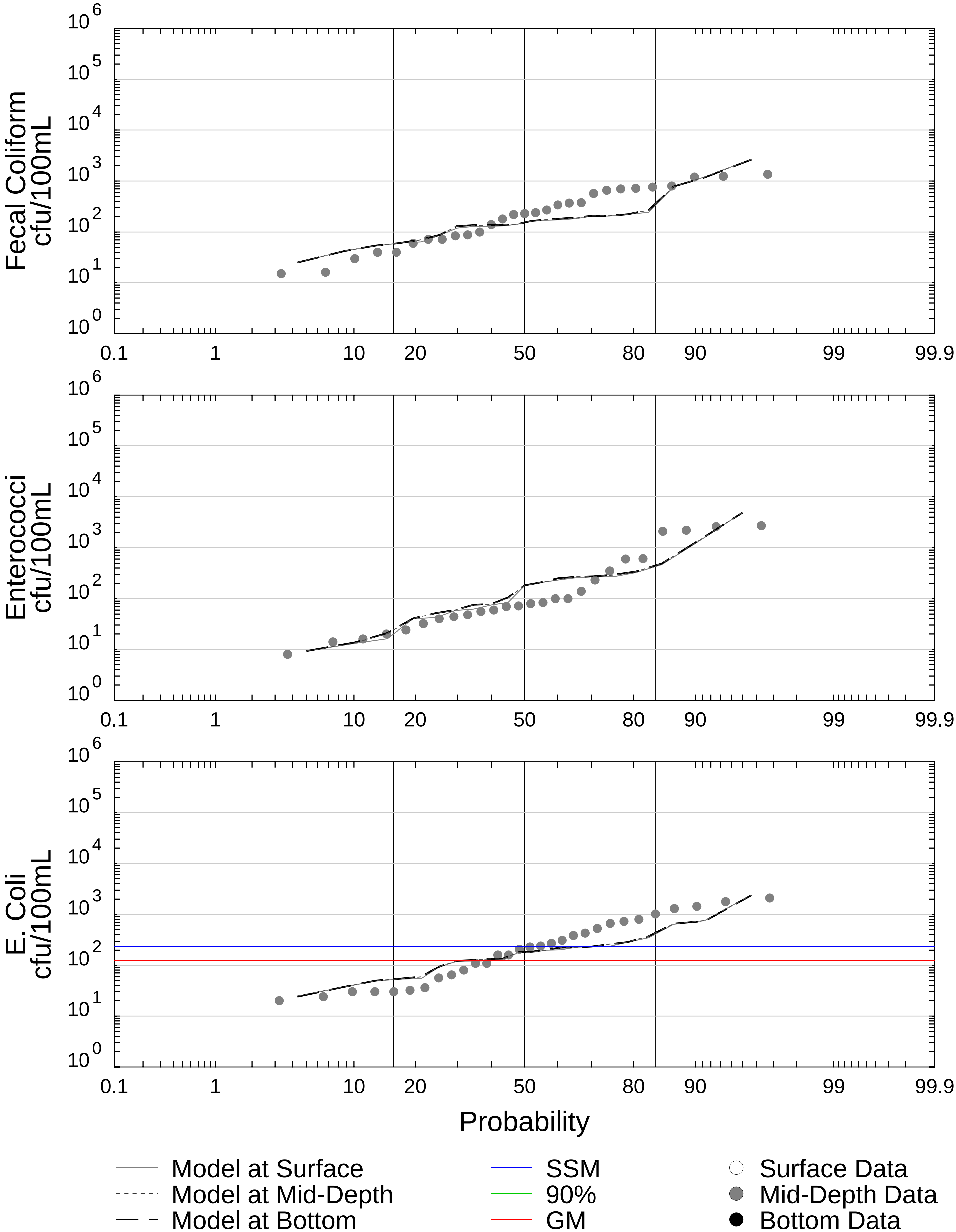


Model Results during data sampling hours only

PASSAIC RIVER

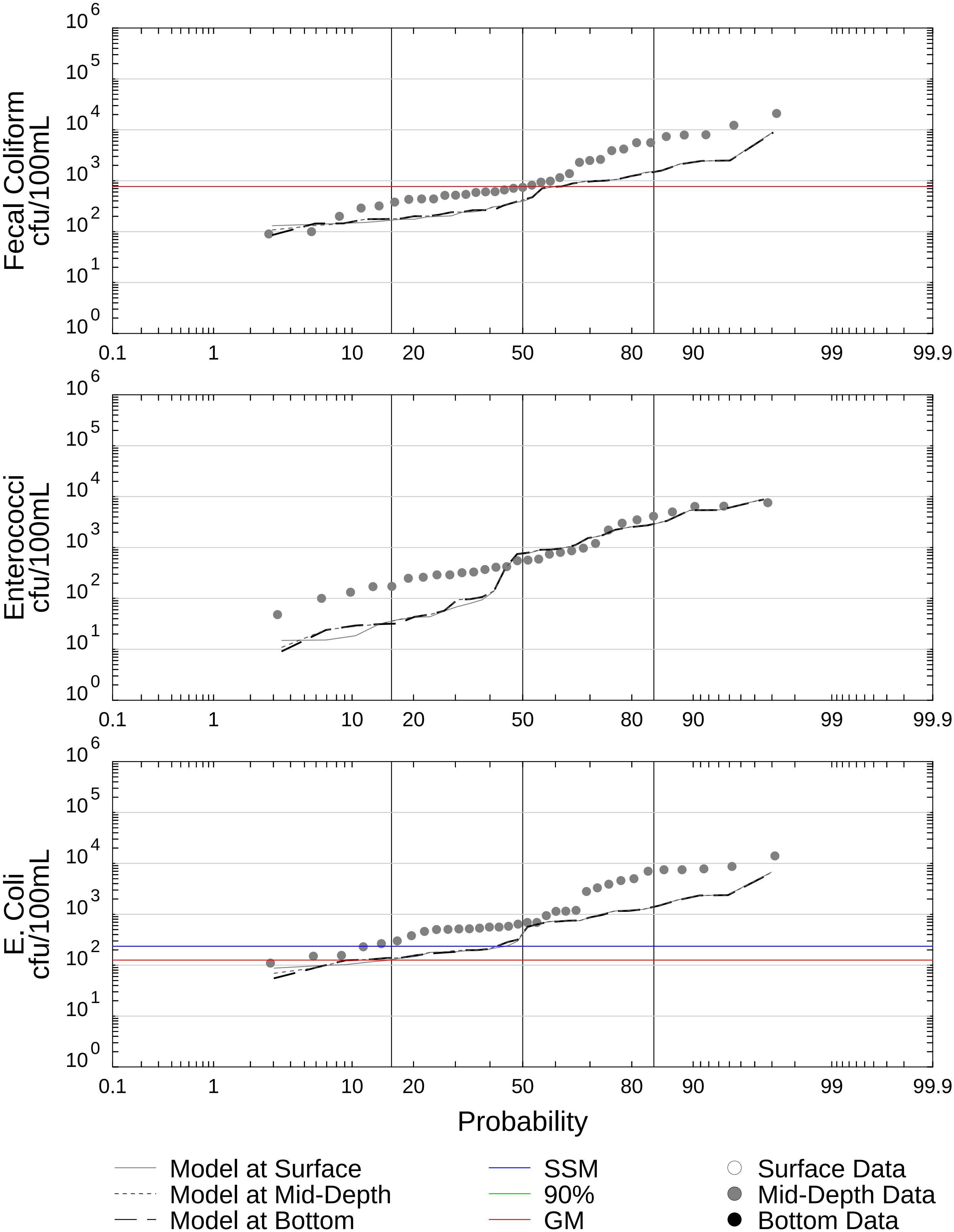
FW2

Station: 5



Model Results during data sampling hours only

Station: 7

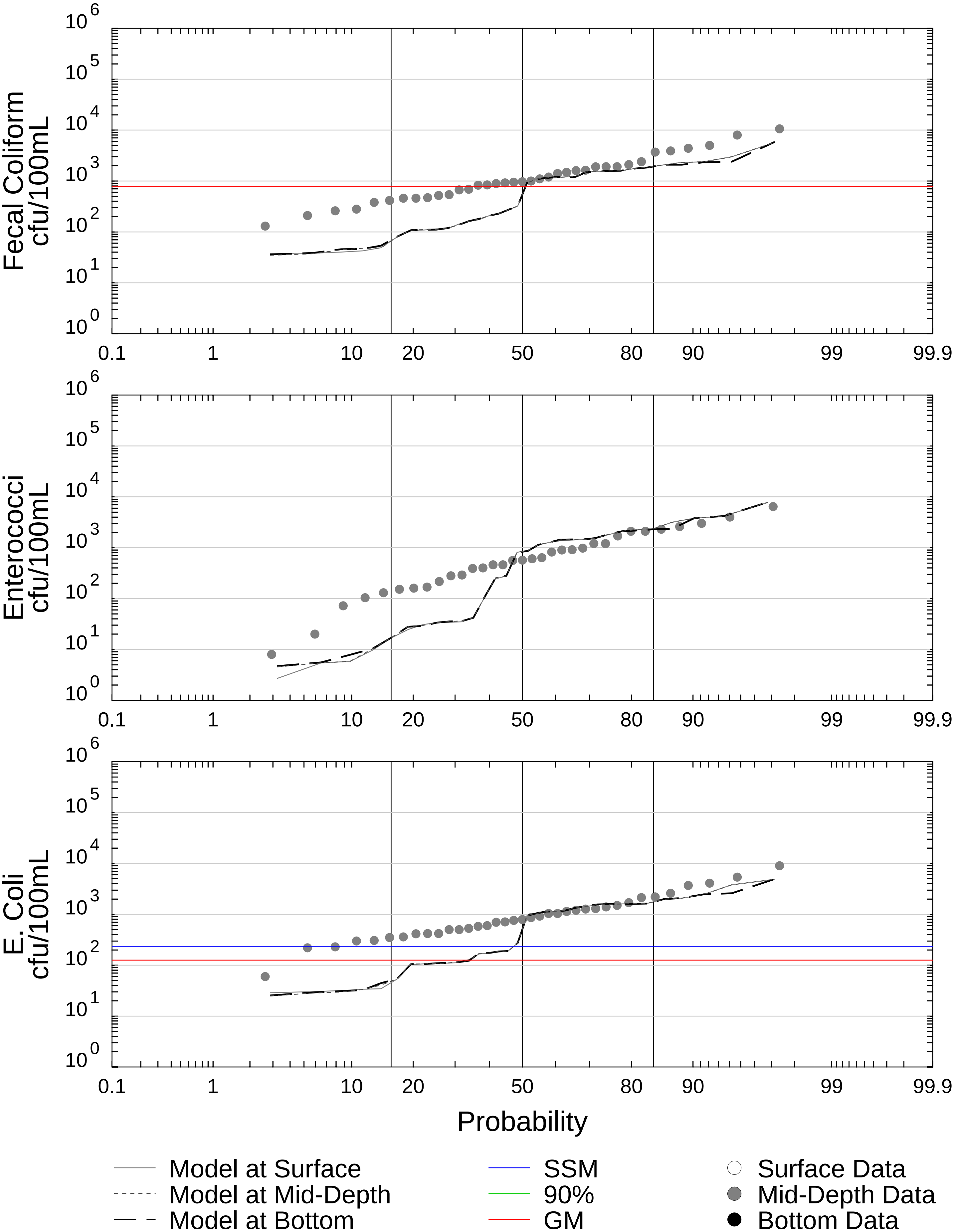


Model Results during data sampling hours only

PASSAIC RIVER

FW2/SE2

Station: 8

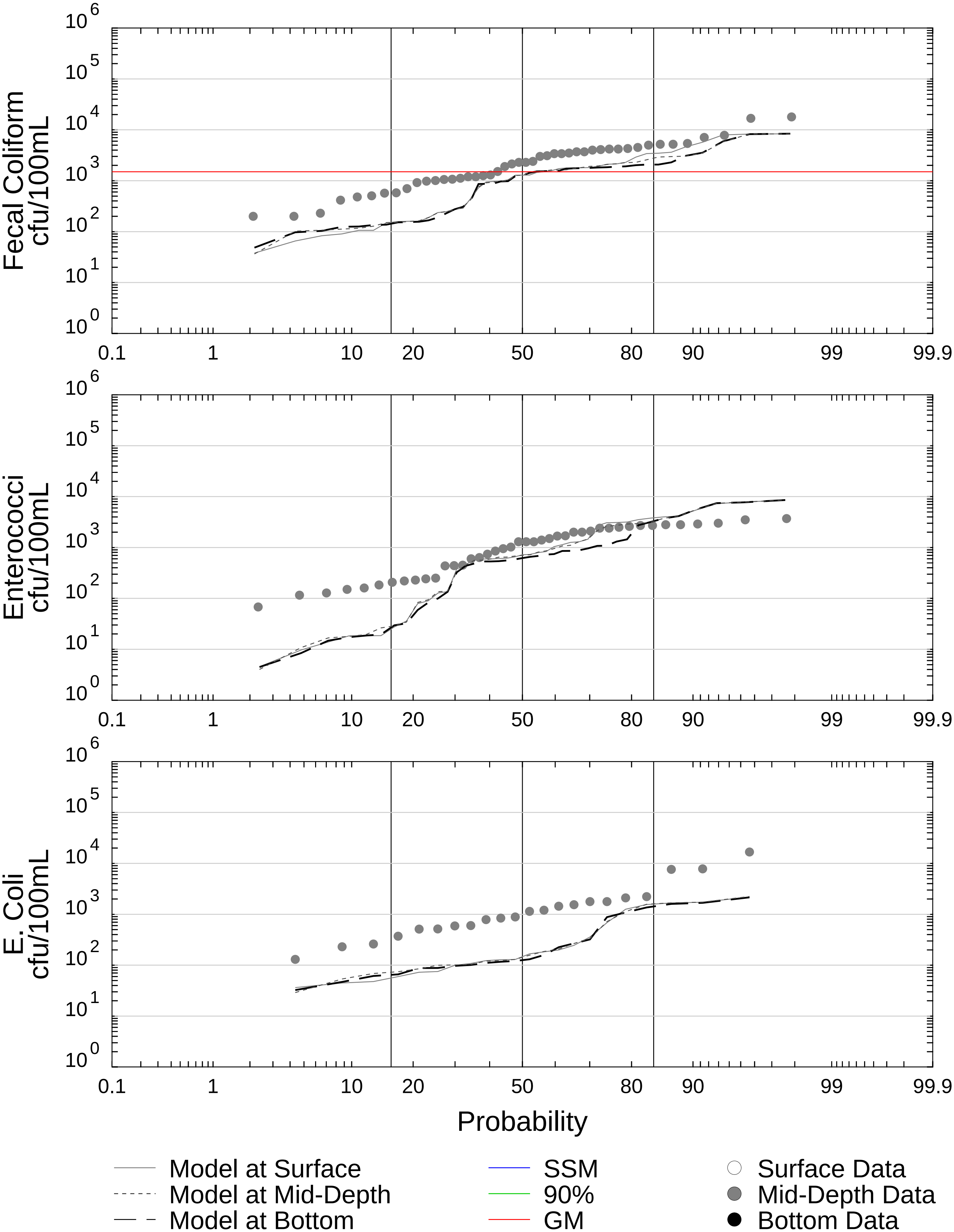


Model Results during data sampling hours only

PASSAIC RIVER

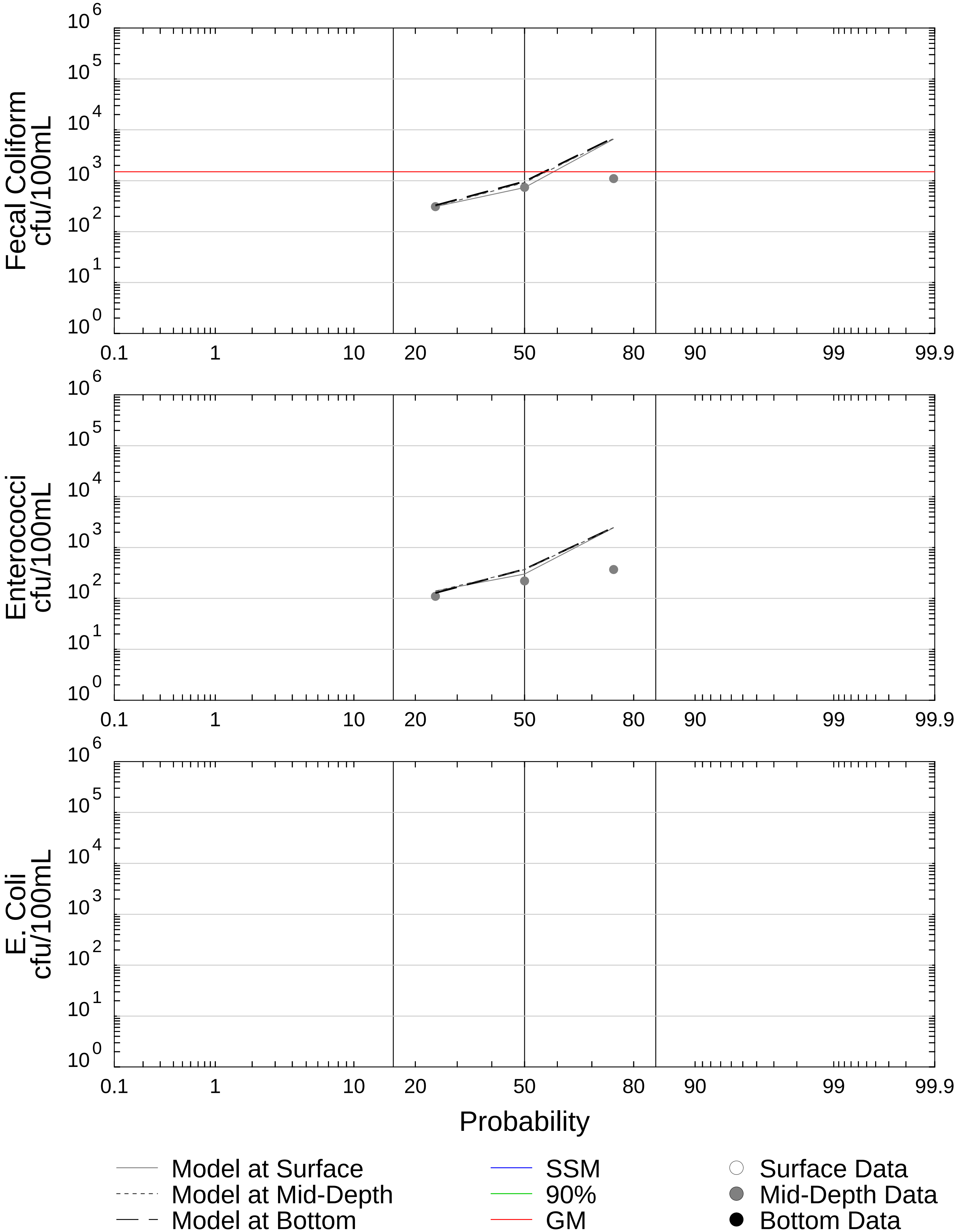
SE3

Station: 10



Model Results during data sampling hours only

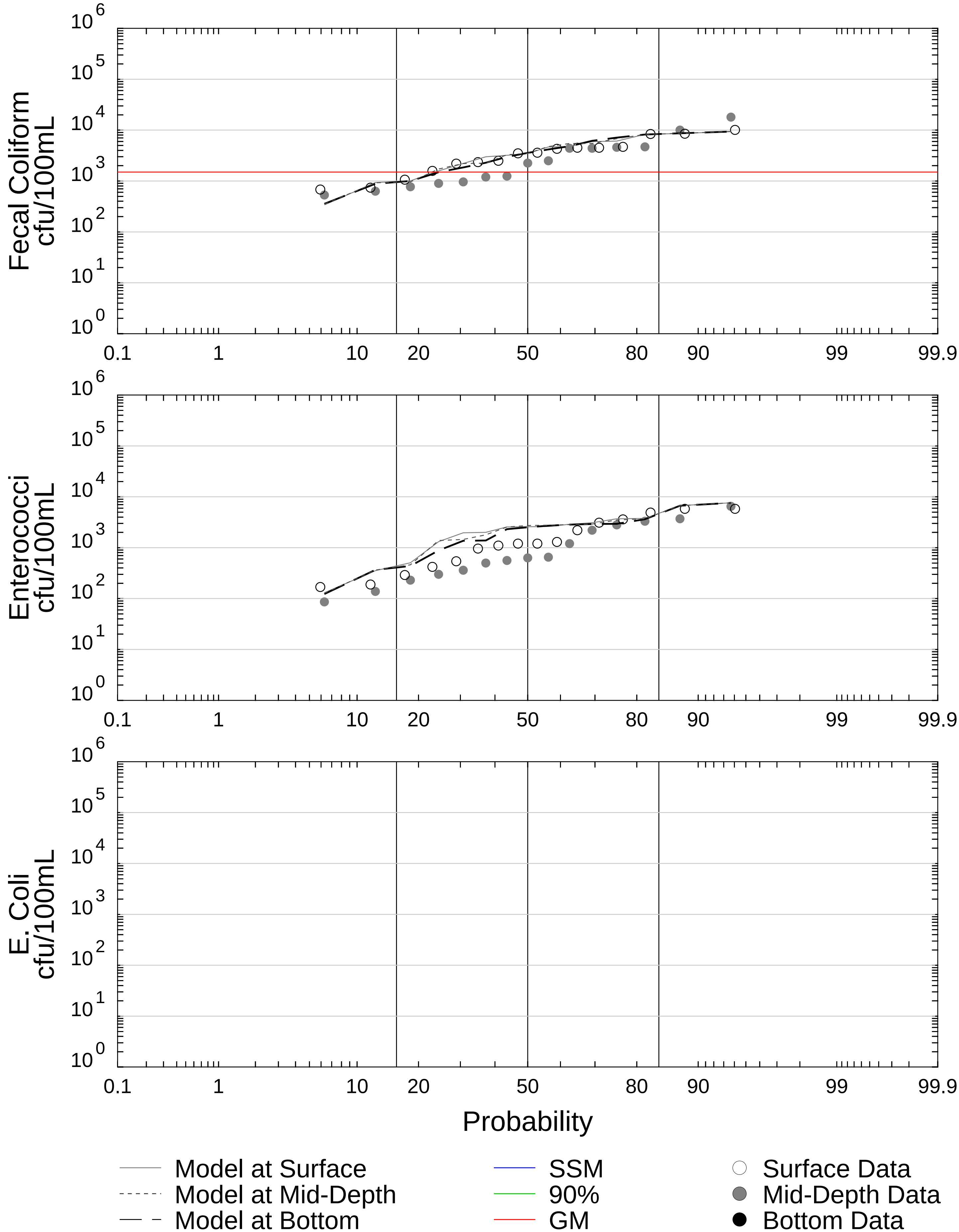
Station: 11



Model Results during data sampling hours only

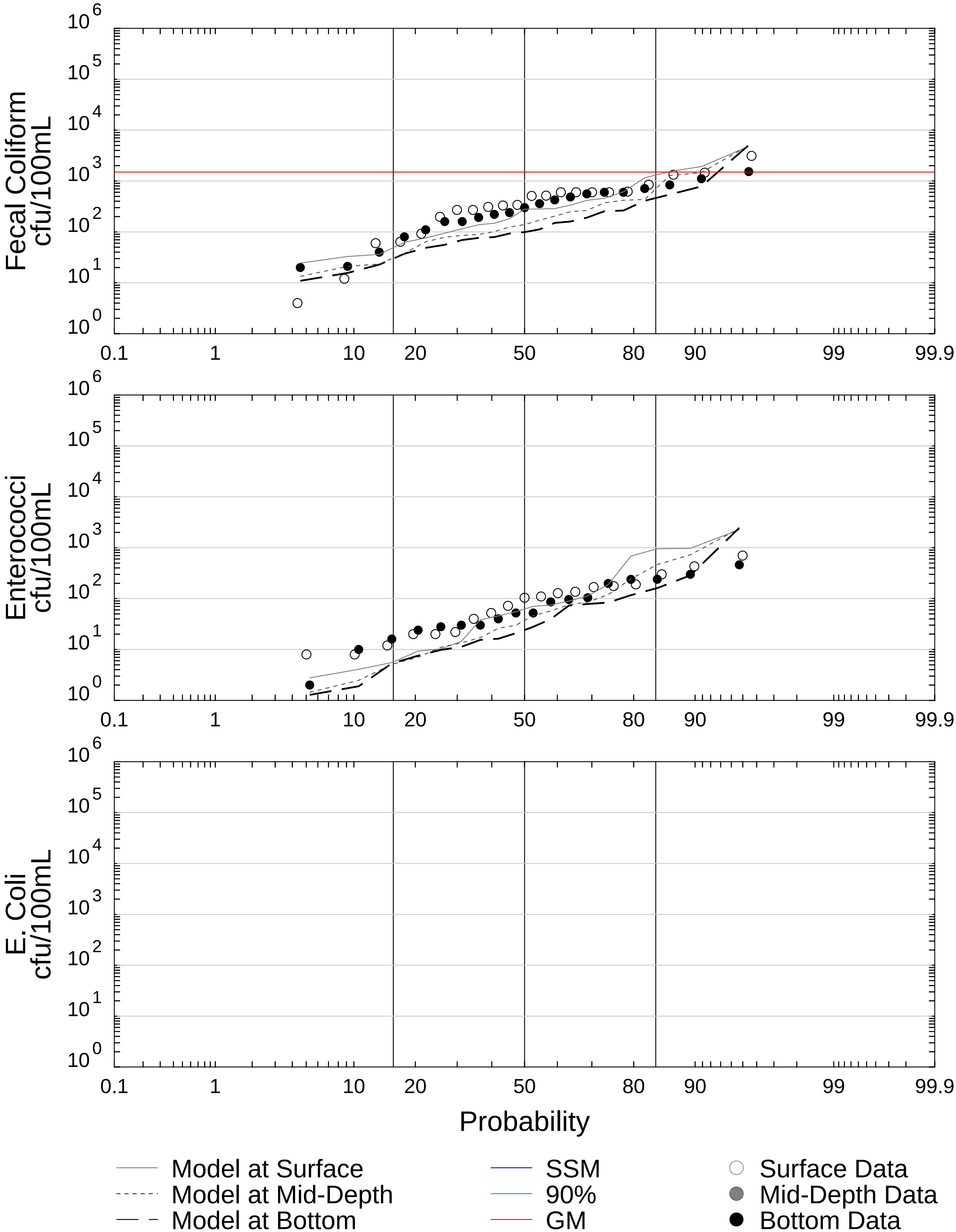
PASSAIC RIVER
SE3

Station: B6



Model Results during data sampling hours only

Station: 12

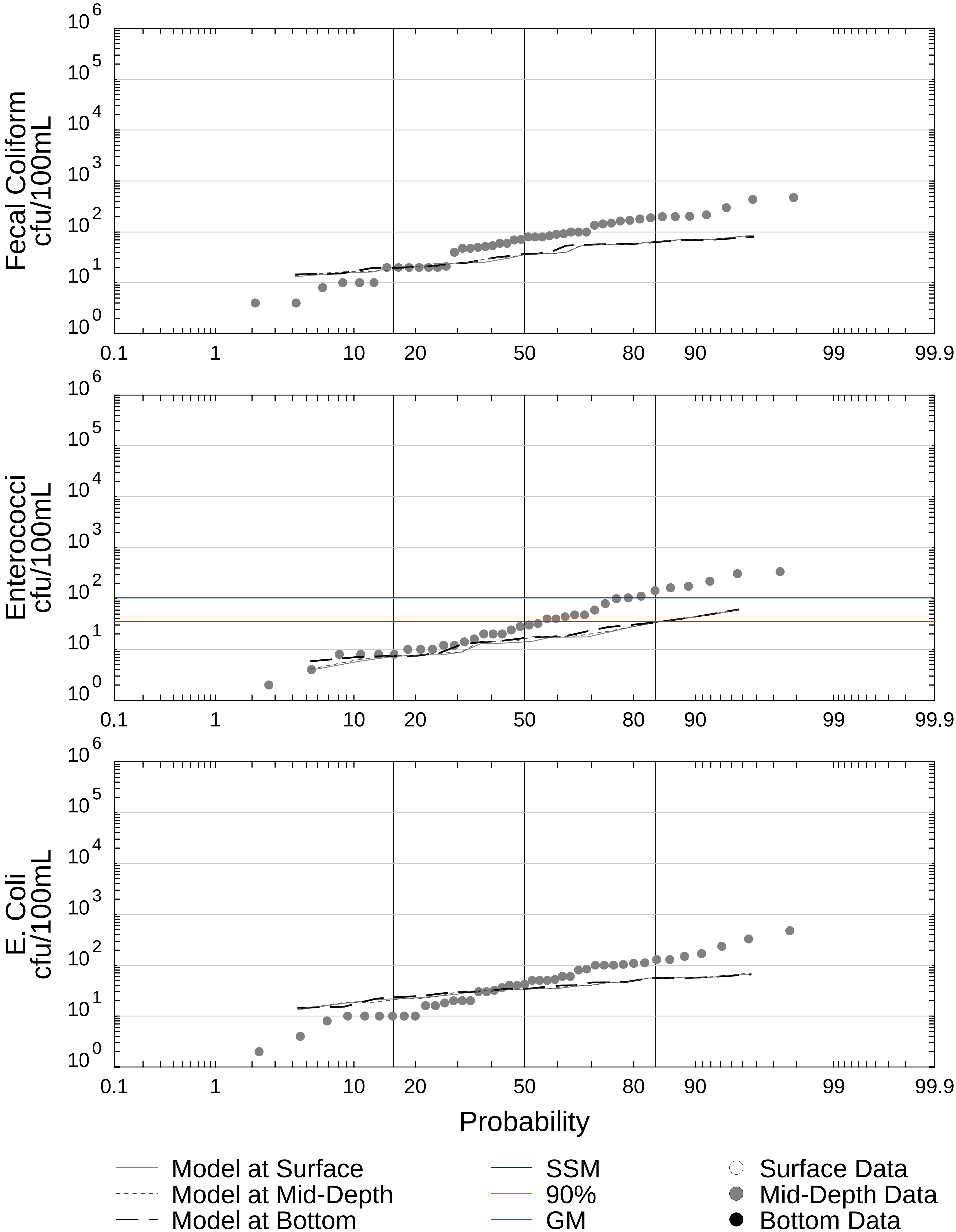


Model Results during data sampling hours only

HACKENSACK RIVER

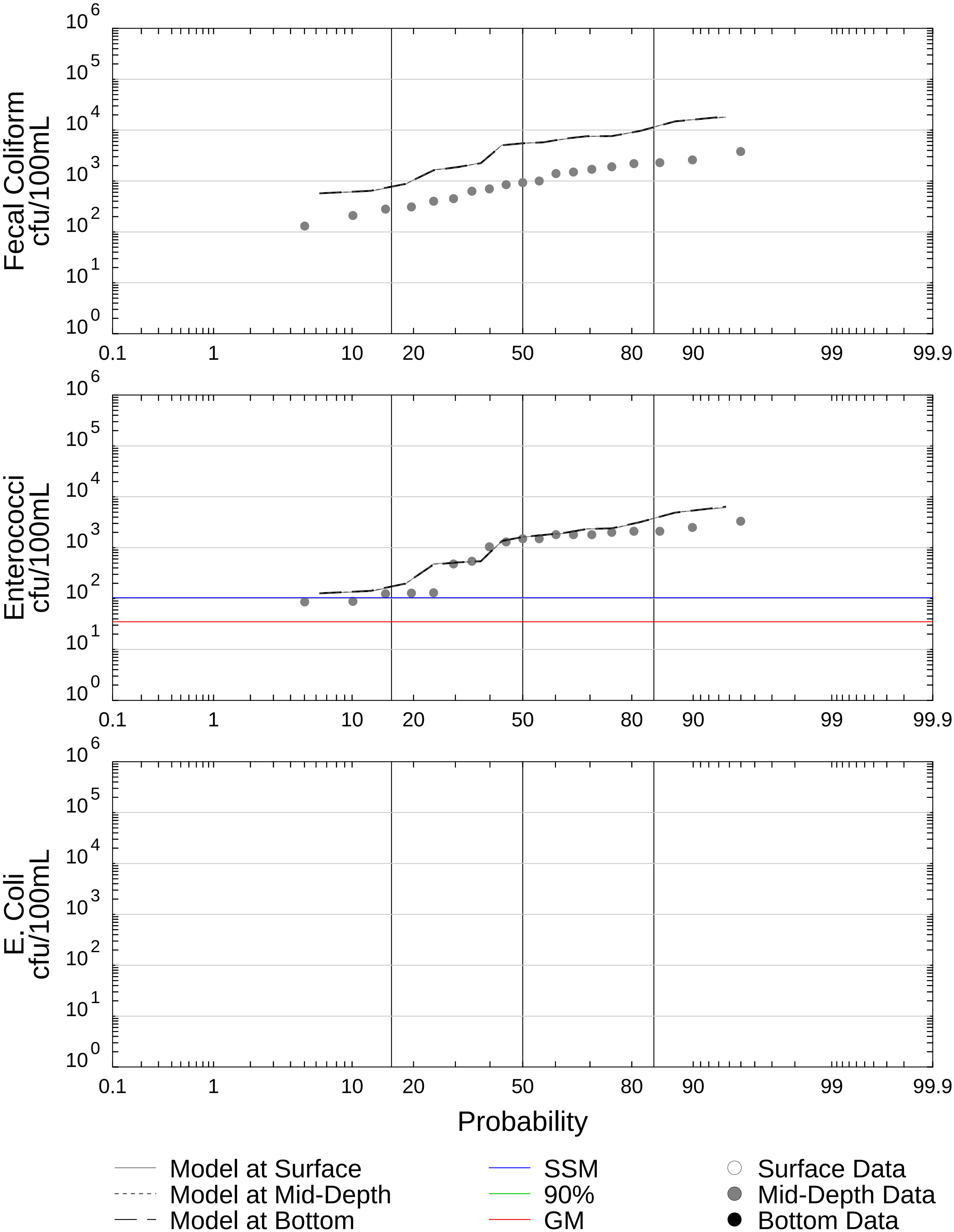
SE1

Station: 13



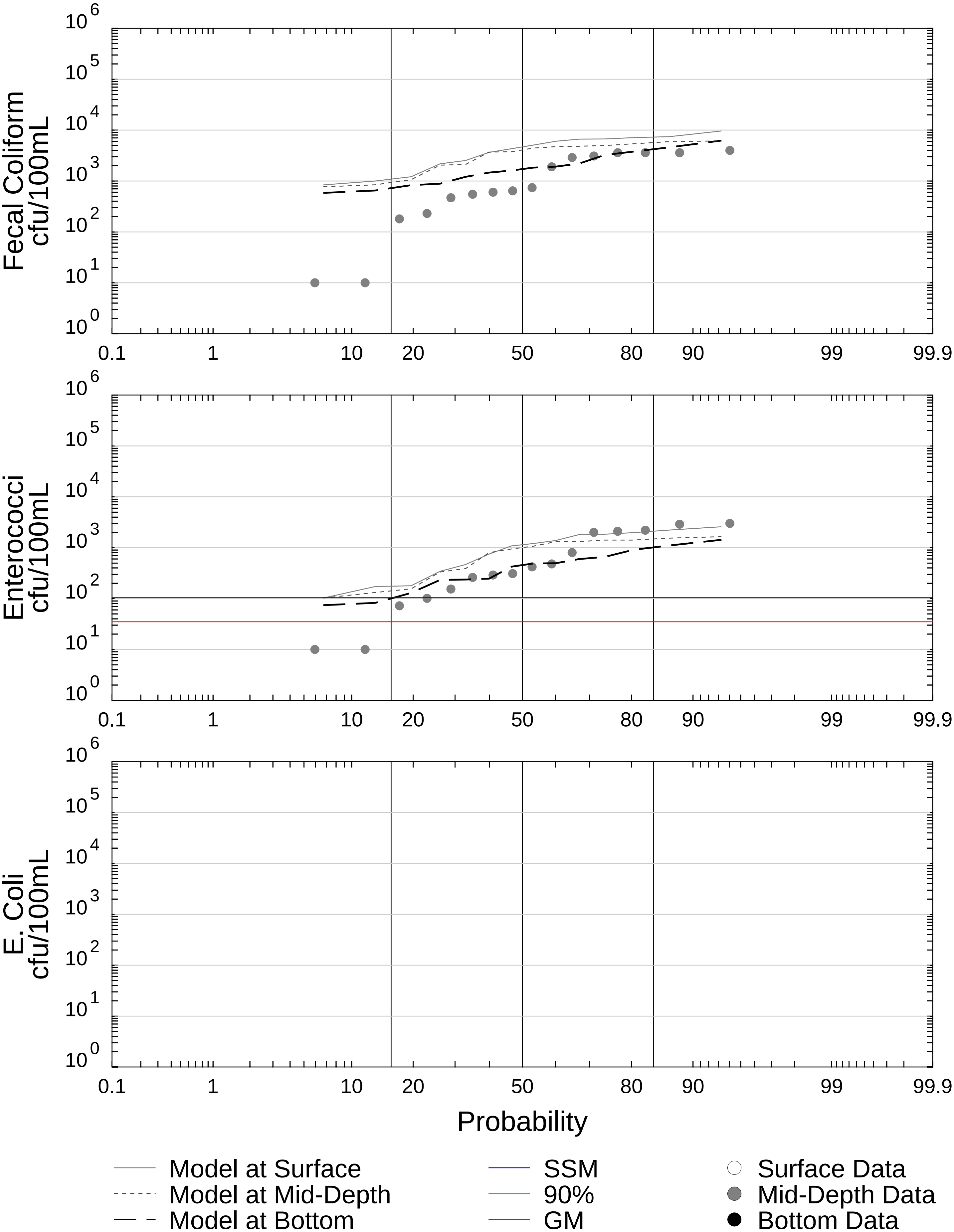
Model Results during data sampling hours only

Station: B1



Model Results during data sampling hours only

Station: B2

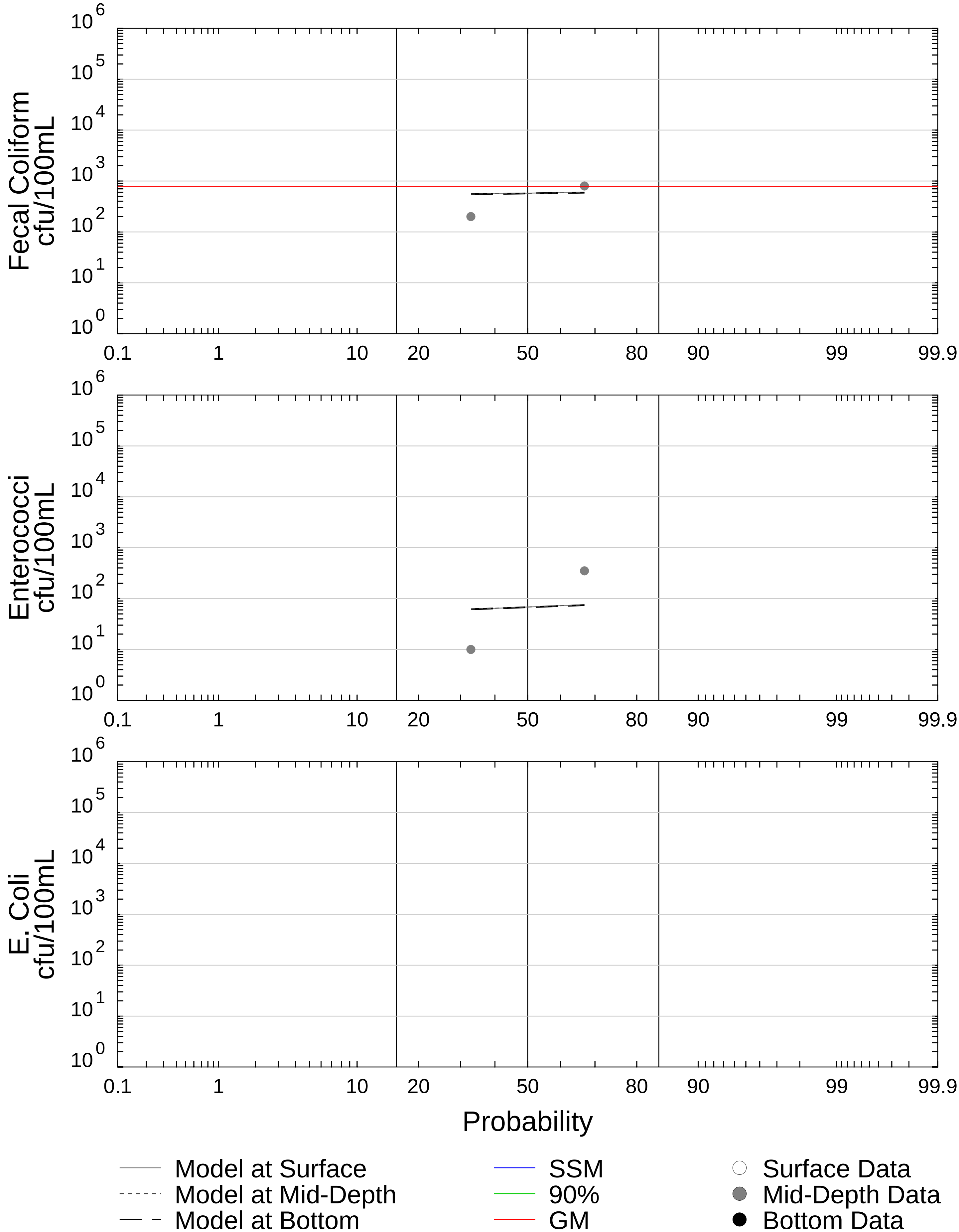


Model Results during data sampling hours only

HACKENSACK RIVER

SE2

Station: B11

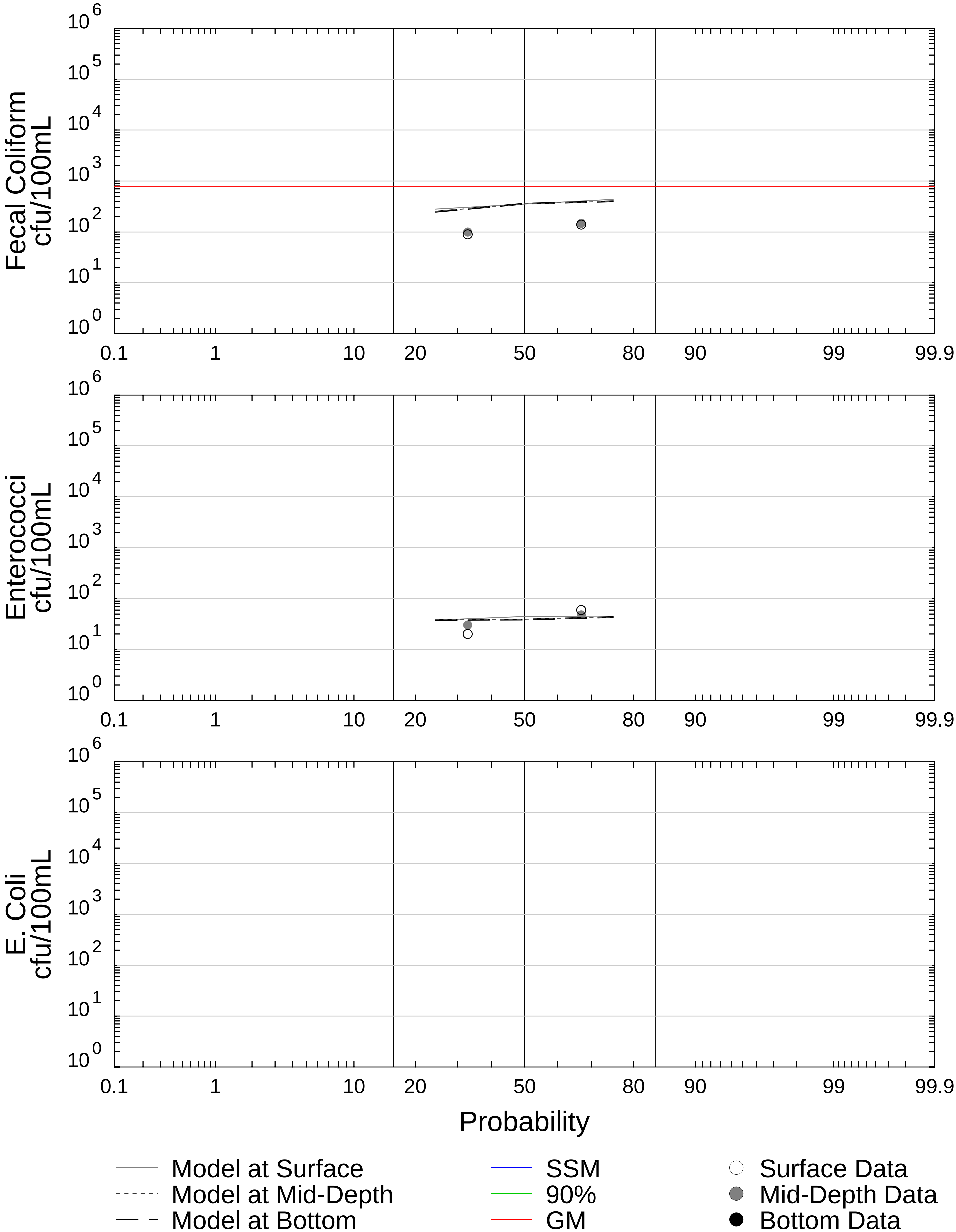


Model Results during data sampling hours only

HACKENSACK RIVER

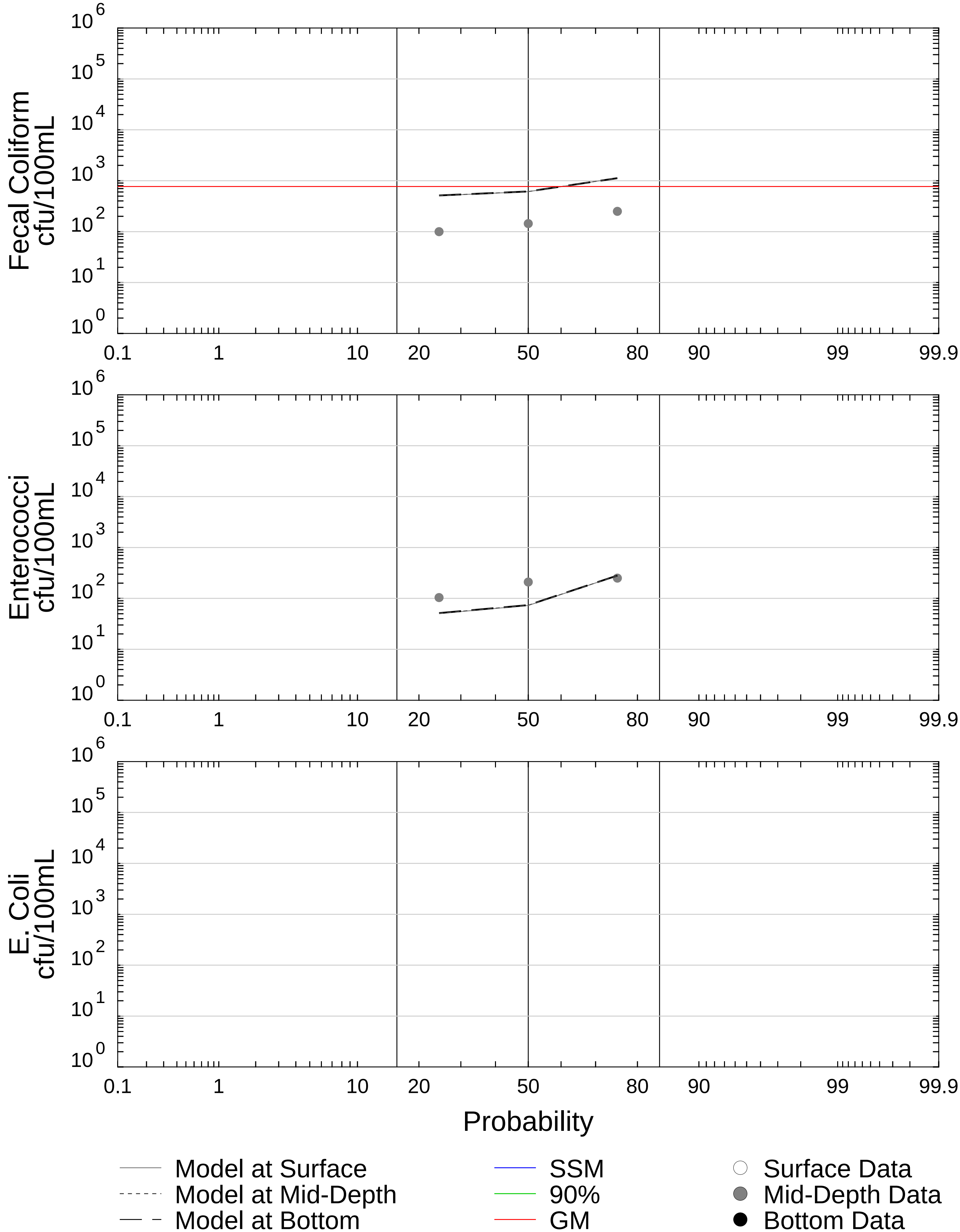
SE2

Station: B3



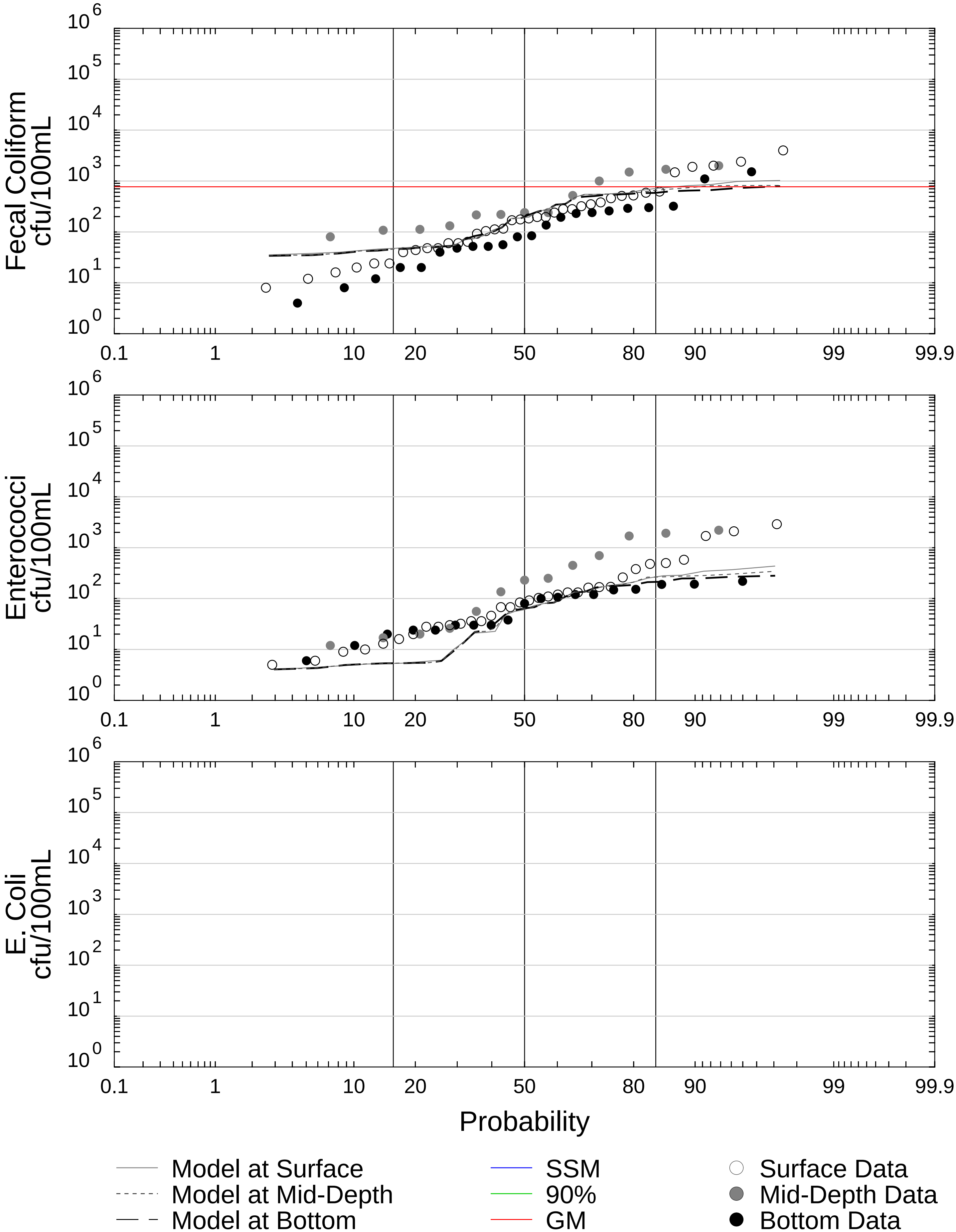
Model Results during data sampling hours only

Station: B4



Model Results during data sampling hours only

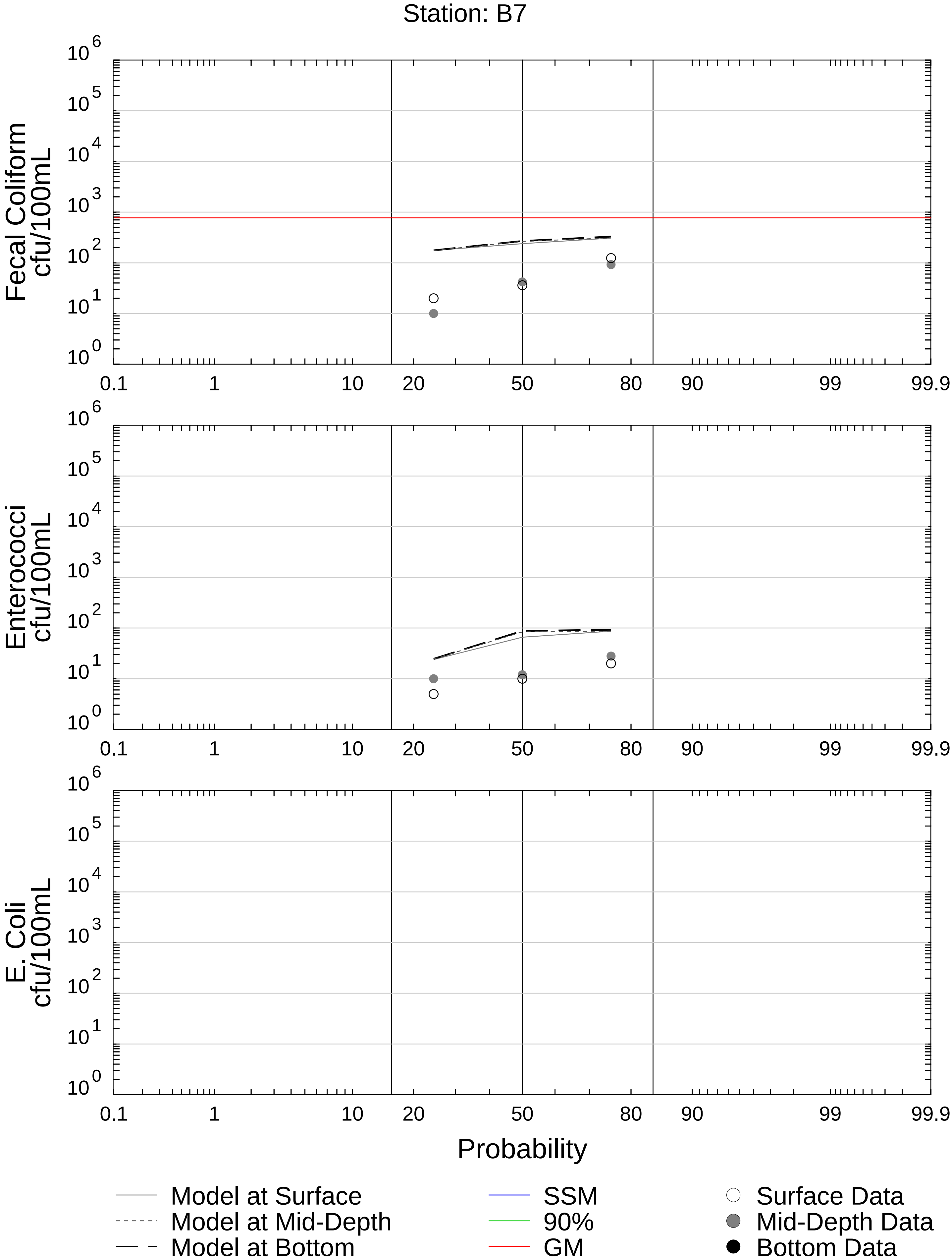
Station: 14



Model Results during data sampling hours only

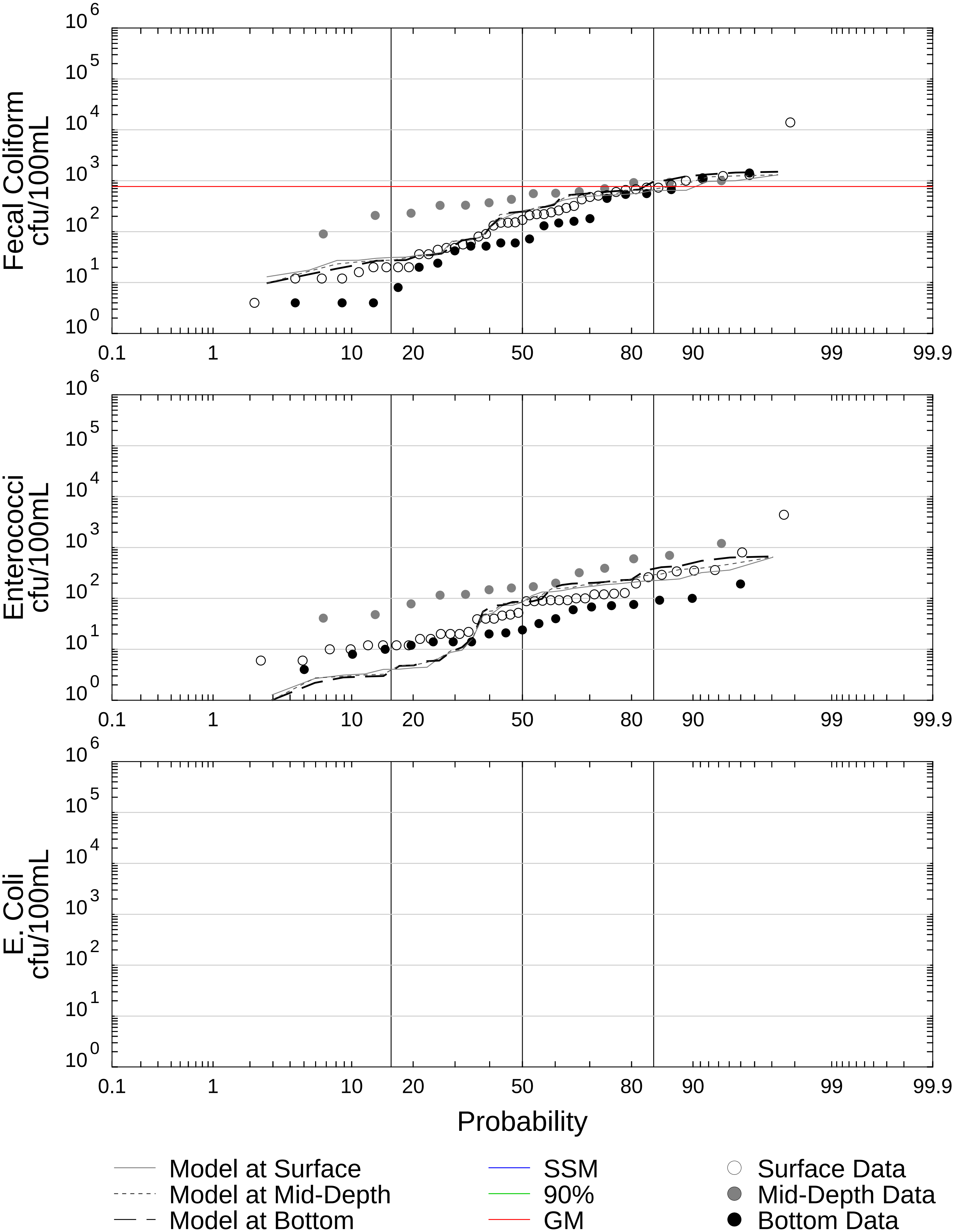
HACKENSACK RIVER

SE2



Model Results during data sampling hours only

Station: 15

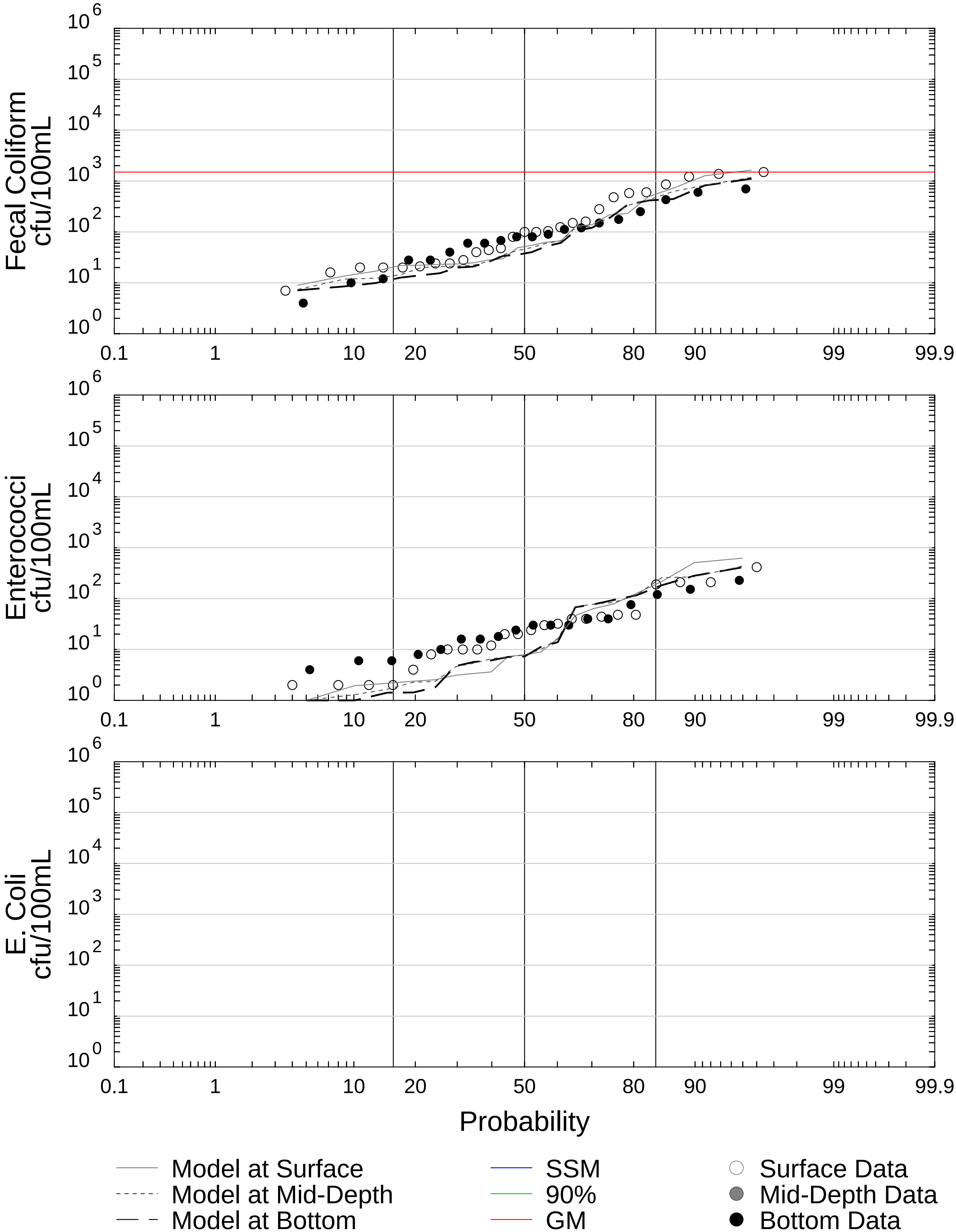


Model Results during data sampling hours only

HACKENSACK RIVER

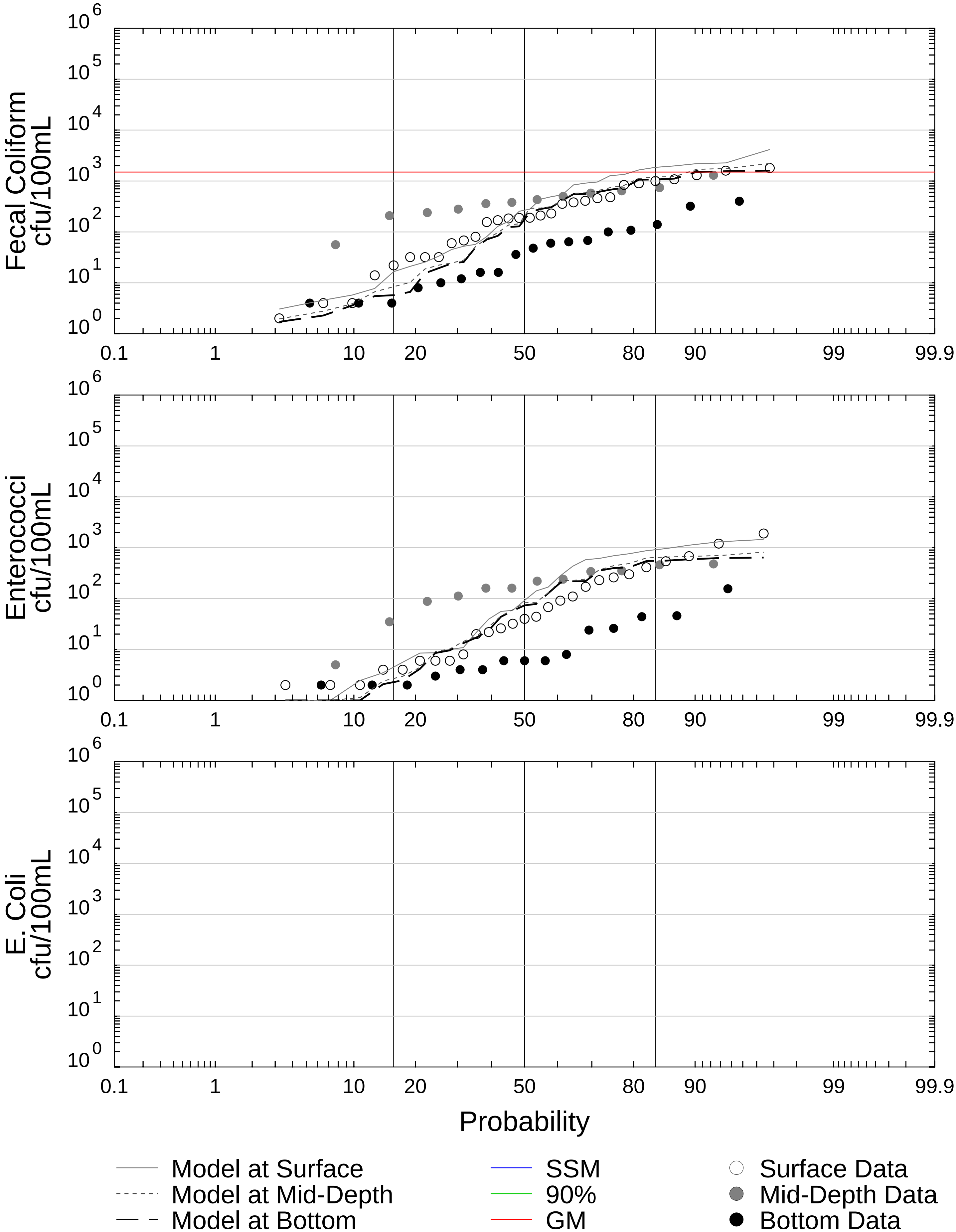
SE3

Station: 16



Model Results during data sampling hours only

Station: 17

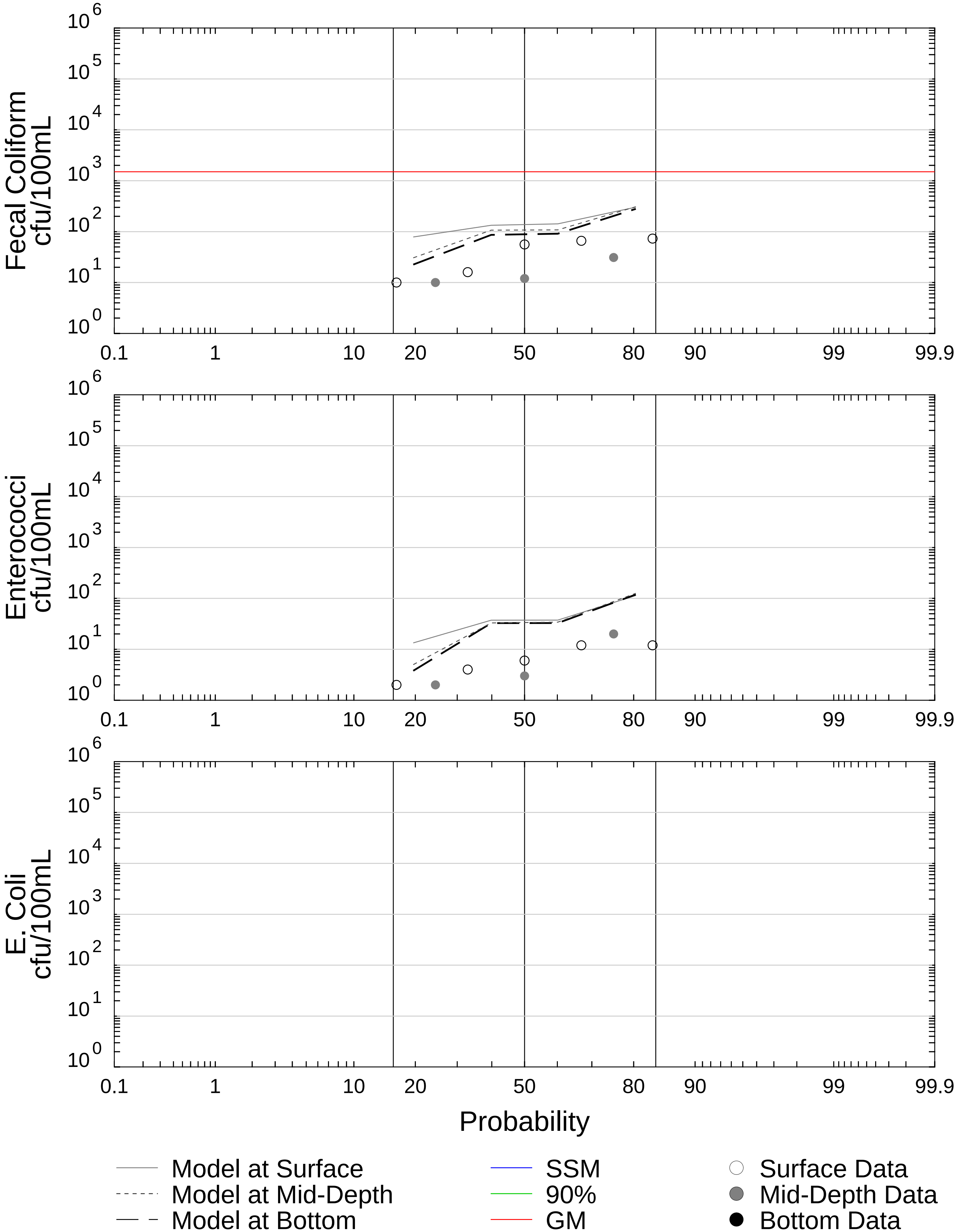


Model Results during data sampling hours only

LOWER PASSAIC RIVER

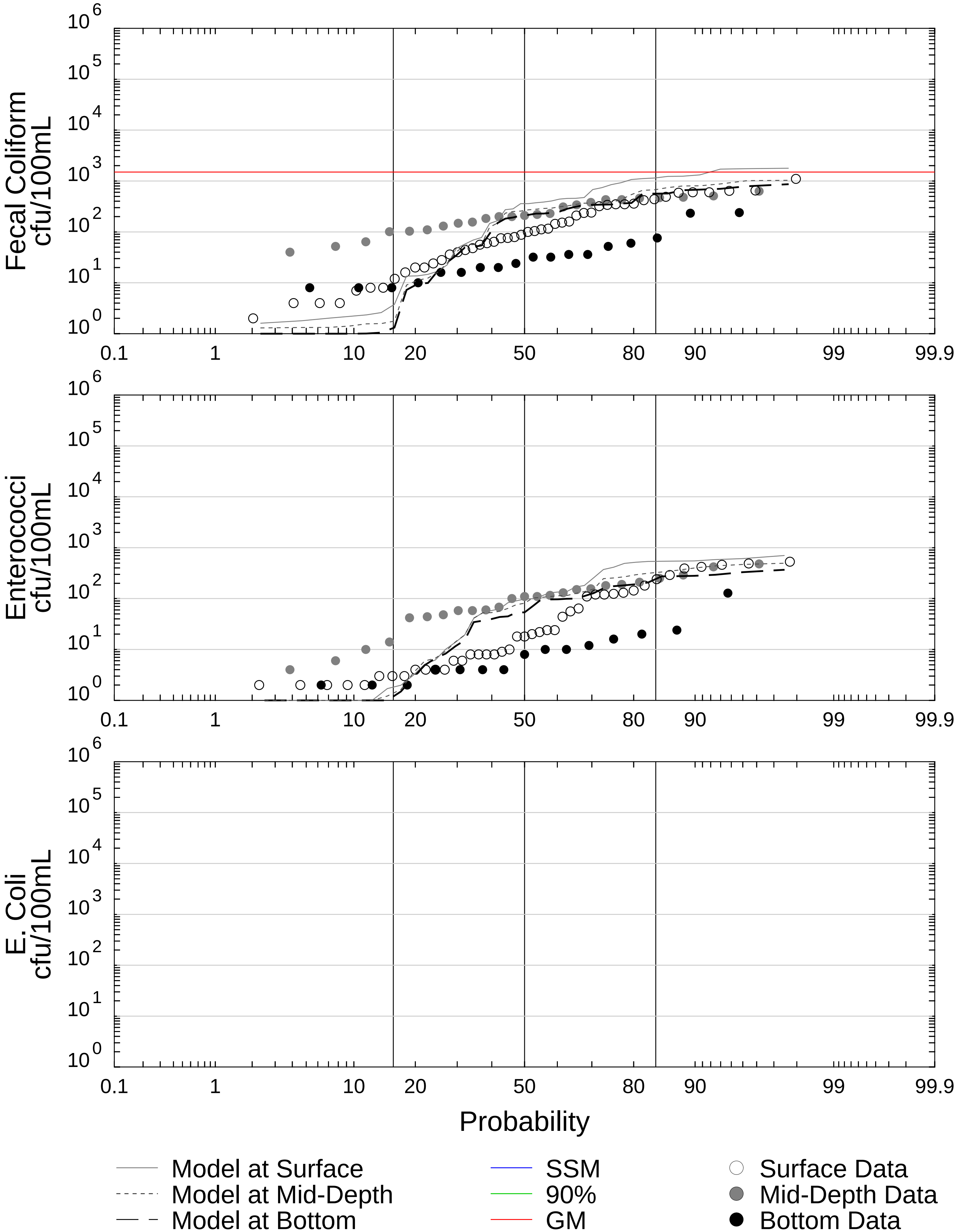
SE3

Station: B10



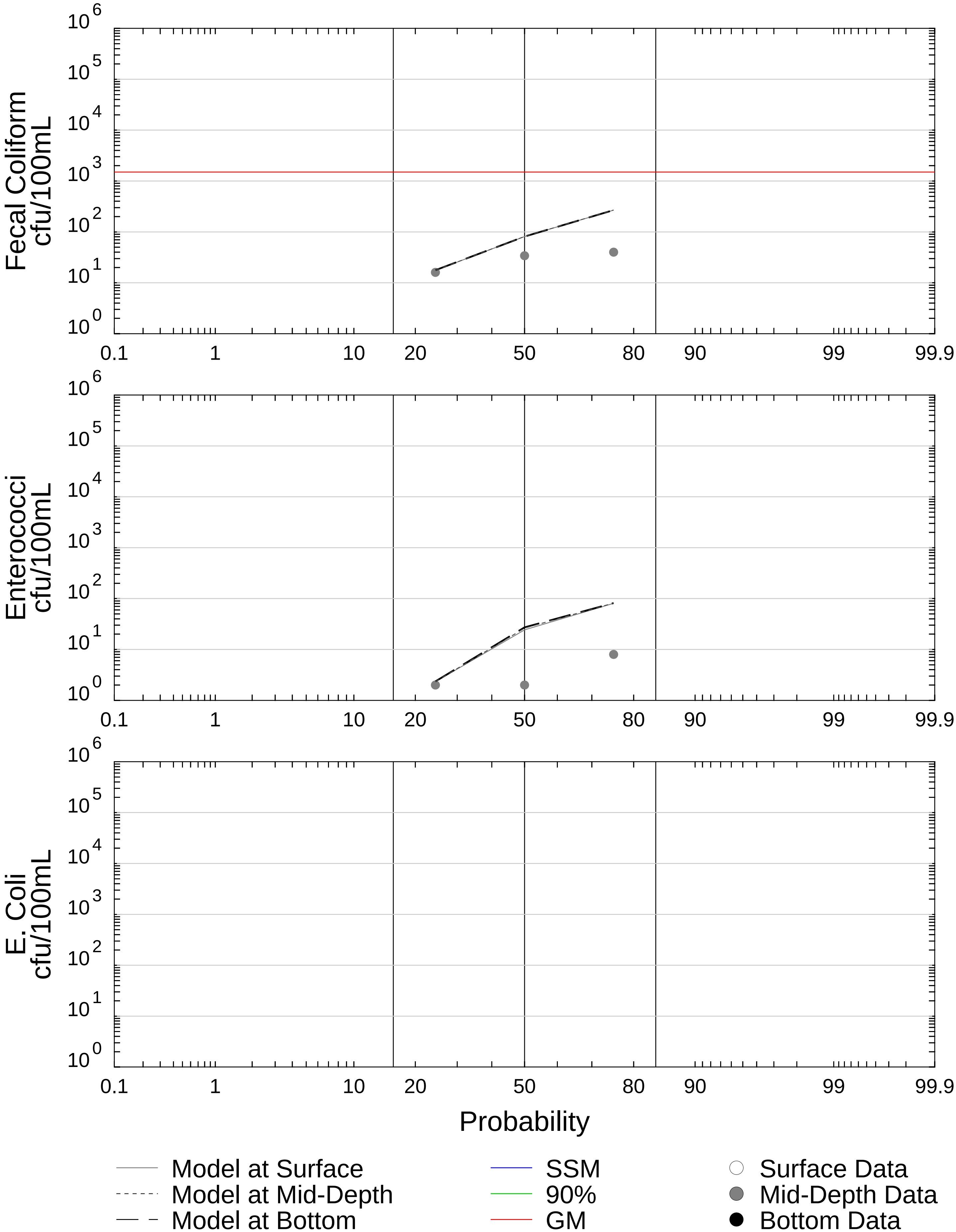
Model Results during data sampling hours only

Station: 18



Model Results during data sampling hours only

Station: B17

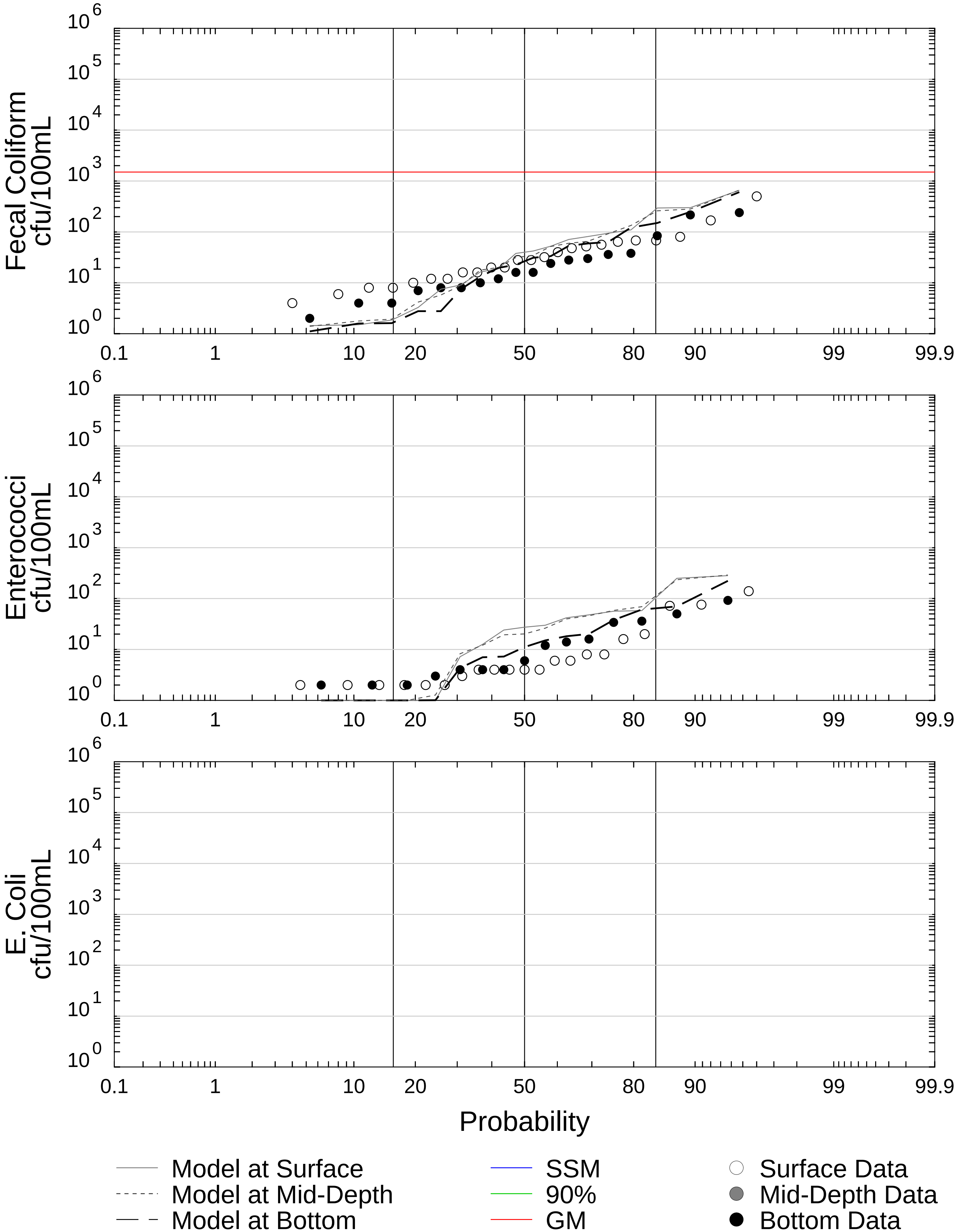


Model Results during data sampling hours only

KILL VAN KULL

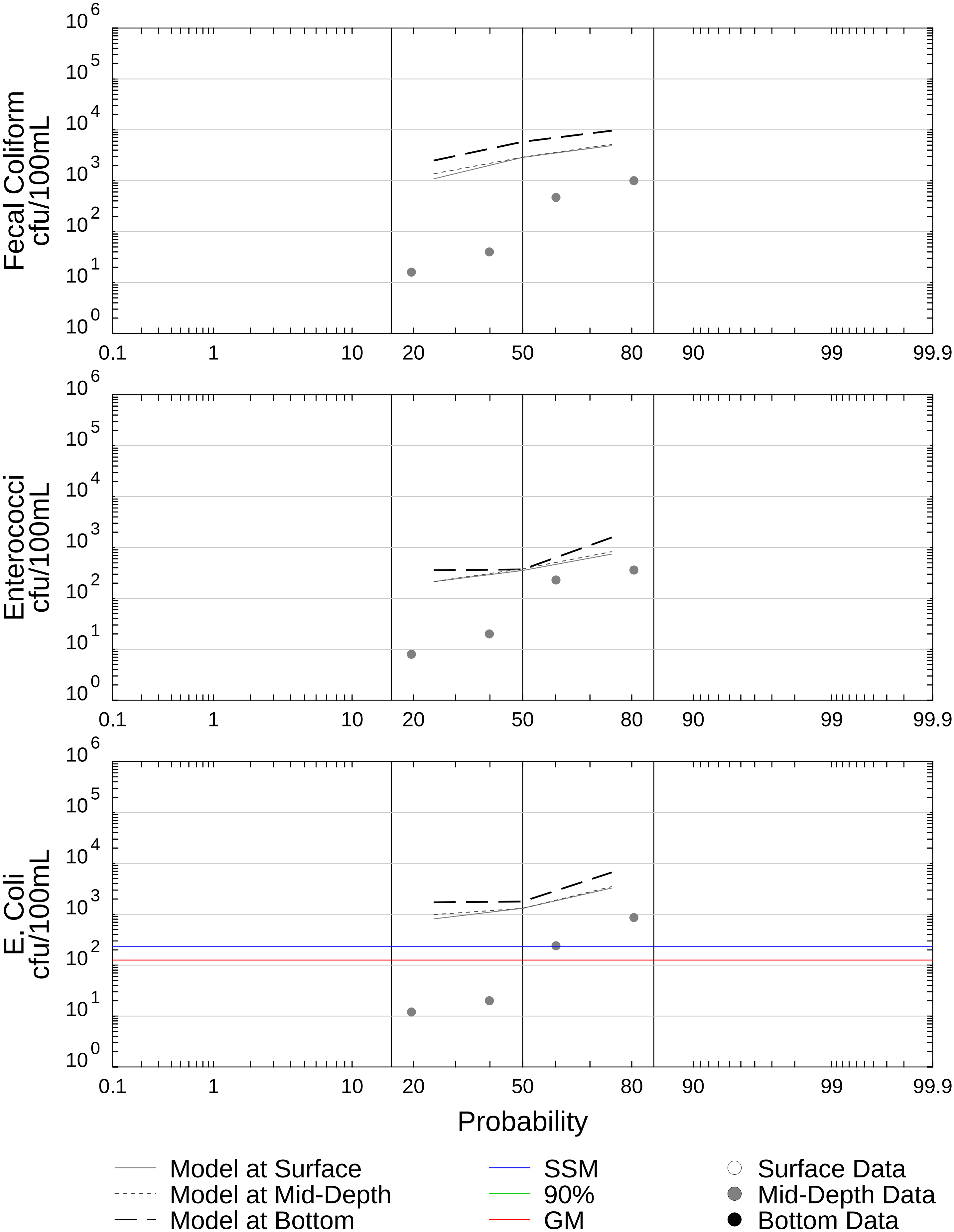
SE3

Station: 19



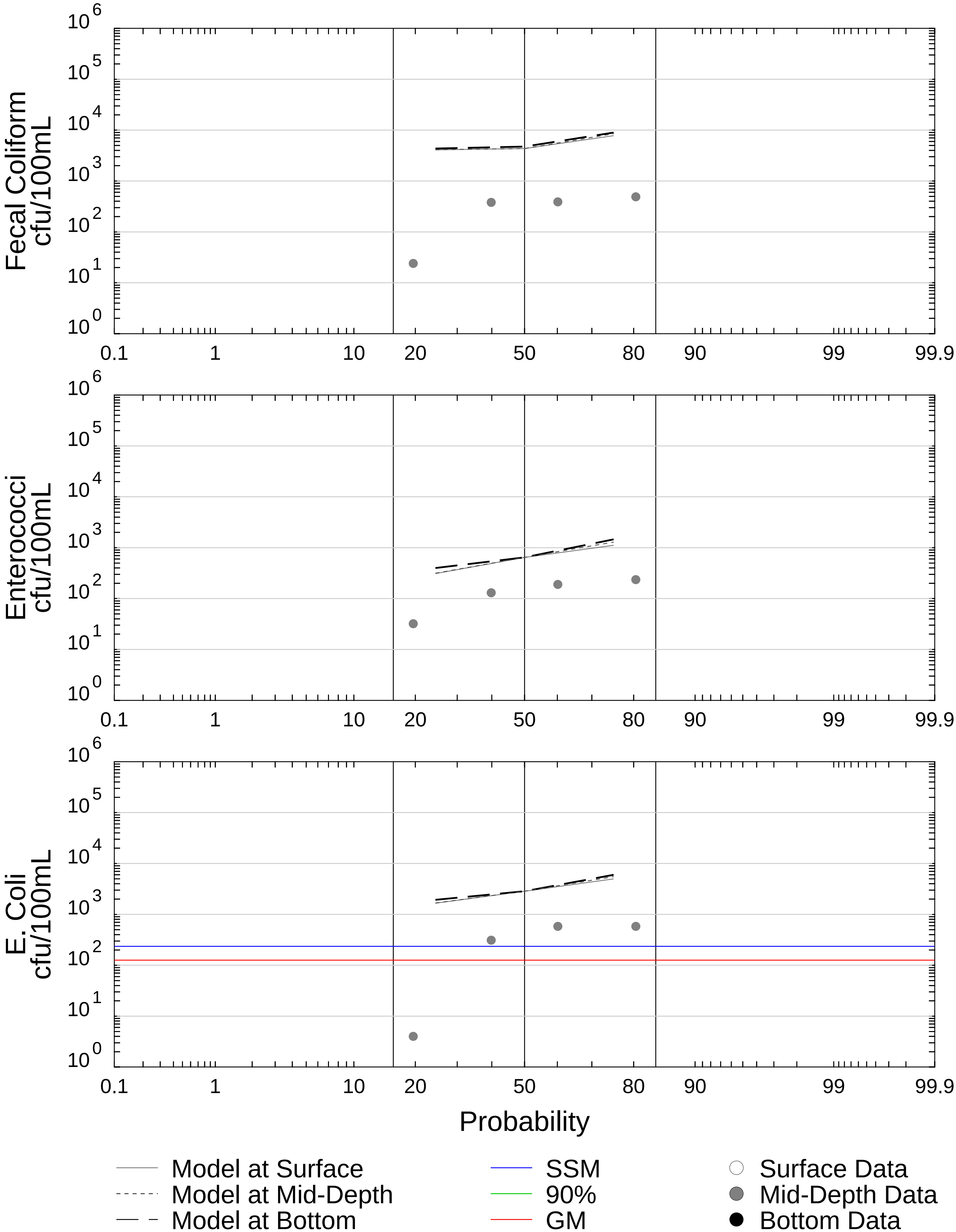
Model Results during data sampling hours only

Station: B16



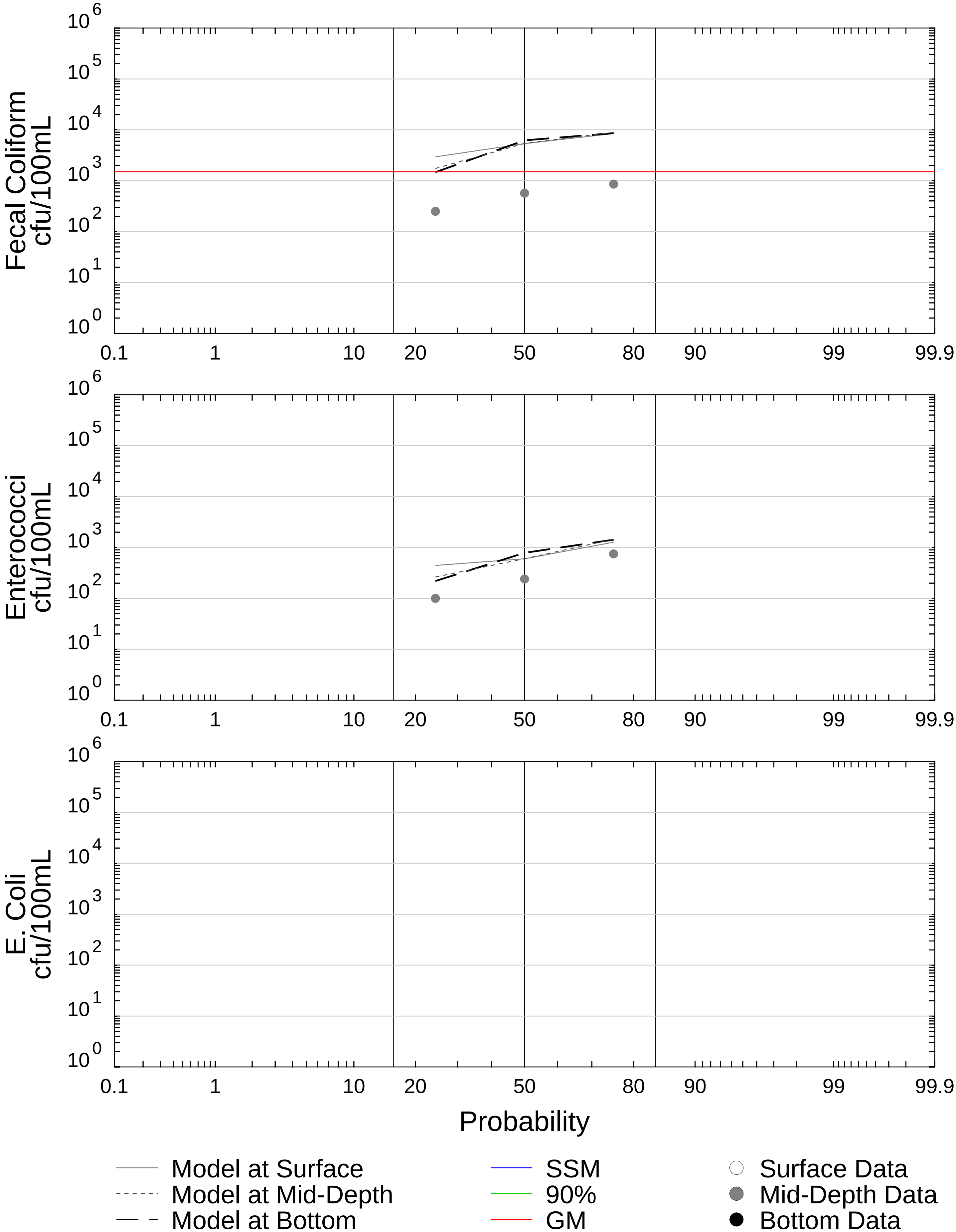
Model Results during data sampling hours only

Station: B14



Model Results during data sampling hours only

Station: B13

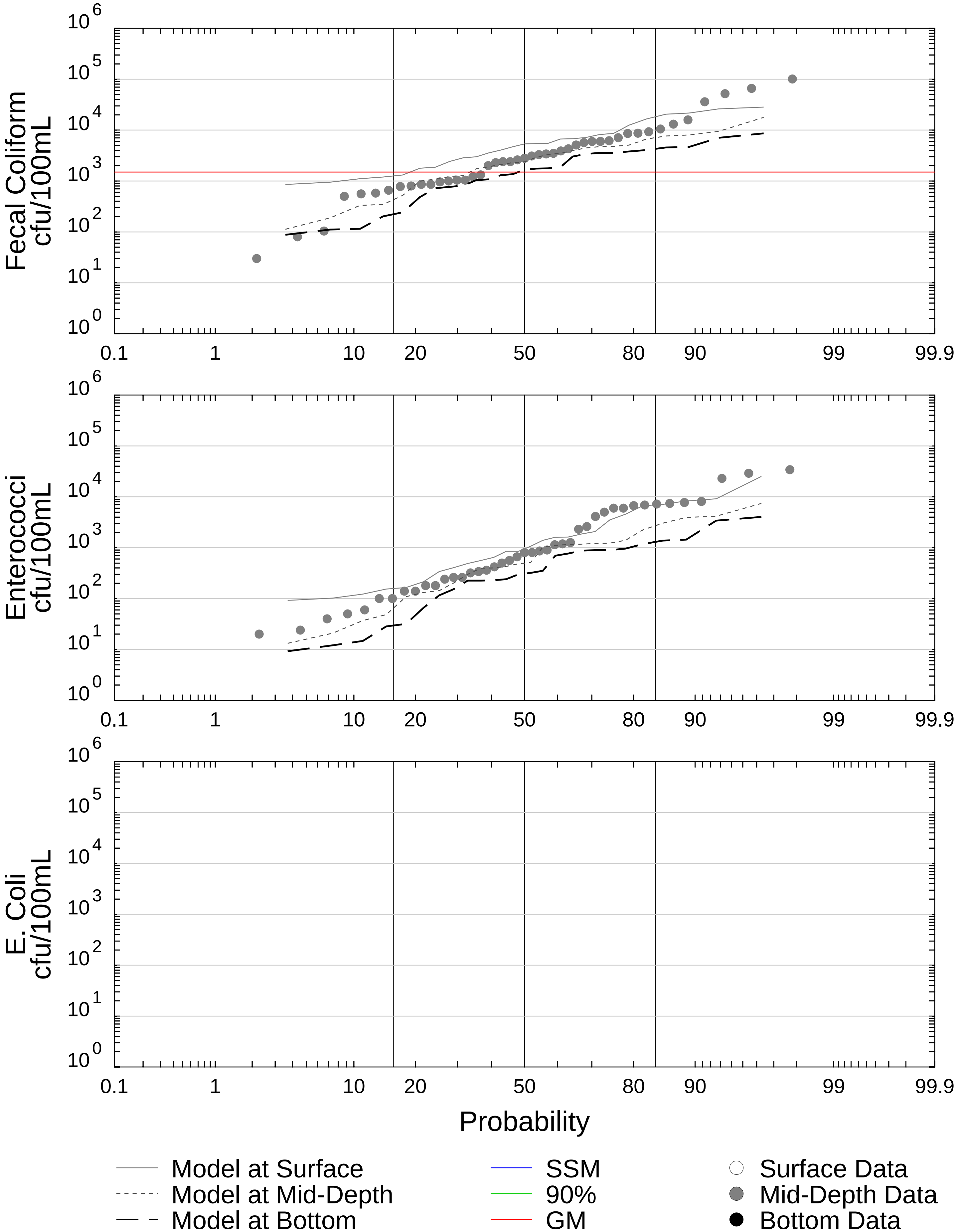


Model Results during data sampling hours only

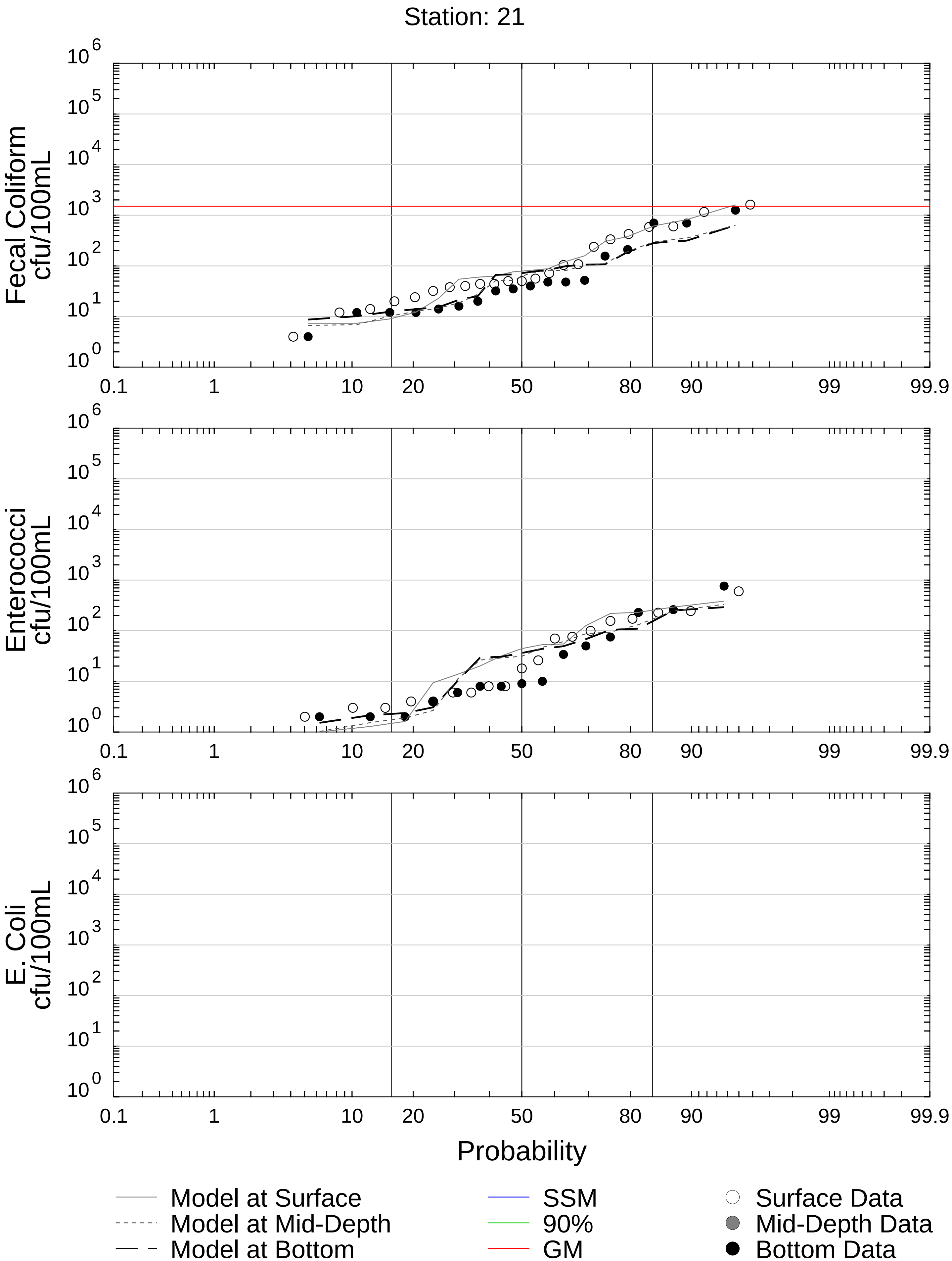
ELIZABETH RIVER

SE3

Station: 20



Model Results during data sampling hours only

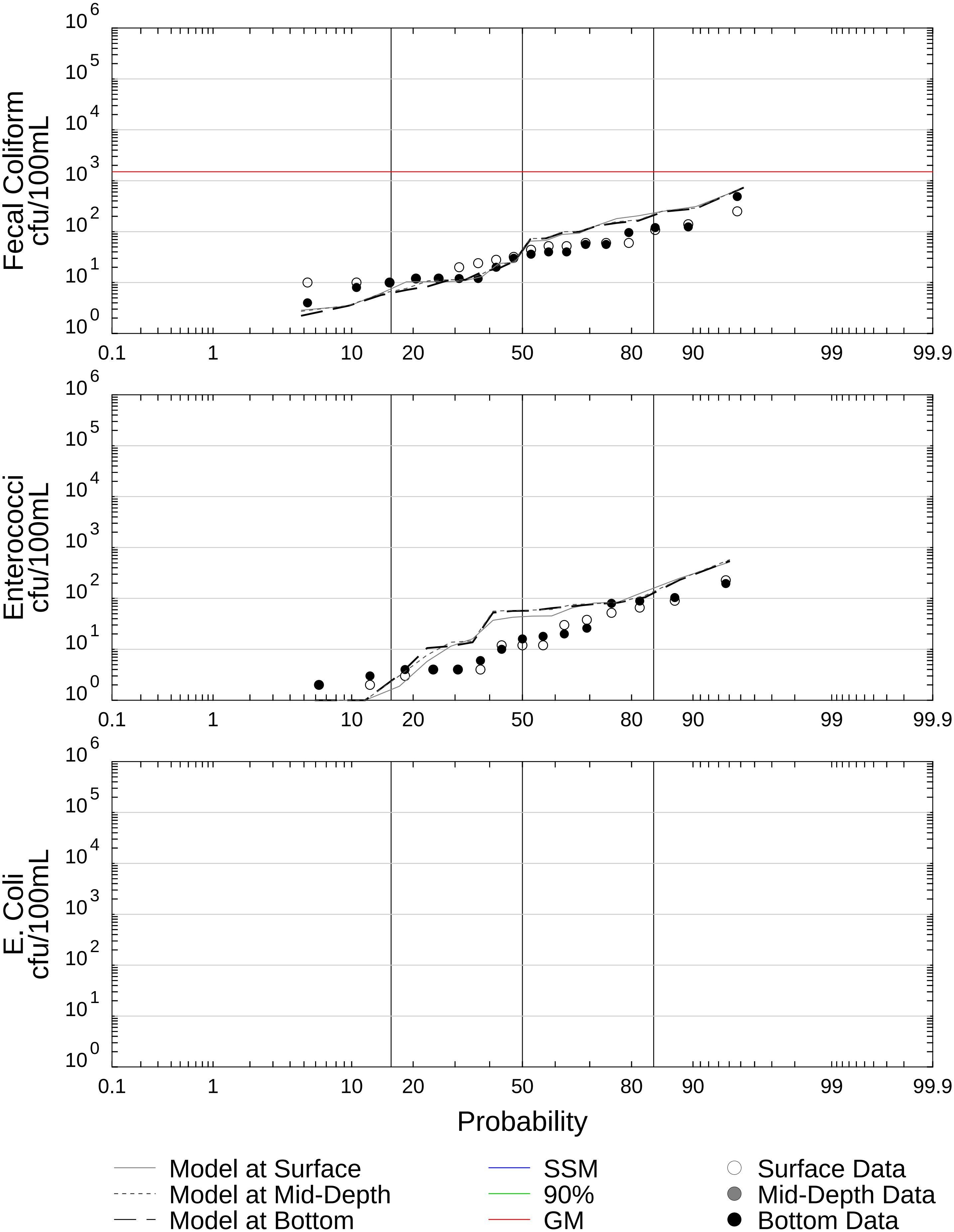


Model Results during data sampling hours only

ARTHUR KILL

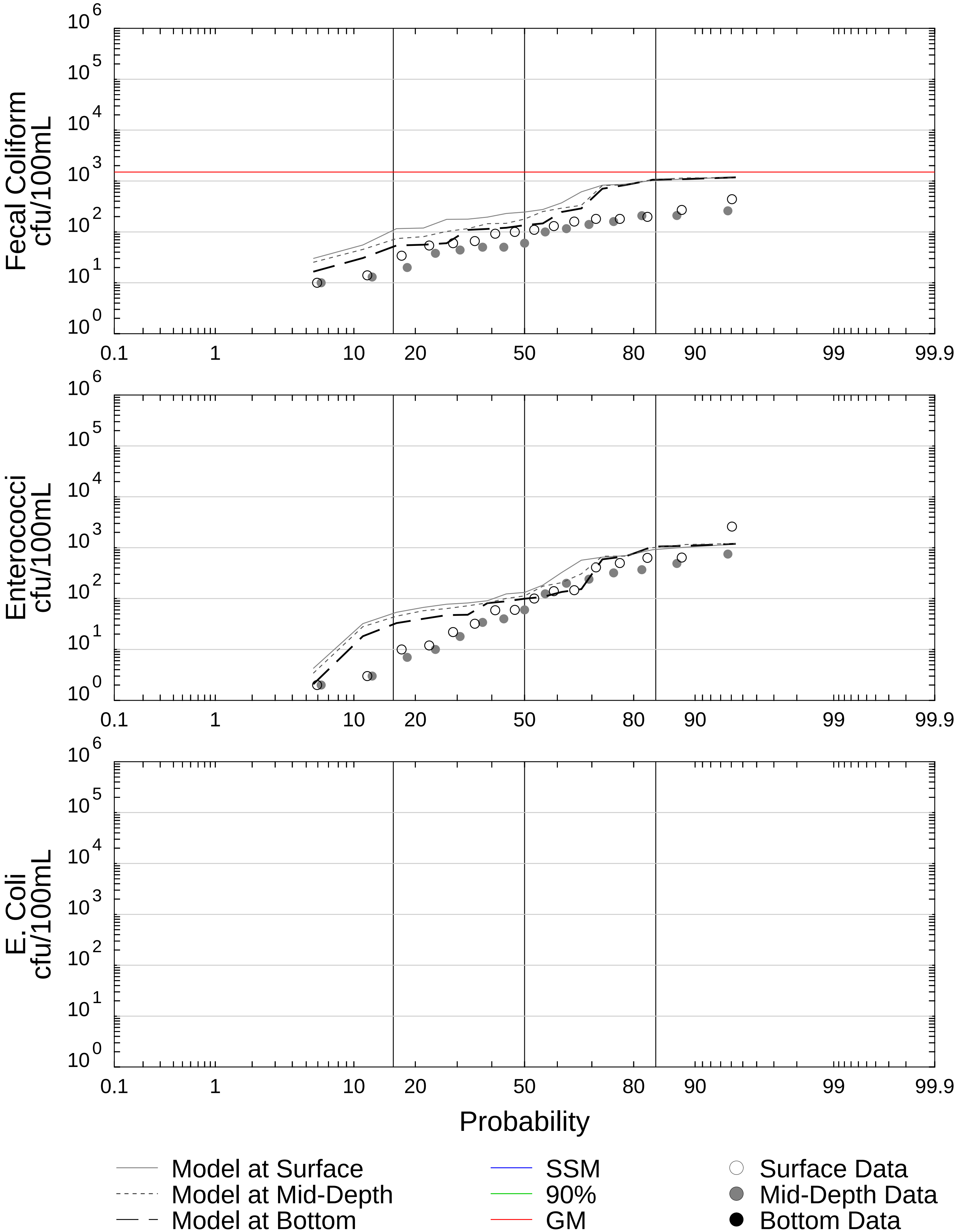
SE3

Station: 23



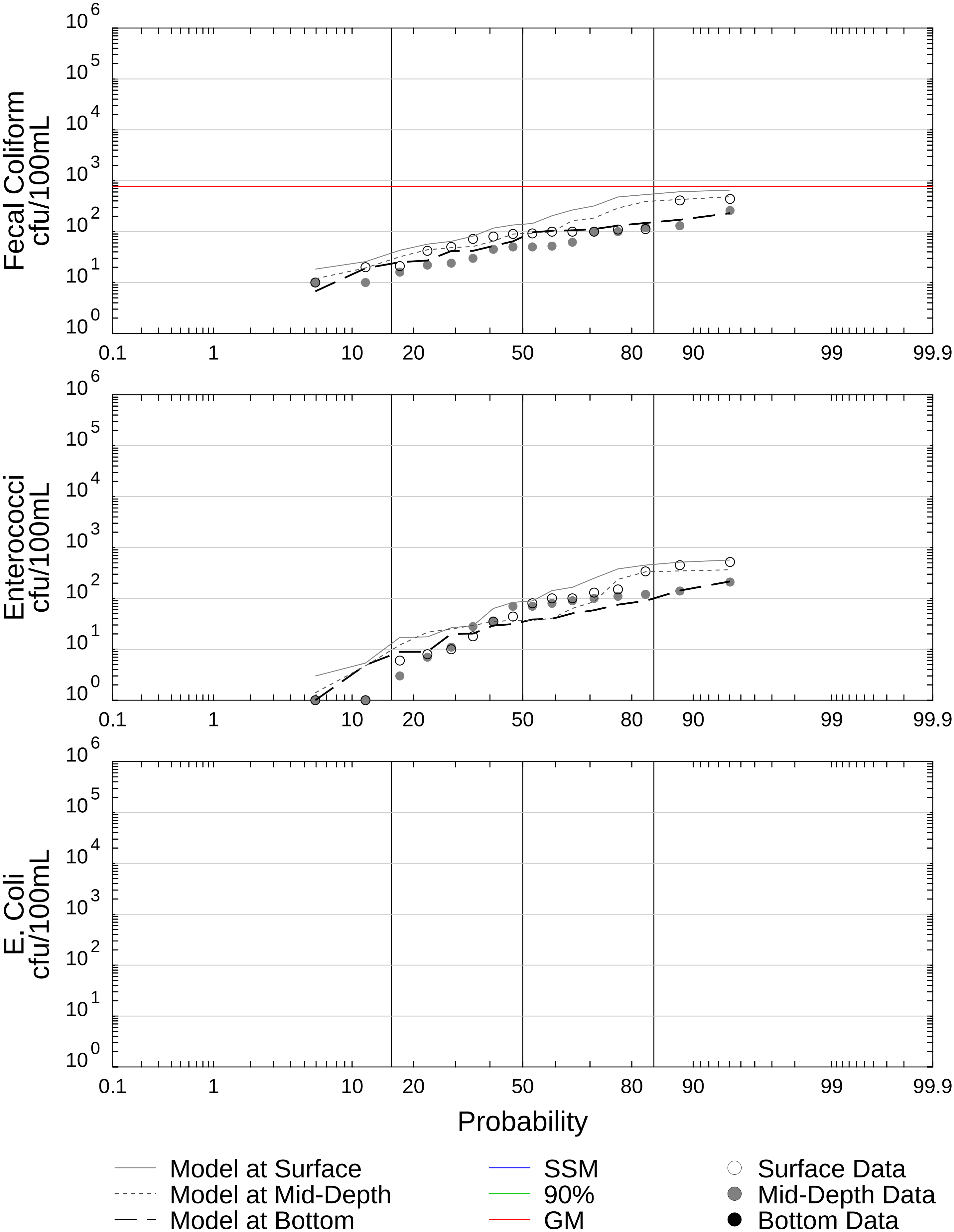
Model Results during data sampling hours only

Station: 24



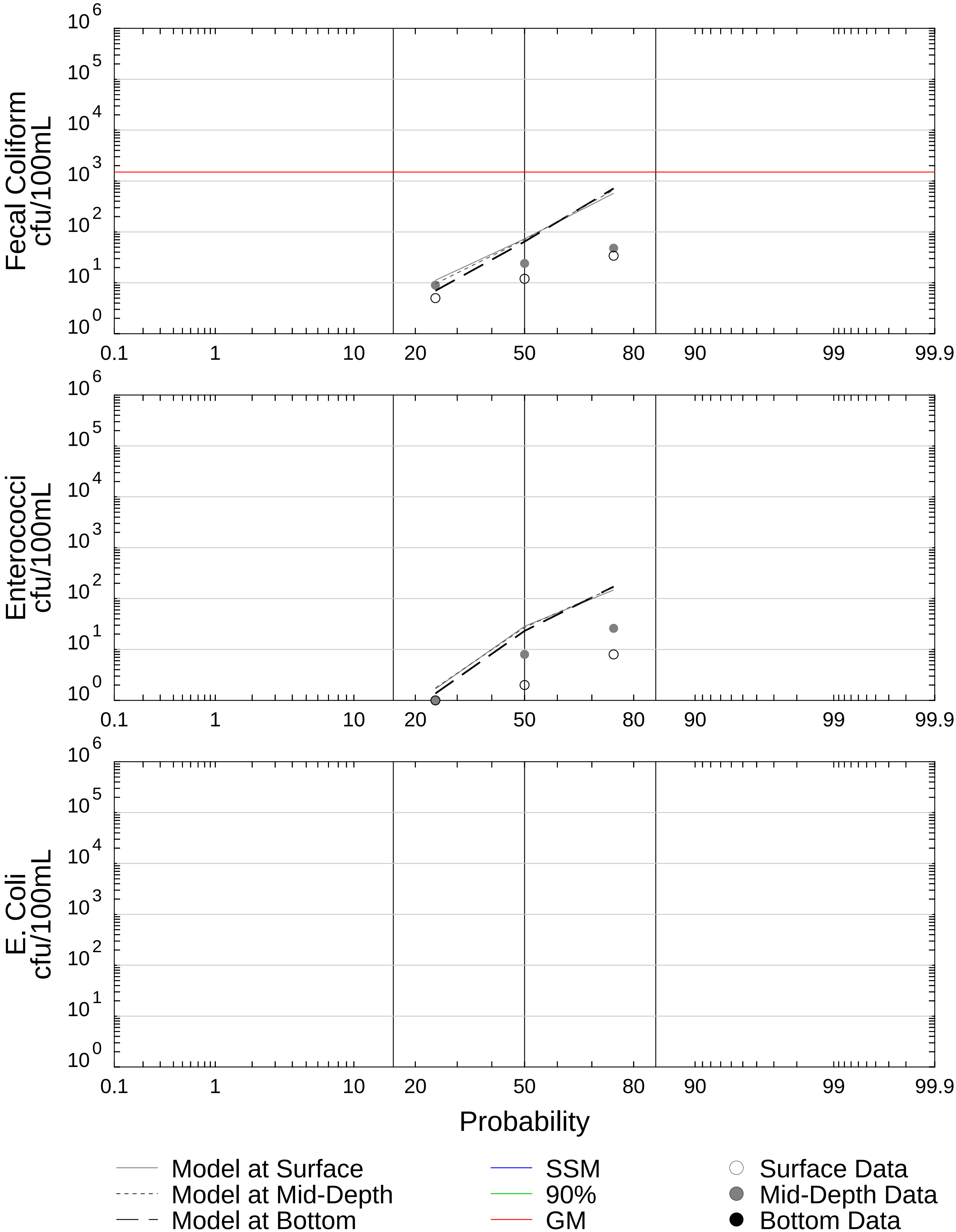
Model Results during data sampling hours only

Station: B15



Model Results during data sampling hours only

Station: B20

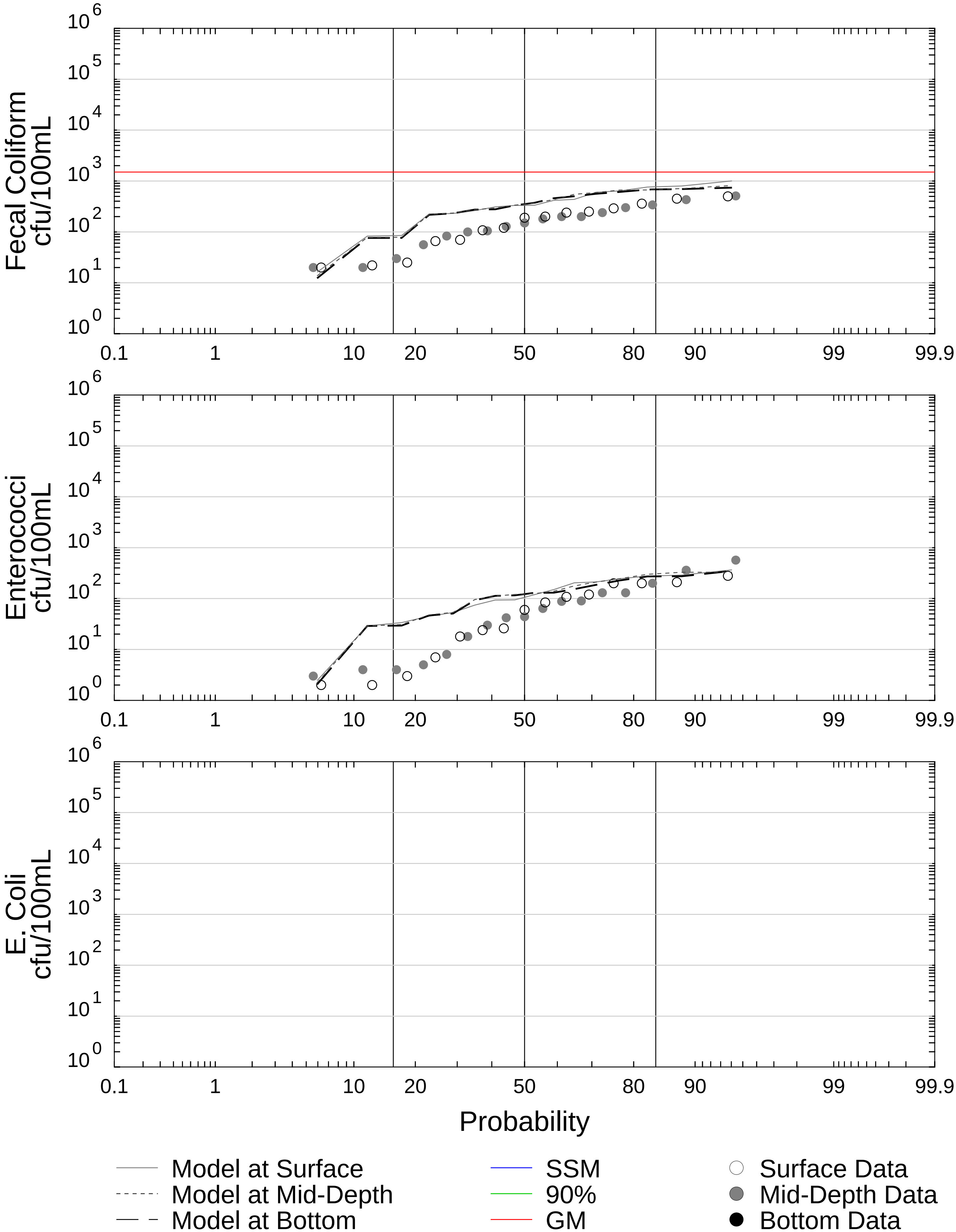


Model Results during data sampling hours only

KILL VAN KULL

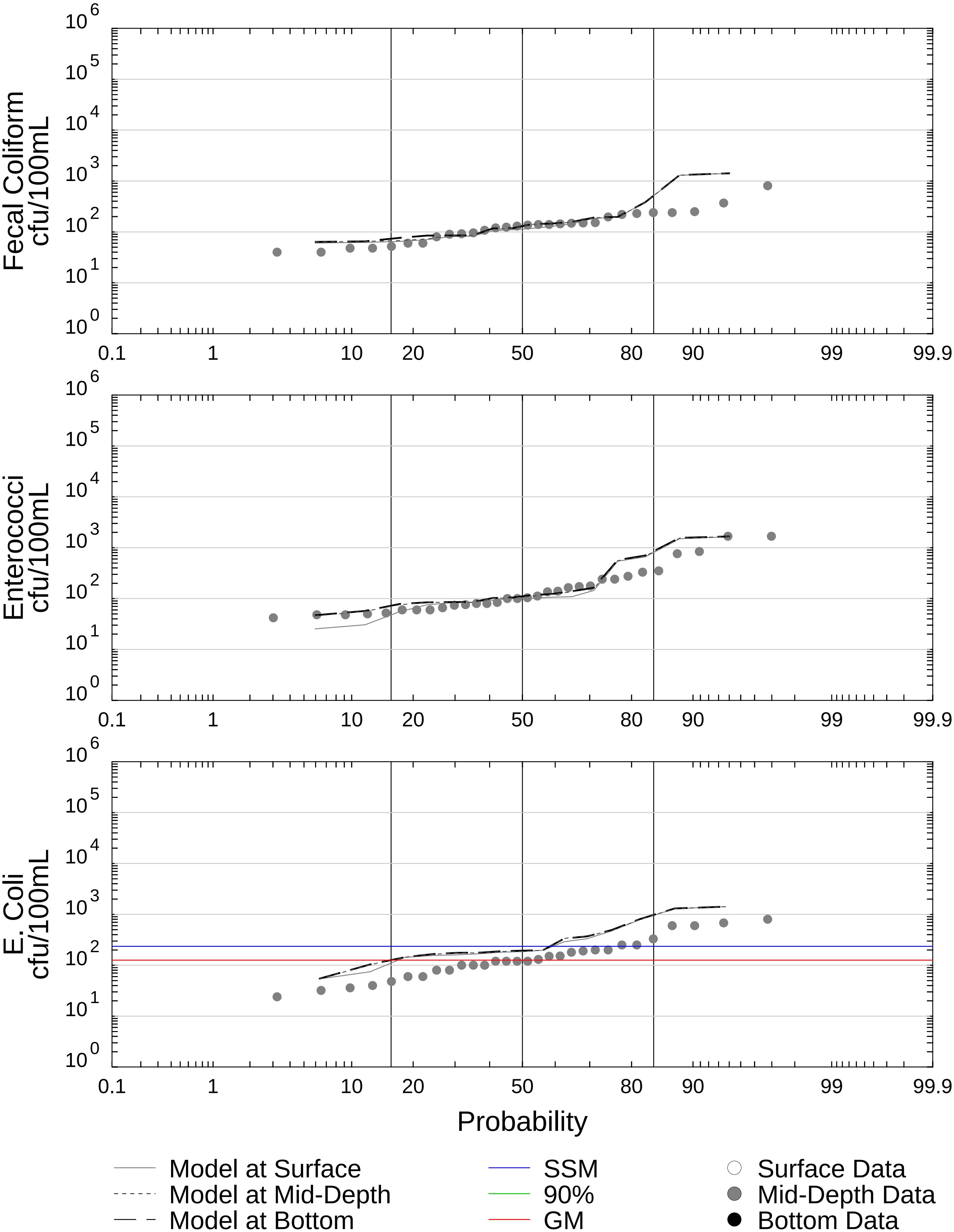
SE3

Station: B12



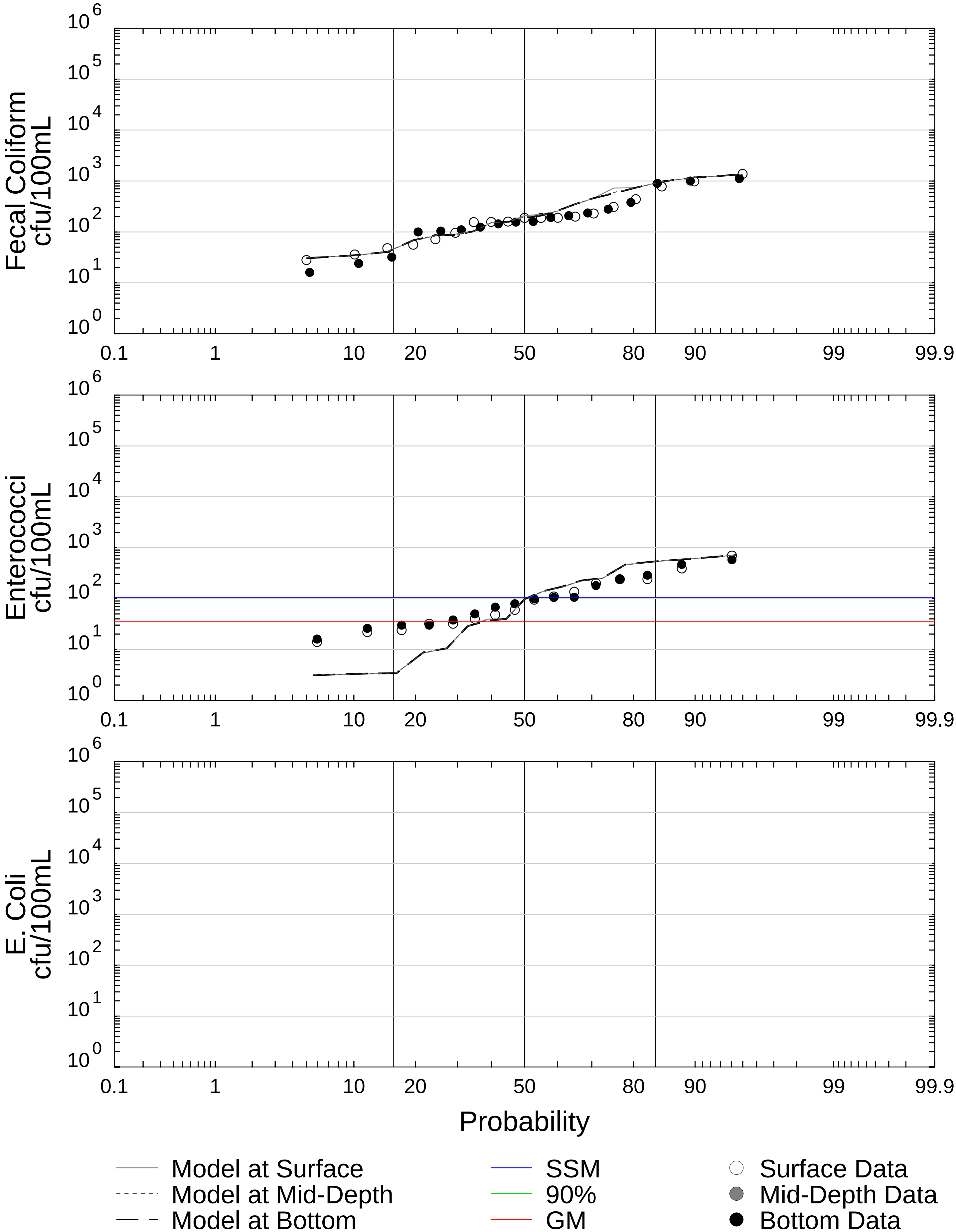
Model Results during data sampling hours only

Station: 25



Model Results during data sampling hours only

Station: 26

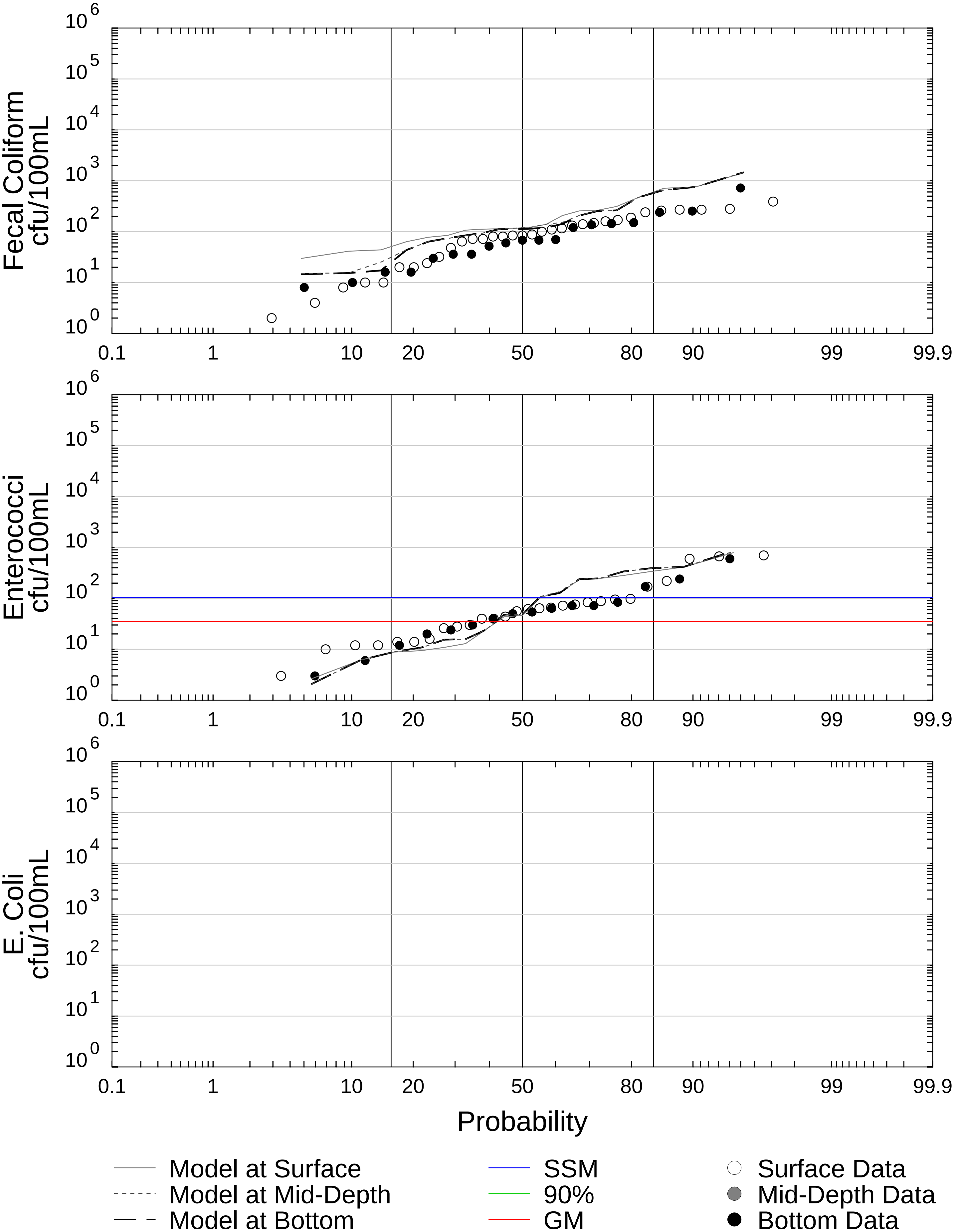


Model Results during data sampling hours only

RARITAN RIVER

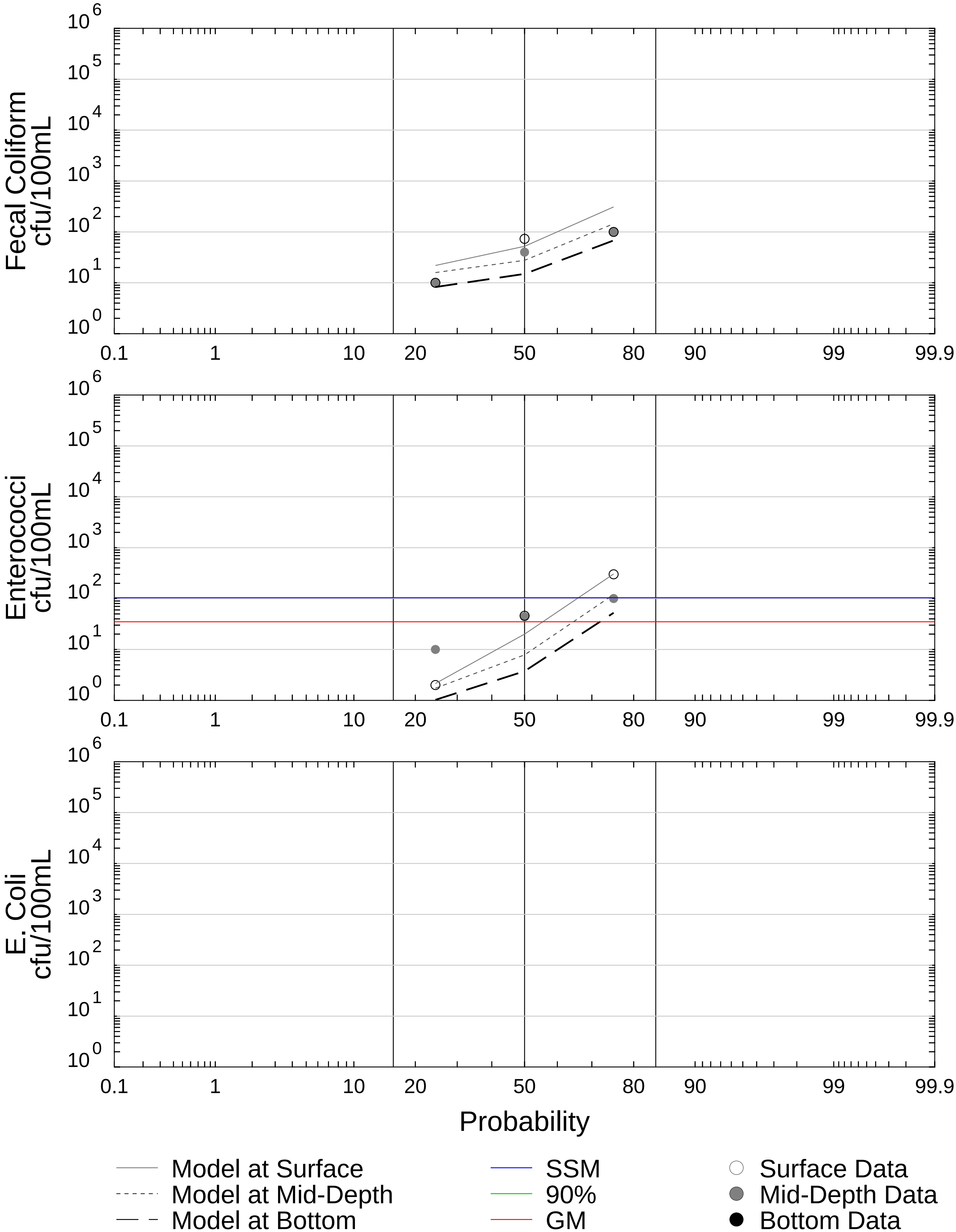
SE1

Station: 27



Model Results during data sampling hours only

Station: B19

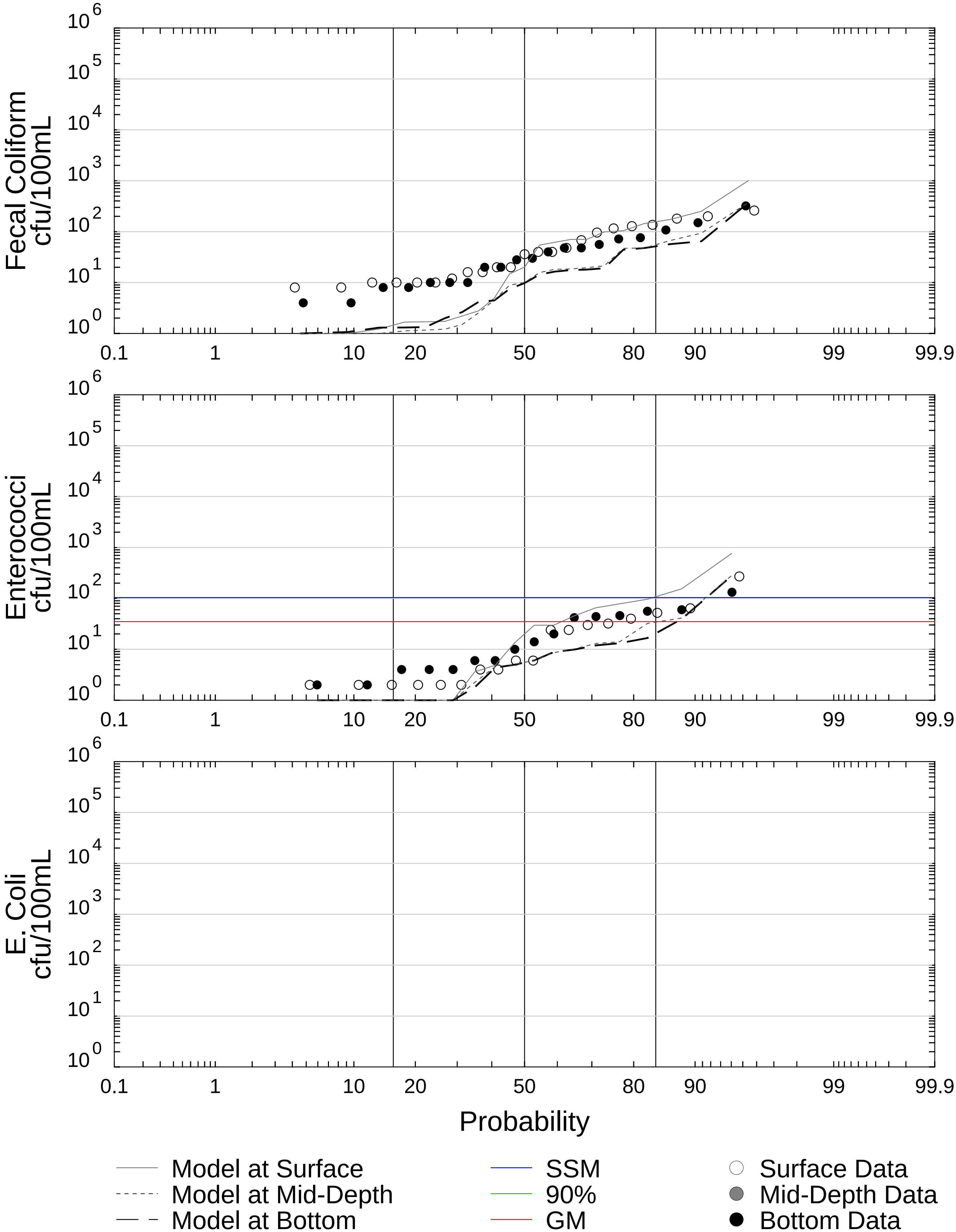


Model Results during data sampling hours only

RARITAN BAY

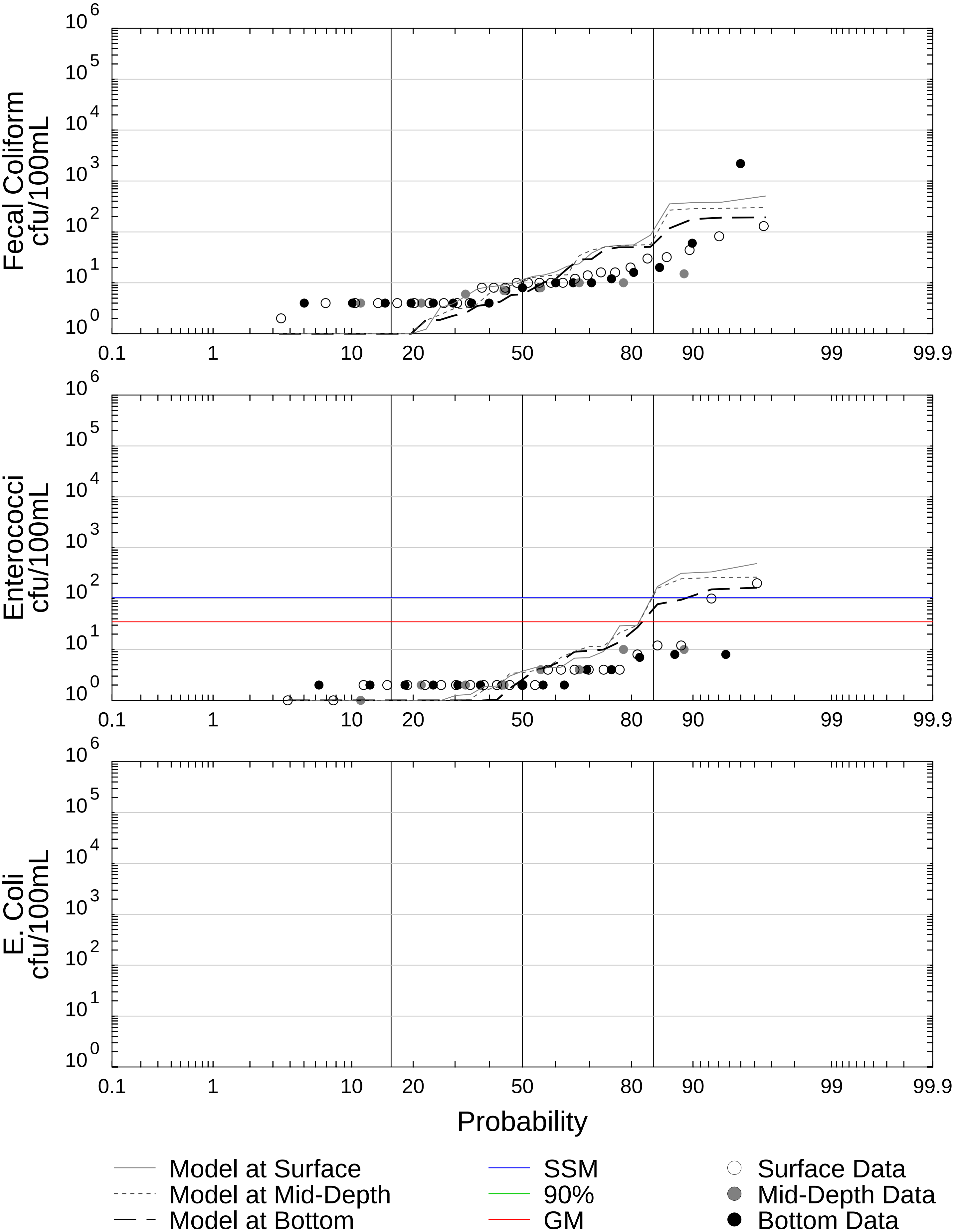
SE1

Station: 28



Model Results during data sampling hours only

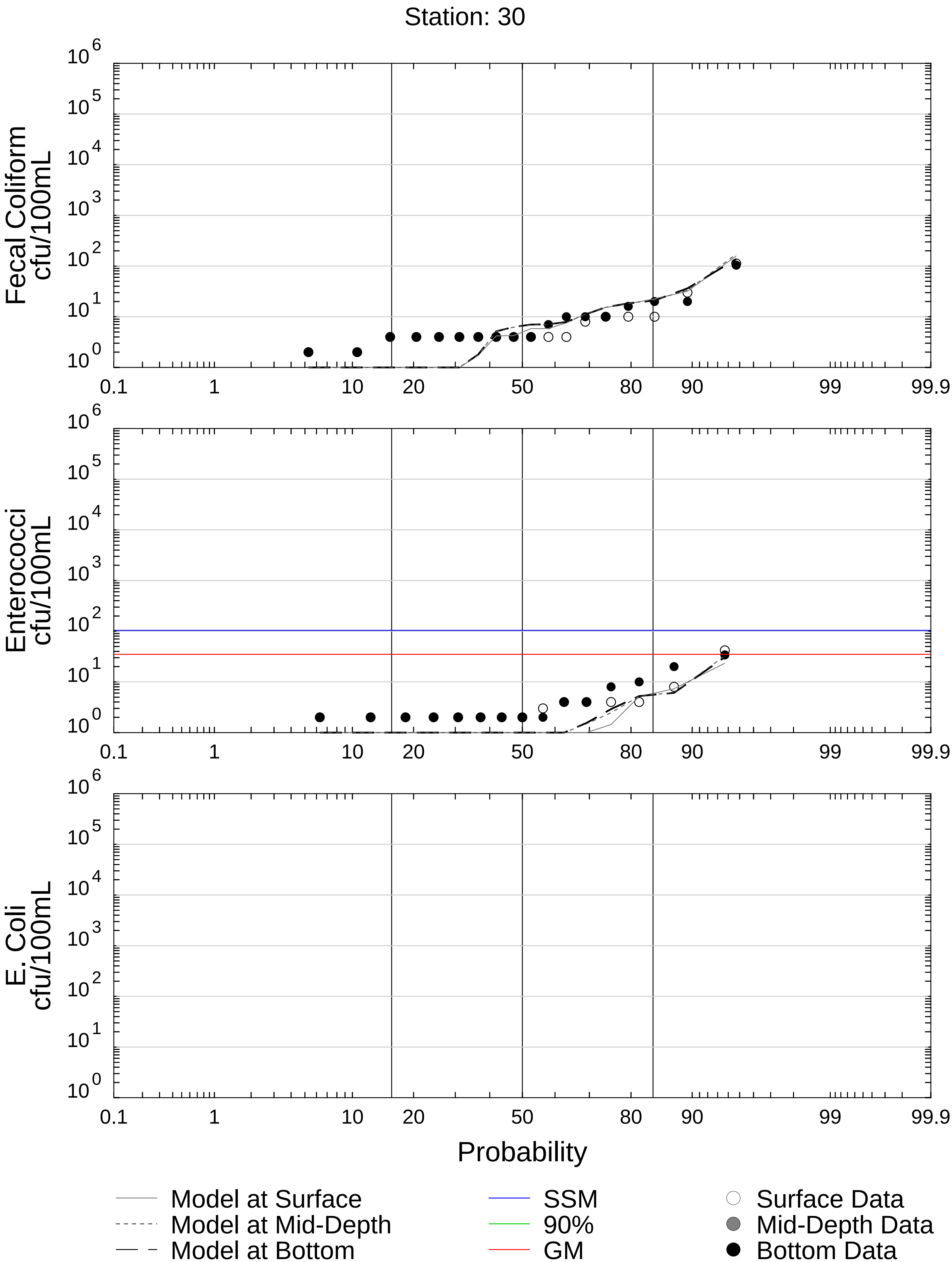
Station: 29



Model Results during data sampling hours only

RARITAN BAY

SE1

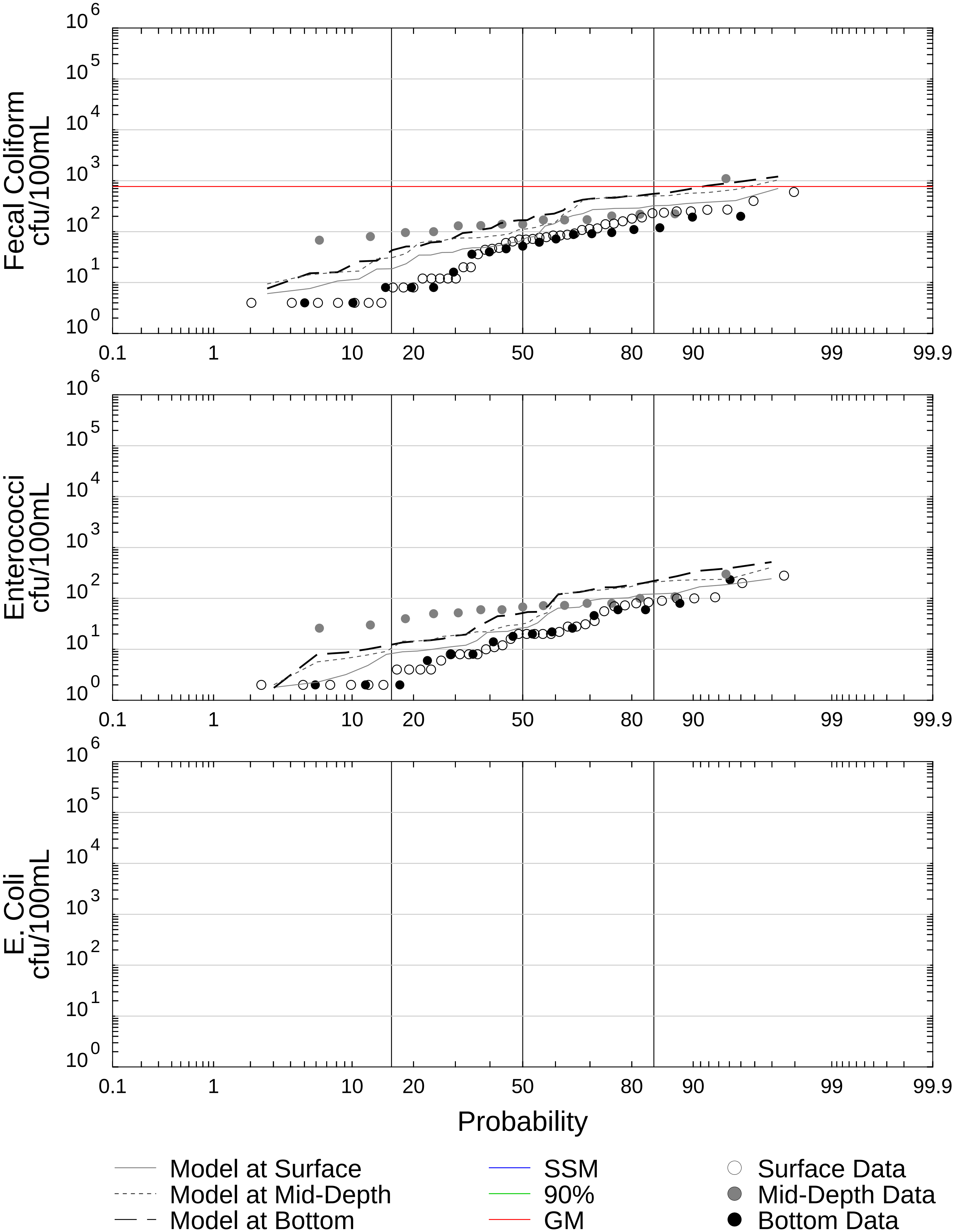


Model Results during data sampling hours only

HUDSON RIVER

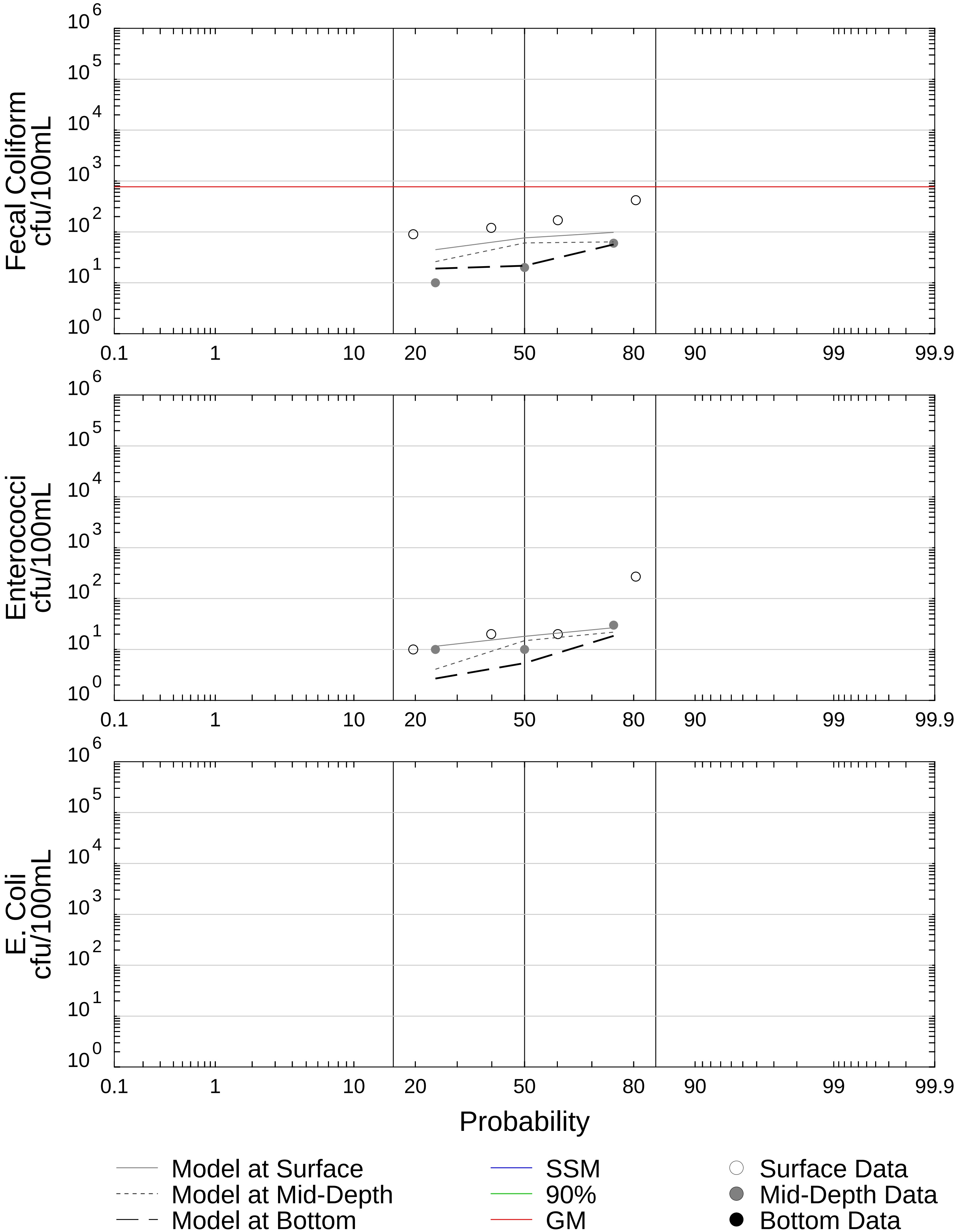
SE2

Station: 31



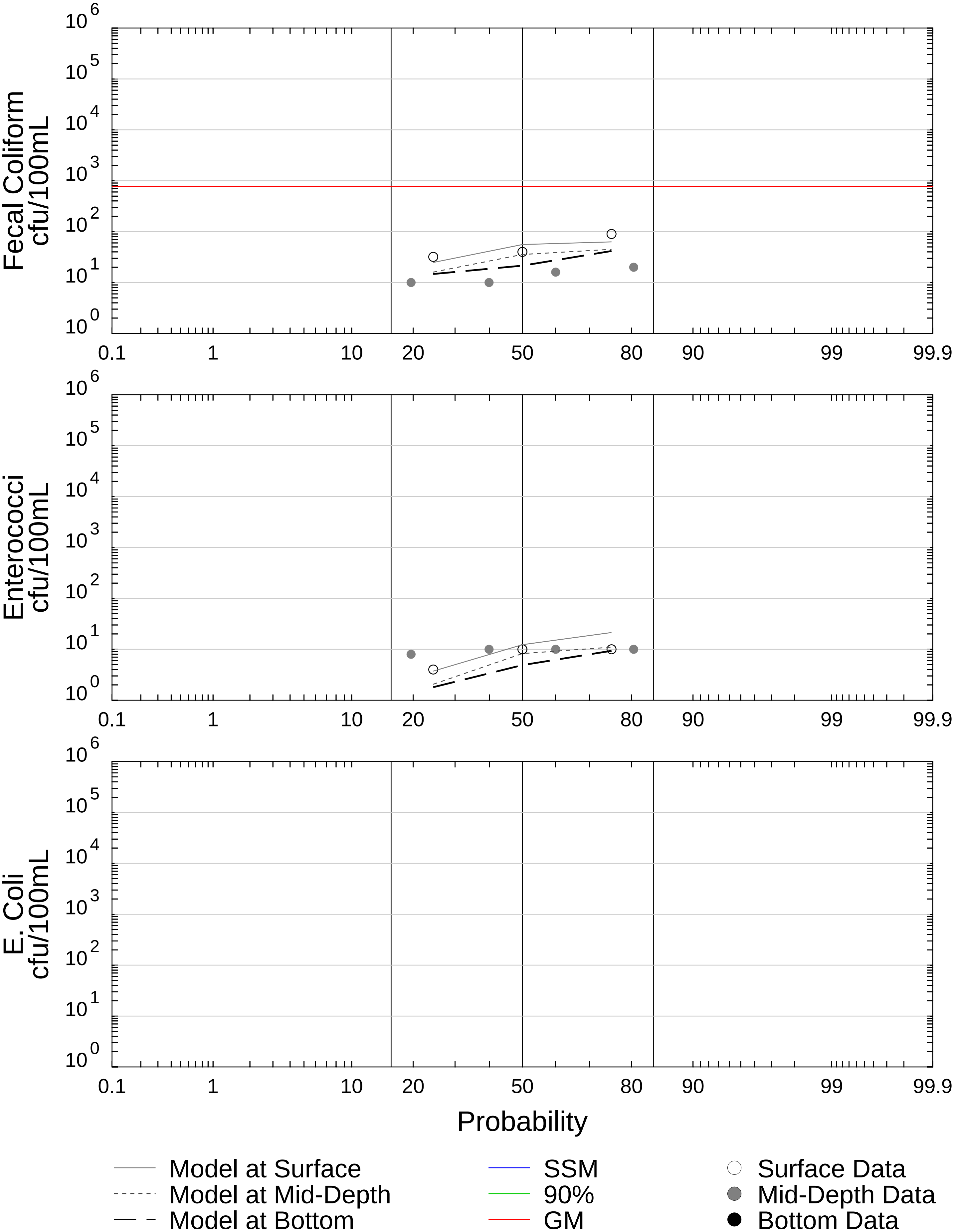
Model Results during data sampling hours only

Station: B5A

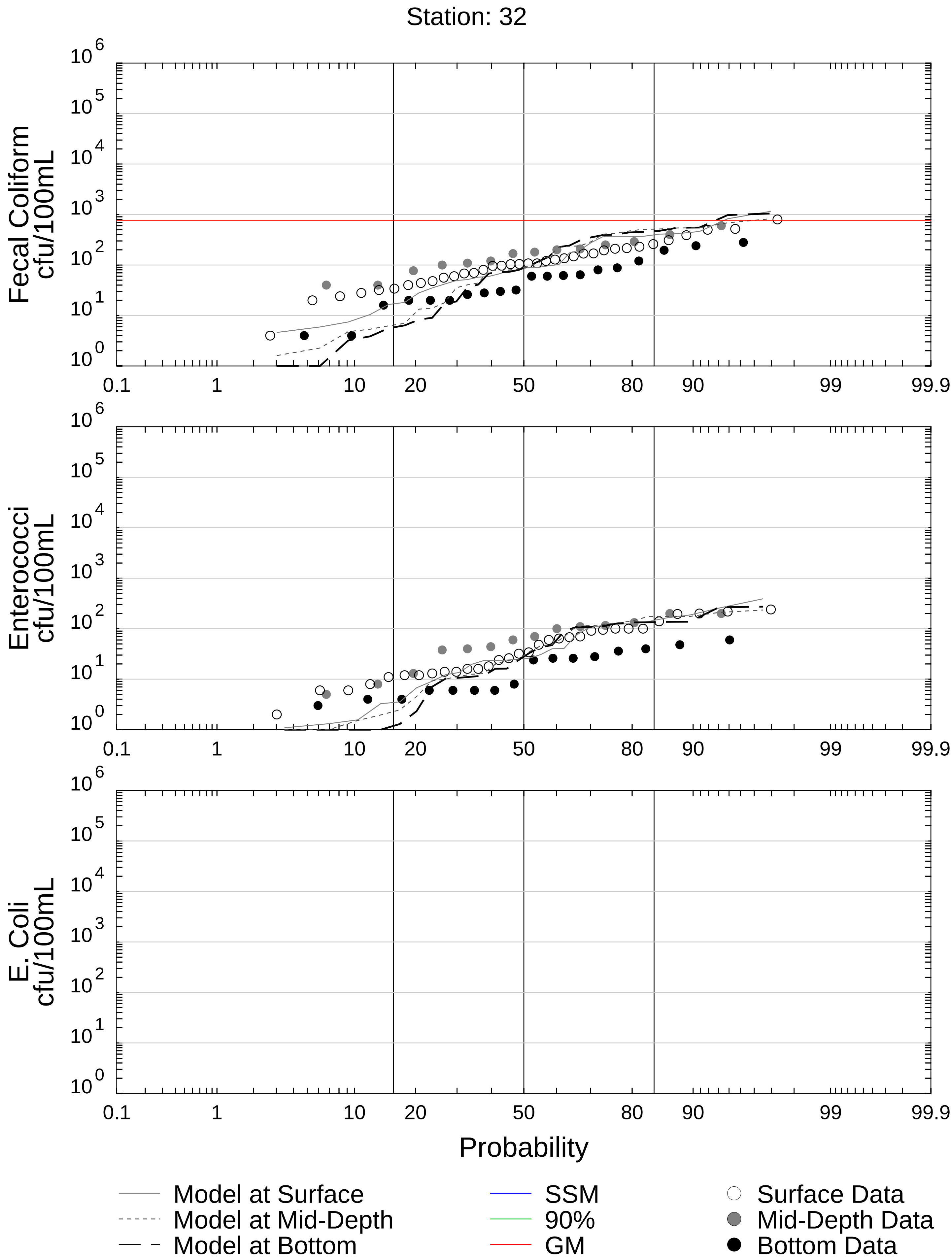


Model Results during data sampling hours only

Station: B5B

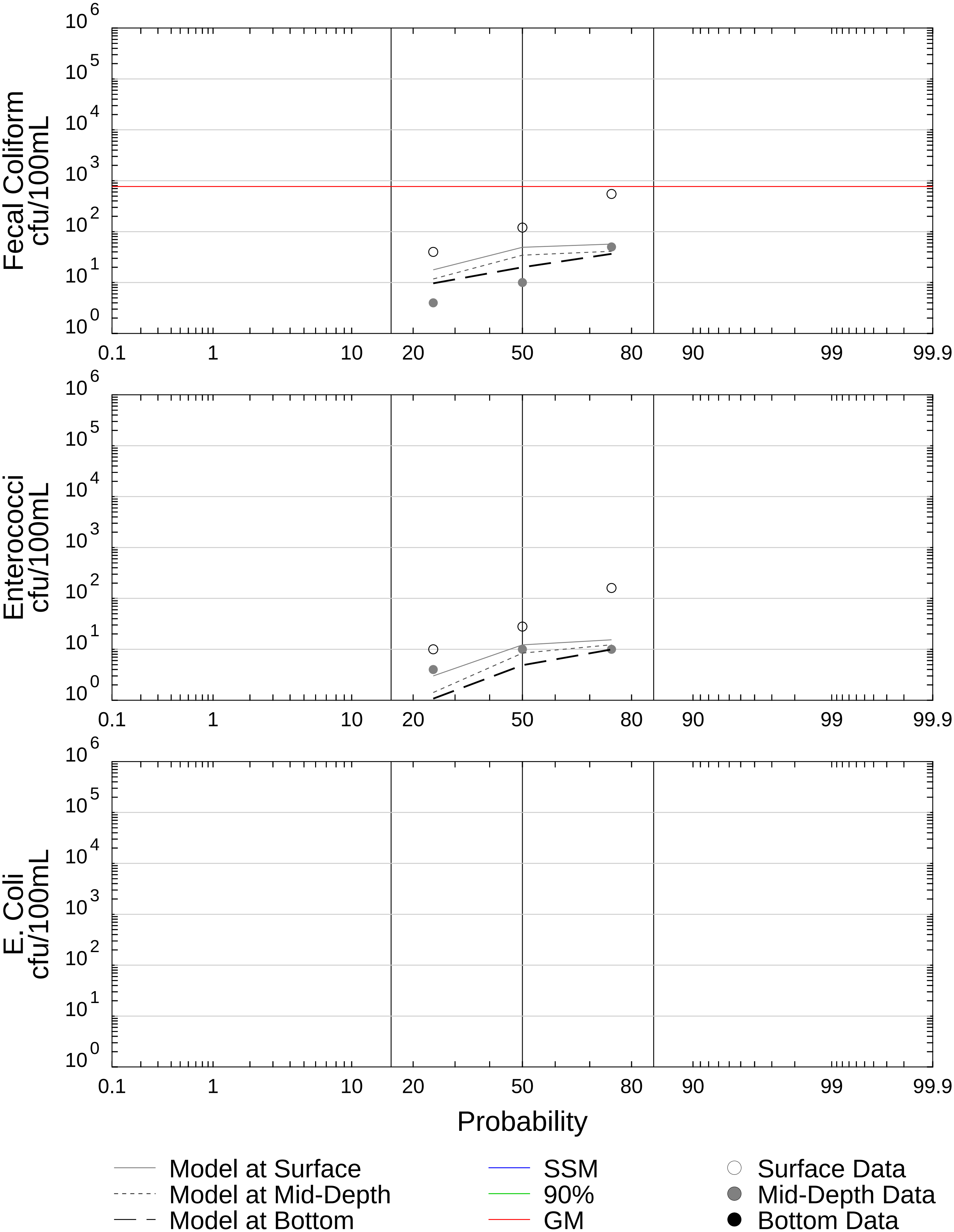


Model Results during data sampling hours only



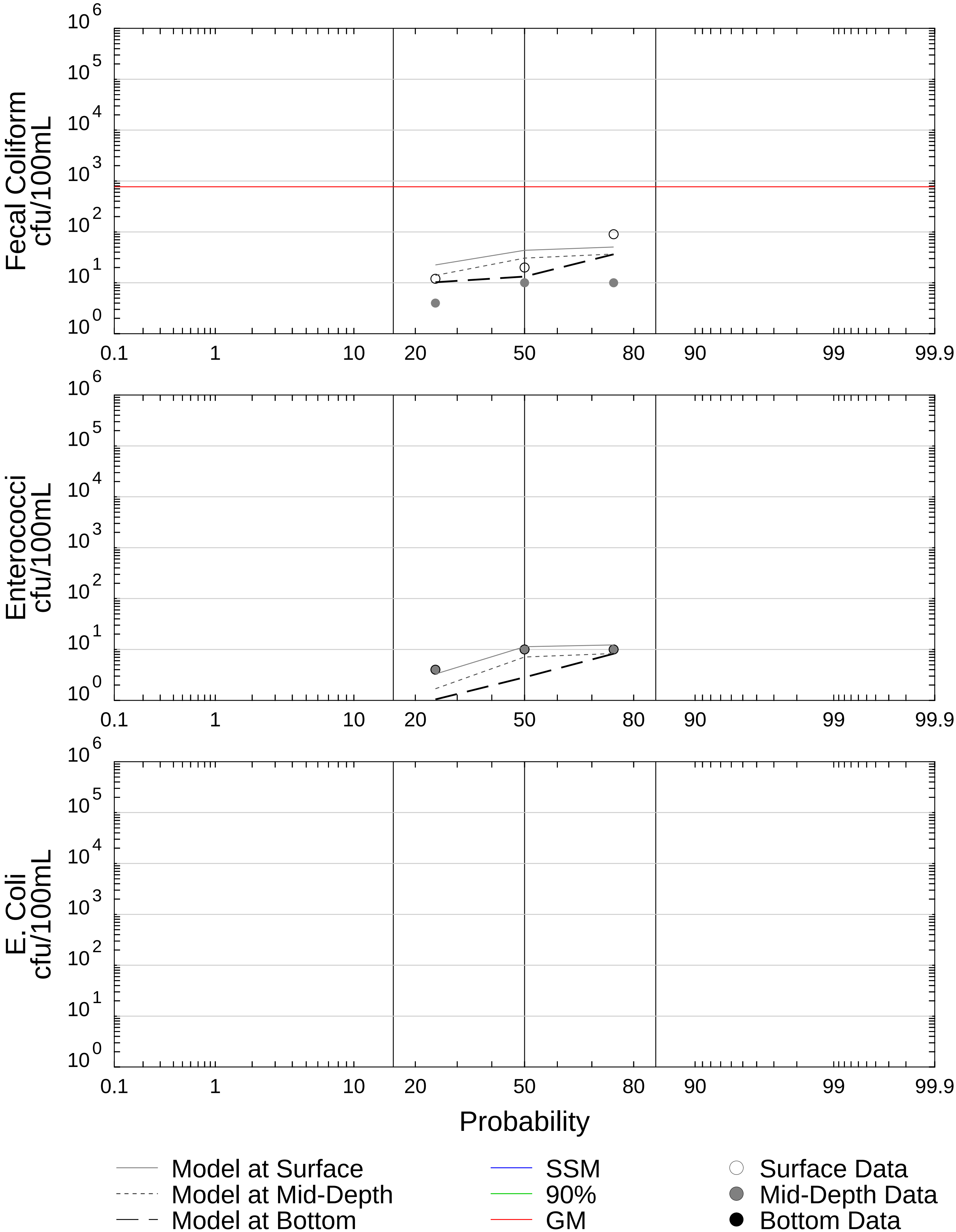
Model Results during data sampling hours only

Station: B18A



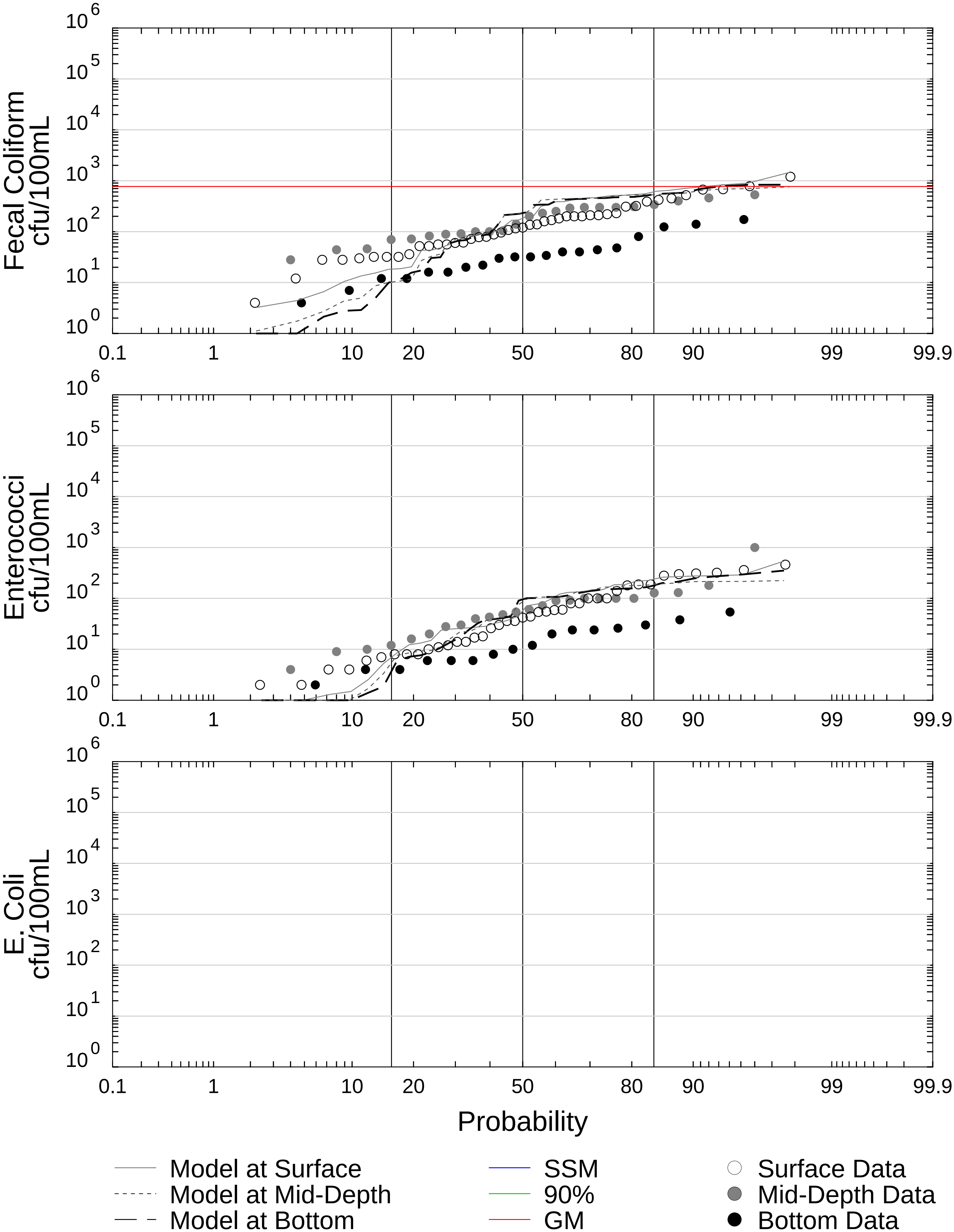
Model Results during data sampling hours only

Station: B18B



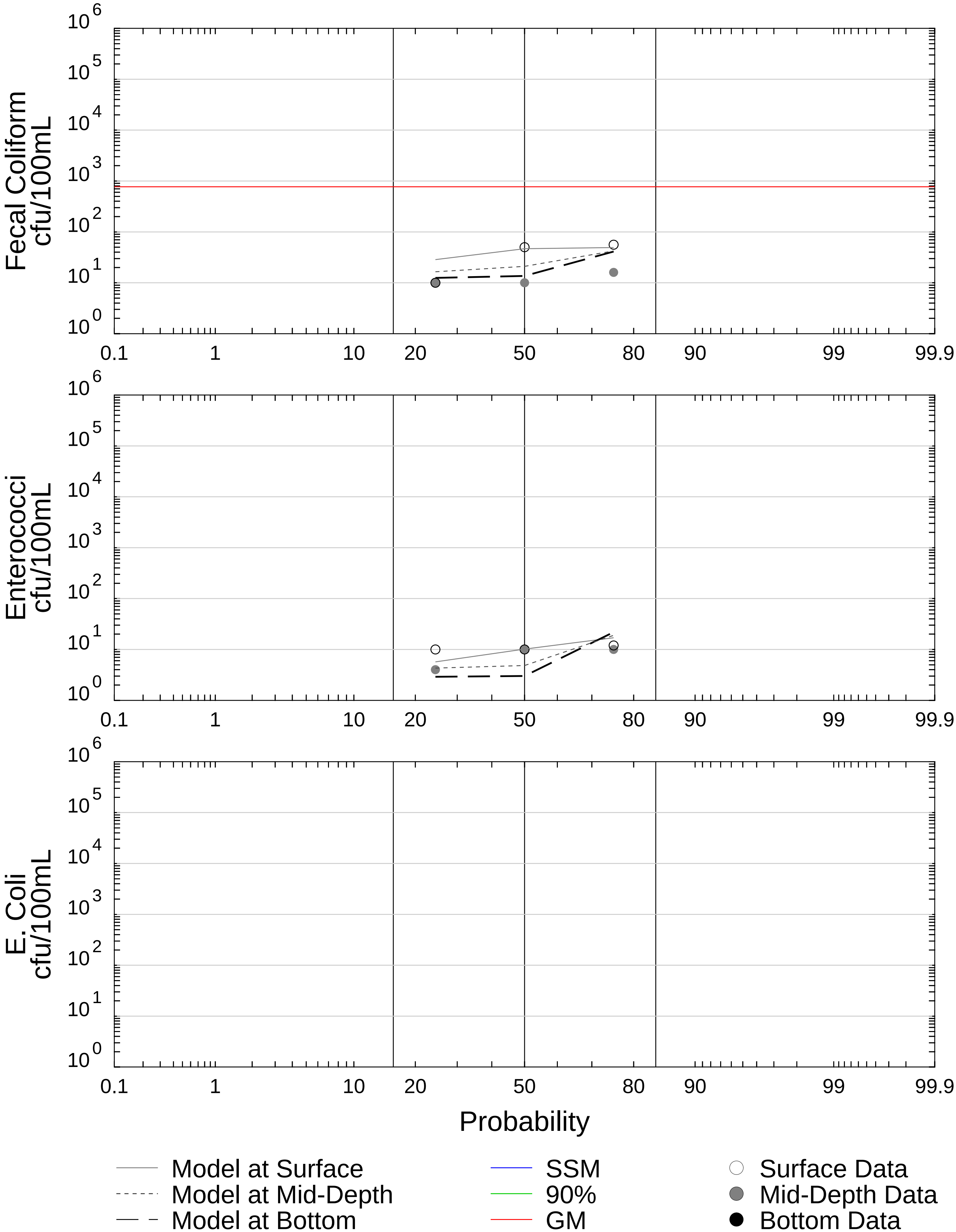
Model Results during data sampling hours only

Station: 33



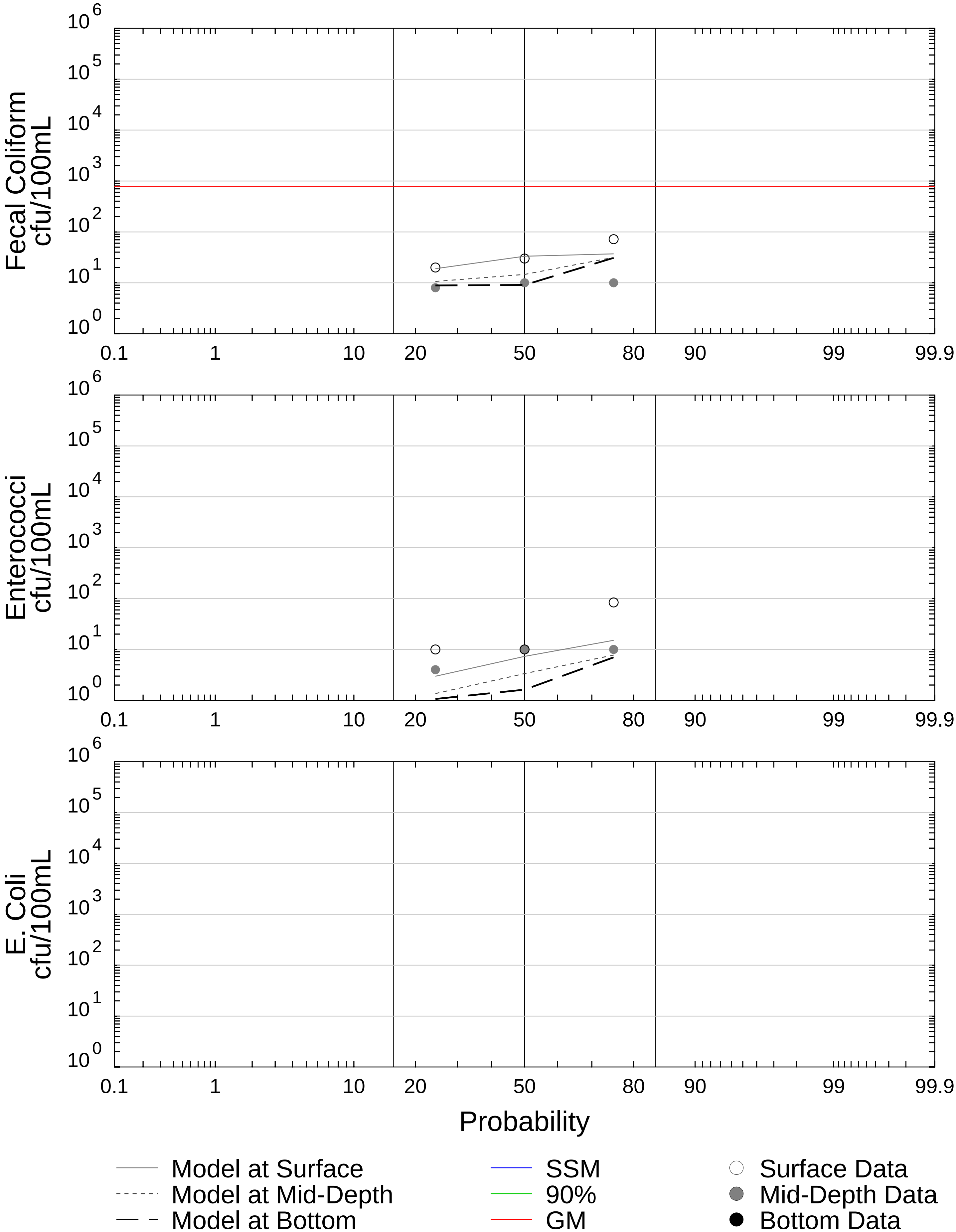
Model Results during data sampling hours only

Station: B23A



Model Results during data sampling hours only

Station: B23B

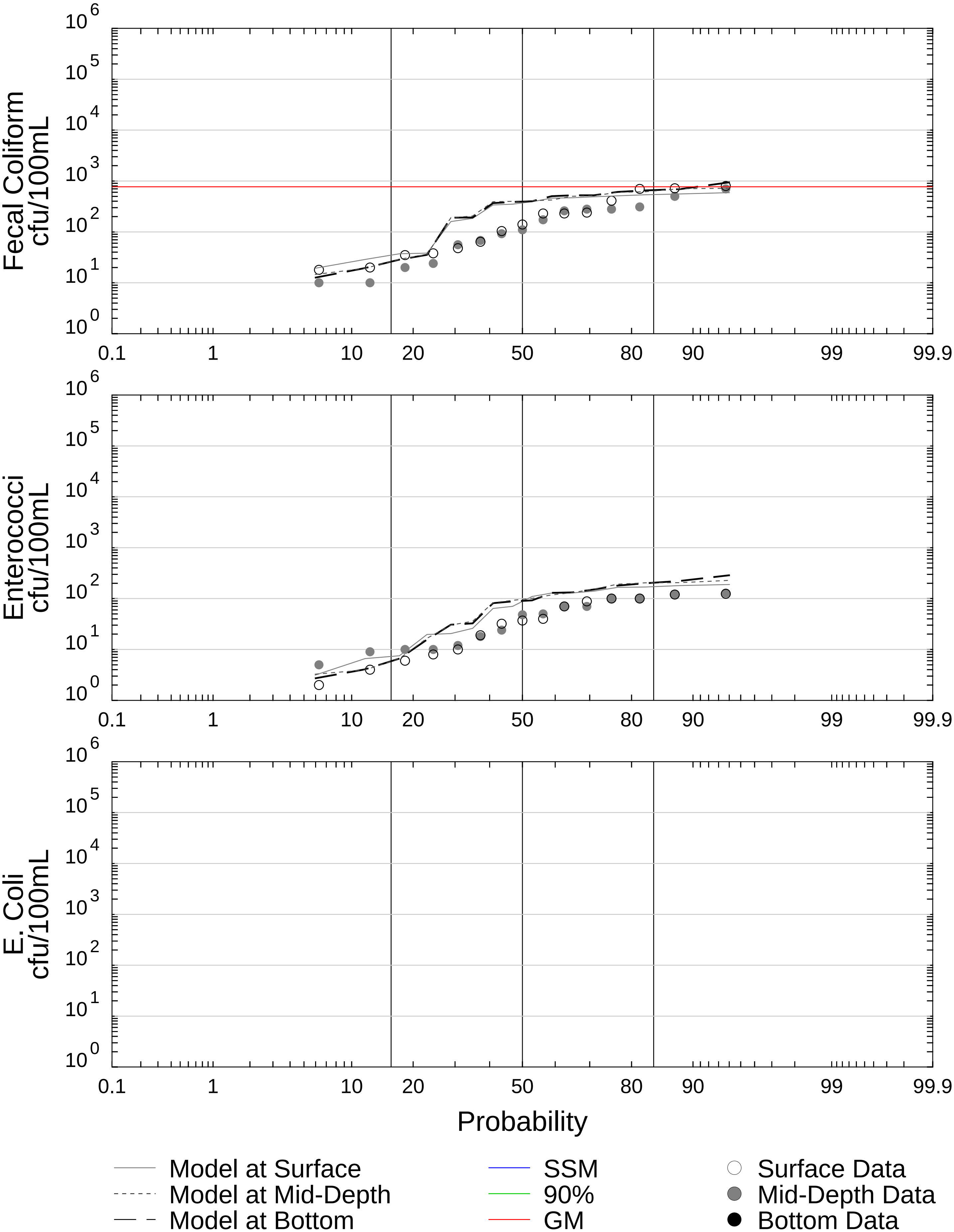


Model Results during data sampling hours only

HUDSON RIVER

SE2

Station: B26

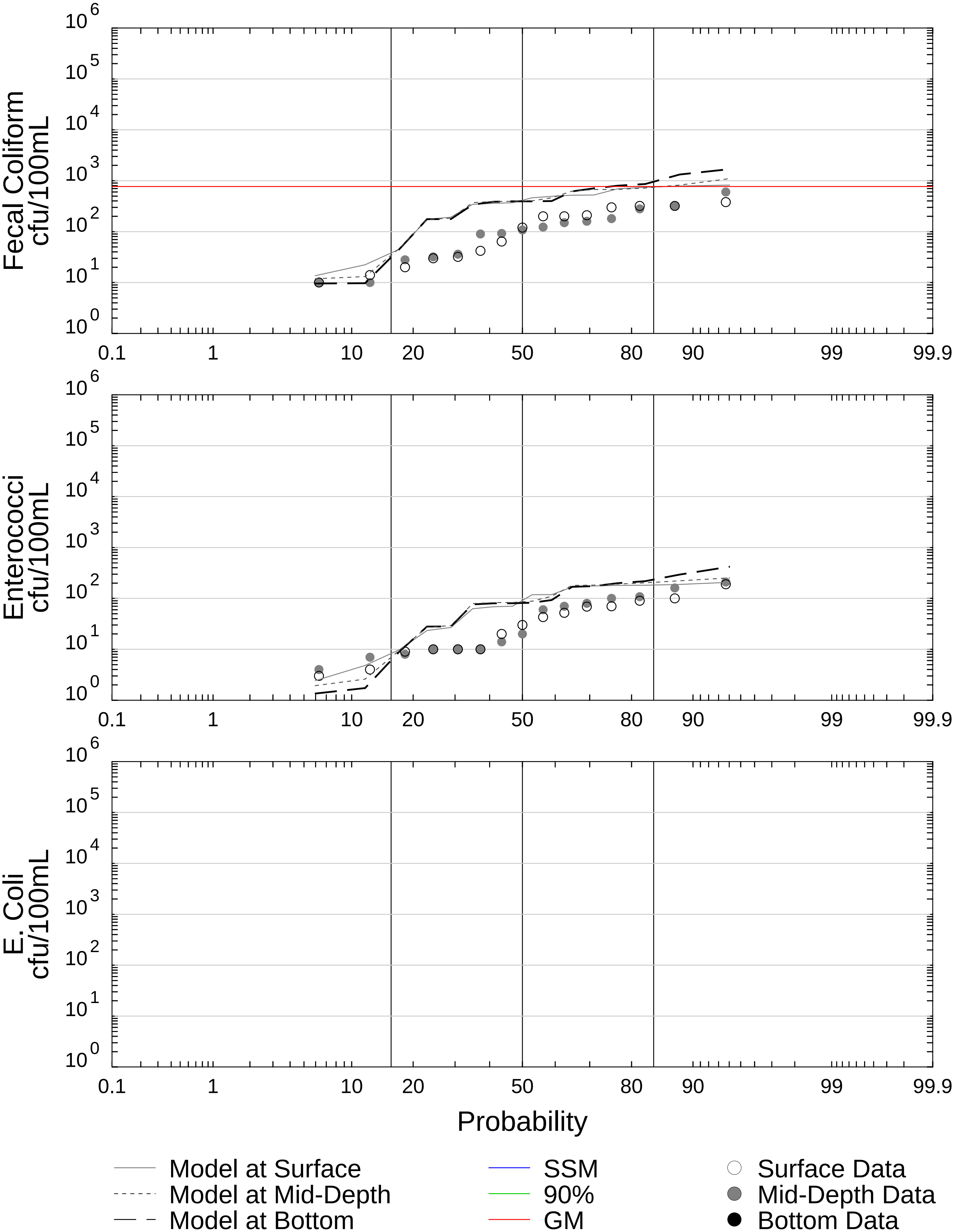


Model Results during data sampling hours only

HUDSON RIVER

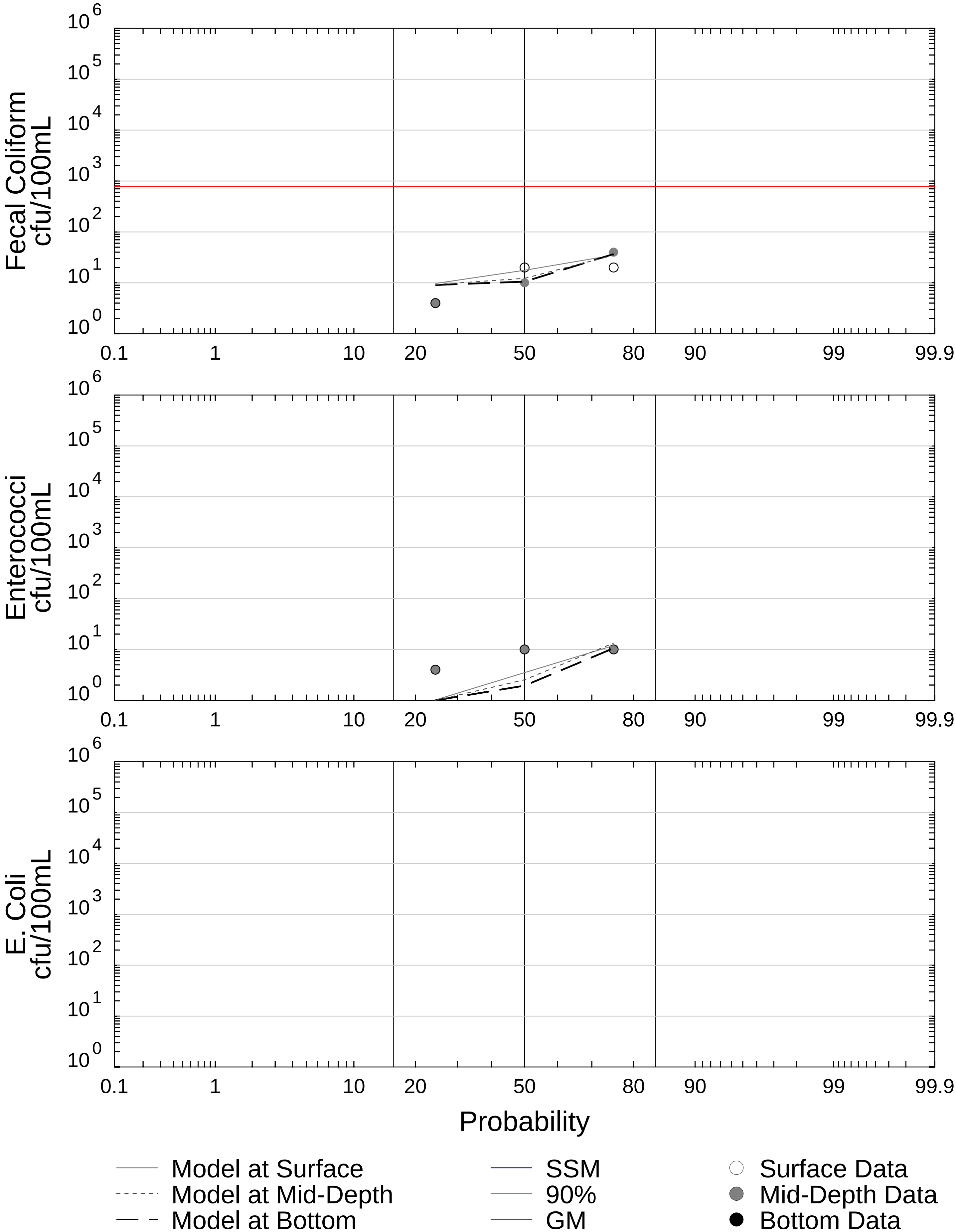
SE2

Station: B27



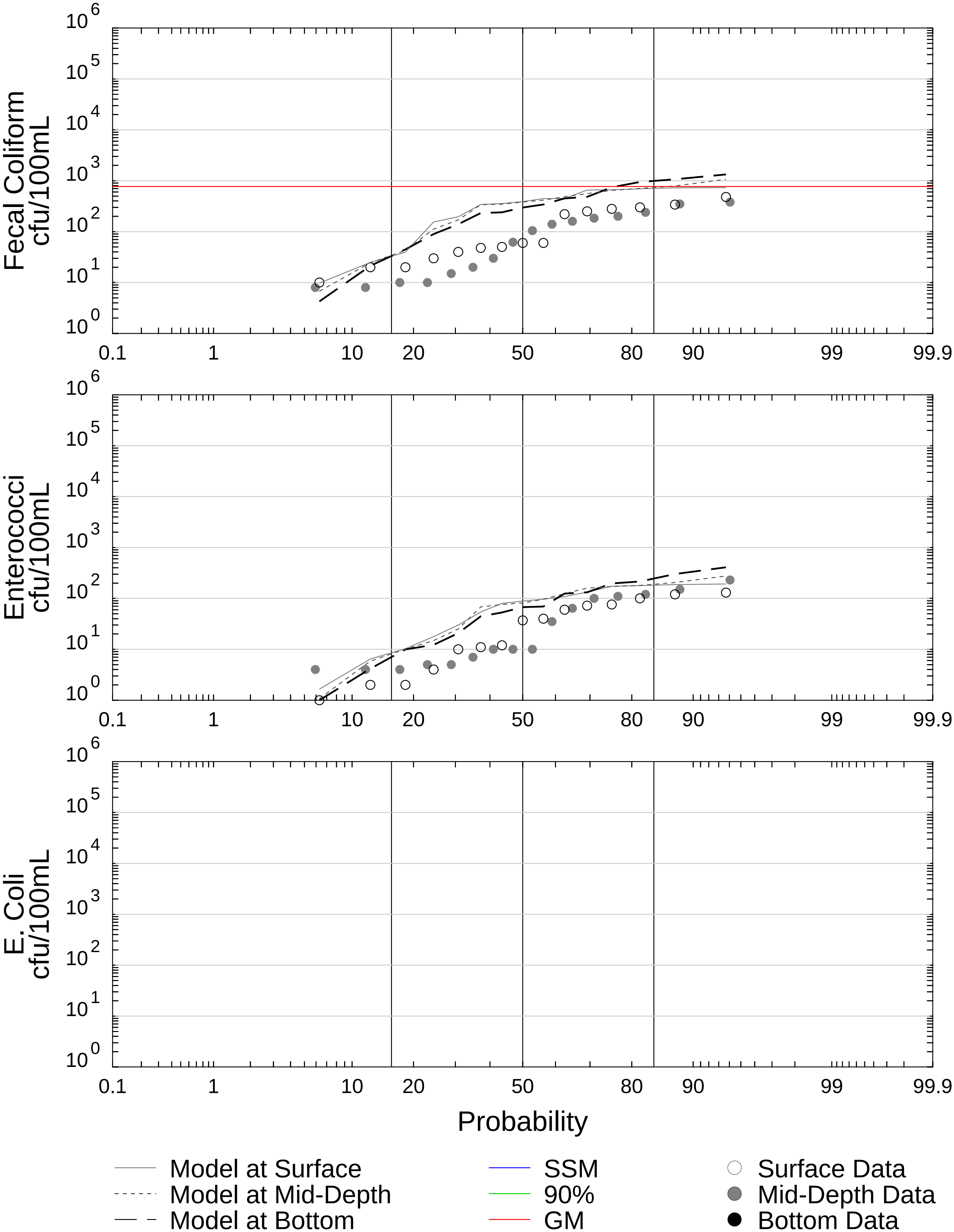
Model Results during data sampling hours only

Station: B9



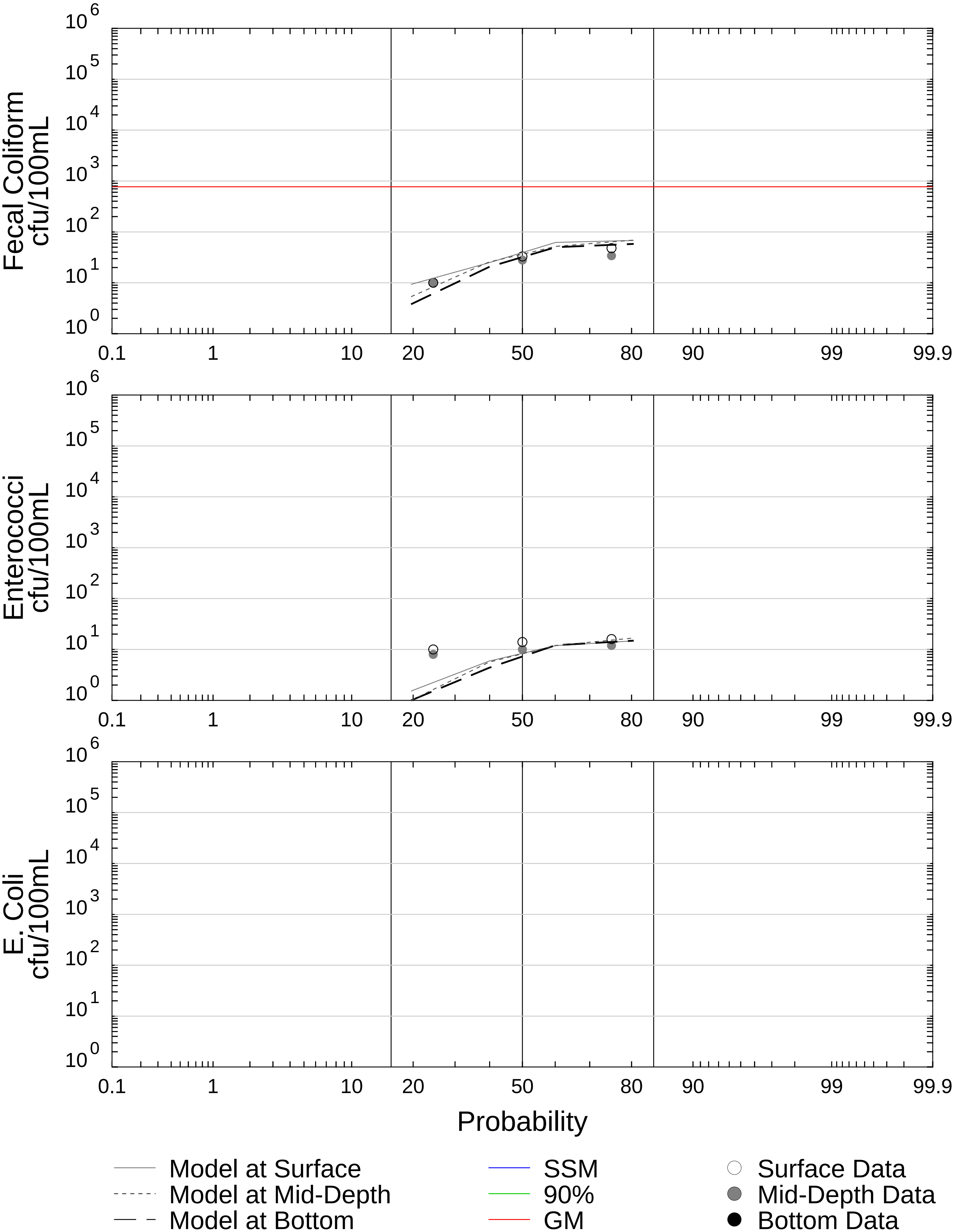
Model Results during data sampling hours only

Station: B28



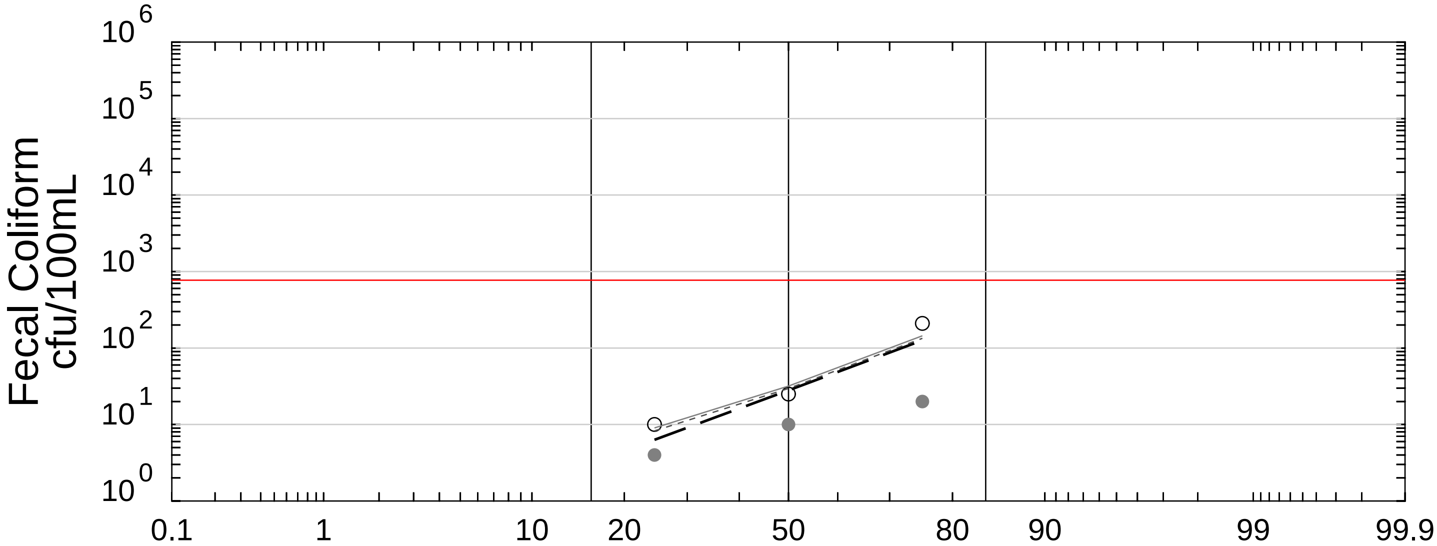
Model Results during data sampling hours only

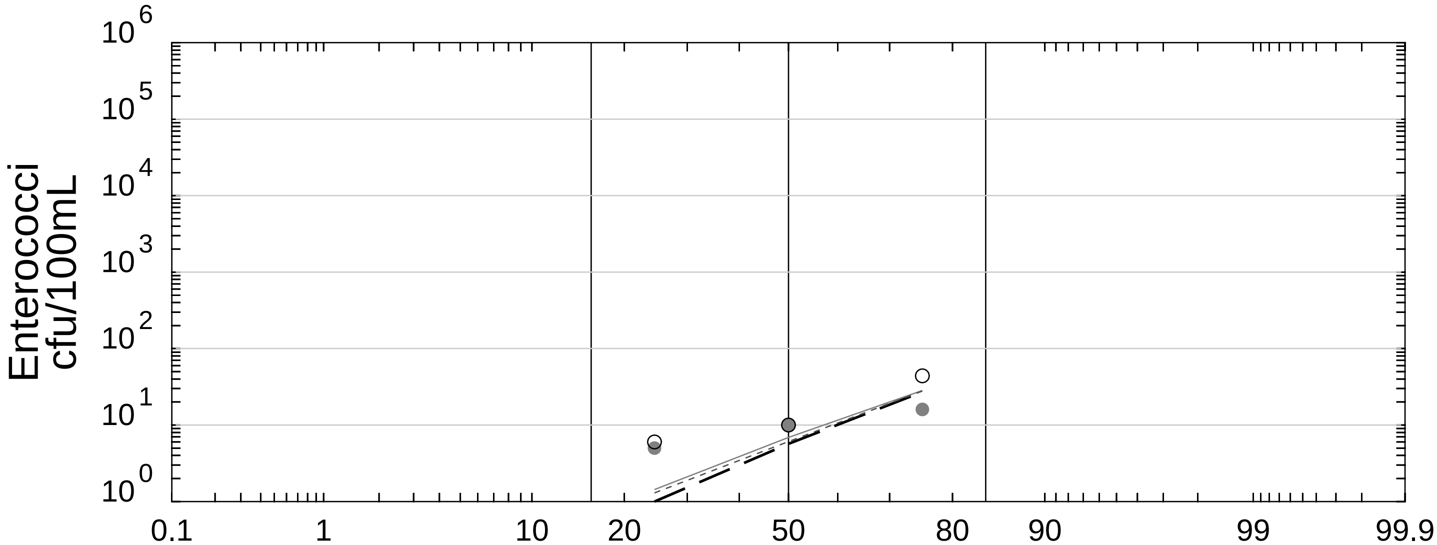
Station: B21A

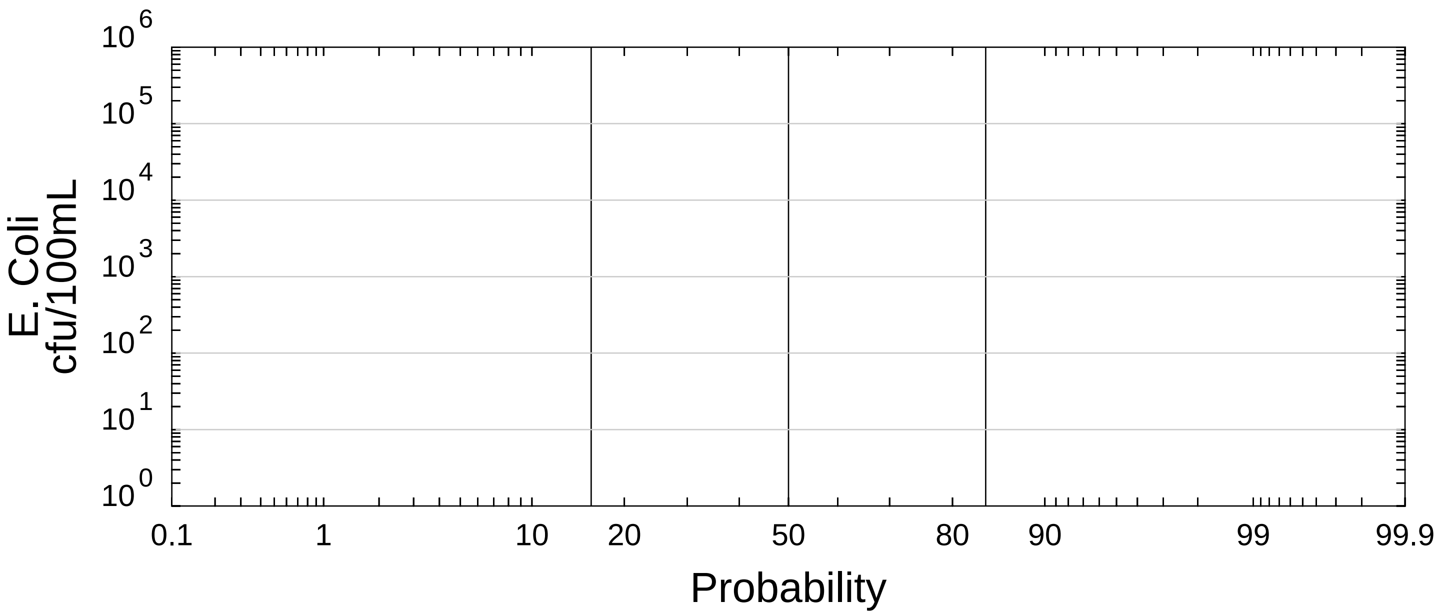


Model Results during data sampling hours only

Station: B21B







Model at Surface
Model at Mid-Depth
Model at Bottom
SSM
90%
GM
Surface Data
Mid-Depth Data
Bottom Data

Model Results during data sampling hours only

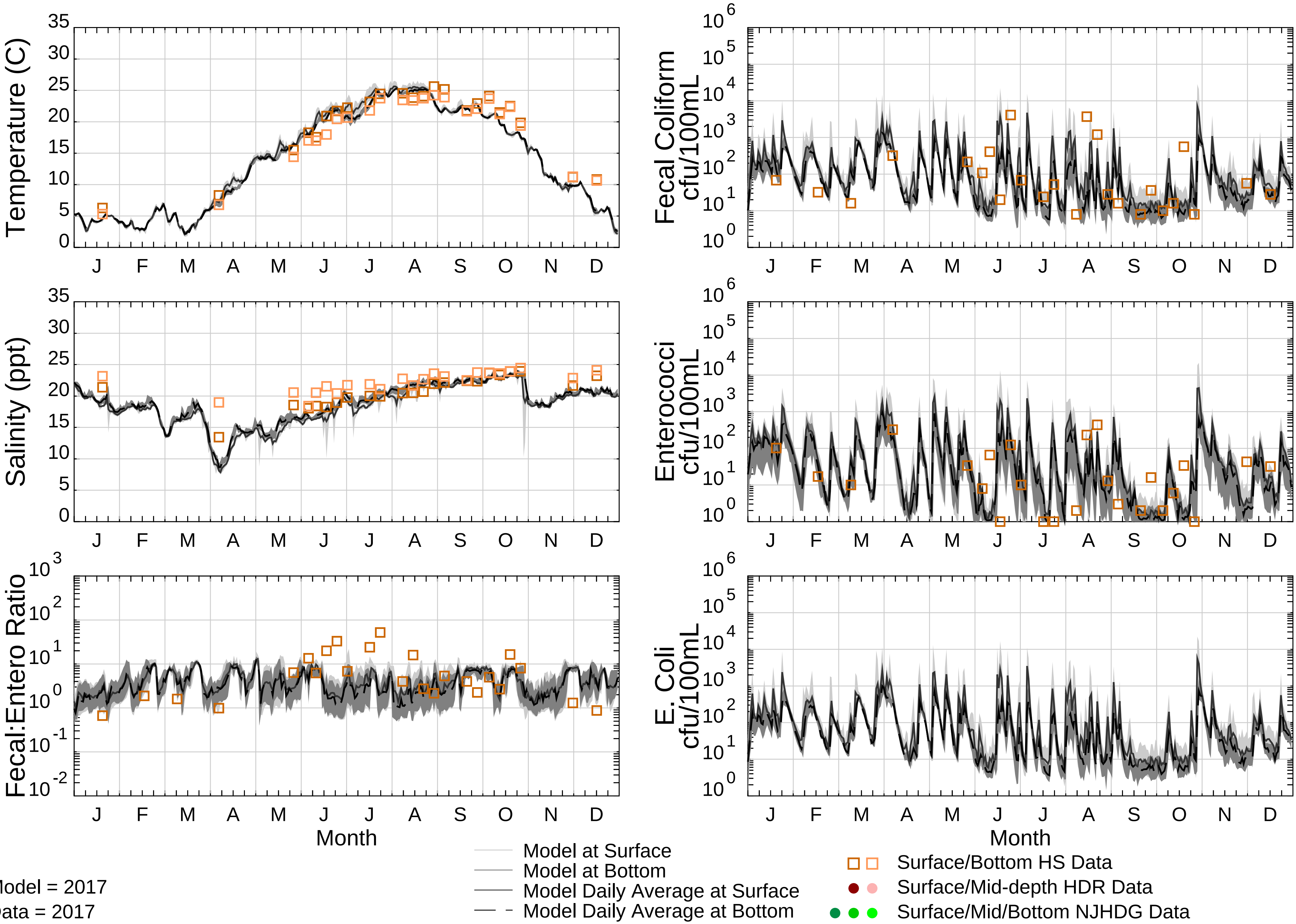
Appendix F-8

Validation Annual Time-Series Figures with NYCDEP Harbor Survey Data

Staten Island
AK Railroad Bridge

I

Station: K3

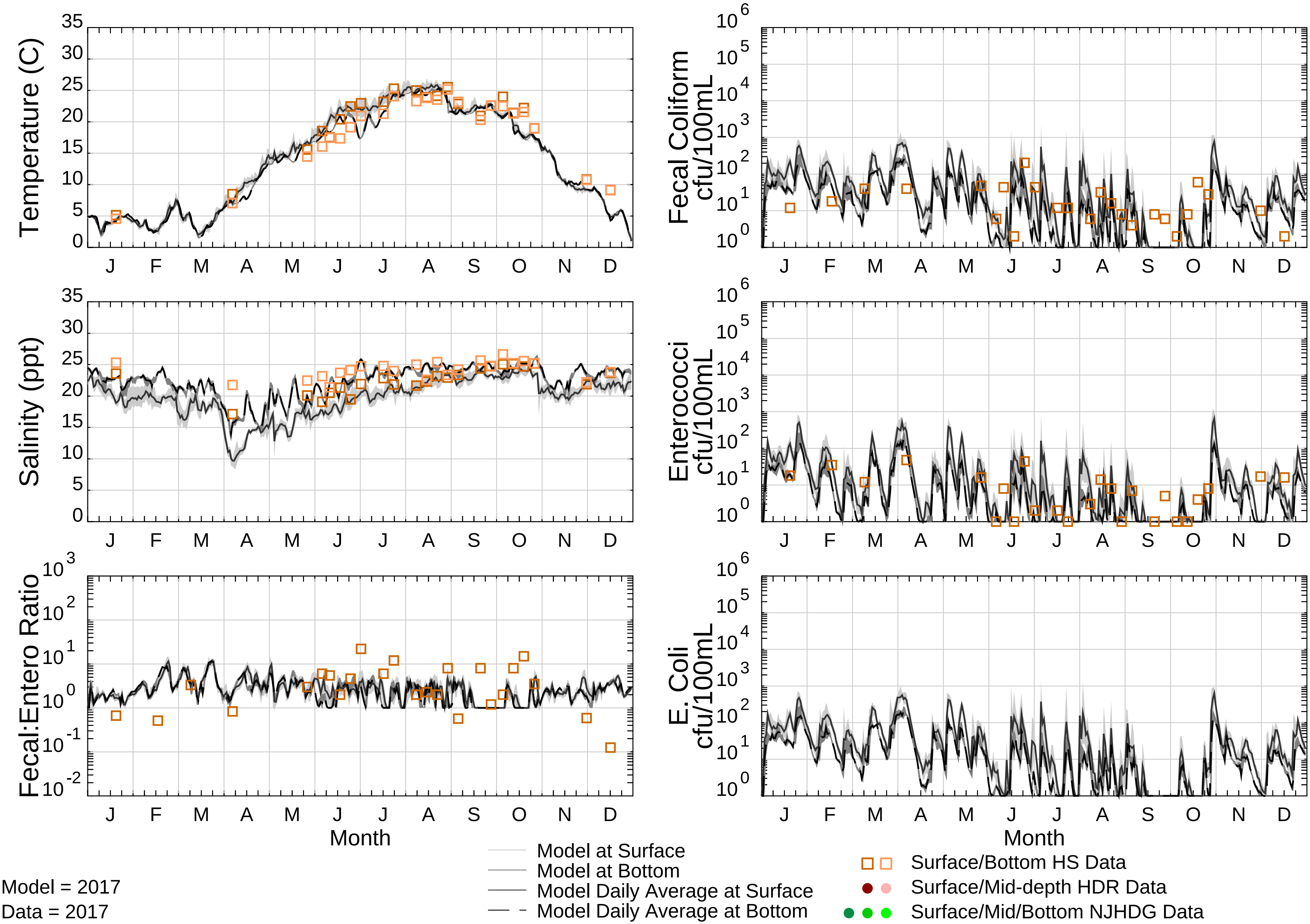


Model = 2017
Data = 2017

Staten Island
Tottenville

I

Station: K5

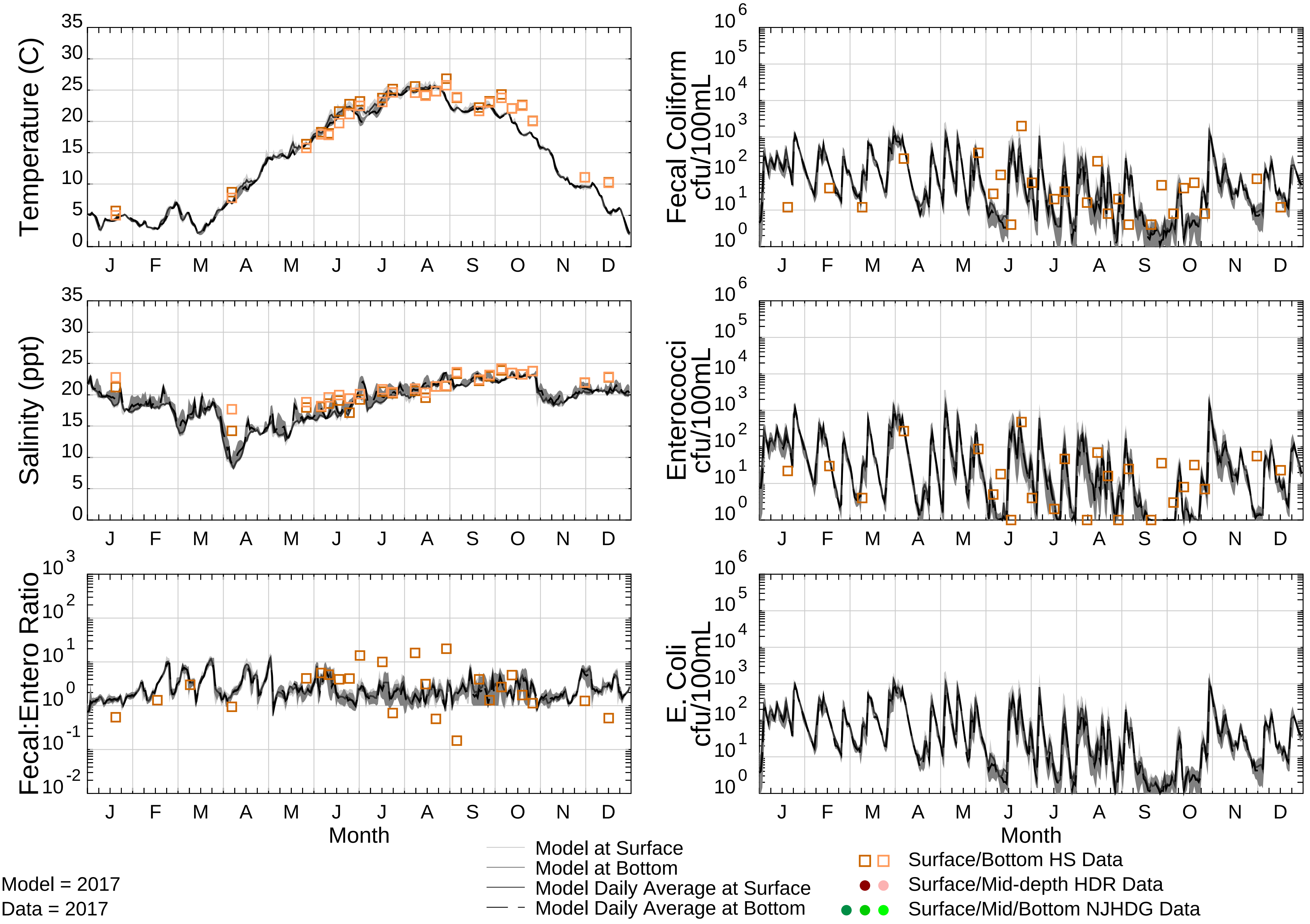


Model = 2017
Data = 2017

Staten Island
Fresh Kills

I

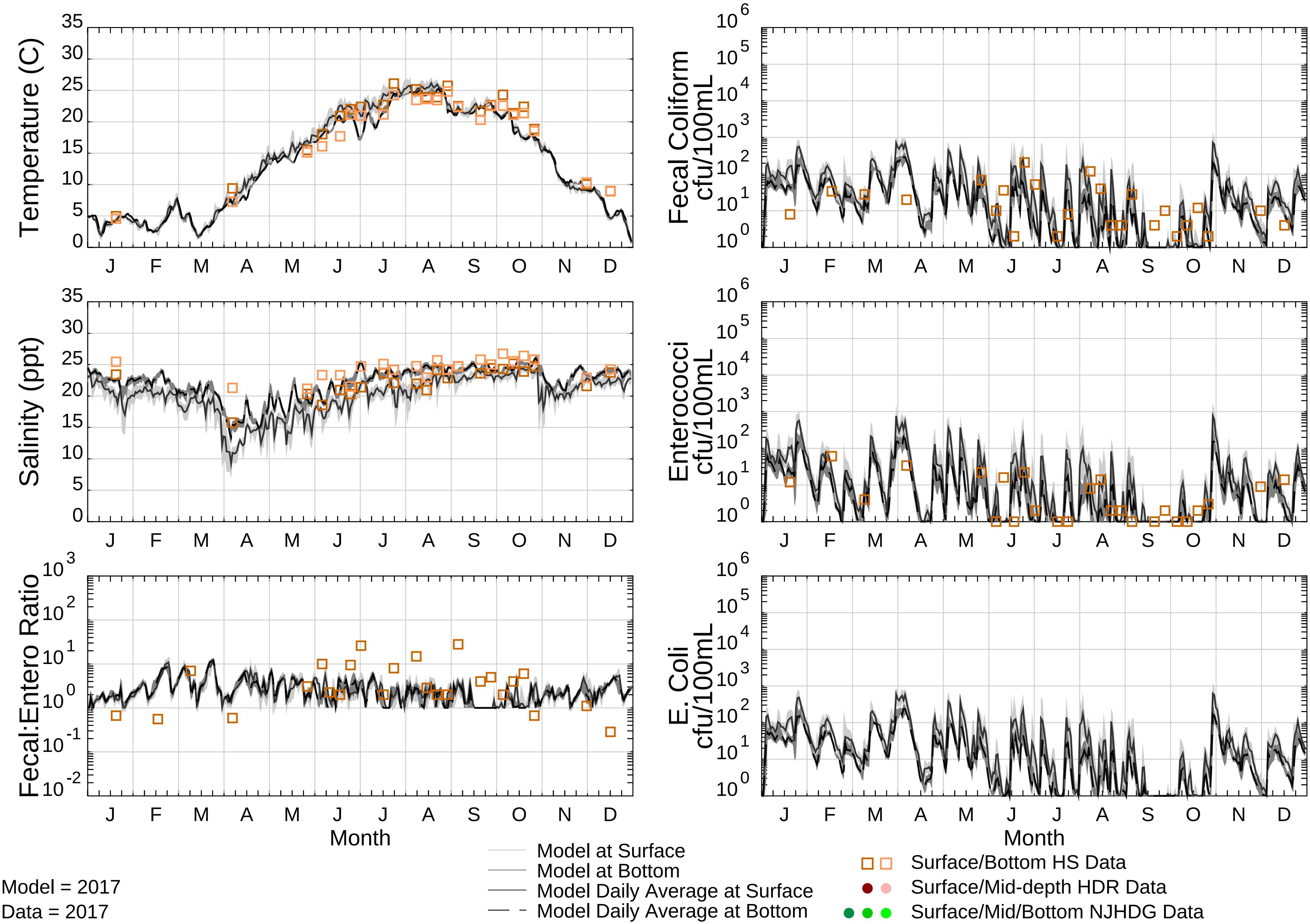
Station: K4



Model = 2017
Data = 2017

Staten Island
Raritan River

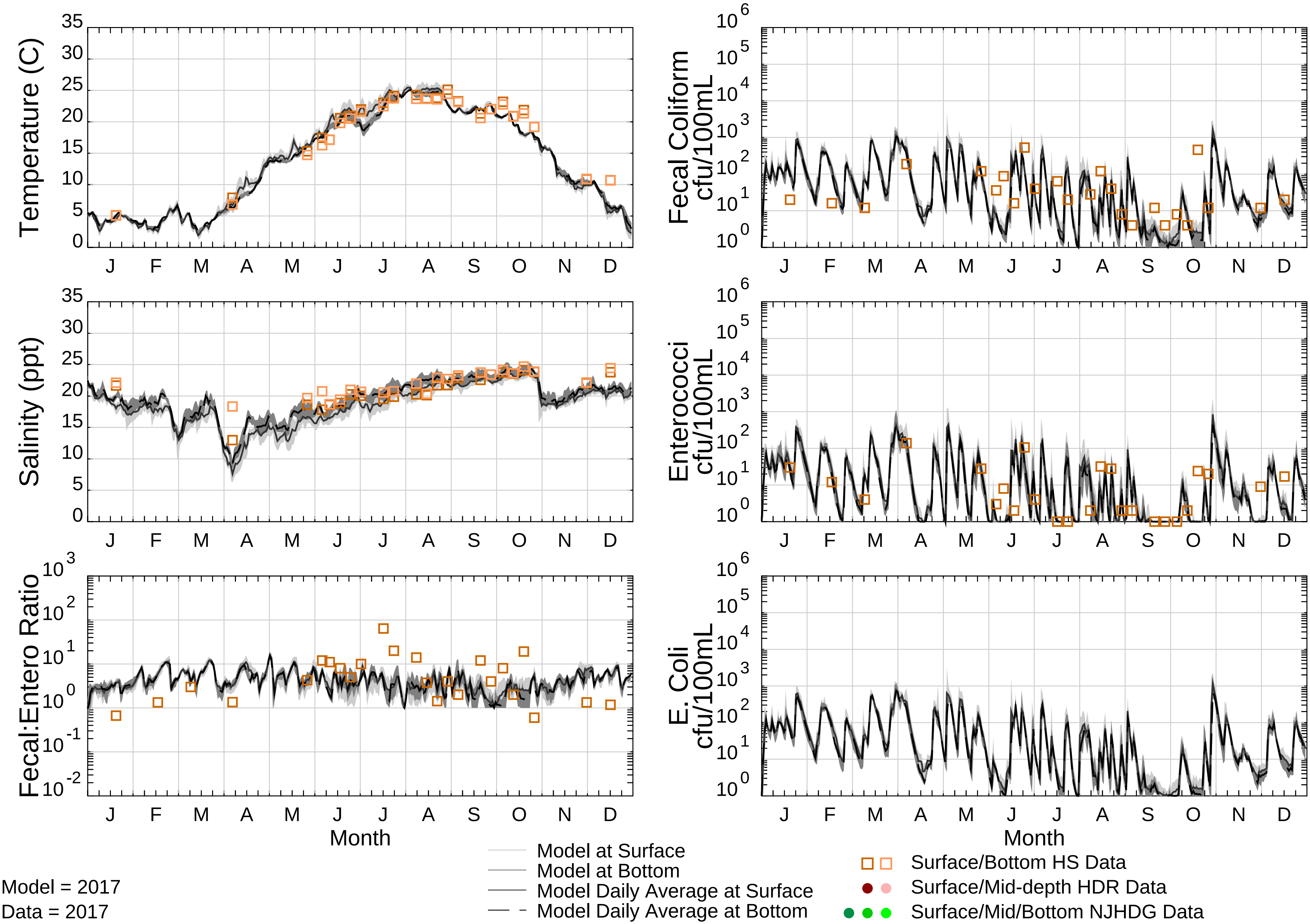
Station: K5A



Model = 2017
Data = 2017

Staten Island
Shooters Island

Station: K2

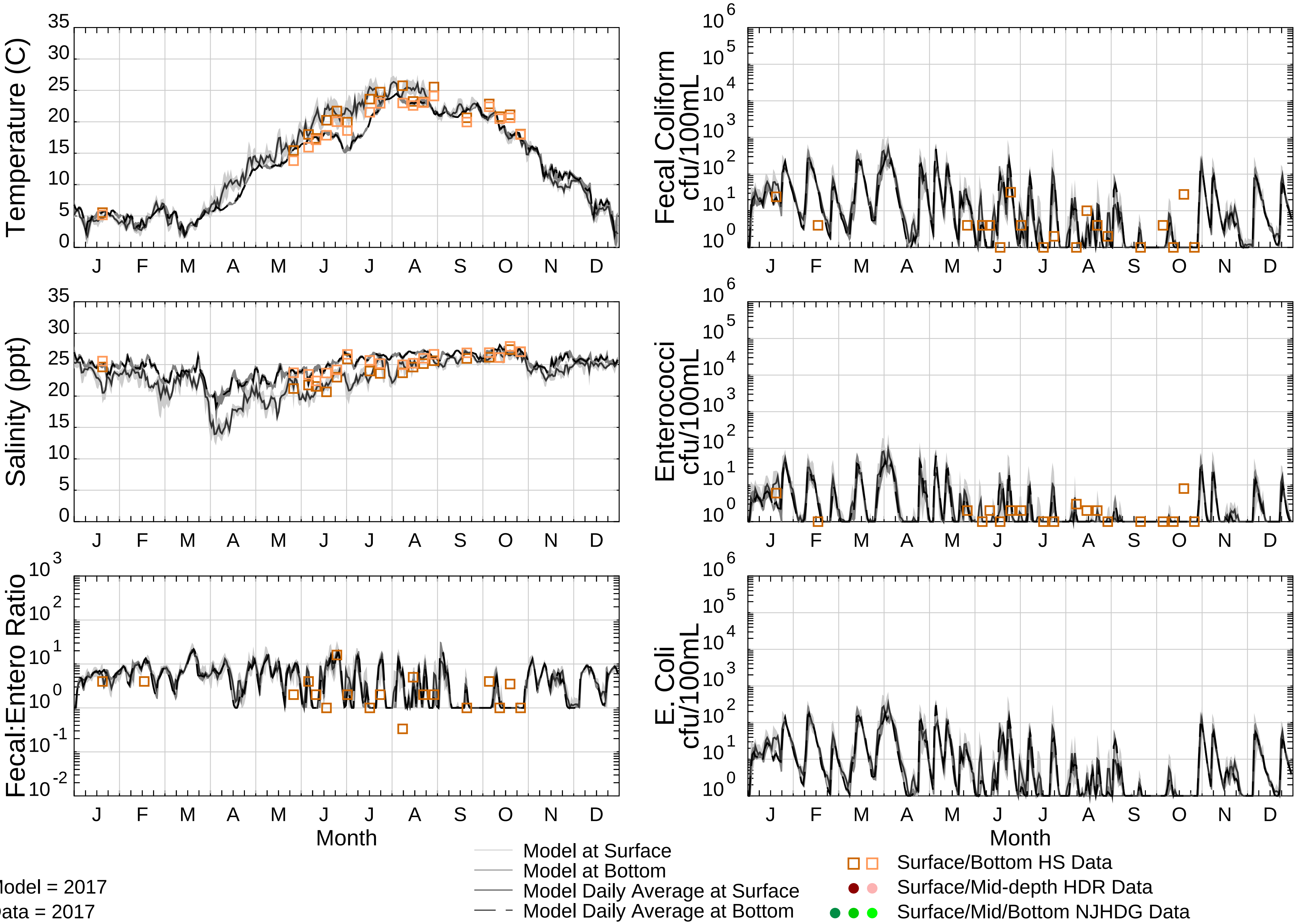


Model = 2017
Data = 2017

Staten Island
Old Orchard Light

I

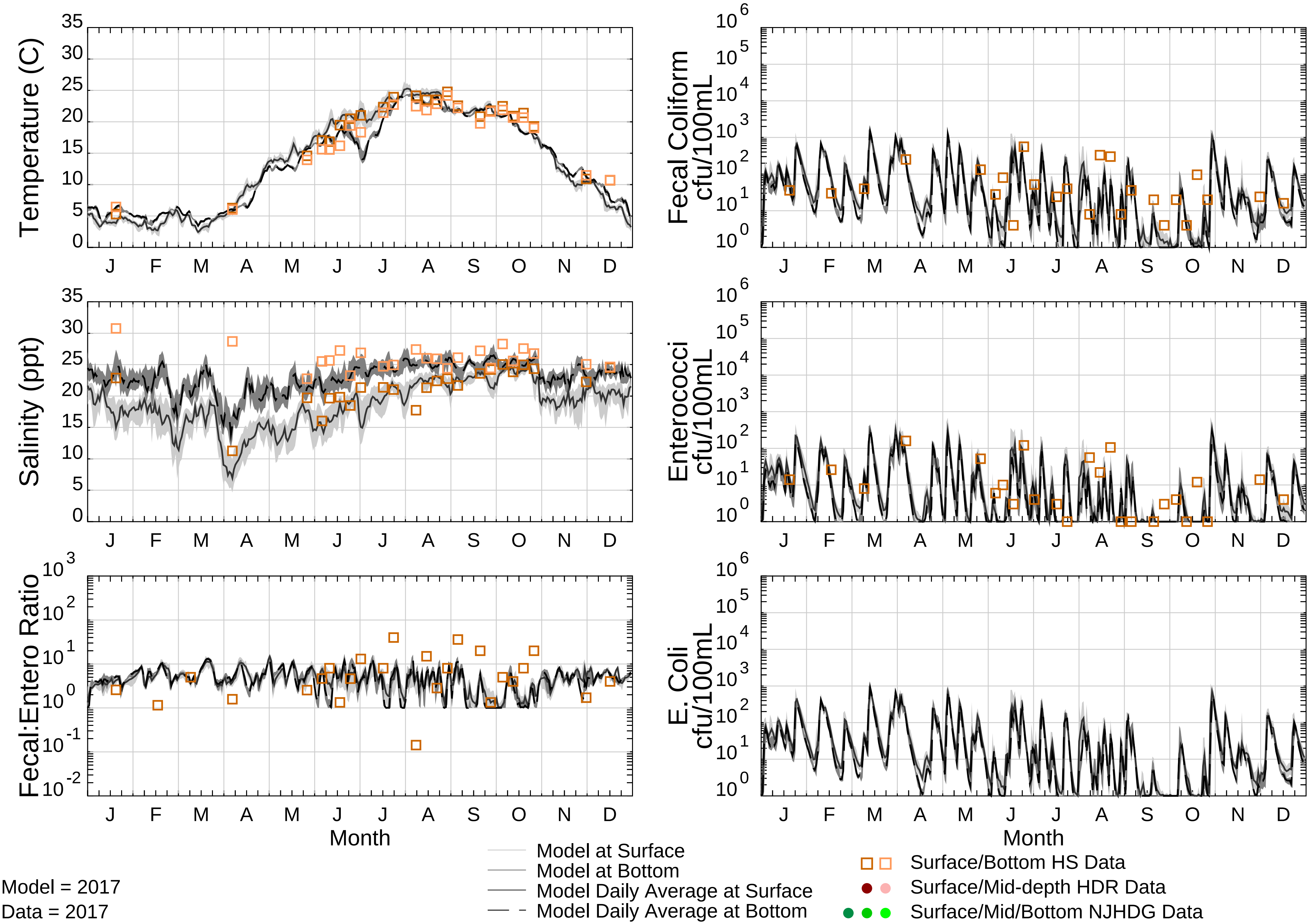
Station: K6



Model = 2017
Data = 2017

Staten Island
St. George

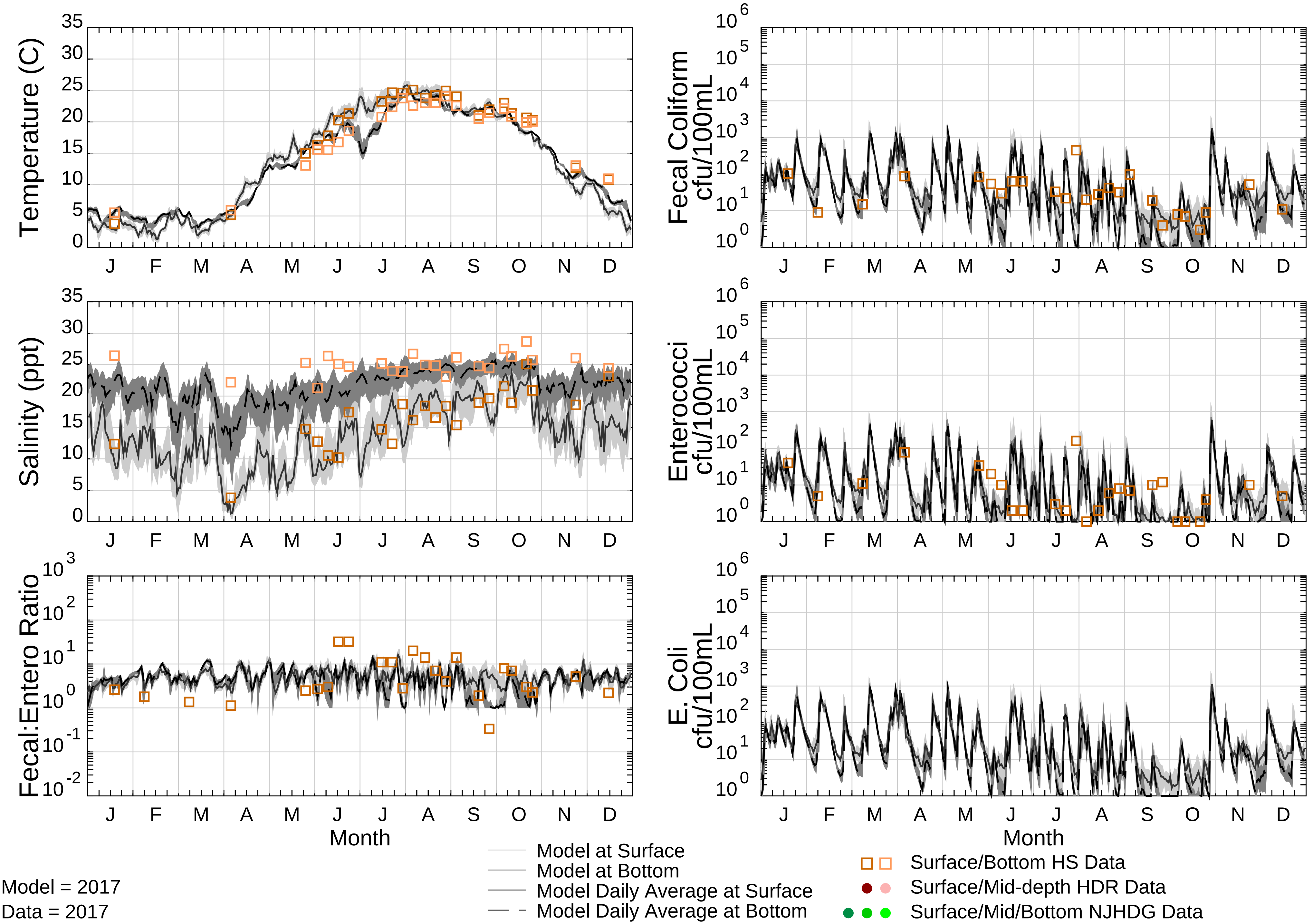
Station: K1



Model = 2017
Data = 2017

Hudson
Pier A - The Battery

Station: N5

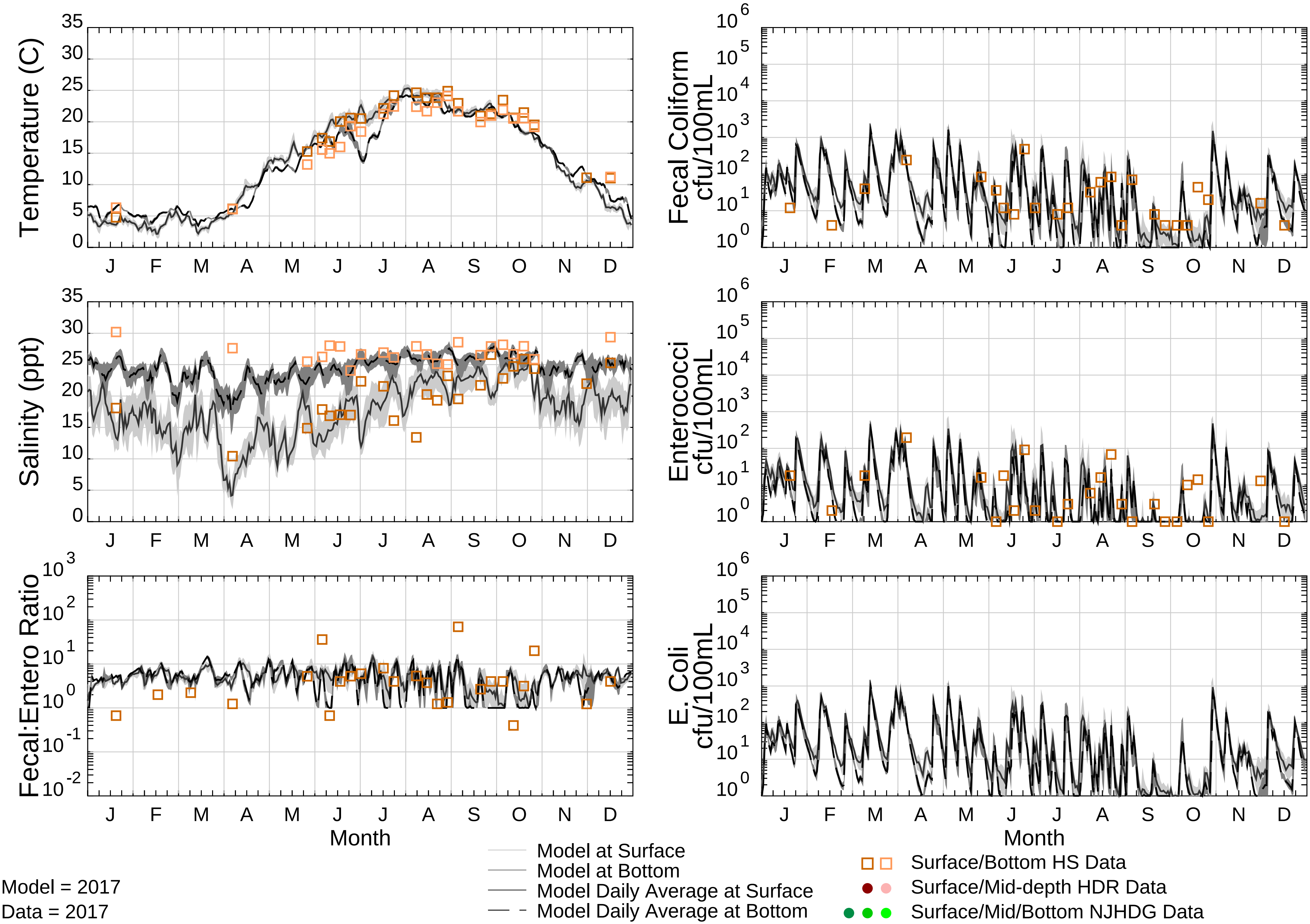


Model = 2017
Data = 2017

Hudson
Bell Buoy 31

I

Station: N6

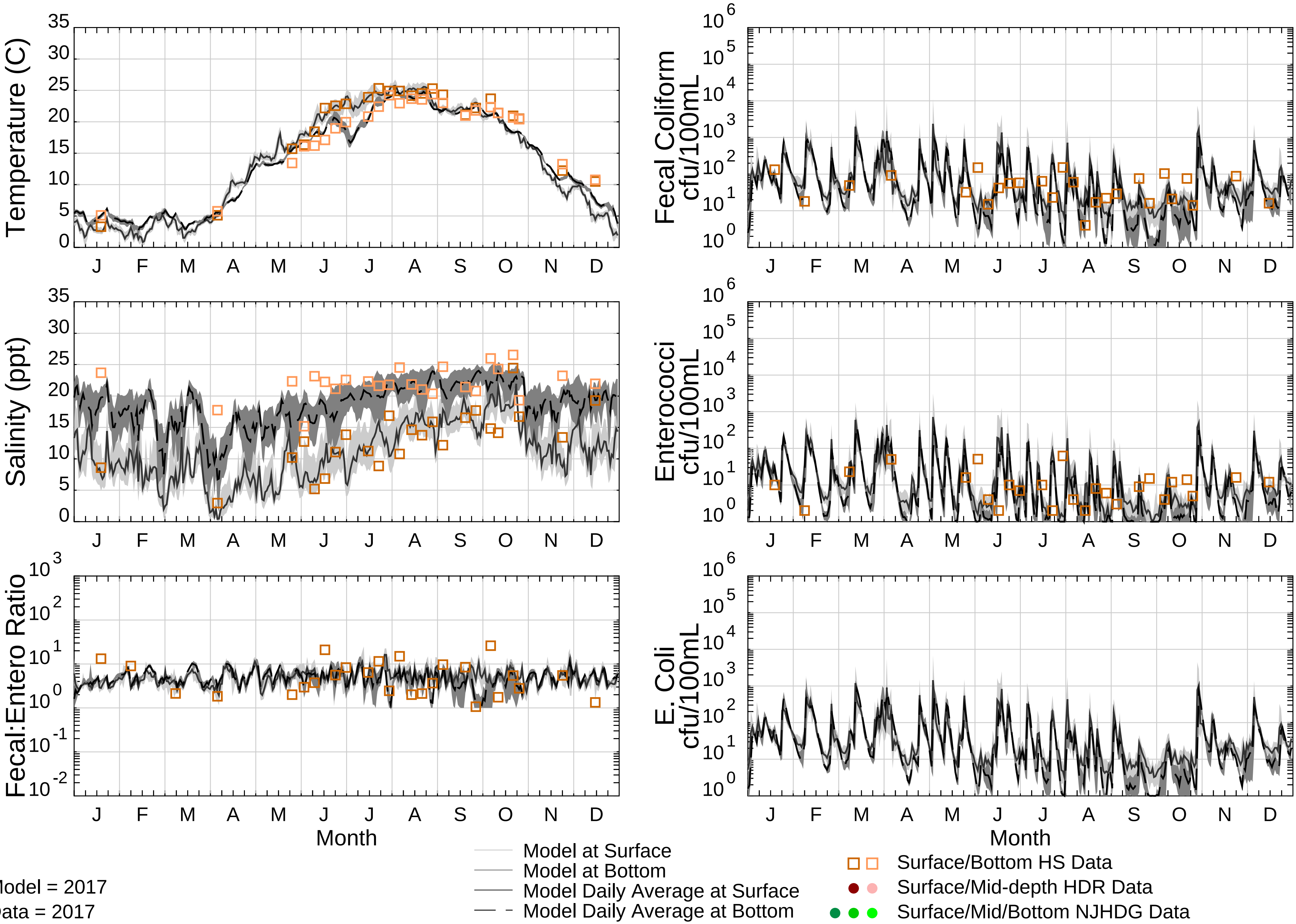


Model = 2017
Data = 2017

Hudson
W. 42 St.

I

Station: N4

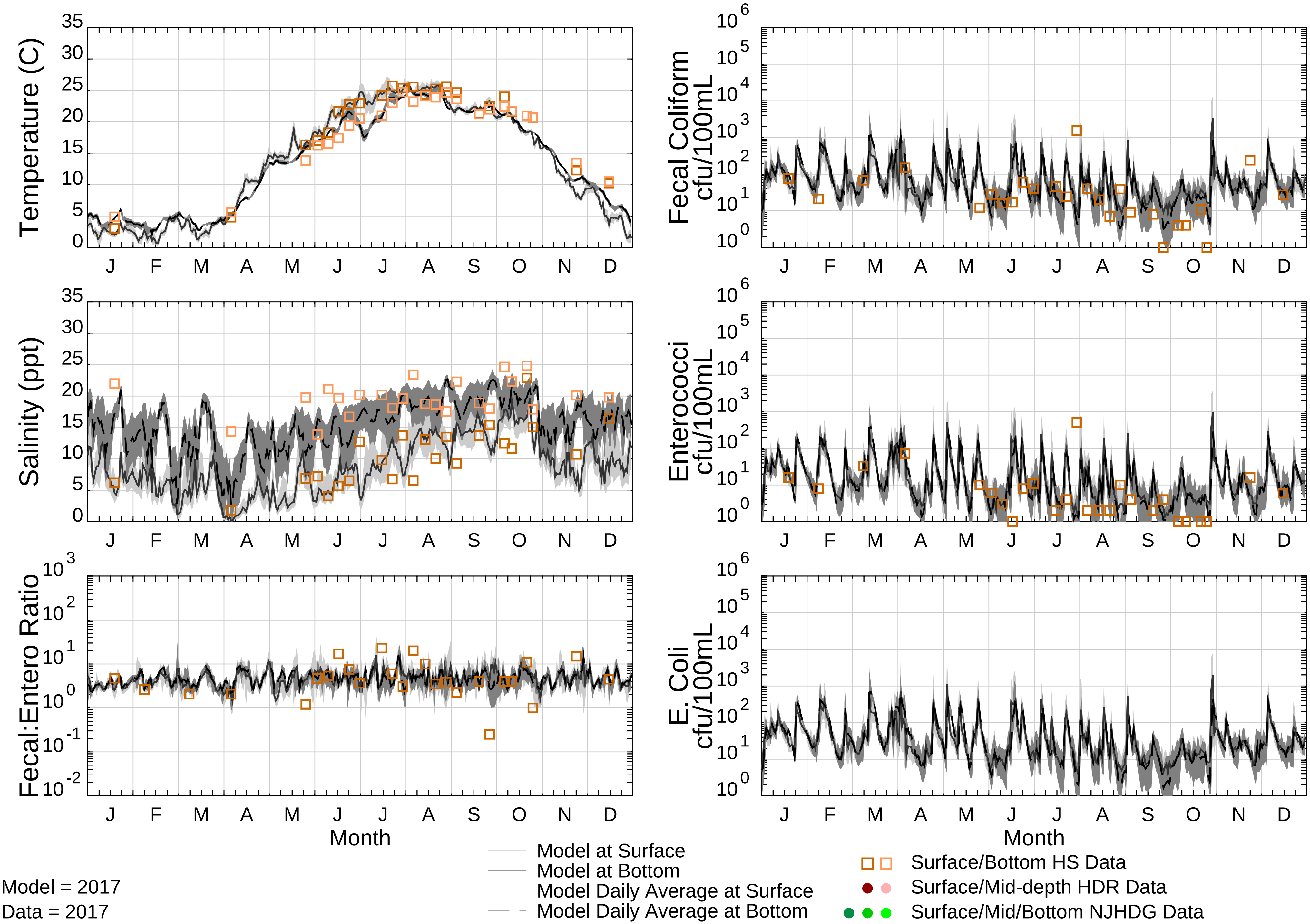


Model = 2017
Data = 2017

Hudson
W. 125 St.

I

Station: N3B

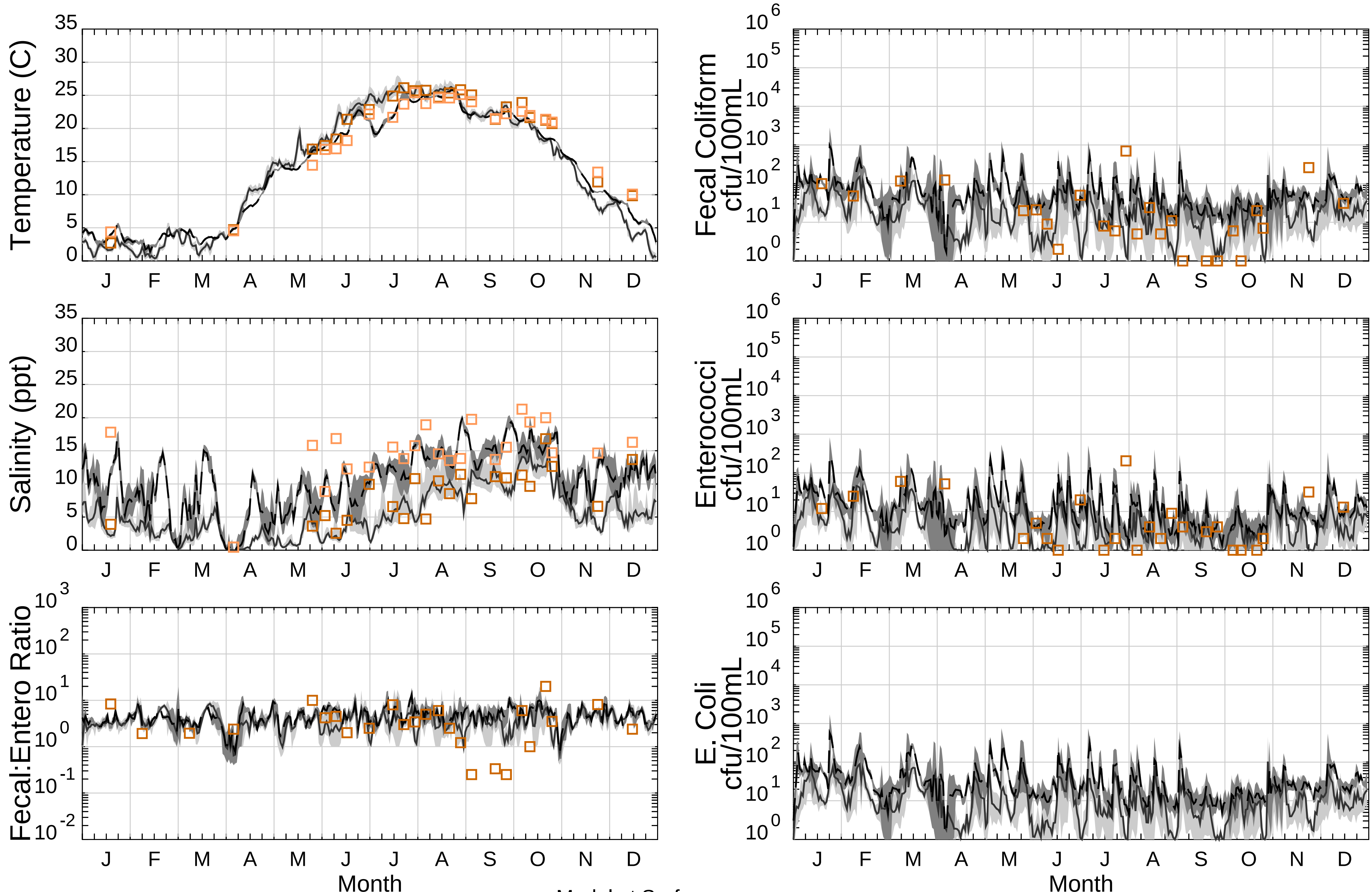


Model = 2017
Data = 2017

Hudson
Mt. St. Vincent

Station: N1

I



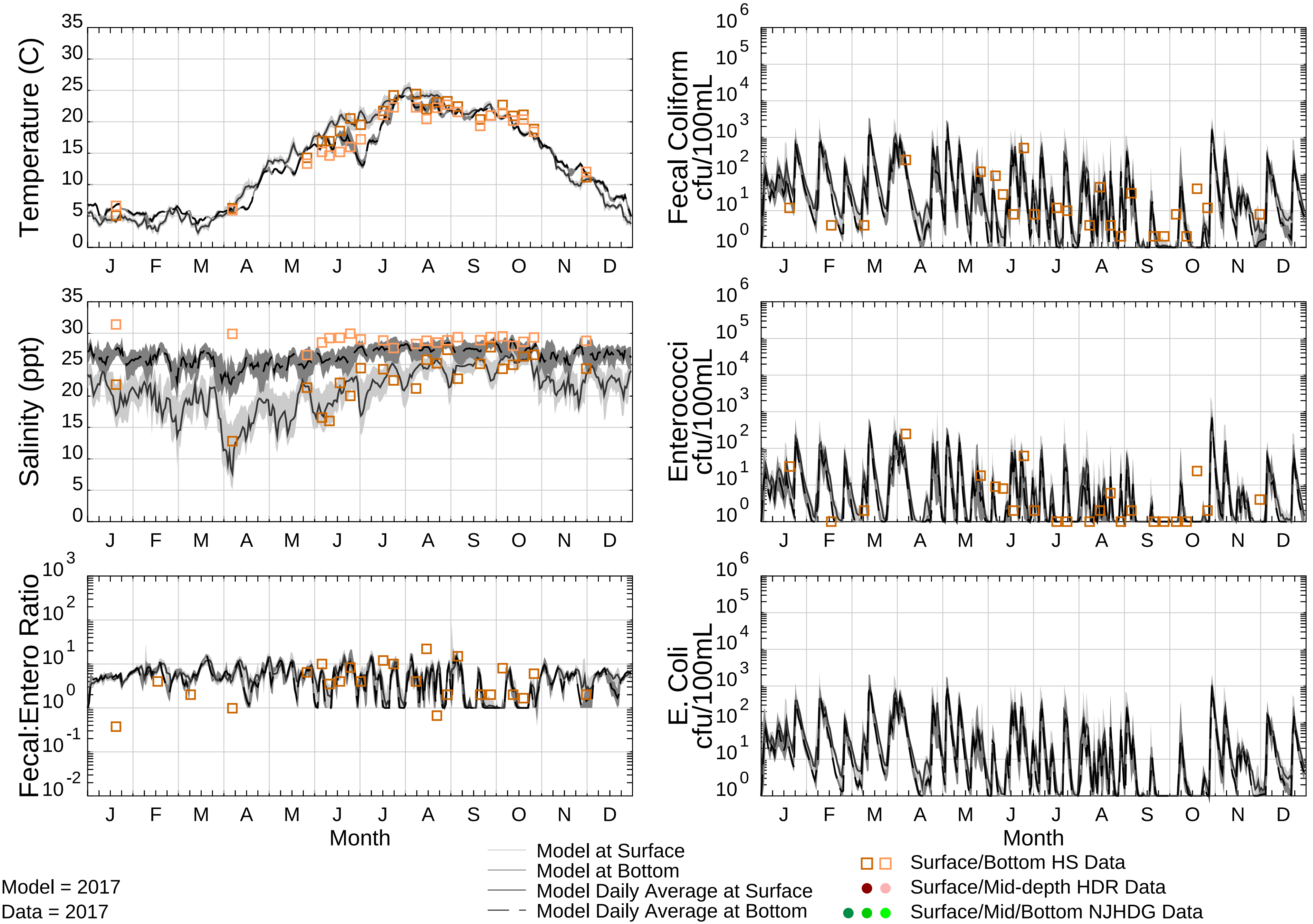
Model at Surface
Model at Bottom
Model Daily Average at Surface
Model Daily Average at Bottom

Surface/Bottom HS Data
Surface/Mid-depth HDR Data
Surface/Mid/Bottom NJHDG Data

Model = 2017
Data = 2017

Jamaica Bay
Coney Is. Outfall

Station: N8

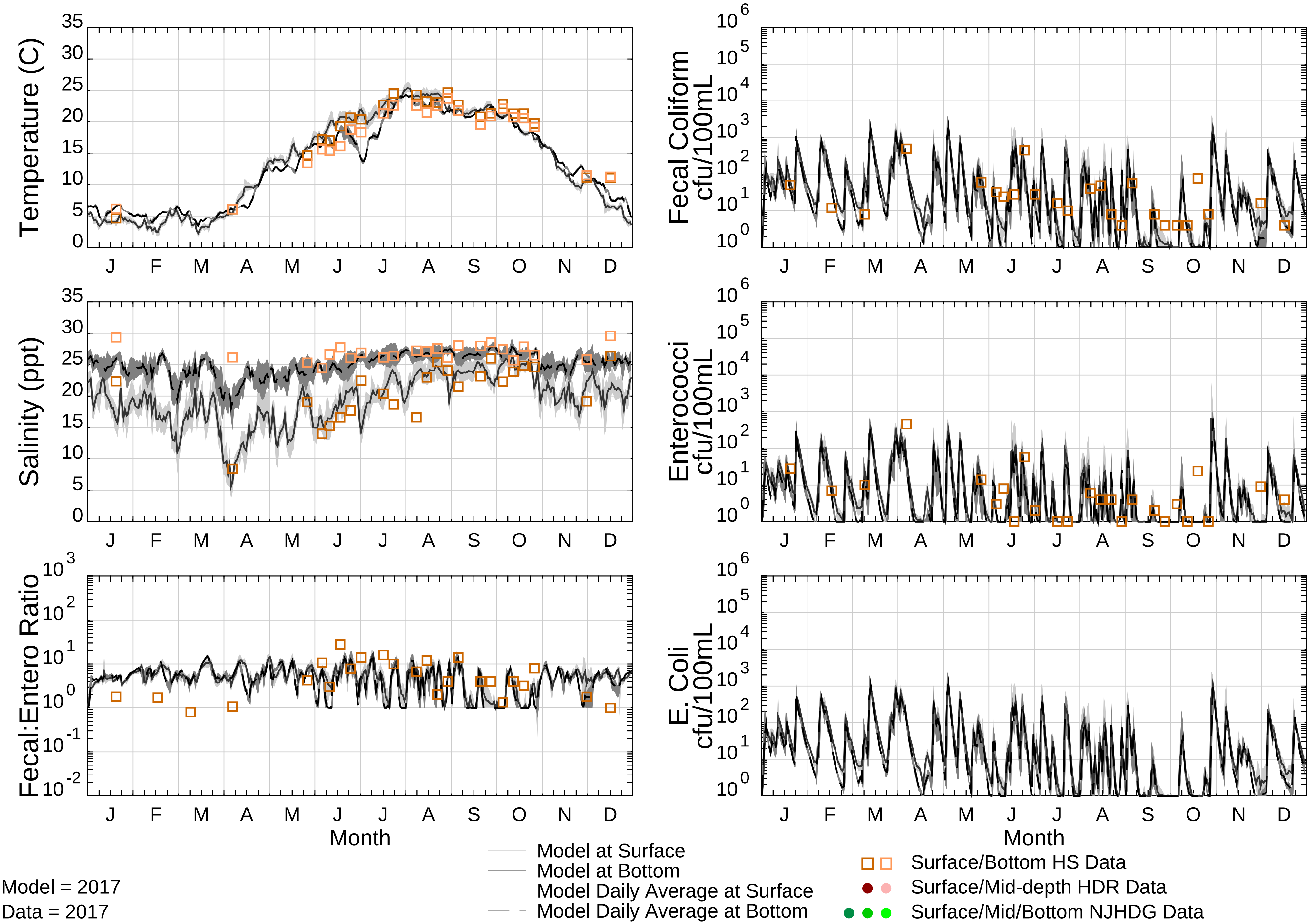


Model = 2017
Data = 2017

Hudson
Robbins Reef

I

Station: N7

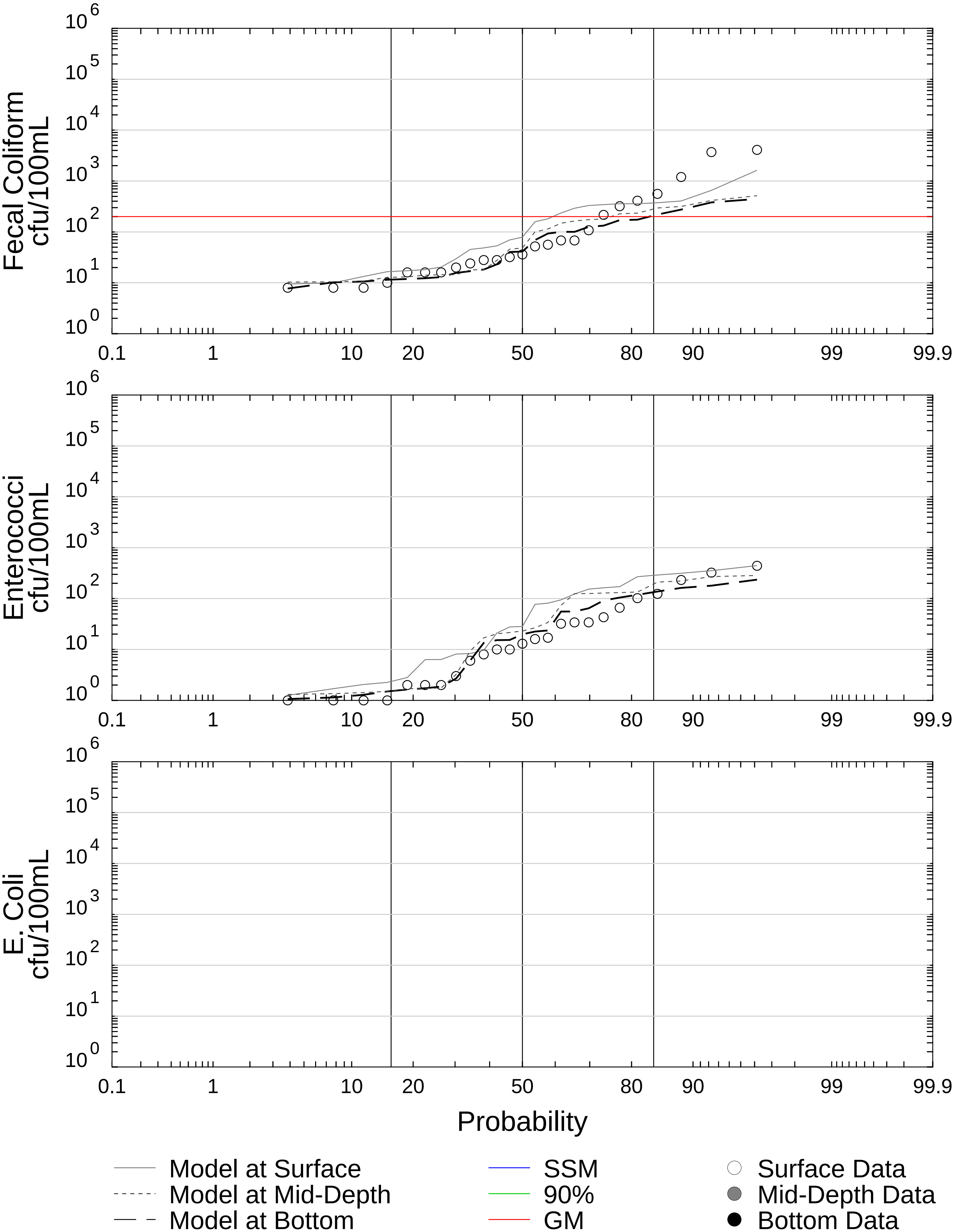


Model = 2017
Data = 2017

Appendix F-9

Validation Probability Figures with NYCDEP Harbor Survey Data

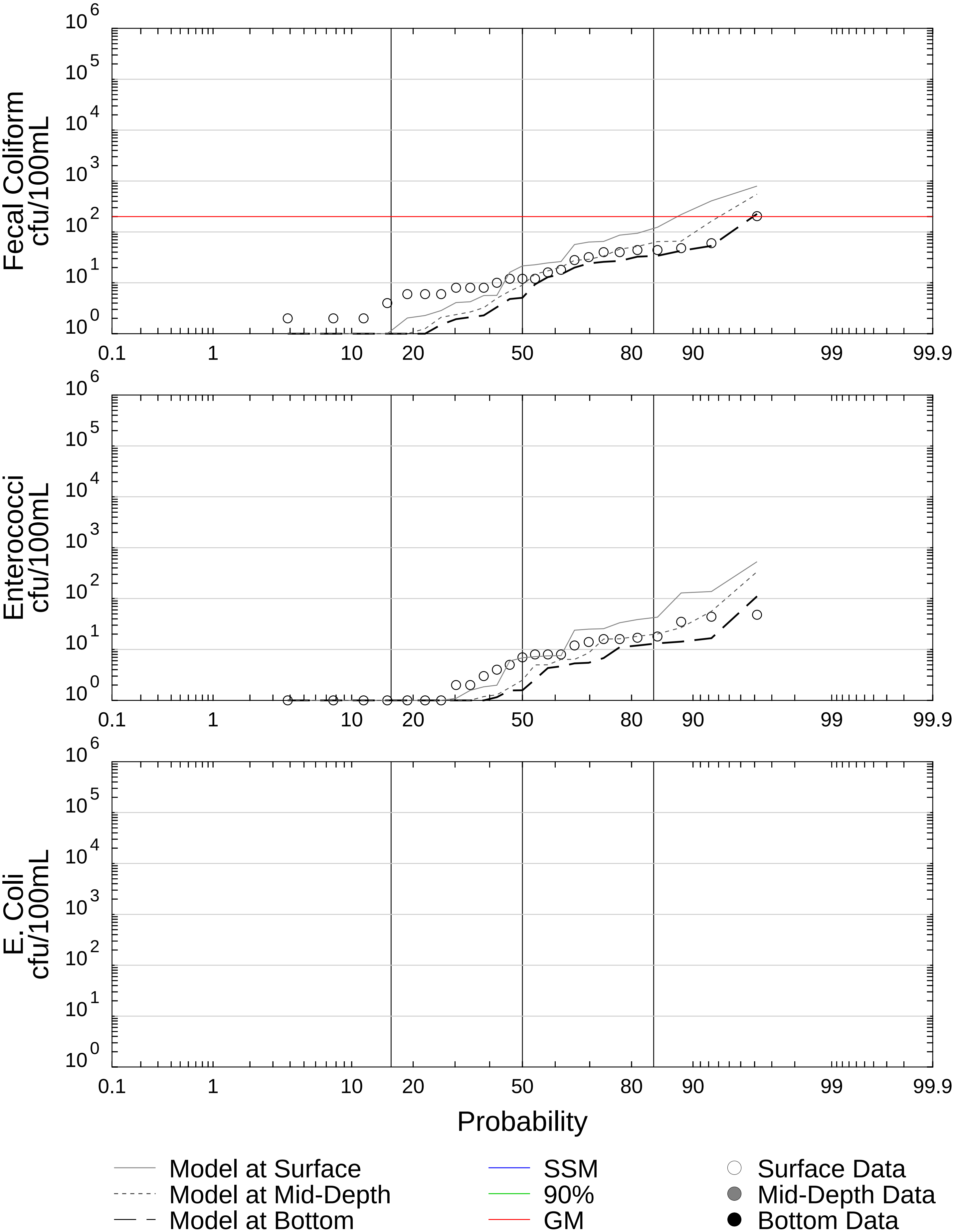
Staten Island
AK Railroad Bridge
Station: K3



Model Results during data sampling hours only

Staten Island
Tottenville

Station: K5

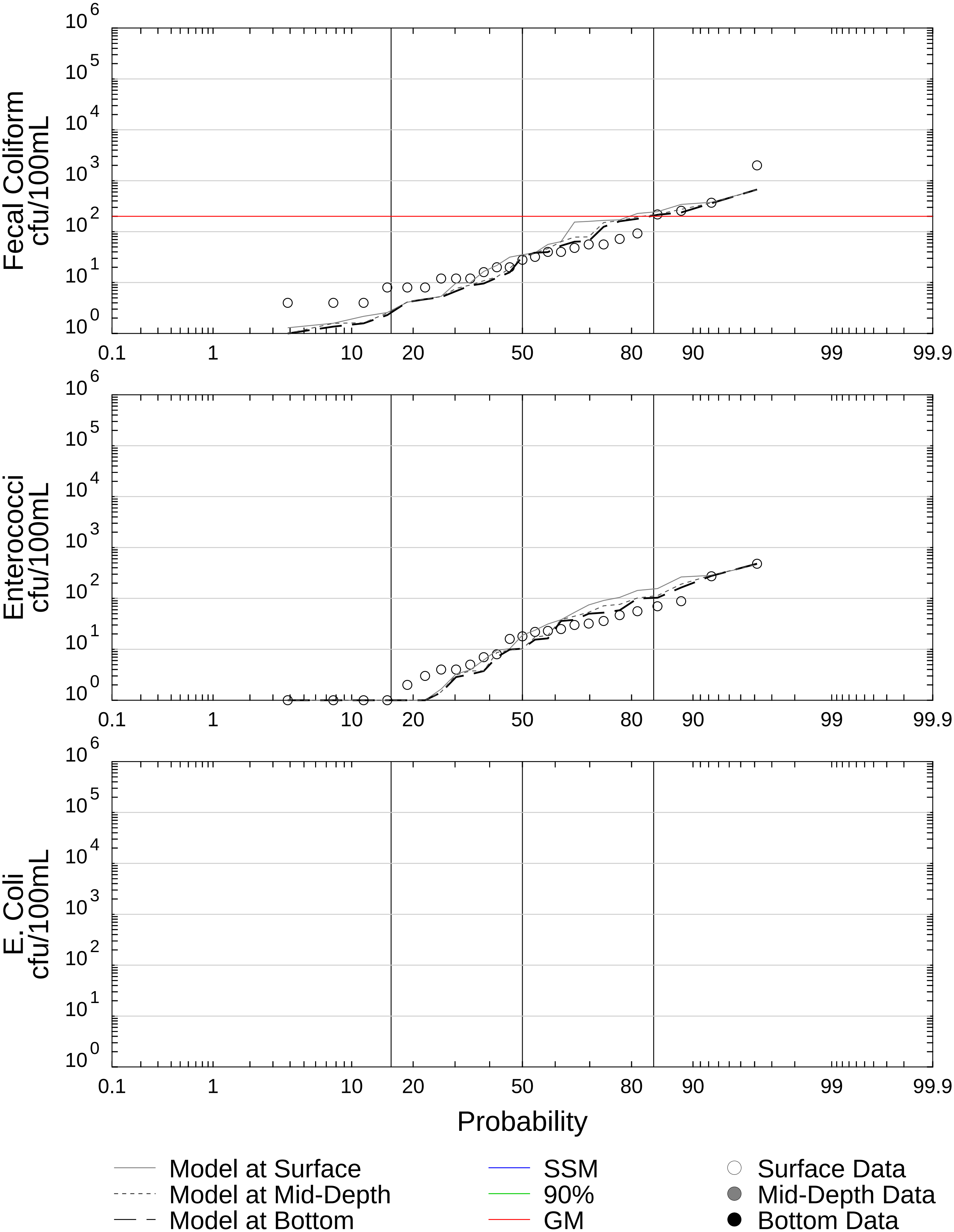


Model Results during data sampling hours only

Staten Island
Fresh Kills

I

Station: K4

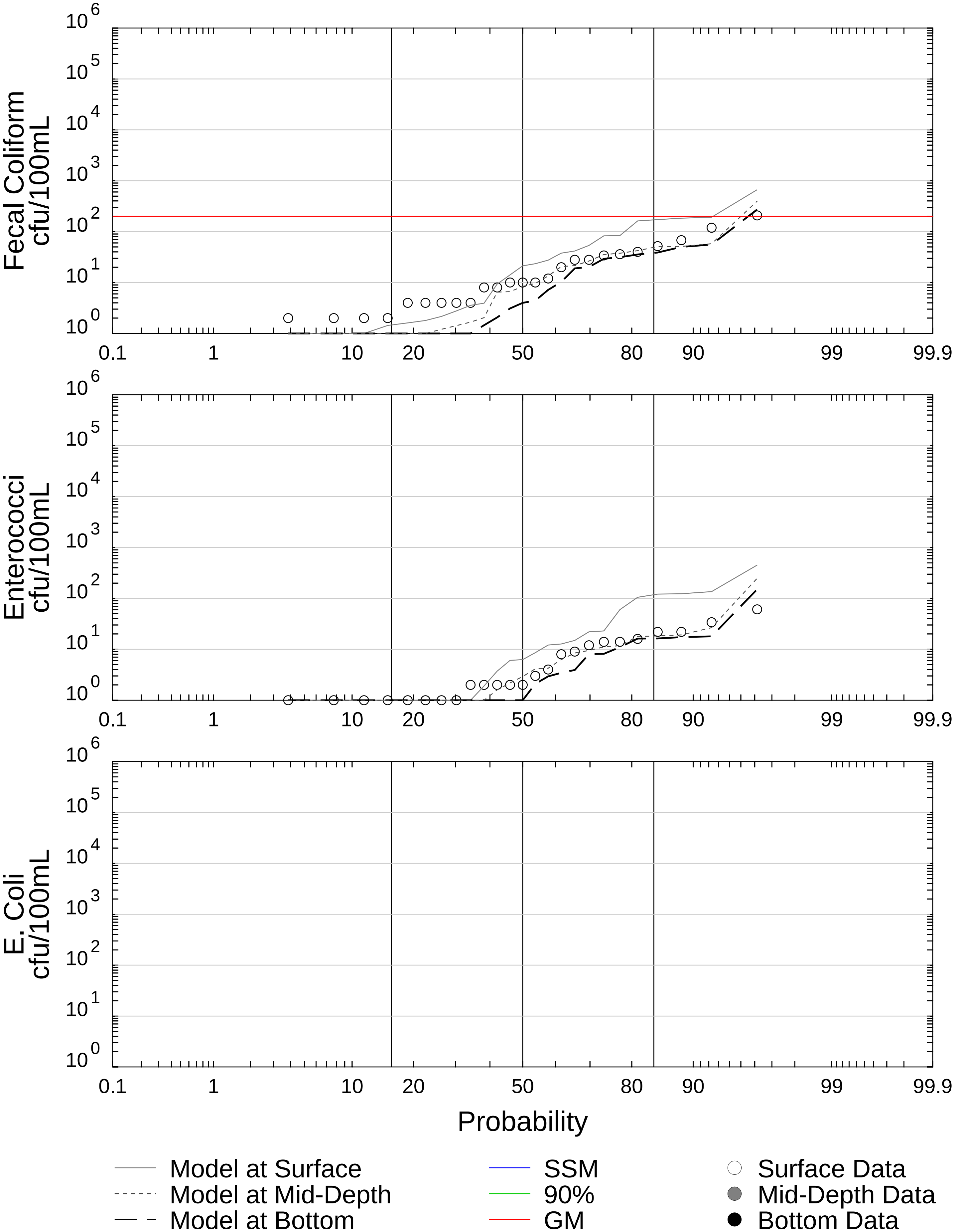


Model Results during data sampling hours only

Staten Island
Raritan River

Station: K5A

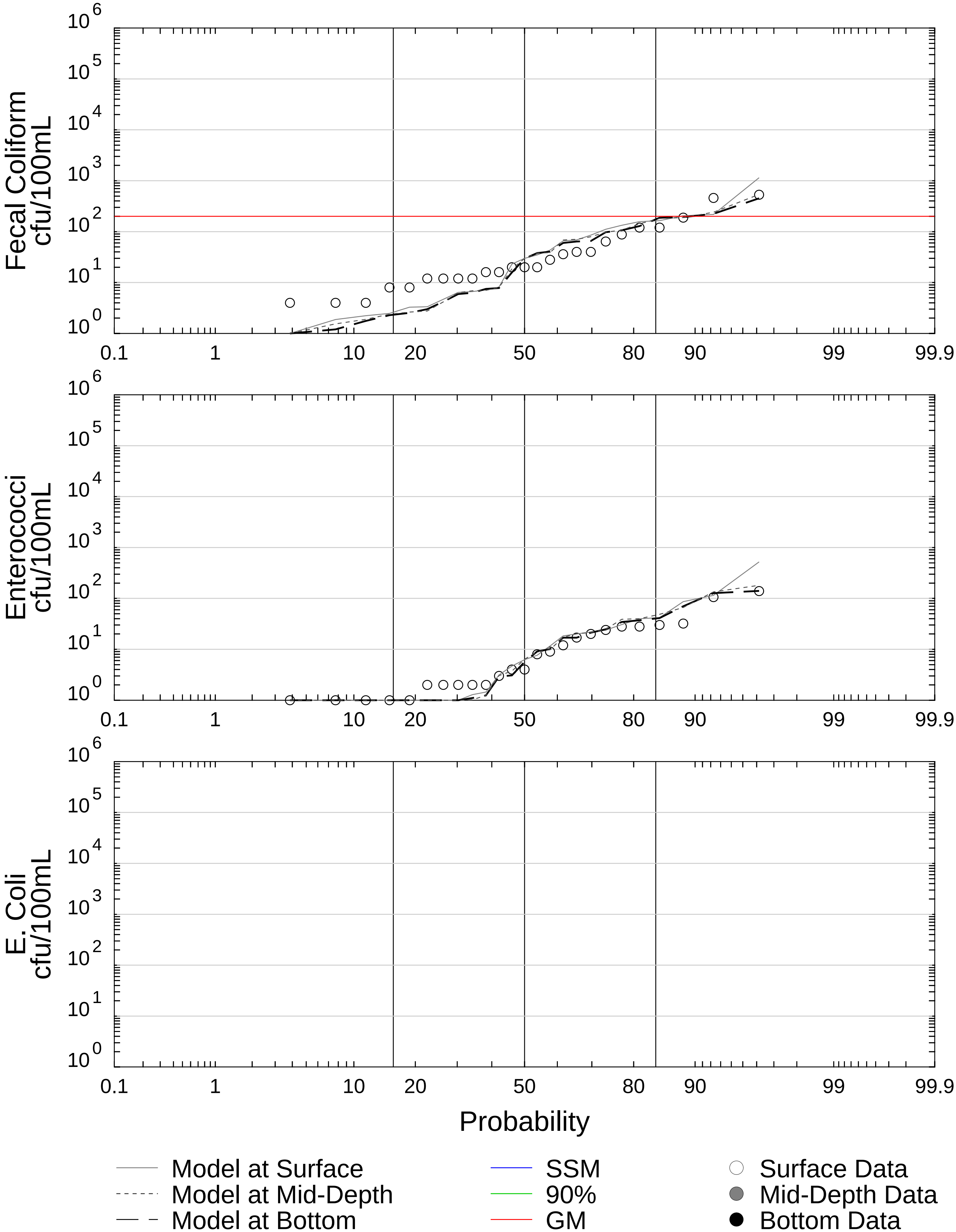
I



Model Results during data sampling hours only

Staten Island
Shooters Island

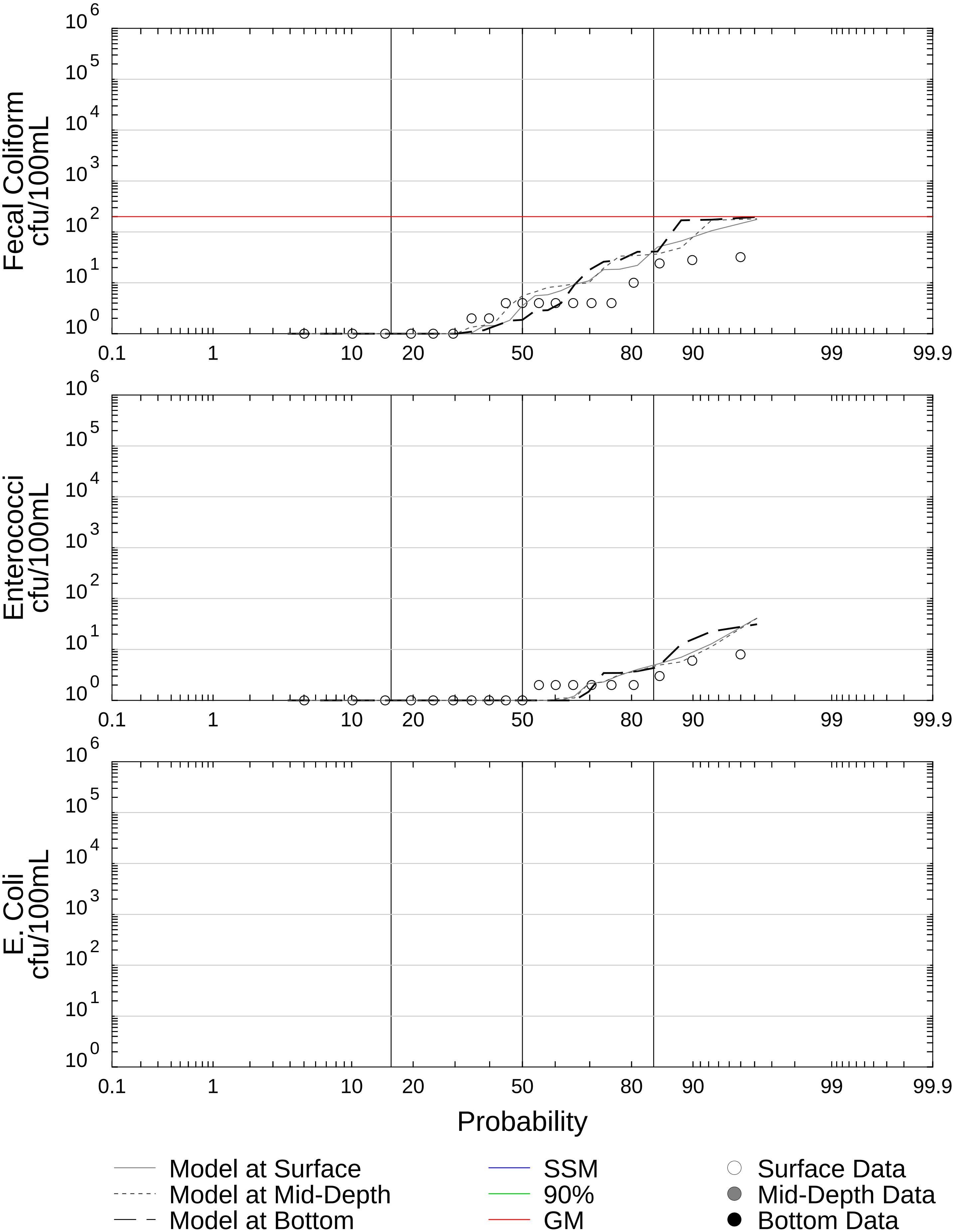
Station: K2



Model Results during data sampling hours only

Staten Island
Old Orchard Light

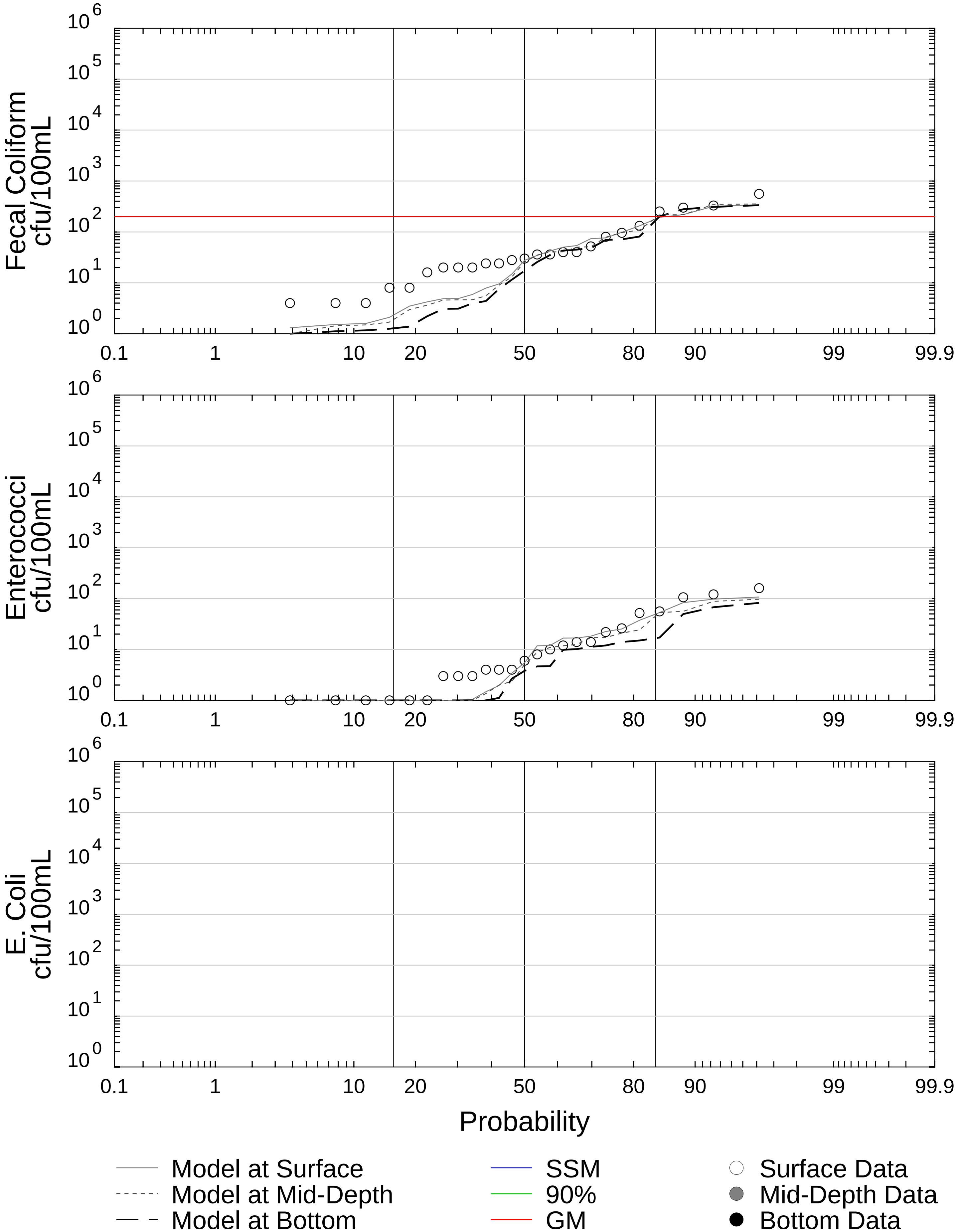
Station: K6



Model Results during data sampling hours only

Staten Island
St. George

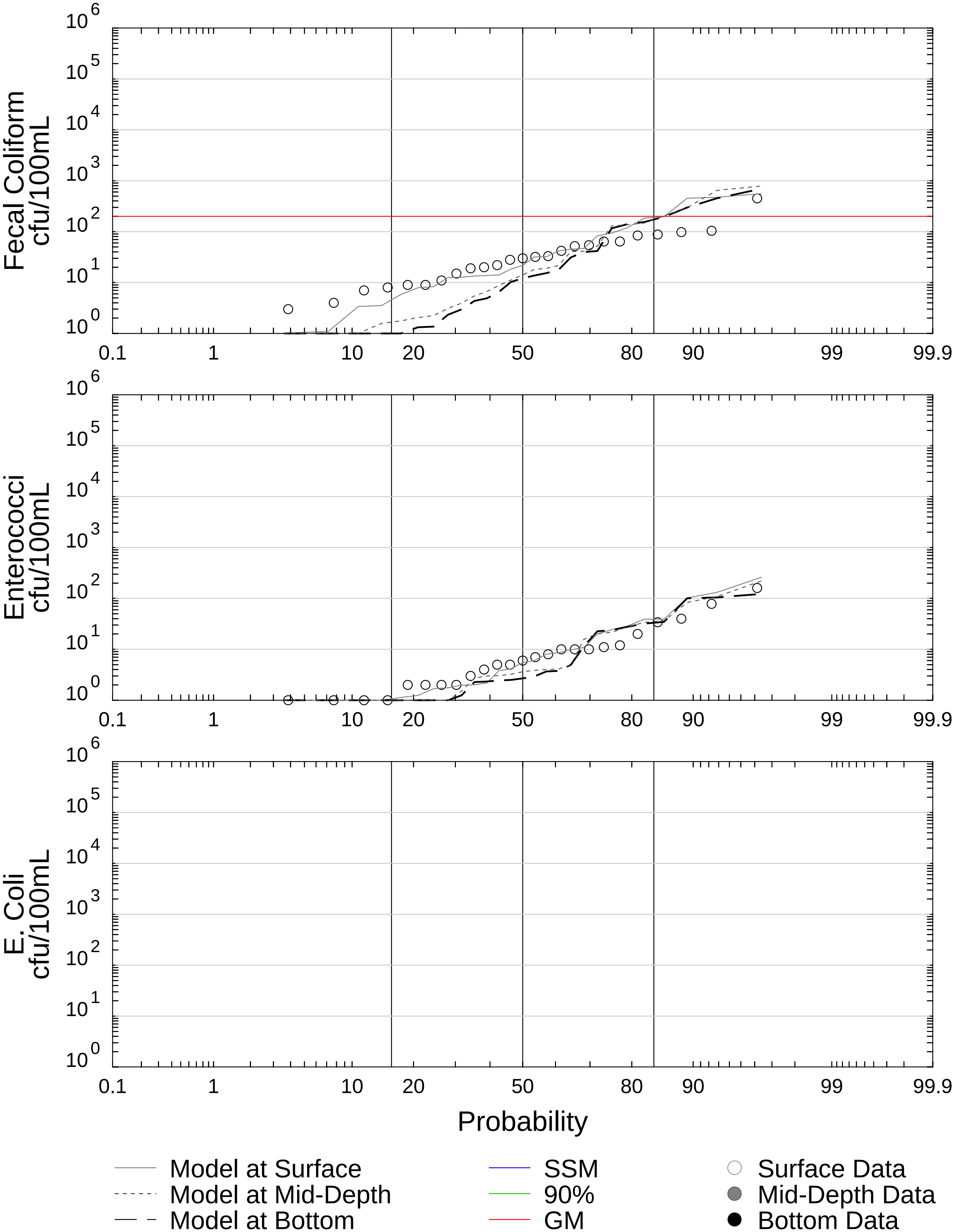
Station: K1



Model Results during data sampling hours only

Hudson
Pier A - The Battery

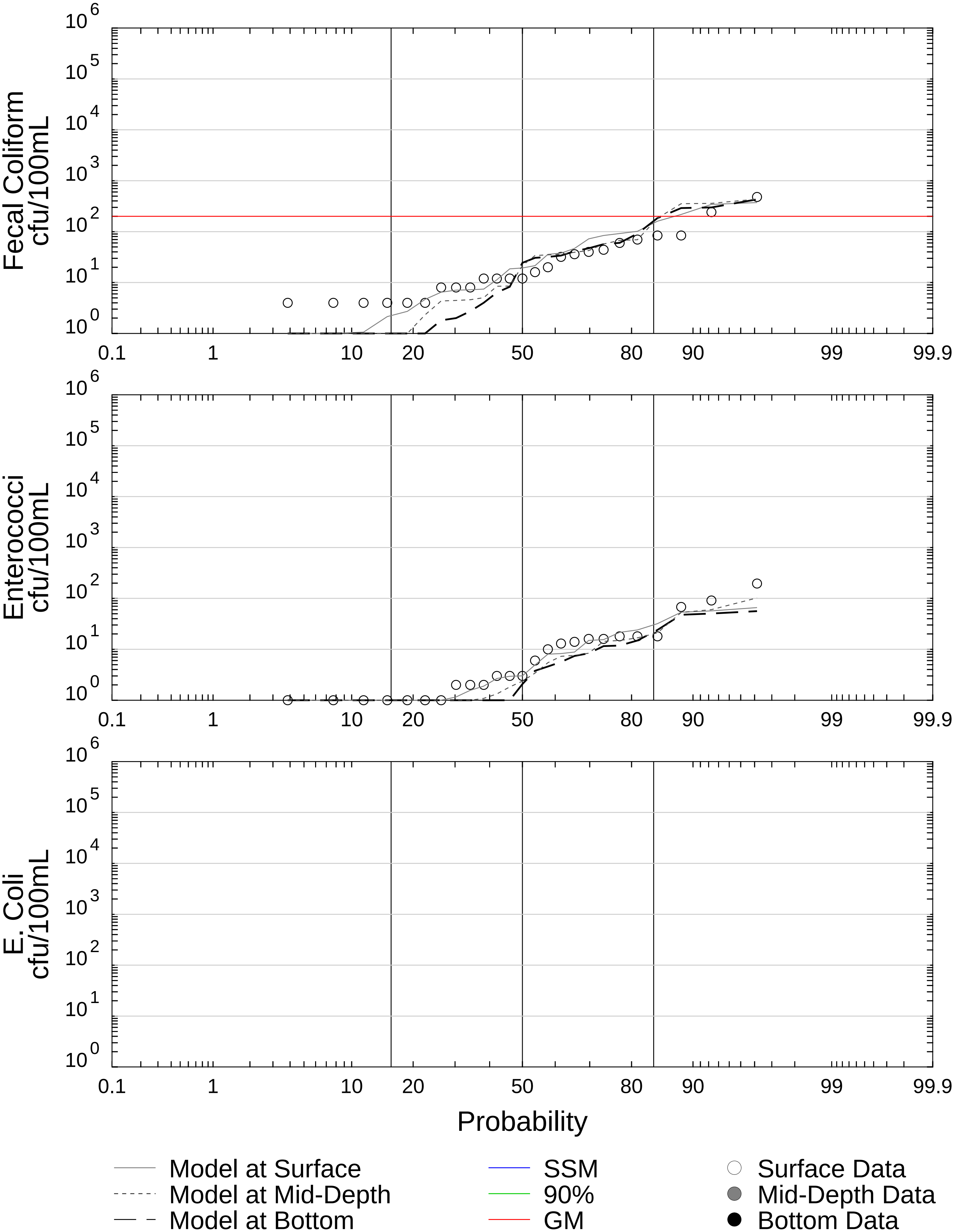
Station: N5



Model Results during data sampling hours only

Hudson
Bell Buoy 31

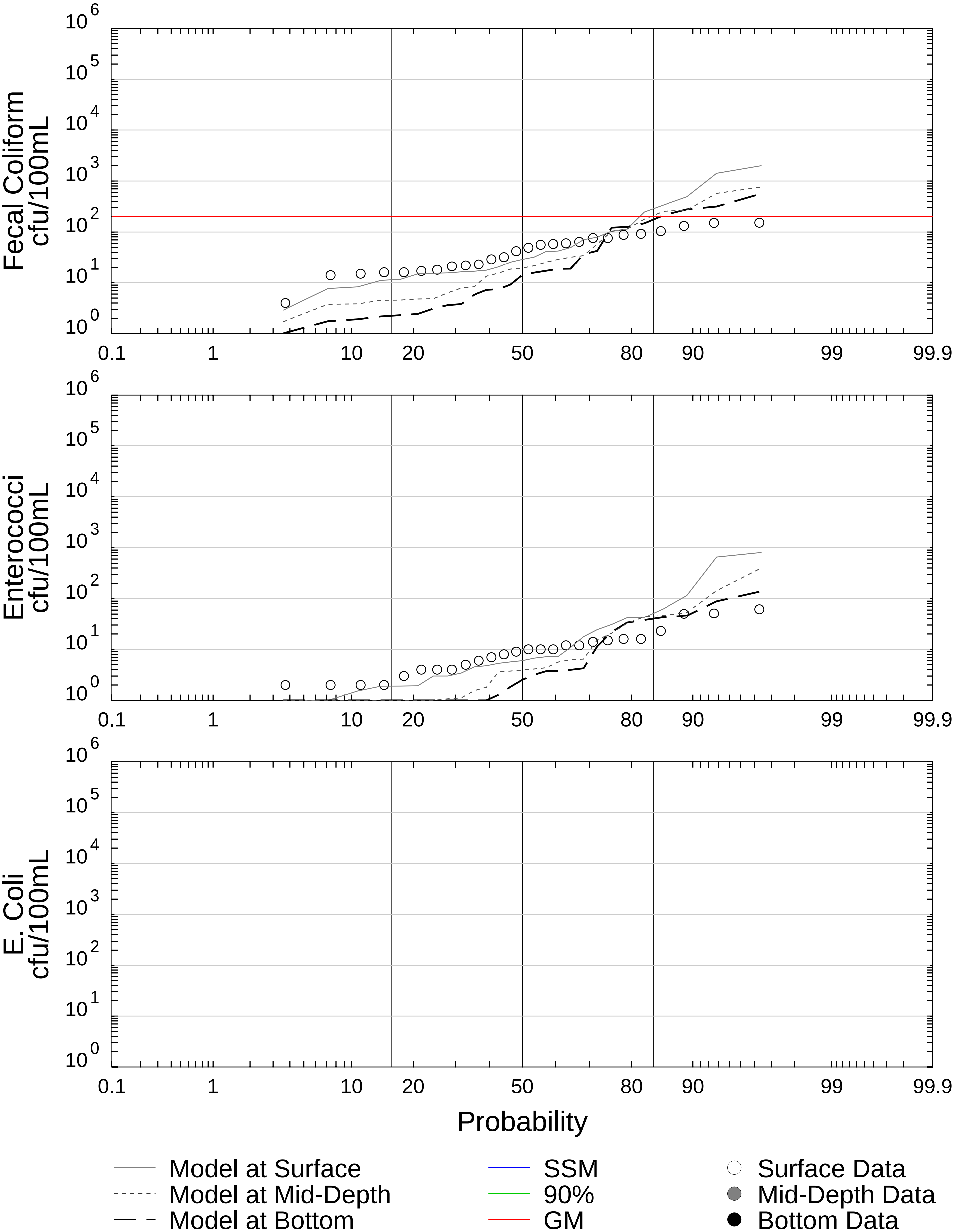
Station: N6



Model Results during data sampling hours only

Hudson
W. 42 St.

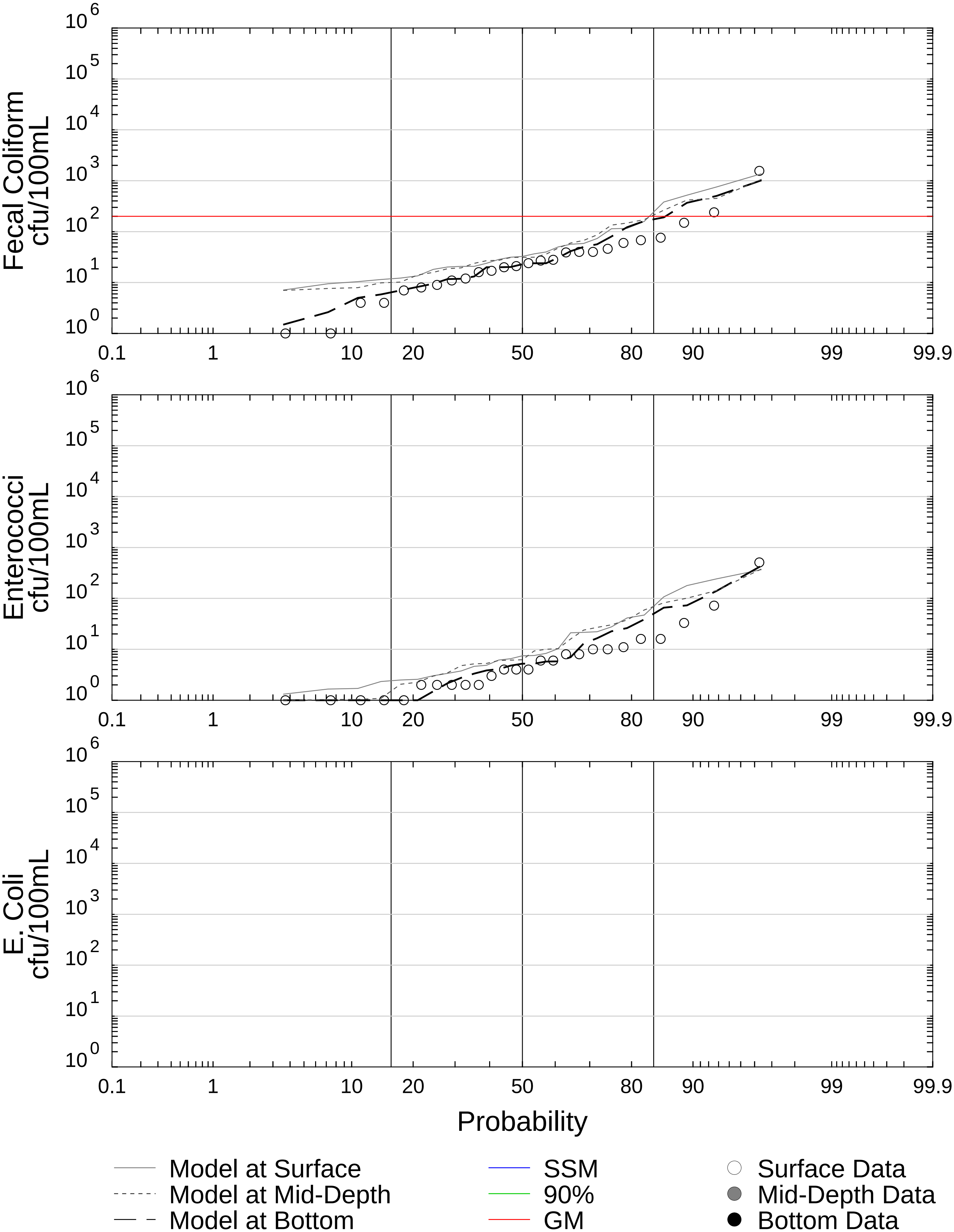
Station: N4



Model Results during data sampling hours only

Hudson
W. 125 St.

Station: N3B

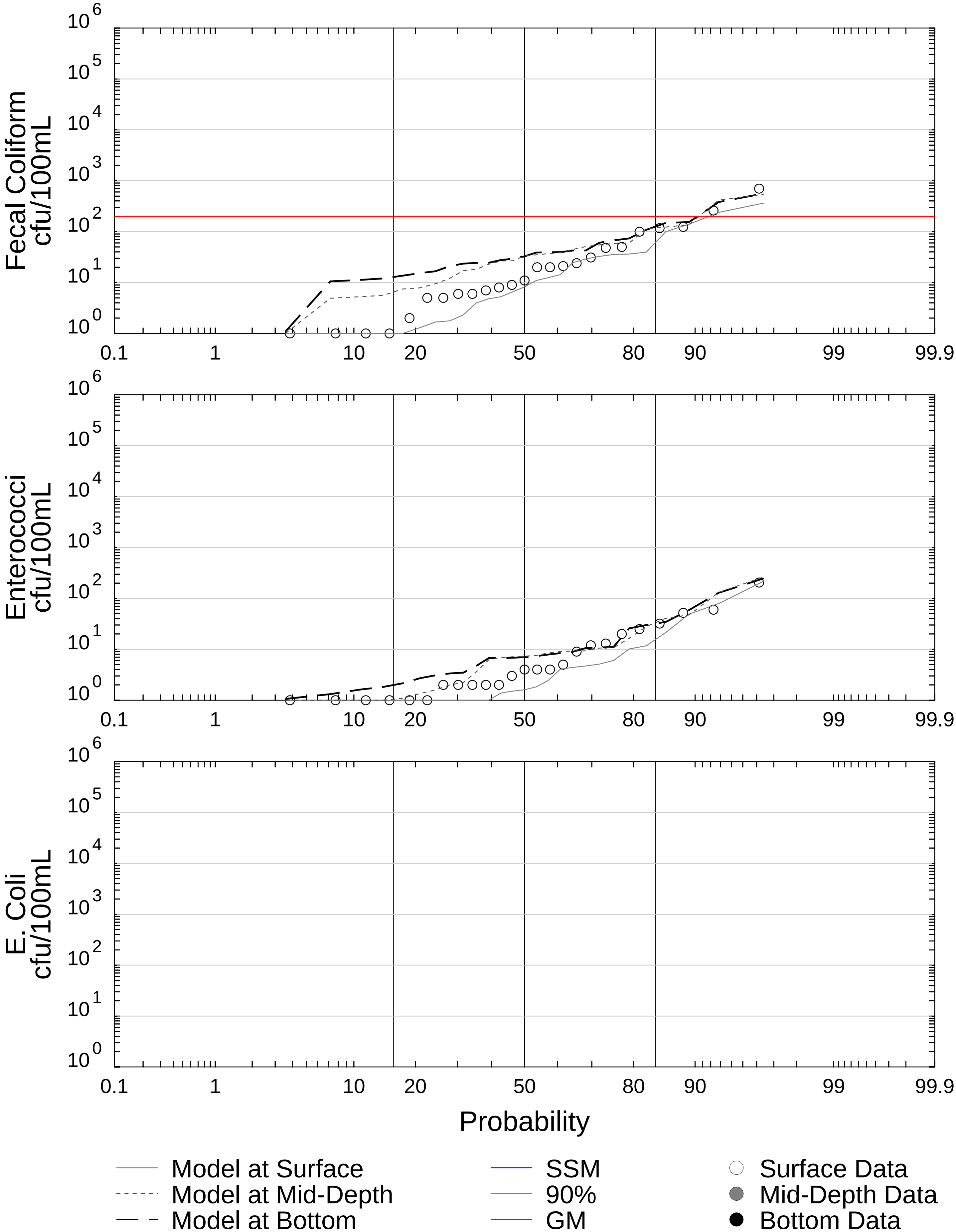


Model Results during data sampling hours only

Hudson
Mt. St. Vincent

I

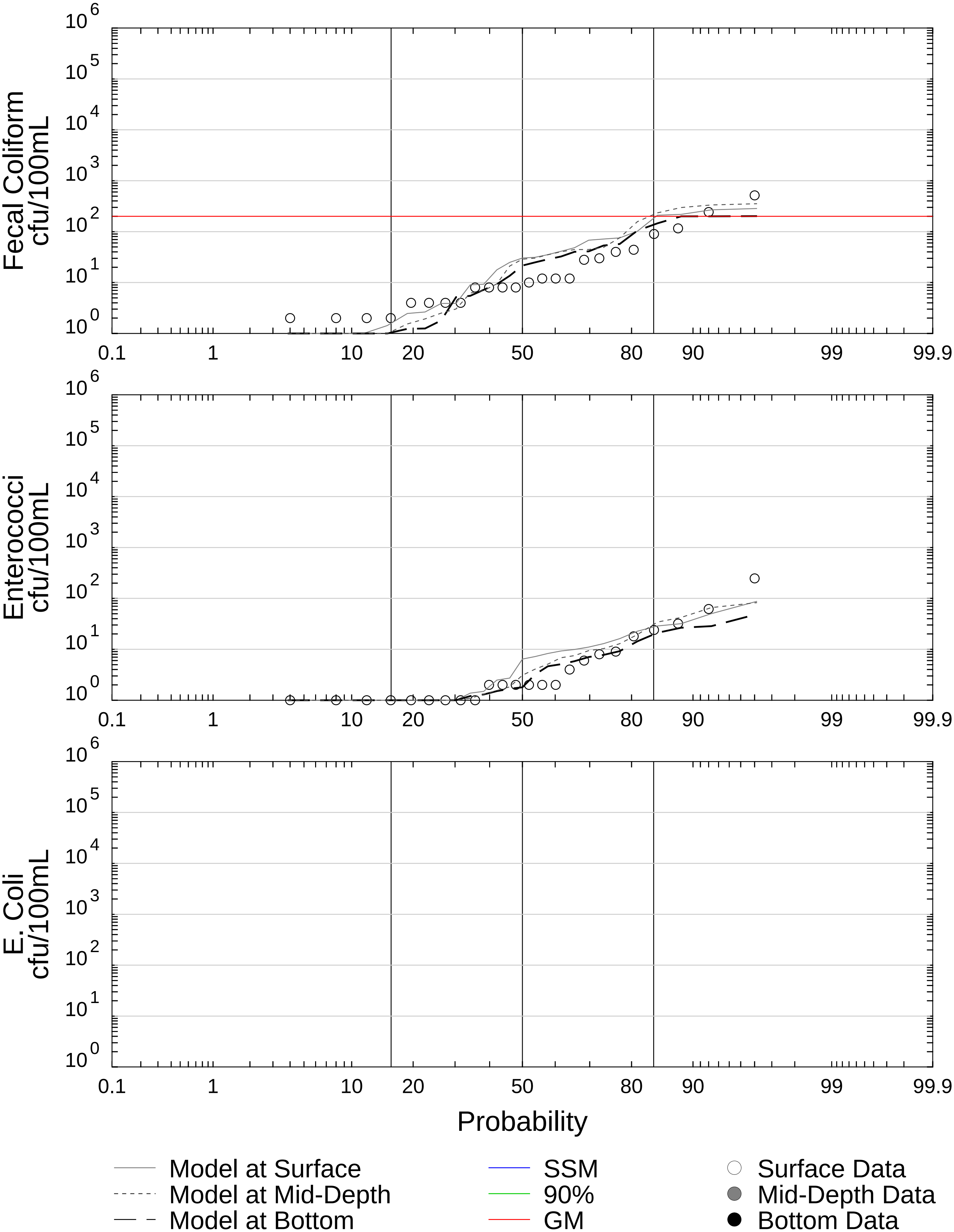
Station: N1



Model Results during data sampling hours only

Jamaica Bay
Coney Is. Outfall

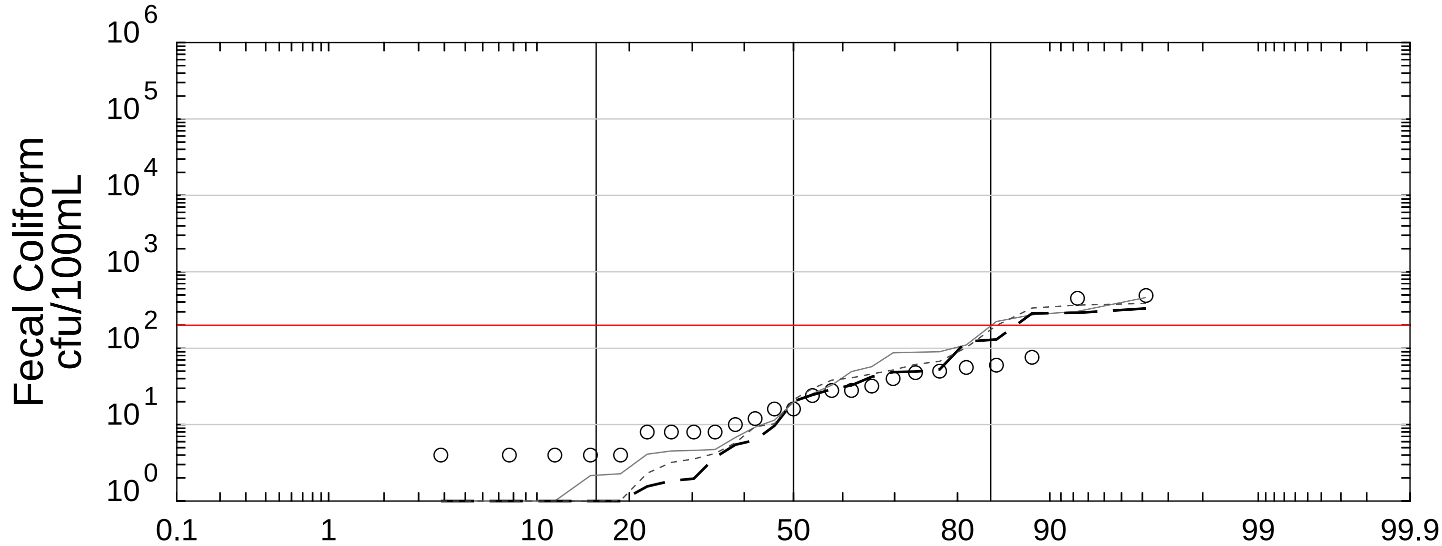
Station: N8

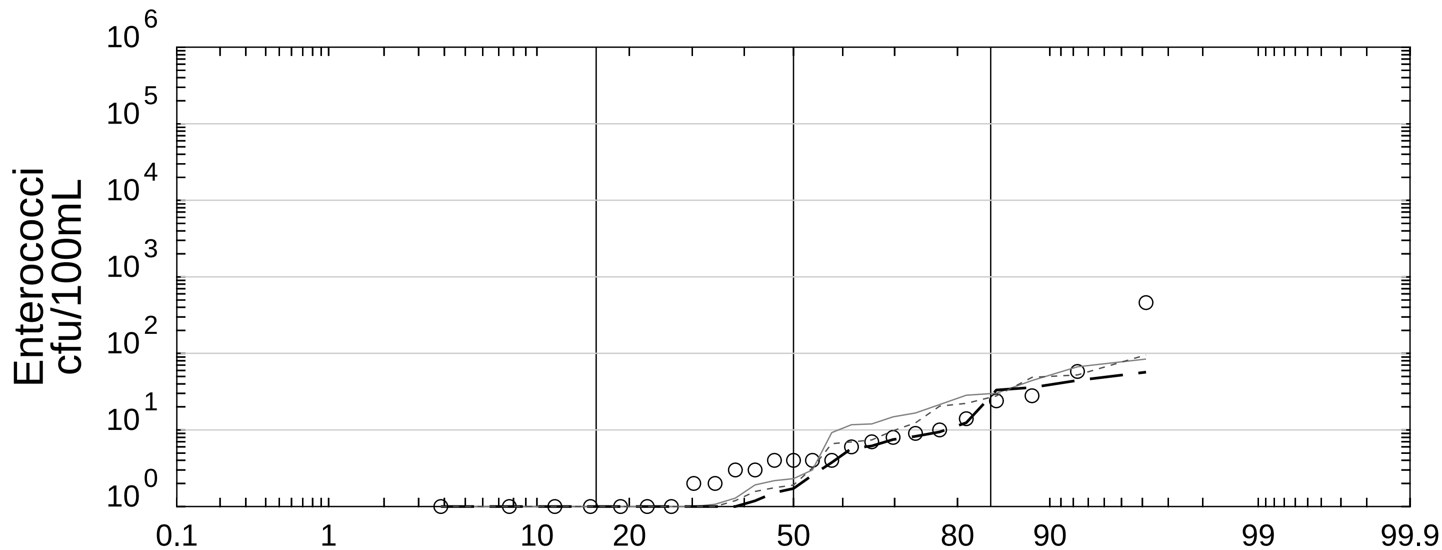


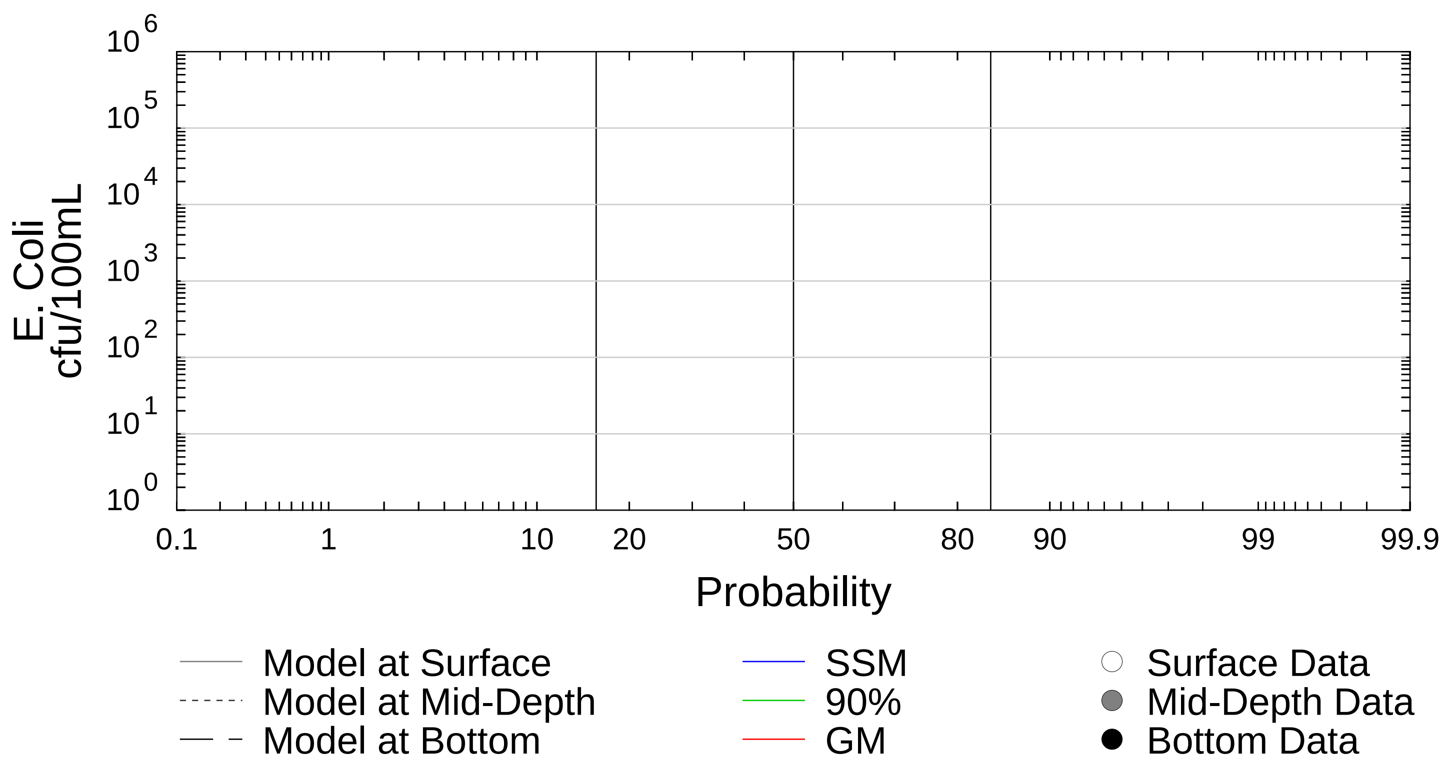
Model Results during data sampling hours only

Hudson
Robbins Reef

Station: N7







Model Results during data sampling hours only

Appendix G

Model Evaluation Group Comments

Memorandum

To: PVSC Long-Term Control Plan Team

From: PVSC Model Evaluation Group – Alan Blumberg, Steve Chapra, Wayne Huber

Date: March 30, 2020

Subject: Water Quality Model & Associated Model Calibration Report Review Comments

This memorandum summarizes comments from the Model Evaluation Group (MEG) related to the Water Quality Model and the Draft Calibration and Validation of the Pathogen Water Quality Model (PWQM) for the Passaic Valley Sewerage Commission Report dated November 2019 developed for PVSC area communities. These comments were prepared following discussion of these items at the MEG Session 5 meeting on November 21, 2019 and review of the Draft Calibration and Validation Report. The MEG Session 5 meeting was attended by NJDEP, PVSC, and the Greeley & Hansen, CDM Smith and HDR Long-Term Control Plan team. HDR presented an overview of the water quality model at this meeting. The PVSC MEG was formed in 2016 and has met five times to review sampling plans, monitoring, and associated hydraulic, hydrologic and water quality modeling for the PVSC Long-Term Control Planning project.

Model and Model Calibration Report Review

The comments presented here address specific questions discussed during the MEG 5 review session, assess the suitability of the model for evaluating current attainment of water quality standards, and assess the model's suitability for identifying potential future improvements.

1. Is the water quality model software appropriate for use in this study?

The model software combines several large, complex state-of-the-art models required to simulate of the generation, transport, and kinetics of pathogens in the Passaic Valley system and adjoining waters. These include highly sophisticated load generation, hydrodynamic, and water quality models into the type of holistic framework necessary to adequately evaluate attainment of current standards and identifying potential future improvements. Beyond the software itself, immense amounts of supporting data were assembled in order that these powerful computational tools would generate sufficiently accurate results. Finally, the consultants who were hired to implement the foregoing are among the best in the world. So, in summary, the modeling framework and supporting data comprises a powerful state-of-the-art tool that is appropriate for use in this study.

2. Was the model developed and calibrated according to meet or exceed industry standards?

   a. Is the hydrodynamic calibration adequate to represent advection and dispersion related to the transport of bacteria within the project area?

   A well-tested and extensively peer reviewed model, ECOMSED, was used to model the advection and dispersion of the study area. The modelers at HDR are expert in ECOMSED's use knowing the model's strengths and limitations. The domain was properly selected and the grid, refined from previous studies, was excellent for the modeling analysis.

   The grid in the Elizabeth River is not reflective of the high quality of the model for other Rivers and could be improved to better reflect actual conditions. The grid there could not resolve the dynamics of the river nor include properly the influence of the DEM. The November 2019 report did not

include any results from the Elizabeth River, but the presentation of November 21, 2019 did.

The model forcing functions, freshwater inflows, water levels, meteorology and the influence of the adjoining offshore coastal ocean were all brought into the model correctly. The accompanying data base to support the modeling and its validation/verification was quite comprehensive. Note that the reference to Figure 2-2 on page 11 is incorrect. It is also curious that the river inflow temperature data shown in Figures 4-5 and 4-6 have interannual fluctuations while the Hudson River inflow temperature does not. Why?

Data observed in the period 2009-2016 were used in the analysis. This in itself was an impressive undertaking. Most modeling efforts run very short periods of time. The validation/verification for water levels showed that the model as configured reproduces the observations. The discrepancies are minor and have little to no impact on the currents. The ability of the model to reproduce currents is simply outstanding. The only issue for validation/verification is that the currents should have also been low-pass filtered as was done for water levels to afford a clearer assessment. Note that Figures 5-6 should include the total water depth, so the reader knows where in the water column the observations come from. The validation/verification for temperature and salinity shows that these quantities are very well modeled. It is hard to find any parts to critique.

The hydrodynamic modeling effort was outstanding, better than what is seen in the literature, reports and presentations. Salinity, a very difficult constituent to model correctly, is done quite correctly suggesting that the advection and dispersion processes related to the transport of bacteria are correct.

b. Is the model's calibration of temperature adequate to represent bacteria decay during the study period?

Temperature was modeled very well. It is primarily driven by the atmosphere with horizontal currents playing a secondary role. The role of vertical mixing is critical in getting temperature correct. Because the modeled temperatures compare well with the observations that suggests the vertical mixing (diffusive) processes are correct.

c. Is the water quality calibration reasonable with respect to observed data?

The modeling of pathogen transport and fate in complex river/estuary systems involves much more uncertainty than hydrodynamic and heat budget (temperature) models. Given this inherent uncertainty, the calibration was good enough to adequately support the use of the model for decision making.

This conclusion is because the comparisons of model output and data were "reasonable" given the state-of-the-art for such comparisons. Further, the fact that the pathogen model rests on the solid shoulders of the load generation and transport models means that it should be very good at simulating the relative spatial and temporal impacts of the individual bacterial inputs.

As we will suggest at the end of this document, the MEG would have preferred that more was done to explore model sensitivity.

d. Was the model calibrated and validated against a range of data with concentrations relevant to the current water quality standards? Is the model response during wet and dry weather adequate to evaluate whether the receiving water is meeting water quality standards?

The model was run for the period where the Team collected data. There were several wet and dry weather events in that period that the model captured well. However, there weren't enough of the events to provide definitive confidence in the model's veracity. Idealized (sensitivity) cases should have been run to examine the processes in the system. For example, the evolution and spatial impact of a large load in one of the rivers would serve to illustrate how the model simulates longer time and space scales than apparent in the data sets.

e. Are the calibrated constants and parameters reasonable?

The calibrated constants and parameters related to bacterial kinetics are consistent with the current state of the science. In particular, the modeling team's extensive experience in simulating bacteria in many receiving waters across the New York Metropolitan Area, provides added confidence that the constants and parameters in the present study are sound.

3. Are the loads for stormwater, CSO, dry weather flow and upstream boundary conditions appropriate and supported by water quality sampling data collected under the approved QAPP?

The Team assembled a very large collection of sanitary sewers, storm sewer, combined sewer and treatment plant pathogen concentrations, both as data sampling within this project and from other agencies and firms. It is hard to imagine a more thorough effort at assembling suitable time series within the constraints of budget, time and weather. Evaluation of consistency of sample data was aided through comparison of model runs for the sampled periods. Suitable assumptions were made for other extraneous inflows and for inflows at the end of upstream tributaries, including the Hudson River. It is important to get baseline conditions correct since impacts of storms will be superimposed on them.

4. Were reasonable assumptions applied in evaluating attainment of water quality standards? The following assumptions were made:

a. Attainment is assessed based on surficial assessment, not depth averaging

This seems reasonable to the MEG in part because surface water layers are the most likely water contact layers. If fish and shellfish are also important considerations, this argument might not hold because these use the entire water column in their life cycle.

b. Measurements are averaged across Assessment Units, not by looking at individual stations

Too many stations to do it otherwise except for some possible key, critical locations.

c. Measurements use a 30-day rolling geometric mean of hourly model output, differing from typical compliance sampling frequency (e.g., weekly grab samples)

In general, the MEG thinks different kinds of averaging are inevitable when dealing with pathogens and a spatial scale of this magnitude.

5. Is the model's calibration adequate to reflect future wet weather flow improvements, which would include reductions in CSO flows and volumes and/or changes in pathogen concentrations associated with inflow and infiltration reduction, sewer separation, treatment, and storage technologies?

The water quality model includes all essential forcing functions and pathogen sources. As such it has great potential to address the significant questions about options for attainment of water quality standards. The water quality calibration is shown in the November 21 presentation as time series plots for the Passaic River Hackensack River, and Newark Bay. Passaic River plots of Figure 5-48, event 3 are the most encouraging regarding agreement of model and data trends. For Newark Bay, agreement of the model with coliform measurements taken over the same time period is generally good although the model predictions remain relatively flat over three days on the log-scale plots in Newark Bay. It is unproven whether the model is truly conservative in its overestimates on days 2 and 3 for Newark Bay (Report, page 139). River transect concentrations on the Hackensack show good similar trends between model and data. Probability plots for the Passaic show good agreement.

Is the model useful for assessing attainment of water quality standards:

a. For existing CSO discharges?

As was discussed in our response to Item 5 above, the MEG feels the model adequately represents current conditions for the water bodies shown in the Report, with some qualifications also discussed above. But existing CSO discharges represent a static condition, for which field data are the definitive metric for judging water quality standards. Most important is Item 6b, below.

b. With possible future CSO mitigation measures implemented?

As mentioned above, the water quality model is quite comprehensive because it includes all the essential forcing functions and pathogen sources. It relies on well-documented hydrology and hydraulics models, both in the drainage system and in the receiving waters in addition to an outstanding effort at assembling necessary data. As such the water quality model has great potential to address the significant questions about options for attainment of water quality standards.

What is missing is a clear demonstration of the sensitivity of model outputs to changes in inputs. The potential model user must clearly see that the model is sensitive to the impacts of likely control options, including strictly hypothetical ones. (Not necessarily for all areas. Insensitivity of a water body to changes in input is often a useful result, if the insensitivity can be explained, e.g., small load into large water body.) Obviously, this analysis is not a simple matter here, with so many forcing functions as well as the several ways in which output concentration responses are displayed over a huge spatial area. But it is important that more effort be expended for this purpose. Section 6.4 Gap Analysis is an example for CSO control, in which the model appears to be relatively insensitive to 100% CSO control for most of the Assessment Units

shown. An explanation of why some AUs are affected more than others would help. The component analysis diagrams are cleverly portrayed. But Report sections 6.4 and 6.5 would carry more weight had the reader seen an earlier demonstration of the model's capabilities in this regard.

Recommendations

- **Graphics typically outstanding. Text well written.**
- **The MEG feels the Team has demonstrated that the hydro/water quality model is adequately calibrated for existing conditions, with all sources taken as a whole and the project represents an effort that is at the state of the art, ie, industry standard.**
- **The Report should include presentation and discussion of the results for the Elizabeth River.**
- **Report talks about tides and tidal forcing. It really should be water levels. Water levels are composed of two parts, tides driven by the moon and sun and "non-tidal" fluctuations driven by meteorology.**
- **The modeling analysis covered a multi-year span, 2009 and 2016. This is a very impressive feat and should be emphasized to all involved.**
- **The entire model validation/verification needs to be more rigorous before going forward. The MEG notes that plots are the main method of comparisons without any quantification or discussion of the discrepancies. Terms like agree very well (56), most of highs and lows reproduced by the model (p62), are in line with observed values (p 62), very good agreement (p69), generally good agreement and tracks very well (p76) are used. What is needed is a statistical quantification of the results, i.e., rmse and percent error.**
- **The breadth and scope of the water quality model is truly a significant accomplishment. Its capabilities are demonstrated in many meaningful ways. However, a clear presentation of the sensitivity of the model, e.g., in percent attainment of water quality goals for specified areas resulting from changes in model loads and other variables, is missing in the documentation and should be supplied in future communications.**

Last Thoughts

This study has been excellent in many respects; the team, the model development, and the data collection and assimilation have all been outstanding. Although the MEG has met with the Project Team five times since 2016, due to NJDEP deadlines, the pace of the study was expedited. The MEG would have been more desirous of a less fast-paced interaction. A slower pace, particularly at the study's end, would have allowed a more critical appraisal of the model's strengths and weaknesses.

As stated above, the quality of the team and the immense effort on this very complex system give us confidence that the framework will provide the necessary predictions to make cost effective and sustainable decisions related to pathogen management and control. On the other hand, the MEG would feel even more comfortable if more effort to present model sensitivity analyses were provided.