Measuring the Value of Water Quality Improvements for Recreation Use on an Urban River in the USA: A Travel Cost Contingent Behavior Approach

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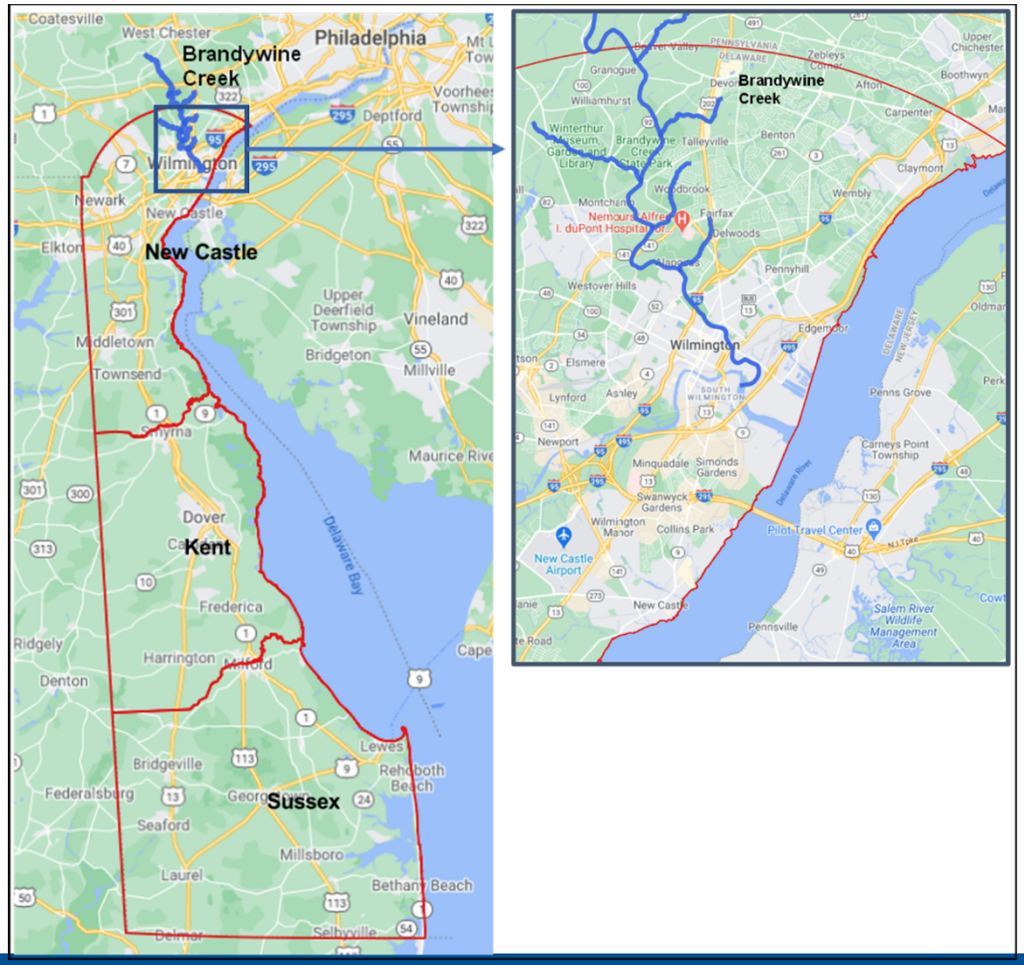

Brandywine Creek
New Castle
Kent
Sussex
Wilmington
Philadelphia
Dover
Delaware Bay
Brandywine Creek
Wilmington

Project WiCCED

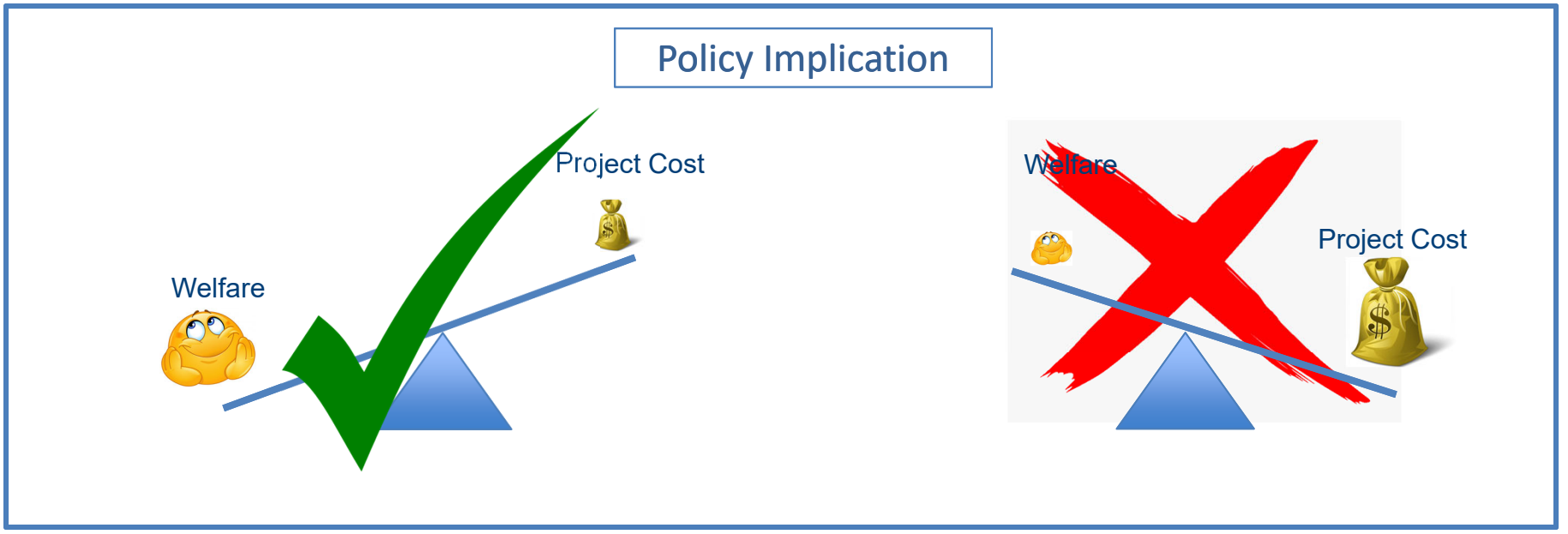
This study is part of Project WiCCED (Water in the Changing Coastal Environment of Delaware), a broad initiative by the State of Delaware in partnership with the National Science Foundation to "**assess major threats to Delaware's water quality and develop viable technological and policy solutions for meeting the challenges imposed by them**"

Motivation

- ✓ There is discussion now of a major revival of water qualities in Delaware
- ✓ Given the importance of the Brandywine and the likelihood that other rivers in similar urban settings may be targets for the same type of initiatives

Objective of the Study

- To value water quality improvements on the Brandywine Creek in Delaware



Recreational Activity

Activity on the water

Fishing	Sailing	Jet skiing
Swimming	Canoeing	Water skiing
Tubing	Kayaking	Motor Boating
Crabbing	Paddle Boarding	Surfing

Activity near the water

Walking	Reading	Relaxing
Hunting	Picnicking	Sunning
Running	Photography/Painting	Wildlife Viewing
Biking	Birding	Inspiration

Study Design

1. Email Based Sample

We drew a stratified random sample from Dynata
60% from New Castel County (Brandywine is locate)
40% from rest of the states

2. Address Based Sample

25% from zip codes touched or contain Brandywine
25% from other zip codes in New Castel County
50% from rest of the states

After cleaning we used 880 samples (413 email based, 467 ABS)

Method

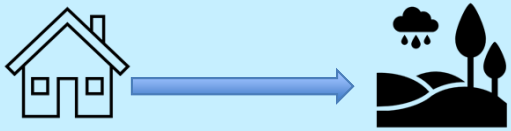
Single site Travel Cost-Contingent Valuation

- ✓ Observed water quality on the Brandywine and its substitute recreation sites in the state showed insufficient variation
- ✓ The changes in water quality we wanted to consider were not observable

Fuel cost + Entry fee + Time cost

How can we measure welfare ?

Revealed Preference

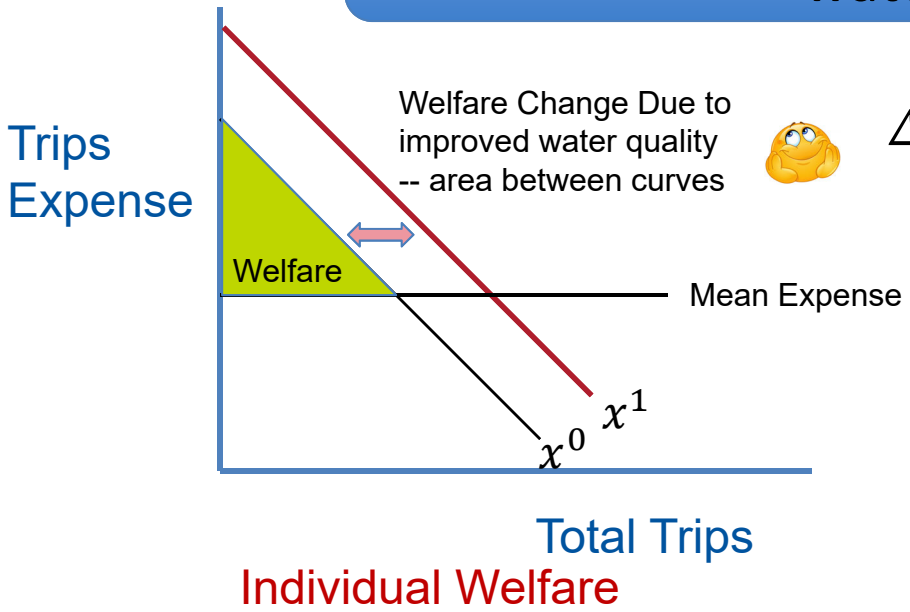


Fuel cost + Entry fee + Time cost

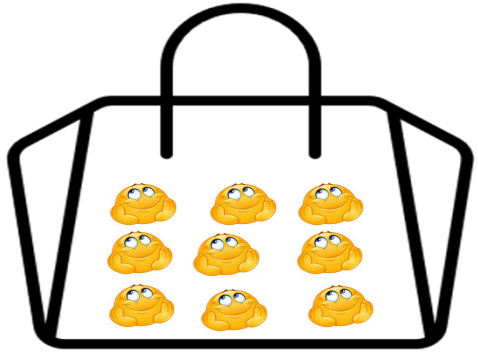
Stated Preference

Category of Water Quality		Current Conditions	Conditions with Improvement
Clarity of Water		Can see to 1.5 feet deep	Can see to 4 feet deep
Safety for Swimming		7% chance of getting sick	0% chance of getting sick
Type of Fish		Fish like Bass, Perch, Catfish occur naturally. Fish supported by stocking like Trout, Salmon	Increased abundance of naturally occurring game fish with catch rates expected to double. Increase in stocking by 50%
Safety of Eating Fish		Eat no more than 3 fish per year caught from these waters.	Unlimited consumption
Ecological Health		Fair	Very Good

How Travel Cost measure welfare on improved water quality ?



$$\Delta W = \int_{tc^0}^{tc^{**}} x^1(tc, q^1, z) - \int_{tc^0}^{tc^*} x^0(tc, q^0, z)$$



Total Welfare

Contingent Scenarios

Category of Water Quality		Current Conditions	Conditions with Improvement
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Safety of Eating Fish		Eat no more than 3 fish per year caught from these waters.	Safe for unlimited consumption
Ecological Health		Fair	Very Good

Contingent Scenario 01

Category of Water Quality	Current Conditions		Conditions with Improvement
Clarity of Water	Can see to 1.5 feet deep	No Change	Can see to 1.5 feet deep
Safety for Swimming	7% chance of getting sick	Improves	0% chance of getting sick
Abundance & Type of Fish	Fish like Bass, Perch, Catfish occur naturally Fish supported by stocking like Trout, Salmon	No Change	Fish like Bass, Perch, Catfish occur naturally Fish supported by stocking like Trout, Salmon
Safety of Eating Fish	Eat no more than 3 fish per year caught from these waters.	Improves	Safe for unlimited consumption
Ecological Health	Fair	Improves	Very Good

Contingent Scenario 02

Model

Utility of an individuals that he maximize

$x_{ij} = f(tc_i, q_{ij}, z_i, y_i)$.

Mixed effect count data model

$$E(x_{ij}) = \mu_{ij} = \exp((\delta + u_i) + \alpha tc_i + \beta q_{ij} + \gamma z_i + \eta y_i)$$

We assume u_i is normally distributed with $E(u_i) = 0$ and $Var(u_i) = \sigma^2$

$$x_{ij} \sim NB(x_{ij} \,|\, |\mu_{ij}\theta) = \frac{\Gamma(x_{ij} + \theta)}{\Gamma(\theta)\Gamma(x_{ij} + 1)} \cdot \left(\frac{\theta}{\mu_{ij} + \theta}\right)^{\theta} \cdot \left(\frac{\mu_{ij}}{\mu_{ij} + \theta}\right)^{\mu_{ij}}$$

where θ is the dispersion parameter controlling for overdispersion, μ_{ij} is the expected number of trips defined by our demand equation, and the variance is $\mu_{ij}(1 + a\mu_{ij})$, where $a = \frac{1}{\theta}$.

Model

$$E(x_{i0}) = \mu_{i0} = exp((\delta + u_i) + \alpha tc_i + \gamma z_i + \eta y_i)$$

$$E(x_{i1}) = \mu_{i1} = \exp((\delta + u_i) + \alpha tc_i + \beta_{2_C} + \beta_{2_S} + \beta_{2_E} + \beta_{2_F} + \gamma z_i + \eta y_i)$$

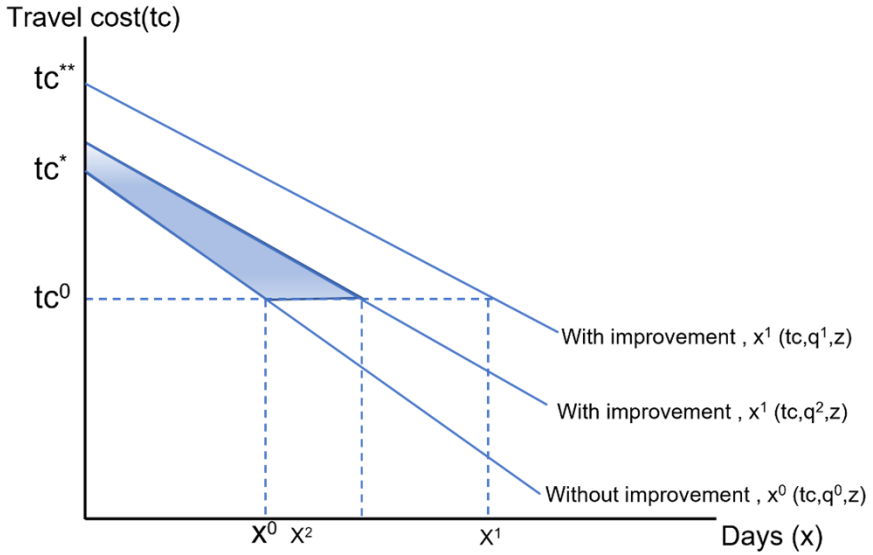
$$E(x_{i2}) = \mu_{i2} = exp((\delta + u_i) + \alpha tc_i + \beta_{2_c} q_C + \beta_{2_S} q_S + \beta_{2_E} q_E + \beta_{2_F} q_F + \beta_{2_F} \gamma z_i + \eta y_i)$$

Individual welfare form water quality improvement

$$\Delta W_{ij} = -\left\{E\left(x_{ij}^*\right) - E\left(x_{ij}\right)\right\}/\alpha$$

population aggregate values in annual terms

$$PAV_j = \{\sum_{i=1}^{880} \Delta W_{ij}\} \cdot (Pop/880)$$



Data

	Contact Trips			Non-contact Trips		
Trips	Current Condition (%)	Small Improvement (%)	Large Improvement (%)	Current Condition (%)	Small Improvement (%)	Large Improvement (%)
0	57.2	46.4	31.6	39.2	34.0	24.7
1 to 5	22.3	23.8	26.0	24.2	19.9	18.3
6 to 10	9.6	11.7	16.1	12.3	13.8	15.5
11 to 25	5.1	10.8	15.5	10.8	15.2	19.1
26 to 50	3.2	4.2	7.3	6.3	8.3	12.3
51 to 100	1.7	1.7	1.6	3.8	5.1	5.7
101 to 200	1.0	1.4	1.7	3.5	3.0	3.1
>200	0.00	0.1	0.2	0.0	0.80	1.5
Total	100	100	100	100	100	100
Mean trip	6.6	8.6	11.2	15.4	18.0	21.1

Non-Respondent Data

	Contact days		Non-Contact days	
	Respondent (%)	Non-respondent (%)	Respondent (%)	Non-respondent (%)
0 days	57.2	53.9	39.2	34.1
1 to 5 days	22.3	19.8	24.2	14.4
6 to 10 days	9.6	9.6	12.3	13.2
11 to 25 days	5.1	9.0	10.8	12.6
26 to 50 days	3.2	5.4	6.3	11.4
51 to 100 days	1.7	1.8	3.8	4.8
101 to 200 days	1.0	0.0	3.5	6.0
> 200 days	0.0	0.6	0.0	3.6
Total	100	100	100	100
Mean Trips	6.6	5.3	15.4	21.0

Weighted Data

	Contact days		Non-contact days	
Number of days	Raw (%)	Weighted (%)	Raw (%)	Weighted (%)
0	57.2	61.3	39.2	46.9
1 to 5	22.3	19.3	24.2	24.7
6 to 10	9.6	9.3	12.3	10.7
11 to 25	5.1	4.5	10.8	9.8
26 to 50	3.2	2.9	6.3	4.2
51 to 100	1.7	1.6	3.8	1.8
101 to 200	1.0	1.1	3.5	2.0
Total	100	100	100	100
Mean Trips	6.6	6.3	15.4	10.0

Variables

Variables	Description
Trip Cost	Travel plus time cost
ln(age)	Natural logarithm of individuals age
Income	Individuals' income in 1000 USD
Child	= 1 if individual lives with dependent children
Nonwhite	= 1 if individual in non-white
Delaware River	= 1 if individual live in a ZIP that touches Delaware River
Delaware Bay	= 1 if individual live in a ZIP within 10 miles of Delaware Bay
Clarity	= 1 if view depth improved from 1.5 ft. to 4 ft.
Swimming safety	= 1 if swimming safety improved from 7% to 0% chance of getting sick
Fish abundance	= 1 if catch rate increase 100% & stocking increase 50%
Safety of eating fish	= 1 if safety of eating fish increase to unlimited consumption
Large Improvement	= 1 if improvement is realized in all four attributes (clarity, swimming safety, fish abundance, safety of eating fish)(this is the first contingent behavior question for each respondent)
Small Improvement	= 1 if improvement is realized less than all four attributes (this is the second contingent behavior question for each respondent)

	Contact Trips			Non-contact Trips		
	Mean	Min	Max	Mean	Min	Max
Constant	7.81*	7.34*	8.32*	4.96*	4.49*	5.38*
	(0.83)	(0.81)	(0.86)	(0.84)	(0.80)	(0.87)
Trip Cost	-0.024*	-0.027*	-0.022*	-0.035*	-0.038*	-0.032*
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Clarity	0.23*	0.17*	0.31*	0.17*	0.13*	0.22*
	(0.05)	(0.05)	(0.06)	(0.04)	(0.03)	(0.04)
Swimming safety	0.35*	0.29*	0.44*	0.19*	0.14*	0.24*
	(0.06)	(0.05)	(0.06)	(0.04)	(0.03)	(0.05)
Fish abundance	0.08*	0.03*	0.16*	0.14*	0.10*	0.19*
	(0.04)	(0.04)	(0.05)	(0.03)	(0.03)	(0.03)
Safe eating fish	0.26*	0.21*	0.31*	0.17*	0.13*	0.21*
	(0.05)	(0.04)	(0.05)	(0.03)	(0.03)	(0.04)
ln(age)	-2.12*	-2.25*	-2.01*	-1.11*	-1.22*	-0.99*
	(0.21)	(0.20)	(0.21)	(0.21)	(0.20)	(0.22)
Income (in $1000)	0.01*	0.01*	0.01*	0.01*	0.01*	0.01*
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Child	0.38*	0.31*	0.47*	0.47*	0.38*	0.54*
	(0.16)	(0.15)	(0.16)	(0.15)	(0.15)	(0.16)
Nonwhite	0.28	0.18	0.37	0.11	-0.01	0.20
	(0.17)	(0.17)	(0.17)	(0.16)	(0.15)	(0.16)
Delaware River	0.17	0.05	0.27	-0.08	-0.20	0.05
	(0.21)	(0.20)	(0.21)	(0.19)	(0.19)	(0.20)
Delaware Bay	-0.01	-0.17	0.12	-0.19	-0.38	-0.04
	(0.22)	(0.22)	(0.23)	(0.24)	(0.23)	(0.24)
ln(alpha)	-2.08*			-3.57*		
	(0.19)			(0.30)		
Var (cons)	3.97*			3.99*		
	(0.29)			(0.29)		
Sample Size	880			880		

Table: Mixed effects negative binomial model with 1000 draws

$41.6

$28.57

	Contact Trips			Non-contact Trips		
	Mean	Min	Max	Mean	Min	Max
Constant	7.81*	7.34*	8.32*	4.96*	4.49*	5.38*
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Trip Cost	-0.024*	-0.027*	-0.022*	-0.035*	-0.038*	-0.032*
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
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	(0.06)	(0.05)	(0.06)	(0.04)	(0.03)	(0.05)
Fish abundance	0.08*	0.03*	0.16*	0.14*	0.10*	0.19*
	(0.04)	(0.04)	(0.05)	(0.03)	(0.03)	(0.03)
Safe eating fish	0.26*	0.21*	0.31*	0.17*	0.13*	0.21*

Effect on contact water based recreation

Category of Water Quality		Current Conditions	Conditions with Improvement
Clarity of Water		Can see to 1.5 feet deep	Can see to 4 feet deep
Safety for Swimming		7% chance of getting sick	0% chance of getting sick
Abundance & Type of Fish		Fish like Bass, Perch, Catfish occur naturally Fish supported by stocking like Trout, Salmon	Increased abundance of naturally occurring game fish Catch rates expected to double Increased stocking by 50%
Safety of Eating Fish		Eat no more than 3 fish per year caught from these waters.	Safe for unlimited consumption
Ecological Health		Fair	Very Good

12.5% 

6.42M

Effect on contact water based recreation

Category of Water Quality		Current Conditions	Conditions with Improvement
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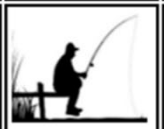
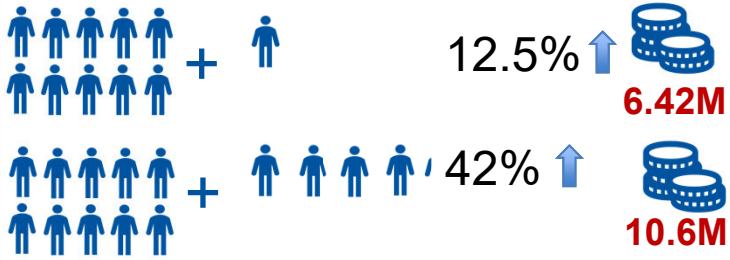
Safety of Eating Fish		Eat no more than 3 fish per year caught from these waters.	Safe for unlimited consumption
Ecological Health		Fair	Very Good



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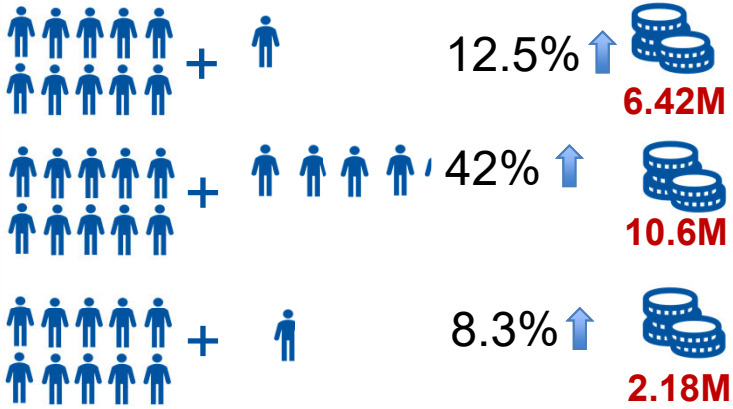

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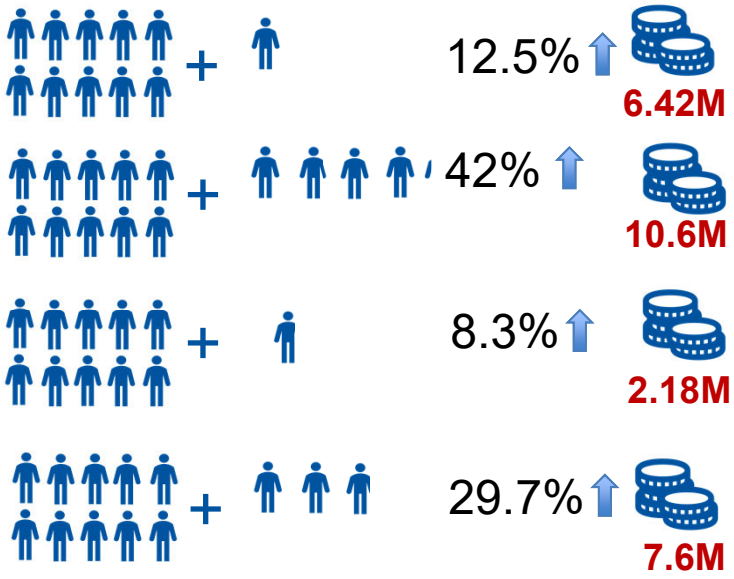

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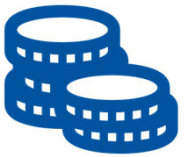
Ecological Health		Fair	Very Good

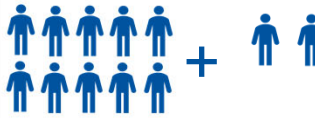
259%



38.4M

Effect on Non-contact water based recreation

Category of Water Quality		Current Conditions	Conditions with Improvement
Clarity of Water		Can see to 1.5 feet deep	Can see to 4 feet deep
Safety for Swimming		7% chance of getting sick	0% chance of getting sick
Abundance & Type of Fish		Fish like Bass, Perch, Catfish occur naturally Fish supported by stocking like Trout, Salmon	Increased abundance of naturally occurring game fish Catch rates expected to double Increased stocking by 50%
Safety of Eating Fish		Eat no more than 3 fish per year caught from these waters.	Safe for unlimited consumption
Ecological Health		Fair	Very Good



18.5% 

9.75M

Effect on Non-contact water based recreation

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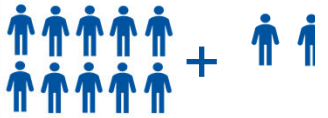
Ecological Health		Fair	Very Good



18.5% ↑ 9.75M

20.1% ↑ 11.2M

Effect on Non-contact water based recreation

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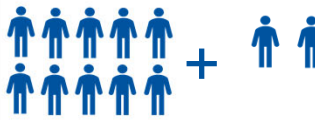

18.5% 9.75M

20.1% 11.2M

15% 2.18M

Effect on Non-contact water based recreation

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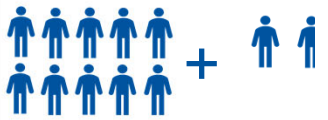

18.5% 9.75M

20.1% 11.2M

15% 2.18M

18.5% 9.75M

Effect on Non-contact water based recreation

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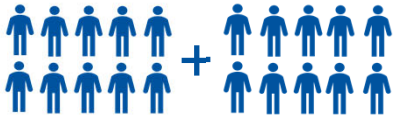
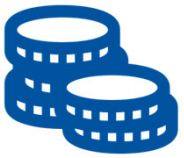


199%



50.36M

Keiser and Shapiro (2019) estimate that it costs about $1.5 million per mile per year to keep a river suitable for fishing.
Brandywine River is about 10 miles long.

So, cost of cleaning is 10 miles*2M/miles= **20M**

Improving catch rate and safety of eating fish together **29.4M**

Thank You !