Introduction to Electric Dispersal Barriers

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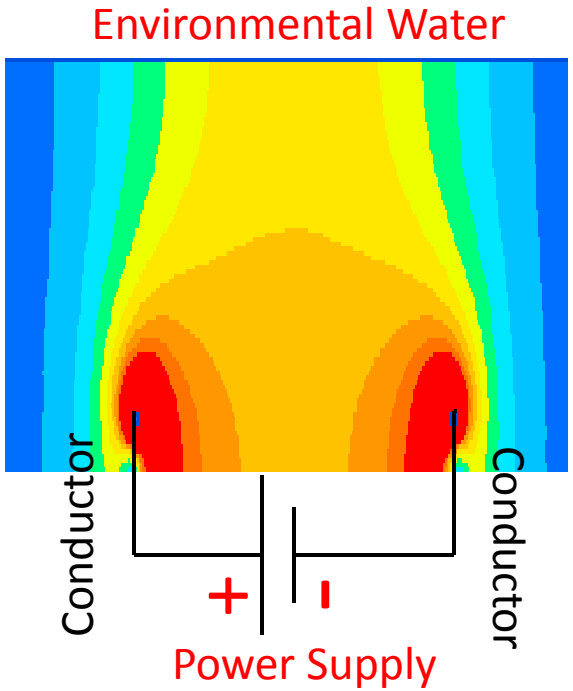
Introduction to Electric Dispersal Barriers

- What are they?
- Conceptual Model
- How do they work?
- Size Selection
- Environmental Factors Influencing Risk for Fish Passage
  - Water Depth
  - Water Velocity
  - Water Conductivity
  - Water Temperature

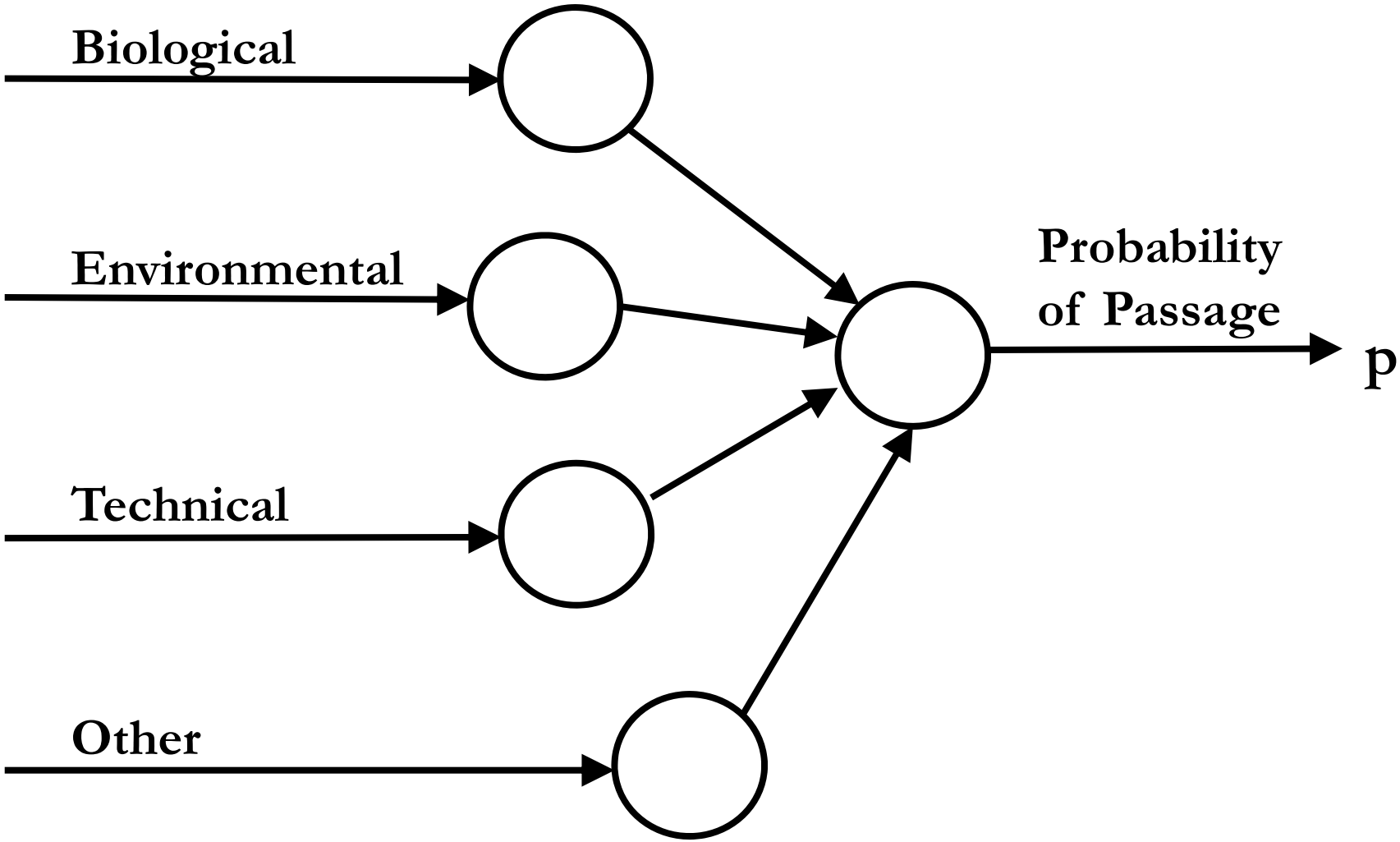
Electric Dispersal Barrier

Waterborne electric field used to guide movement or deter passage of fish.



Moy et al. 2011

EDB Risk Model



Electric Dispersal Barriers

Technical Factors	Biological Factors	Environmental Factors
Electrode Orientation	Fish Size	Water Depth
Field Temporal Properties Current Characteristics Time Characteristics	Fish Species	Water Velocity
Field Spatial Properties Maximum Field Strength Field Strength Distribution	Swimming Speed	Water Conductivity
	Behavior Ecological Motivation	Water Temperature

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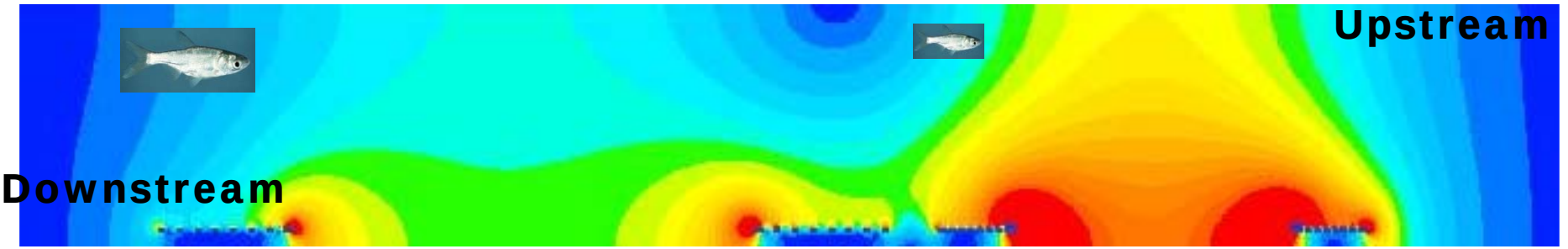
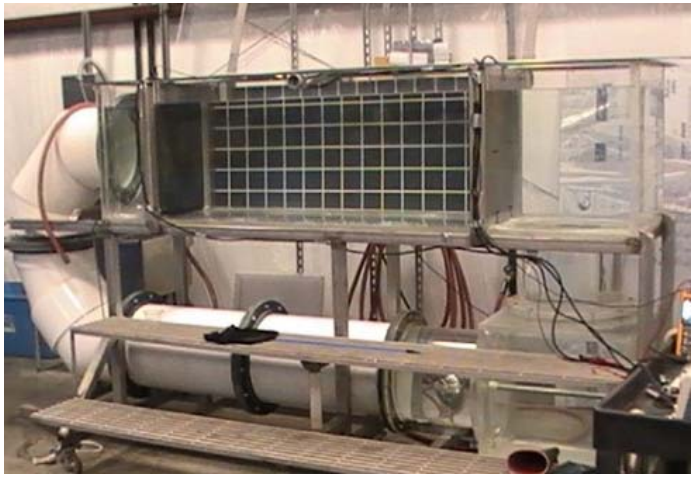
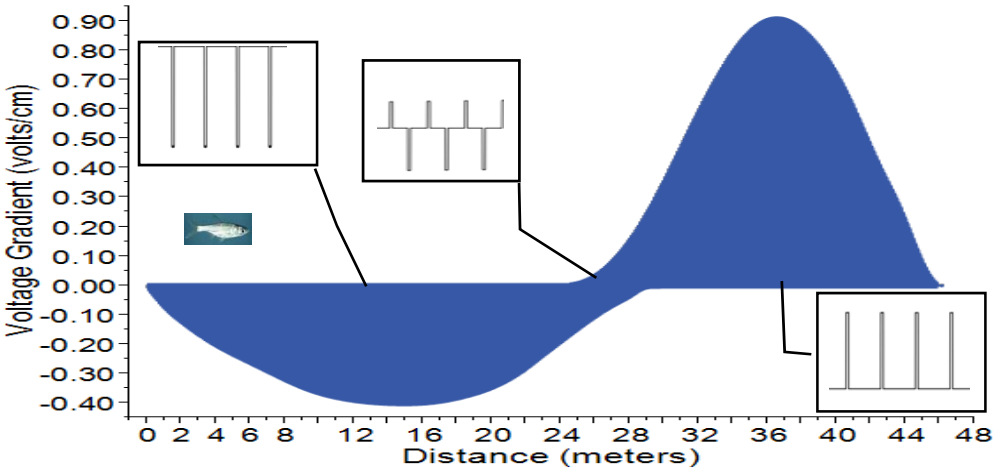
Modeling and Simulation
Scaled Model Approach

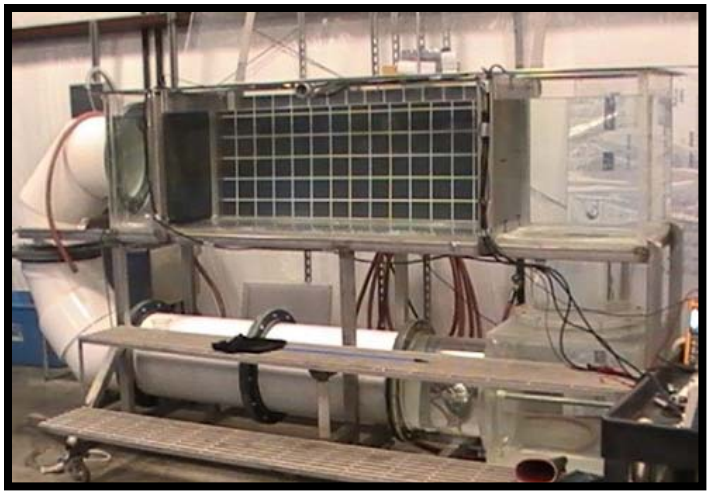


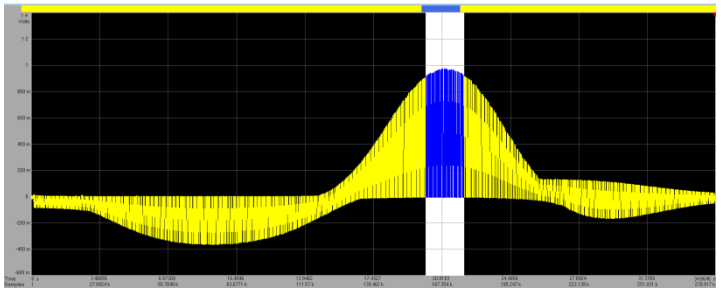




Modeling and Simulation

- Modeling and Simulation
  - Scaled Model
  - Physical Model
  - Based on field data or model data
  - Cheaper
  - Safer
  - Faster
  - Flexible





Electric Dispersal Barriers

Theory

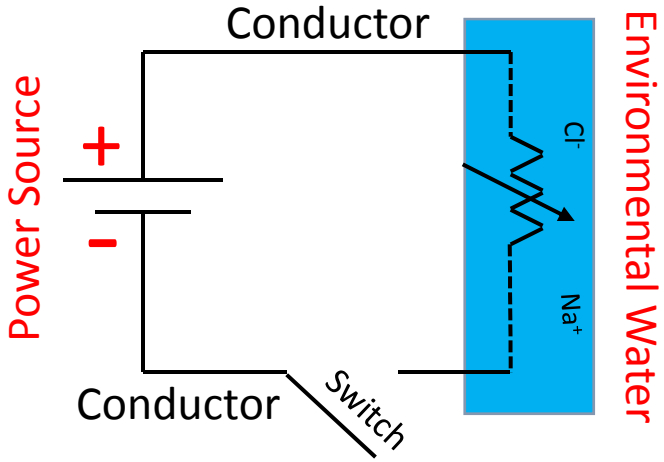
- Behavioral Barrier.
- Electric field of increasing intensity.
- Gradually introduced to increasingly unpleasant sensation.
- Fish can penetrate as far as they are able.
  - Large fish stop at an early stage.
  - Small fish intrude further.
- Biological/Physiological Barrier.

Electric Dispersal Barrier

- Wide range of sizes & complexity
  - Irrigation ditch
  - Chicago Sanitary Ship Canal
- Three primary components
  - Physical structures
  - Electrode system
  - Power supply

Moy et al. 2011

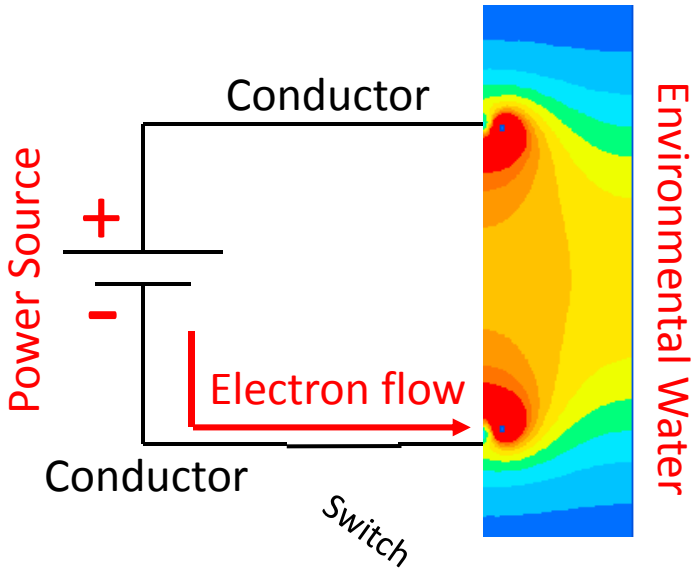
Waterborne Electric Field

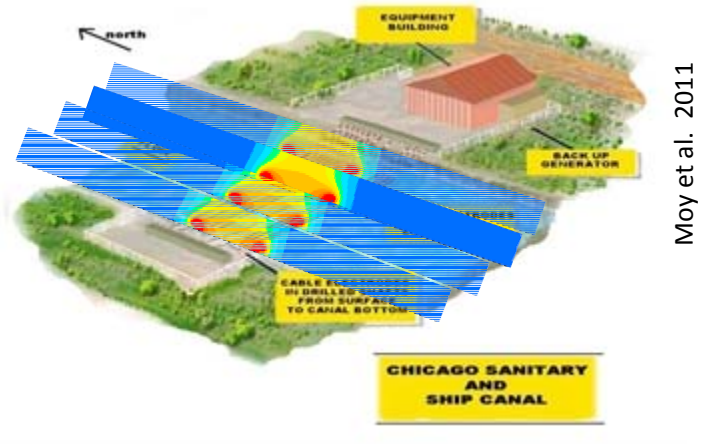


Moy et al. 2011

- Ions are the charge carriers.
- The concentration of ions in the water and water temperature determines the resistance for the circuit.
- Water conductivity
  - Specific conductivity – temperature effects removed (usu. ref. to 25^{o} C).
  - Ambient conductivity – similar to electrical conductivity.

Waterborne Electric Field





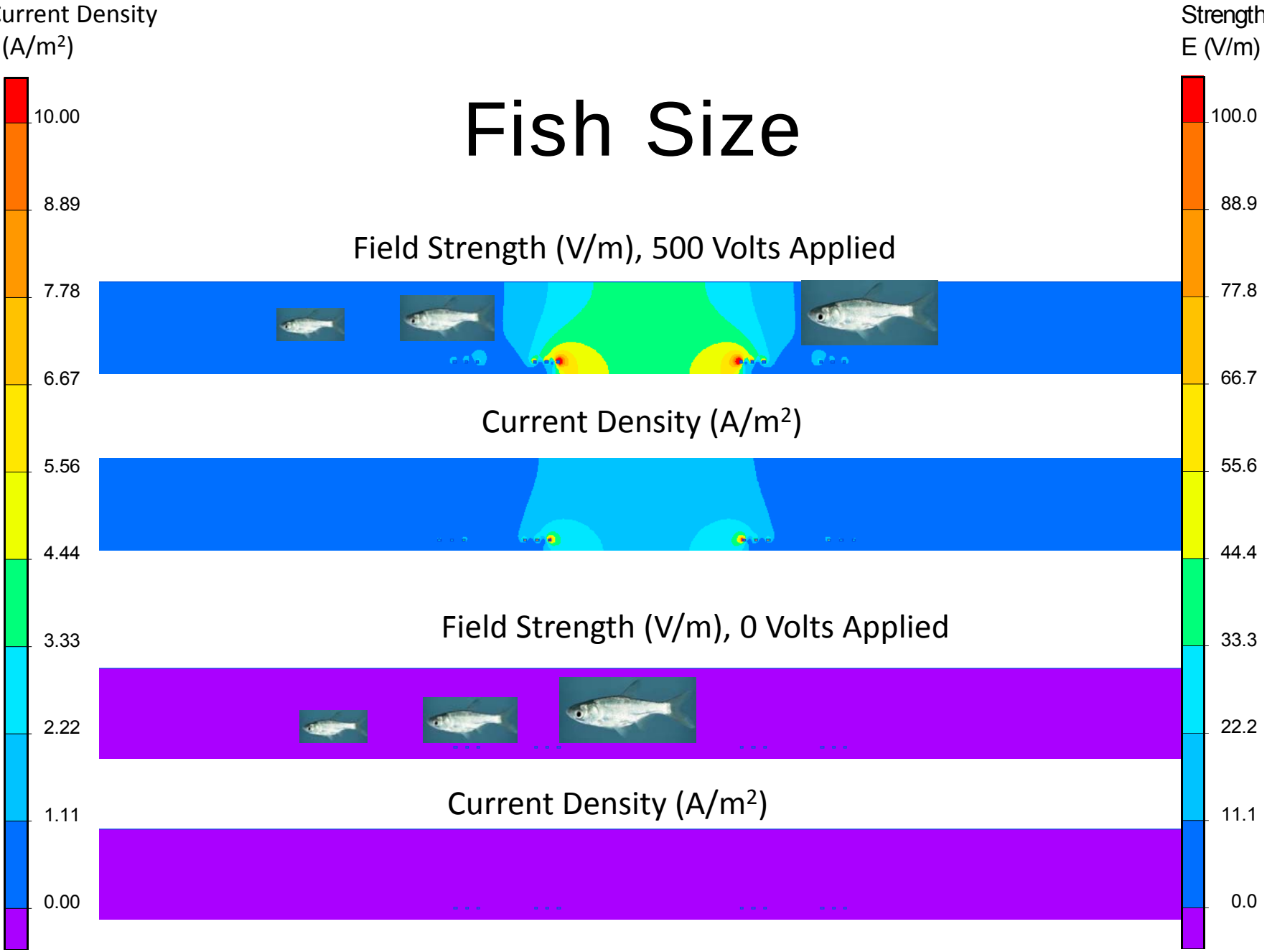
Moy et al. 2011

Electrical potential applied to submersed electrodes causes electric current to flow through environmental water creating a waterborne electric field.

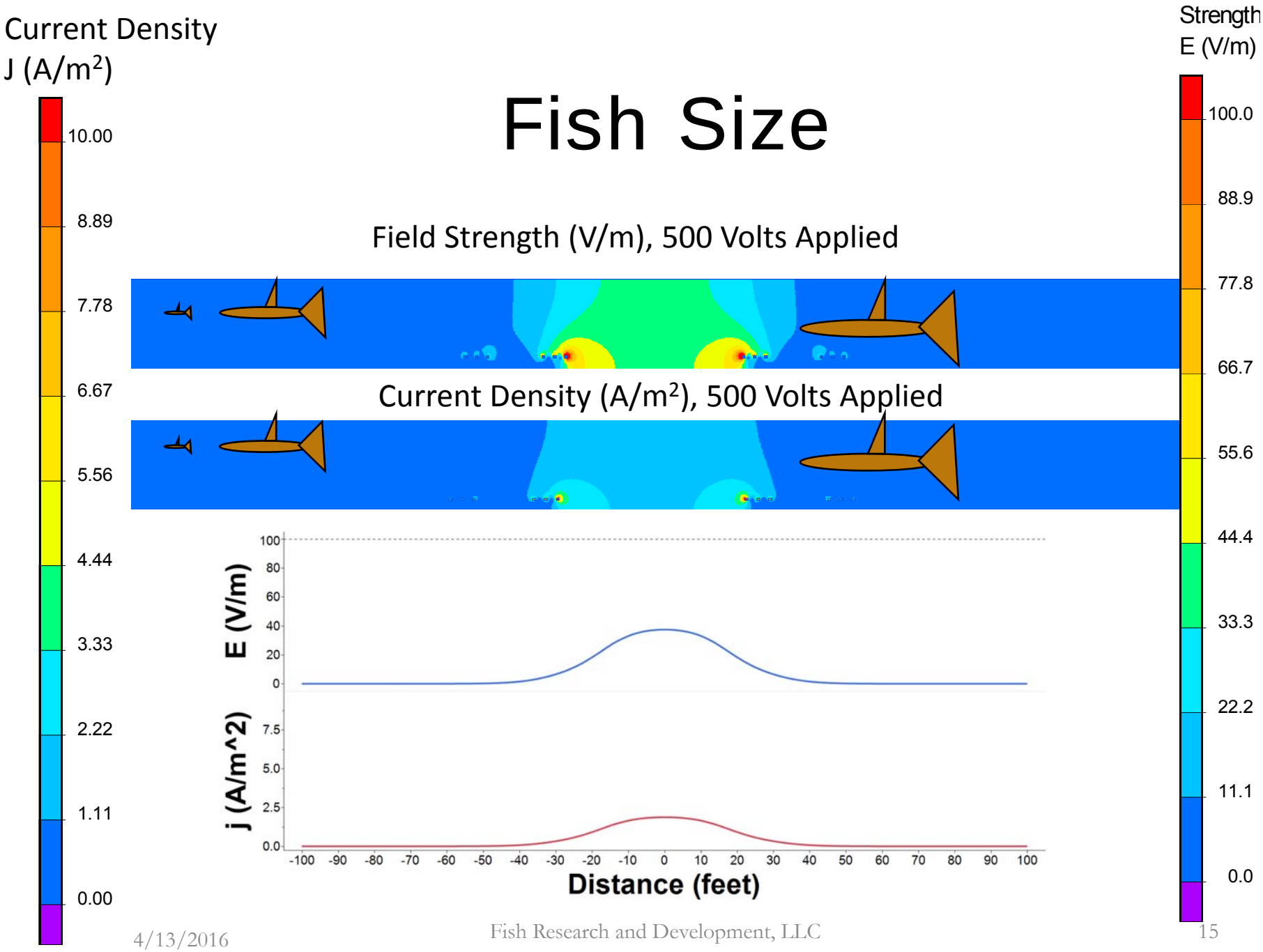
Electric Dispersal Barriers

Technical Factors	Biological Factors	Environmental Factors
Electrode Orientation	Fish Size	Water Depth
Field Spatial Properties Maximum Field Strength Field Strength Distribution	Fish Species	Water Velocity
Field Temporal Properties Current Characteristics Time Characteristics	Swimming Performance	Water Conductivity
	Behavior Ecological Motivation	Water Temperature

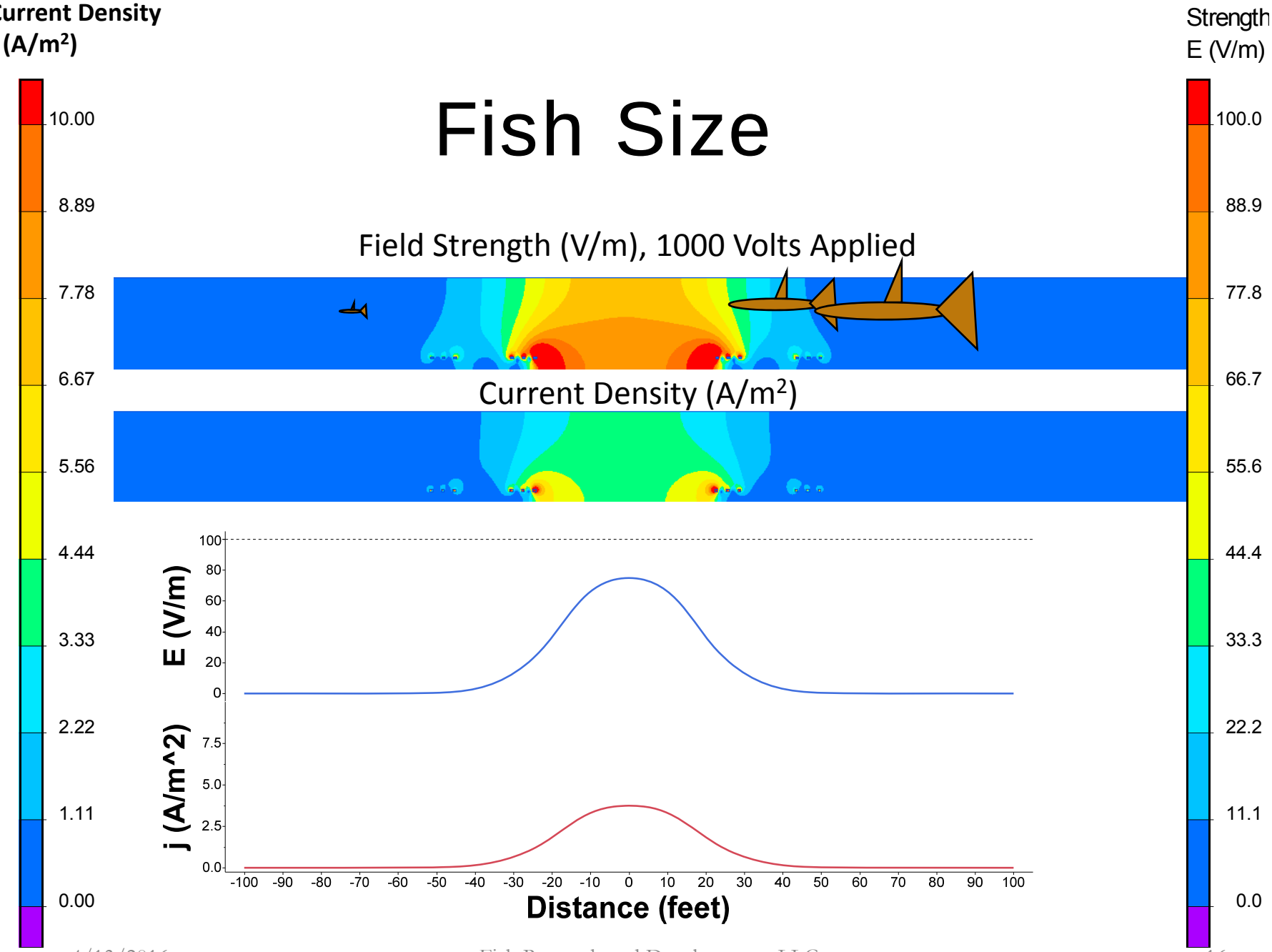
Fish Size


Current Density
J (A/m²)
10.00
8.89
7.78
6.67
5.56
4.44
3.33
2.22
1.11
0.00
Field Strength (V/m), 500 Volts Applied
Current Density (A/m²)
Field Strength (V/m), 0 Volts Applied
Current Density (A/m²)
Strength
E (V/m)
100.0
88.9
77.8
66.7
55.6
44.4
33.3
22.2
11.1
0.0

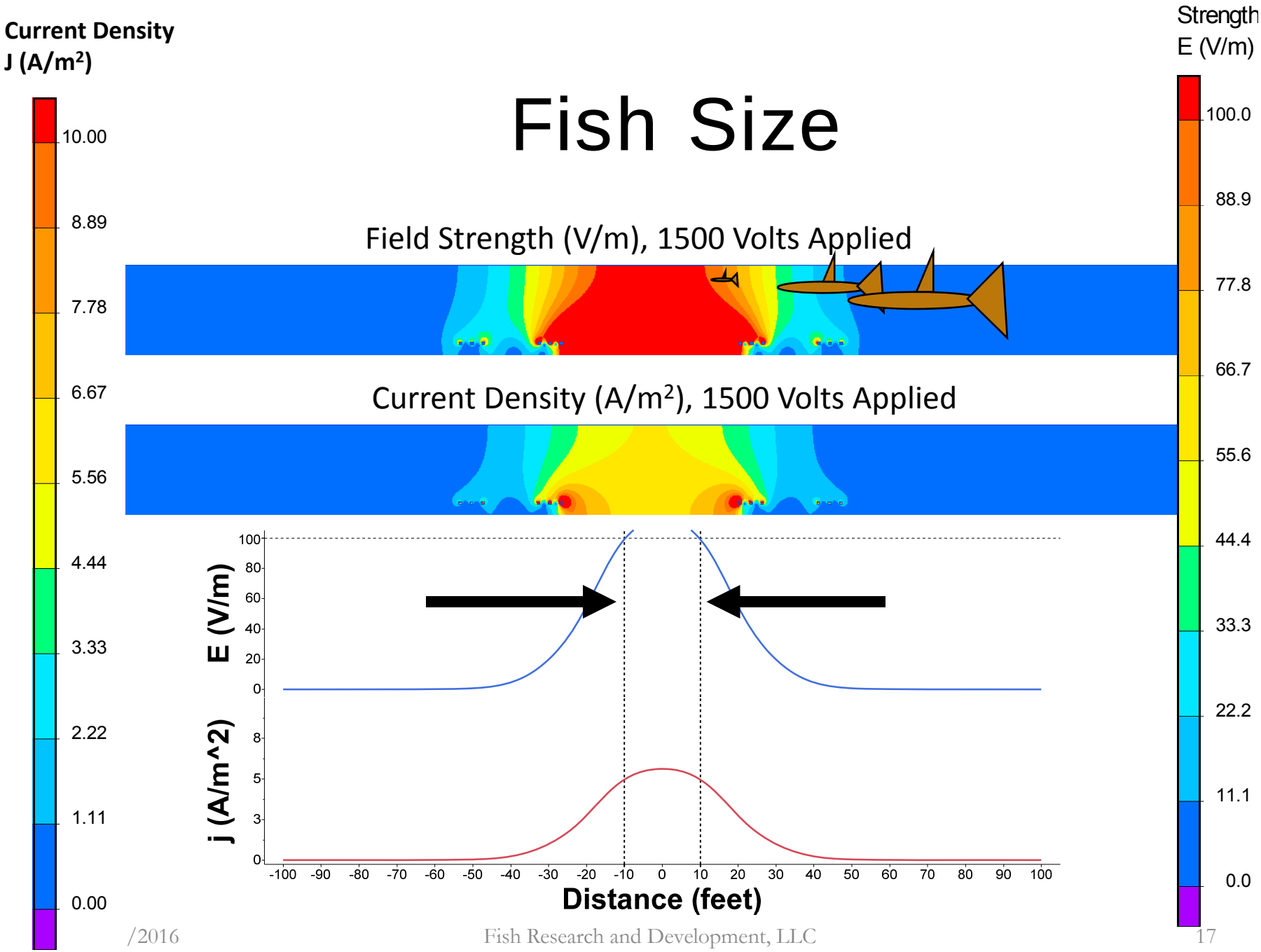
Fish Size


Current Density
J (A/m²)
10.00
8.89
7.78
6.67
5.56
4.44
3.33
2.22
1.11
0.00
Field Strength (V/m), 500 Volts Applied
Current Density (A/m²), 500 Volts Applied
E (V/m)
j (A/m^2)
Distance (feet)
Strength
E (V/m)
100.0
88.9
77.8
66.7
55.6
44.4
33.3
22.2
11.1
0.0

Fish Size

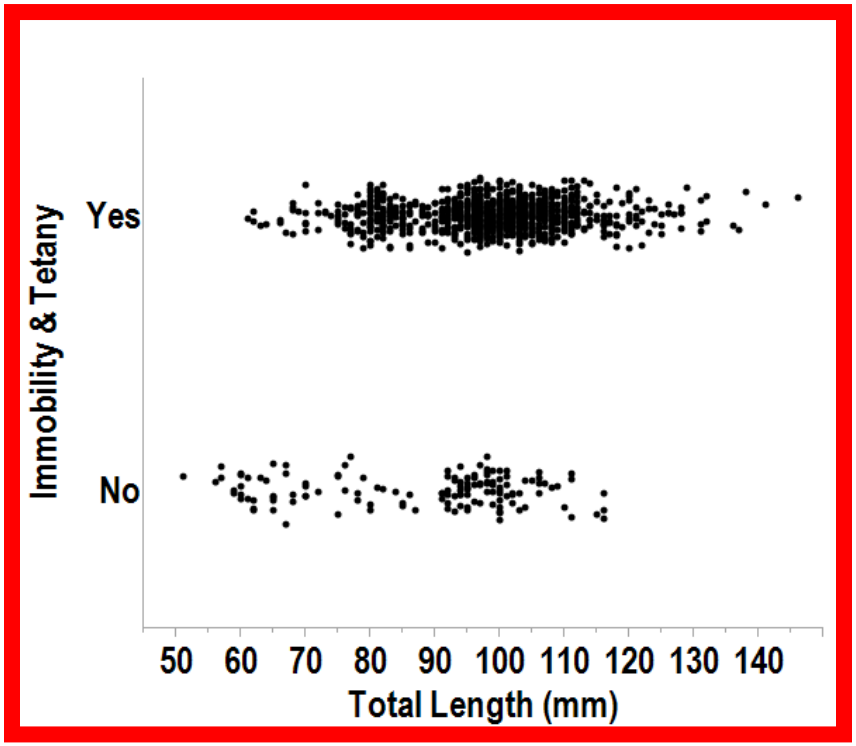

Current Density
J (A/m²)
10.00
8.89
7.78
6.67
5.56
4.44
3.33
2.22
1.11
0.00
Field Strength (V/m), 1000 Volts Applied
Current Density (A/m²)
E (V/m)
j (A/m^2)
Distance (feet)
Strength
E (V/m)
100.0
88.9
77.8
66.7
55.6
44.4
33.3
22.2
11.1
0.0

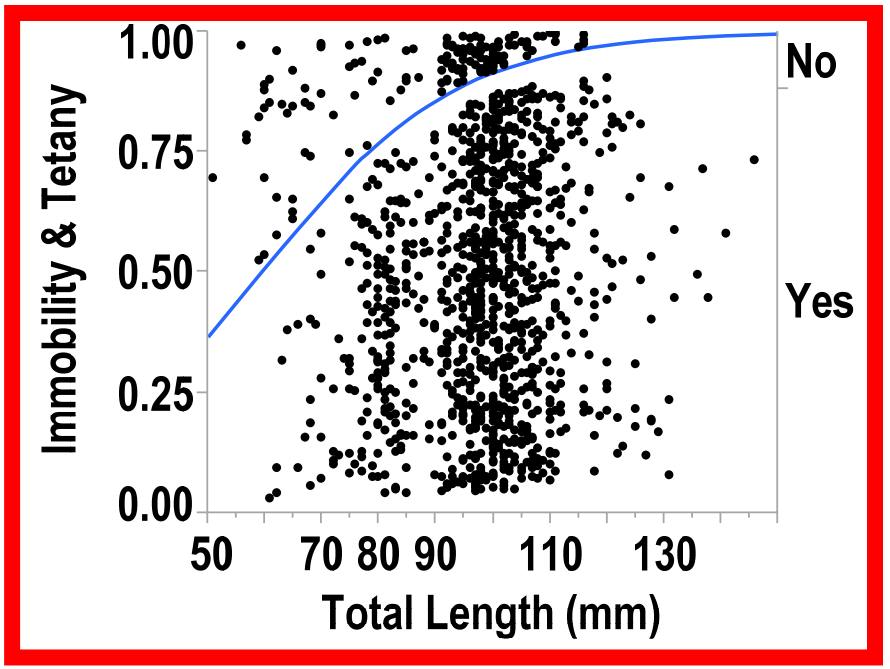
Fish Size


Current Density
J (A/m²)
10.00
8.89
7.78
6.67
5.56
4.44
3.33
2.22
1.11
0.00
Field Strength (V/m), 1500 Volts Applied
Current Density (A/m²), 1500 Volts Applied
E (V/m)
j (A/m^2)
Distance (feet)
Strength
E (V/m)
100.0
88.9
77.8
66.7
55.6
44.4
33.3
22.2
11.1
0.0

Modeling and Simulation

Fish Size

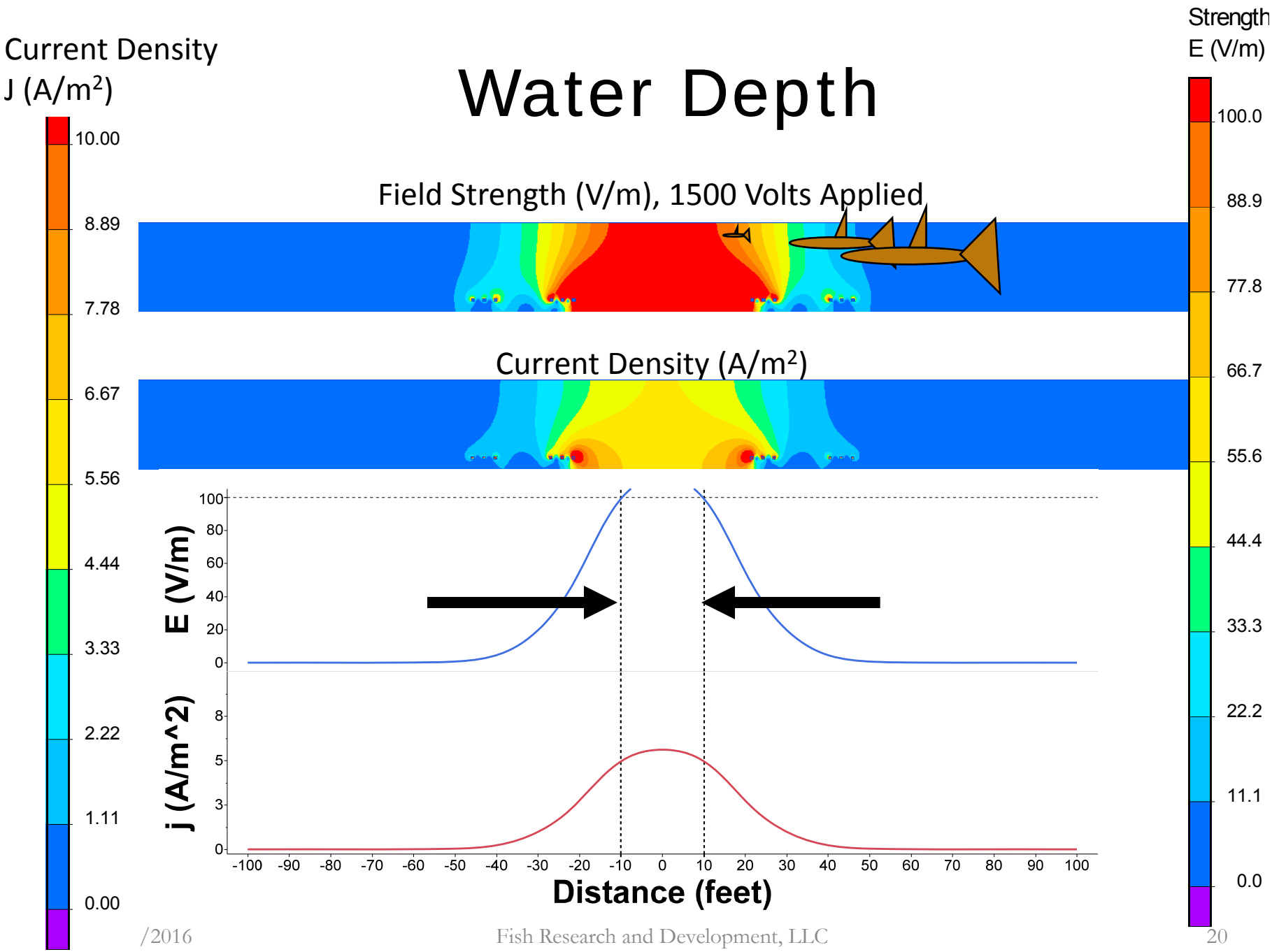




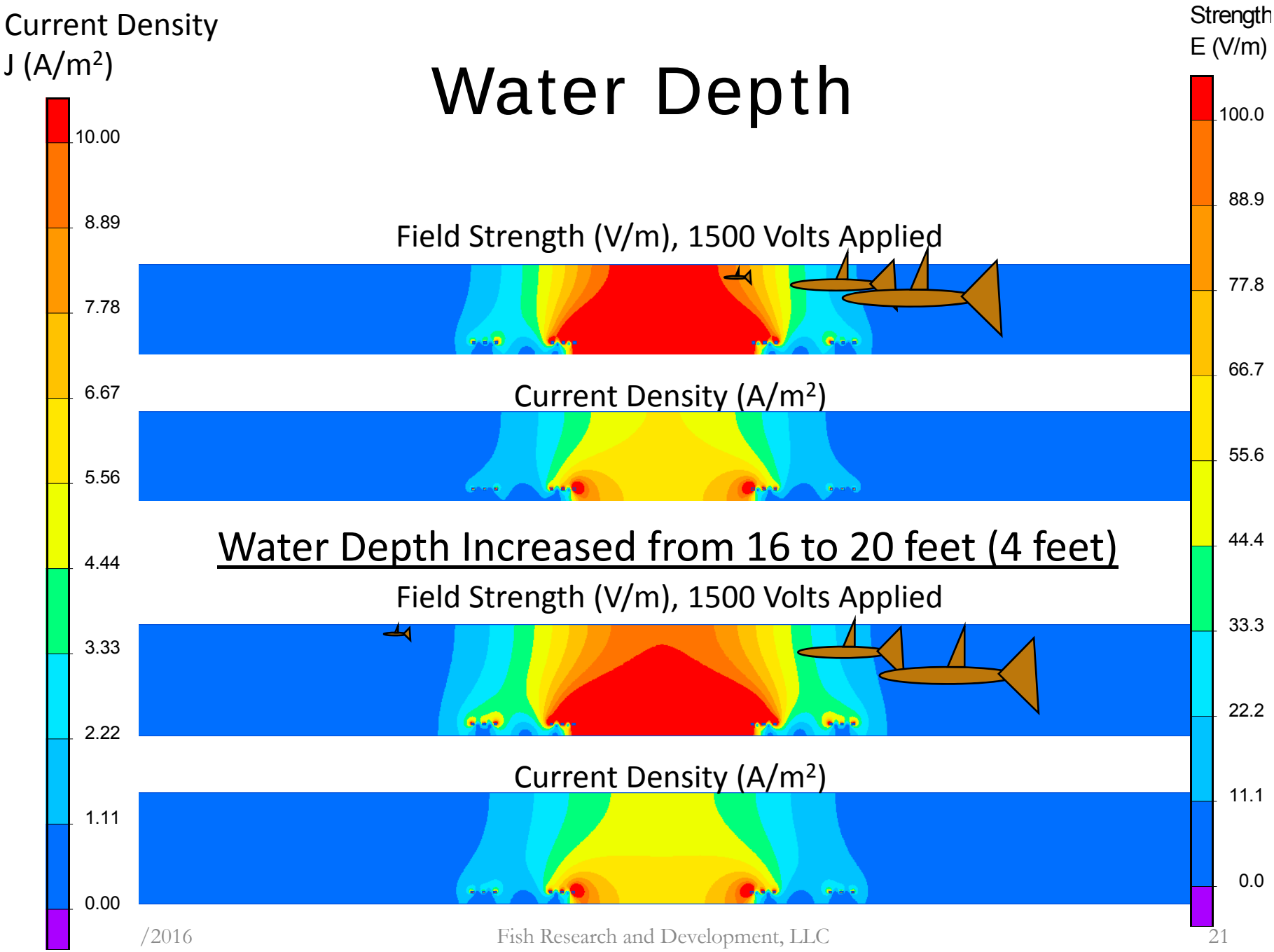
Electric Dispersal Barriers

Technical Factors	Biological Factors	Environmental Factors
Electrode Orientation	Fish Size	Water Depth
Field Spatial Properties Maximum Field Strength Field Strength Distribution	Fish Species	Water Velocity
Field Temporal Properties Current Characteristics Time Characteristics	Swimming Speed	Water Conductivity
	Behavior Ecological Motivation	Water temperature

Water Depth

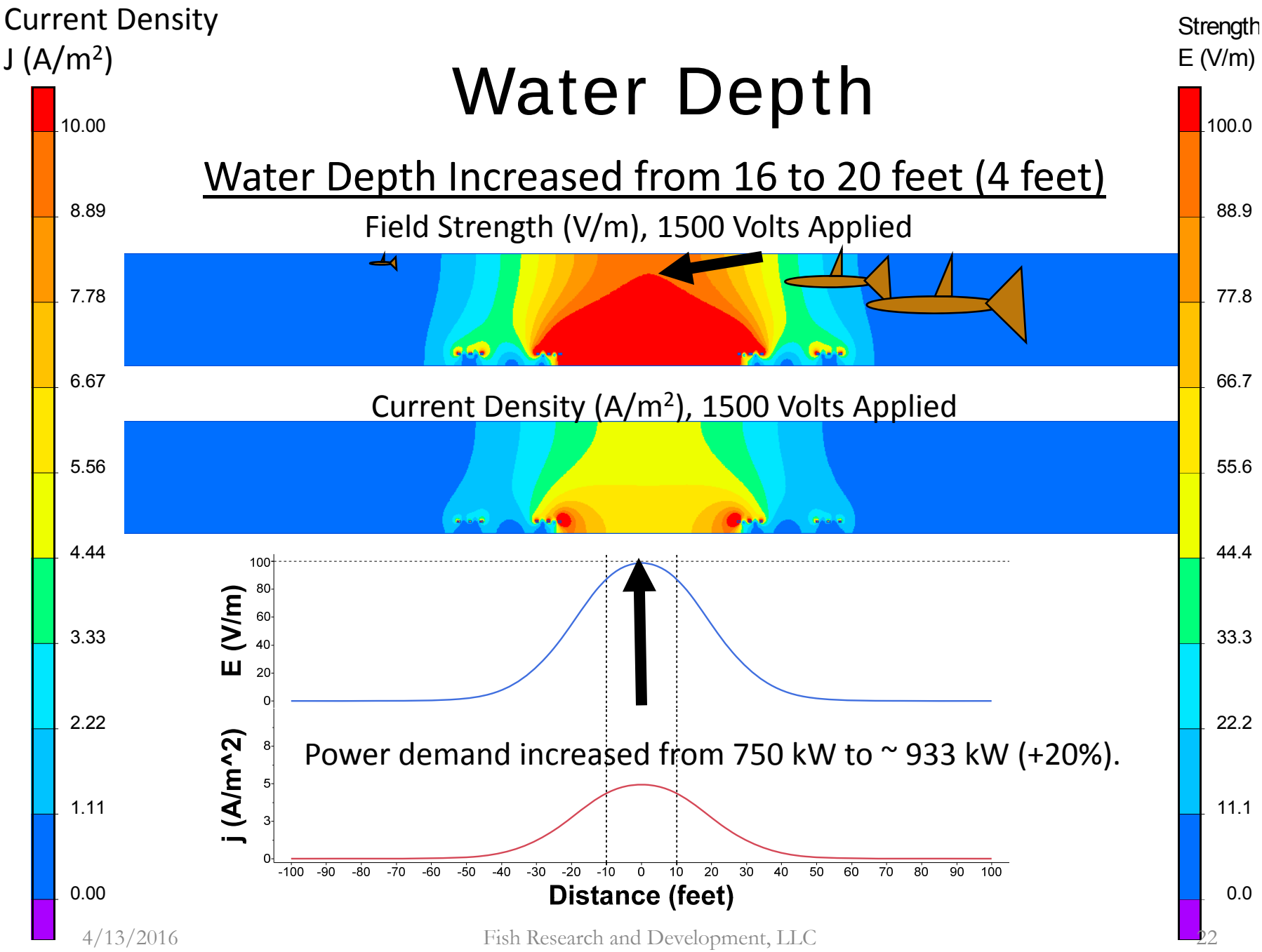

Current Density
J (A/m²)
10.00
8.89
7.78
6.67
5.56
4.44
3.33
2.22
1.11
0.00
Field Strength (V/m), 1500 Volts Applied
Current Density (A/m²)
E (V/m)
j (A/m^2)
Distance (feet)
Strength
E (V/m)
100.0
88.9
77.8
66.7
55.6
44.4
33.3
22.2
11.1
0.0

Water Depth


Current Density
J (A/m²)
10.00
8.89
7.78
6.67
5.56
4.44
3.33
2.22
1.11
0.00
Field Strength (V/m), 1500 Volts Applied
Current Density (A/m²)
Water Depth Increased from 16 to 20 feet (4 feet)
Field Strength (V/m), 1500 Volts Applied
Current Density (A/m²)
Strength
E (V/m)
100.0
88.9
77.8
66.7
55.6
44.4
33.3
22.2
11.1
0.0

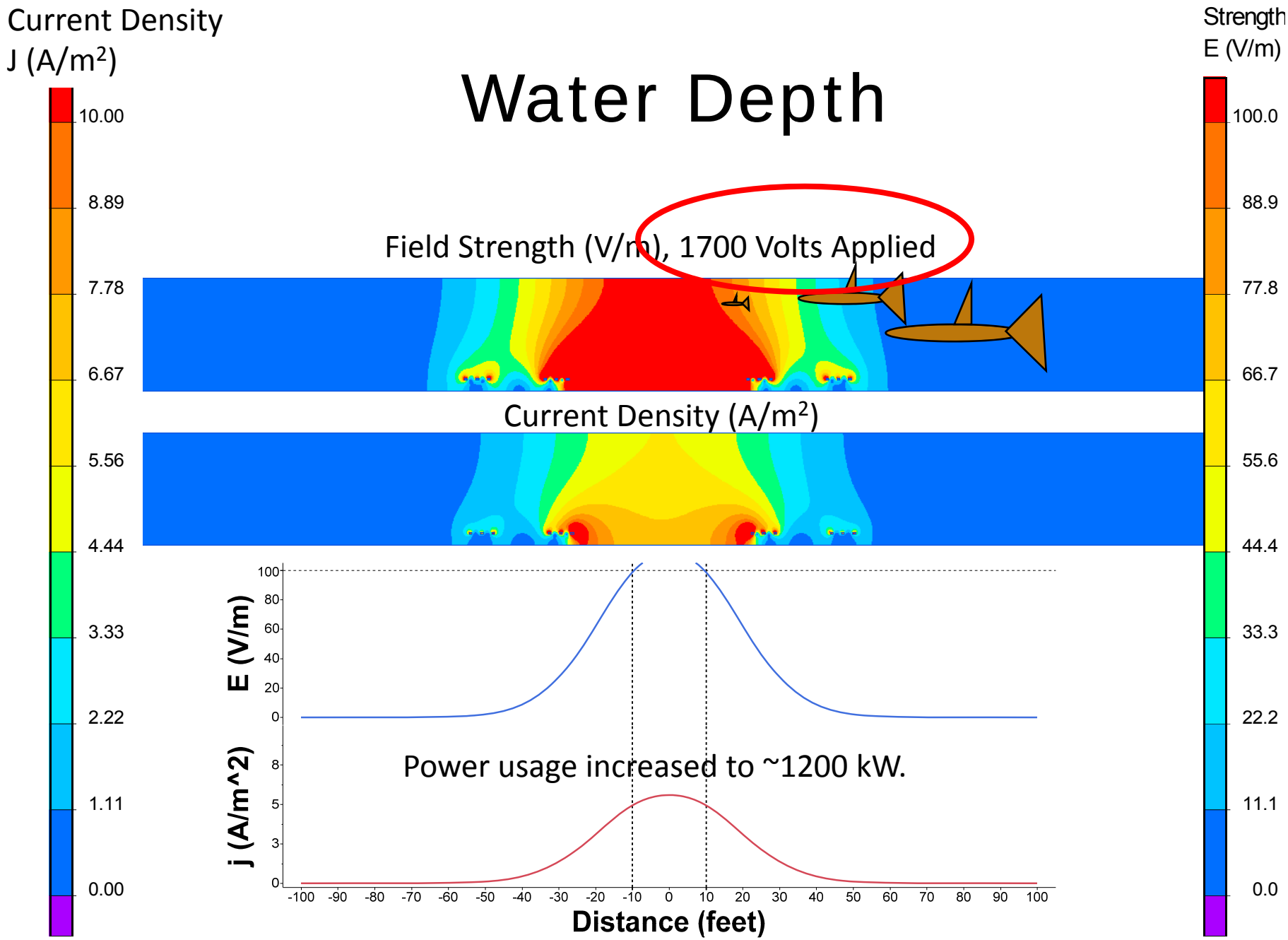
Water Depth

Water Depth Increased from 16 to 20 feet (4 feet)



Power demand increased from 750 kW to ~ 933 kW (+20%).

Water Depth


Current Density
J (A/m²)
10.00
8.89
7.78
6.67
5.56
4.44
3.33
2.22
1.11
0.00
Strength
E (V/m)
100.0
88.9
77.8
66.7
55.6
44.4
33.3
22.2
11.1
0.0
Field Strength (V/m), 1700 Volts Applied
Current Density (A/m²)
E (V/m)
j (A/m^2)
Power usage increased to ~1200 kW.
Distance (feet)

Electric Dispersal Barriers

Technical Factors	Biological Factors	Environmental Factors
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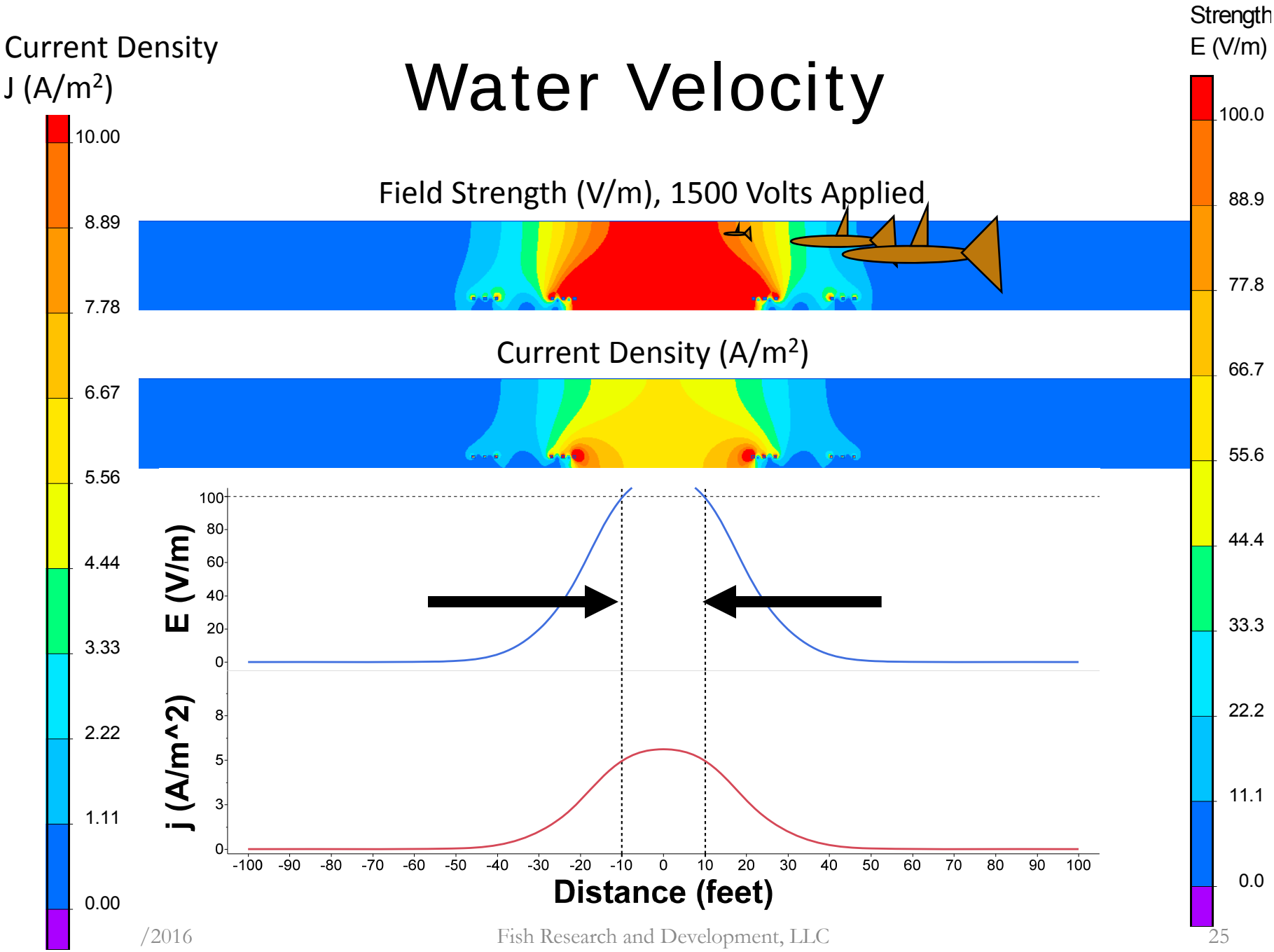
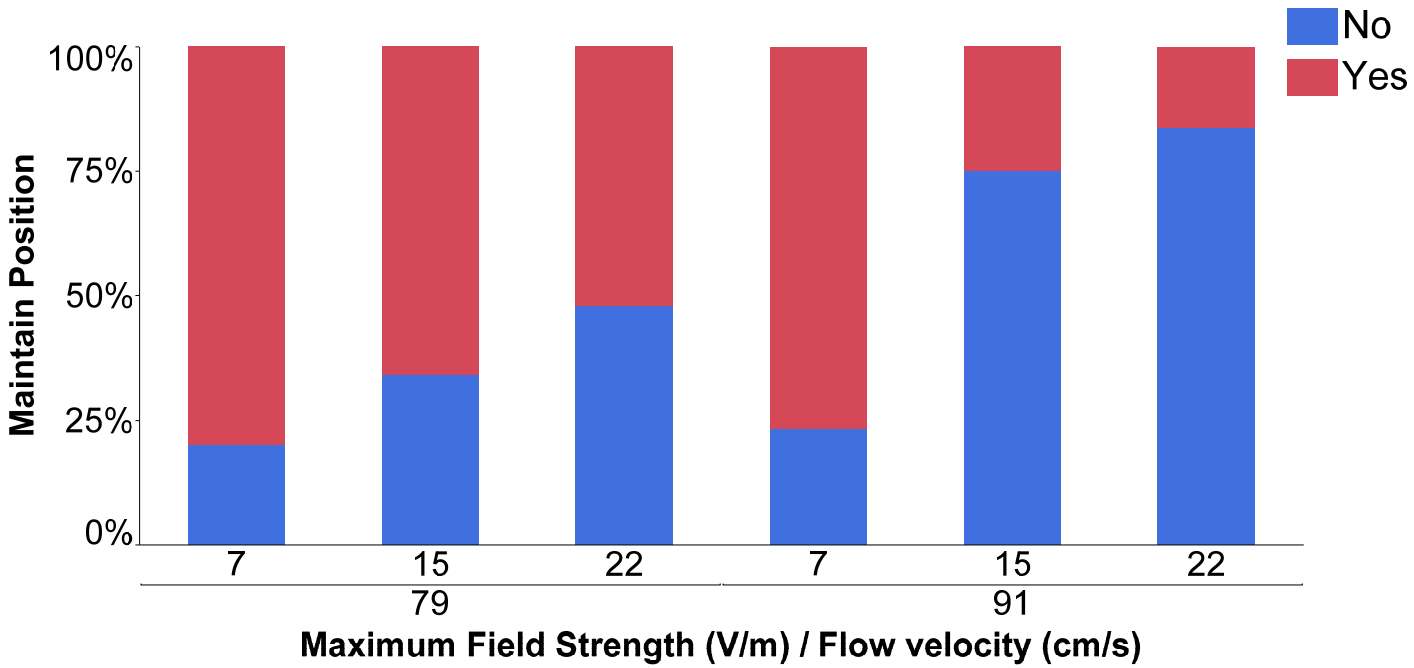
Field Temporal Properties Current Characteristics Time Characteristics	Swimming Speed	Water Conductivity
	Behavior Ecological Motivation	Water temperature

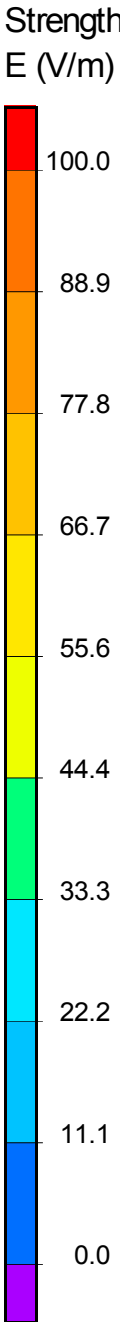
Water Velocity



Water Velocity

Modeling and Simulation





Based on outcomes of experiment with juvenile bighead carp increased flow is expected to reduce risk for fish to breach barrier.

Electric Dispersal Barriers

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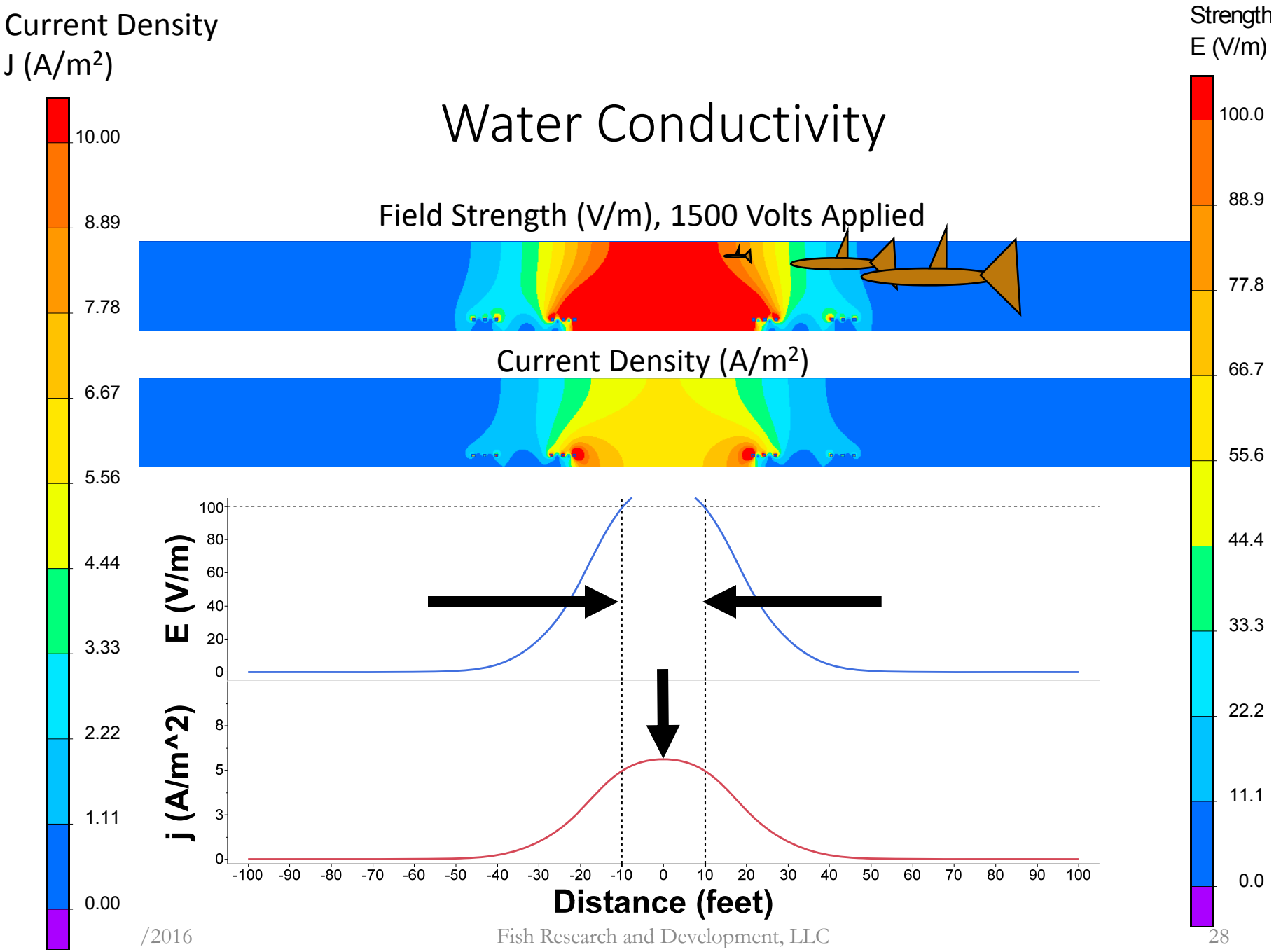
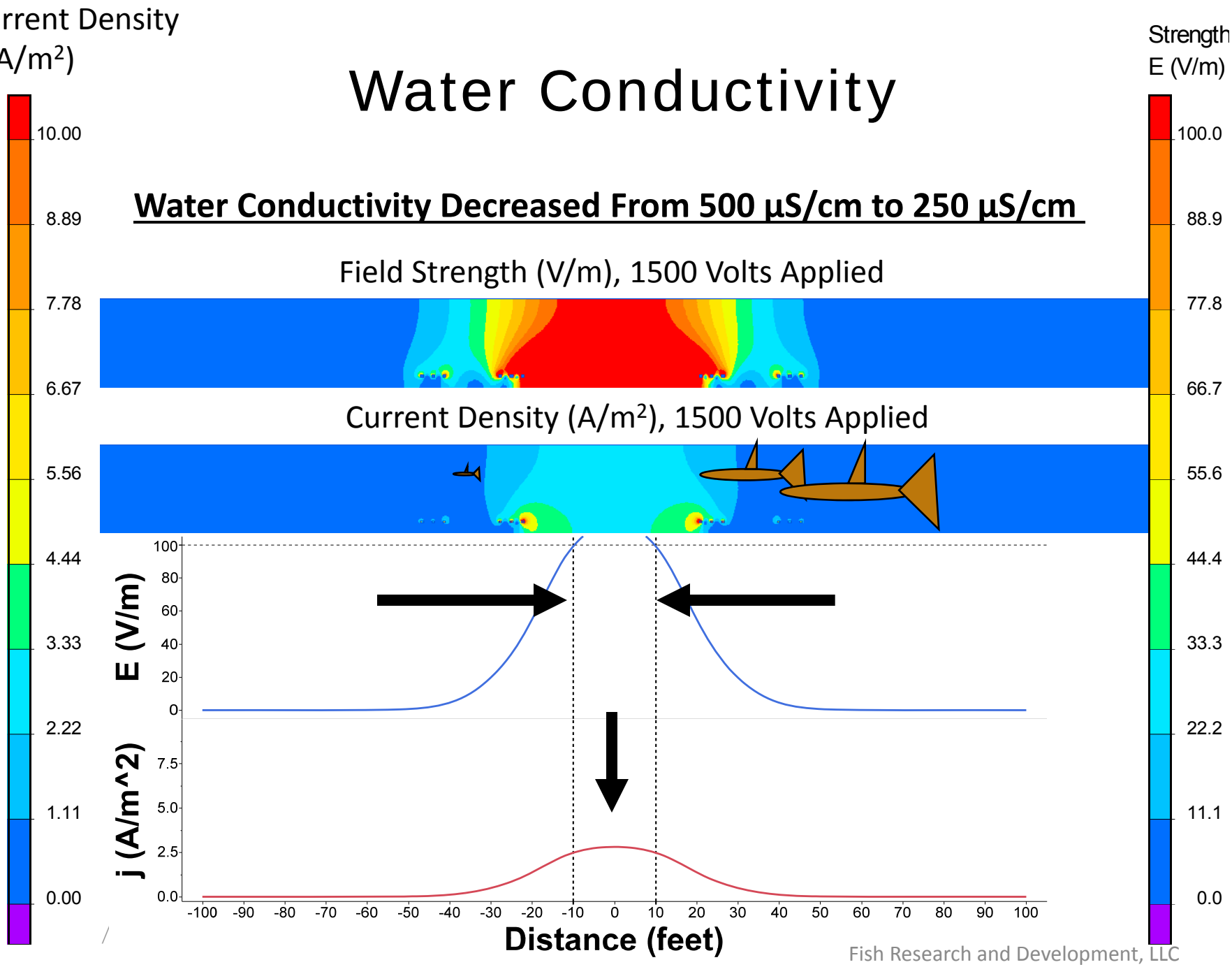
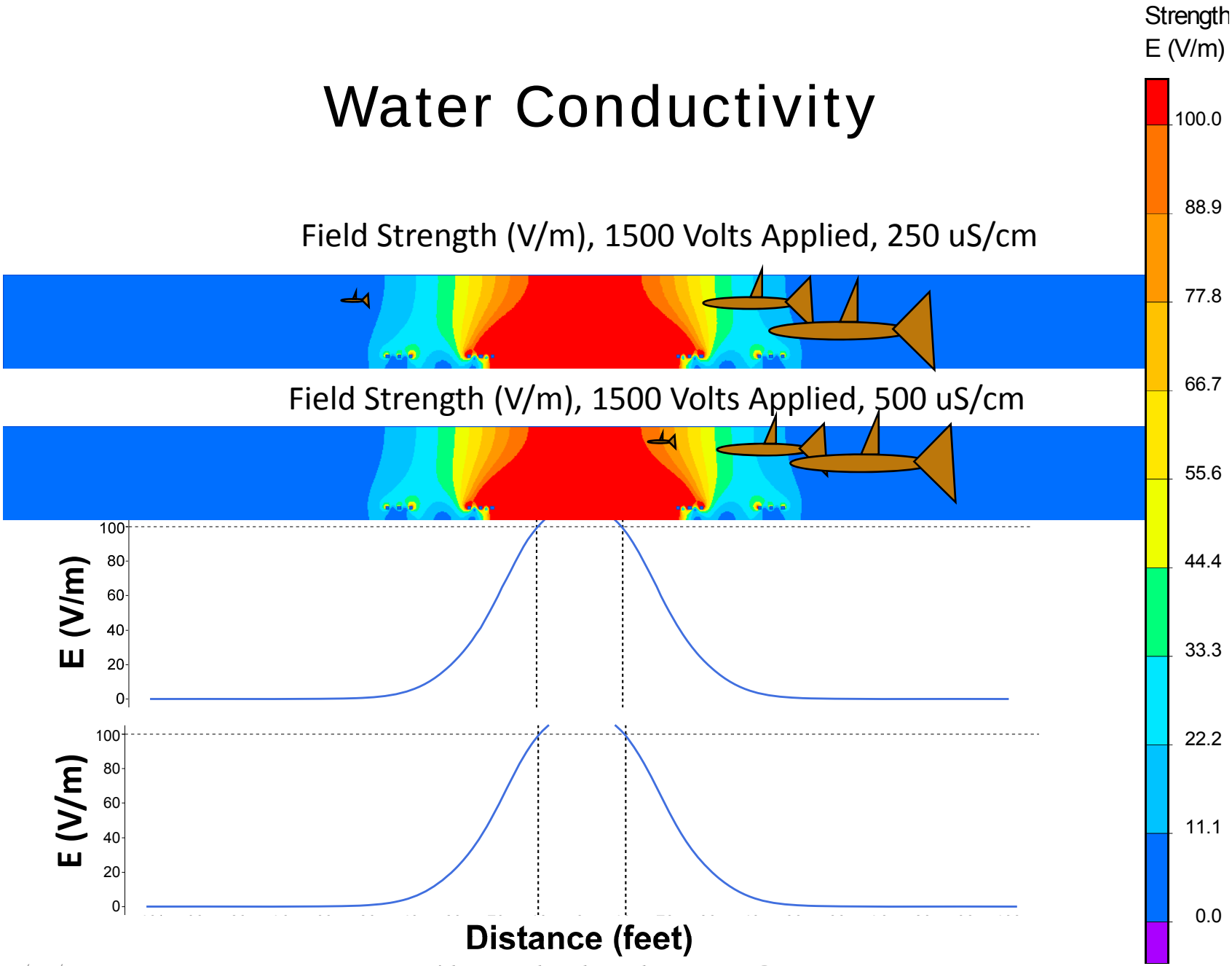
Water Conductivity



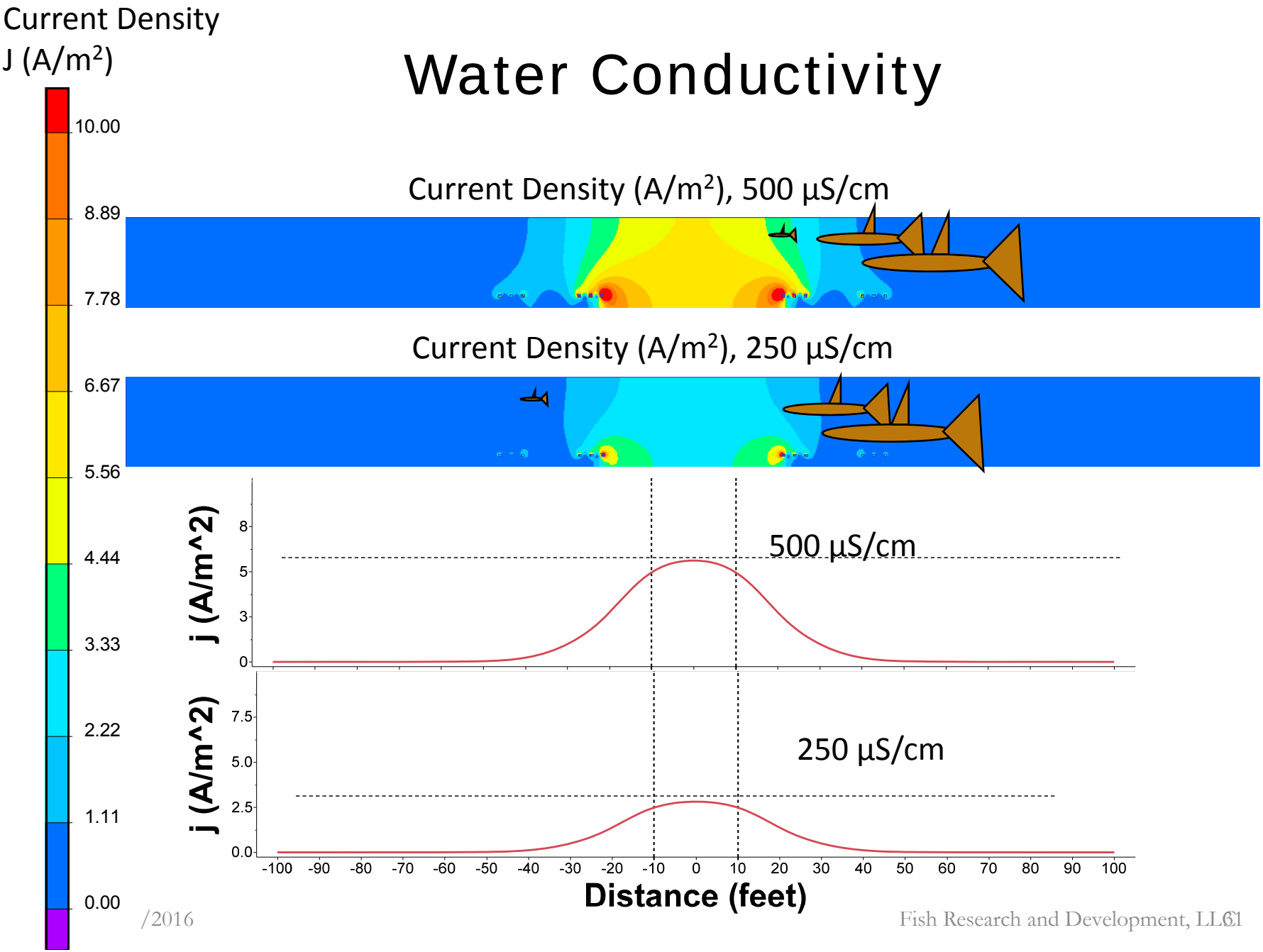
Water Conductivity



Water Conductivity



Water Conductivity



Power Transfer Theory

- Applied Power (first form)
- In-water Power (second form)
- Applied Power
  - C_w = 500 uS/cm, P_t =750 kW
  - C_w = 250 uS/cm, P_t = 375 kW
- New Power Goal = 510.4 kW need to increase voltage to 1750 volts

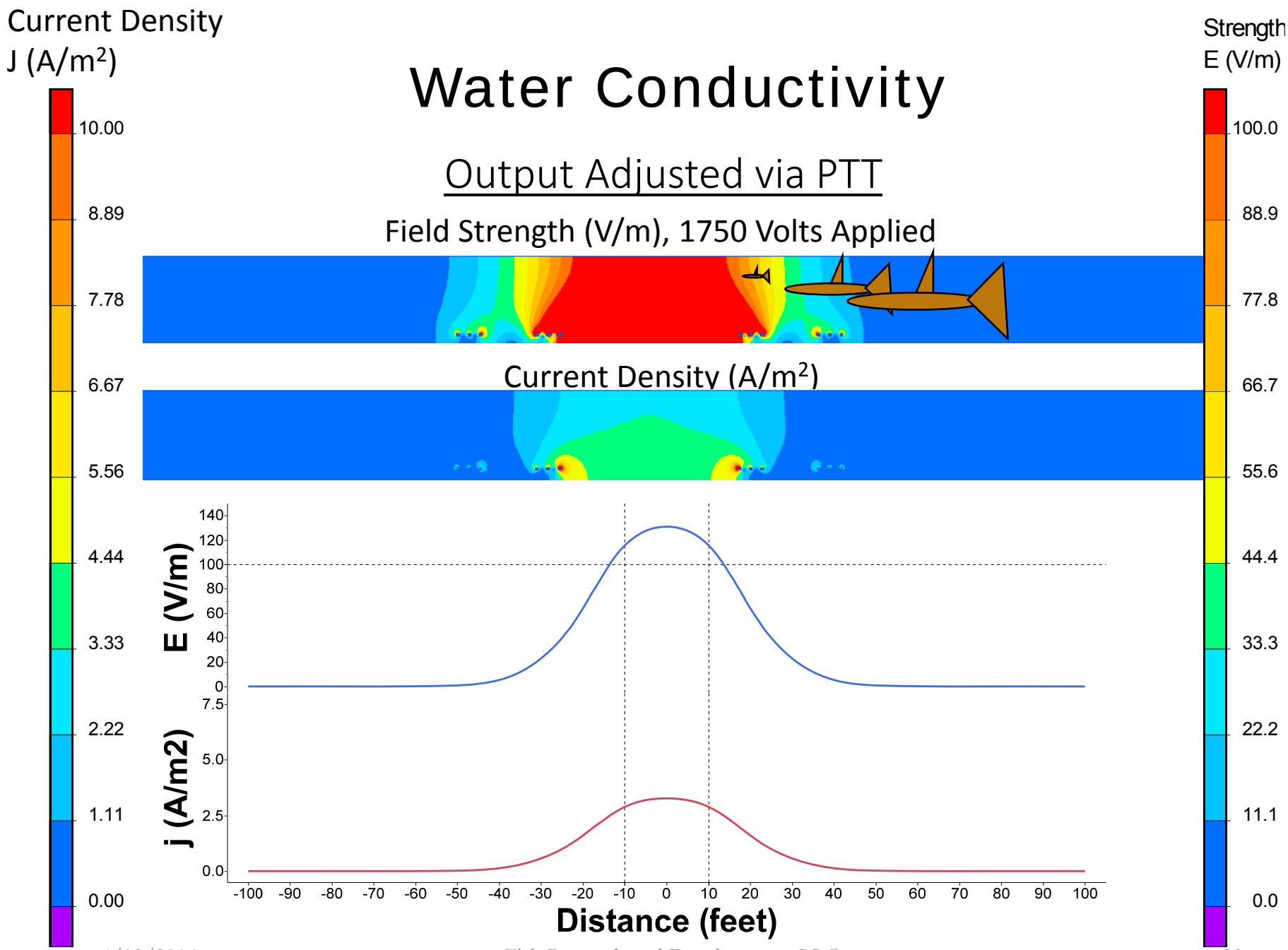
First form		Second form
V = I x R	Ohm's Law	E = J/δ
P = I x V	Power equation	D = J x E
P = I^2 x R	Power equation	D = J^2/δ
P = V^2/R	Power equation	D = E^2 x δ
V	Voltage gradient	E
I	Current density	J
R	Resistivity	1/δ

Kolz 1989; Burkhardt & Gutreuter 1995; Miranda 2009

$$P_t' = P_t \frac{\left(1 + \frac{c_f}{c_w}\right)^2}{\left(4 \times \frac{c_f}{c_w}\right)}$$

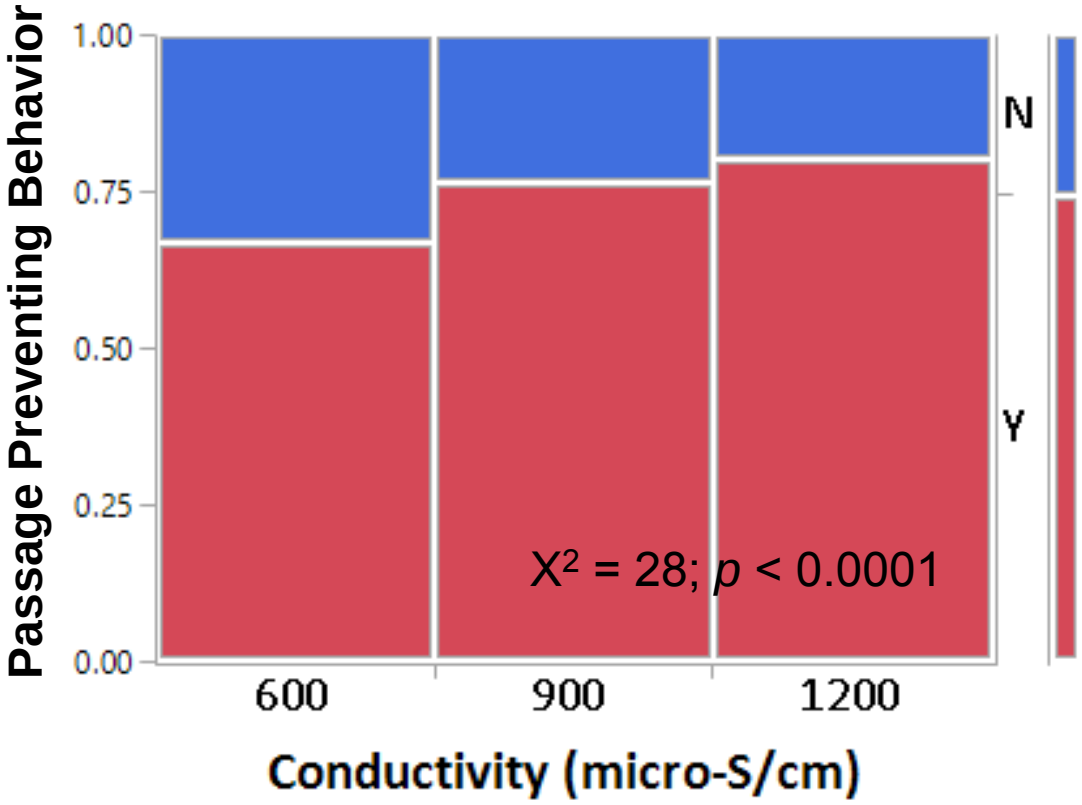
Water Conductivity

Output Adjusted via PTT



Water Conductivity

Modeling and Simulation



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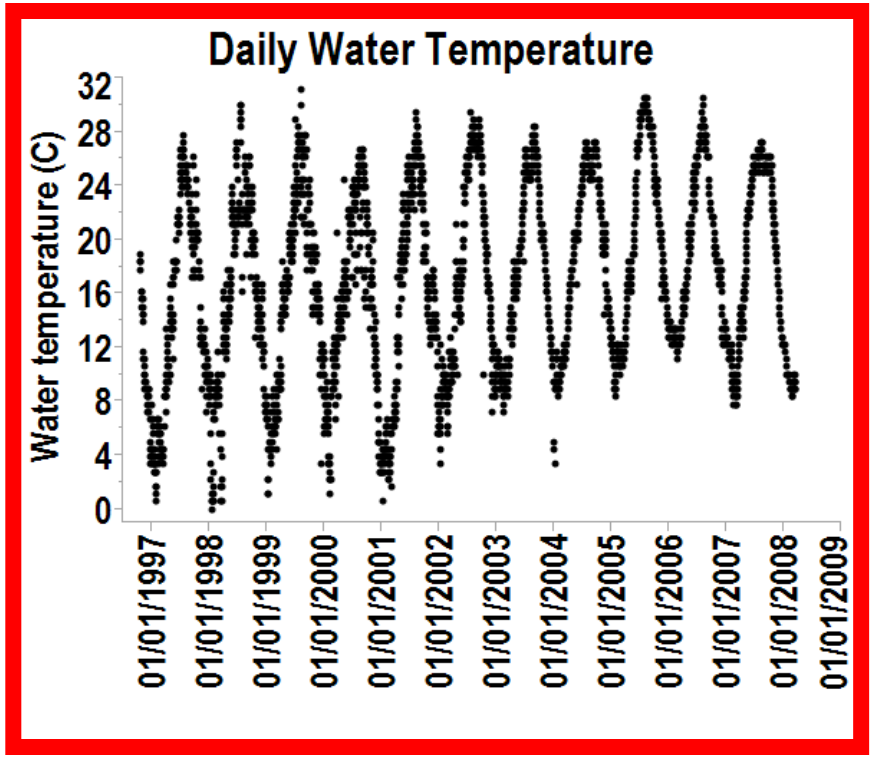
Water Temperature



Extensive esearch on the various effects that water temperature has on fish but not on temperature and electroshock-induced behaviors.

Anectdotal reports of
↑ susceptibility with ↓ T

(Zalewski and Cowx 1990)

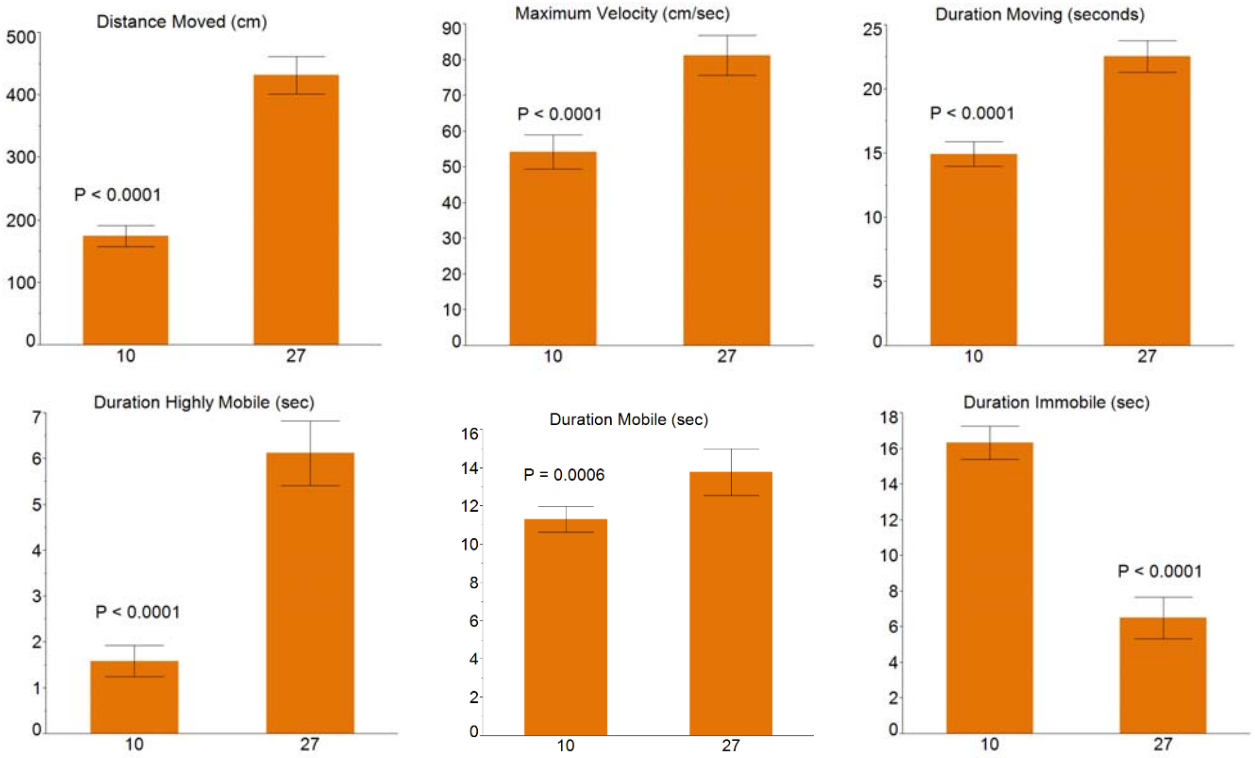
Susceptibilty ↓ as T ↑

(Penaz and Prokes 1973)

Water Temperature

Modeling and Simulation

Metrics of Swimming Performance During the Electrical Exposures Differed Significantly Between Temperatures

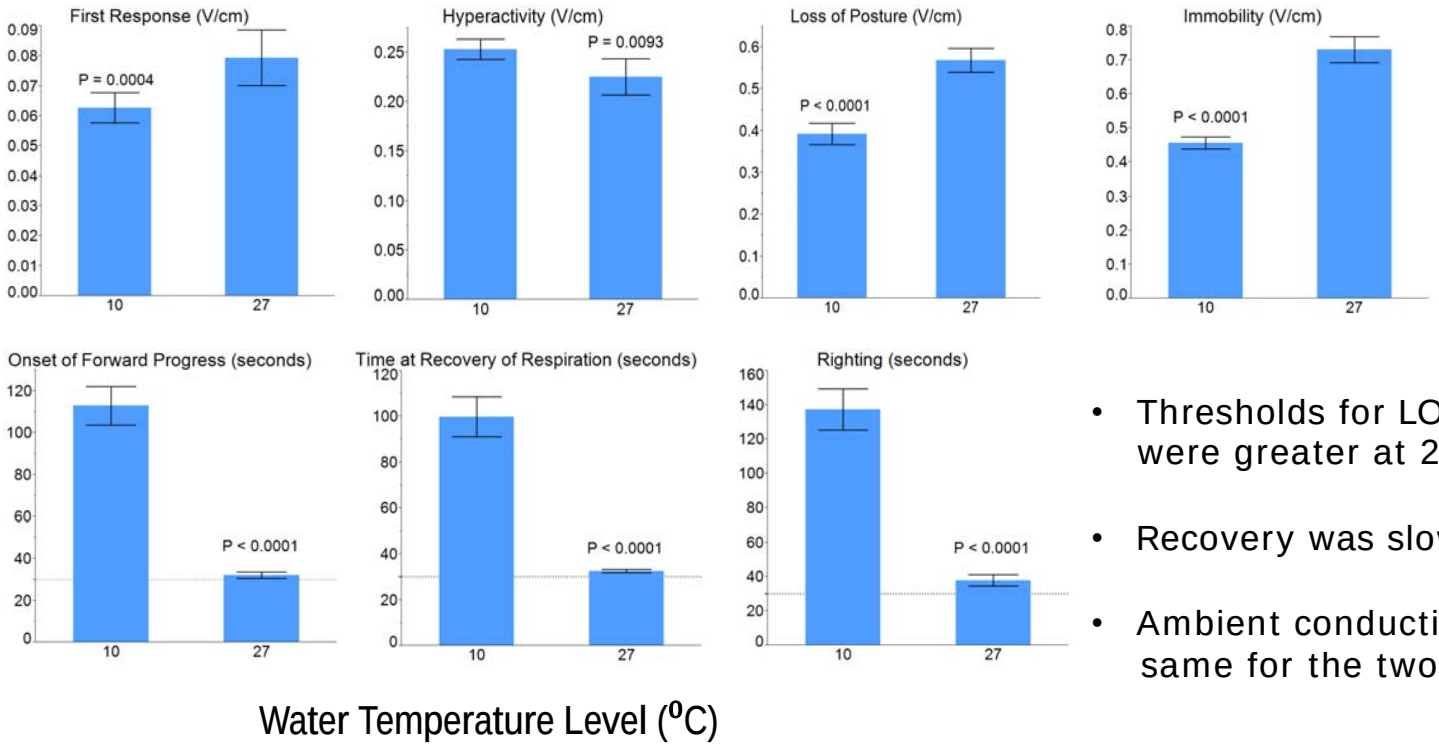


Activity and locomotion were significantly greater at 27^0 C.

Water Temperature

Modeling and Simulation

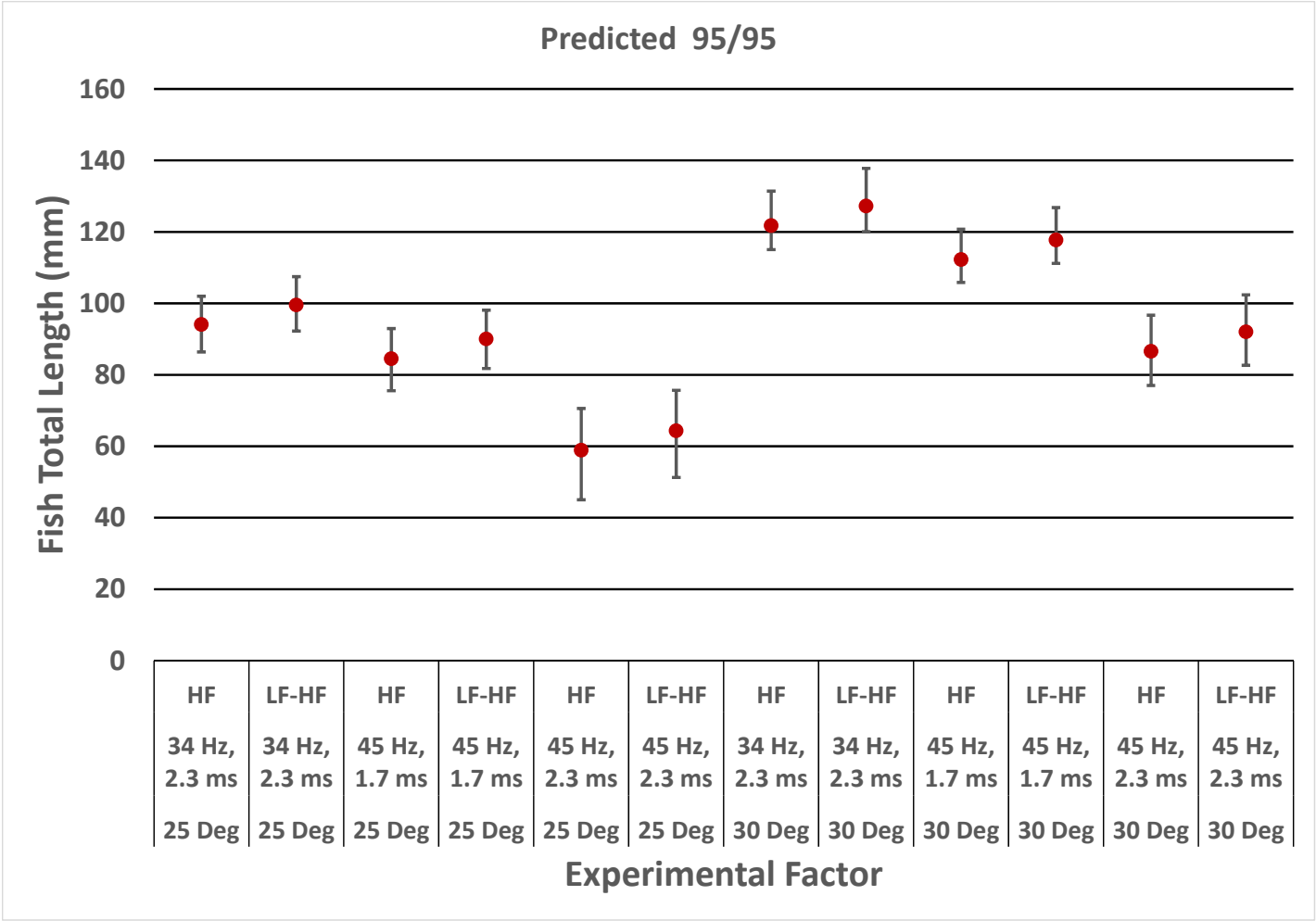
Threshold Voltage Gradients for Behavioral Endpoints & Indexes of Recovery Differed Significantly Between Temperatures



- Thresholds for LOP & Immobility were greater at 27° C.
- Recovery was slower at 10° C.
- Ambient conductivity was the same for the two temperatures.

Water Temperature

Predicted Fish Length (& 95% CI) at 95% Probability of Immobility



Introduction to Electric Dispersal Barriers

Questions?