



# Testing the Effects of Fish Farming on Salmon (TEFFS)

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# Aquaculture vs. Wild Salmon in British Columbia

- Salmon Farming: contributes \$800M annually
- Wild Salmon: formerly contributed > \$1,000M annually (25 yrs ago)
  - *Have we simply replaced one “free” resource with another requiring significant inputs to production?*

*Or...*

- *Can we have our cake and eat it too?*

# TEFFS Research Goals

- 1. Establish whether fish farm exposure reduces the subsequent survival of wild smolts (the key question).***
- 2. Provide clear data for a policy decision by government.***
- 3. Satisfy stakeholders on both sides of the issue that sound science has been used.***
- 4. Demonstrate the validity of high-performance array designs for improved science—and develop support for next-generation arrays.***

# A Philosophical Perspective

## Discovery Science

- ❑ **Observational (Natural History)**
- ❑ **The Search for something "cool & neat" that we don't already know**
- ❑ **"Slow & Steady"**
- ❑ **Assumes (probably correctly) that new facts will advance society**
- ❑ **Can be done using an "ad hoc" telemetry array**

## Experimental Science

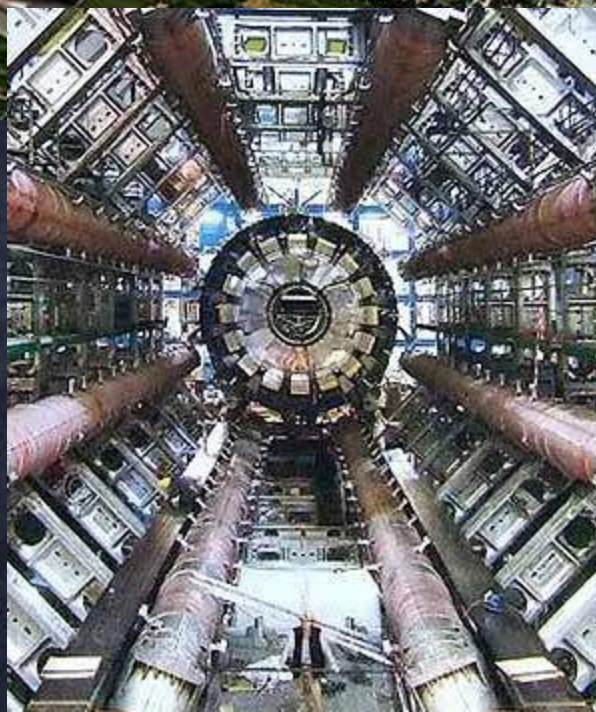
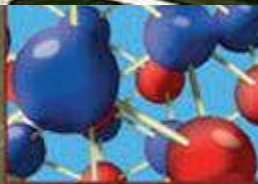
- ❑ **Measurement Based**
- ❑ **Hypothesis Driven**
- ❑ **Needs Crisply Stated Theories to Tear Down (& annoy) your colleagues**
- ❑ **Historically, characterized by very rapid progress from transformational results**
- ❑ **Requires a rigorous, precisely calibrated measurement tool ("The Array")**

# The Power of Scientific Hypothesis Testing

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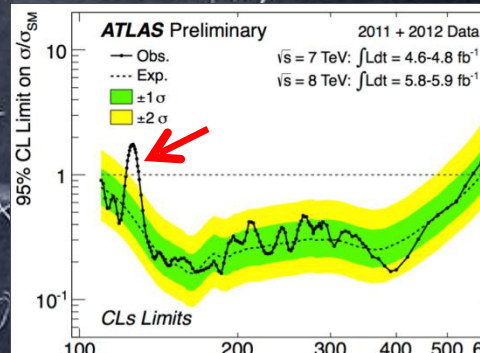
Antoi  
and His Impact o



*Hint: Governments  
Actually Like "Big  
Infrastructure"*



$D + \dots = \frac{1}{4} \dots$   
 $= 2 \dots - i e A \dots$   
 $= 2 \dots$   
 $\dots = 0$



# Influence of multiple dam passage on survival of juvenile Chinook salmon in the Columbia River estuary and coastal ocean

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Edited by Peter M. Kareiva, The Nature Conservancy, Seattle, WA, and approved February 11, 2013 (received for review November 29, 2012)

Multiple dam passage during seaward migration is thought to reduce the subsequent survival of Snake River Chinook salmon. This hypothesis developed because juvenile Chinook salmon from the Snake River, the Columbia River's largest tributary, migrate >700 km through eight hydropower dams and have lower adult return

freshwater smolt survival, smolt-to-adult return rates (SARs) of the aggregate wild Snake River spring Chinook salmon run averaged only 1.1% over the last decade (15), which is well below the recovery target of 4% and the minimum target of 2% (16). Therefore, approximately one in two smolts survive the hydrosystem, but only one

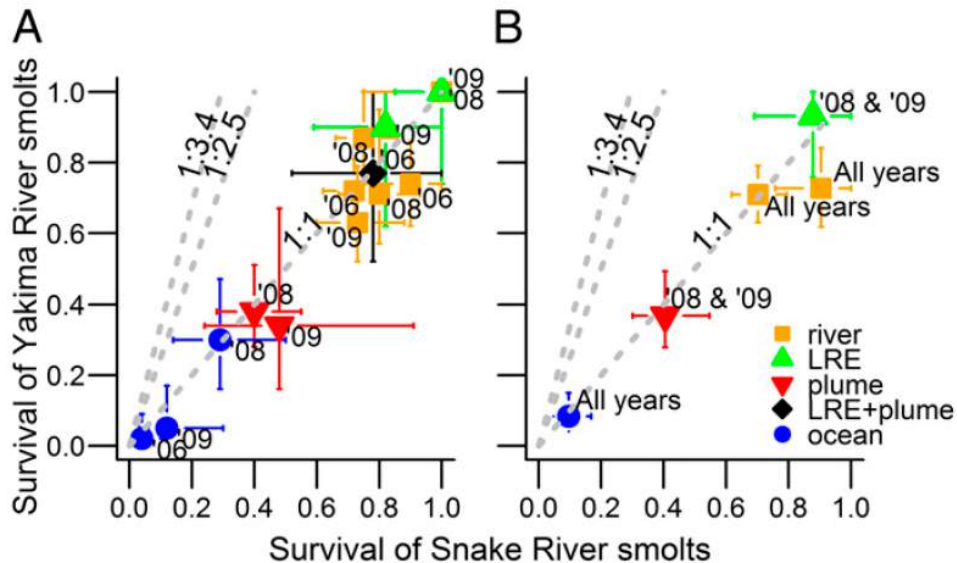


Fig. 2. Comparative survival of acoustic-tagged Snake River and Yakima River spring Chinook salmon smolts in each migration segment (A) in 2006, 2008, and 2009 and (B) in all years combined. The dashed 1:1 line represents



# Estuarine and early-marine survival of transported and in-river migrant Snake River spring Chinook salmon smolts

SUBJECT AREAS:  
ANIMAL BEHAVIOUR  
ECOLOGY  
ZOOLOGY  
OCEANOGRAPHY

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***Well-run arrays  
can be multi-  
purpose***

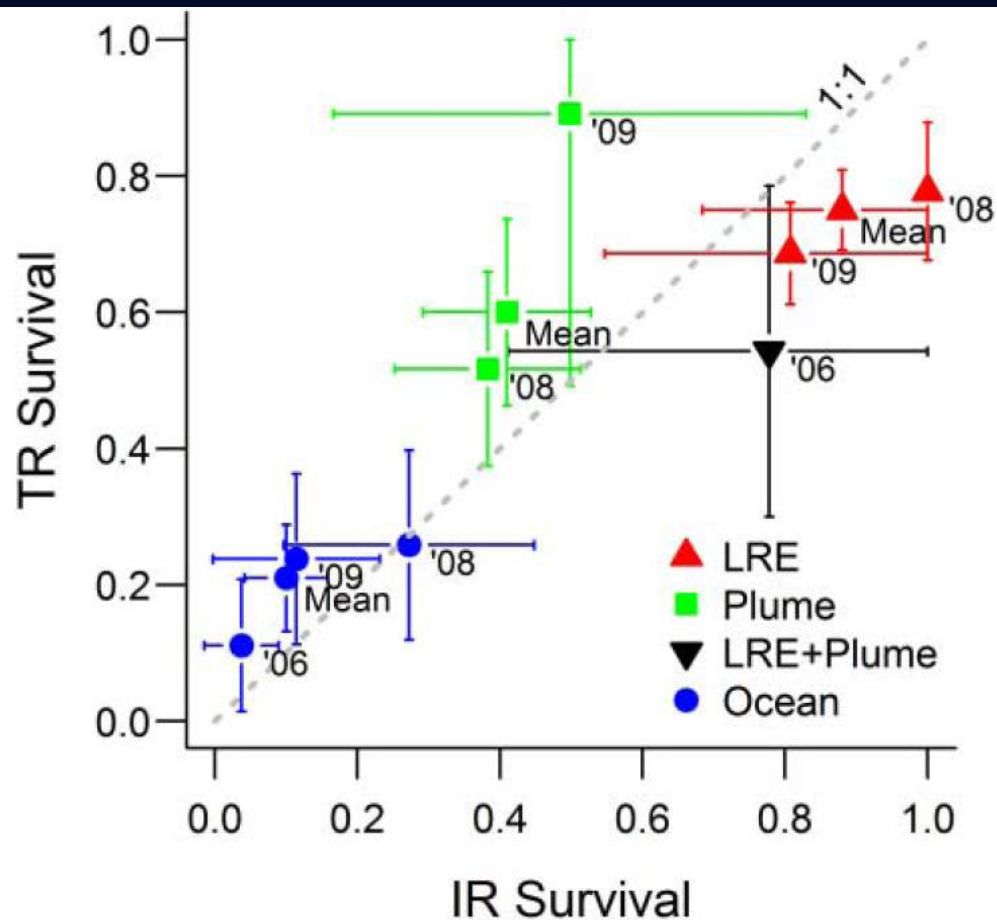


Figure 3 | Comparative survival of in-river (IR) and transported (TR) Dworshak hatchery spring Chinook smolts (error bars are 95% confidence intervals). The dashed 1 : 1 line represents equal survival of both treatment types; data points falling below the line indicate lower survival of TR fish. The Astoria sub-array was not deployed in 2006;



# “POST” as a Large-Scale Constrained Optimization Problem

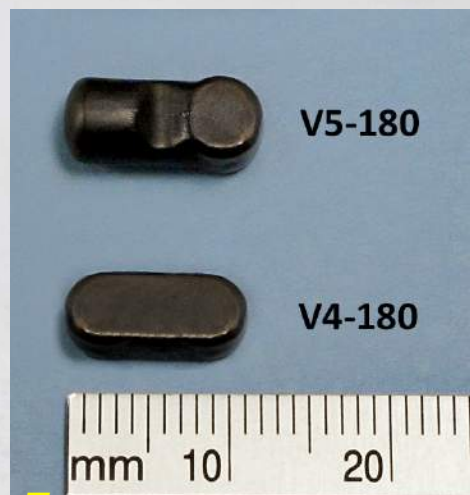
**MAXIMIZE Statistical (Scientific) Precision {Receiver Number, Receiver Geometry, Tag Numbers, Tag Programming}**

**Subject to:**

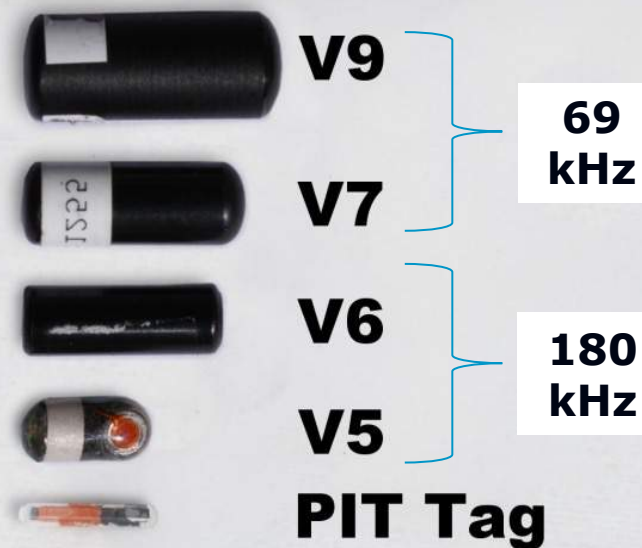
- Minimizing Overall Cost (Tags+Array)
- Maximizing Biological Information
- Maximizing Tag Lifespan

- ✓ Minimizes capital cost of the array
- ✓ Reduces acoustic tag costs
- ✓ Reduces use of animals (Ethics & staff time)
- ✓ Increases number of populations under study

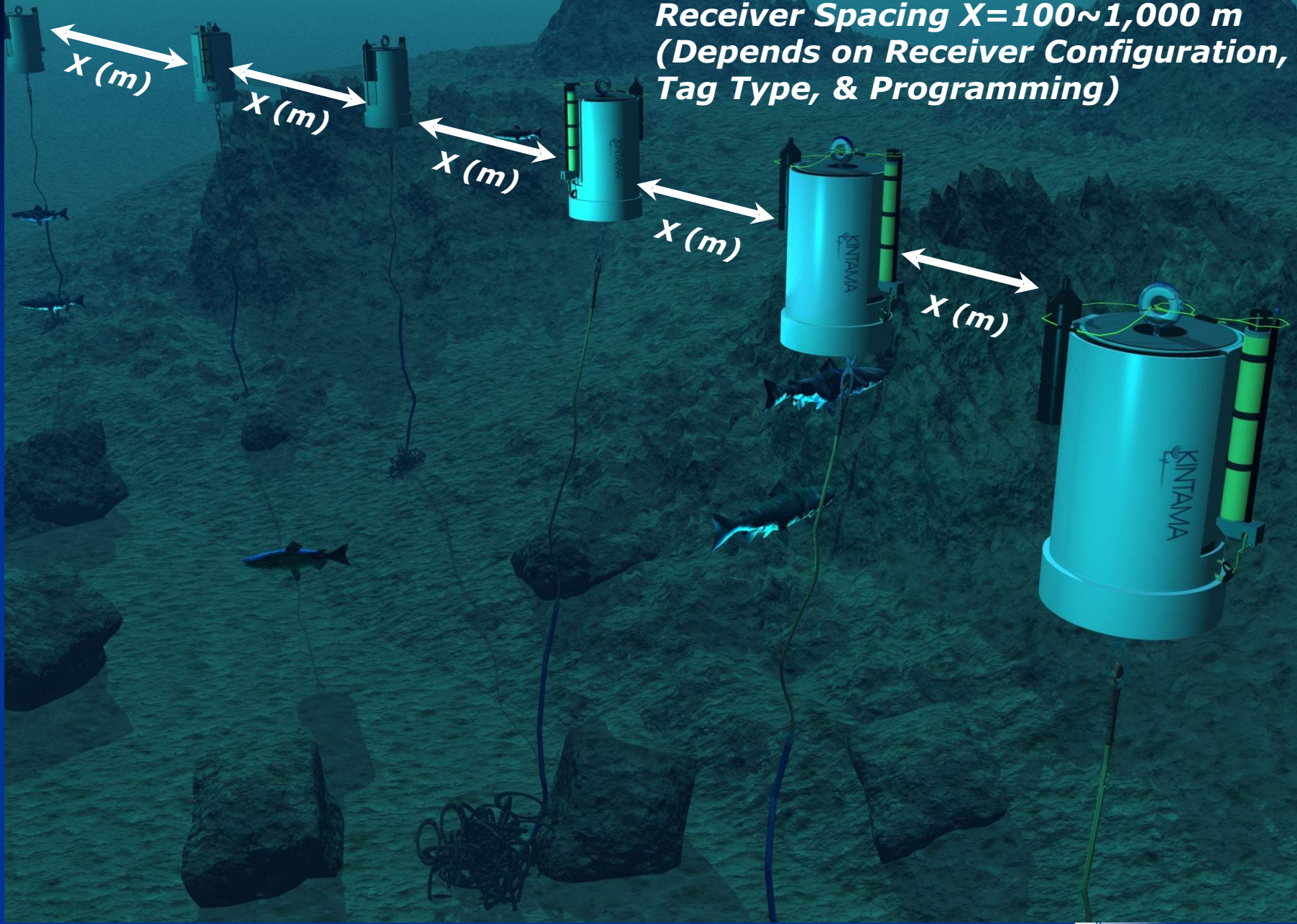
# Biological Accuracy & Scientific Precision: PIT & Acoustic Tag Smolt Survival

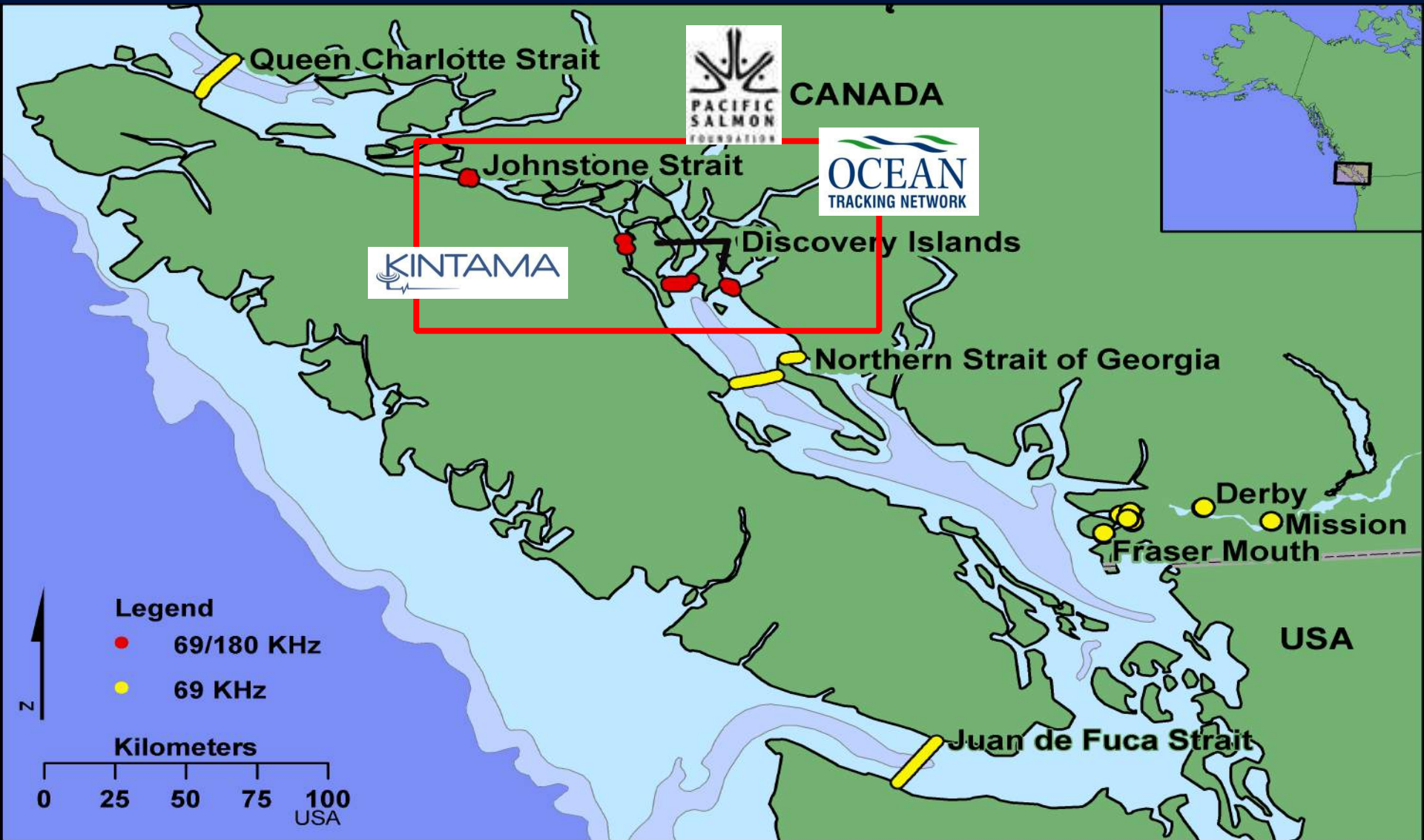


From:  
[www.vemco.com](http://www.vemco.com)



**Receiver Spacing  $X=100\sim 1,000$  m  
(Depends on Receiver Configuration,  
Tag Type, & Programming)**







- Active salmon farms
- Inactive farms
- Johnstone Strait sub-array
- 2015 Discovery Is. sub-array

V9 (69 kHz ~400m)

V7 (69 kHz ~300m)

V4 (180 kHz ~100m)

# DISCOVERY PASSAGE

Scale 1:40 000 (50'15"N) Echelle

Projection: Mercator

LETINGS are in meters and are reduced to Chart Datum (lowest normal tide), which at Campbell Head is 2.4 meters below Mean Water Level.

SOUNDINGS, spot elevations and contours are in fathoms above High Water. Large fathoms are indicated by an "F" and are in the inner part of the passage. Small fathoms are in the outer part. Small fathoms are in the outer part. Small fathoms are in the outer part.

HORIZONTAL DATUM: North American Datum 1983 (NAD 83), which is equivalent to WGS 84.

SOURCES: The hydrographic data are shown on the chart. The bathymetric data are shown on the chart. The bathymetric data are shown on the chart.

LES PROFONDEURS sont en mètres et sont réduites au datum (la plus basse marée normale) à Campbell Head, qui est de 2,4 mètres au-dessous du Niveau Moyen des Eaux.

LES PROFONDEURS, les hauteurs et les courbes sont en mètres au-dessus de l'eau haute. Les grandes profondeurs sont indiquées par un "F" et sont dans la partie intérieure du passage. Les petites profondeurs sont dans la partie extérieure. Les petites profondeurs sont dans la partie extérieure.

DATE DE LA CHARTRE: Système de référence géodésique de l'Amérique du Nord 1983 (NAD 83), qui est équivalent au WGS 84.

SOURCES: Les données hydrographiques sont indiquées sur la carte. Les données bathymétriques sont indiquées sur la carte. Les données bathymétriques sont indiquées sur la carte.

DISCOVERSON 01

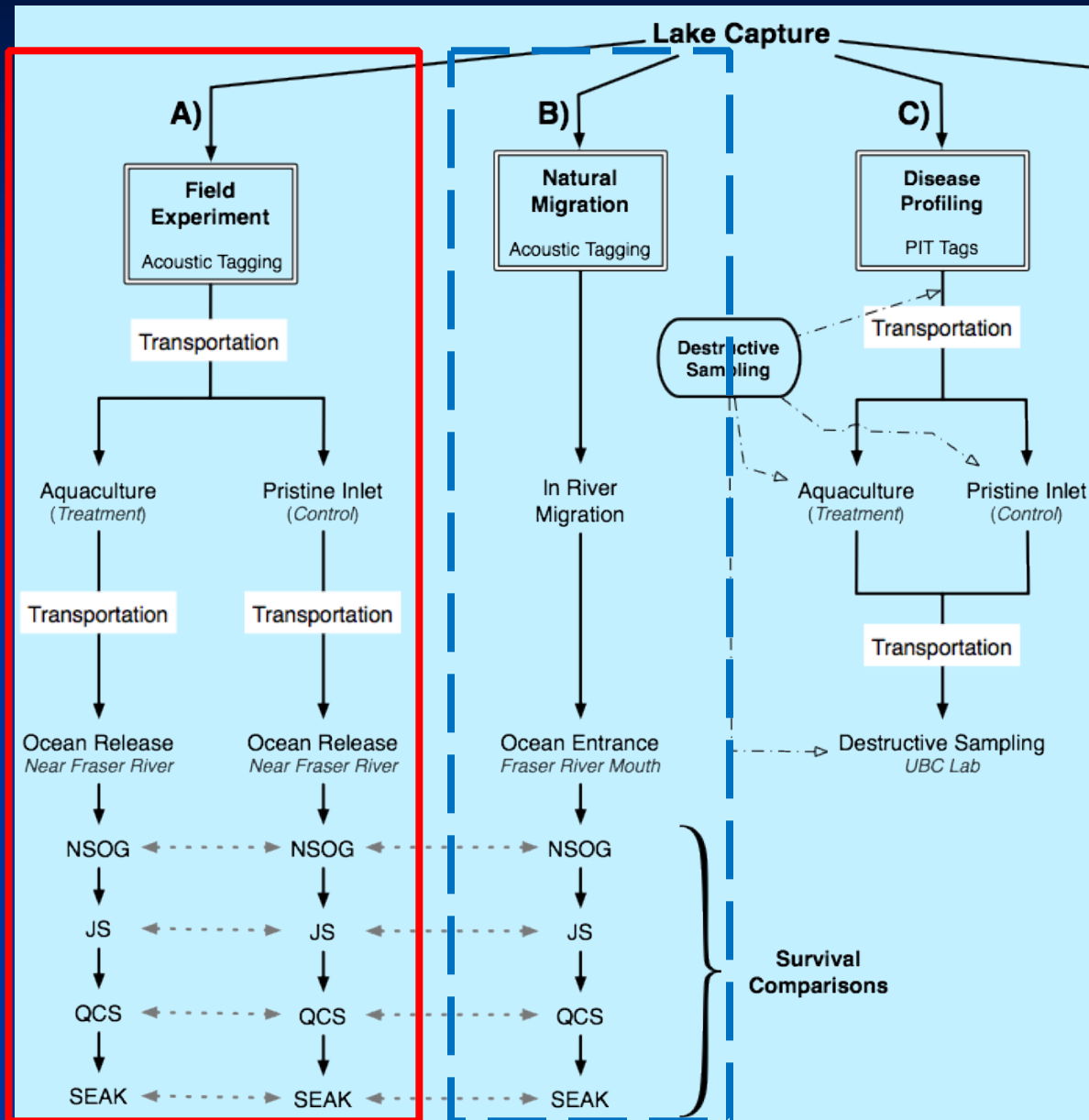
C 089.3° T  
D 2.089 km

# TEFFS Experimental Test Overview



- Capture & tag smolts
- Treatments
  - Fish farm
  - Control
- Move to release location
- Compare subsequent survival
- $H_0: S_{\text{Treatment}} = S_{\text{Control}}$

# TEFFS Proposed Experiment(s)





## Perspective

# Improving Bioscience Research Reporting: The ARRIVE Guidelines for Reporting Animal Research

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**1** The National Centre for the Replacement, Refinement and Reduction of Animals in Research, London, United Kingdom, **2** School of Veterinary Science, University of Bristol, Bristol, United Kingdom, **3** School of Biological Sciences, University of Bristol, Bristol, United Kingdom, **4** National Heart and Lung Institute, Imperial College London, United Kingdom, **5** Centre for Statistics in Medicine, University of Oxford, Oxford, United Kingdom

Schulz *et al. Trials* 2010, **11**:32  
<http://www.trialsjournal.com/content/11/1/32>



## RESEARCH

## Open Access

## CONSORT 2010 Statement: updated guidelines for reporting parallel group randomised trials

Kenneth F. Schulz<sup>1\*</sup>, Douglas G. Altman<sup>2</sup>, David Moher<sup>3</sup>, the CONSORT Group

**Abstract**

The CONSORT statement is used worldwide to improve the reporting of randomised controlled trials. Kenneth Schulz and colleagues describe the latest version, CONSORT 2010, which updates the reporting guideline based on new methodological evidence and accumulating experience.

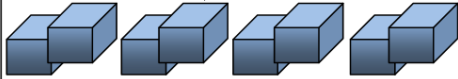
To encourage dissemination of the CONSORT 2010 Statement, this article is freely accessible on [bmj.com](http://bmj.com) and will also be published in the *Lancet*, *Obstetrics and Gynecology*, *PLoS Medicine*, *Annals of Internal Medicine*, *Open Medicine*, *Journal of Clinical Epidemiology*, *BMC Medicine*, and *Trials*.

## Collect and tag smolts

(Random allocation to treatments)

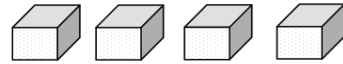
Acoustic & PIT tag

PIT tag



**Survival Analysis**

(N=21 smolts / tank)



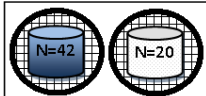
**Physiological/Genomic Sampling**

(N=20 smolts / tank)

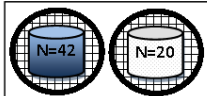
Recovery (24 hrs)

Transition to 25‰ salt water (24 hrs)

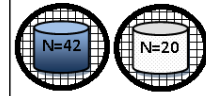
**Transport**



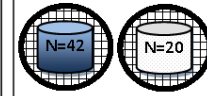
Fish Farm Area 1



Fish Farm Area 2



Control Site 1



Control Site 2

REPLICATE 3 TIMES

**7 day Exposure**

Transport and Release Acoustic

Euthanize PIT tagged smolts

**Survival Analysis**

**Physiological/Genomic Analysis**

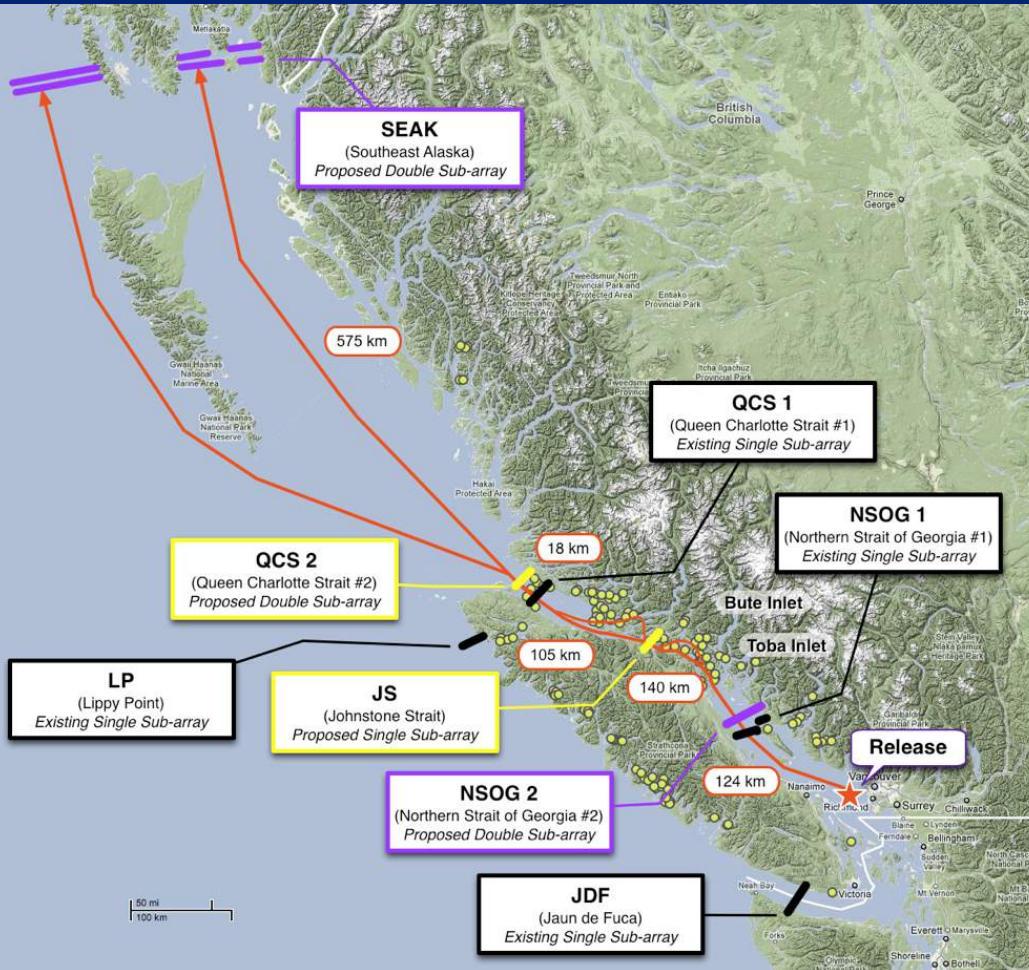
# Smolt Handling, Transport, & Experimental Allocation

# Statistical Power Analysis

# Statistical Power Analysis

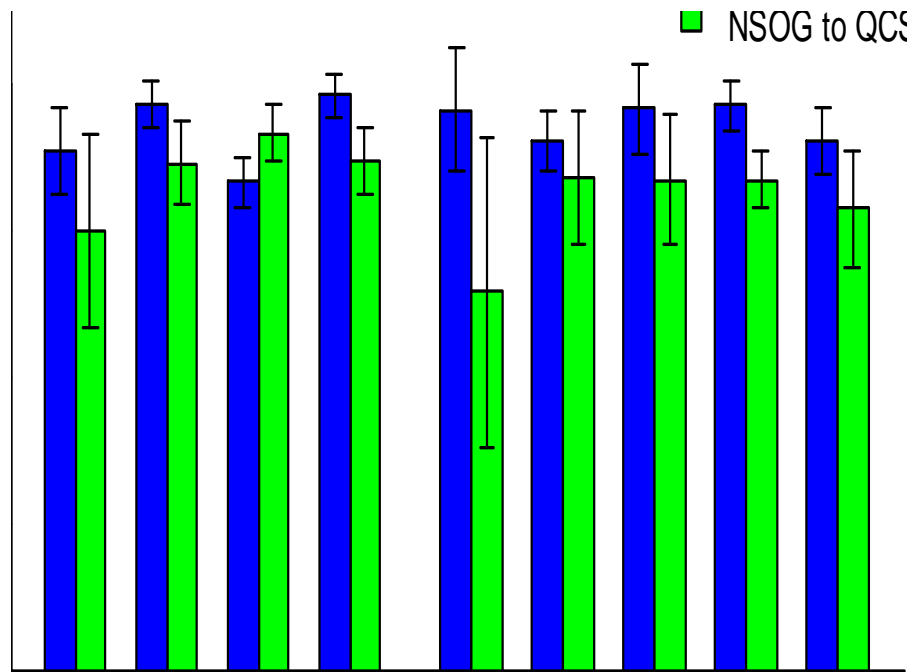
- Considered the manipulative field experiment.
- Looked at *plausible* extensions of the current OTN/POST array (3 sub-arrays or “lines”).
- Looked at power to detect differences in weekly survival.
- Ran calculations for a series of possible survival differences.

# Plausible Receiver Configurations Investigated



- Black = Existing Arrays
- Yellow = Proposed
- Purple = Considered
- Double receiver arrays allows absolute survival in the final segment to be estimated.

# Sockeye Survival by Area



❑ *Survival rates in the Discovery Passage area are lower than in the Strait of Georgia.*

❑ *Not reported in 2009 CJFAS paper, because we did not scale survival for migration time.*

❑ *Several possible causes for lower Discovery Passage survival rates:*

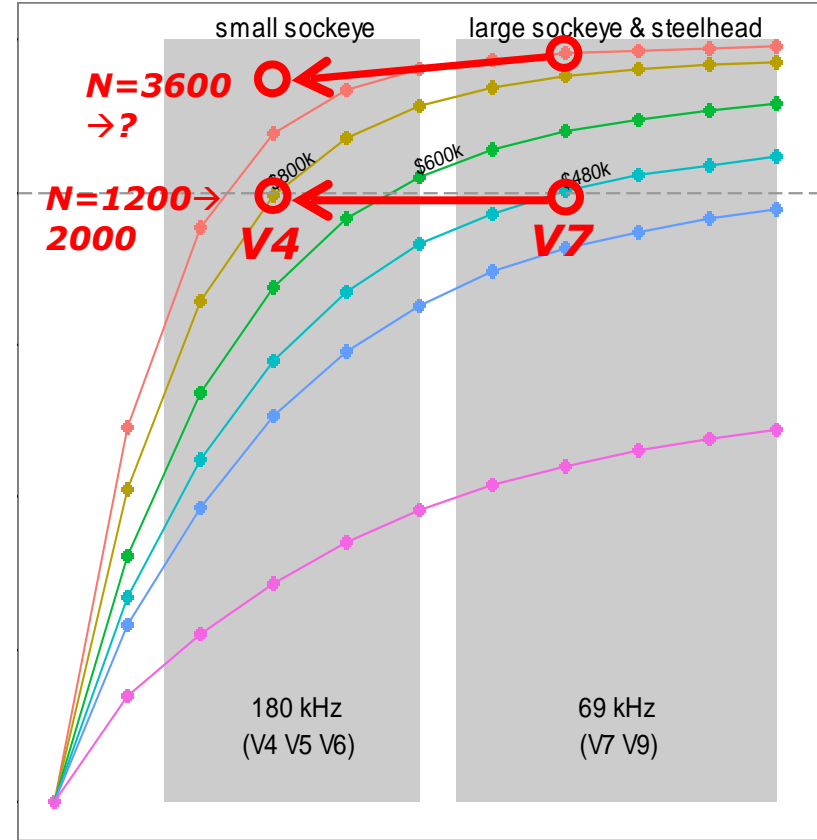
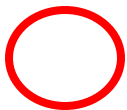
- *Fish Farms (Disease)?*
- *More predators?*
- *Weakening tag battery?*
- *Something else?*

# Statistical Power



Tag Detection Efficiency

\$0.5M in tags



# Sentinel™ Tracking Array

KINTAMA



0 250 500 750 1,000  
Kilometers



KINTAMA  
KINTAMA



**Questions?**