Forecasting Blue Crab Distributions Using an Individual-Based Population Model

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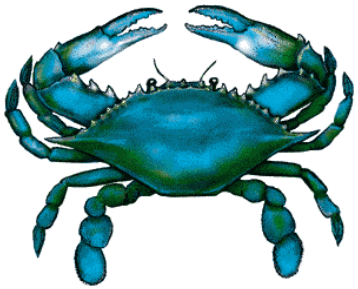
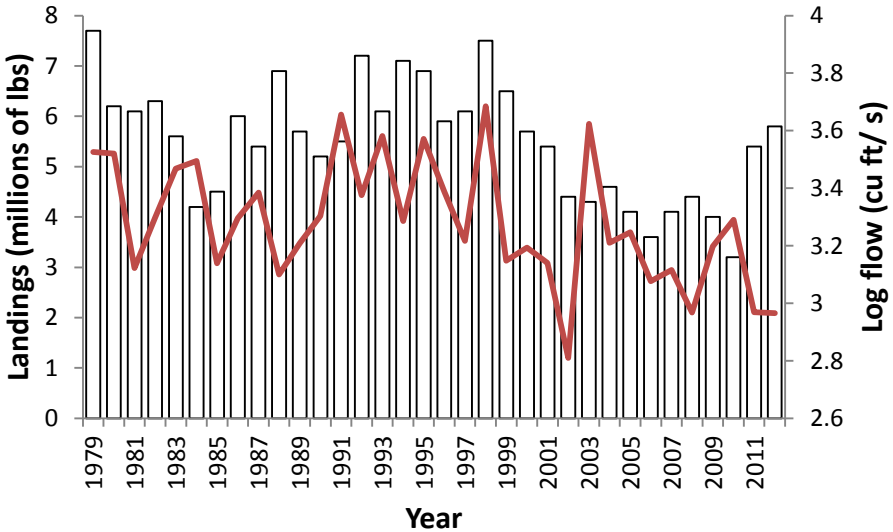
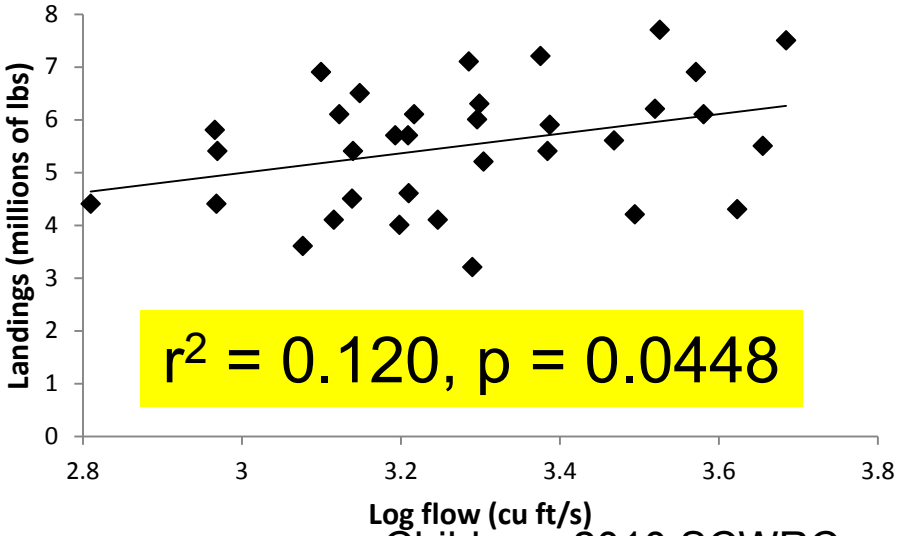
Clemson University



Why are blue crabs declining?

- SC crab landings have declined by 40% since 1998.
- The steepest decline corresponded to the extended drought period from 1999–2002.
- Overall landings are positively related to freshwater discharge



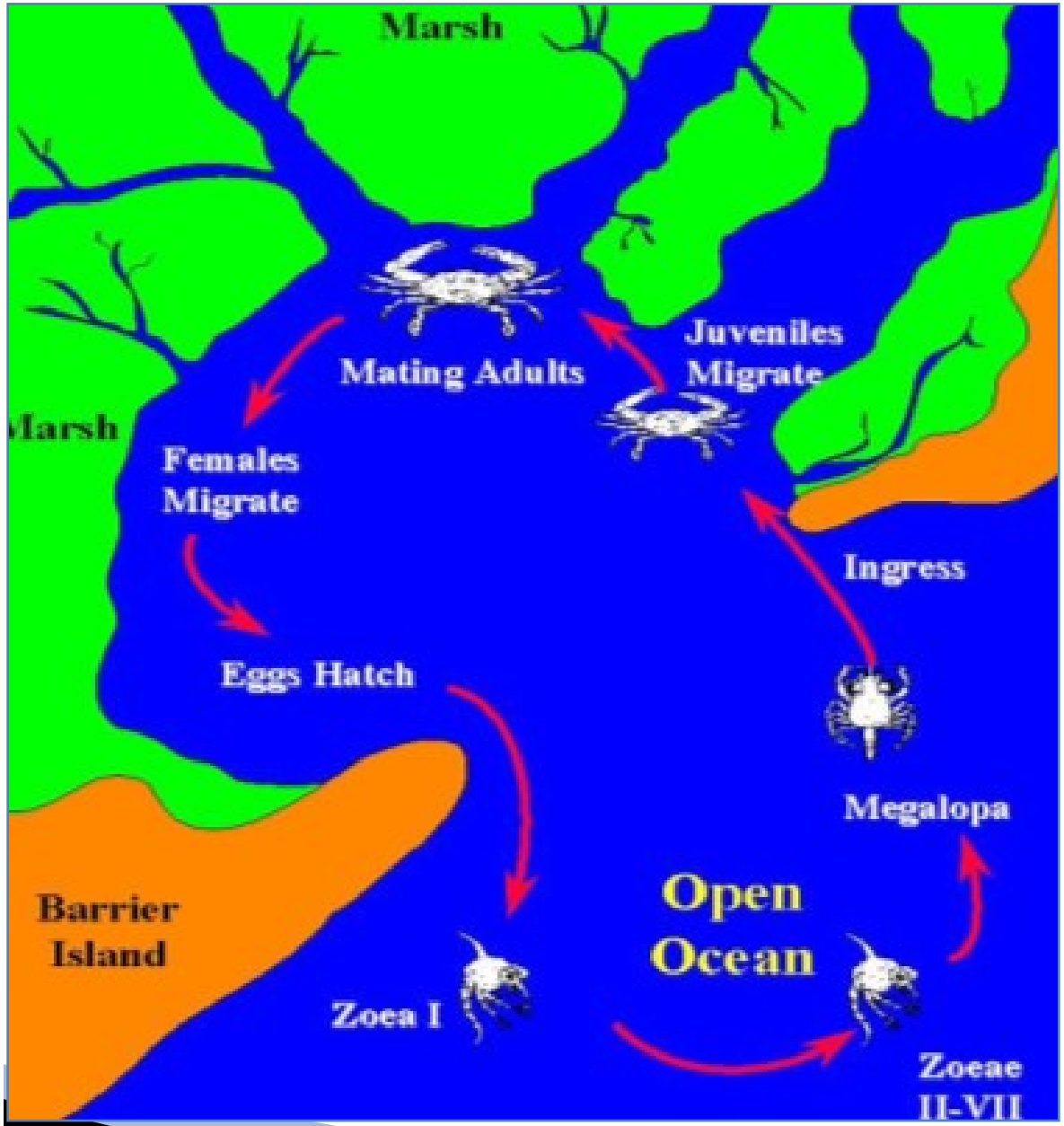


Childress 2010 SCWRC

Blue Crab

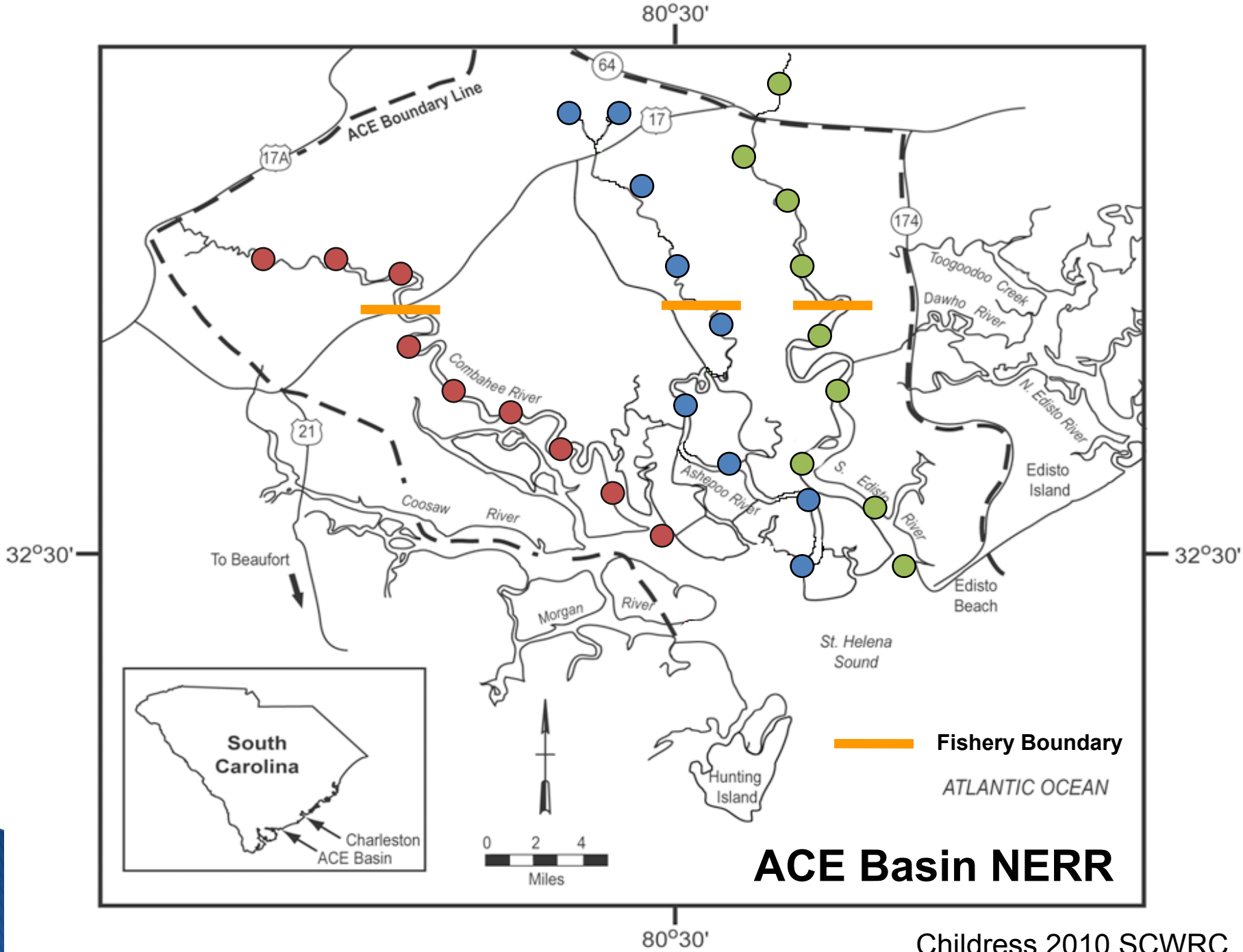
Callinectes sapidus

- Settlement = high salinity
- Maturation = low salinity
- Mating = low salinity
- Spawning = high salinity



Objectives of this study

- To parameterize an individual-based population model of South Carolina blue crabs using empirical data from the ACE Basin NERR
- To link this IBM with real-time freshwater discharge data from the USGS to forecast future abundance, landings and economic value of blue crabs.
- To distribute this forecast to fishermen, marine scientists and fisheries managers via web resources and social media.



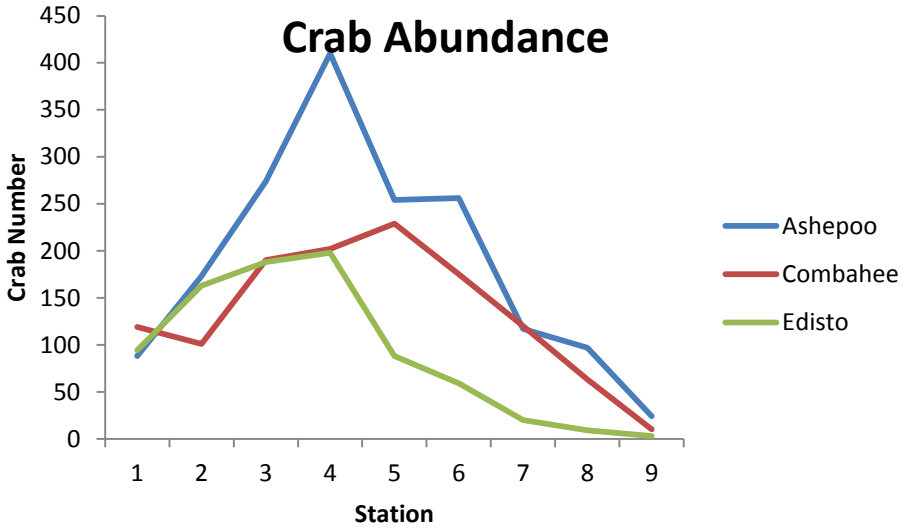
Childress 2010 SCWRC

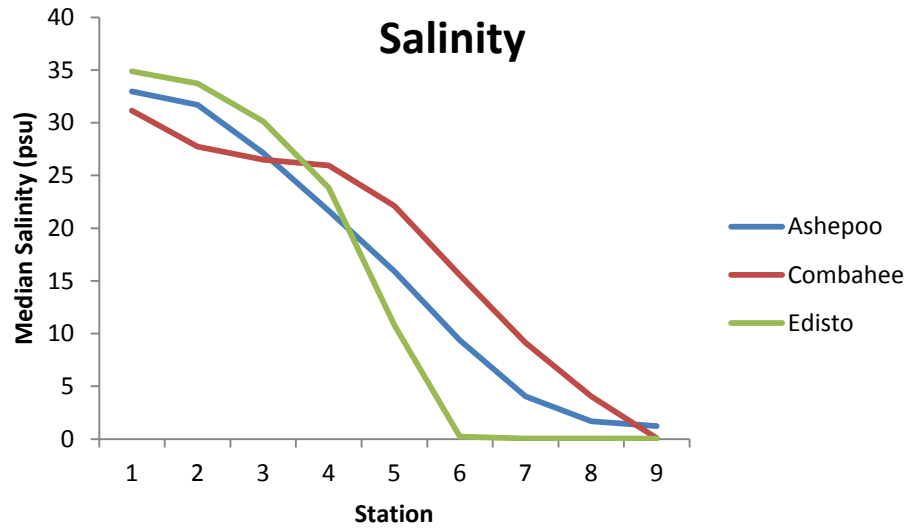
Water Quality

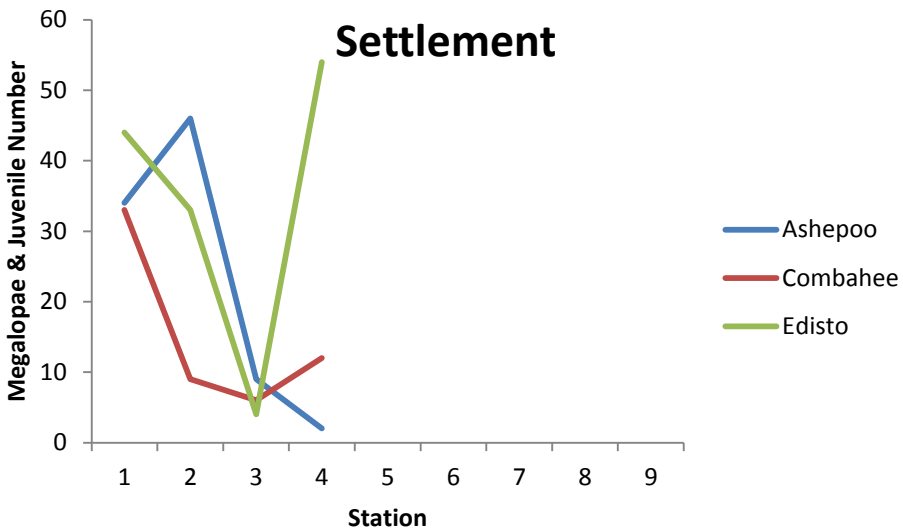
Disease

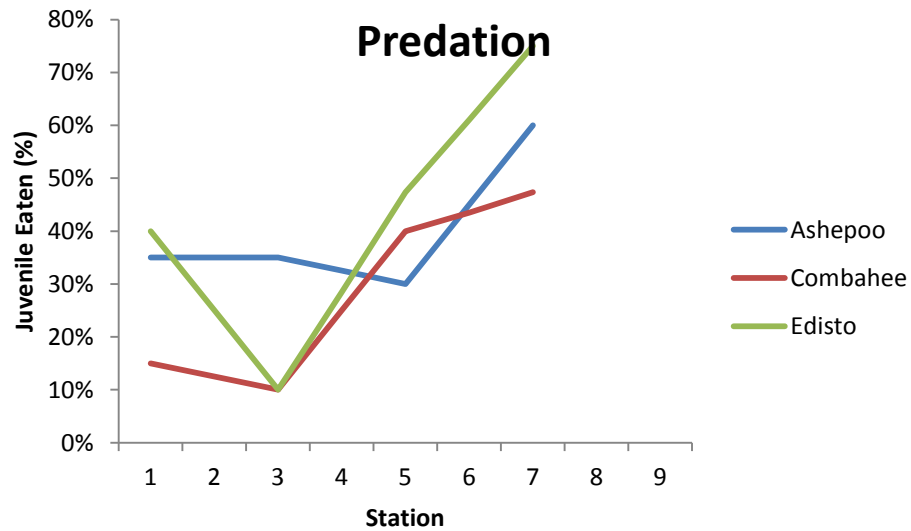
Settlement

Predation







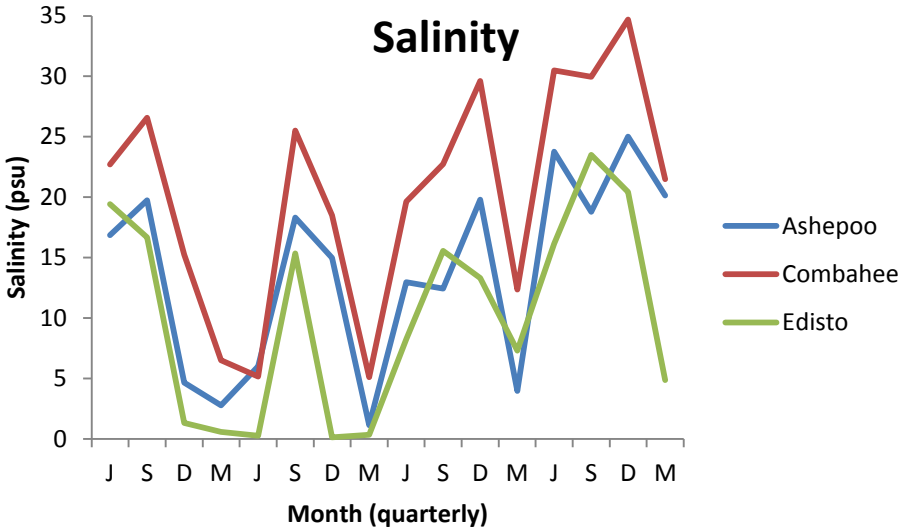


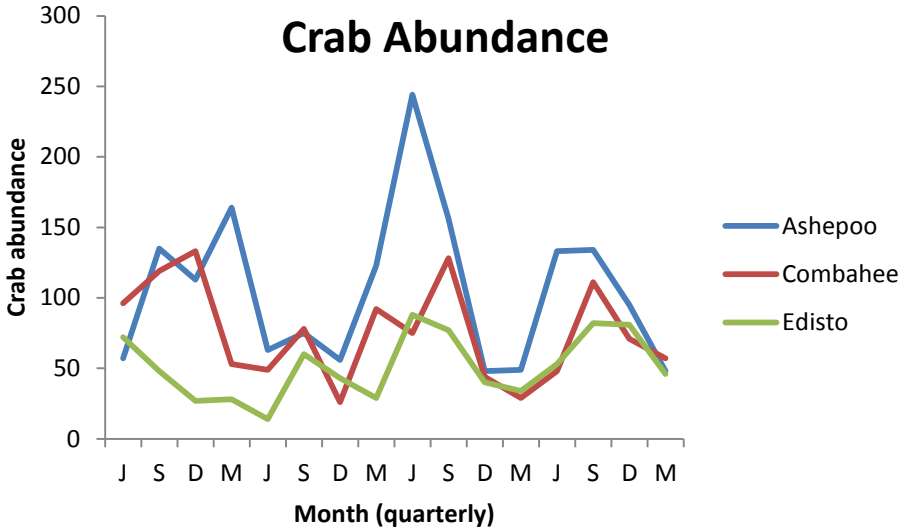
Crabs: $r^2 = 0.240$, $p = 0.3225$

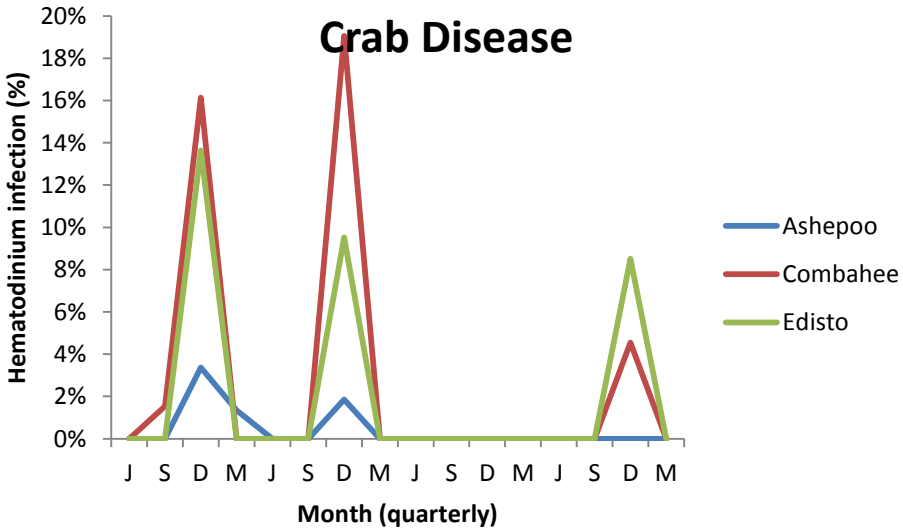
Salinity: $r^2 = 0.051$, $p = 0.1720$

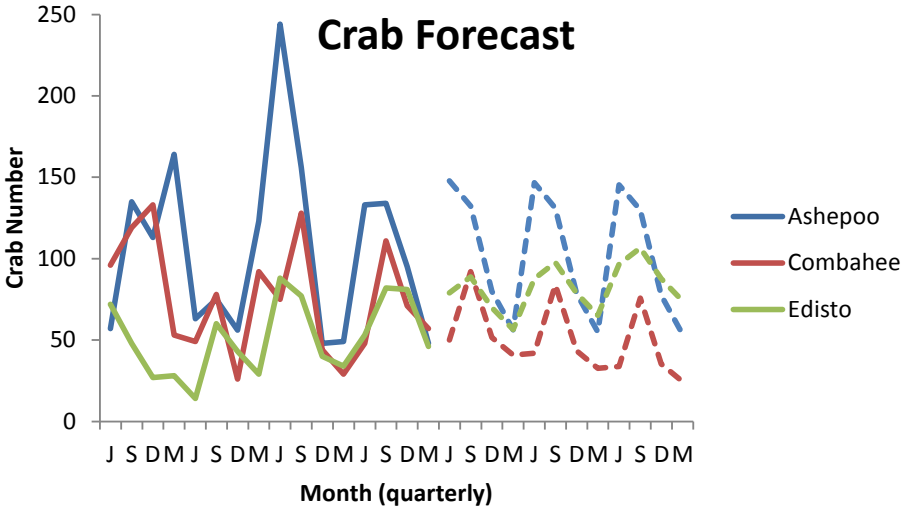
Crabs: $r^2 = 0.040$, $p = 0.5389$

Salinity: $r^2 = 0.743$, $p = 0.0003$



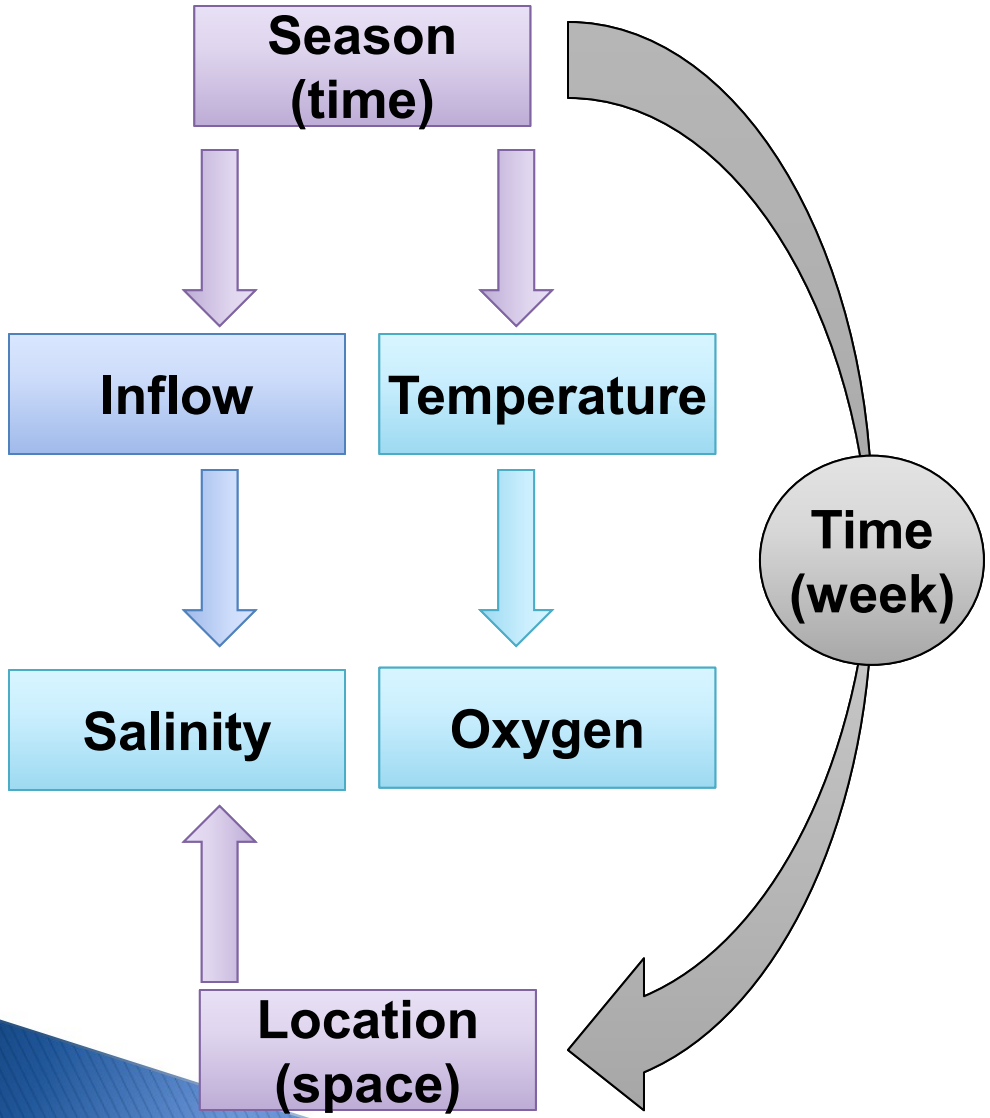


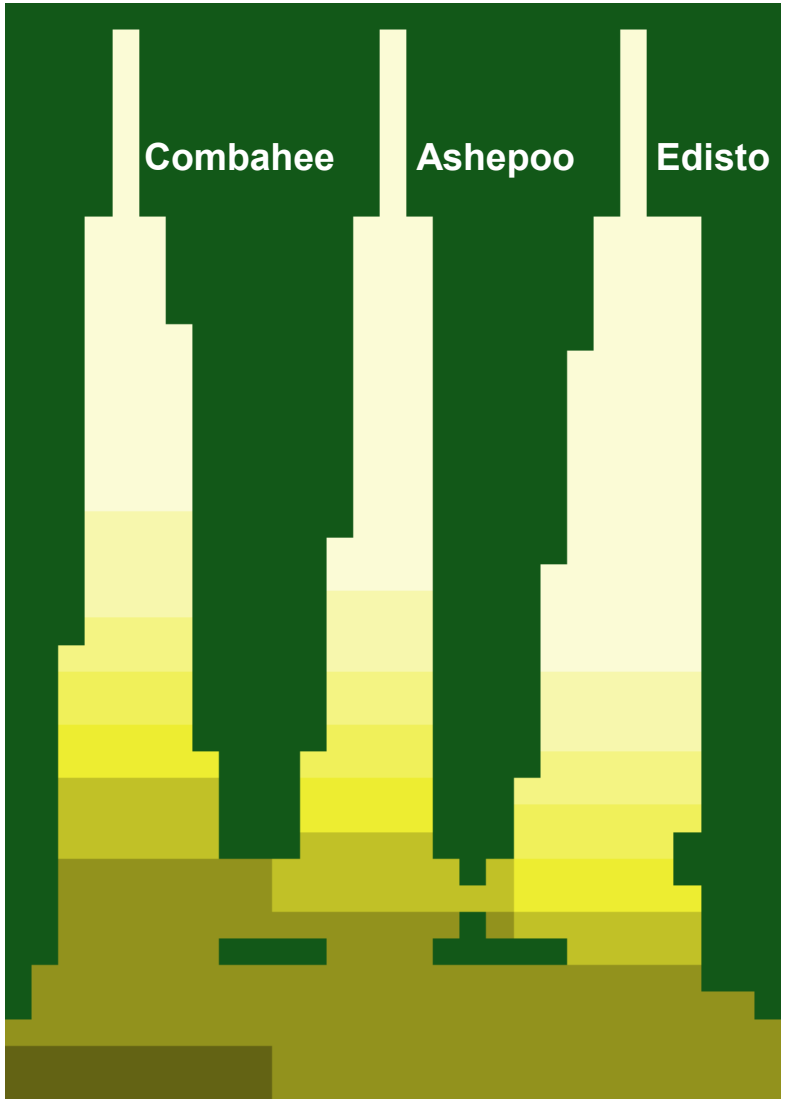




Parmenter 2012 Dissertation

IBM Crab Model Subroutines

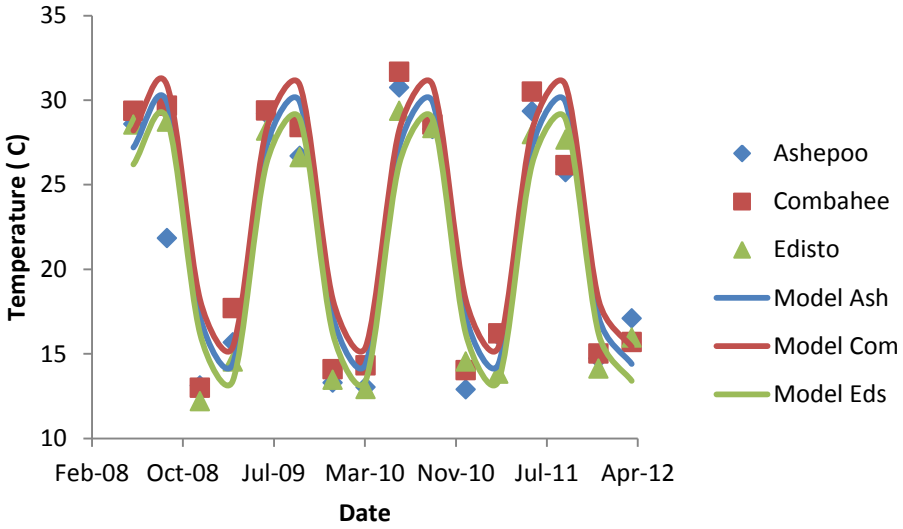


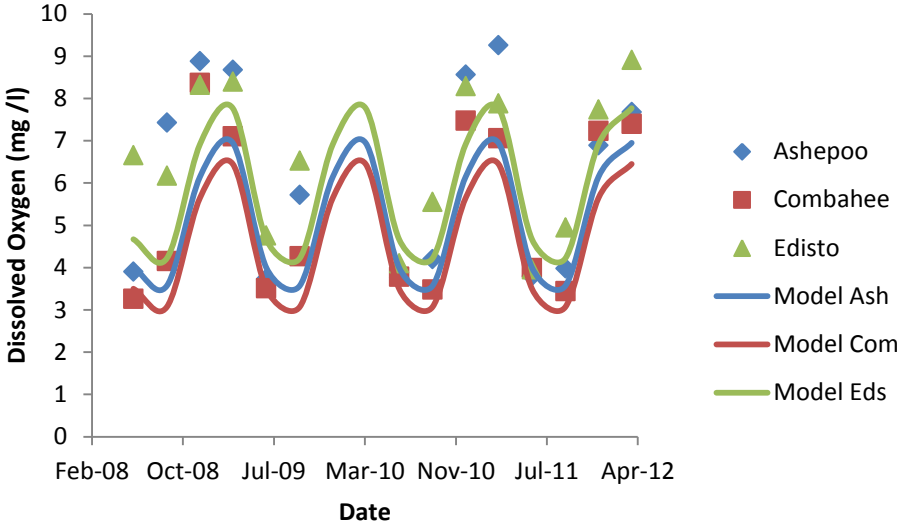


Childress 2010 SCWRC

Temperature & DO

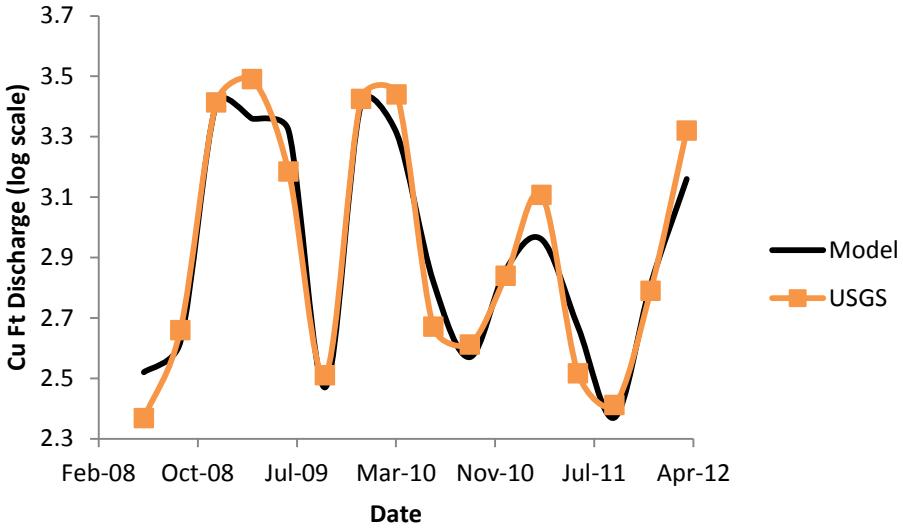
- Temperature sine curve from ACE NERR data @ St. Pierre Creek
- Dissolve oxygen calculated based on temperature – DO relationship
- Added correction factor by river

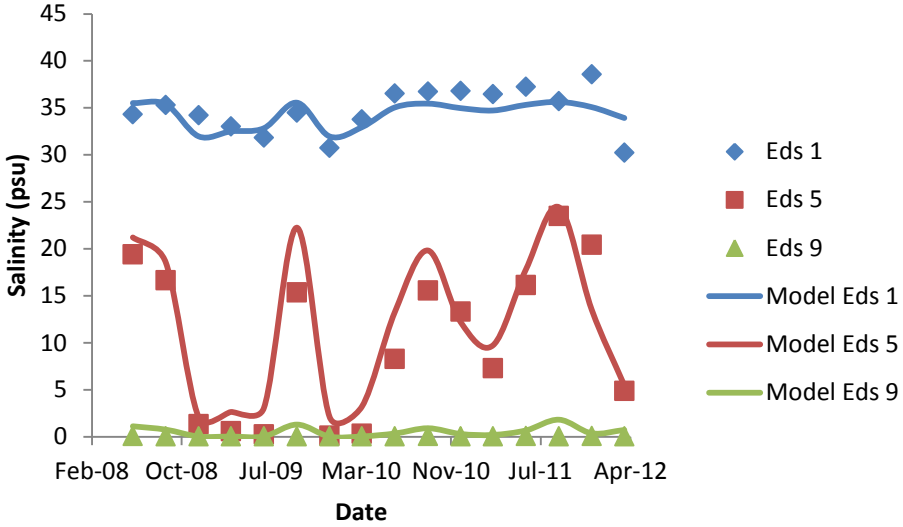




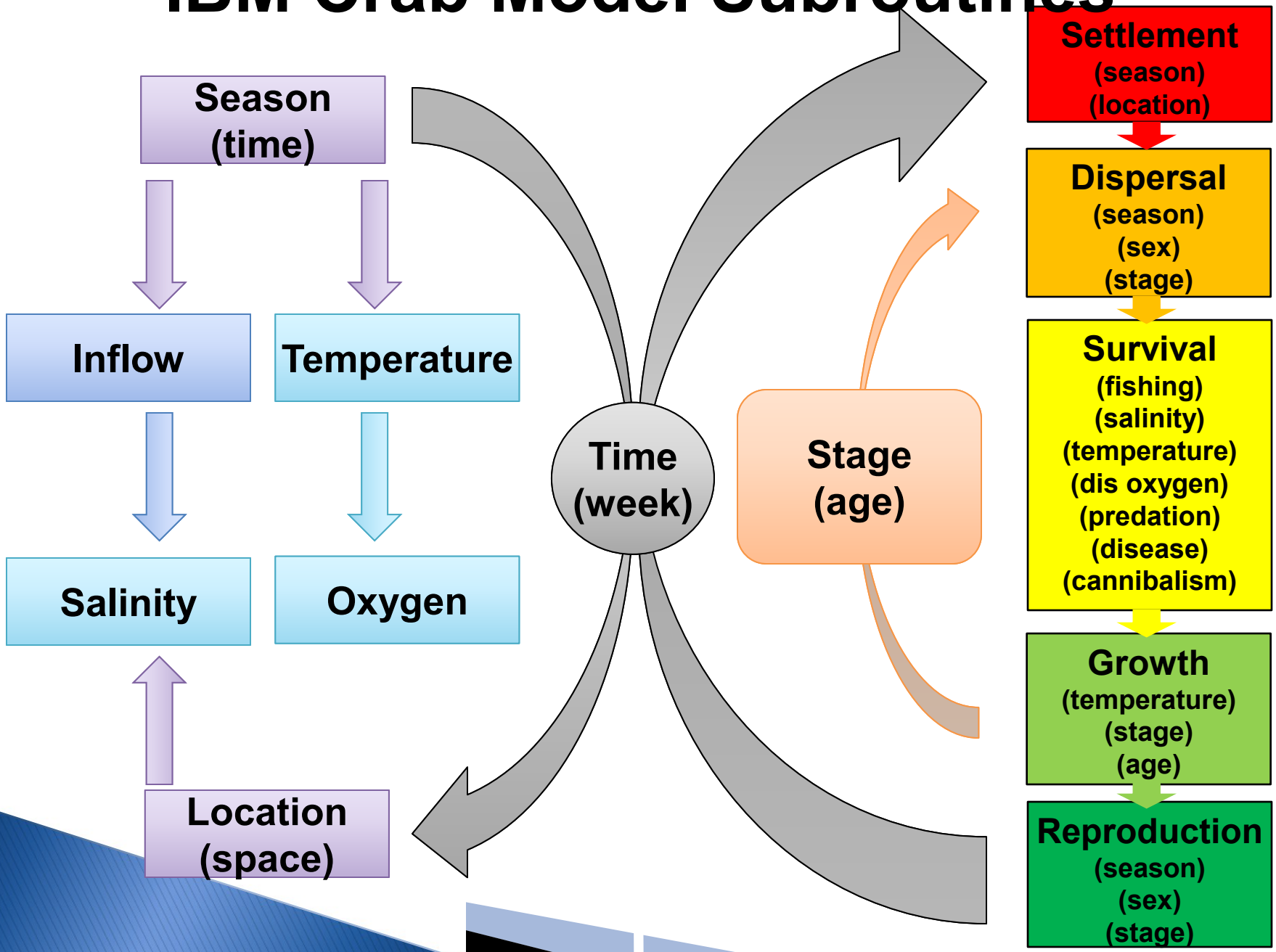
Discharge & Salinity

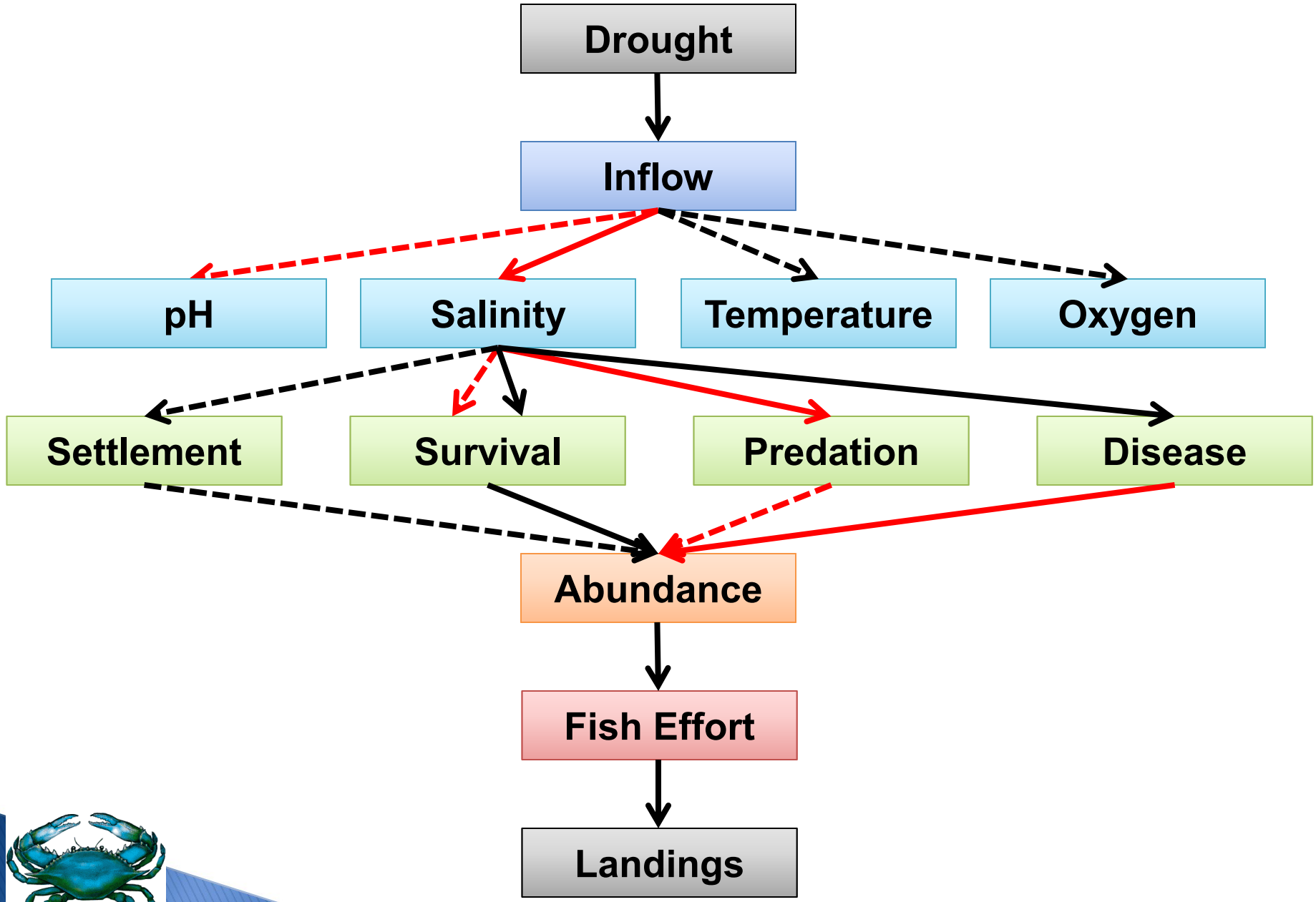
- Discharge sine curve from USGS station 02175000 – Givhans Ferry, Edisto River
- Corrected by monthly deviation from historical mean discharge
- Multiplied by logistic curve to represent spatial salinity gradient





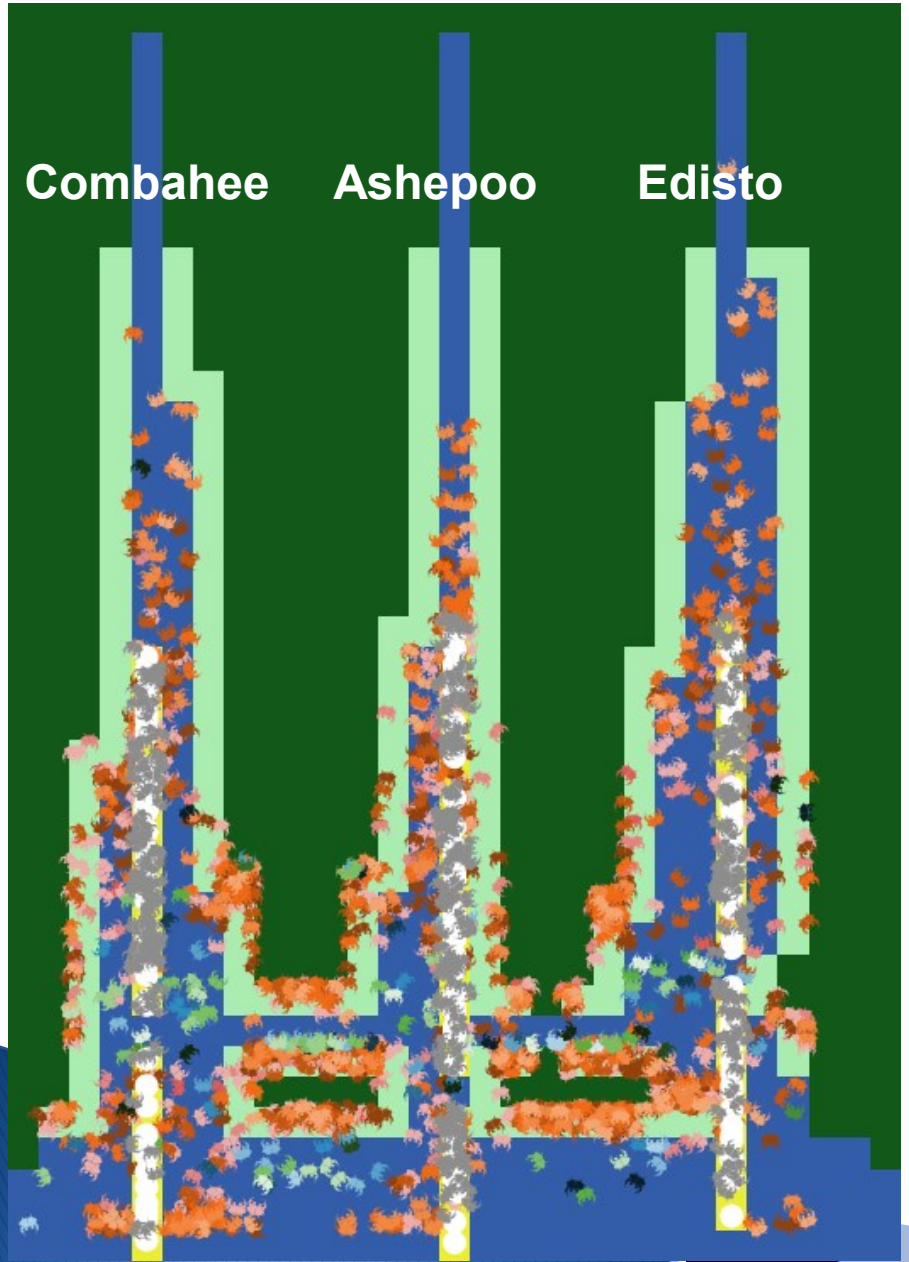
IBM Crab Model Subroutines

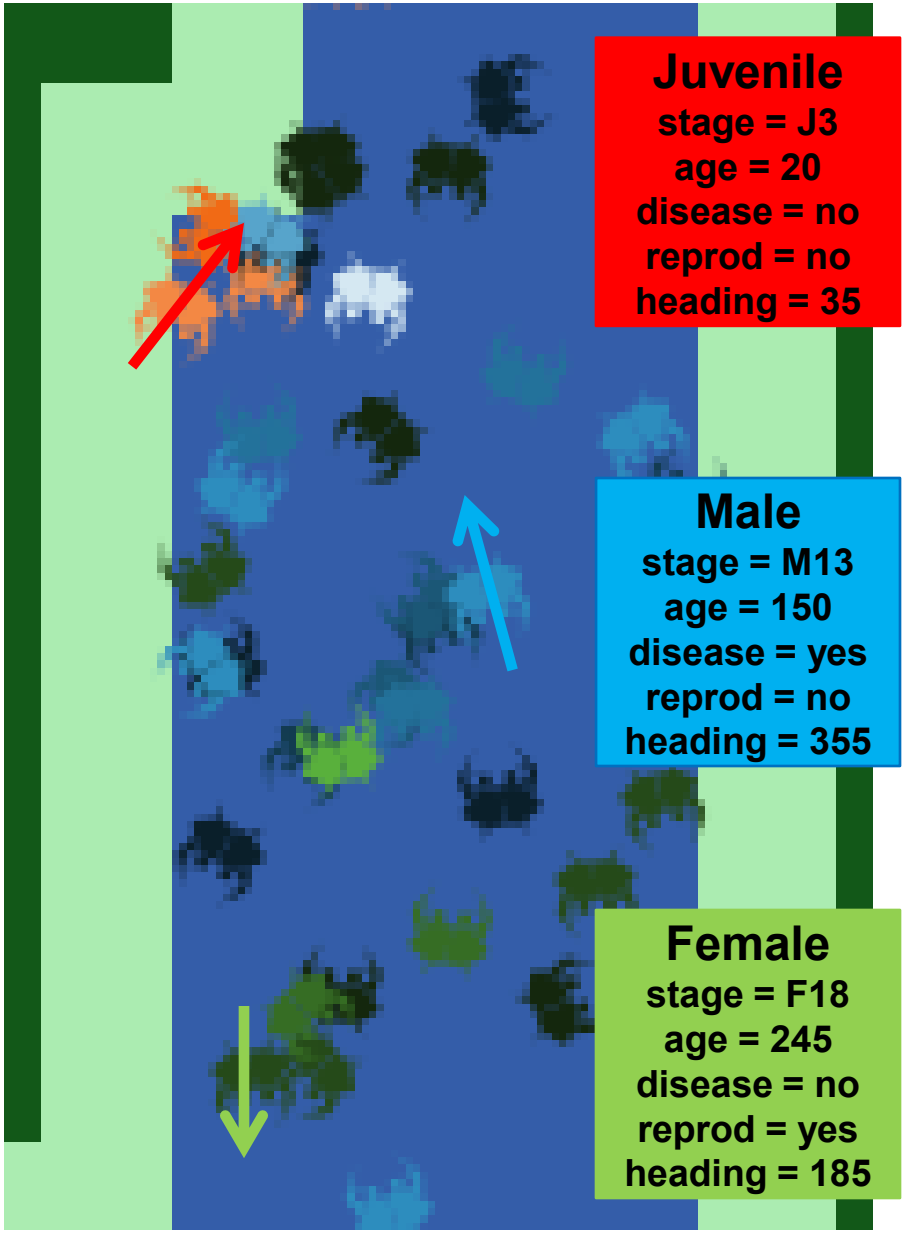




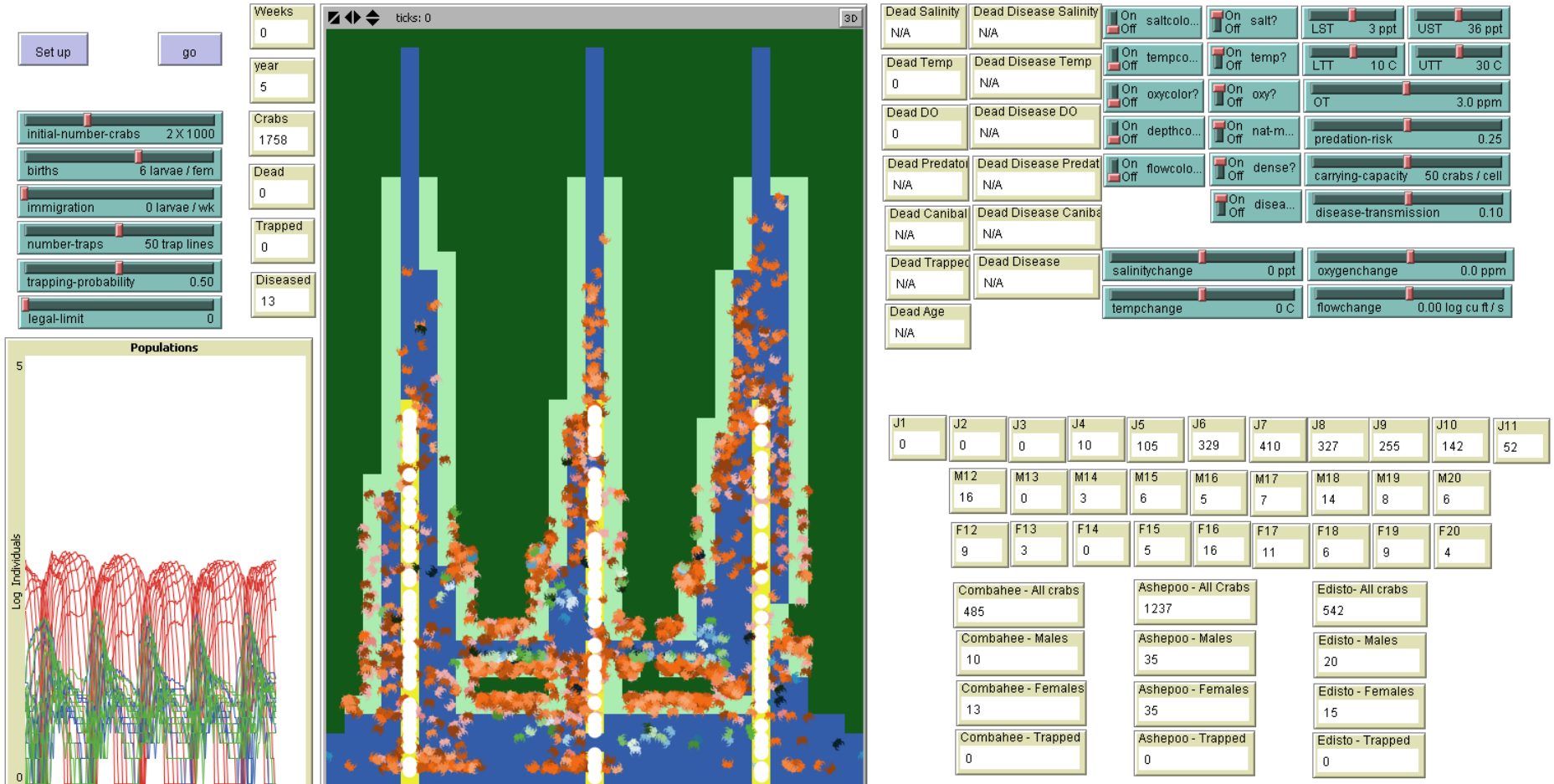
Childress & Parmenter 2012 SCWRC

IBM Crab Model Spatial Structure



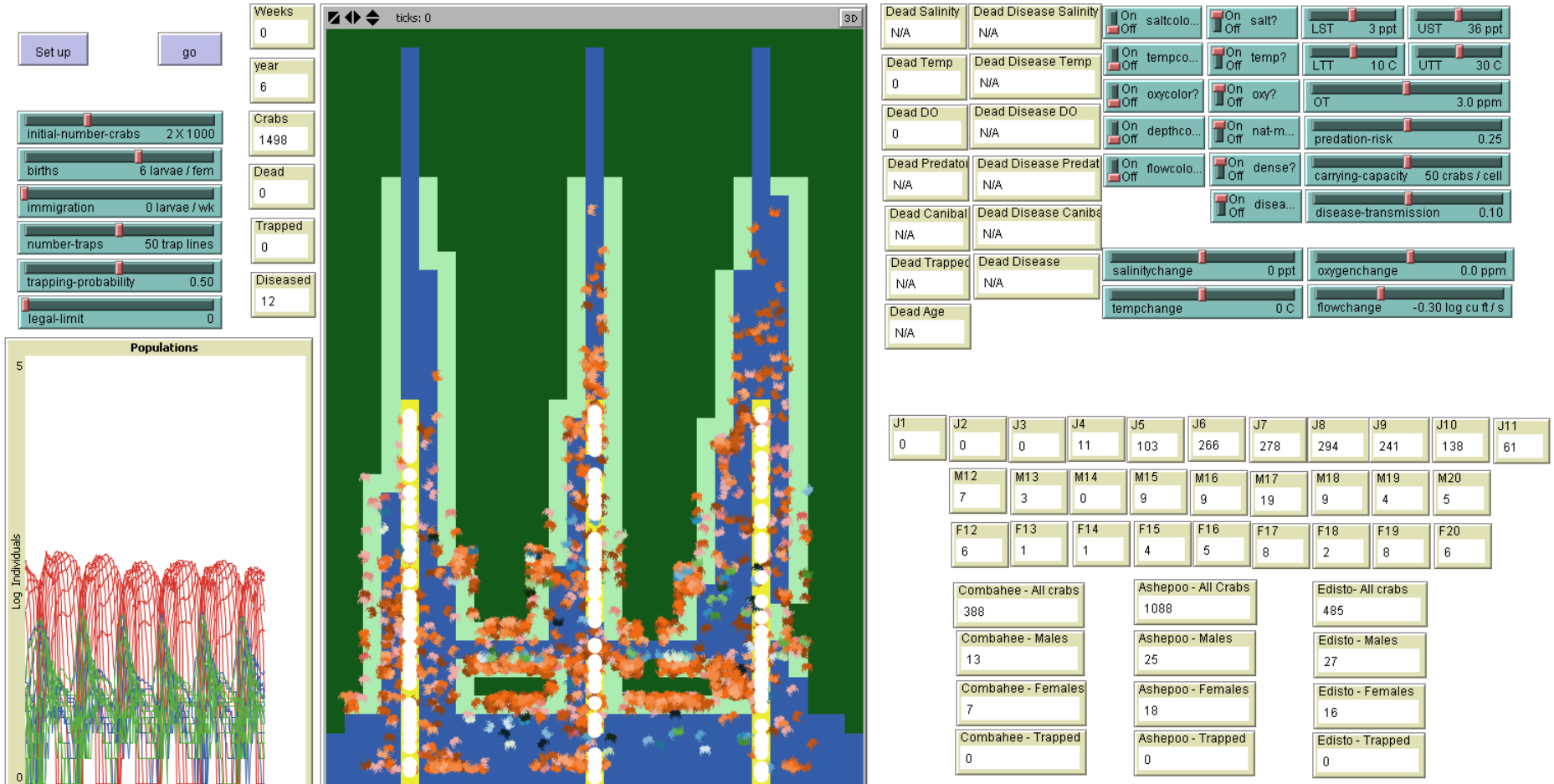


2000 - 01


Set up
go
Weeks
0
year
5
Crabs
1758
Dead
0
Trapped
0
Diseased
13
initial-number-crabs 2 X 1000
births 6 larvae / fem
immigration 0 larvae / wk
number-traps 50 trap lines
trapping-probability 0.50
legal-limit 0
Populations
Log Individuals
Time (Weeks)
ticks: 0
3D
Dead Salinity N/A
Dead Disease Salinity N/A
Dead Temp 0
Dead Disease Temp N/A
Dead DO 0
Dead Disease DO N/A
Dead Predator N/A
Dead Disease Predat N/A
Dead Canibal N/A
Dead Disease Caniba N/A
Dead Trapped N/A
Dead Disease N/A
Dead Age N/A
saltcolo...
salt?
LST 3 ppt
UST 36 ppt
tempco...
temp?
LTT 10 C
UTT 30 C
oxycolor?
oxy?
OT 3.0 ppm
depthco...
nat-m...
predation-risk 0.25
flowcolo...
dense?
carrying-capacity 50 crabs / cell
disea...
disease-transmission 0.10
salinitychange 0 ppt
oxygenchange 0.0 ppm
tempchange 0 C
flowchange 0.00 log cu ft / s
J1 0
J2 0
J3 0
J4 10
J5 105
J6 329
J7 410
J8 327
J9 255
J10 142
J11 52
M12 16
M13 0
M14 3
M15 6
M16 5
M17 7
M18 14
M19 8
M20 6
F12 9
F13 3
F14 0
F15 5
F16 16
F17 11
F18 6
F19 9
F20 4
Combahee - All crabs 485
Combahee - Males 10
Combahee - Females 13
Combahee - Trapped 0
Ashepoo - All Crabs 1237
Ashepoo - Males 35
Ashepoo - Females 35
Ashepoo - Trapped 0
Edisto- All crabs 542
Edisto - Males 20
Edisto - Females 15
Edisto - Trapped 0

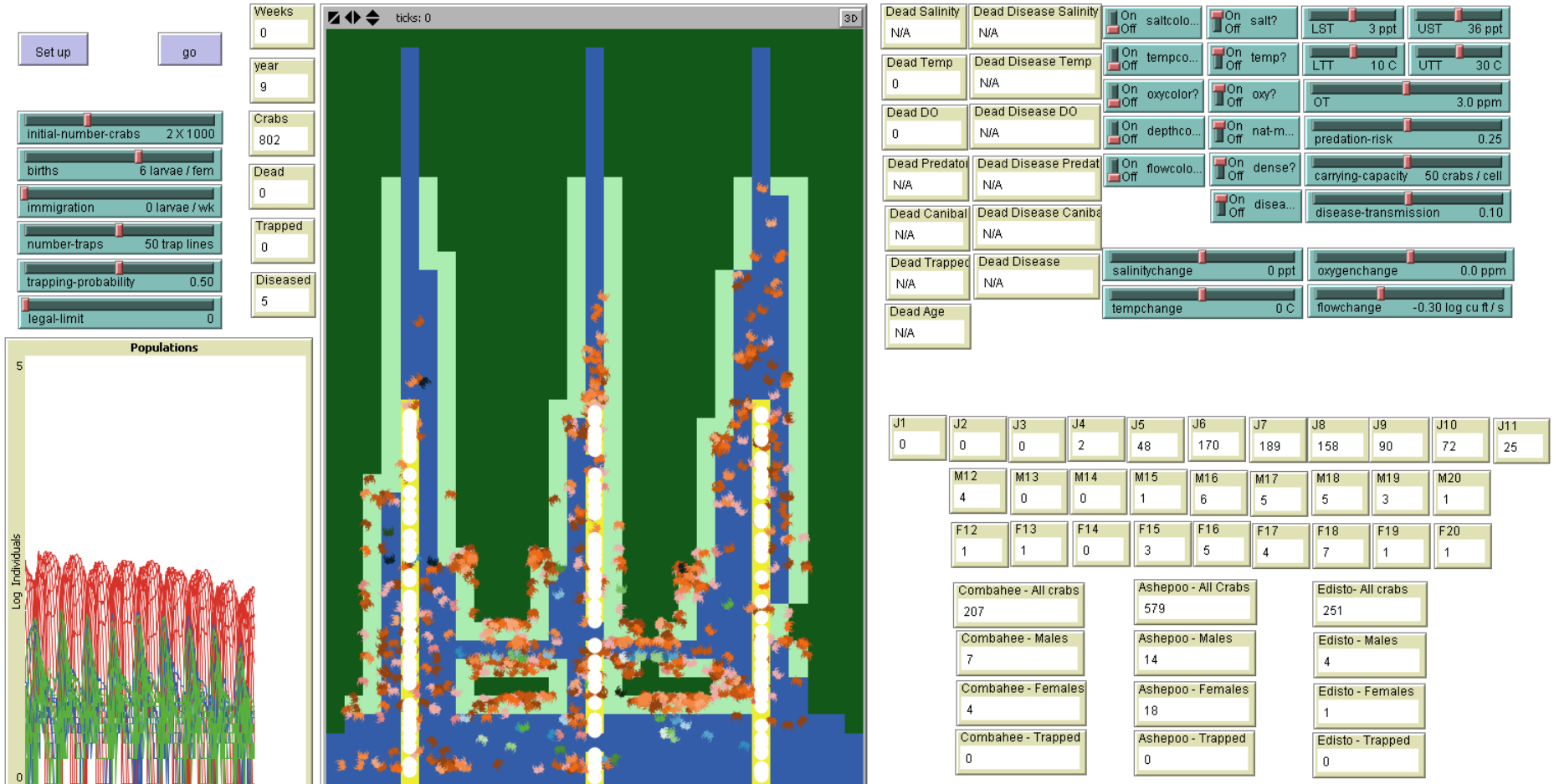
0.00

2001 - 01


Set up
go
Weeks
0
year
6
Crabs
1498
Dead
0
Trapped
0
Diseased
12
initial-number-crabs 2 X 1000
births 6 larvae / fem
immigration 0 larvae / wk
number-traps 50 trap lines
trapping-probability 0.50
legal-limit 0
Populations
Log Individuals
Time (Weeks)
0
364
5
ticks: 0
3D
Dead Salinity N/A
Dead Disease Salinity N/A
Dead Temp 0
Dead Disease Temp N/A
Dead DO 0
Dead Disease DO N/A
Dead Predator N/A
Dead Disease Predat N/A
Dead Canibal N/A
Dead Disease Caniba N/A
Dead Trapped N/A
Dead Disease N/A
Dead Age N/A
On Off saltcolo...
On Off salt?
On Off tempco...
On Off temp?
On Off oxycolor?
On Off oxy?
On Off depthco...
On Off nat-m...
On Off flowcolo...
On Off dense?
On Off disea...
LST 3 ppt
UST 36 ppt
LTT 10 C
UTT 30 C
OT 3.0 ppm
predation-risk 0.25
carrying-capacity 50 crabs / cell
disease-transmission 0.10
salinitychange 0 ppt
oxygenchange 0.0 ppm
tempchange 0 C
flowchange -0.30 log cu ft / s
J1 0
J2 0
J3 0
J4 11
J5 103
J6 266
J7 278
J8 294
J9 241
J10 138
J11 61
M12 7
M13 3
M14 0
M15 9
M16 9
M17 19
M18 9
M19 4
M20 5
F12 6
F13 1
F14 1
F15 4
F16 5
F17 8
F18 2
F19 8
F20 6
Combahee - All crabs 388
Combahee - Males 13
Combahee - Females 7
Combahee - Trapped 0
Ashepoo - All Crabs 1088
Ashepoo - Males 25
Ashepoo - Females 18
Ashepoo - Trapped 0
Edisto- All crabs 485
Edisto - Males 27
Edisto - Females 16
Edisto - Trapped 0

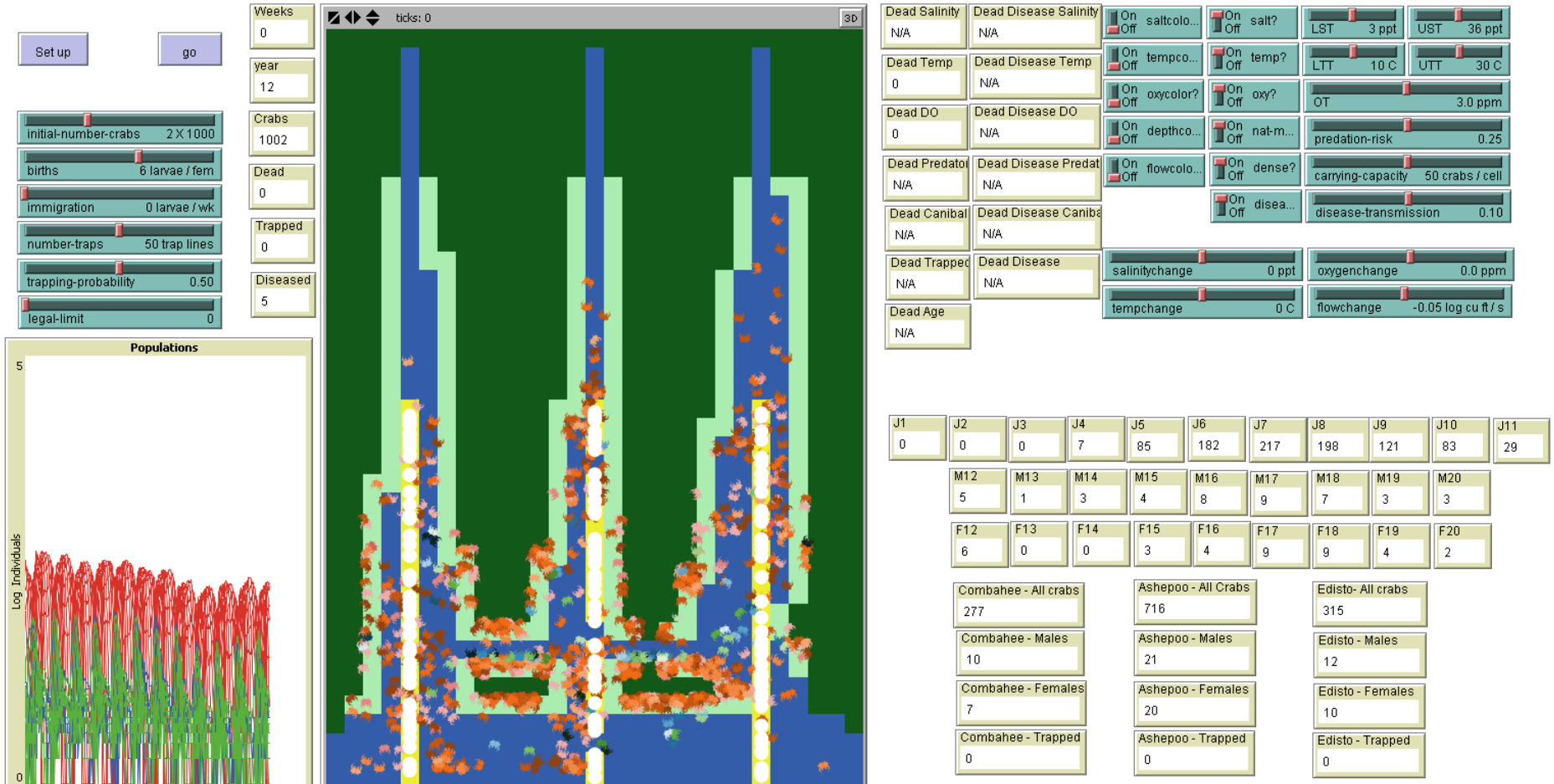
-0.30

2004 - 01


Set up
go
Weeks
0
year
9
Crabs
802
Dead
0
Trapped
0
Diseased
5
initial-number-crabs 2 X 1000
births 6 larvae / fem
immigration 0 larvae / wk
number-traps 50 trap lines
trapping-probability 0.50
legal-limit 0
Populations
Log Individuals
Time (Weeks)
0
571
ticks: 0
3D
Dead Salinity N/A
Dead Disease Salinity N/A
Dead Temp 0
Dead Disease Temp N/A
Dead DO 0
Dead Disease DO N/A
Dead Predator N/A
Dead Disease Predat N/A
Dead Canibal N/A
Dead Disease Caniba N/A
Dead Trapped N/A
Dead Disease N/A
Dead Age N/A
On Off saltcolo...
On Off salt?
On Off tempco...
On Off temp?
On Off oxycolor?
On Off oxy?
On Off depthco...
On Off nat-m...
On Off flowcolo...
On Off dense?
On Off disea...
LST 3 ppt
UST 36 ppt
LTT 10 C
UTT 30 C
OT 3.0 ppm
predation-risk 0.25
carrying-capacity 50 crabs / cell
disease-transmission 0.10
salinitychange 0 ppt
oxygenchange 0.0 ppm
tempchange 0 C
flowchange -0.30 log cu ft / s
J1 0
J2 0
J3 0
J4 2
J5 48
J6 170
J7 189
J8 158
J9 90
J10 72
J11 25
M12 4
M13 0
M14 0
M15 1
M16 6
M17 5
M18 5
M19 3
M20 1
F12 1
F13 1
F14 0
F15 3
F16 5
F17 4
F18 7
F19 1
F20 1
Combahee - All crabs 207
Combahee - Males 7
Combahee - Females 4
Combahee - Trapped 0
Ashepoo - All Crabs 579
Ashepoo - Males 14
Ashepoo - Females 18
Ashepoo - Trapped 0
Edisto- All crabs 251
Edisto - Males 4
Edisto - Females 1
Edisto - Trapped 0

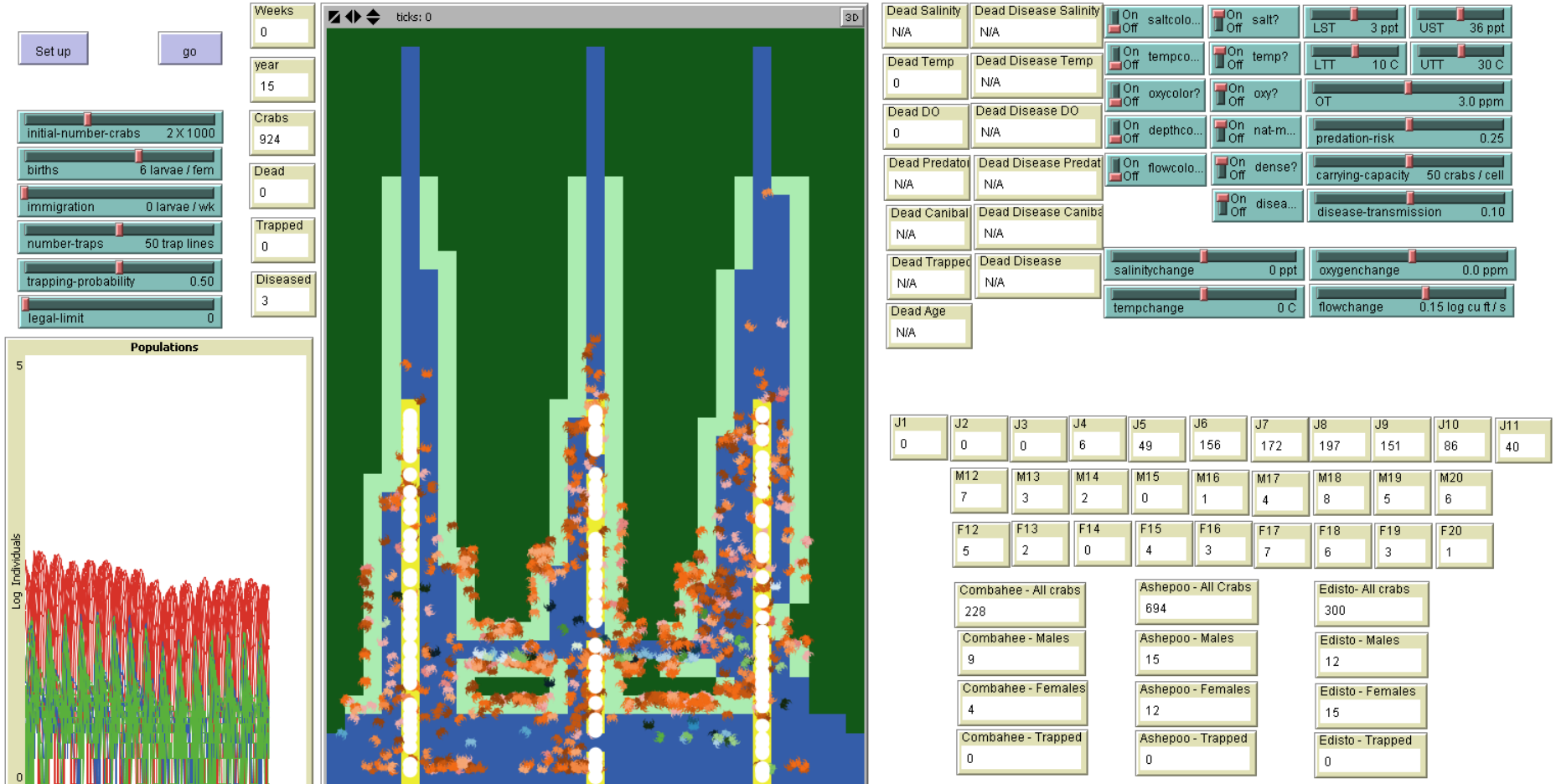
-0.30

2007 - 01


Set up
go
Weeks
0
year
12
Crabs
1002
Dead
0
Trapped
0
Diseased
5
initial-number-crabs 2 X 1000
births 6 larvae / fem
immigration 0 larvae / wk
number-traps 50 trap lines
trapping-probability 0.50
legal-limit 0
Populations
Log Individuals
Time (Weeks)
0
715
ticks: 0
3D
Dead Salinity N/A
Dead Disease Salinity N/A
Dead Temp 0
Dead Disease Temp N/A
Dead DO 0
Dead Disease DO N/A
Dead Predator N/A
Dead Disease Predat N/A
Dead Canibal N/A
Dead Disease Caniba N/A
Dead Trapped N/A
Dead Disease N/A
Dead Age N/A
On Off saltcolo...
On Off salt?
On Off tempco...
On Off temp?
On Off oxycolor?
On Off oxy?
On Off depthco...
On Off nat-m...
On Off flowcolo...
On Off dense?
On Off disea...
LST 3 ppt
UST 36 ppt
LTT 10 C
UTT 30 C
OT 3.0 ppm
predation-risk 0.25
carrying-capacity 50 crabs / cell
disease-transmission 0.10
salinitychange 0 ppt
oxygenchange 0.0 ppm
tempchange 0 C
flowchange -0.05 log cu ft / s
J1 0
J2 0
J3 0
J4 7
J5 85
J6 182
J7 217
J8 198
J9 121
J10 83
J11 29
M12 5
M13 1
M14 3
M15 4
M16 8
M17 9
M18 7
M19 3
M20 3
F12 6
F13 0
F14 0
F15 3
F16 4
F17 9
F18 9
F19 4
F20 2
Combahee - All crabs 277
Combahee - Males 10
Combahee - Females 7
Combahee - Trapped 0
Ashepoo - All Crabs 716
Ashepoo - Males 21
Ashepoo - Females 20
Ashepoo - Trapped 0
Edisto- All crabs 315
Edisto - Males 12
Edisto - Females 10
Edisto - Trapped 0

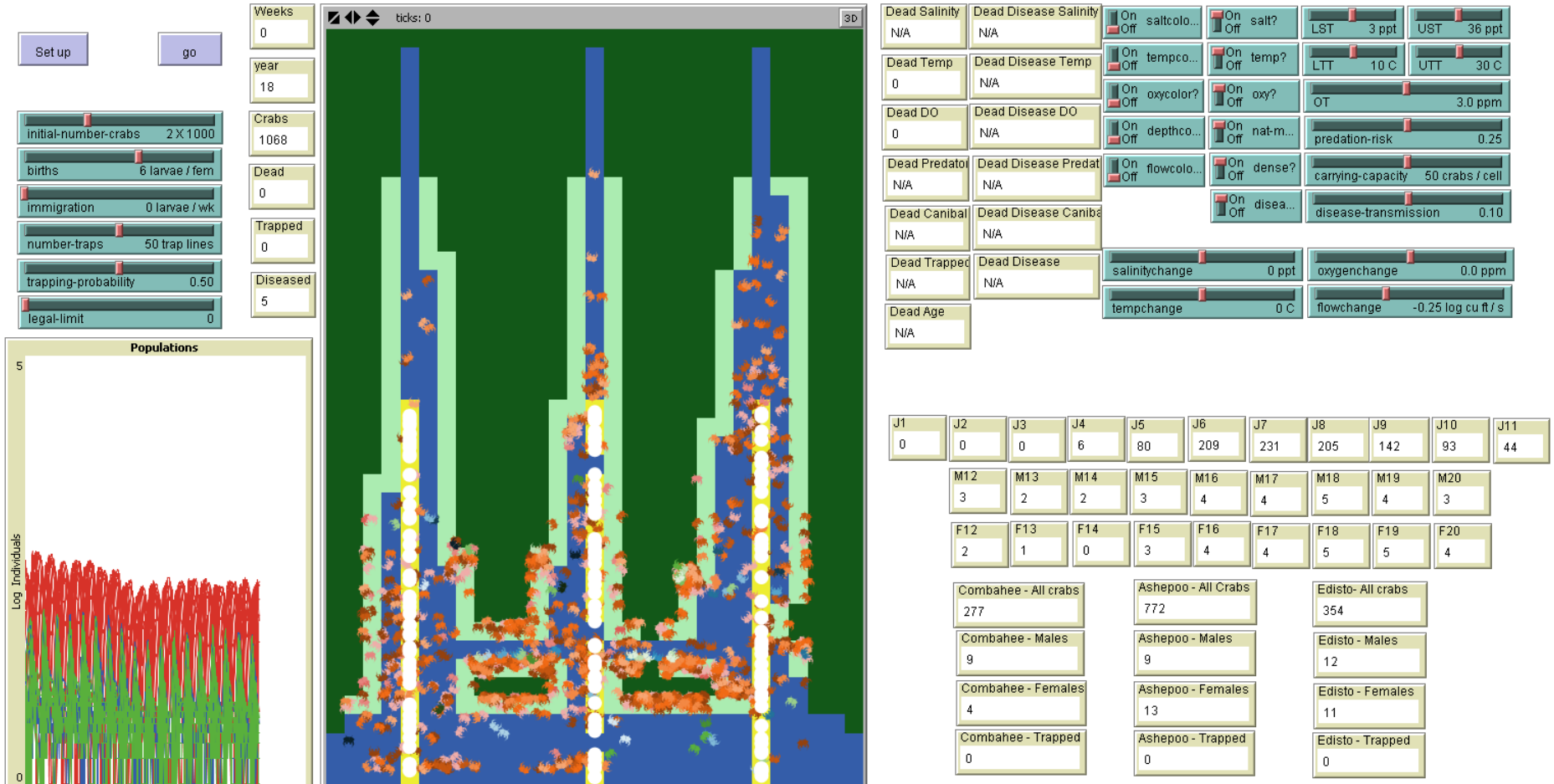
-0.05

2010 - 01


Set up
go
Weeks
0
year
15
Crabs
924
Dead
0
Trapped
0
Diseased
3
initial-number-crabs 2 X 1000
births 6 larvae / fem
immigration 0 larvae / wk
number-traps 50 trap lines
trapping-probability 0.50
legal-limit 0
Populations
Log Individuals
Time (Weeks)
0
895
ticks: 0
3D
Dead Salinity N/A
Dead Disease Salinity N/A
Dead Temp 0
Dead Disease Temp N/A
Dead DO 0
Dead Disease DO N/A
Dead Predator N/A
Dead Disease Predat N/A
Dead Canibal N/A
Dead Disease Caniba N/A
Dead Trapped N/A
Dead Disease N/A
Dead Age N/A
saltcolo...
salt?
LST 3 ppt
UST 36 ppt
tempco...
temp?
LTT 10 C
UTT 30 C
oxycolor?
oxy?
OT 3.0 ppm
depthco...
nat-m...
predation-risk 0.25
flowcolo...
dense?
carrying-capacity 50 crabs / cell
disea...
disease-transmission 0.10
salinitychange 0 ppt
oxygenchange 0.0 ppm
tempchange 0 C
flowchange 0.15 log cu ft / s
J1 0
J2 0
J3 0
J4 6
J5 49
J6 156
J7 172
J8 197
J9 151
J10 86
J11 40
M12 7
M13 3
M14 2
M15 0
M16 1
M17 4
M18 8
M19 5
M20 6
F12 5
F13 2
F14 0
F15 4
F16 3
F17 7
F18 6
F19 3
F20 1
Combahee - All crabs 228
Combahee - Males 9
Combahee - Females 4
Combahee - Trapped 0
Ashepoo - All Crabs 694
Ashepoo - Males 15
Ashepoo - Females 12
Ashepoo - Trapped 0
Edisto- All crabs 300
Edisto - Males 12
Edisto - Females 15
Edisto - Trapped 0

0.15

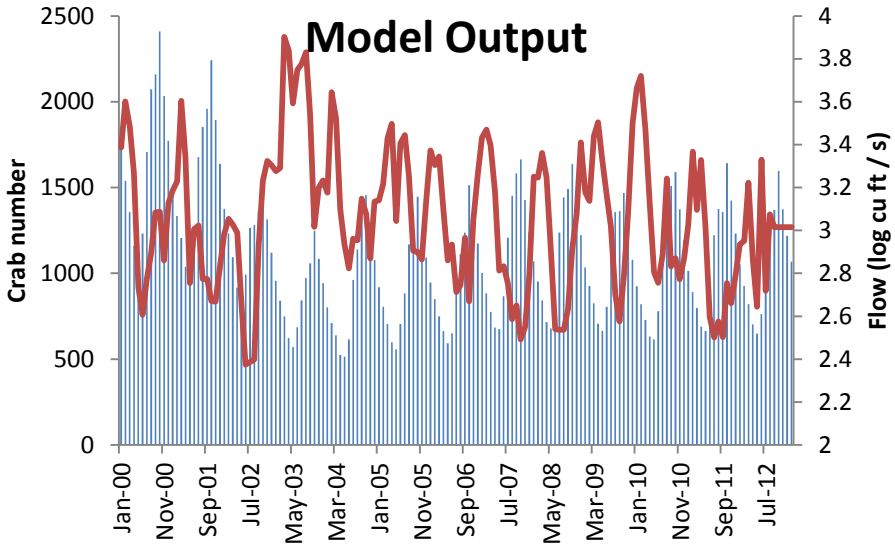
2013 - 01

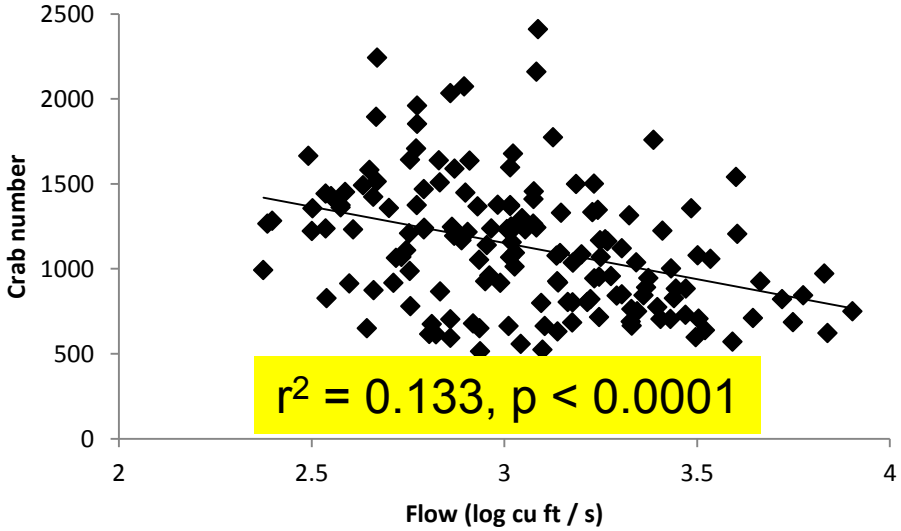

Set up
go
Weeks
0
year
18
Crabs
1068
Dead
0
Trapped
0
Diseased
5
initial-number-crabs 2 X 1000
births 6 larvae / fem
immigration 0 larvae / wk
number-traps 50 trap lines
trapping-probability 0.50
legal-limit 0
Populations
Log Individuals
Time (Weeks)
0
1120
5
ticks: 0
3D
Dead Salinity N/A
Dead Disease Salinity N/A
Dead Temp 0
Dead Disease Temp N/A
Dead DO 0
Dead Disease DO N/A
Dead Predator N/A
Dead Disease Predat N/A
Dead Canibal N/A
Dead Disease Caniba N/A
Dead Trapped N/A
Dead Disease N/A
Dead Age N/A
On Off saltcolo...
On Off tempco...
On Off oxycolor?
On Off depthco...
On Off flowcolo...
On Off salt?
On Off temp?
On Off oxy?
On Off nat-m...
On Off dense?
On Off disea...
LST 3 ppt
UST 36 ppt
LTT 10 C
UTT 30 C
OT 3.0 ppm
predation-risk 0.25
carrying-capacity 50 crabs / cell
disease-transmission 0.10
salinitychange 0 ppt
oxygenchange 0.0 ppm
tempchange 0 C
flowchange -0.25 log cu ft / s
J1 0
J2 0
J3 0
J4 6
J5 80
J6 209
J7 231
J8 205
J9 142
J10 93
J11 44
M12 3
M13 2
M14 2
M15 3
M16 4
M17 4
M18 5
M19 4
M20 3
F12 2
F13 1
F14 0
F15 3
F16 4
F17 4
F18 5
F19 5
F20 4
Combahee - All crabs 277
Combahee - Males 9
Combahee - Females 4
Combahee - Trapped 0
Ashepoo - All Crabs 772
Ashepoo - Males 9
Ashepoo - Females 13
Ashepoo - Trapped 0
Edisto- All crabs 354
Edisto - Males 12
Edisto - Females 11
Edisto - Trapped 0

-0.25

Model Density vs. Model Flow

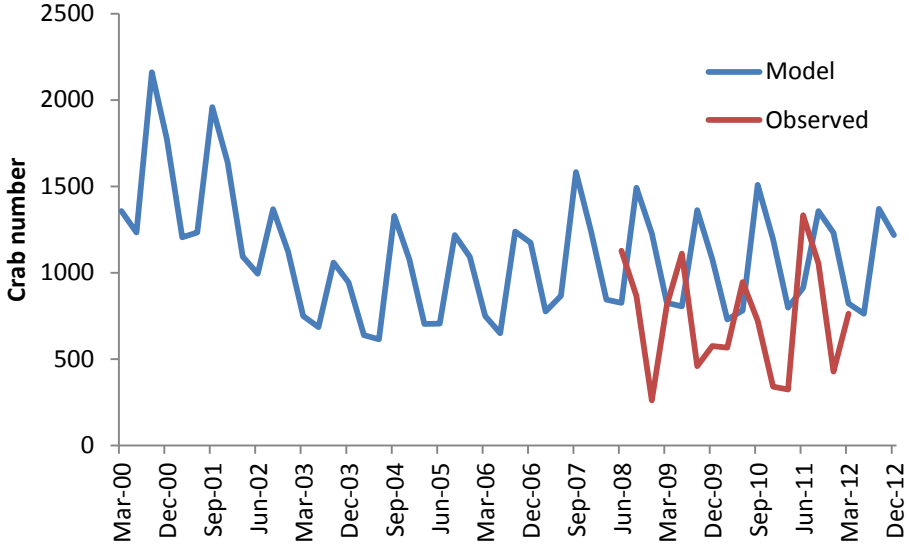
- Model captures the drought of ’99 –’02
- Model population declines during drought
- Model population high during summer when flow is low
- Negative correlation between crab number and flow

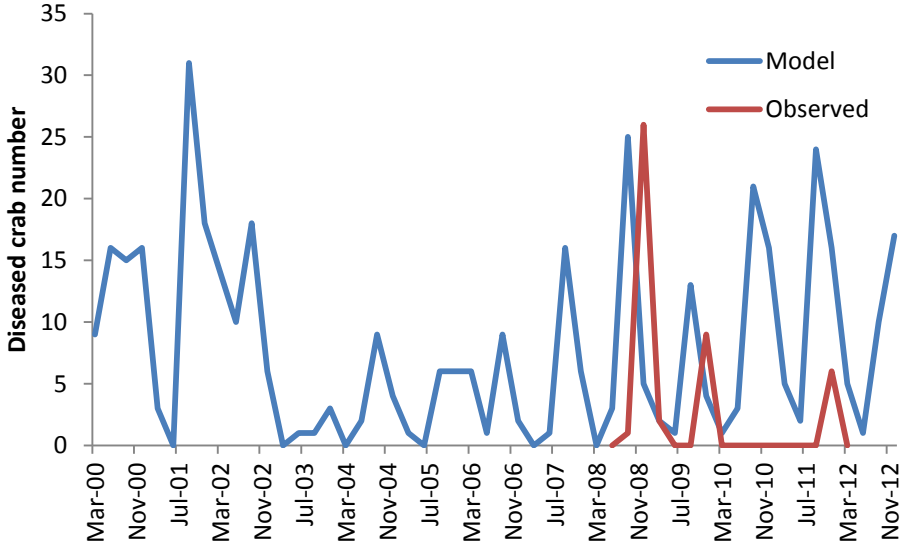




Model Density vs. ACE Density

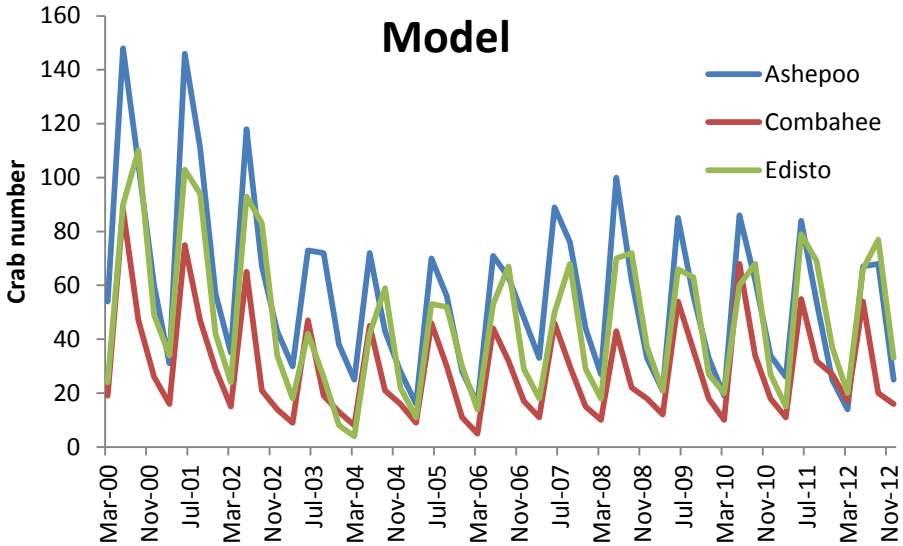
- Model population show consistent seasonal cycle more than ACE population
- Model disease show similar peaks as observed peaks in the ACE population

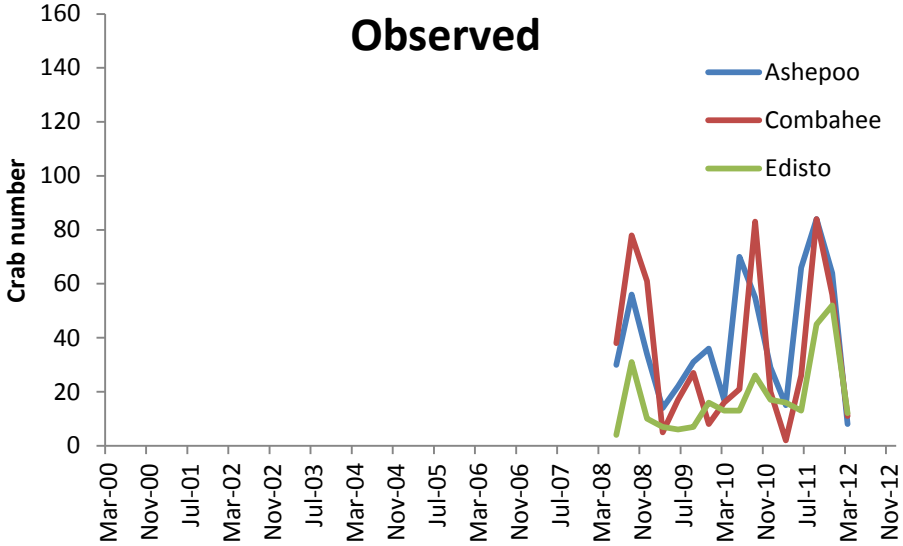




Model Density vs. ACE Density

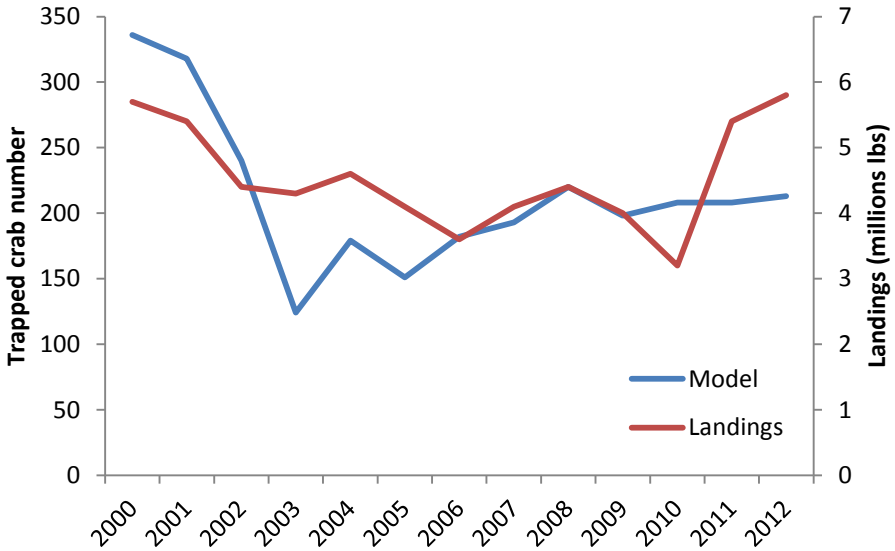
- Model predicts crab densities Ash > Eds > Com
- ACE observations crab densities Ash > Com > Eds

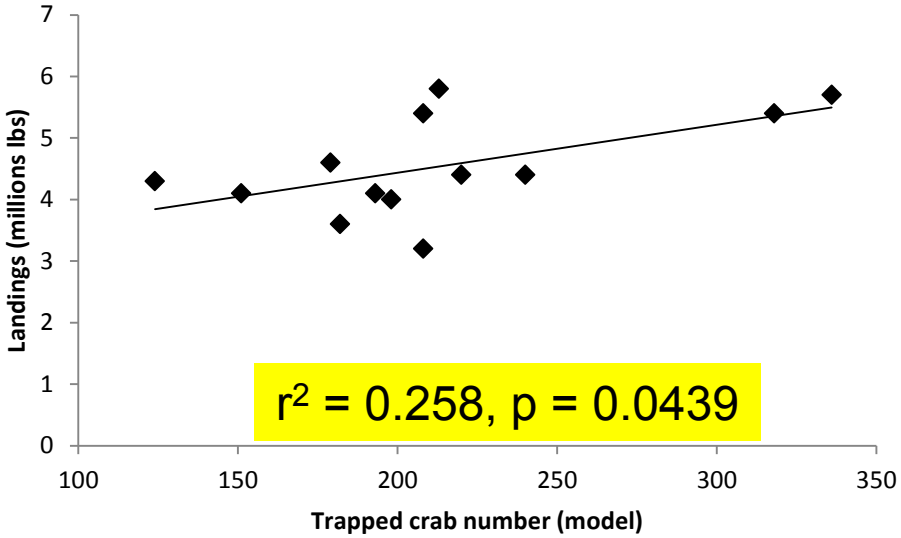


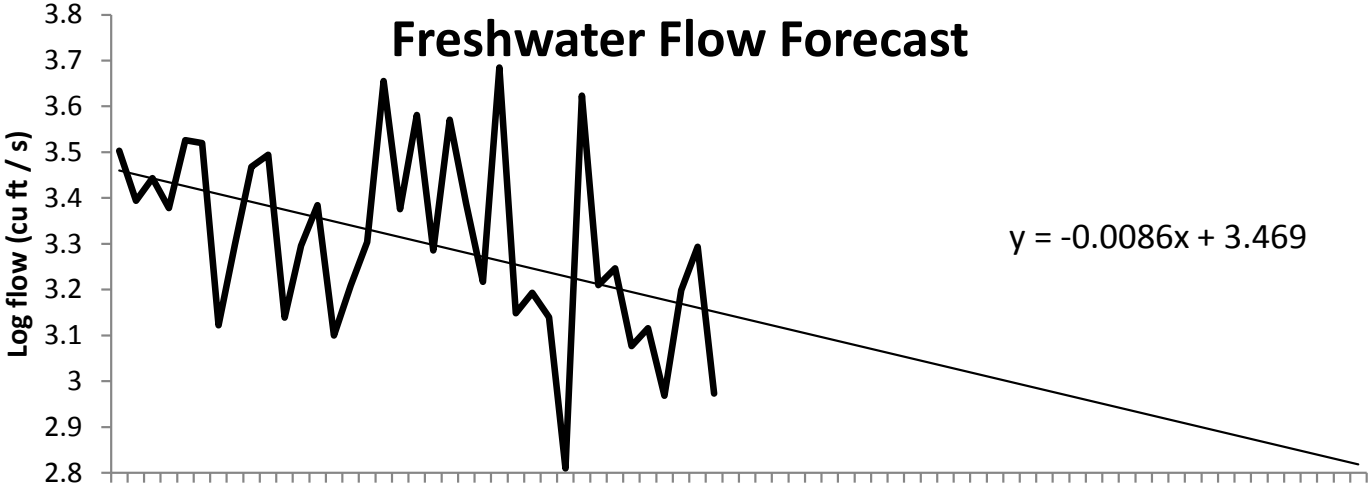


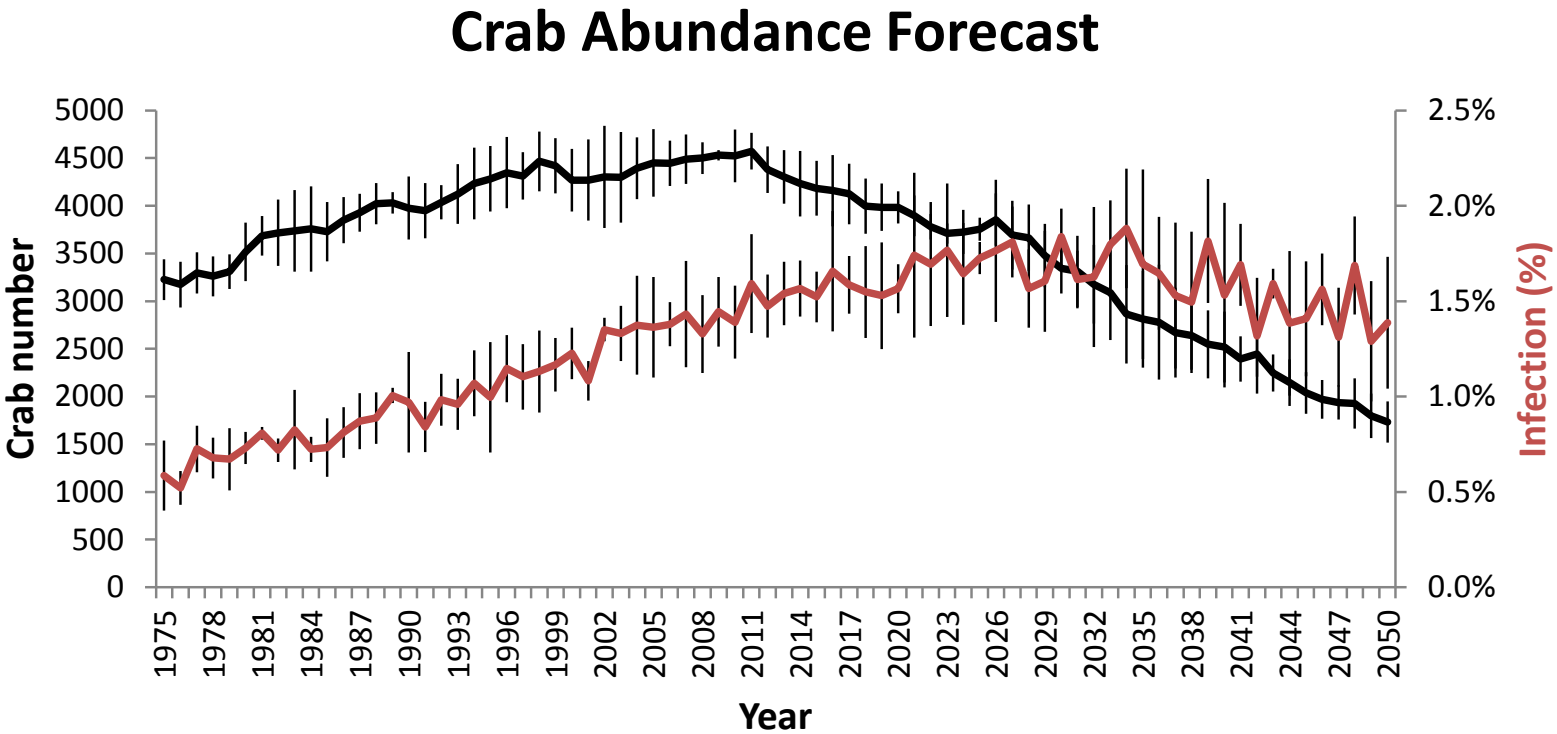
Model Landings vs. SC Landings

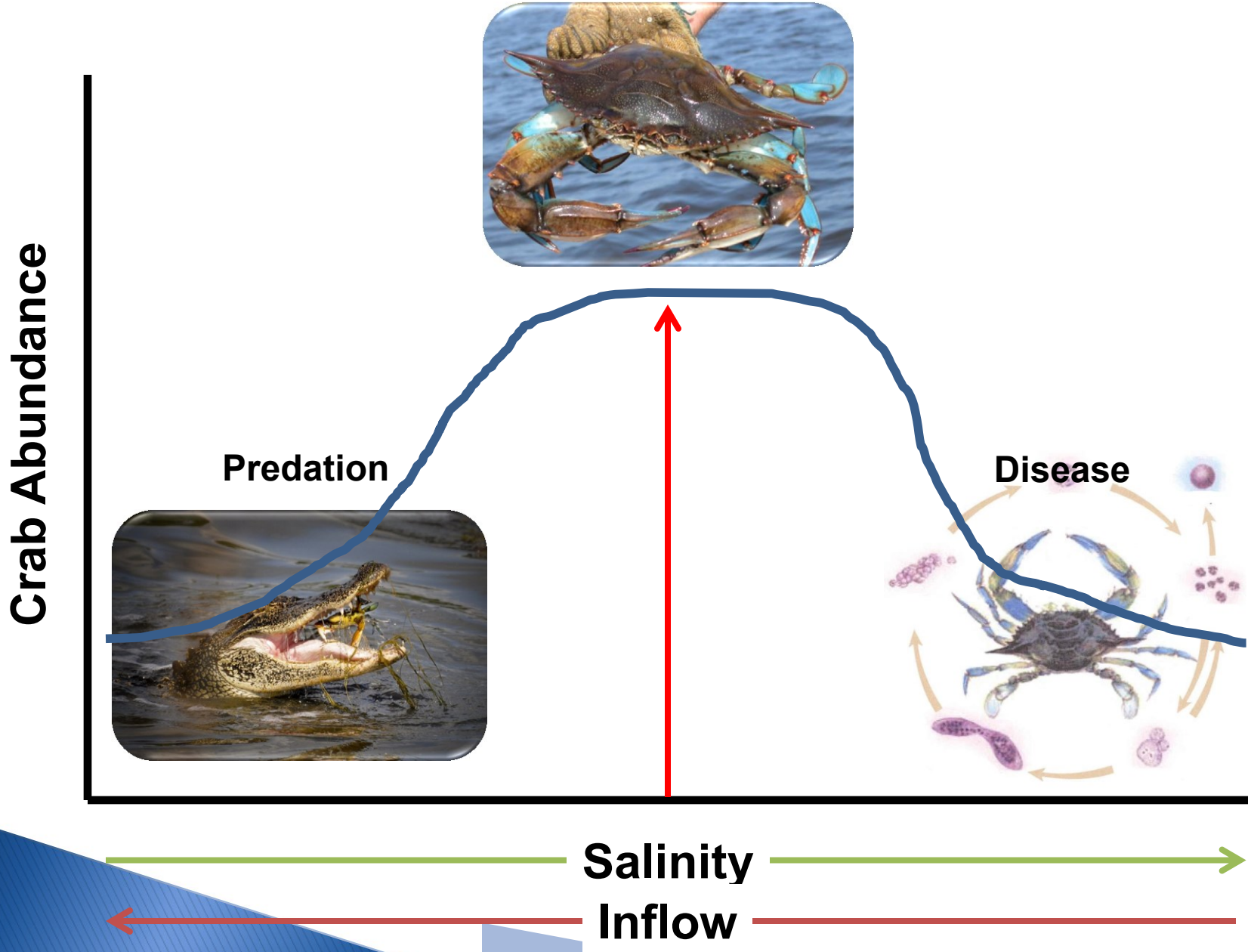
- Model forecasts steep decline during ’99 – ’02 drought
- Model fails to forecast increased landings ’10 –’12
- Model predicts 25.8% of observed landing variation
- This is twice the predictive power of using river discharge alone






Freshwater Flow Forecast
Log flow (cu ft / s)
3.8
3.7
3.6
3.5
3.4
3.3
3.2
3.1
3
2.9
2.8
y = -0.0086x + 3.469


Crab Abundance Forecast
Crab number
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
Infection (%)
2.5%
2.0%
1.5%
1.0%
0.5%
0.0%
1975
1978
1981
1984
1987
1990
1993
1996
1999
2002
2005
2008
2011
2014
2017
2020
2023
2026
2029
2032
2035
2038
2041
2044
2047
2050
Year


Crab Abundance
Predation
Disease
Salinity
Inflow

Conclusions

- Crab landings is positively correlated with river discharge
- River discharge is negatively correlated with marsh salinity
- Salinity has both positive & negative effects on crabs
- Low salinity decreases survival & increases predation
- High salinity decreases survival & increases disease

Conclusions

- Model predicts ACE crab density
  - Seasonal (n = 16) 5.7% of variation (p = 0.3744)
  - Annual (n = 4) 51.7% of variation (p = 0.1767)
- Model predicts ACE crab disease
  - Seasonal (n = 16) 1.6% of variation (p = 0.6379)
  - Annual (n = 4) 25.9% of variation (p = 0.2885)
- Model predicts ACE crab landings
  - Seasonal (n = 16) **41.3% of variation (p = 0.0073)**
  - Annual (n = 4) 12.3% of variation (p = 0.6494)
- Model predicts SC crab landings
  - Annual (n = 13) **25.8% of variation (p = 0.0439)**

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  - Anna Gurley
  - Jennifer Micklewright
  - Kaighn Morlok
  - Tim Jordan
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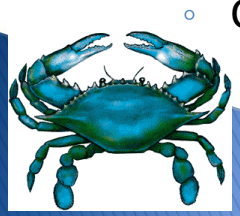
  - Patrick Vigueira
  - Pete Bouwma
  - Conservation of Marine Resources Team



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