Occupancy sampling approaches for monitoring lamprey

October 27-29, Tualatin National Wildlife Refuge

Welcome

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Day 1 Classroom

Protocols for sampling, implementation and analysis

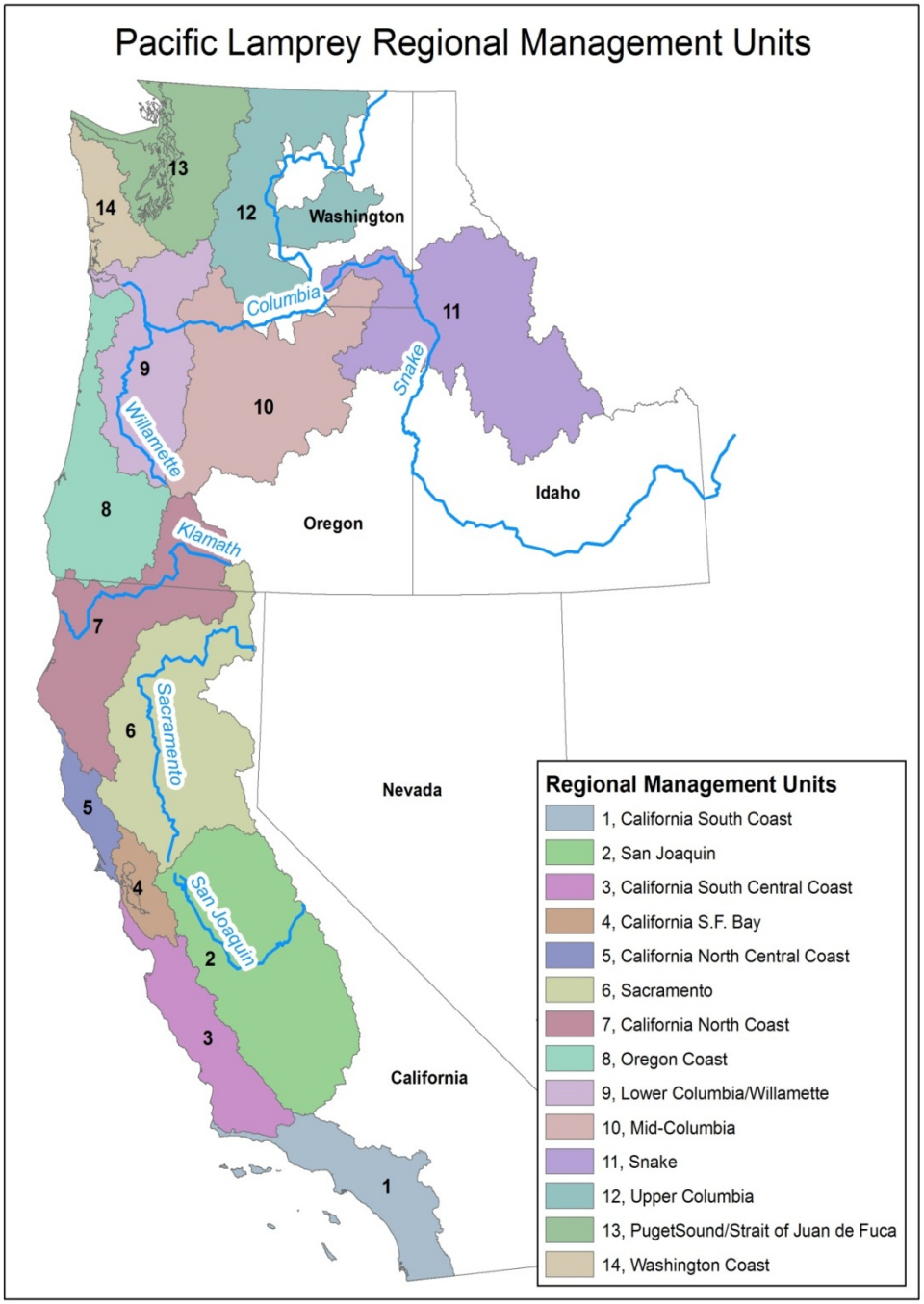
- Welcome – Tualatin Refuge
- Introduction – Purpose of the Workshop
- Sample Framework
- Sample Effort
- Field Protocols and Techniques
- Sample Units and Occupancy Examples
- Big Picture - Lamprey Conservation Initiative
- Tualatin Basin Overview and Issues

Purpose of the Workshop

- Need cost effective way for collecting demographic information for status - distribution
  - Pacific Lamprey Assessment and Template for Conservation Measures
  - Informs changes in status and threats
  - Informs efficacy of restoration actions
- Large gaps in distribution information
- Limited resources for sampling
- Collaborative collection of occupancy data to inform changes in distribution at three spatial scales

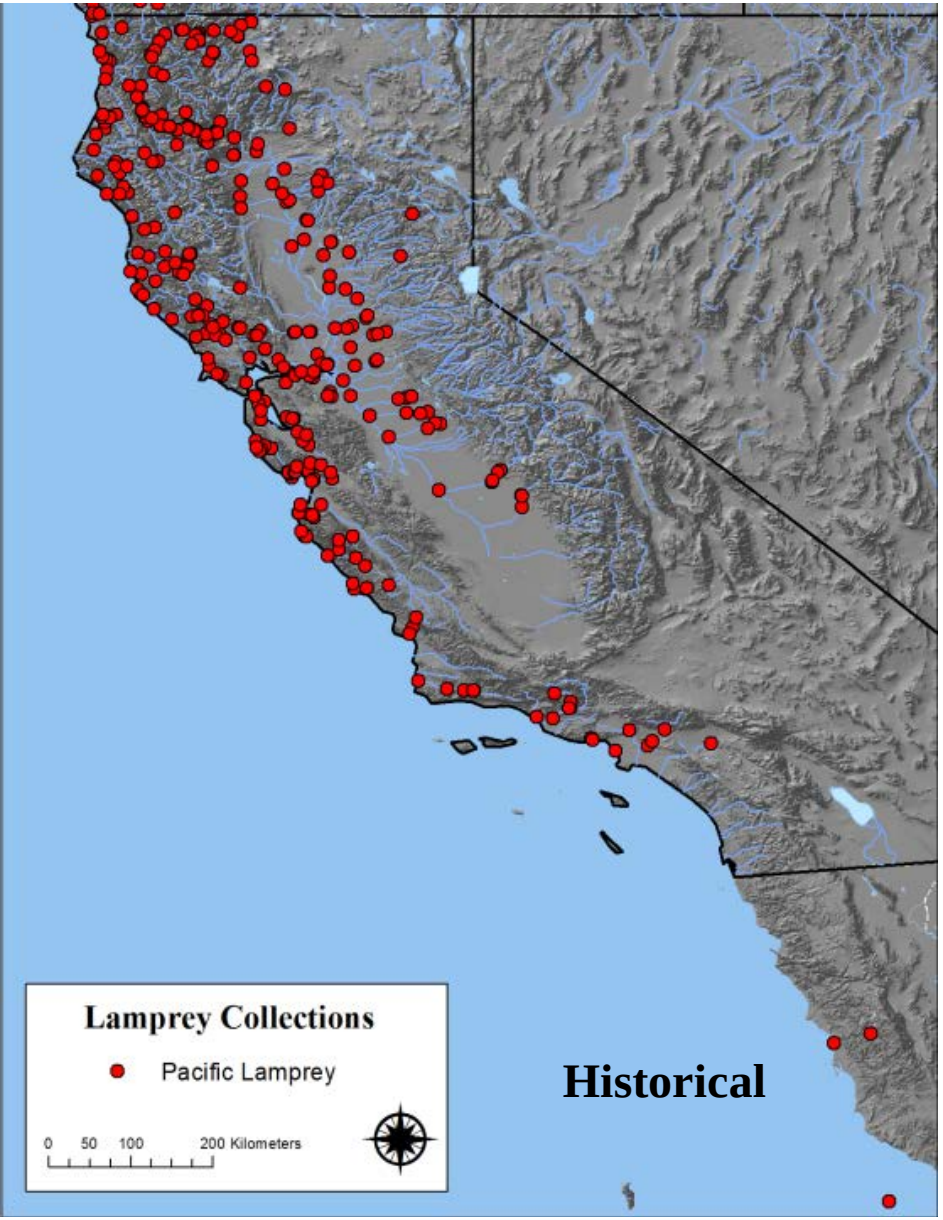
Three Spatial Scales

1. Regional Management Units (RMUs)
2. 4th level Hydrologic Unit Code (HUC)
   - The first two levels focus on evaluating changes in distribution at those spatial scales
3. Finer scale analysis units within each 4th level HUC
   - The third level would help to inform finer scale issues such as effectiveness of restoration actions or informing our knowledge on detection probabilities for lamprey

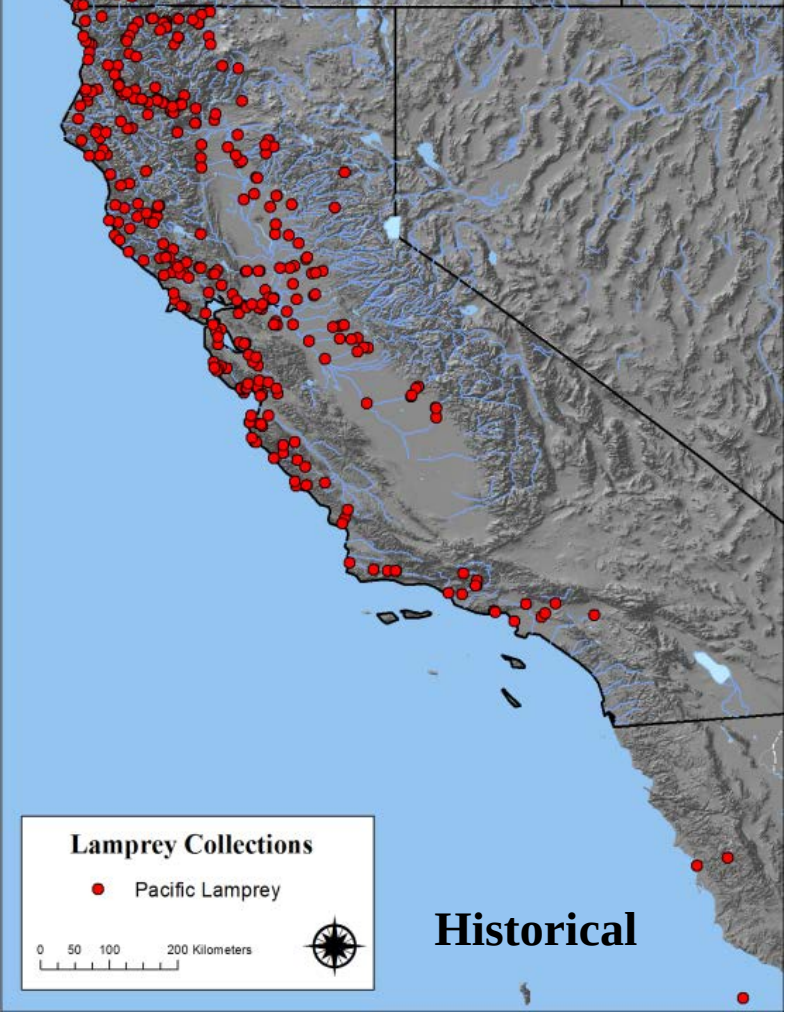


1. RMU

- Identify historic and current distribution in each RMU to detect changes in distribution to evaluate the efficacy of conservation actions across the RMU
- Determine if occupancy of HUCs in an RMU have changed between assessment periods

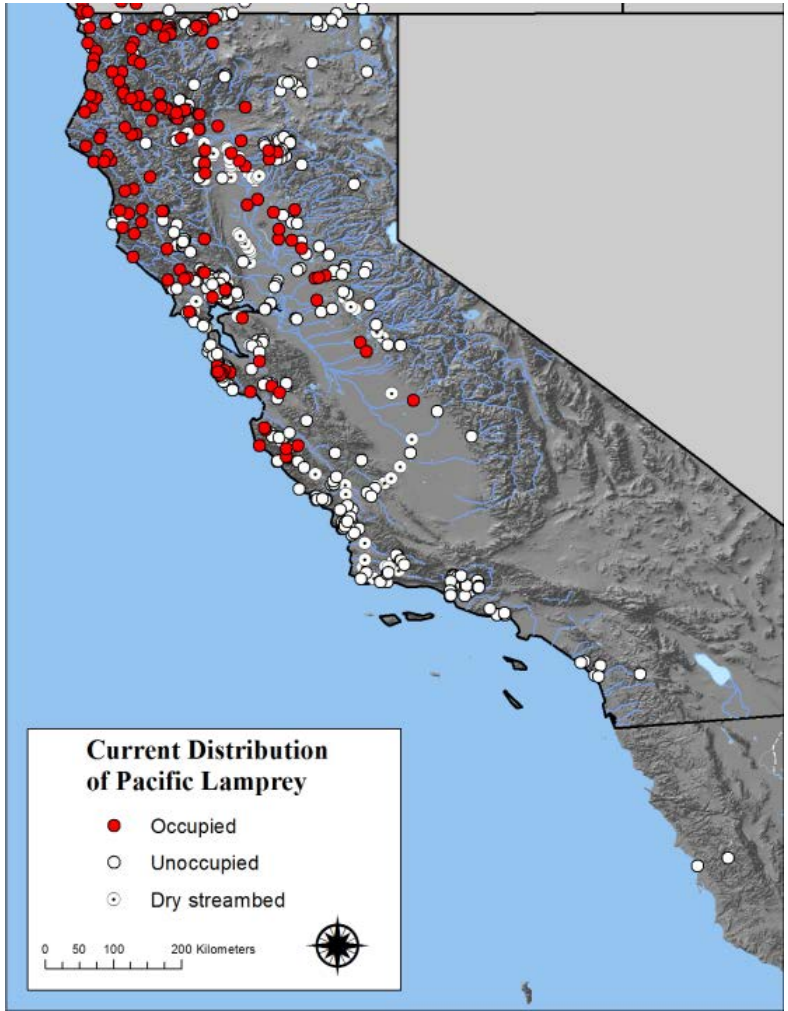


Determine the change in distribution within each 4th level HUC to update the risk status assessment and evaluate the efficacy of specific suites of actions (e.g., passage improvement projects)



Example of how distribution changed from known occupancy; however,

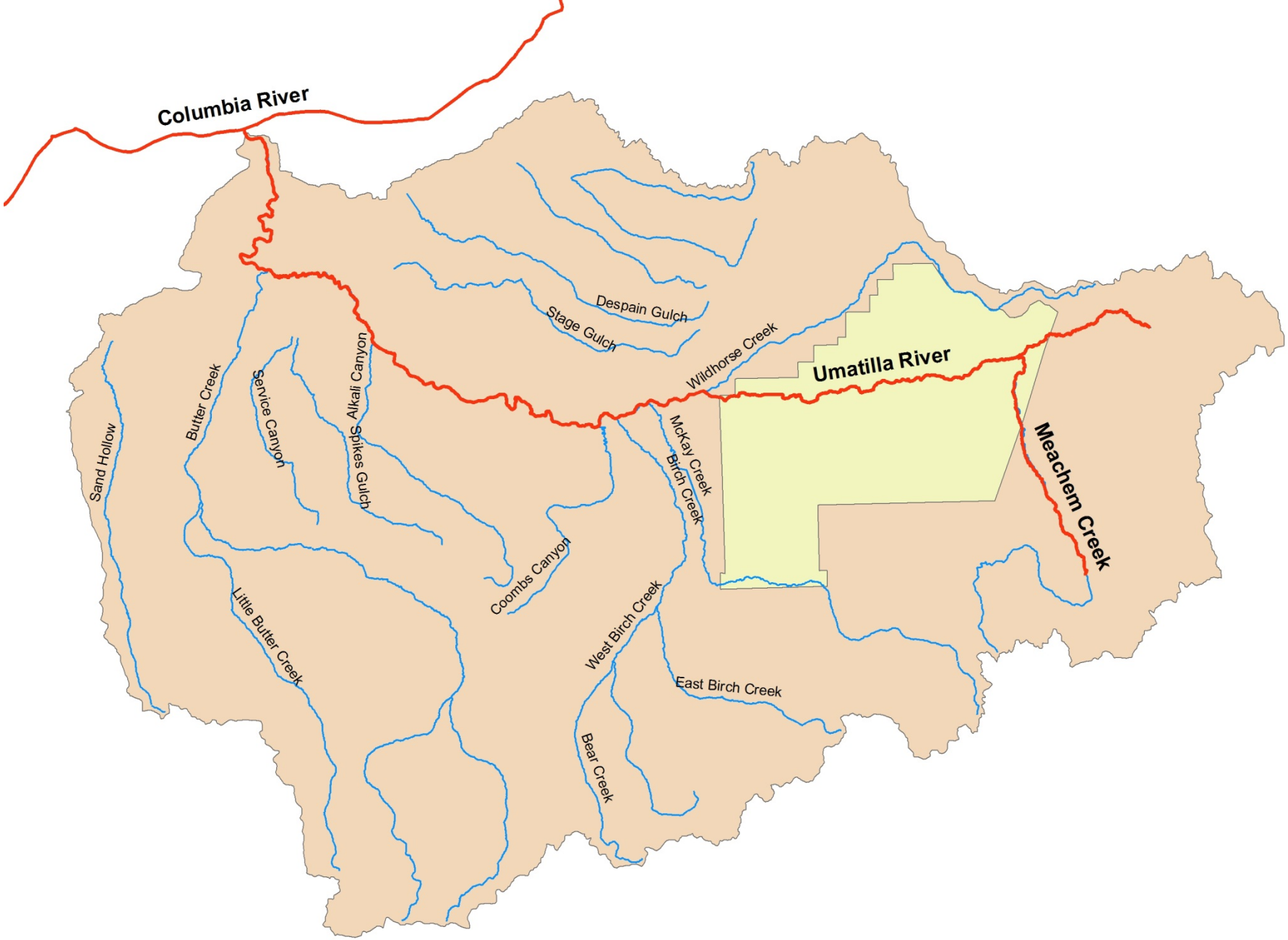
- No data for many points
- Zeros
- Non lamprey targeted surveys
- Non probabilistic sampling

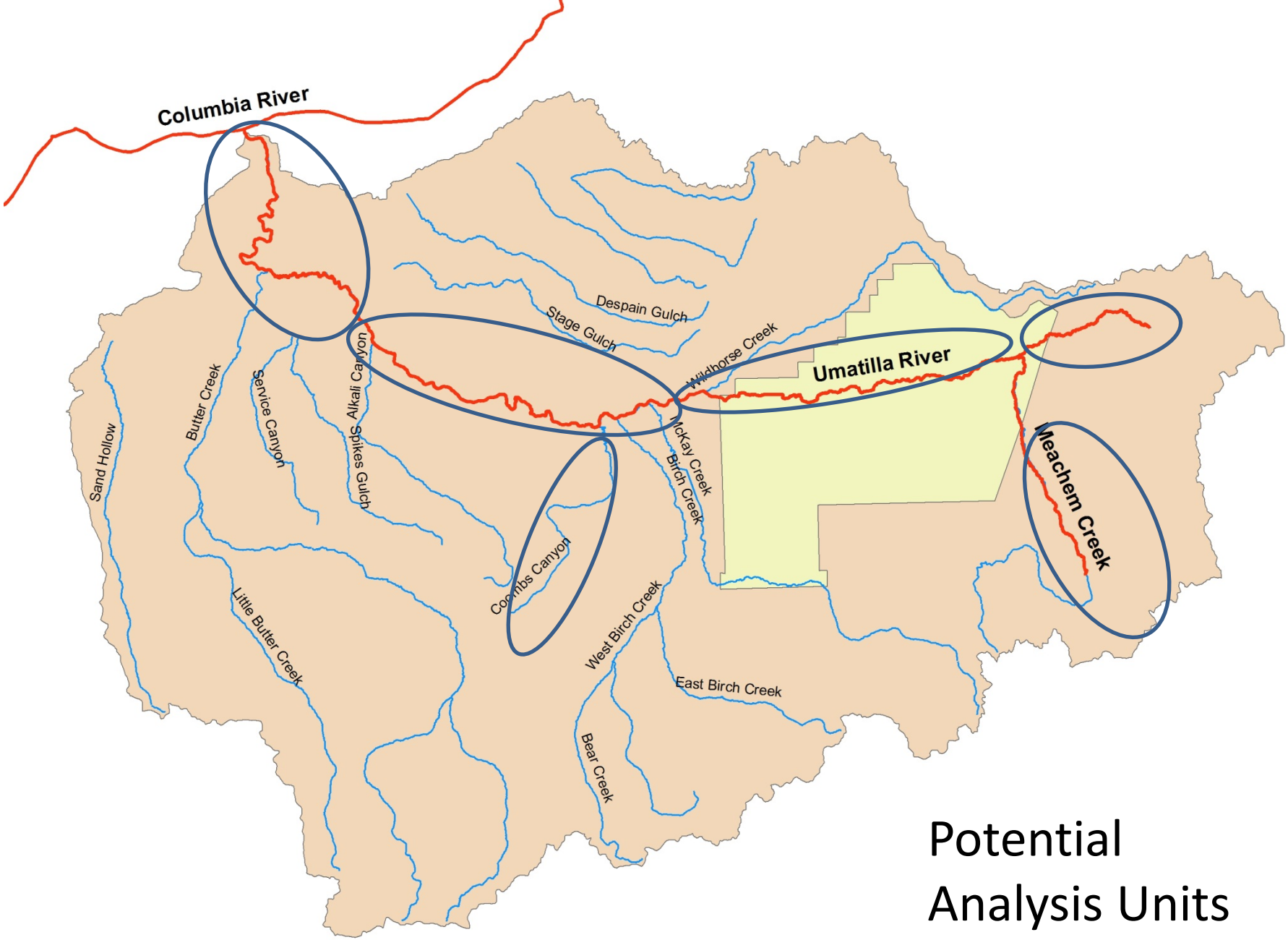


Sampling design focuses on filling in unknown and uncertain non-occupancy

2. 4th Level HUC

- Determine if the distribution within a 4th level HUC changes between assessment periods
  - Use analysis units, wadeable subunits of the HUC, to capture the changes in distribution from the historical to current period
  - Analysis units can be 5th level HUCs or smaller units to capture distribution changes
  - To estimate distribution we probabilistically sample each of the analysis units for occupancy
  - Distribution is the spatial arrangement of occupied analysis units

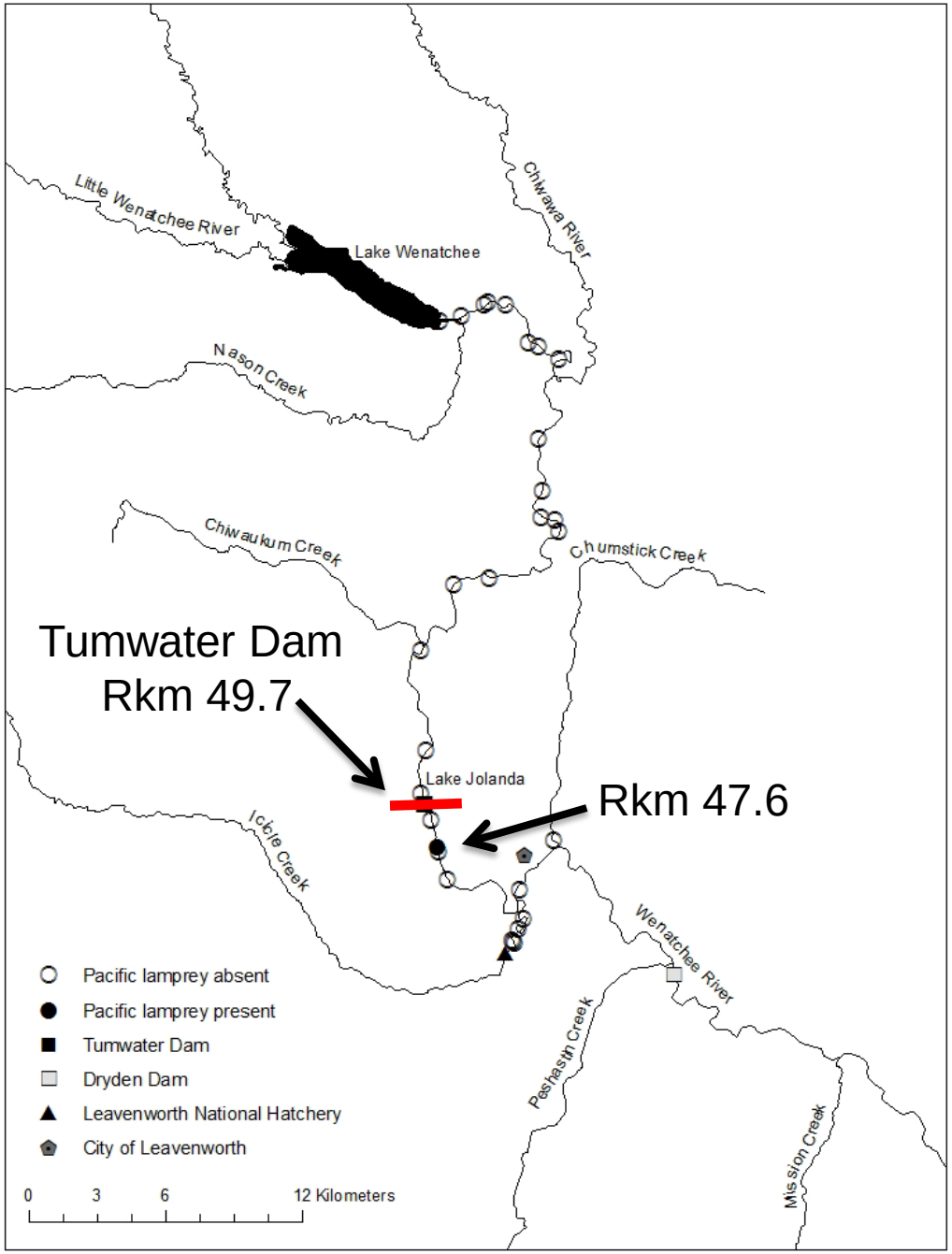

Columbia River
Umatilla River
Meachem Creek
Despain Gulch
Stage Gulch
Wildhorse Creek
Alkali Canyon
Spikes Gulch
Service Canyon
Butter Creek
Sand Hollow
Little Butter Creek
Coombs Canyon
McKay Creek
Birch Creek
West Birch Creek
East Birch Creek
Bear Creek



Potential
Analysis Units

3. Intensively Monitored Fine Scale Analysis Units

- Evaluate lamprey distribution and abundance
  - Determine how many larvae were produced by translocated adults
  - Evaluate a site specific conservation action
- Contrast treated and untreated areas by measuring abundance, density or occupancy (at a small spatial scale)
- Analysis units for 4th level HUC occupancy overlap with the analysis units for the intensive monitoring in wadeable streams



Designed to look at efficacy of action or actions

Workshop Goals

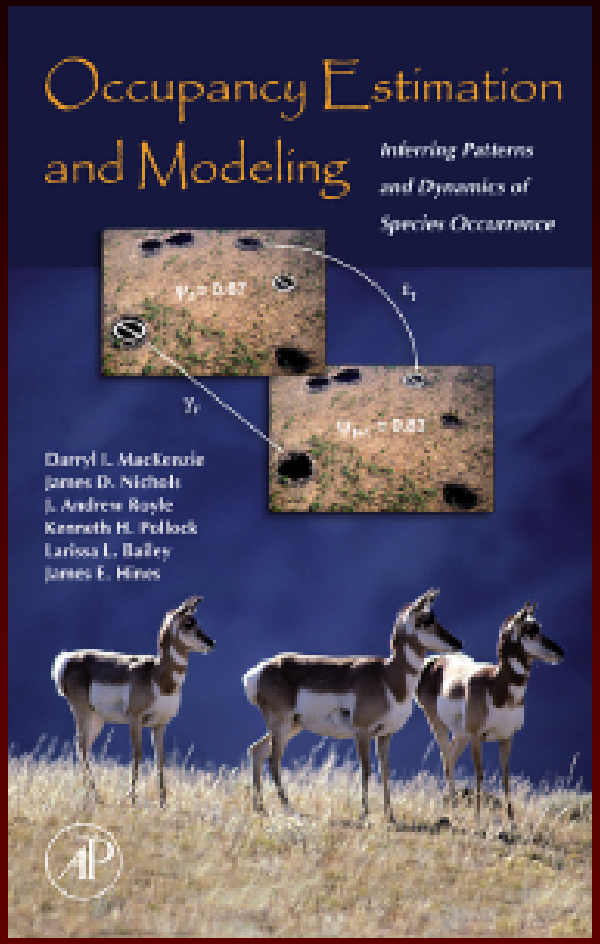
- Provide instruction for sampling framework applied at these three scales
- Identify sampling effort when you continue to get zeros
- Learn how collective efforts will help inform distribution and status and improve efficiency of sampling

Sample Framework

Jeff Jolley – USFWS, CRFPO

What is occupancy?

- **Occupancy: locations where a species is present (proportion of area, patches, or sample units that are occupied)**
- **Why occupancy?**
  - **Estimating changes in absolute abundance or density is logistically impossible**
  - **Species is cryptic, rare, and/or patchily distributed**
- **Capture probability - key concept for making robust inference about abundance, survival, and other parameters (MacKenzie et al. 2006).**
- **Ignoring detectability produces unreliable inferences**
- **Concepts of occupancy sampling have been around for awhile but have only recently gained a wider application in the natural resources**



Why occupancy?

- It is a natural state variable in questions of distribution and range
- Surrogate for abundance
- Less effort required especially when species is rare
- Efficient

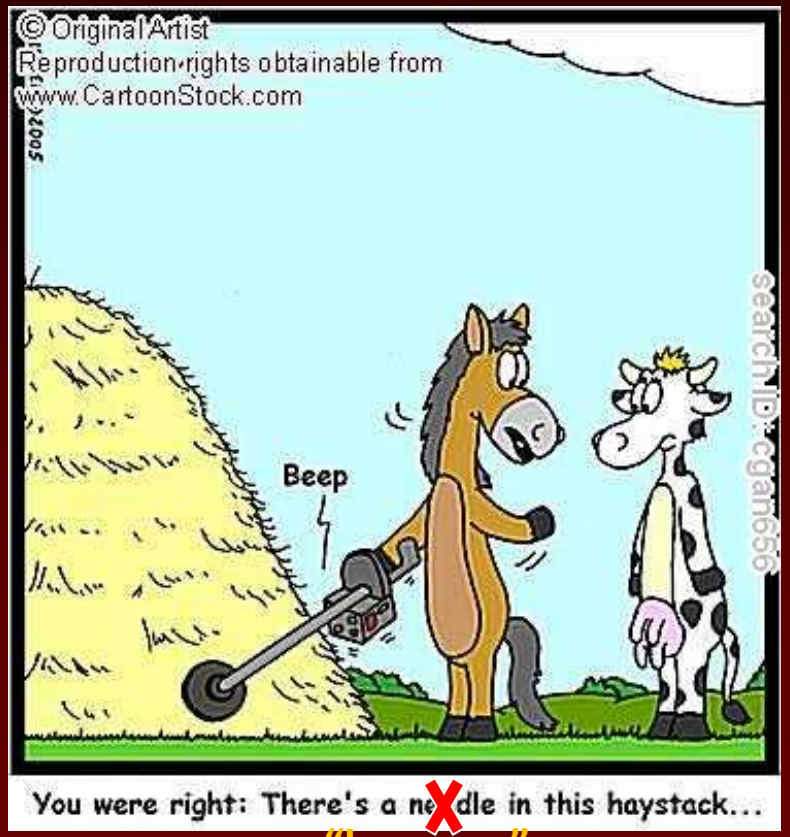
Who uses occupancy?

- Amphibians –focused discussion on methodology started (USGS ARMI)
- Birds (spotted owl)
- Bull trout (Isaak et al. 2009; http://www.fs.fed.us/rm/pubs/rmrs_gtr224.pdf)

What is occupancy?

Important concept! Present is present. When is it truly absent and what can you say about this?

The problem of Detection Probability



"lamprey"

Sample	Actual: Present	Actual: Absent
Present	Occupied	Error 'Incorrect Identification'
Absent	Error 'Non-detection'	Unoccupied

Sample framework for an occupancy-based approach

1. What is the question?
2. What do you care about?
3. What is your area of interest (e.g. a lake, a river, a HUC4, a county) – in-depth discussion of this to come…
   - What is your "universe"?
4. Where will you look (sampling unit; entire lake?, entire stream?, 1 m^2 quad?, 50-m reach of stream)?
5. How do you select your subset of sampling units? (GRTS)
6. How hard to you look? ….or when do you STOP looking?
7. What is your confidence in your result (especially when you fail to detect the species)?

GRTS Procedure
Generalized random tessellation stratified

GRTS Procedure

- EPA/EMAP approach (Stevens and Olsen 2004)
- Can be multiple dimensions
- For random samples of size *n*, the *n* samples will be spatially balanced ("spread out") – the procedure uses reverse hierarchical ordering to achieve the spatial balance
- Additional samples can be added – doesn't compromise the spatial balance (landowner denial, dry sites, ship anchored at the site)

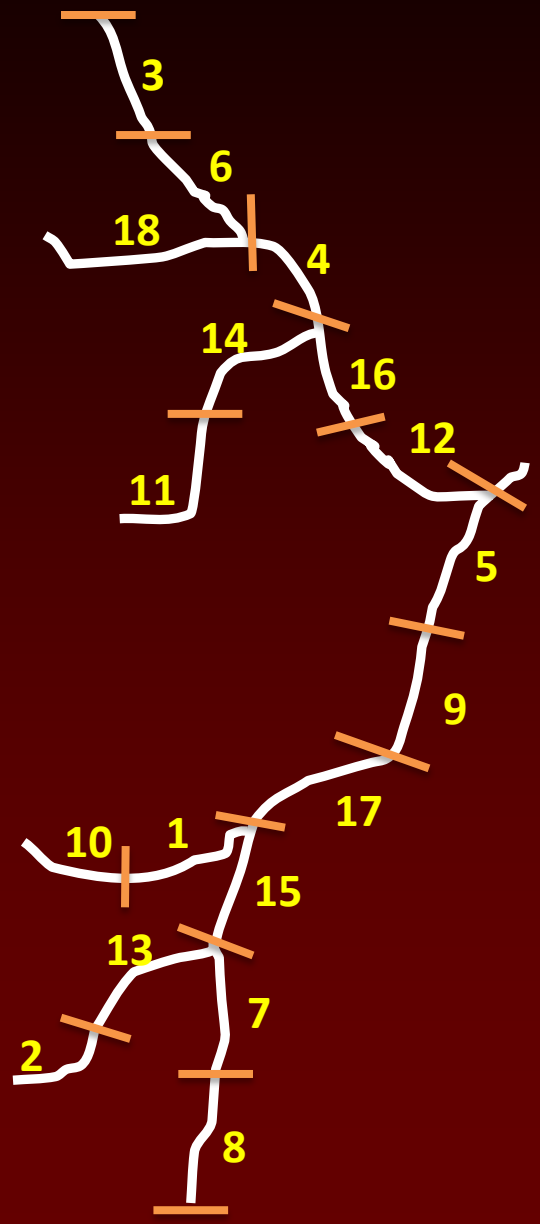
GRTS Procedure

```
# Load the spsurvey library
library(spsurvey)
# Read the attribute table from the shapefile
att <- read.dbf("WillowCreek_Drainage")
# Equal probability GRTS survey design
cat("\nEqual probability GRTS survey design\n")
# Create the design list
EqualdsgN <- list(None=list(panel=c(Panel_1=676), seltype="Equal"))
# Create the GRTS survey design
cat("\nThe following information is printed by \"grts\" while it is executing:\n")
EqualSites <- grts(design=EqualdsgN,
                   DesignID="WillowCreek_GRTS",
                   type.frame="linear",
                   src.frame="shapefile",
                   in.shape="WillowCreek_Drainage",
                   att.frame=att,
                   prjfilename="WillowCreek_Drainage",
                   out.shape="WillowCreek_GRTS")
```

Example area of interest: Hockalugee Creek Basin

Framework

1. Map exercise
    1. Divide area into 50 m stream reaches
    2. Obtain the UTMs for each reach
2. Analysis exercise (GRTS)
    1. Generalized, random, tessellated, stratified sample
    2. Statistically robust and spatially balanced
3. Select sampling reaches (lowest ordered from GRTS exercise
4. Determine your sample effort….



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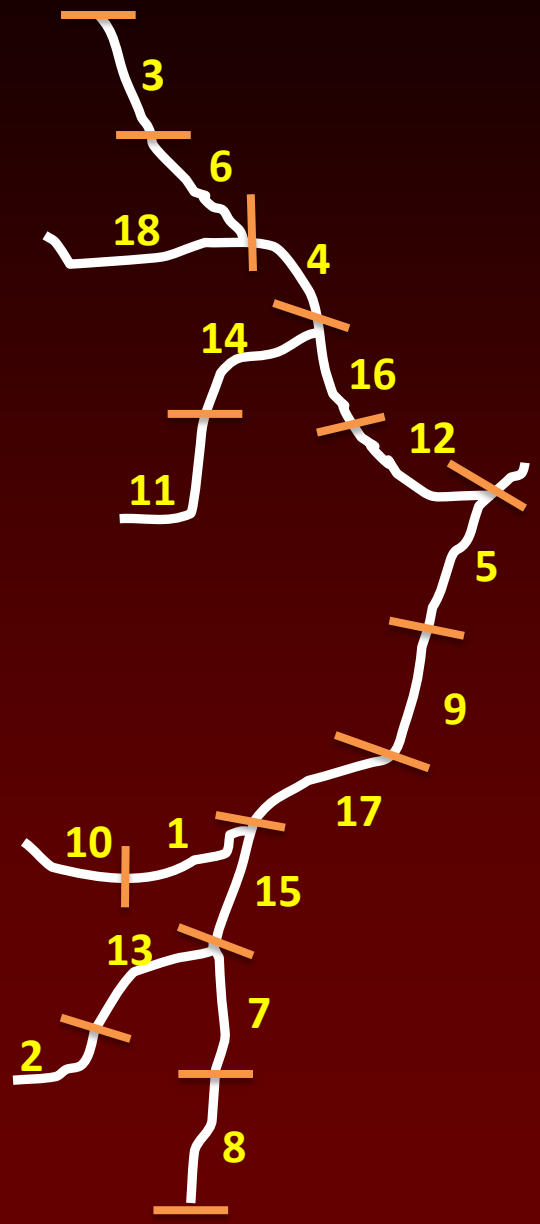


What is occupancy?

- Simplest form: It is present/absent - based (0s and 1s)
- What will call a “0” and what will you call a “1”?
  - Somewhat arbitrary and imperfect – but attempt to represent something biologically
  - We will use two possible criteria
    - 2 larvae are found that are at least 20 mm different in TL = “1” (perhaps trying to increase the chance that they are from different cohorts)
    - 5 larvae of any size are found = “1”
    - 1 larvae found = “0”, <5 larvae found < 20 mm TL difference = “0”
    - 0 larvae found = “0”

Occupancy Sampling Benefits

- It is quantitative
- Evaluate distribution across a landscape at different spatial scales:
  - Identify areas of conservation value and restoration need
  - Examine what factors affect distribution
  - See if distribution grows or shrinks as a result of time, a management action, a natural disturbance, human interaction, etc.
- Evaluate local patterns in colonization and extirpation
- Comparatively low effort method to assess status
  - Just need to collect a minimal number to say a site is “occupied”
  - The number of occupied sites within a larger area can indicate relative abundance
- But…what does it mean if you sample, but do not collect any individuals?

Year	Reach	*d*	Pacific lamprey	Western brook lamprey	Unid	Total	Source
2009	Lower Willamette River	0.07	5	6	1	12	Jolley et al. 2012c
2010	Bonneville Reservoir	0.02	1	0	0	1	Jolley et al. 2011a
	Bonneville Tailwater	0.00	0	0	0	0	
2011	Bonneville Tailwater	0.03	0	1	0	1	Jolley et al. 2012a
	Hood River mouth	0.06	1	1	0	2	
	Klickitat River mouth	0.00	0	0	0	0	
	White Salmon River mout	0.00	0	0	0	0	
	Wind River mouth	0.29	22	9	6	37	
	Lower Klickitat River	0.26	13	0	2	15	Jolley et al. 2012b
	Lower White Salmon Rive	0.29	5	11	3	19	
	Lower Wind River	0.32	13	9	4	26	
2012	Klickitat River mouth	0.12	3	0	2	5	Jolley et al. 2013b
	White Salmon River mout	0.03	1	0	0	1	
	Wind River mouth	0.29	6	15	16	37	
	Lower Klickitat River	0.03	1	0	0	1	
	Lower White Salmon Rive	0.09	0	4	0	4	
	Lower Wind River	0.24	4	10	1	15	
	The Dalles Pool	0.00	0	0	0	0	Jolley et al. 2013a
	Deschutes River mouth	0.00	0	0	0	0	
2013	Deschutes mouth	0.09	5	0	2	7	Jolley et al. *in prep*
	Klickitat mouth	0.15	4	1	1	6	
	Klickitat mouth	0.26	49	4	0	53	
	Klickitat mouth	0.35	34	7	1	42	
	Wind mouth	0.18	4	11	1	16	
	Wind mouth	0.21	6	17	0	23	
	Wind mouth	0.24	5	20	0	25	
	Hood mouth	0.09	3	3	0	6	
	White Salmon mouth	0.15	3	4	0	7	
	Little White Salmon mout	0.09	0	4	0	4	
	Bonneville Reservoir	0.03	2	0	0	2	
	The Dalles Reservoir	0.00	0	0	0	0	
2014	Bonneville shallow	0.03	1	1	0	2	

What Does My Sample Mean?

Sample \ Actual	Present	Absent
Present	Occupied	Error 'Incorrect Identification'
Absent	Error 'Non-detection'	Unoccupied

Non-detection or non-occupancy?

Sample \ Actual	Present	Absent
Present	Occupied	Error 'Incorrect Identification'
Absent	Error 'Non-detection'	Unoccupied

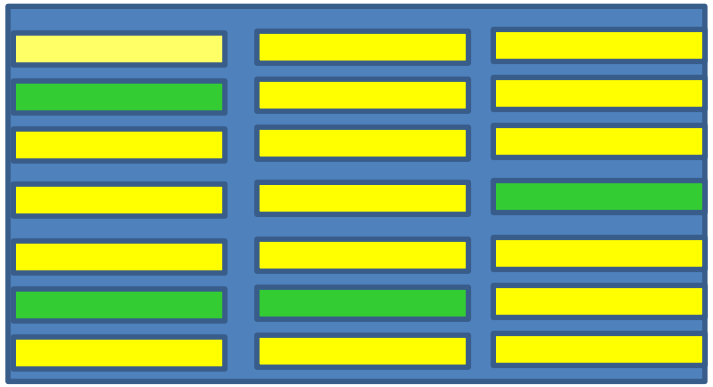
Current focus: You sample and don't detect presence

- **How many random samples do we need to collect to have some confidence about non-detection vs. non-occupancy?**
- You can never be 100% sure that an area is unoccupied
- **Purpose:** to make a statement about non-occupancy with some amount of confidence, if you don't detect presence

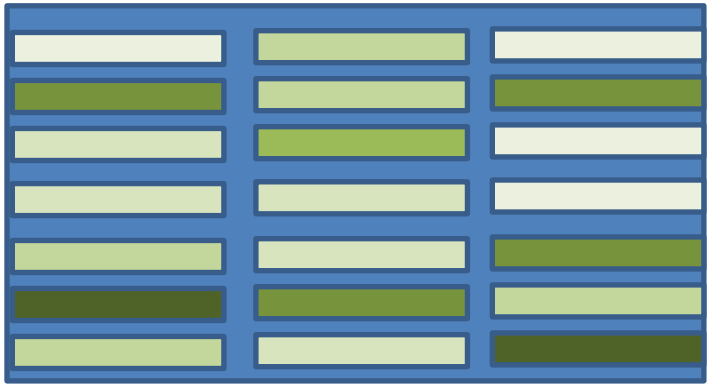
Non-Detection

- Non-detection is when you fail to detect the species of interest when the area of interest is actually occupied
- Common causes of non-detection:
  - A selected site within the occupied area of interest has no presence
  - Individuals in a selected site with presence are not captured/observed

Example area of interest: It is occupied
Sites with presence
Sites with absence



Example area of interest: It is occupied
Ability to detect presence at a site is affected by density, environmental factors, or gear



- **How many randomly selected sites we need to sample depends on detection probability?**

Detection probability

- **The probability that you will detect presence at a site, given that the area of interest is occupied**
- It is always between 0 and 1
- It is a function of distribution and abundance of the species in the area, as well as gear capture efficiency
  - Can be affected by environmental variables
- To select a detection probability you should consider:
  - The spatial scale of your system of interest
  - What you know about the system/species/life stage
  - What other information you plan to collect
- **An estimate of detection probability is needed to evaluate how many sites you need to sample to obtain confidence about occupancy, if no individuals are collected**

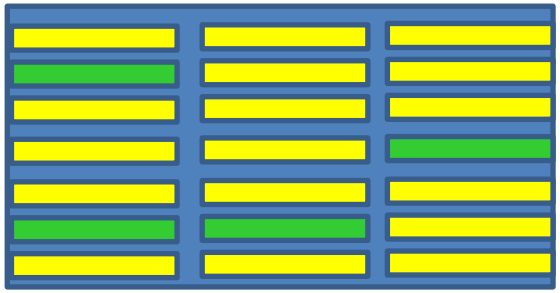
Selecting a detection probability

- When selecting a detection probability, what should I use?
- Detection probability can be estimated—we discuss this later

- **Example 1:** Use an estimate from a similar occupied system
  - Say an occupied 3rd order stream nearby had a detection probability of 0.8, consider using 0.8 as the detection probability for the similar 3rd order stream
- **Example 2:** Pick a low estimate
  - Say evidence from many occupied 3rd order streams suggests that detection probability is at least as good as 0.5, consider using 0.5 as detection probability
  - This approach may seem too conservative, but estimates from other systems are only those in which individuals were found, so an average might be biased high

Detection probability and spatial scale

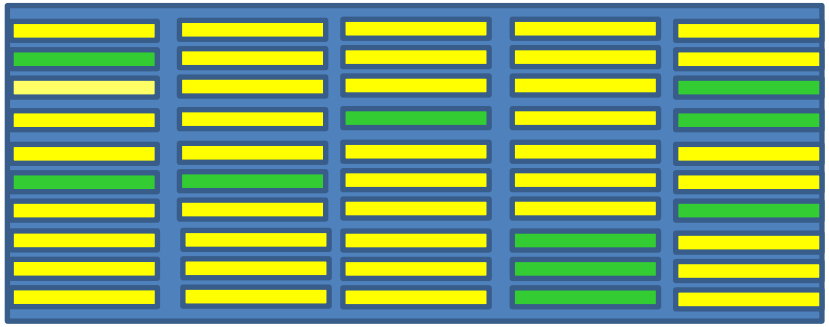
- **Example 3: Is this 5th-level HUC occupied?**
  - There are 21 total 3rd order streams in this HUC
  - You think at least **4** of the 3rd order streams have presence
  - Detection in similar 3rd order streams is 0.8



- What can you do?
  - You assume at least 4/21 or 19% of the sampling universe (all 3rd order streams in the HUC) have presence and detection probability in 3rd order streams is 0.8
  - Detection at the HUC-5: percent presence*detection probability or 0.19*0.8 = 0.152
  - **Lower detection probability than in the 3rd order stream because it is not assumed that all streams in the HUC need will be positive for presence for the HUC to be occupied**

Detection probability and spatial scale

- **Example 4: Is this 50-m reach occupied?**
  - You think at least **10** of the sub-reaches (1 m plots maybe?) have presence
  - You think density in a sub-reach with presence is at least 20 individuals (maybe from knowledge of habitat quality?)
  - Estimated capture efficiency is 0.5 (maybe from an experimental study?)



- **What can you do?**
  - Use efficiency, density, and percent with presence to estimate detection probability
  - Detection probability is percent with presence*(1-(1-capture efficiency)^density)
  - Detection probability = (10/50)*(1-(1-0.5)^20) = 0.2
  - **Information on larval lamprey distribution, density, and capture efficiency in different habitats is important because it impacts detection probability—we discuss this later**

Using detection probability

- **Selecting a detection probability can be difficult, but is necessary to identify the number of sites that need to be sampled to obtain confidence about non-occupancy vs. no-detection**
- There are multiple methods for selecting a detection probability
- Using detection probability to determine the # sites to sample within an area of interest to determine non-occupancy with some level of confidence is straightforward
- Model described by Peterson and Dunham (2001)
- Indicates the # of sites that need to be sampled to conclude the area of interest is unoccupied (if no sites are positive for presence) with a desired level of power

Peterson and Dunham (2001) Model

- The probability of non-occupancy, given we did not sample presence

Sample \ Actual	Present	Absent
Present	Occupied	Error 'Incorrect Identification'
Absent	Error 'Non-detection'	Unoccupied

This model allows us to assign a probability to "non-detection" and "Unoccupied", if we don't get presence (i.e., we have a sample with absence)

Probability of occupancy given no detection at a site = $\frac{P(Co/F)*P(F)}{P(Co/F)*P(F)+P(Co/\sim F)*P(\sim F)}$

P(Co/F): probability of not finding the species when it is there (1-detection probability)
P(F): probability of species presence
P(Co/~F): probability of not detecting a species when it is absent
P(~F): probability of species absence (1-P(F))

Simplifying the Model

- Assume a 50/50 probability of occupancy in an unstudied representative area (i.e., P(F)=P(~F))
- Assume there is no incorrect species identification, when it is not there, it will not be detected

Probability of presence given no detection at a site = $\frac{P(Co/F)*P(F)}{P(Co/F)*P(F)+1*P(\sim F)}$

P(Co/F): probability of not finding the species when it is there (1-detection probability)
P(F): probability of species presence—Set to 0.5
P(Co/~F): probability of not detecting a species when it is absent—Set to 1
P(~F): probability of species absence (1-P(F))—Set to 0.5

Probability of occupancy, given detection probability

- Simplified probability of area occupancy given no detection at any sampled sites, with different numbers of sampling sites

Probability of presence given no detection at a site = $\frac{P(Co/F)}{P(Co/F)+1}$

Probability of presence given no detection at a site = $\frac{(1-dp)}{(1-dp)+1}$

Probability of area occupancy given no detection at multiple sites = $\frac{((1-dp)^{sites})}{((1-dp)^{sites} + 1)}$

Probability of occupancy, given detection probability

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Probability of presence given no detection at a site = $\frac{P(Co/F)}{P(Co/F)+1}$

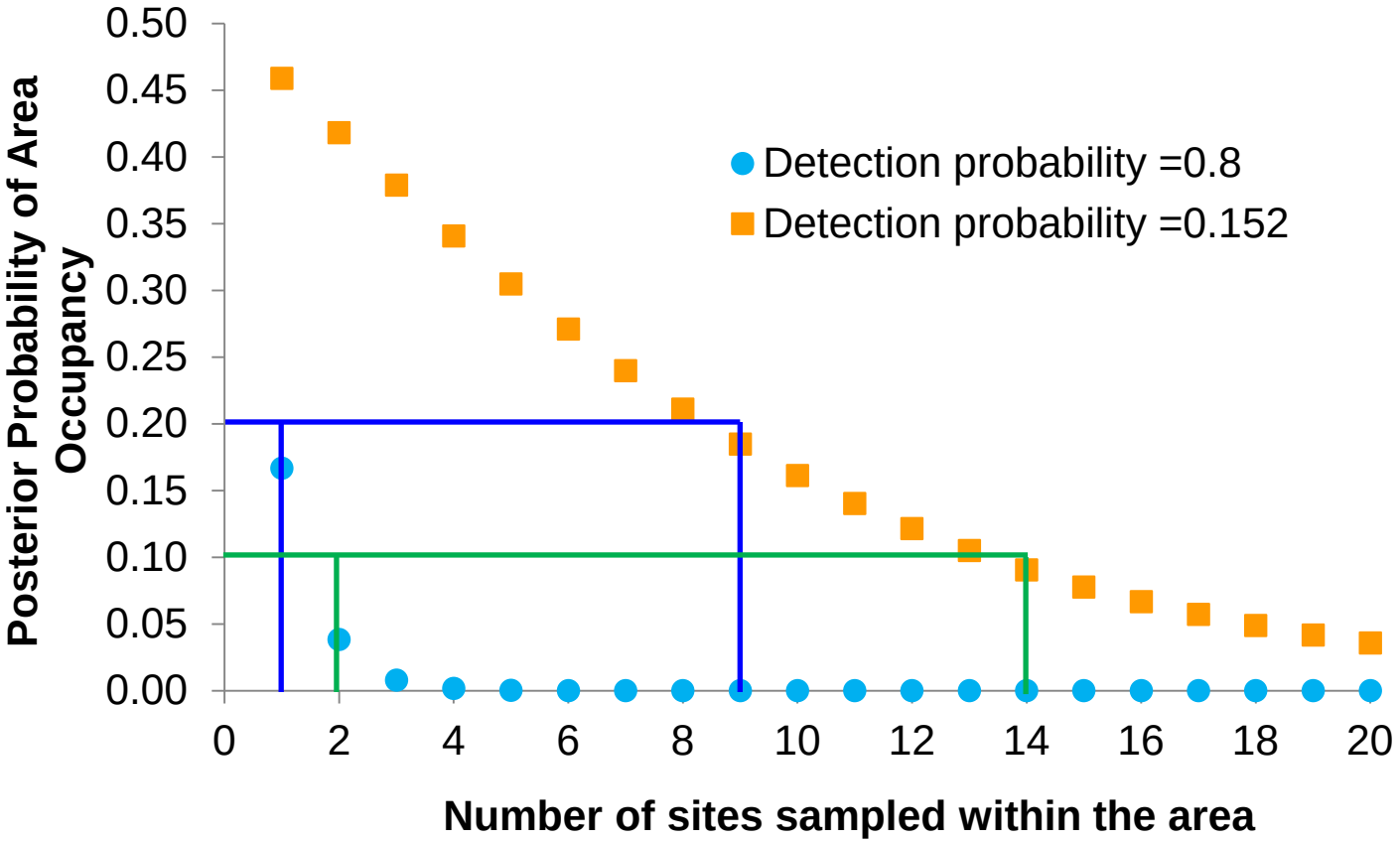
Probability of presence given no detection at a site = $\frac{(1-dp)}{(1-dp)+1}$

Probability of area occupancy given no detection at multiple sites = $\frac{((1-dp)^{sites})}{((1-dp)^{sites} + 1)}$

- Final model to use to determine the number of sites to sample
- Detection probability informs the model

Examples

- 3rd order stream example: detection probability = 0.8
- HUC-5 example: detection probability = 0.152



80% probability that the area is unoccupied (20% probability it is occupied)

90% probability that the area is unoccupied (10% probability that it is occupied)

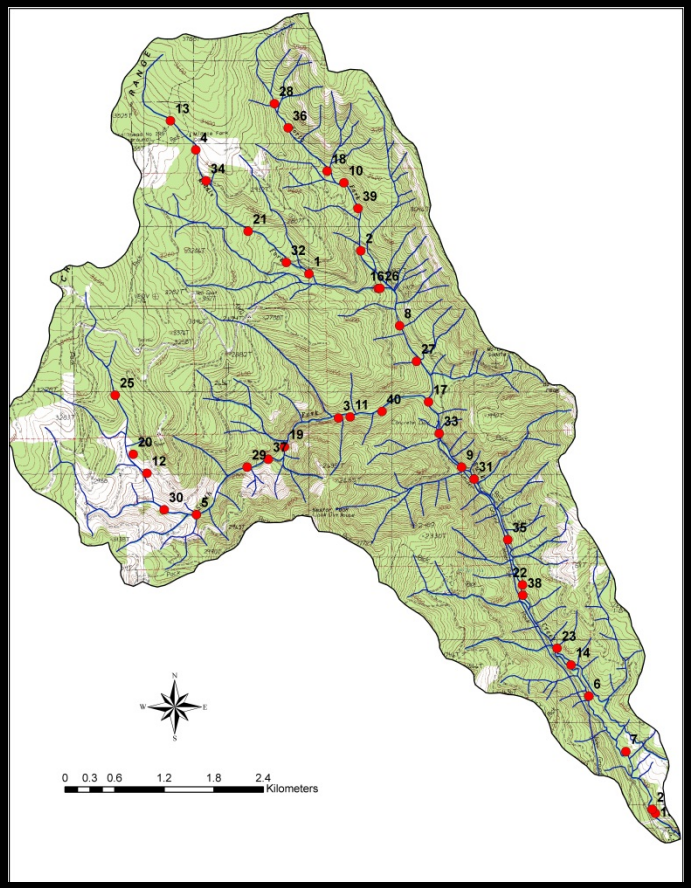
Wrap-up: How many sites do I sample?

- **Purpose:** to make a probabilistic statement about occupancy relative to non-detection
- **Steps:**
  - Refine your question and decide what information you plan to collect
  - Select an appropriate detection probability (can be difficult)
  - Plug the estimate of detection probability into the Peterson and Dunham (2001) model to identify how many randomly selected sites you may need to sample, if you do not detect presence
  - Sample those sites (in any order) until you detect that it is occupied
  - If no individuals are collected, make the final probabilistic statement, given your assumptions: **"Given that detection probability is 0.4, we are 90% certain that the area of interest is unoccupied"**
- **Value:** you can actually make a probabilistic statement about occupancy, relative to false absence, if you do not detect presence

Occupancy Sampling

Field Protocols and Techniques

- **GRTS Reach Sampling**
- **Electrofisher Types and Settings**
- **Habitat Data Collection**
- **Biological Data Collection**



Occupancy Sampling

GRTS Reach Sampling Methods

- Identify 'highest priority' (lowest numbered) 50 m GRTS reaches in unit
- Navigate to bottom of reach w/GPS (starting here)
- Measure reach before sampling (or during sampling if 2 people)
- Record temperature and conductivity

Occupancy Sampling

GRTS Reach Sampling Methods

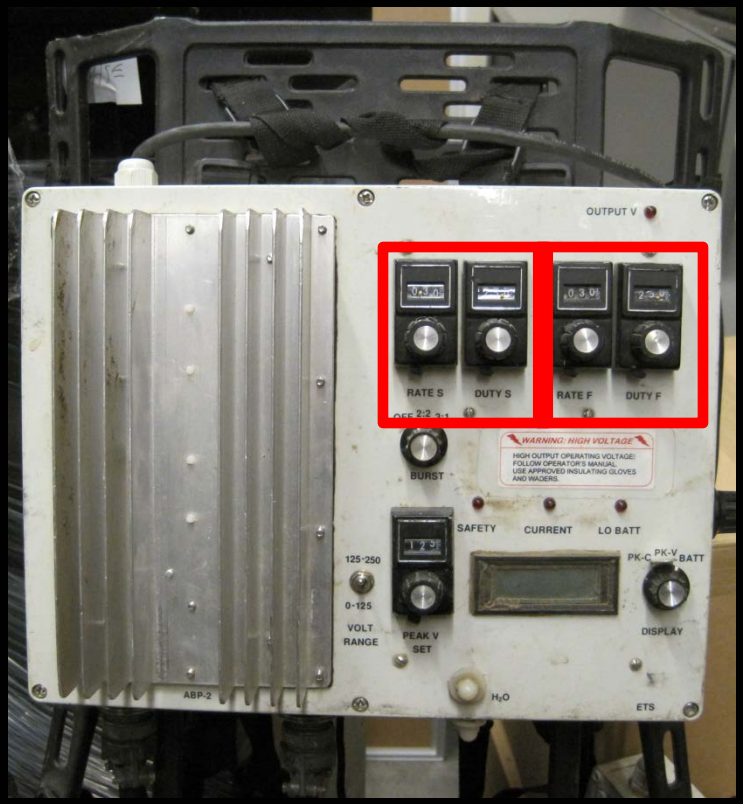
- Sample downstream to upstream
- 1-2 netters (w/small dipnets, larger fine-meshed nets)
- Cover most of the channel if possible/practical
- Focus sampling effort on Type I habitat
- Cease sampling reach when occupancy criteria are satisfied: 5+ larvae, or 2+ larvae greater than 20 mm difference in length

- Move to next GRTS reach, repeat

Occupancy Sampling

ETS AbP-2 Electrofisher (aka 'Wisconsin shocker')

- Dual output mode
  - I. Slow pulse (aka 'tickle mode')
    - 3 pulses/second
    - 25% duty cycle
    - 3:1 burst pulse train (3 pulses on, 1 off)
    - 125 V; Cold water (<10° C) or low cond. (<~50 µS) 150-175 V
  - II. Fast pulse (aka 'stun mode')
    - 30 pulses/second, standard pulse
    - Voltage & duty cycle same as above



Occupancy Sampling

Smith-Root LR-24 Electrofisher Settings

- Factory default waveform #9 - Dual output mode
  - I. Primary waveform (aka 'tickle')
    - Burst of 3 pulses (@4 Hz)
    - 1 Hz cycle frequency
    - 25% duty cycle
    - 100 V; increase to 125 V (higher in cold water, low conductivity)
  - II. Secondary waveform (aka 'stun')
    - 30 pulses/second, standard pulse
    - Voltage & duty cycle same as above

Occupancy Sampling

Habitat Data Collection

- Stream Name, GRTS Reach #
- Date
- Crew
- Water temperature
- Conductivity
- Time: start and end
- Shock time (sec)
- Weather conditions
- Water clarity/visibility
- Proportion Type I habitat: Estimate % Type I substrate in reach
- Other relevant habitat covariates, as desired

Occupancy Sampling

Habitat Types – from Slade et al. 2003

Qualitative definitions based on components and compactness

- Type I: Preferred habitat. Located primarily in depositional zones… consists primarily of a mixture of sand and fine organic matter
- Type II: Shifting sand and some gravel… utilized by some larvae for burrowing, but at lower densities
- Type III: Hard packed gravel, hard-pan clay, and bedrock, larvae are unable to burrow into these substrates

Occupancy Sampling

Biological Data Collection

- Anesthetize (buffered MS-222 150 mg/L)
- ID to Genus (*Entosphenus* or *Lampetra*), *ID methods below*
- Life Stage
- Total length
- Weight
- Fin clip (caudal), VIE tag, etc.

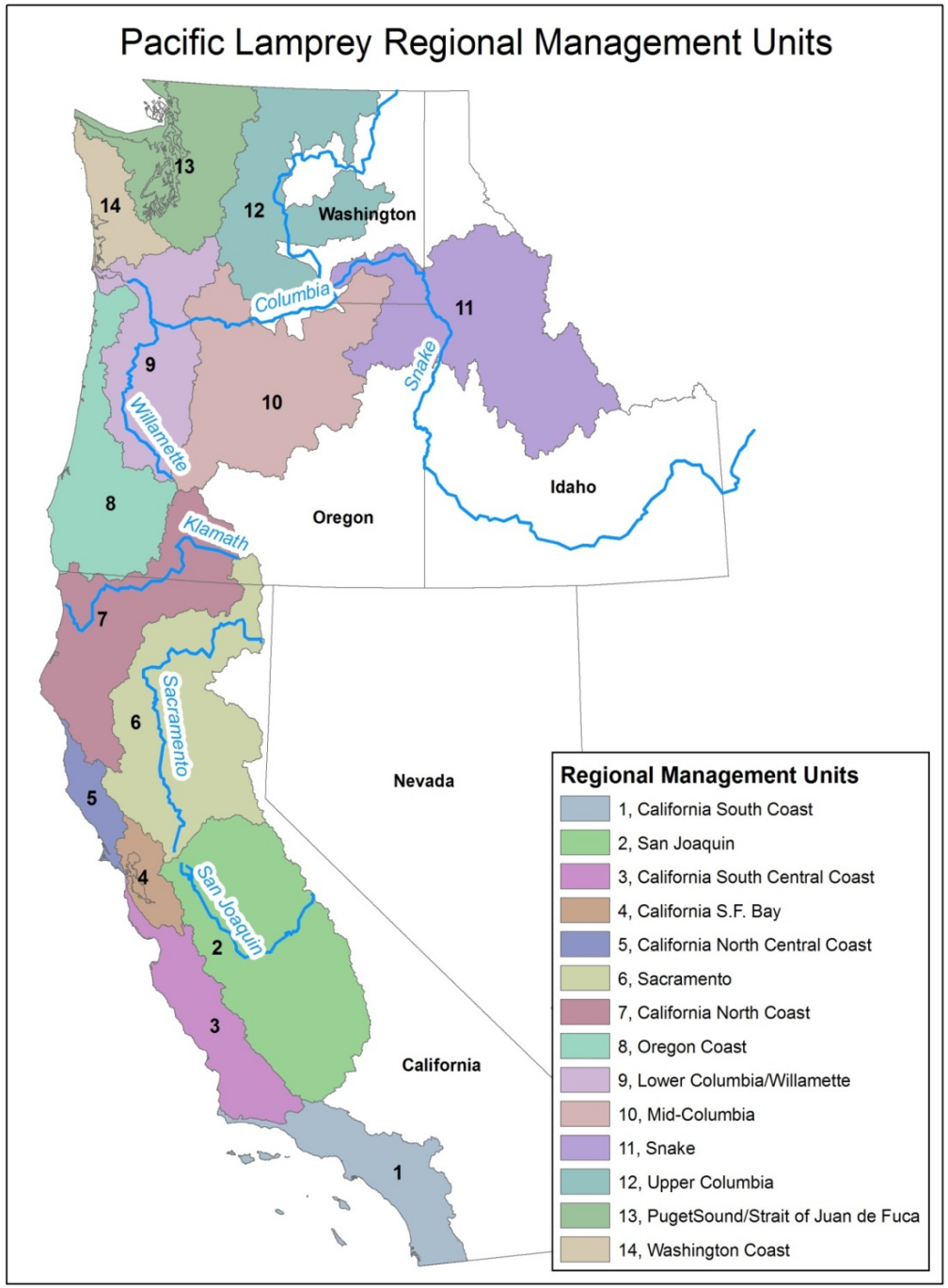
Sample Units and Occupancy Examples

Jeff Jolley, David Hines, Christina Wang

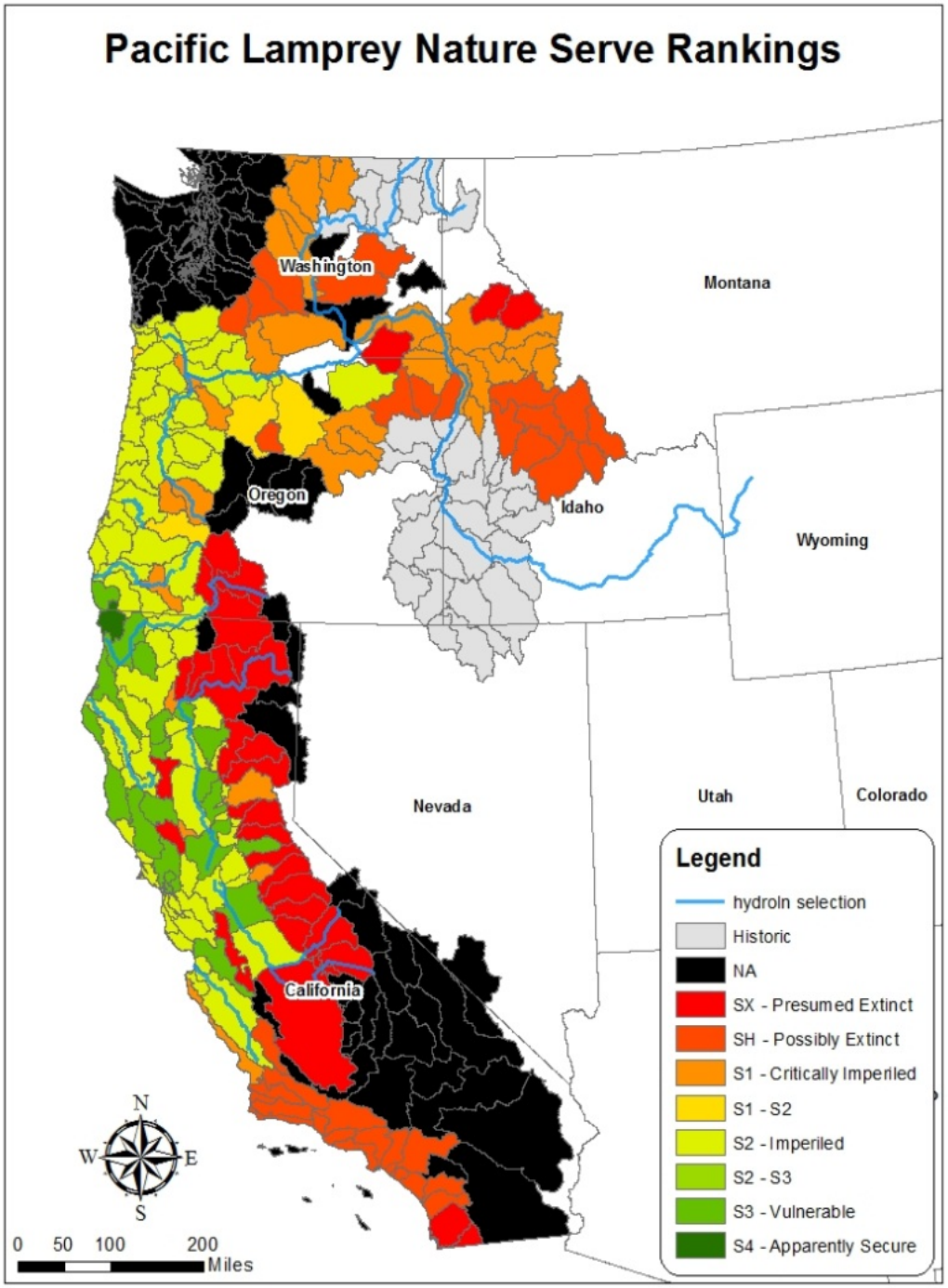
RMUs, HUC 4, smaller unit (<HUC4, subbasin, orders, etc).

Flow – small scale informs all larger levels above

Examples –Tualatin, White Salmon, Tumwater

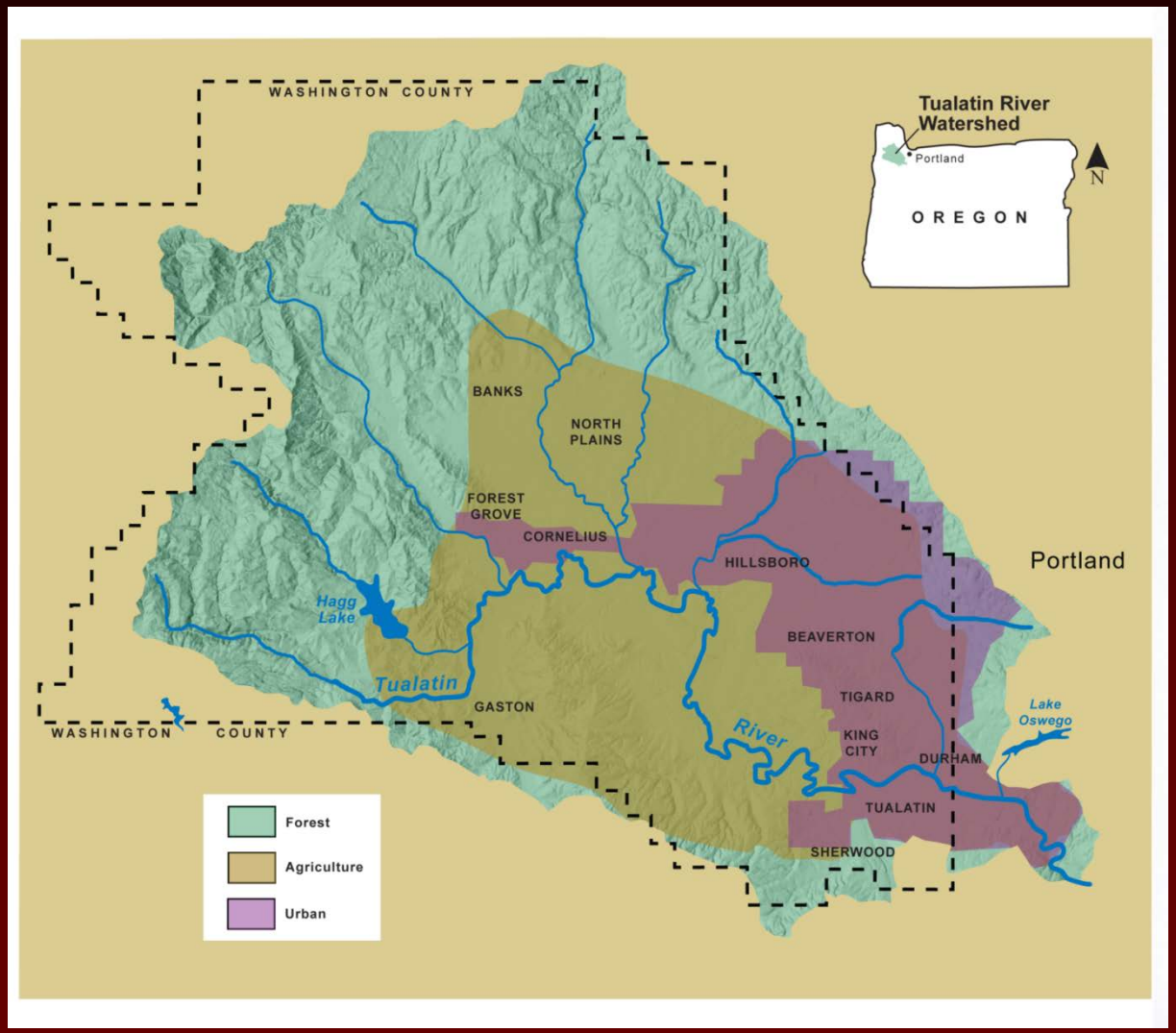


Regional Management Unit


Pacific Lamprey Nature Serve Rankings
Washington
Montana
Oregon
Idaho
Wyoming
Nevada
Utah
Colorado
California
Legend
hydroln selection
Historic
NA
SX - Presumed Extinct
SH - Possibly Extinct
S1 - Critically Imperiled
S1 - S2
S2 - Imperiled
S2 - S3
S3 - Vulnerable
S4 - Apparently Secure
N
W
E
S
0 50 100 200
Miles

HUC 4

Tualatin HUC 4



Sample Units

- Occupancy framework can be applied to ANY scale
- Choice of unit needs to be anchored in by your goals and objectives
- Results will be scale specific….but can be nested within larger scale/units and also inform in a bottom-up method

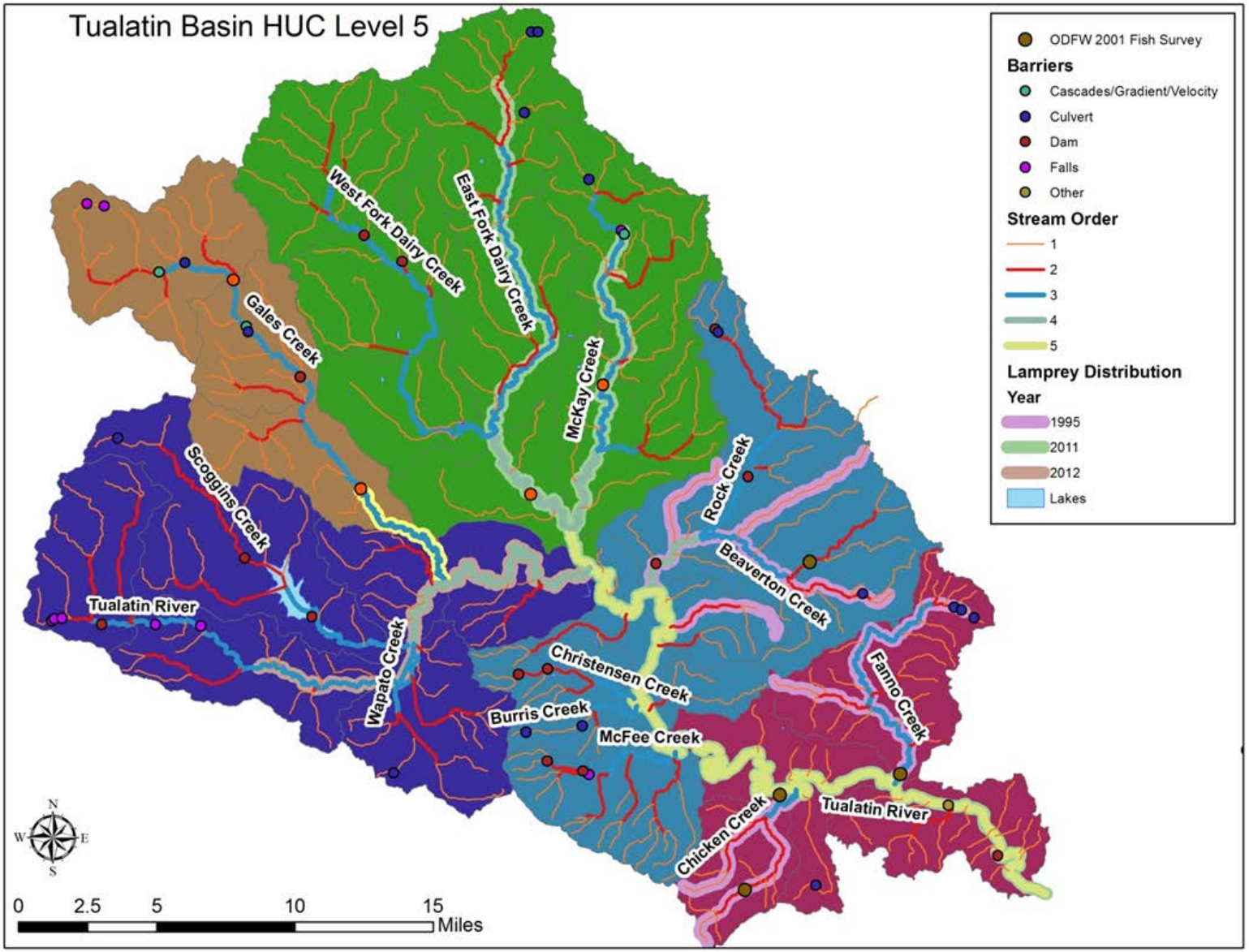
Sample Units

- Example – occupancy sampling in one subbasin → informs occupancy within the basin → informs occupancy within the HUC4 → informs occupancy within the RMU → informs occupancy within the range

Example: Tualatin

- Entire basin is a HUC4
- Located within the Lower Willamette/Columbia RMU

Tualatin example

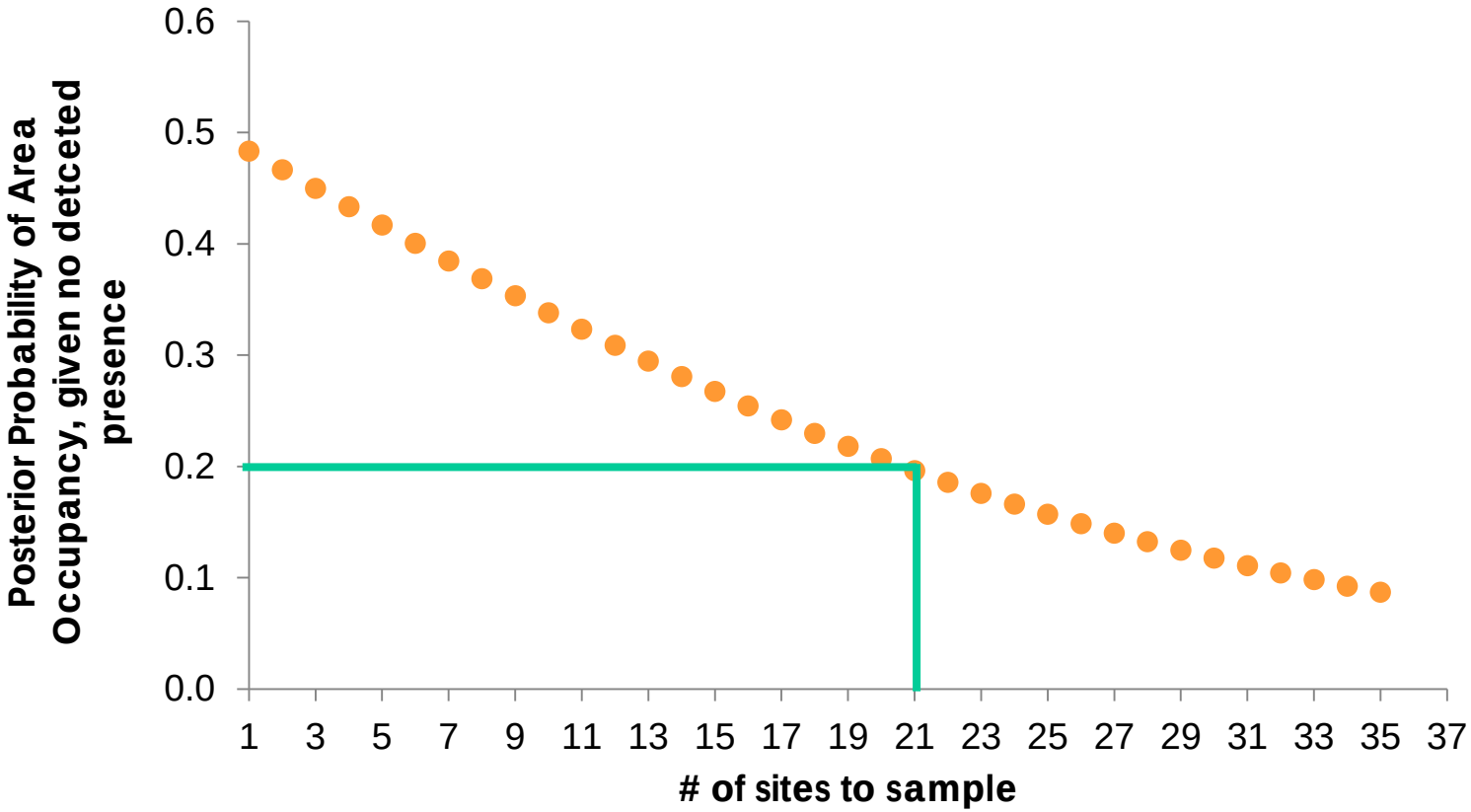


Example: White Salmon River Basin

1. Question: distribution within basin prior to removal of Condit Dam
2. Scale: Fine-scale, entire WSR is a HUC5 (HUC4 contains Hood, Wind, Little White, et al.)
3. Framework: 3rd order watershed (biological basis, intrinsic potential (steelhead similarity for spawning);
4. Effort – 21 reaches to generate a WSR specific DP, reduced to 6 based on detection in Trout Lake Creek

How many sites in the White Salmon?

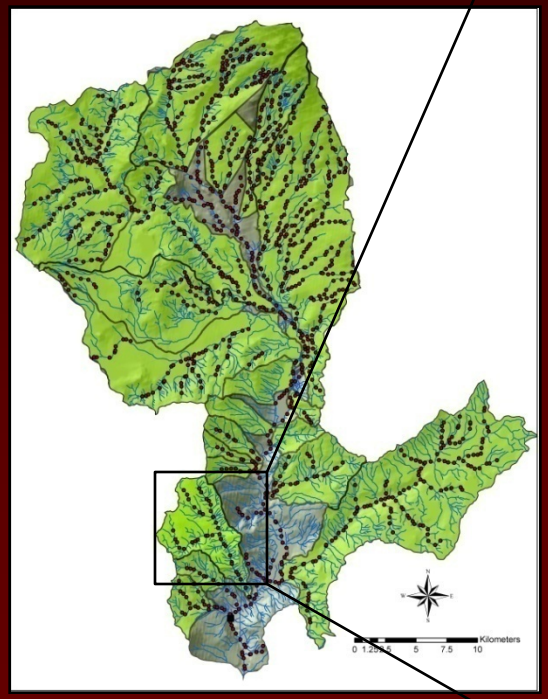
- Conservative detection probability of 0.065
- 80% confidence of non-occupancy, if presence not detected
- Peterson and Dunham (2001) model suggests 21 sites

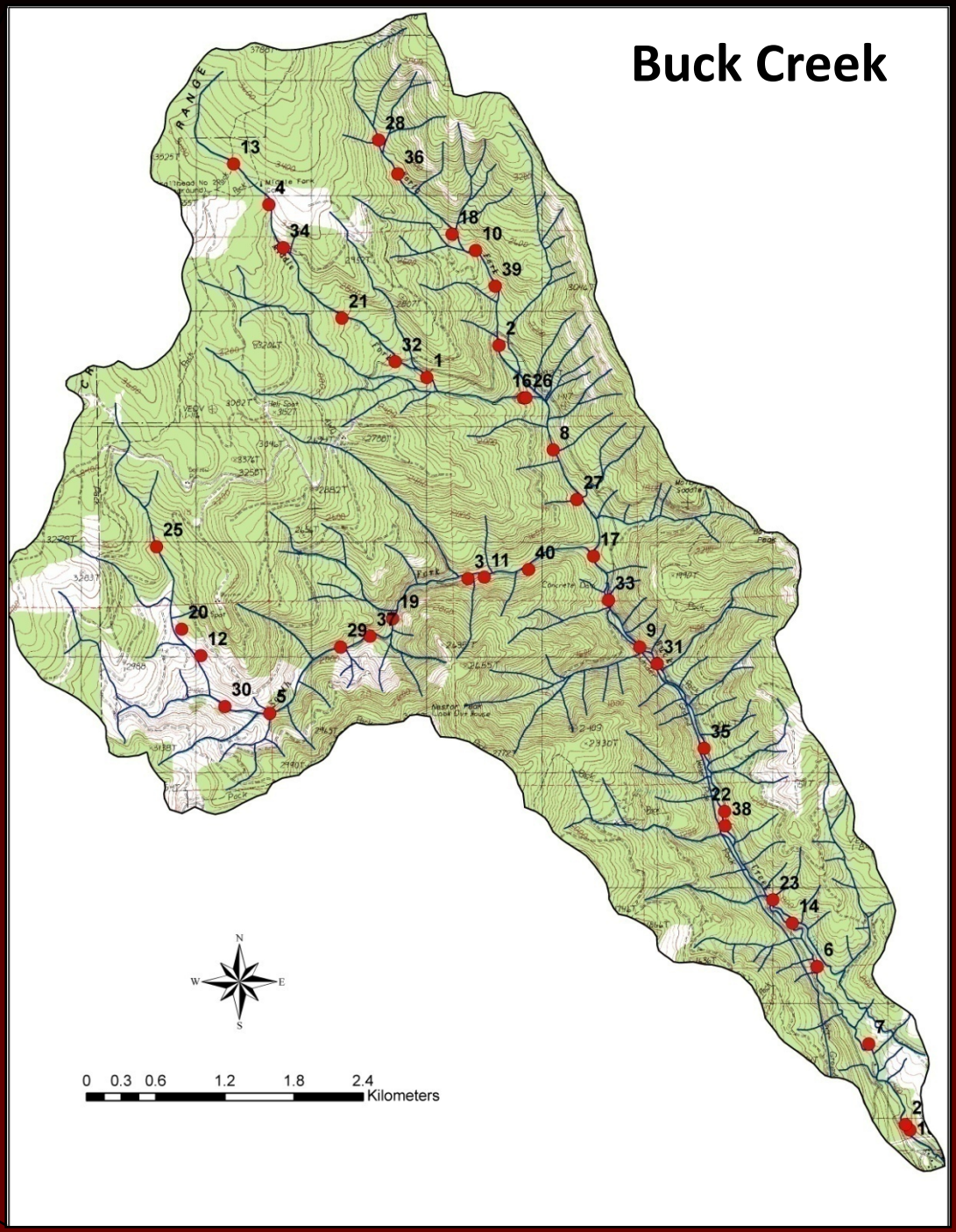


Identify sample reaches within the watershed units

Identify sample reaches within the watershed units

- 1st 21 sampled for lamprey
- If reaches are dry or inaccessible, then move to higher # reaches

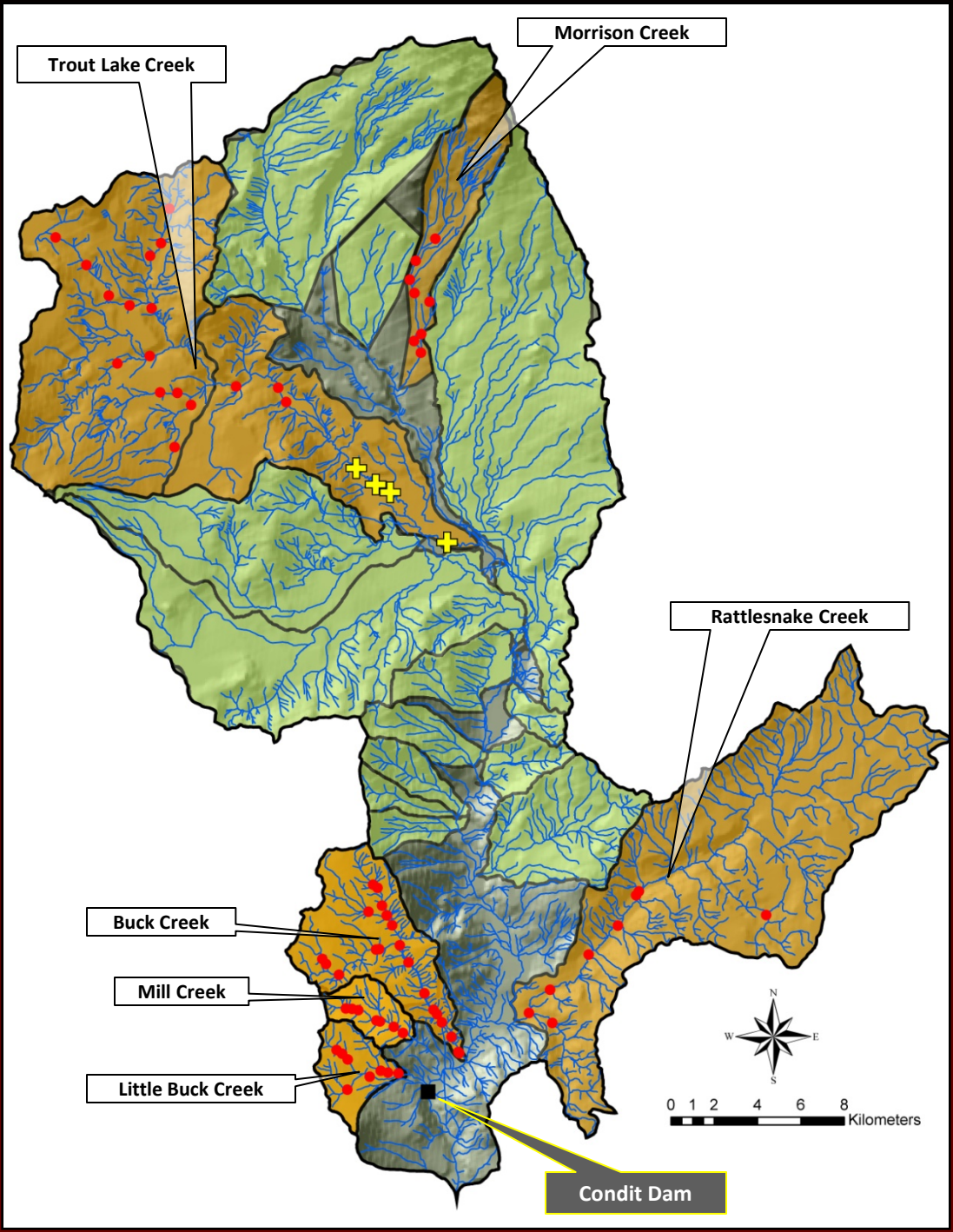




Results

- **Lampreys captured in 1 of 6 watershed units**

		Western Brook Lamprey	
Watershed Unit	Total # Reaches Surveyed	# Reaches Lamprey Detected ✚	# Reaches Lamprey Not Detected ●
Trout Lake Creek	21	4	17
Buck Creek	21	0	21
Rattlesnake Creek	8	0	8
Little Buck Creek	8	0	8
Mill Creek	7	0	7
Morrison Creek	8	0	8



White Salmon River - Conclusions

An unprecedented opportunity to study Pacific lamprey recolonization of a river basin.

Do Pacific lamprey return to the White Salmon River?
How long until they return?
How many return?
Where do they go in the basin and why?

WBL occupied above

WBL and PCL occupied below

Follow-up surveys planned

Occupancy approach will allow comparison

Fine Scale Example: Wenatchee River and Tumwater Dam

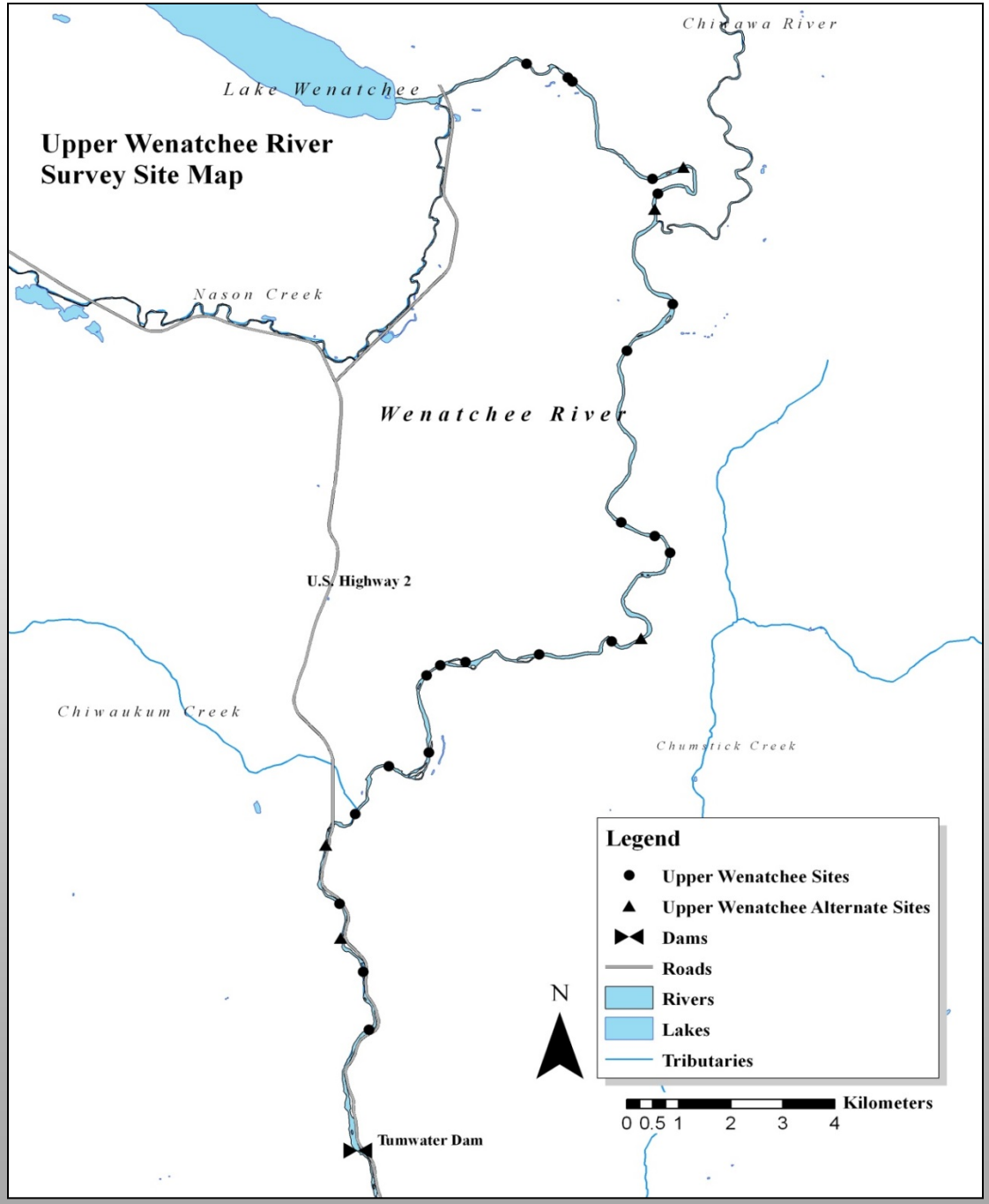
Question: Is Tumwater Dam a passage barrier?

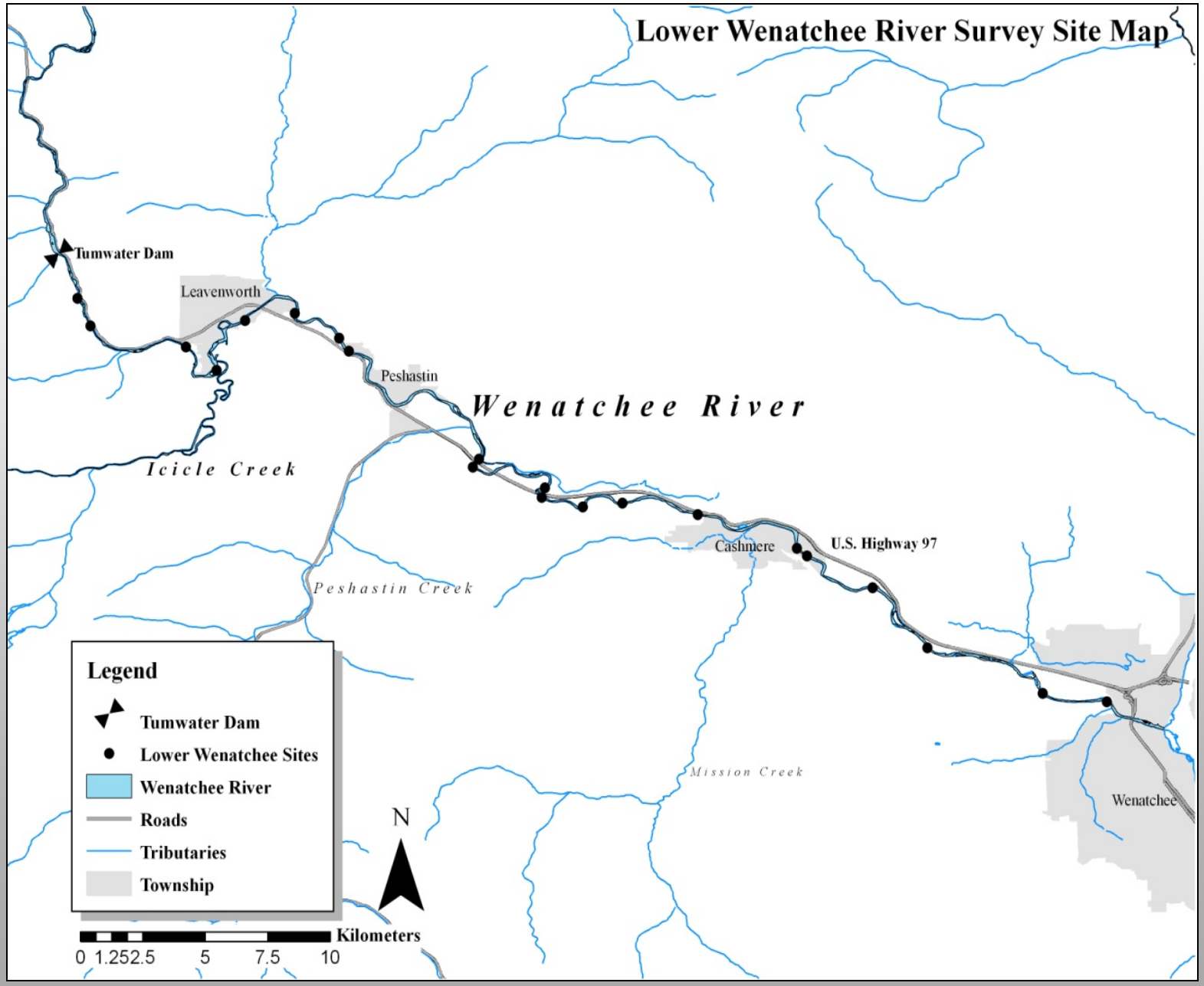
Tumwater Dam

- Ammocoete surveys (not probabilistic design) found lamprey occupancy below the dam (within 1 km) and not above in 2010-2011
- Questioned validity of absence above the dam

Tumwater Dam

- Designed a hybrid sampling scheme to probabilistically survey for occupancy above and below the dam
  - Identified treated and non-treated areas
  - Identified 50 m sampling sites through EMAP
  - Determined the number of sample sites necessary to achieve 95% power (21 sites)


Upper Wenatchee River
Survey Site Map
Lake Wenatchee
Chiwawa River
Nason Creek
Wenatchee River
U.S. Highway 2
Chiwaukum Creek
Chumstick Creek
Tumwater Dam
Legend
Upper Wenatchee Sites
Upper Wenatchee Alternate Sites
Dams
Roads
Rivers
Lakes
Tributaries
N
Kilometers
0 0.5 1 2 3 4


Lower Wenatchee River Survey Site Map
Tumwater Dam
Leavenworth
Peshastin
Wenatchee River
Icicle Creek
Cashmere
U.S. Highway 97
Peshastin Creek
Mission Creek
Wenatchee
Legend
Tumwater Dam
Lower Wenatchee Sites
Wenatchee River
Roads
Tributaries
Township
N
Kilometers
0 1.252.5 5 7.5 10

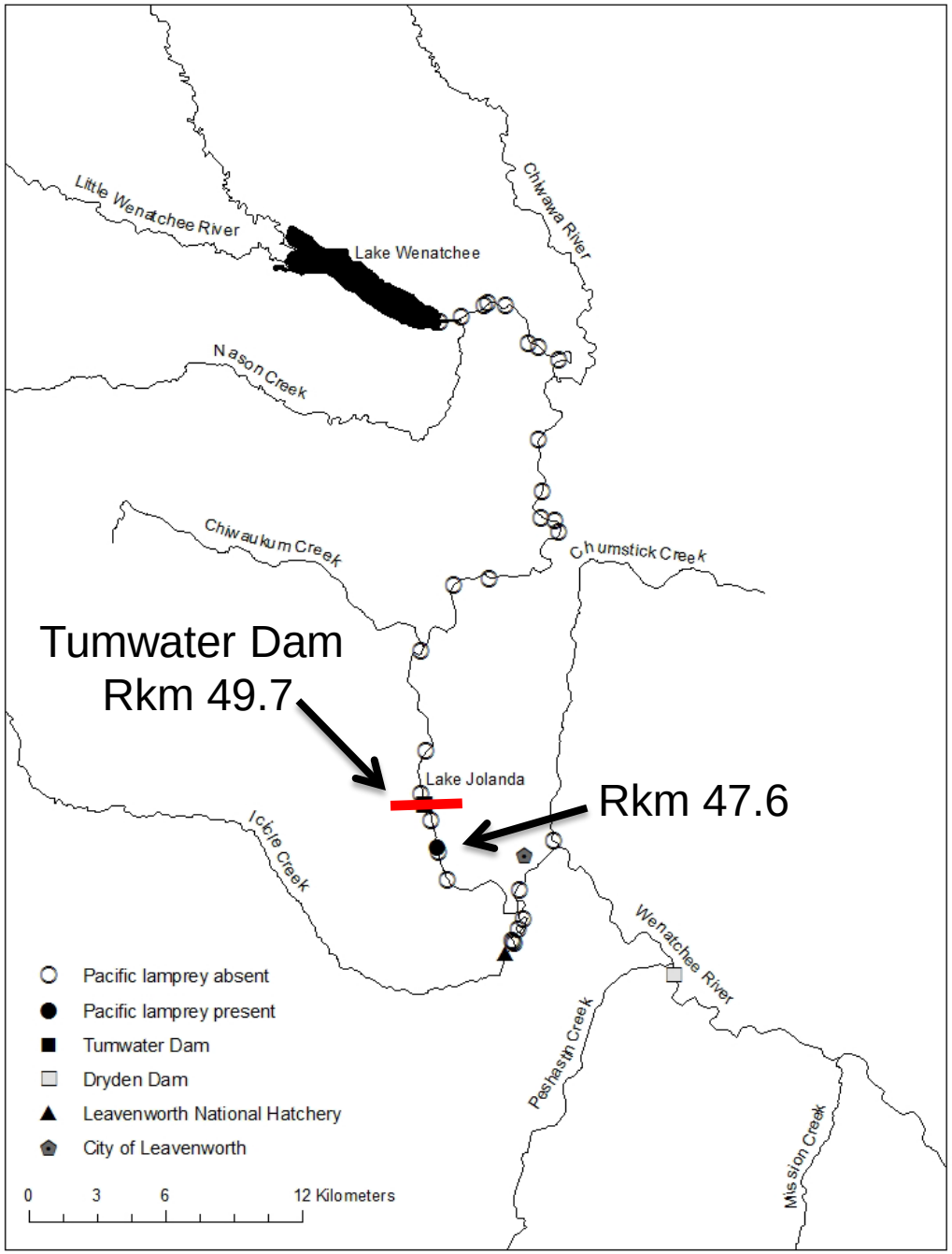
Tumwater Dam

- Found no occupancy in 21/21 sites above the dam and occupancy in 20/21 sites below the dam
- Results and records of historical distribution suggest Tumwater dam is limiting upstream extent of lamprey
- Modifications to the salmon fishway in the late 80's potentially impacted upstream passage of lamprey
- Establishment of absence (with 95% certainty) above the dam will help initiate studies to improve passage above Tumwater dam
- Also, intensive monitoring helps inform detection probabilities for future sampling

Lamprey Sampling Integration

- By coordinating all of the lamprey sampling we will better be able to evaluate lamprey status, efficacy of conservation actions and prioritization of future activities
  - Improved rangewide and basin specific distribution monitoring
  - Multiple use of intensive monitoring sites
    - inform wide range distribution
    - site specific abundance and survival
    - site specific action effectiveness
  - Consistent maintenance of information in the data clearinghouse to provide wide access

2011

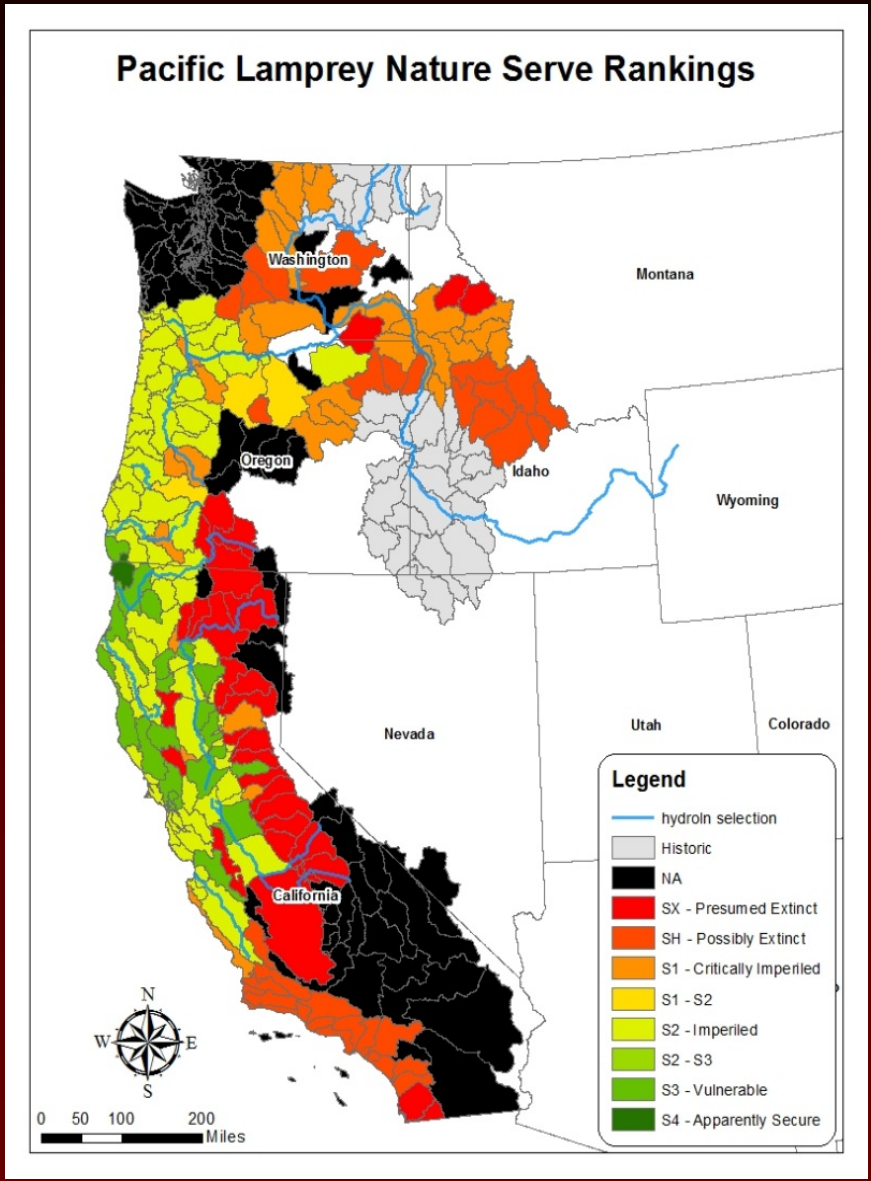

Little Wenatchee River
Lake Wenatchee
Chiwawa River
Nason Creek
Chiwaukum Creek
Chumstick Creek
Tumwater Dam
Rkm 49.7
Lake Jolanda
Rkm 47.6
Icicle Creek
Wenatchee River
Peshastin Creek
Mission Creek
Pacific lamprey absent
Pacific lamprey present
Tumwater Dam
Dryden Dam
Leavenworth National Hatchery
City of Leavenworth
0
3
6
12 Kilometers

Occupancy Sampling, Spatial Scales and the PLCI or … What can occupancy data do for you?

- How did the previous examples give us information that informs…
- How to bring it all full circle
- Segue into specifics of Tualatin Basin – questions, etc.

Assessment

- Will be updated in 2016
- Collaborative approach
- Multiple scales inform distribution and status



Pacific Lamprey Conservation Initiative Goals

- U.S. Fish and Wildlife Service's strategy to improve the status of Pacific Lamprey throughout their range by helping implement research and conservation actions
- The Assessment tracks the current knowledge of Pacific Lamprey habitat requirements; abundance; historic and current distribution; describes threats and factors for decline; and identifies conservation actions and research, monitoring, and evaluation needs

Pacific Lamprey Conservation Initiative Goals

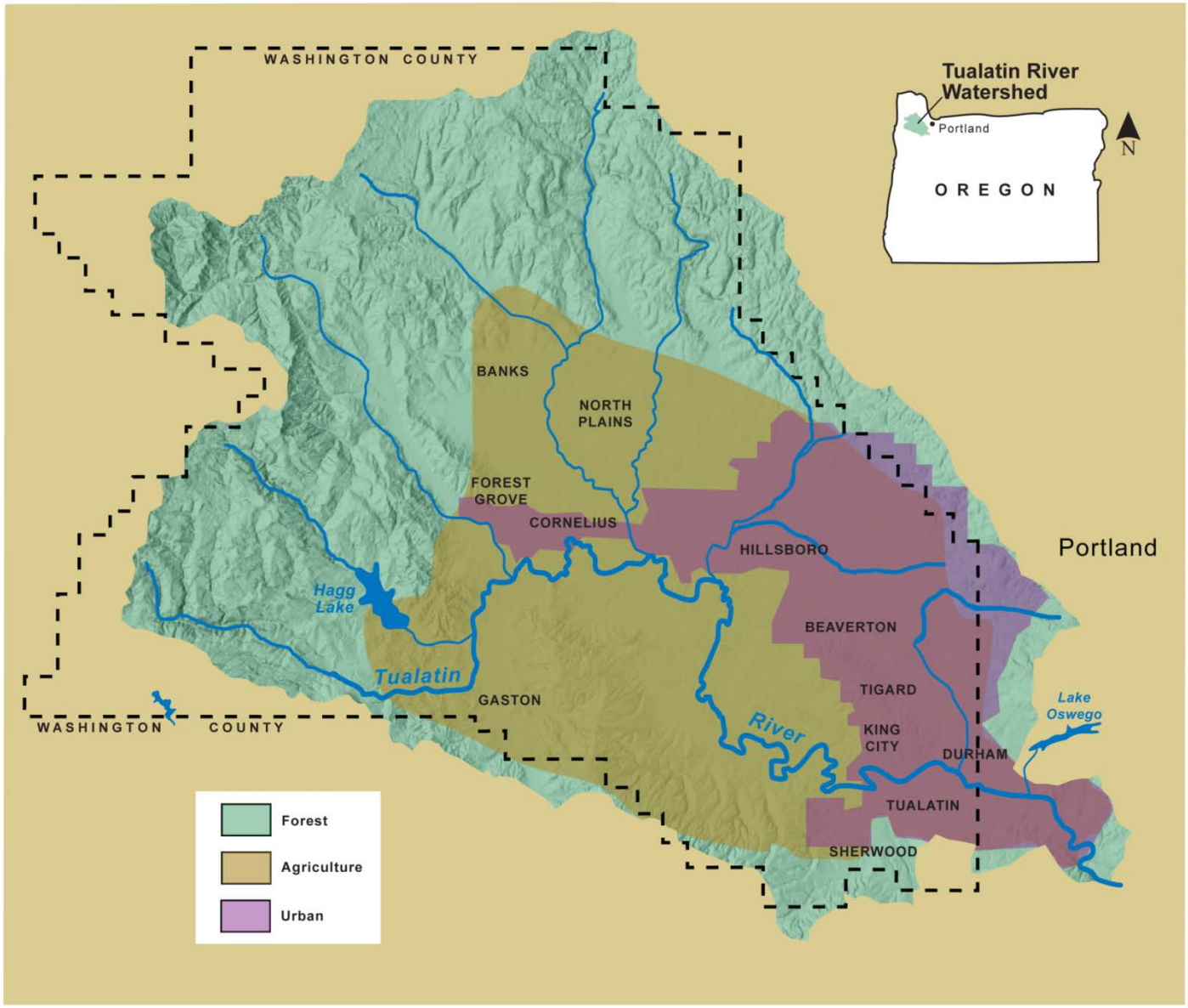
- The Conservation Agreement is a voluntary commitment by the interested parties to collaborate on efforts that reduce or eliminate threats to Pacific Lamprey to the greatest extent possible.
- The goal is to achieve long term persistence and support traditional tribal cultural use of Pacific Lamprey throughout their range
- Provides a mechanism for interested parties to collaborate and pool available resources to expeditiously and effectively implement conservation actions

Pacific Lamprey Conservation Initiative Goals

- Conservation will be advanced by the development of Regional Implementation Plans, which will prioritize implementation of conservation actions and evaluate action effectiveness
- Build upon existing restoration plans
- Identify additional conservation actions needed at the watershed scale to address threats and issues

Welcome!
Tualatin River National Wildlife Refuge

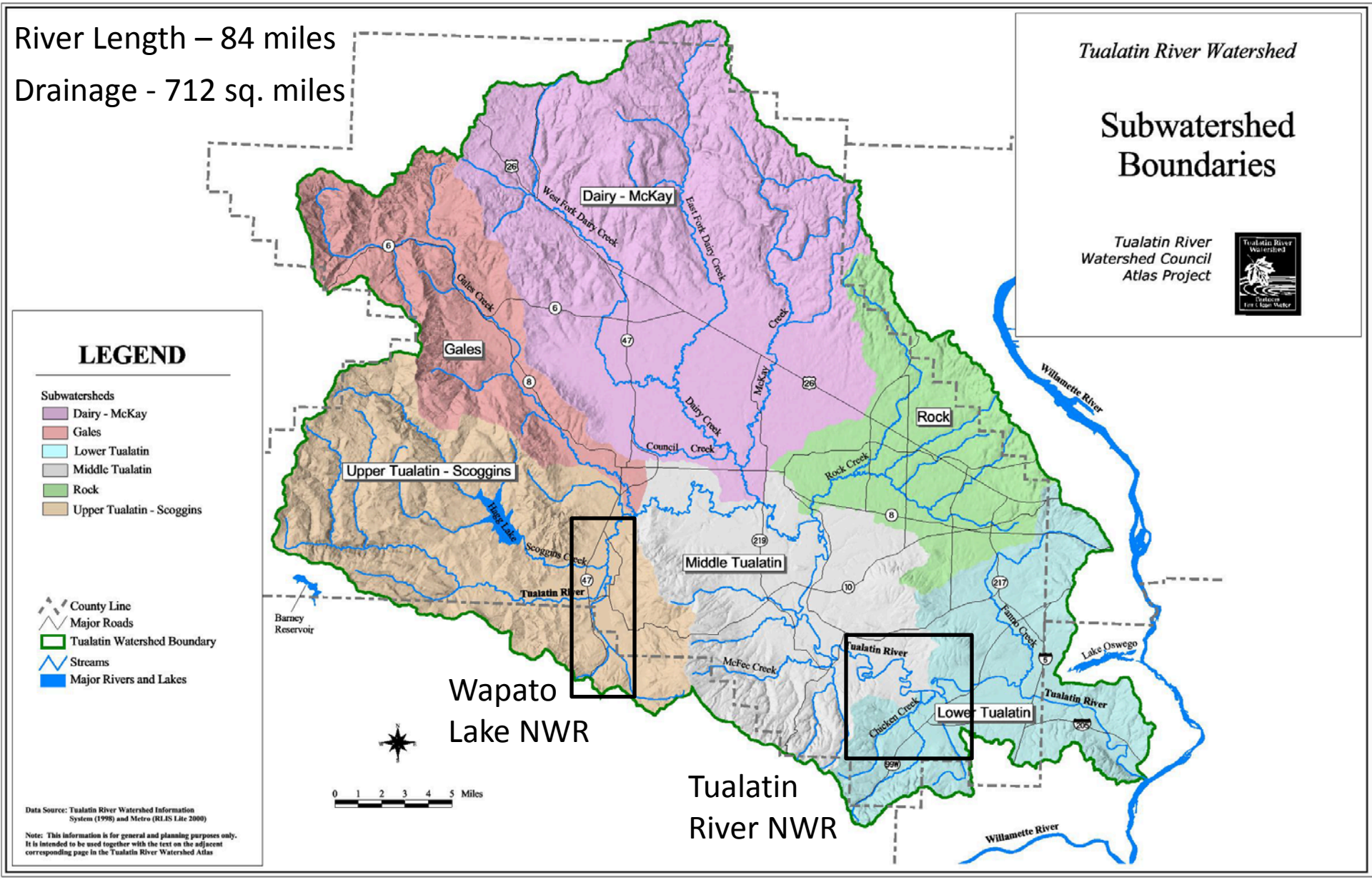
Tualatin River Watershed



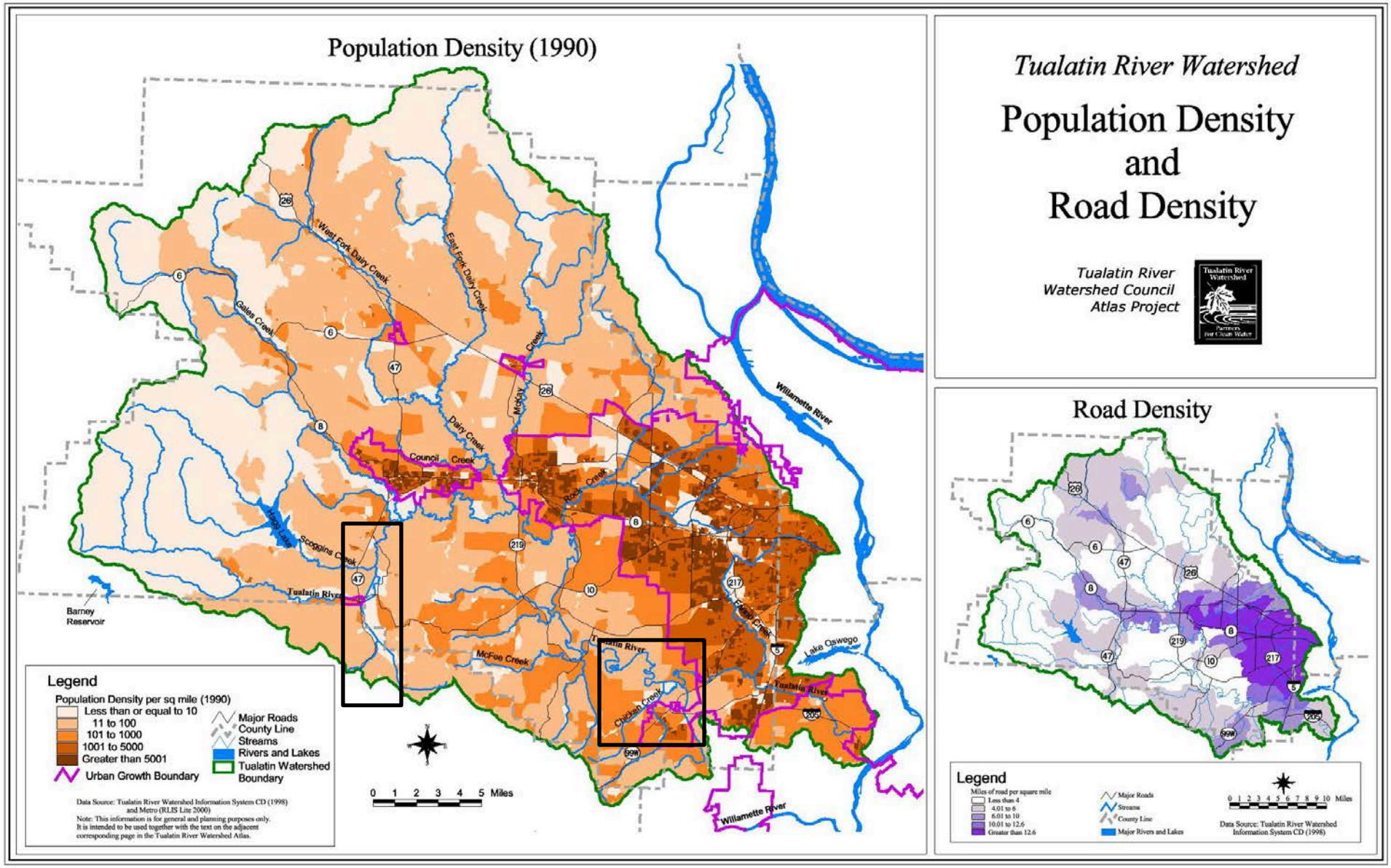
Tualatin River Watershed

River Length – 84 miles

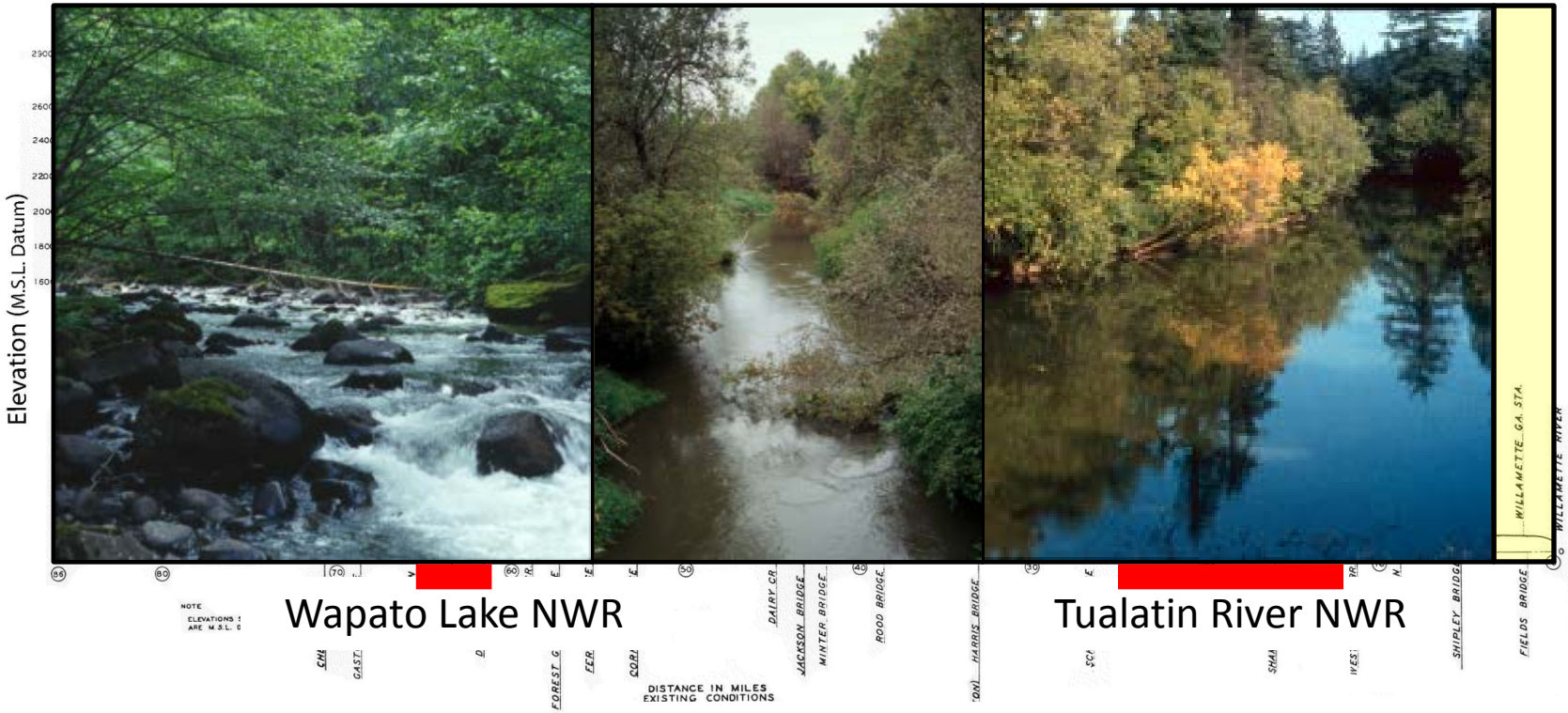
Drainage - 712 sq. miles



Tualatin River Watershed



Mountain Reach | Meander Reach | Reservoir Reach | Riffle Reach



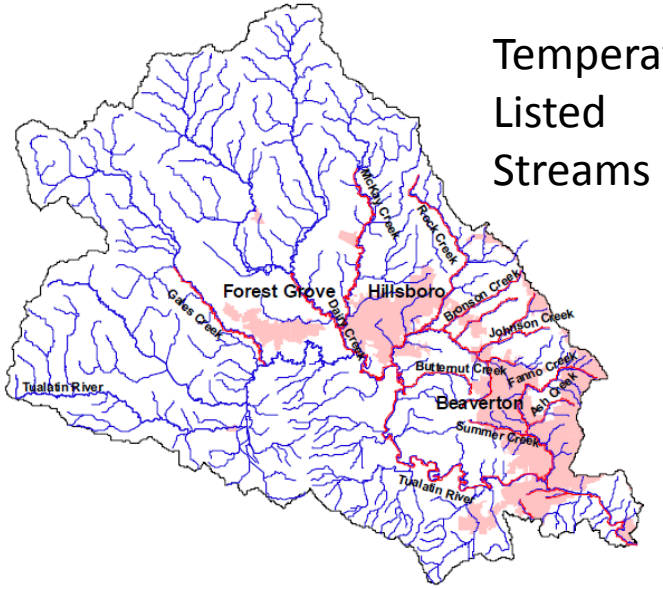
Average width – 15 ft
Slope – 74 ft per mile
Land use - forestry

Average width – 50 ft
Slope – 1.3 ft per mile
Land use - agriculture

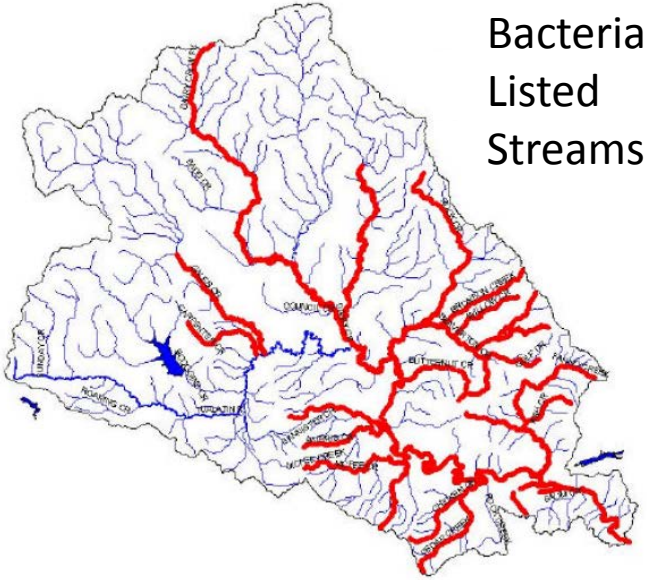
Average width – 150 ft
Slope – 0.08 ft per mile
Land use – ag/urban

TUALATIN RIVER
PLATE I

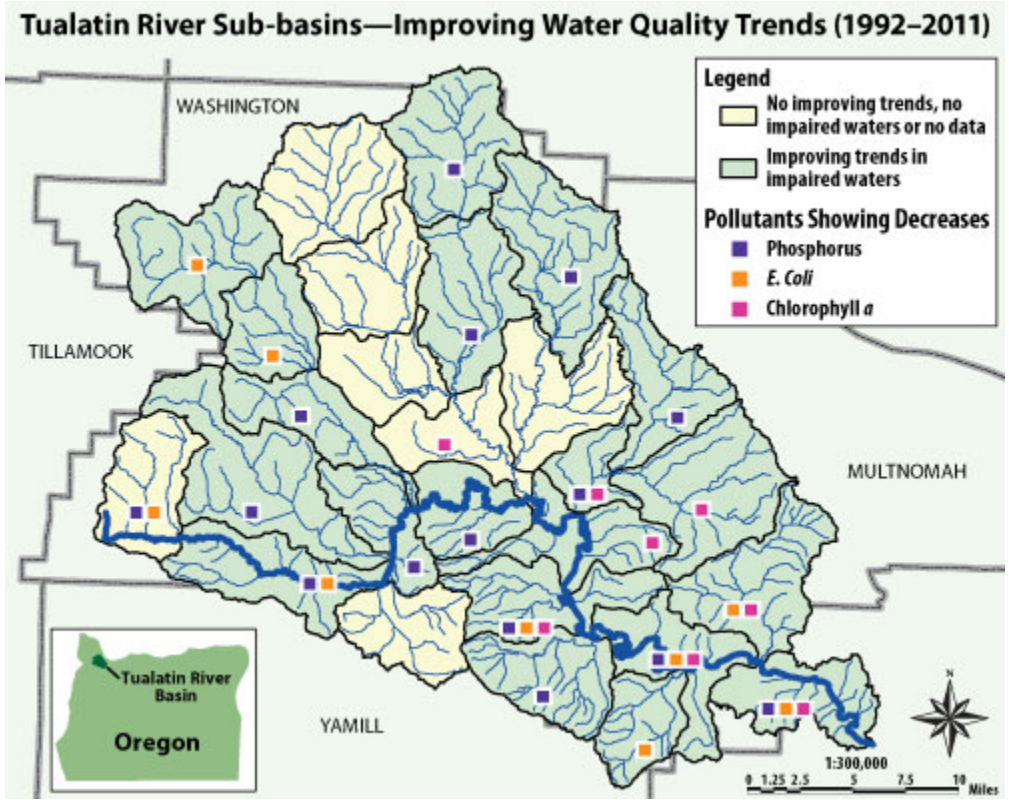
Impaired Streams



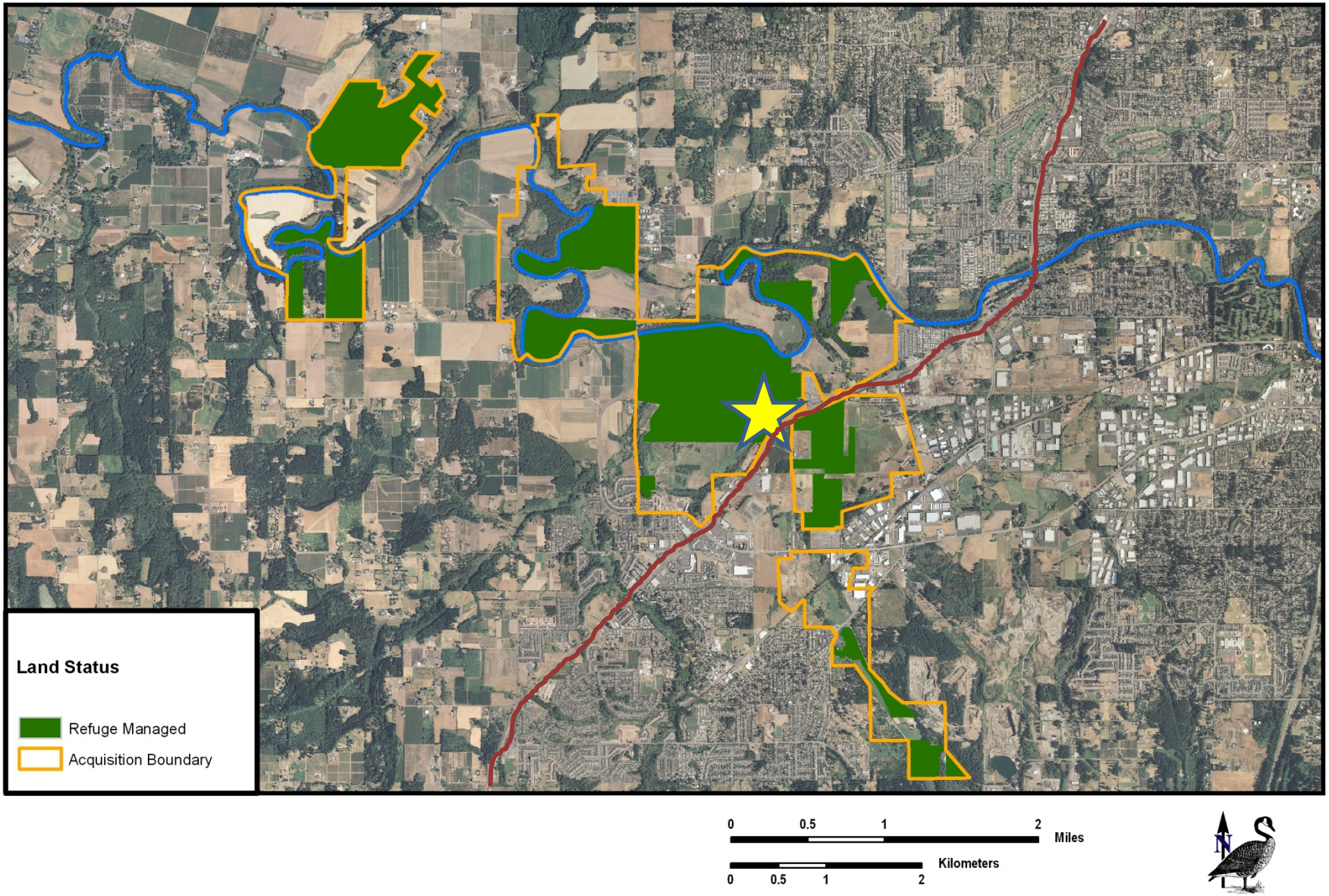
Temperature Listed Streams

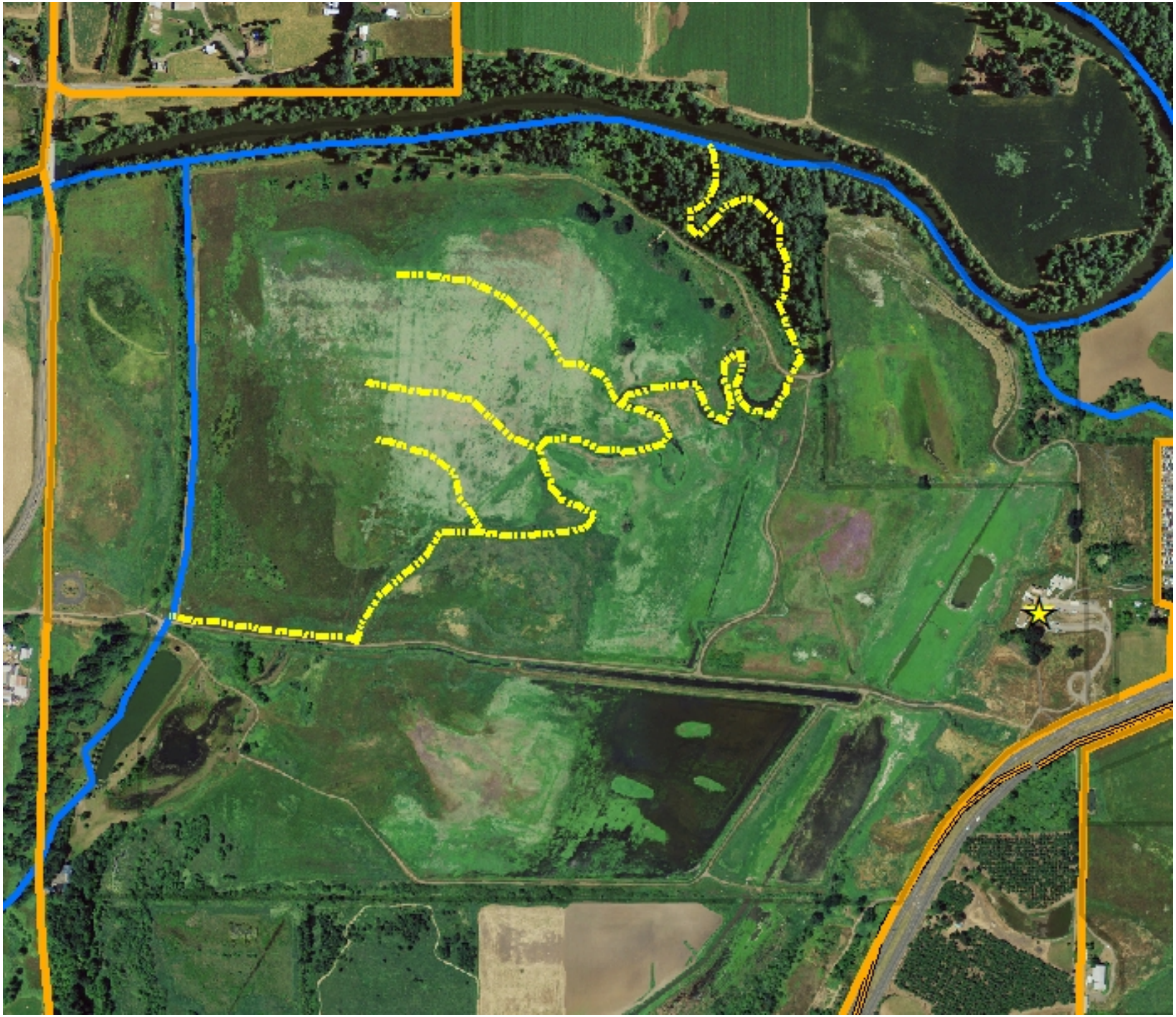


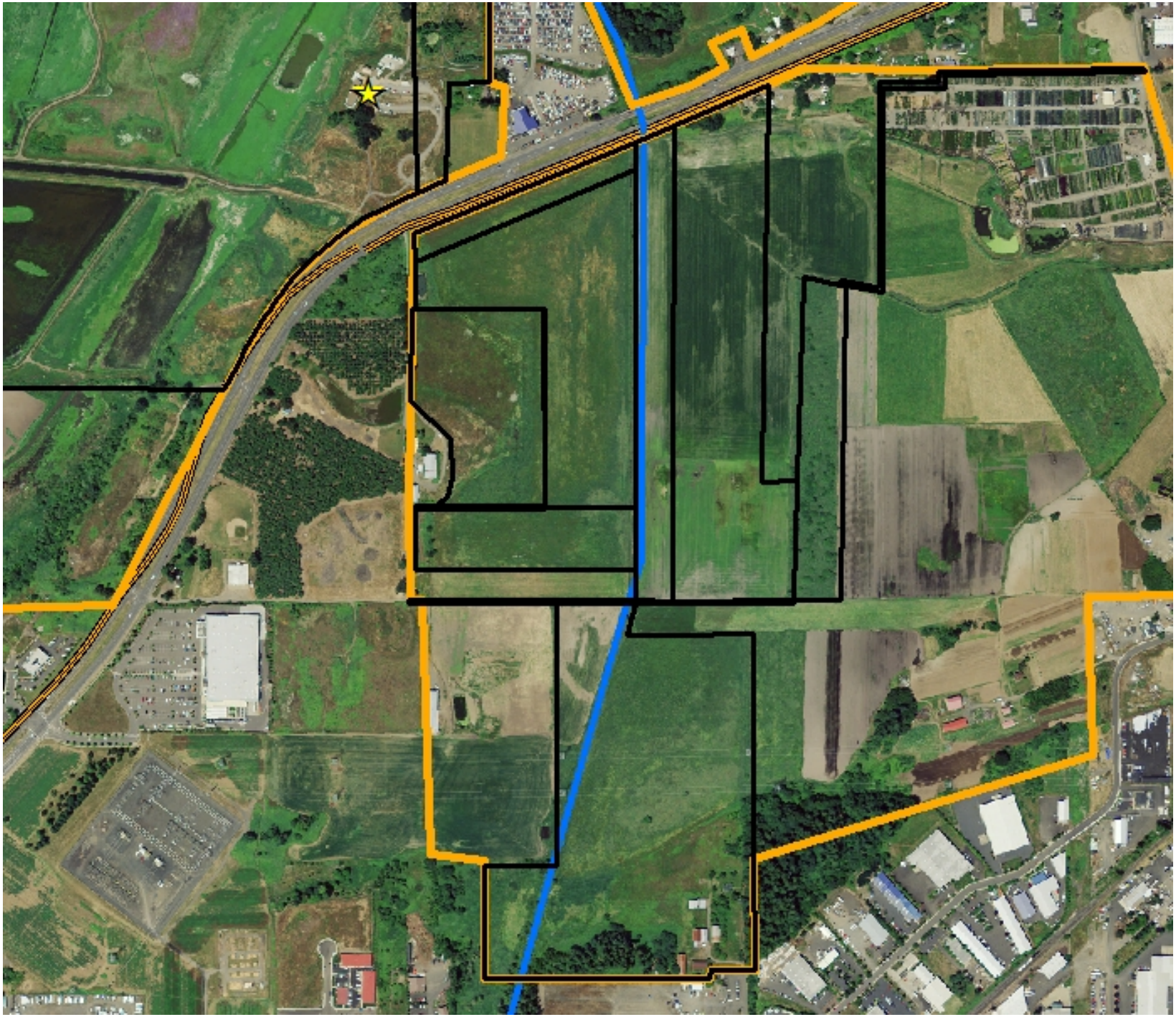
Bacteria Listed Streams

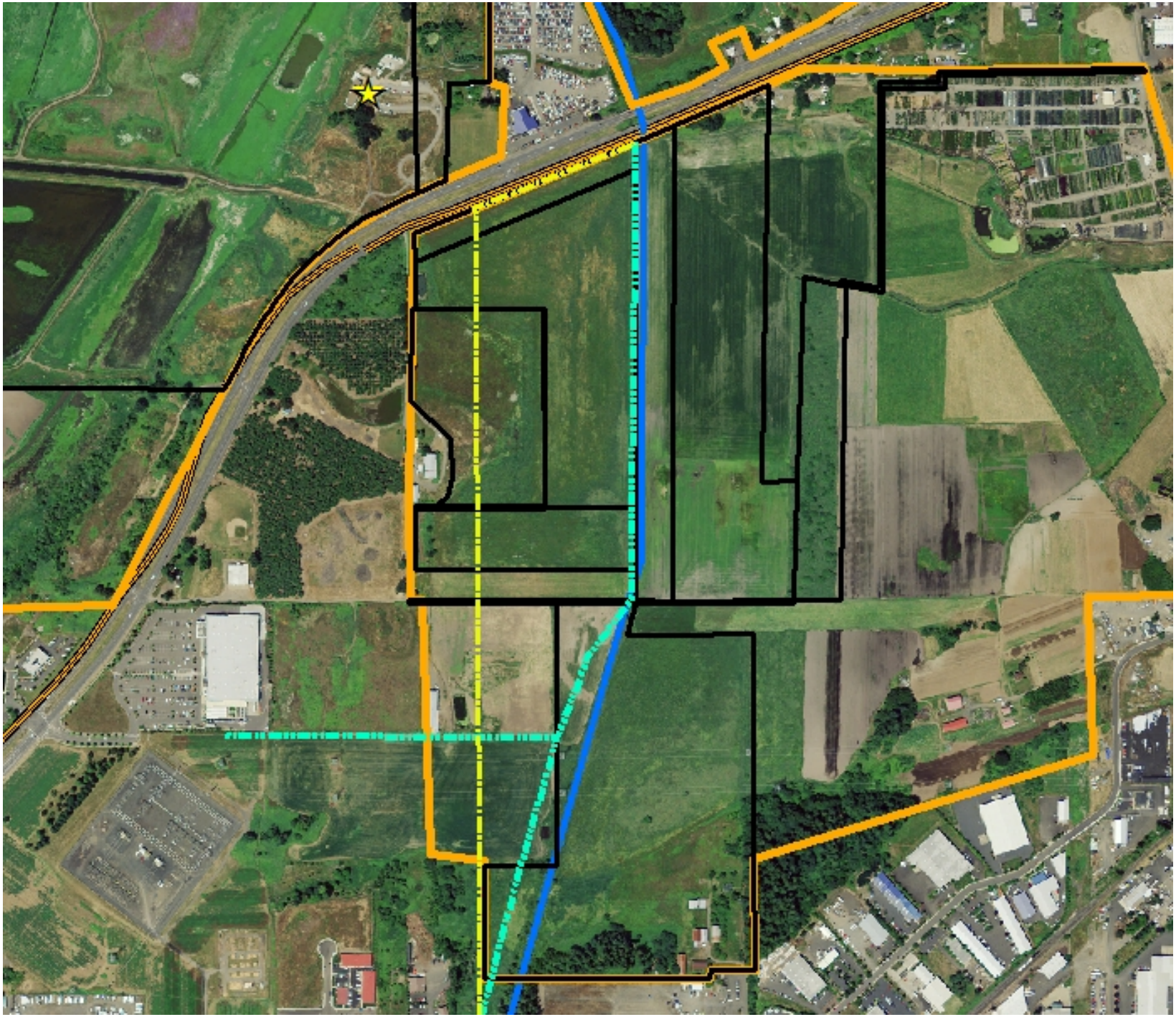


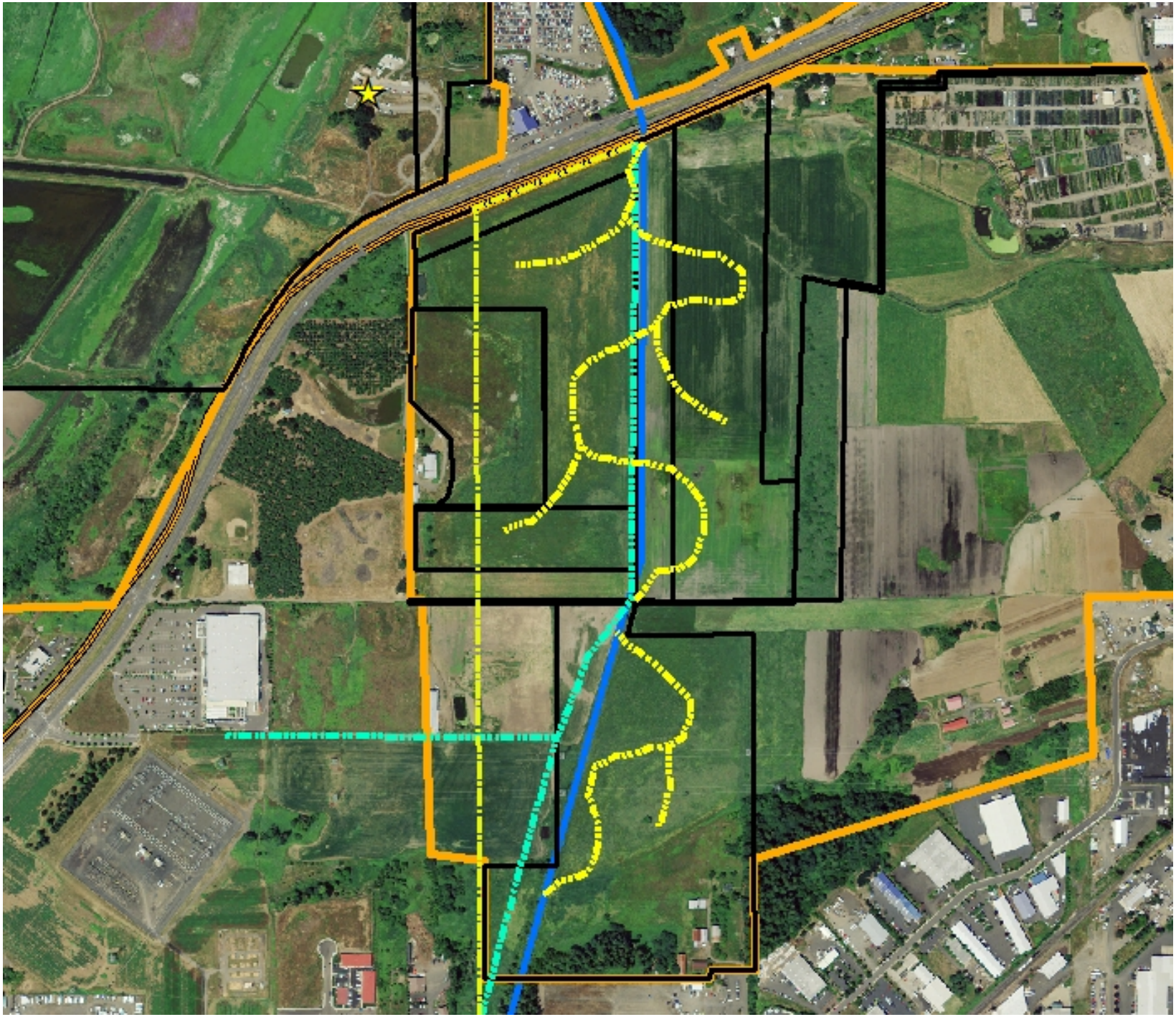
Tualatin River National Wildlife Refuge, Sherwood Units



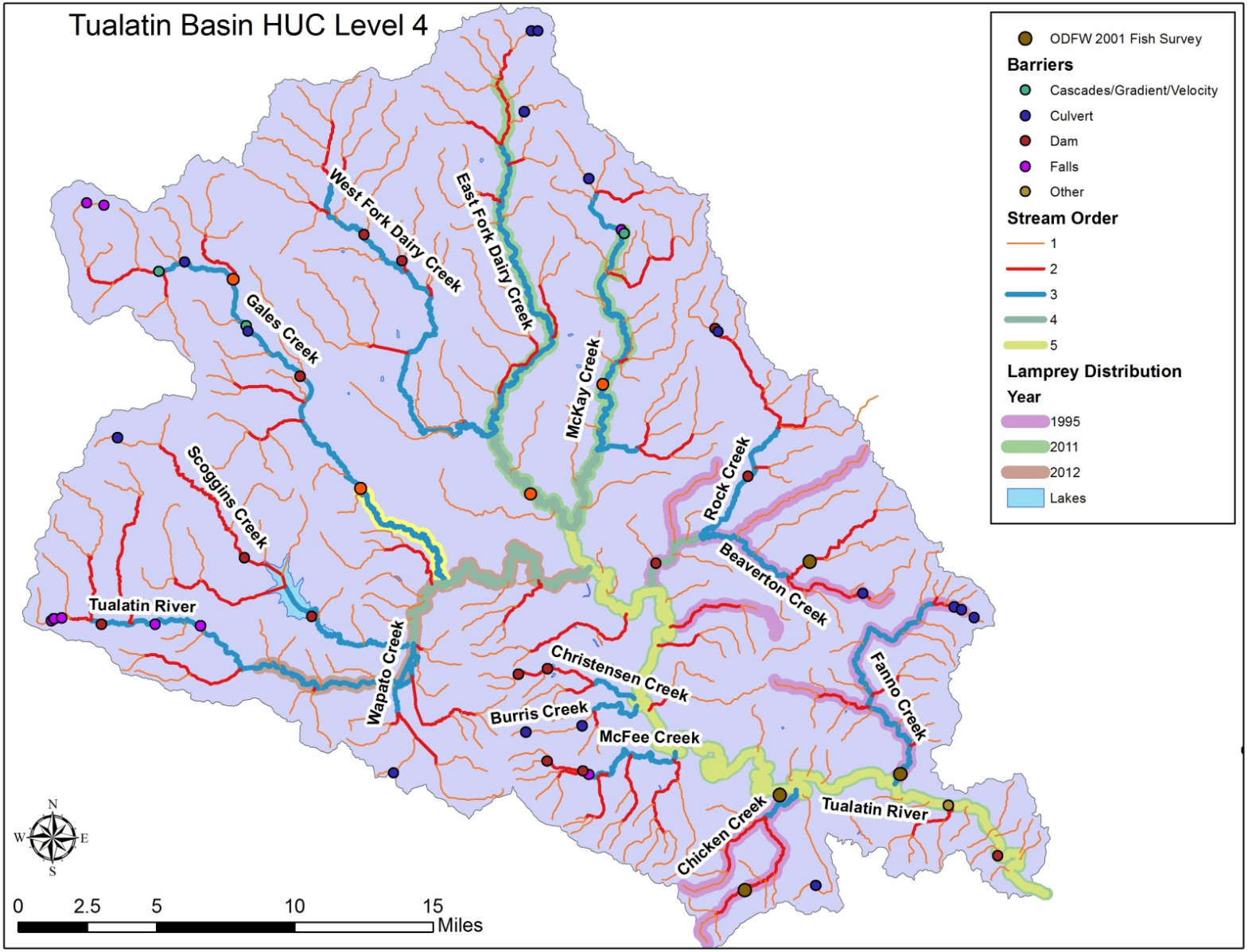








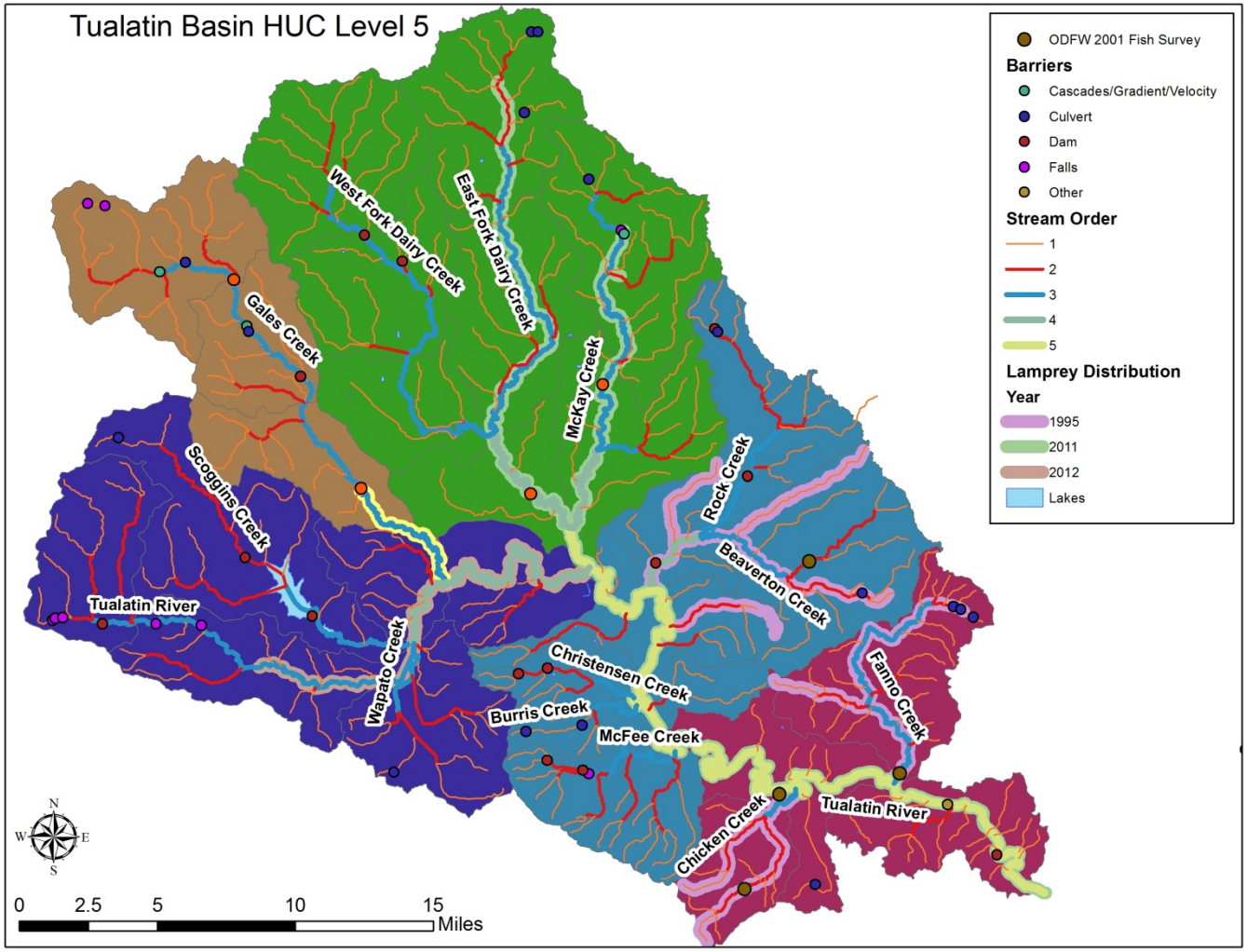
Tualatin


Tualatin Basin HUC Level 4
ODFW 2001 Fish Survey
Barriers
Cascades/Gradient/Velocity
Culvert
Dam
Falls
Other
Stream Order
1
2
3
4
5
Lamprey Distribution
Year
1995
2011
2012
Lakes
West Fork Dairy Creek
East Fork Dairy Creek
Gales Creek
McKay Creek
Scoggins Creek
Rock Creek
Beaverton Creek
Tualatin River
Wapato Creek
Christensen Creek
Fanno Creek
Burris Creek
McFee Creek
Chicken Creek
Tualatin River
N
W
E
S
0
2.5
5
10
15
Miles

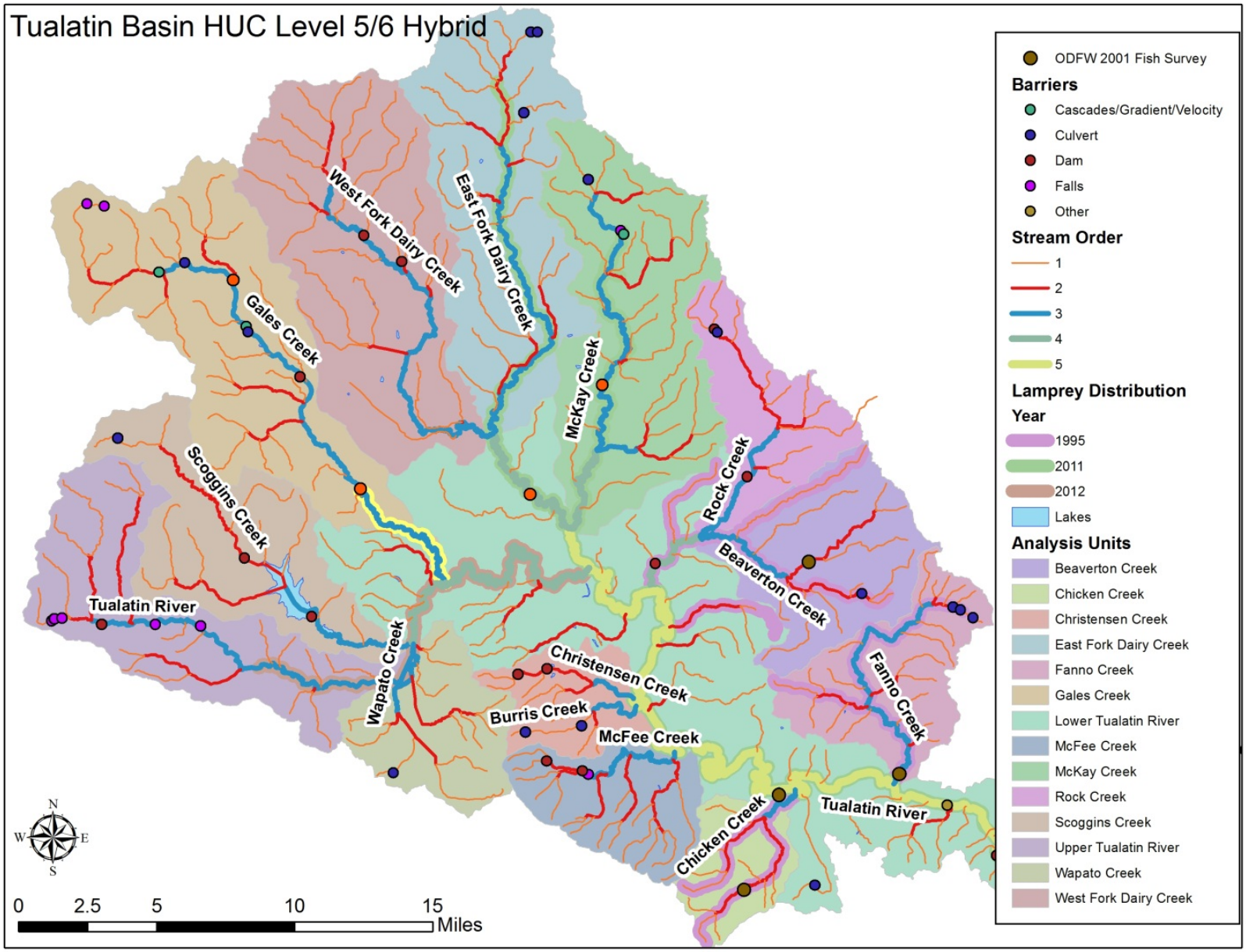
Tualatin example

- Steps – what is the question/goal?
- Figure out what we know and don’t know
- There are known knowns, known unknowns, and unknown unknowns
- Find existing data, make calls, dig in databases, scour reports
- Map the data

Tualatin example



Tualatin example



Refuge specific needs

- Stream channel restorations are planned
- Not a clear picture of lamprey distribution within the refuge
- Occupancy approach can inform and all higher levels – fine scale

Tualatin example

Working Example: Tualatin River Basin

1. Question: There are multiple
   - Occupancy and distribution within the Basin
   - Occupancy above and below a potential passage barrier on Gales Creek (Is Balm Grove Dam a barrier)?
   - Occupancy before/after refuge restorations
2. Scale: Multiple
3. Effort
4. Results
5. Conclusion

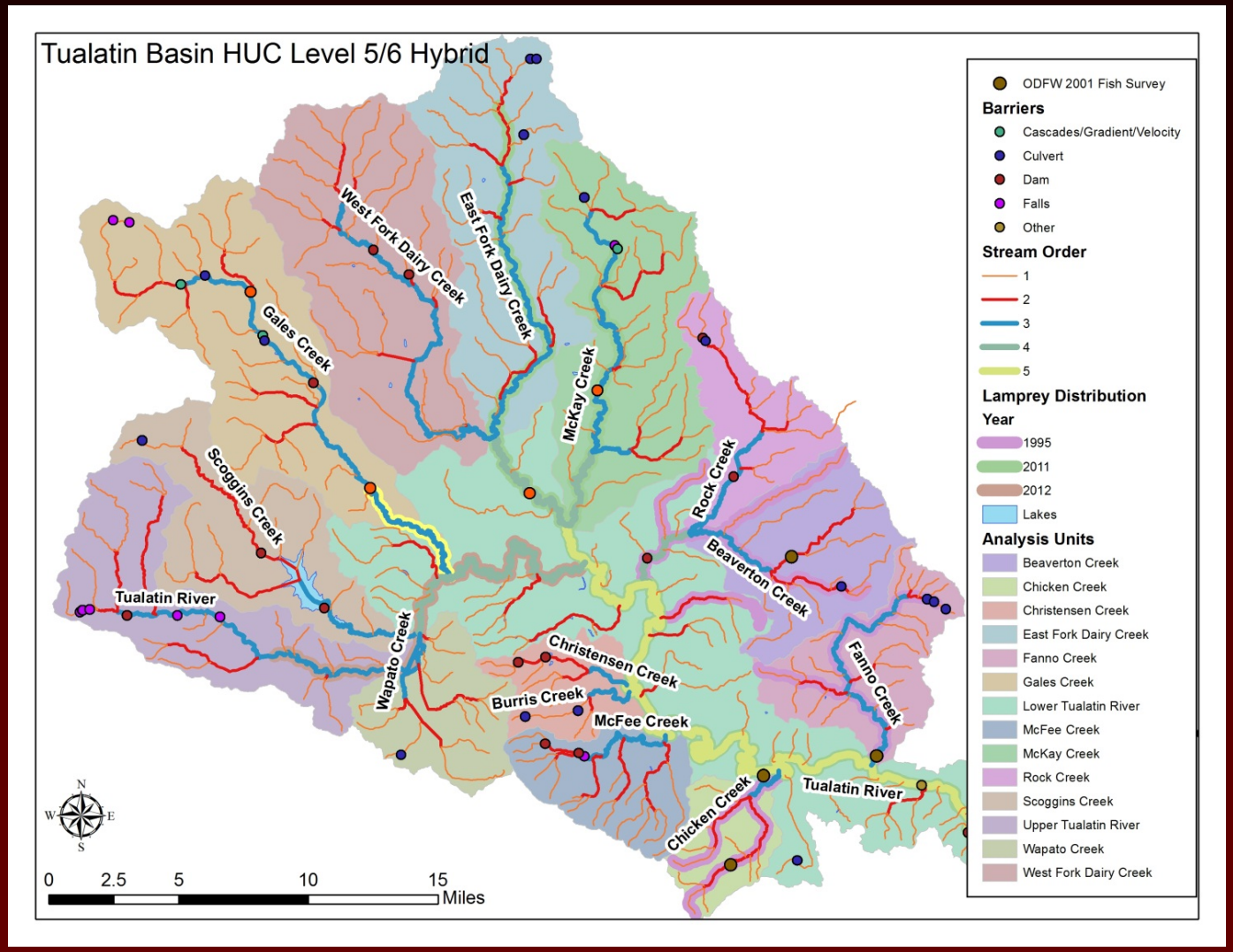
Simulated examples coming tomorrow

Occupancy Sampling Steps

1. State the occupancy question
2. Note what you know that might be useful to sampling
3. Select or estimate a detection probability
4. State the desired level of confidence that an area is unoccupied, if you do not detect presence
5. Identify the number of sites needed to obtain that level of confidence
6. Use GRTS to determine which sites to sample
7. Sample the sites (in any order) until you detect presence or you have finished all sites
8. State your final outcome:
    1. The area is occupied
    2. We are X% confident that the area is unoccupied at a detection probability of Y

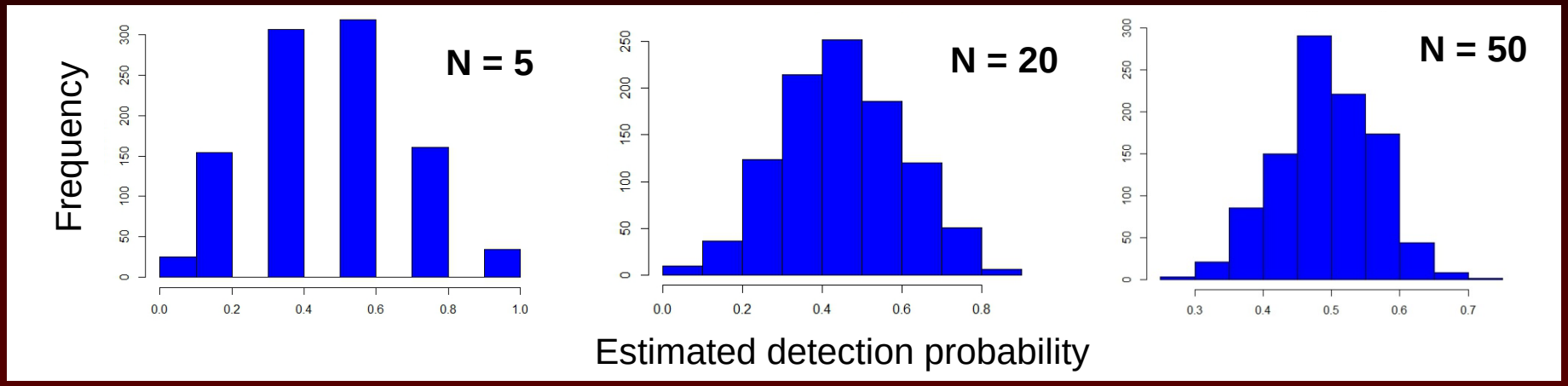
Tualatin Basin: Mock Example

- We “sampled” in Dairy Creek, Gales Creek, and Fanno Creek



Estimating Detection Probability

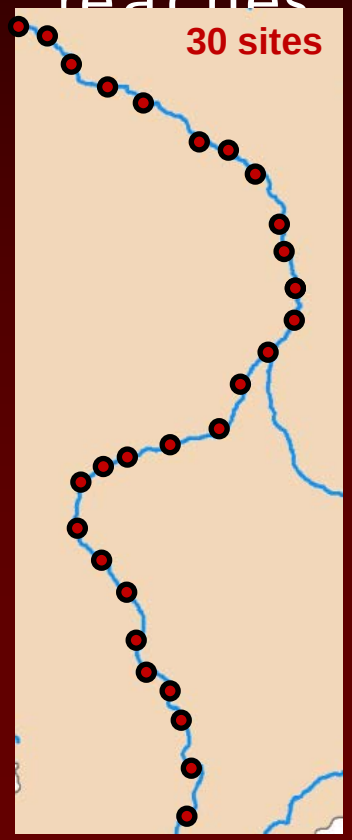
- Sample a large number of sites within an area of interest
  - “a large number” will depend on the spatial scale and expected detection probability
  - The larger the sample, the higher the precision
  - Example: True detection probability = 0.5

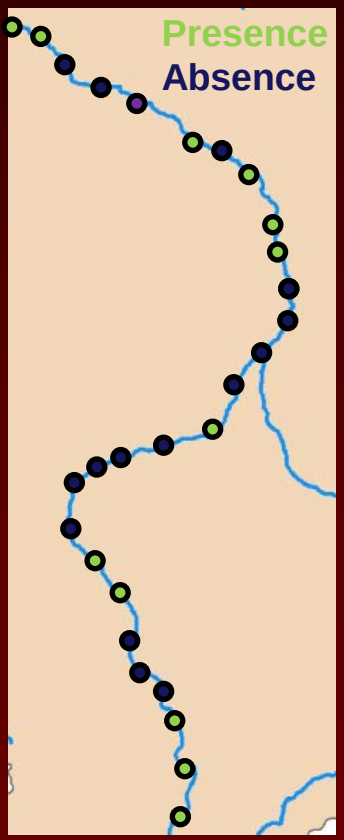


- Note at how many sites you detected presence
- The total number of sites with presence divided by the total number of sites sampled is detection probability
- **How to estimate detection probability example:**
  - Sampled at 20 sites
  - 16 had presence
  - Detection probability = 16/20 or 0.8

Estimating Detection Probability: Dairy Creek

- Sampled 30 reaches to estimate detection probability
- Used GRTS to pick the 30 reaches from all possible reaches





- 12 of 30 samples were positive for presence
- Detection probability: 12/30 or 0.4
- We used this detection probability for similar streams in the Tualatin basin

Gales Creek

1. Question: Is Gales Creek occupied both above and below Balm Grove Dam?
2. Information: Gales Creek in a 3rd order stream in the Tualatin Basin. We know that it was occupied in the past. It can be sampled well at low water. The sampling universe includes 27, 50-m reaches above and 44, 50-m reaches below the dam
3. Detection Probability: We use the detection probability from Dairy creek of 0.4, since it is a similar stream in the same basin. We assume this detection probability for both above and below Balm Grove Dam
4. Desired level of confidence: 95%

Balm Grove Dam

Question – Balm Grove Dam

Question:

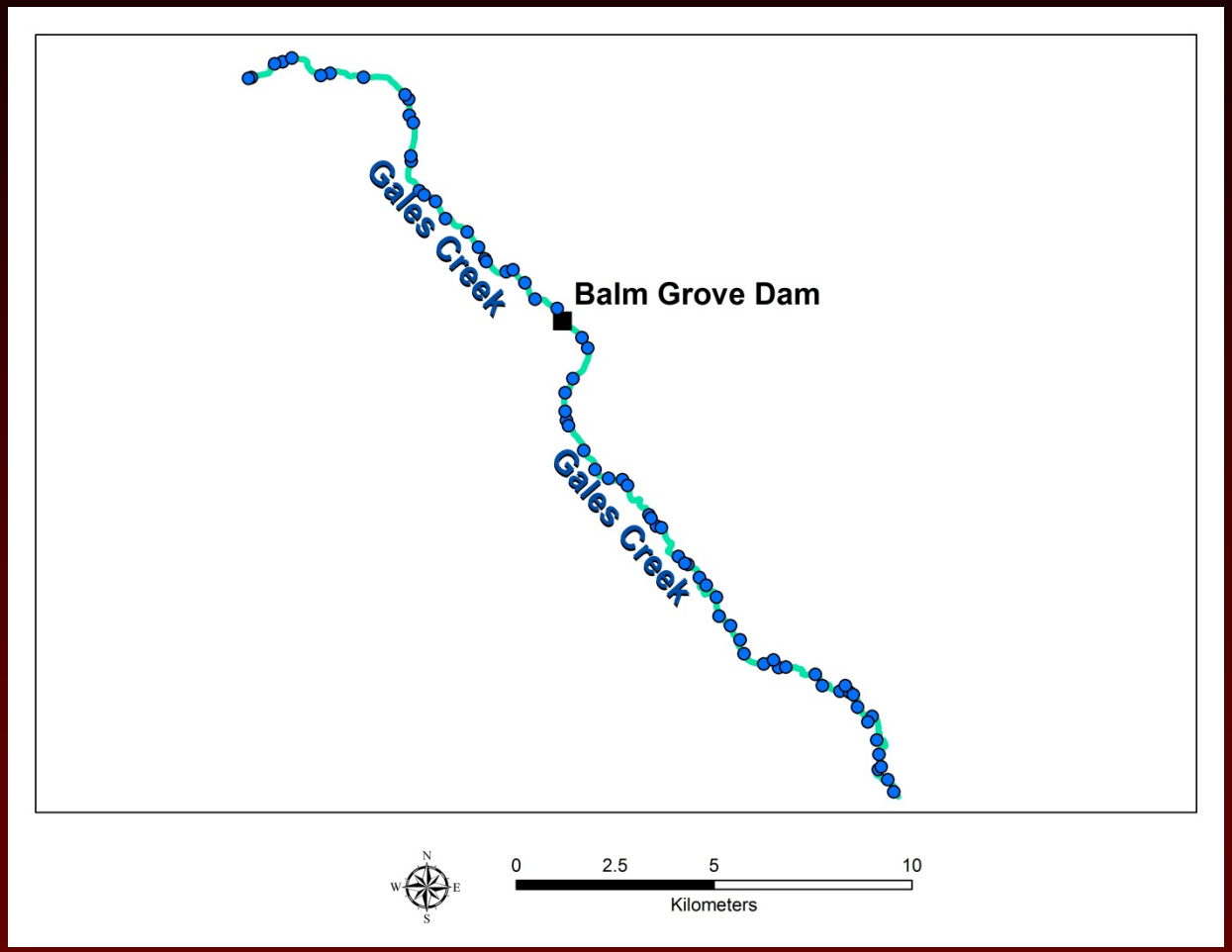
- **Is there evidence that the dam is a passage barrier to Pacific lamprey?**

Approach:

- **Do lamprey occupy Gales Creek below the dam?**
- **Do lamprey occupy Gales Creek above the dam?**

Sample Framework – Balm Grove

- Gales Creek sample universe
- GRTS Reaches

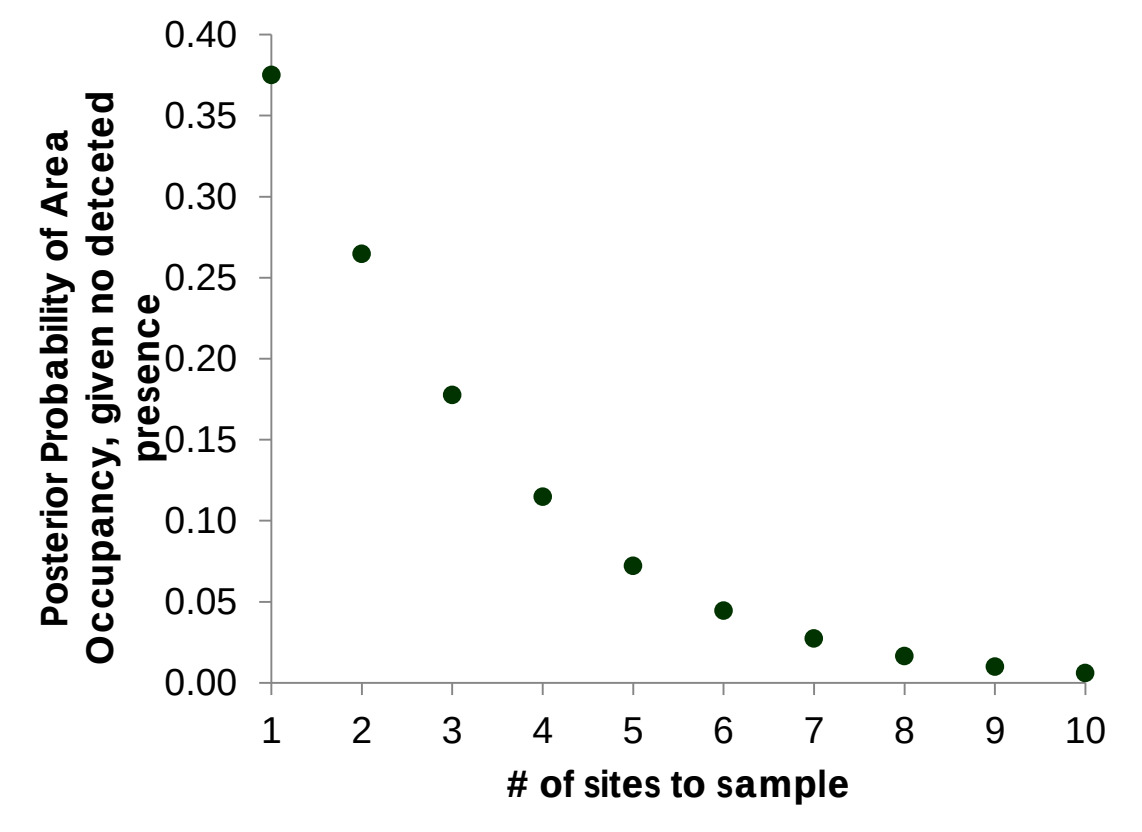


Gales Creek: How many sites?

- Plug the selected detection probability (0.4) into the equation:

Probability of area occupancy given no detection at multiple sites $= \dfrac{((1-dp)^{sites})}{((1-dp)^{sites} + 1)}$

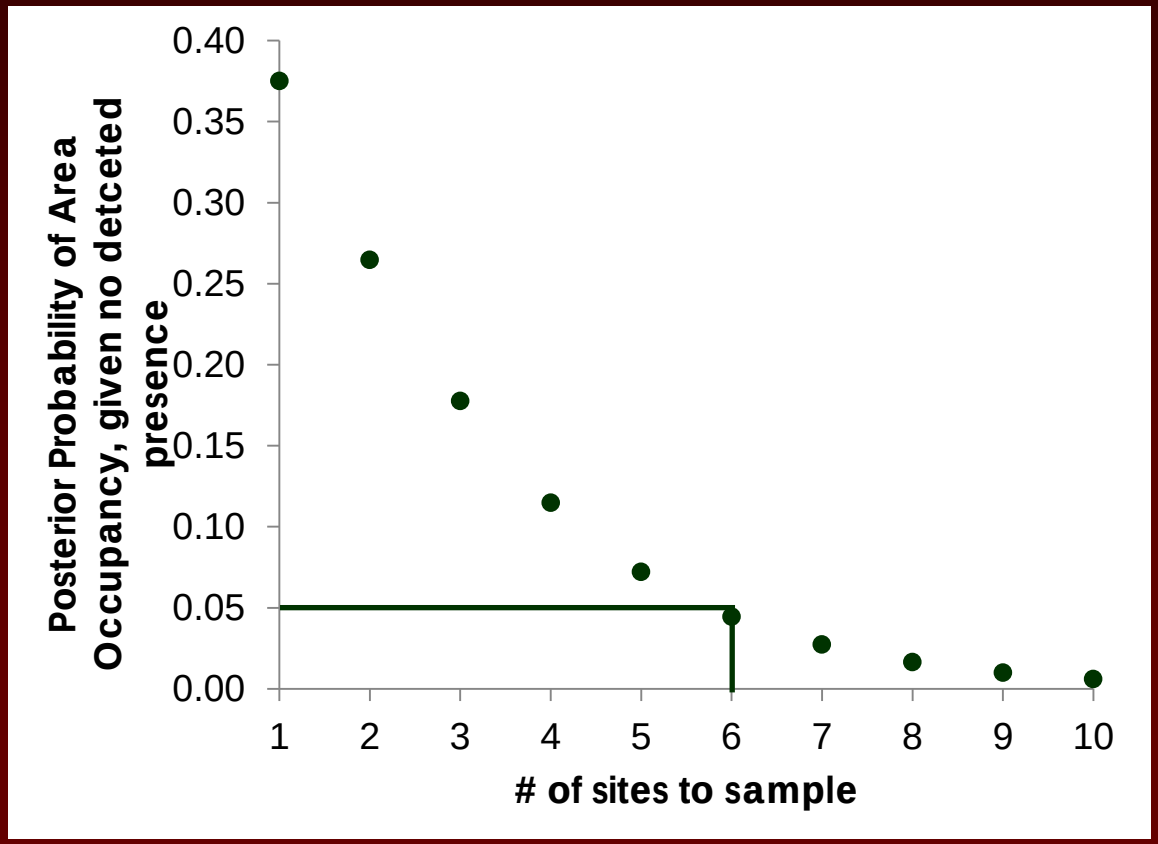
# of sites	PP of Occupancy
1	0.38
2	0.26
3	0.18
4	0.11
5	0.07
6	0.04
7	0.03
8	0.02
9	0.01
10	0.01



Gales Creek: How many sites?

- We need to sample 6 reaches above and 6 reaches below to obtain 95% confidence that each area is unoccupied if we do not detect presence

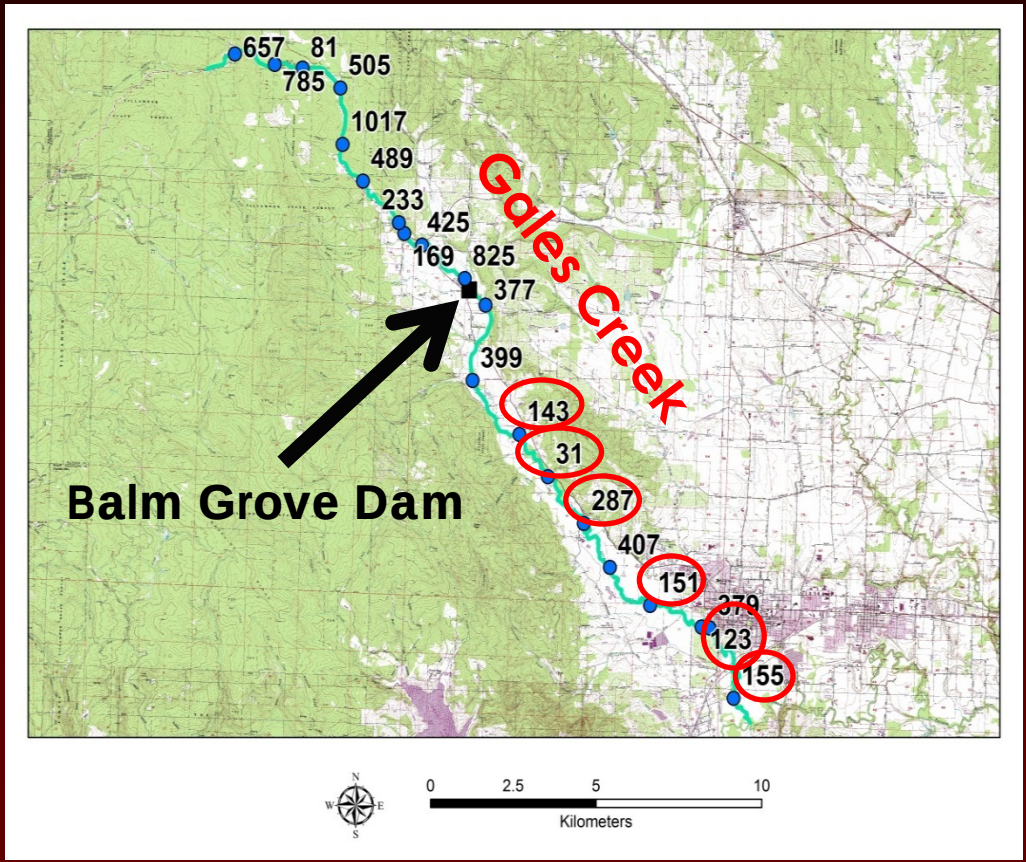
# of sites	PP of Occupancy
1	0.38
2	0.26
3	0.18
4	0.11
5	0.07
6	**0.04**
7	0.03
8	0.02
9	0.01
10	0.01



Gales Creek Site Selection

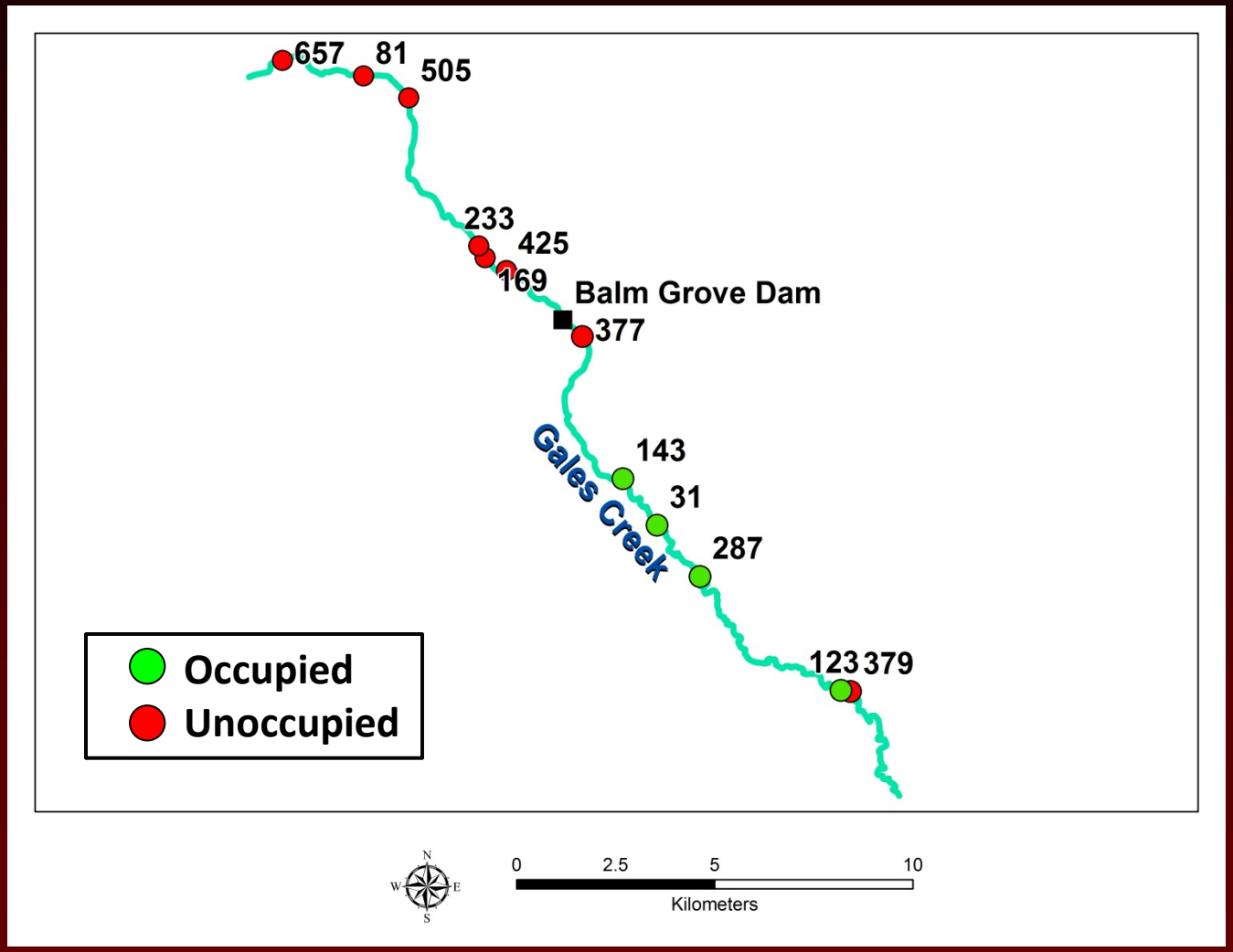
GRTS Reach Sampling Approach

- 10 lowest numbered (highest priority) above & below Balm Grove Dam
- 6 GRTS reaches/unit
  - Sample 6 lowest numbered, <u>viable</u> GRTS reaches/unit
  - Eliminate <u>non-viable</u> reaches, move down list
- Sample in any order, maybe start with 155 and move up



Results – Balm Grove Dam

- 4 of 6 GRTS reaches below Balm Grove occupied
- 0 of 6 above Balm Grove Dam occupied



Conclusions – Balm Grove Dam

Occupy below?

- **Yes**
- **Revised detection probability = 0.66**

Occupy above?

- **Assuming a Dp of at least 0.4, we are 95% confident Gales Creek above Balm Grove Dam is not occupied by larval Pacific lamprey**

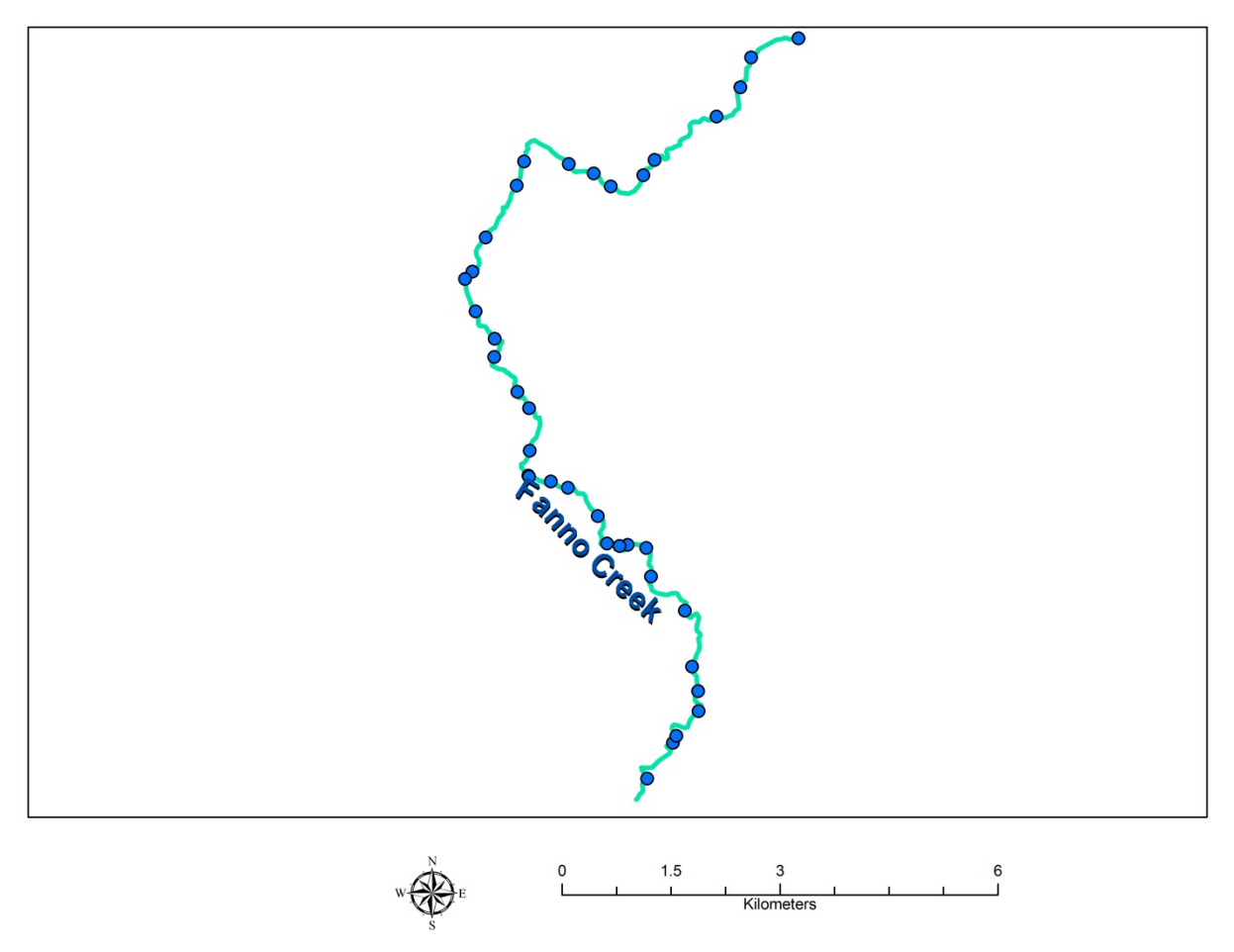
Dam appears to be a passage barrier

Fanno Creek

1. **Question: Is Fanno Creek occupied? Has the distribution of Pacific lamprey within the Tualatin HUC4 changed?**
2. **Information: Fanno Creek a 3rd order stream and part of a HUC5 within the Tualatin. Historic data indicate that Pacific Lamprey previously occupied Fanno Creek, and the HUC5 of which it is part, but it is unclear if the creek is still occupied. There are 36, 50-m reaches in Fanno Creek (our sampling universe).**
3. **Detection Probability: We use the detection probability from Dairy Creek of 0.4, since it is a similar stream in the same basin.**
1. **Desired level of confidence: 95%**

Sample Framework – Fanno Creek

- **Fanno Creek sample universe**
- **GRTS Reaches**

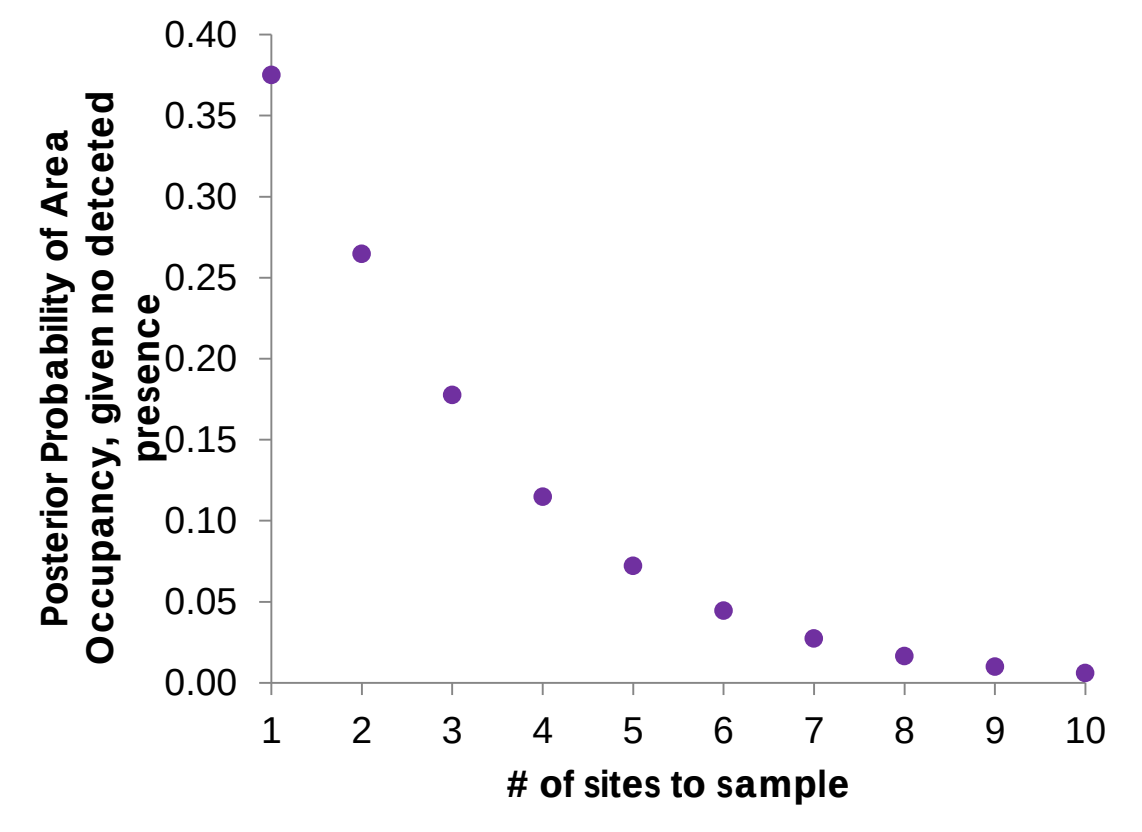


Fanno Creek: How many sites?

- Plug the selected detection probability (0.4) into the equation:

Probability of area occupancy given no detection at multiple sites $= \dfrac{((1-dp)^{sites})}{((1-dp)^{sites} + 1)}$

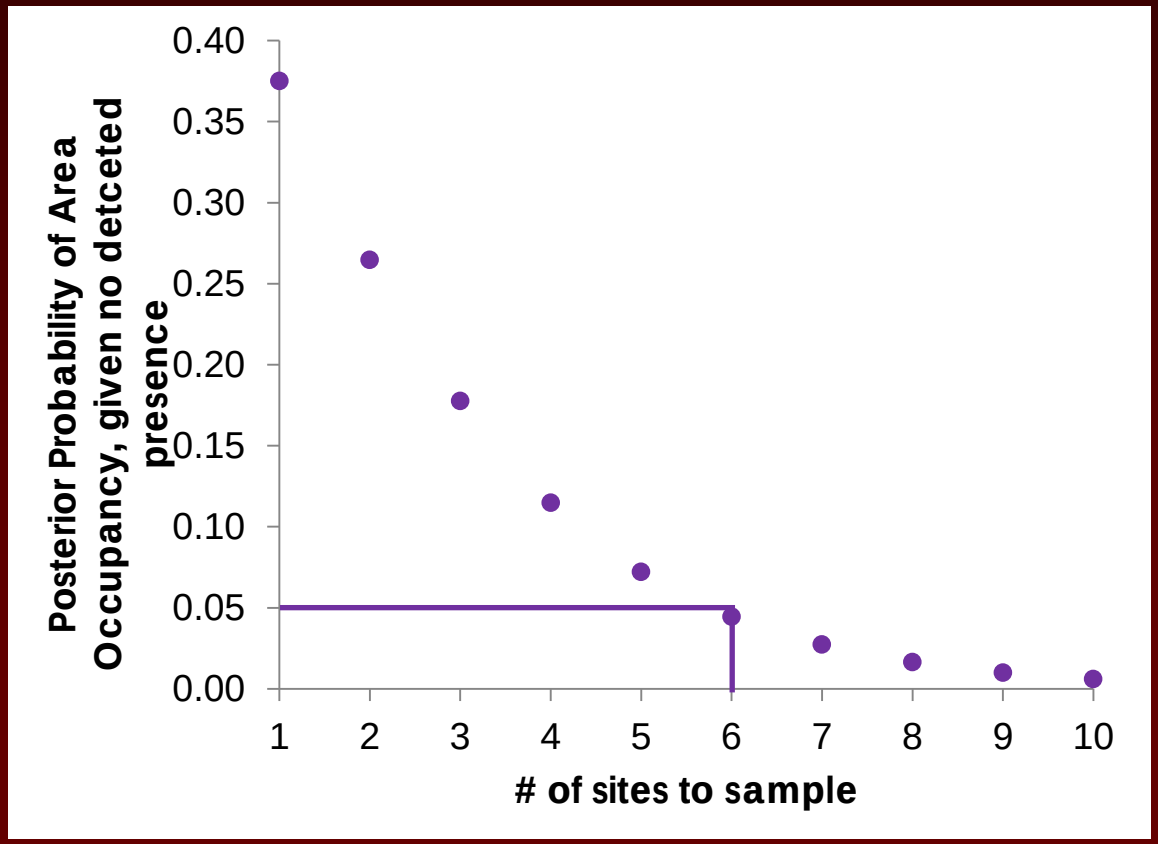
# of sites	PP of Occupancy
1	0.38
2	0.26
3	0.18
4	0.11
5	0.07
6	0.04
7	0.03
8	0.02
9	0.01
10	0.01



Fanno Creek: How many sites?

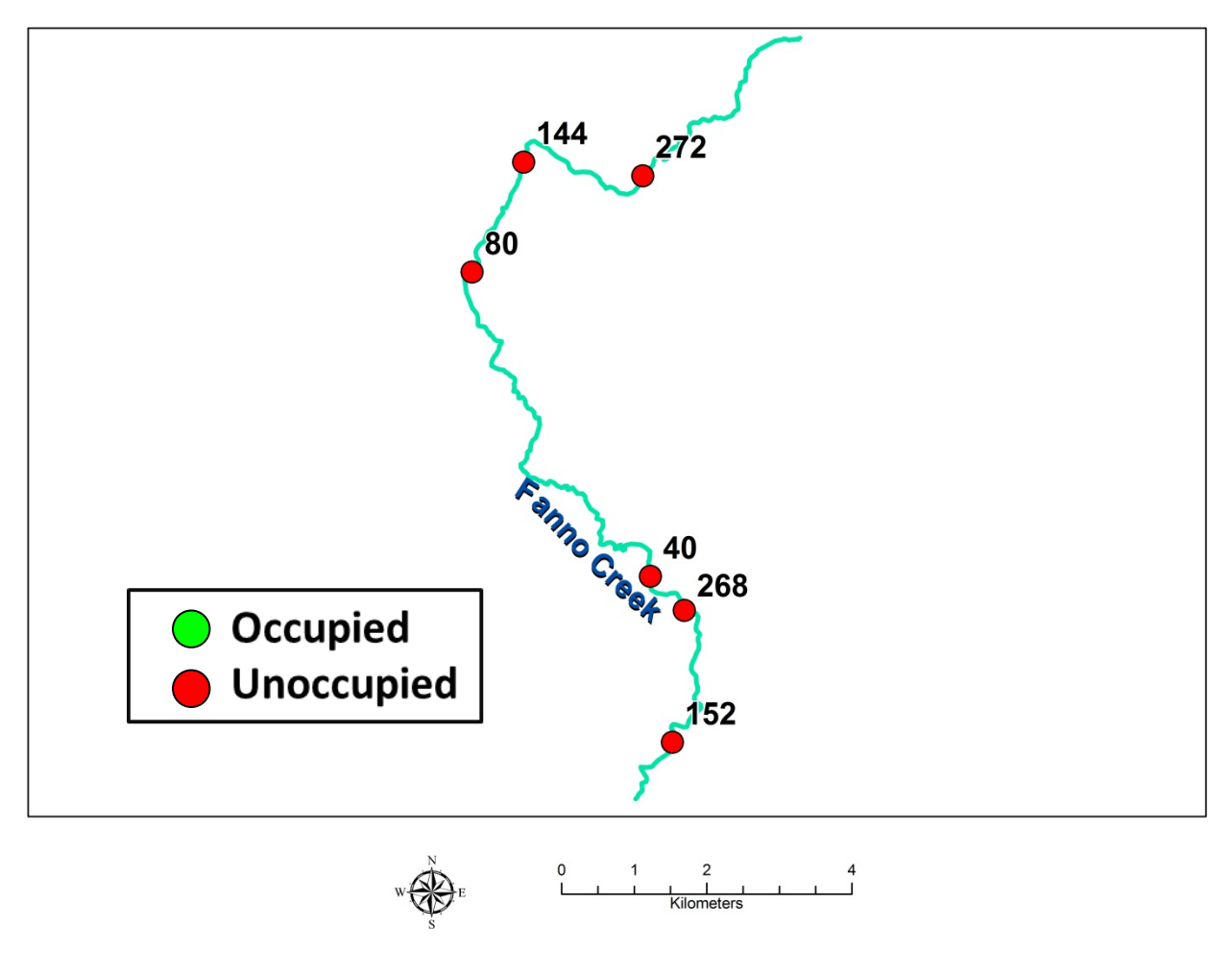
- We need to sample 6 reaches in Fanno Creek to obtain 95% confidence that the area is unoccupied if we do not detect presence.

# of sites	PP of Occupancy
1	0.38
2	0.26
3	0.18
4	0.11
5	0.07
6	**0.04**
7	0.03
8	0.02
9	0.01
10	0.01



Results – Fanno Creek

- **0 of 6 reaches occupied**



Conclusion – Fanno Creek

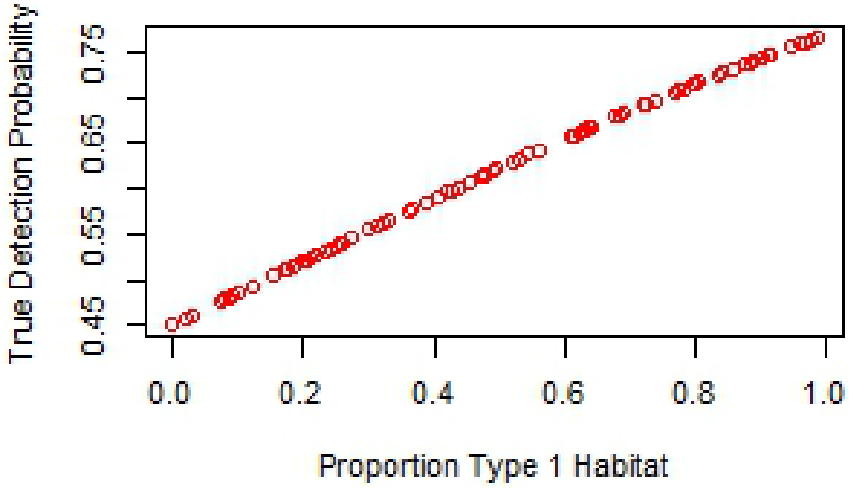
- **Is Fanno Creek occupied?**
- **Assuming a Dp of at least 0.4, we are 95% confident Fanno Creek is not occupied by larval Pacific lamprey**
- **Suggests that distribution within HUC4 (relative the this specific HUC5) has contracted**

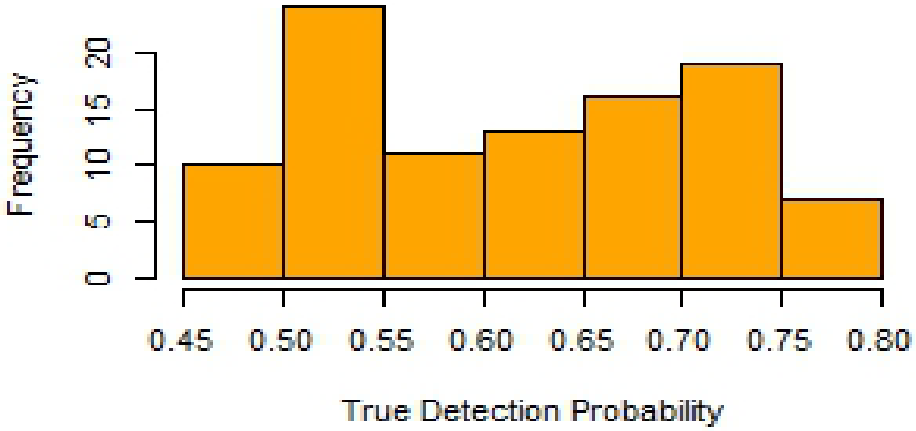
Detection probability estimation and environmental covariates

- Habitat can affect detection probability
- If we all use standardized protocols to estimate detection probability, in the future, we will have a better understanding of the relationship between habitat covariates and detection probability
- This will help us better evaluate occupancy
- Overall this will be labor intensive, but if we all contribute, it could be possible

Detection probability and environmental covariates: a simulation with fake data

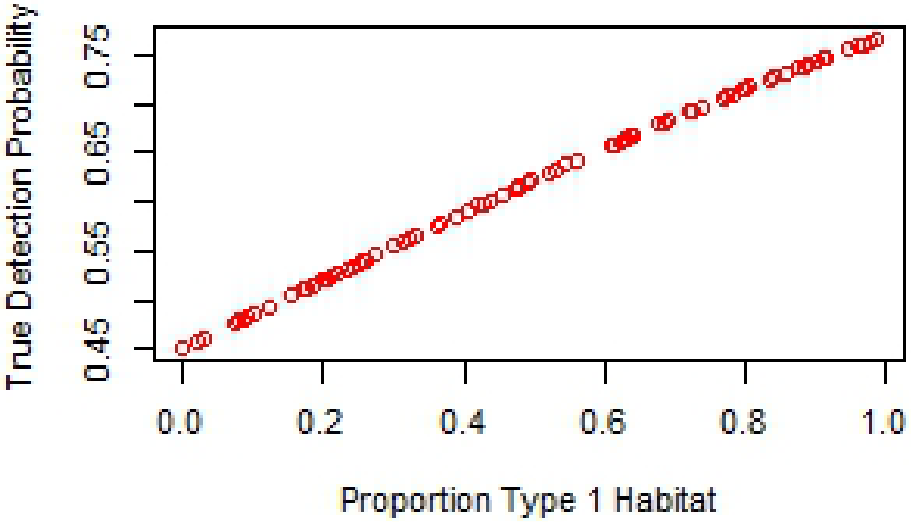
- **Example: detection in different habitats (simulation)**
  - Type-1 habitat impacts detection probability
  - Simulate 100 areas each with a different proportion Type-1 habitat
  - The proportion of Type-1 habitat impacts detection probability
  - Detection probability: 0.45 to 0.75, based on proportion Type-1 habitat
  - Mean detection probability: 0.61

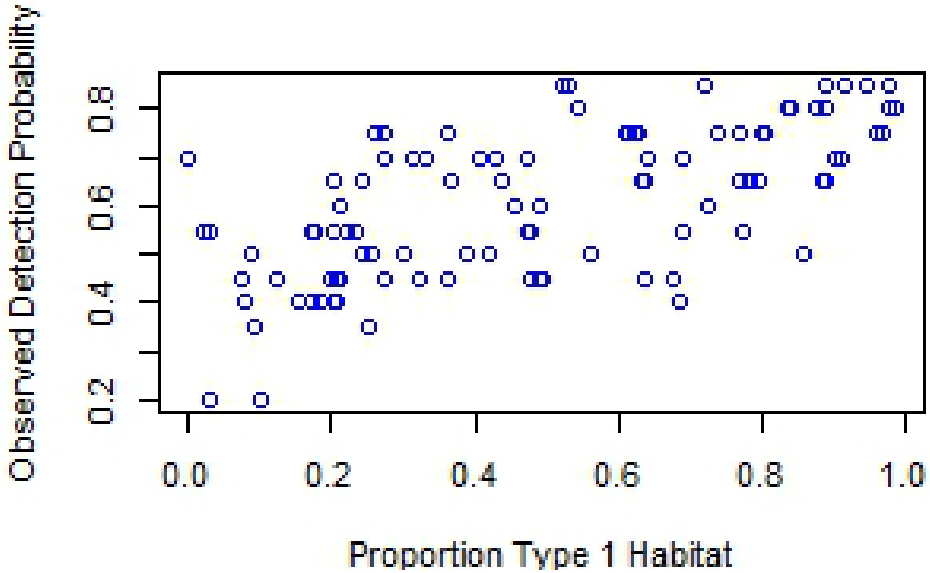




Detection probability and environmental covariates: adding sampling error

- **Add sampling error**
- **We "sampled" 20 sites within each of the 100 areas**
  - "True" relationship between proportion Type-1 habitat and detection probability would be apparent with infinite samples
  - "Observed" relationship is seen with 20 samples
  - "Observed" relationship has variability
  - No need to sample exactly 20 sites in each area for this to work



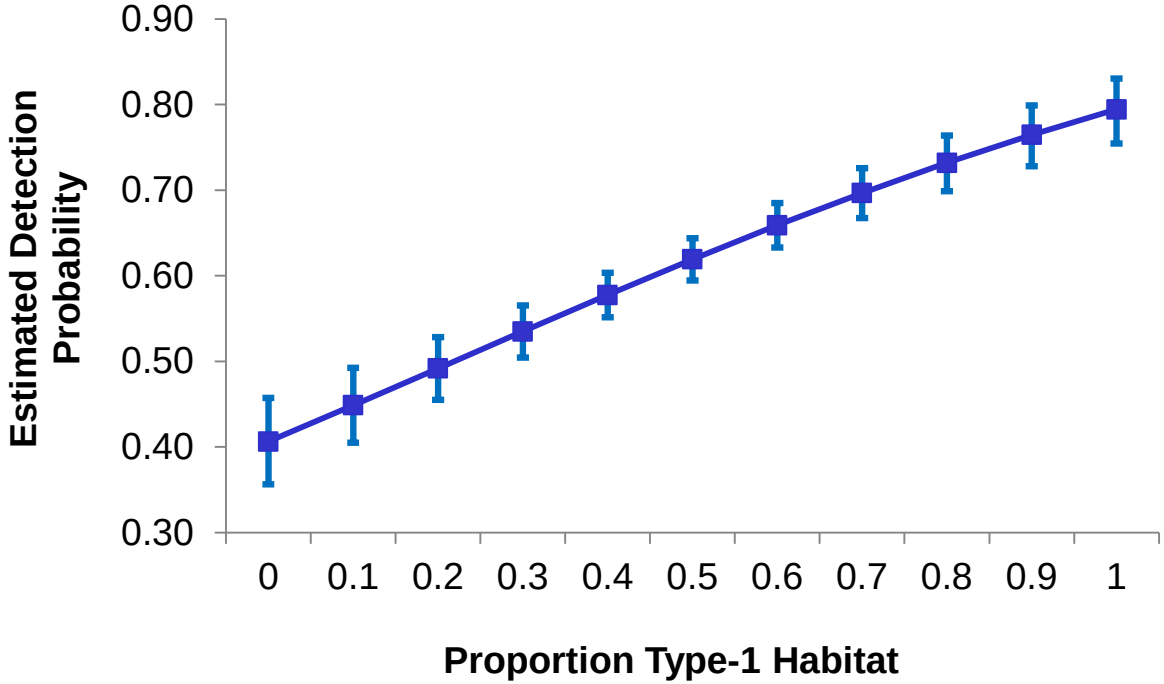


Model: Logistic Regression

- **Use logistic regression to evaluate detection probability as a function of proportion Type-1 habitat**
- A logistic function is used to convert a linear combination of independent variables to a probability of detecting presence
  - Same family as a simple linear regression, but the response variable is either a 0 or 1 (i.e., presence not detected or presence detected)
  - Any number of independent variables
- 1) First model run: no covariates
- 2) Second model run: proportion Type-1 habitat as a covariate
  - In the future, models could have more complicated relationships and/or multiple covariates

Environmental Covariates Results

- No covariate:
  - Mean estimated detection probability: 0.61 (95%: 0.58-0.65)
  - Estimated standard deviation: 0.53 (95%: 0.40-0.69)
- Proportion Type-1 habitat as a covariate:
  - Estimated standard deviation: 0.21 (95%: 0.02-0.38)
  - Detection probability as a function of Type-1 Habitat



We get an estimate of detection probability based on the proportion Type-1 habitat.

We can use this in future occupancy sampling, if we have information on the proportion of Type-1 habitat.

What does this analysis show us?

- If multiple studies to estimate detection probability included measurement of habitat covariates, we could model the relationship between the habitat covariates and detection probability and have a better understanding of what our detection probability should be in areas of unknown occupancy, if we know something about the habitat there
- We could have knowledge of habitat from previous studies, GIS layers, current sampling, etc.
- Could include multiple environmental factors and use model selection tools to pick out the most important
- These analyses would be done as more information on detection probability is collected over time
  - We all can contribute, if we use similar sampling methods
- The habitat variables of interest would be scale dependent
  - Microhabitat variables may be very important in small-scale studies
  - Macro-scale variables for larger scale

Discussion:

- What environmental covariates are important at what scales?
- How would this affect your sampling?

Larval Identification

Larval Lamprey - Genus ID

- Caudal pigmentation patterns; > 60 mm TL
- *Entosphenus* - Pacific lamprey (PCL; *Entosphenus tridentatus*)
- *Lampetra*
  - Western brook lamprey (WBL; *Lampetra richardsoni*)
  - River lamprey (RL; *Lampetra ayresii*)

Juvenile & Adult Lamprey

- Dentition
- PCL vs. RL (vs. Adult WBL)

Larval Identification

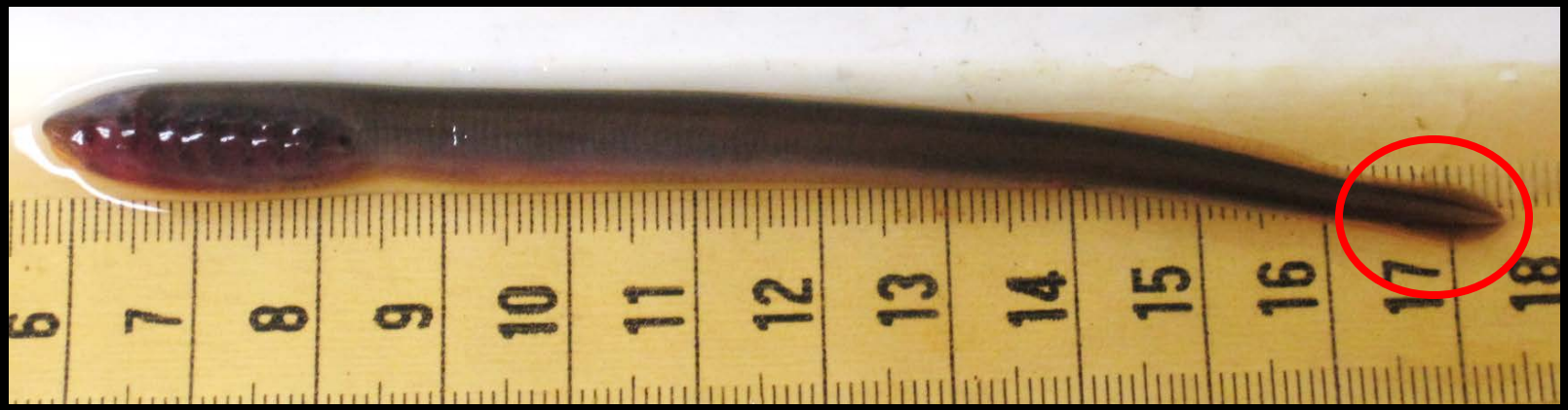
Goodman et al. 2009

- Morphological diagnosis of *Entosphenus* and *Lampetra* ammocoetes (Petromyzontidae) in Washington, Oregon, and California. Biology, management, and conservation of lampreys in North America. American Fisheries Society, Symposium 72, Bethesda, Maryland

Richards et al. 1982

- Descriptions and keys for ammocoetes of lampreys from British Columbia, Canada. Canadian Journal of Fisheries and Aquatic Sciences 39:1484-1495

•Relative differences in caudal region pigmentation



Larval Identification

Caudal anatomy: Ridge vs. Fin

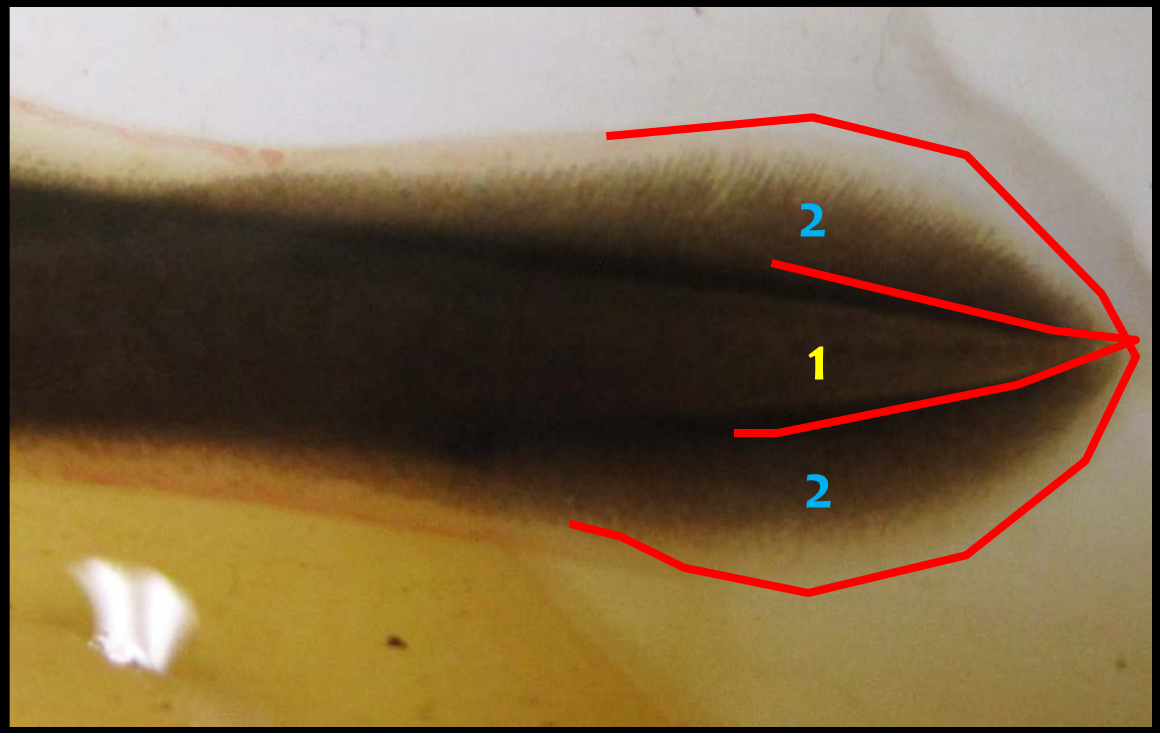
Caudal ridge (1)

- Posterior-most trunk myomeres in center of tail

Caudal fin (2)

- Thin, fin tissue

**Pigmentation differences in both regions can be used to differentiate *Entosphenus* from *Lampetra*

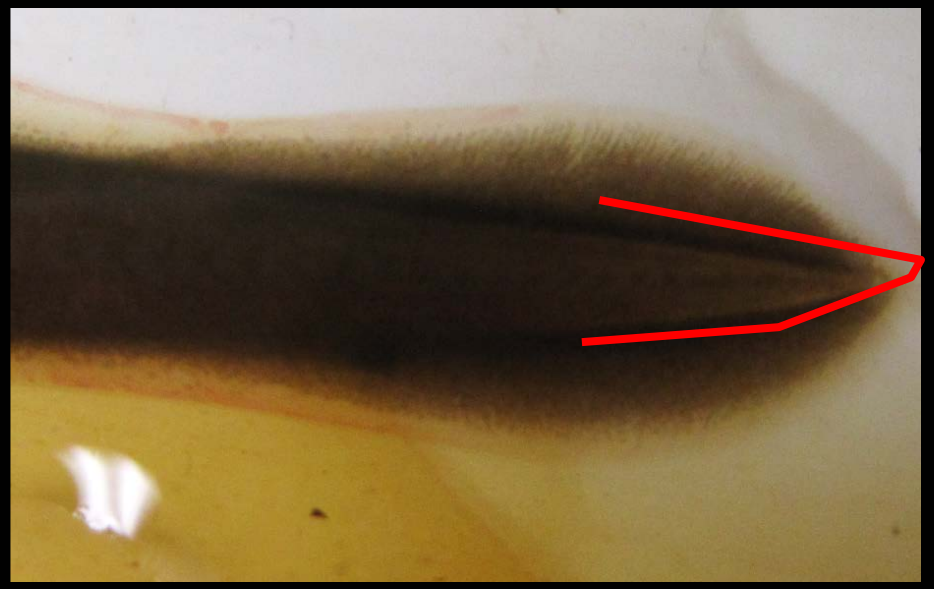


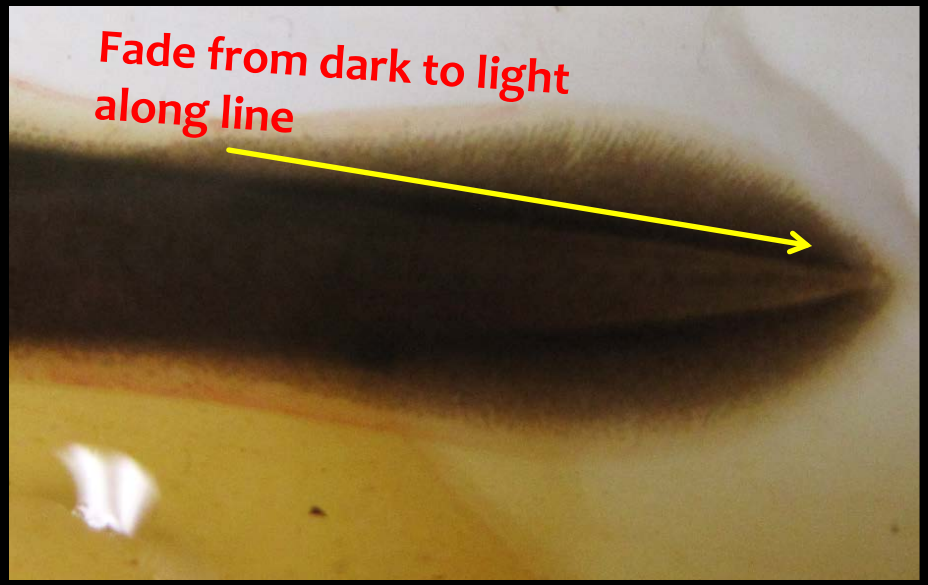
Larval Identification

Pacific lamprey Larvae

Caudal ridge FADE

- Pigmentation transitions from dark to light from anterior to posterior: <u>FADE</u>
- Center of tail lightly pigmented at tip



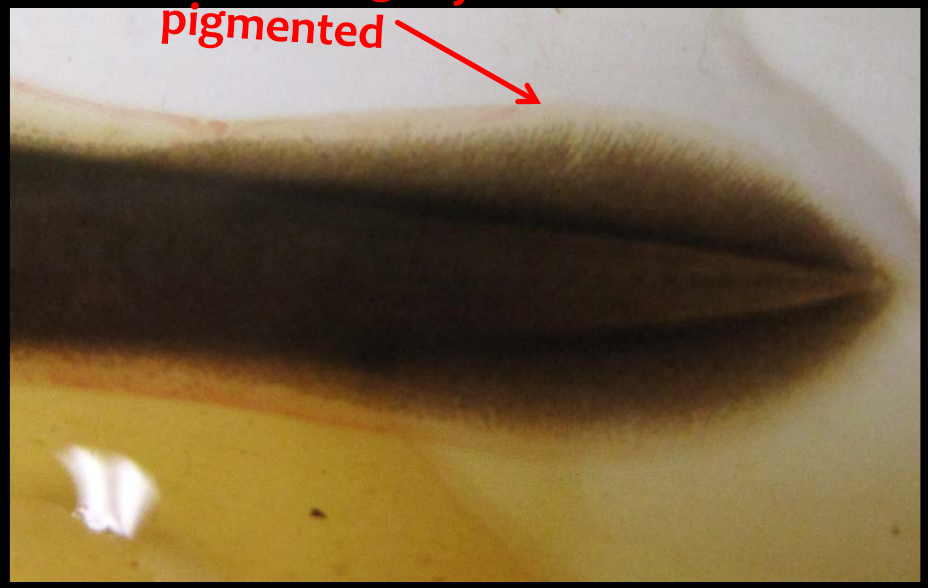


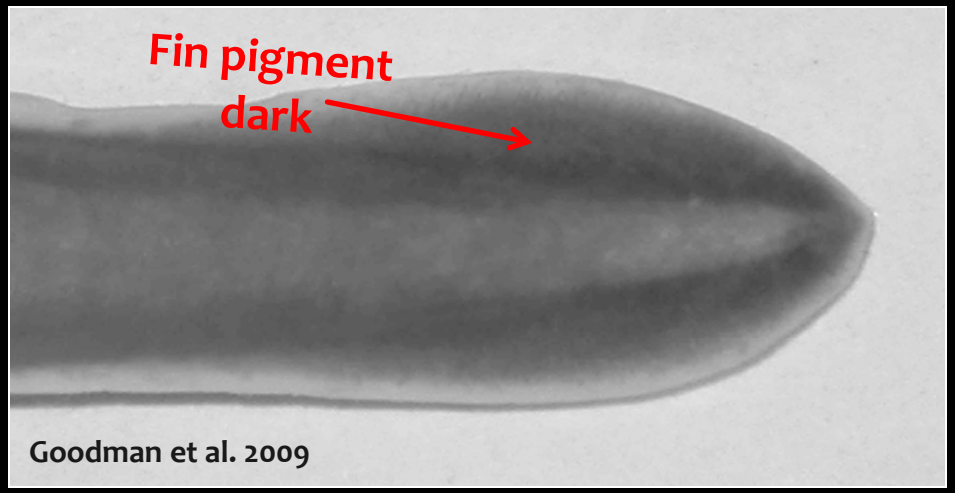
Larval Identification

Pacific lamprey Larvae

Caudal fin

- Darkly pigmented <u>except at distal margin of fin</u>
- Perimeter of fin lightly pigmented





Goodman et al. 2009

Larval Identification

Lampetra/Western brook Larvae

Caudal ridge

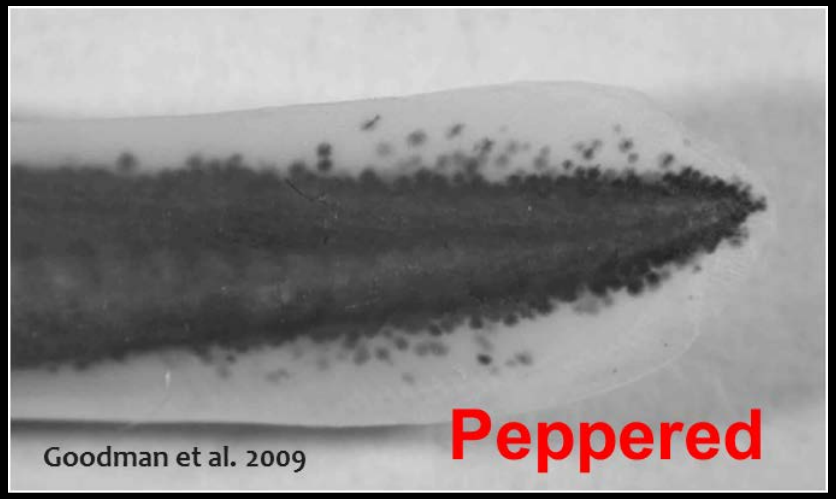
- Pigmentation uniformly dark, no fade towards tip

Larval Identification

Lampetra/Western brook Larvae

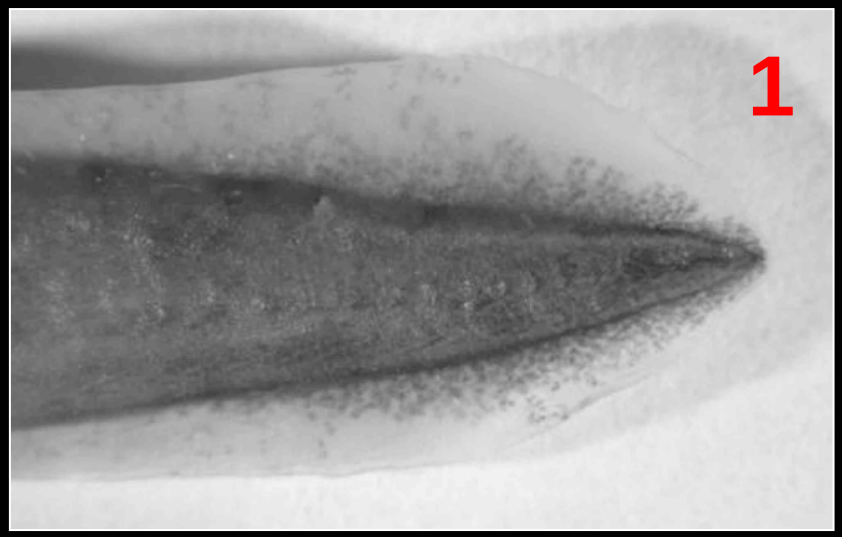
Caudal fin

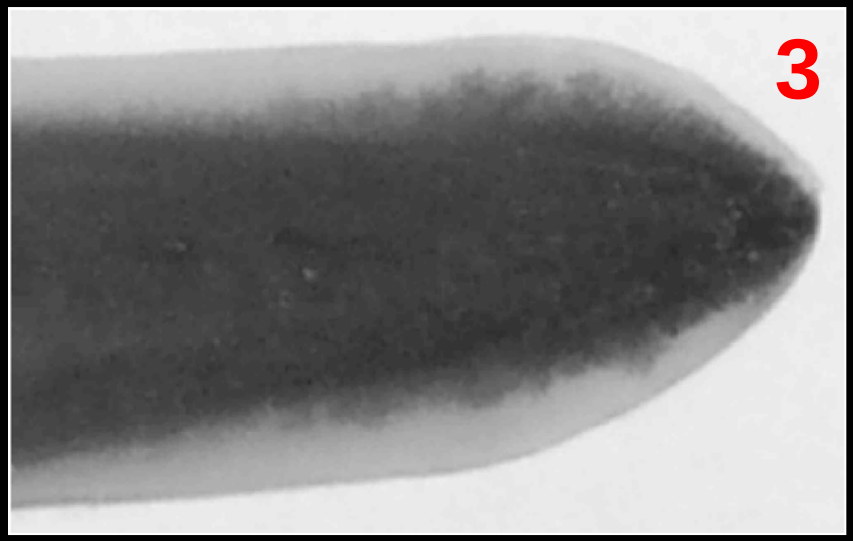
- Pigmentation in fin mostly absent
- Concentrated at base of caudal fin, diffusing toward margin
- Or 'Peppered'



Larval Identification

Lampetra/Western brook – fin variation





Fin pigment variation

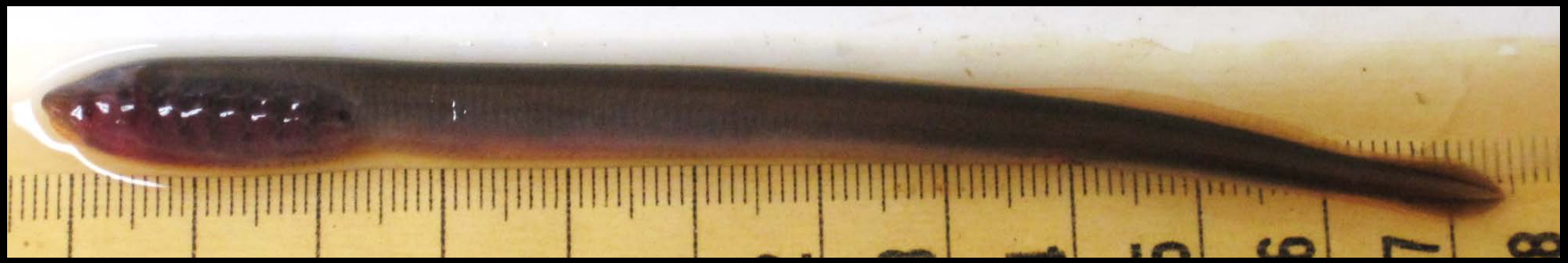
1. Absent pigmentation in fin- mostly clear
2. Peppered pigmentation in fin
3. Pigmentation mostly at base of caudal fin, diffusing toward margin

From Goodman et al. 2009

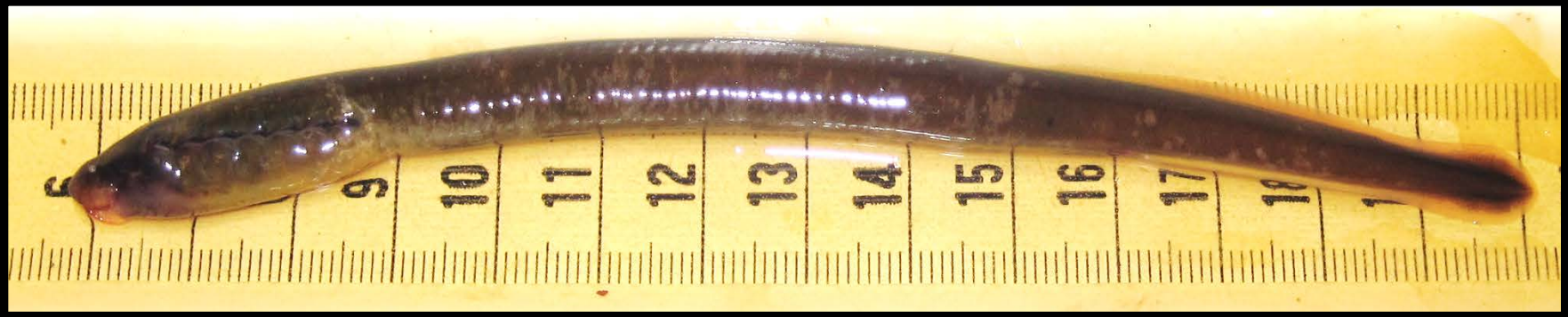
Larval Identification

PCL vs. *Lampetra*/WBL Larvae

Pacific lamprey



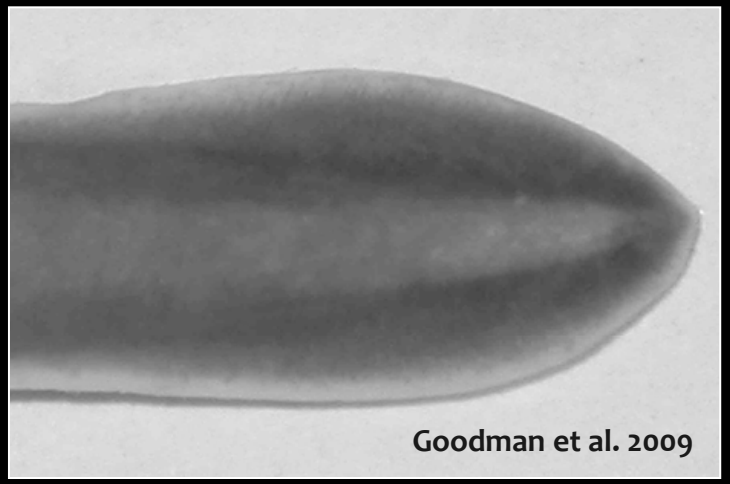
Lampetra/Western brook lamprey



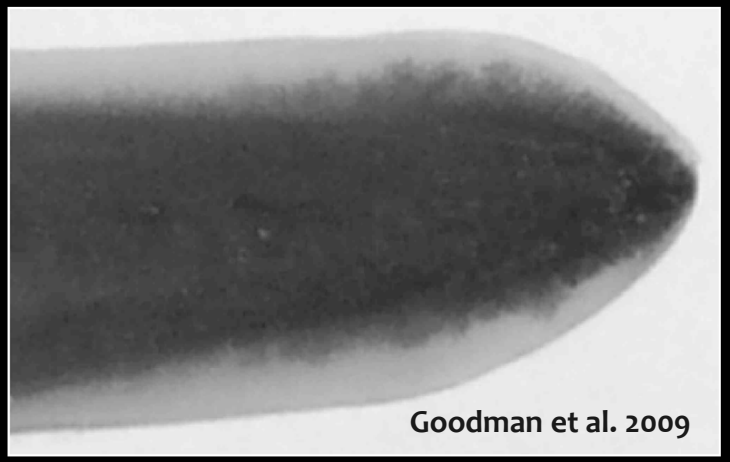
Larval Identification

Ammocoetes: PCL vs. WBL

Pacific



Lampetra/WBL



Juvenile Identification

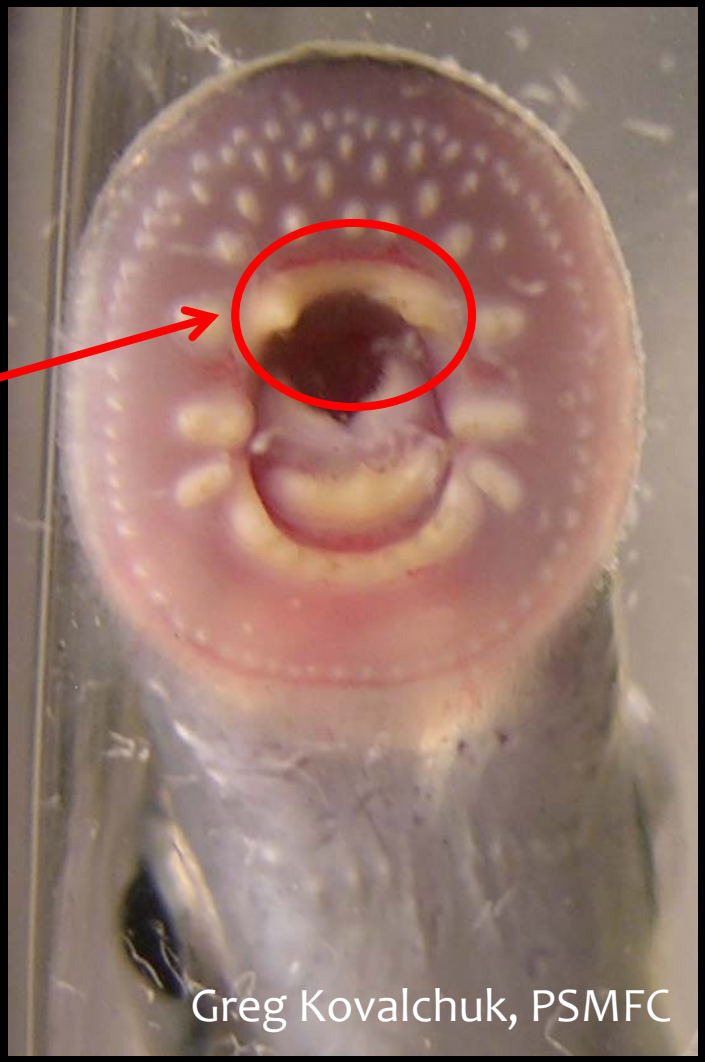
Macrophthalmia

Juvenile Identification

Pacific lamprey

3 cusps on supraoral tooth plate (lamina)

River Lamprey (WBL Adult)

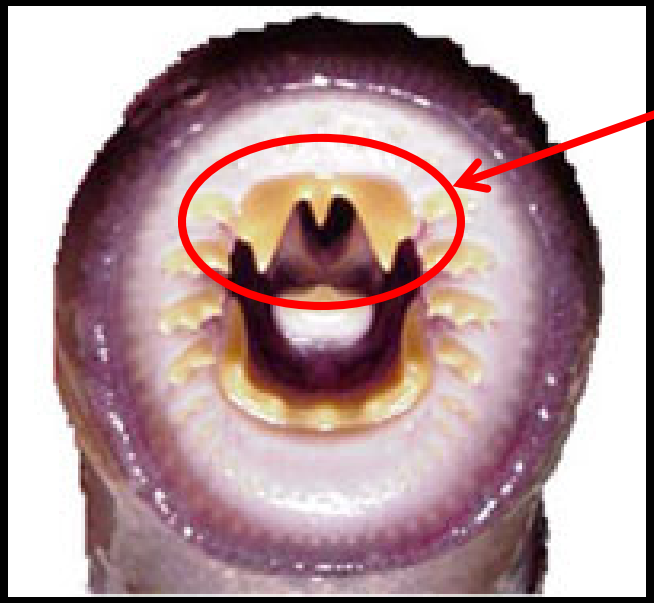


2 cusps on supraoral tooth plate (lamina)

Greg Kovalchuk, PSMFC

Adult Identification

Adult Pacific lamprey

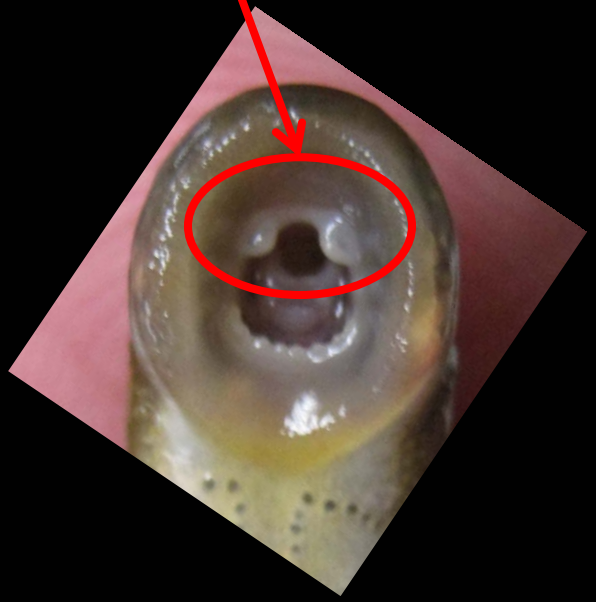


3 cusps on supraoral lamina

2 cusps on supraoral lamina

Adult River lamprey

Adult Western brook



Adult Identification

Pacific lamprey - Adult

Adult Identification

Western brook lamprey - Adult

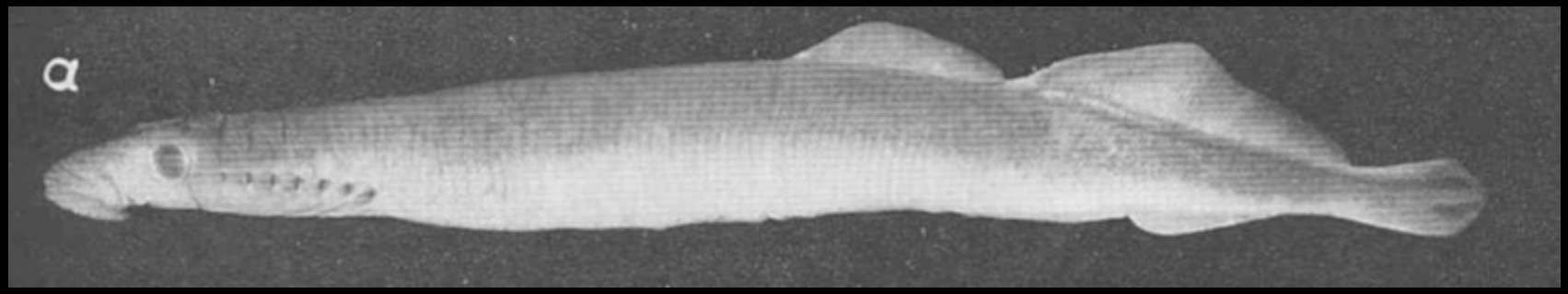
Lamprey Identification

Western brook lamprey adult – size overlap w/PCL Mac

Pacific lamprey macrophthalmia

Lamprey Identification

RIVER LAMPREY….



PACIFIC LAMPREY DATA CLEARINGHOUSE

US Fish & Wildlife Service
Columbia River Fisheries Program Office
David Hines, GIS Analyst

Background

Conservation Agreement for Pacific Lamprey 2012

Objective 4: Data sharing

Continue to build and maintain Pacific Lamprey databases and Geographic Information System layers to facilitate information sharing among partners.

Objective 5: Identify historic and present distributions of Pacific Lamprey in each RMU and monitor them to detect changes in distribution and status as conservation actions are implemented.

Tribal Pacific Lamprey Restoration Plan 2011

Section 4.6.3 Data Management

Project Goal

The goal of this project is to enable and enlist our partners to address information needs identified in the Pacific Lamprey Conservation Agreement to promote Pacific Lamprey conservation.

This will be accomplished by:

1) Collaboratively collecting and sharing occupancy and distribution data at multiple scales.

2) Creating a Pacific Lamprey data clearinghouse for all partners to contribute and access information.

Project Components

- Repository for Pacific Lamprey literature, reports, conservation plans, assessments and other information and media types.

- Collection of GIS layers and online mapping interface for conservation assessment, distribution, observations, threats, conservation actions, and fine scale assessments.

Project Challenges

- Sharing information across agency and partner secure computer networks.
- Agreeing on scales and standards of geographic and database information.
- Compiling information from multiple desperate sources, formats, and scales.
- Outreach campaign aimed at informing and convincing researchers to contribute information.

Proposed Project Storage Solution

USGS ScienceBase - a collaborative scientific database enhancing scientific inquiry and acuity.

https://www.sciencebase.gov/catalog/

Key Elements:

- Data cataloging and collaborative data management platform
- Central search and discovery application
- GIS Web services facilitating other applications
- Research community catalogs

ScienceBase Pacific Lamprey Community Demo

https://www.sciencebase.gov/catalog/folder/53ad8d9de4b0729c15418232

http://nplcc.databasin.org/datasets/fb4c6a49a017424b8c78e81ec55a1927

Existing GIS Layers

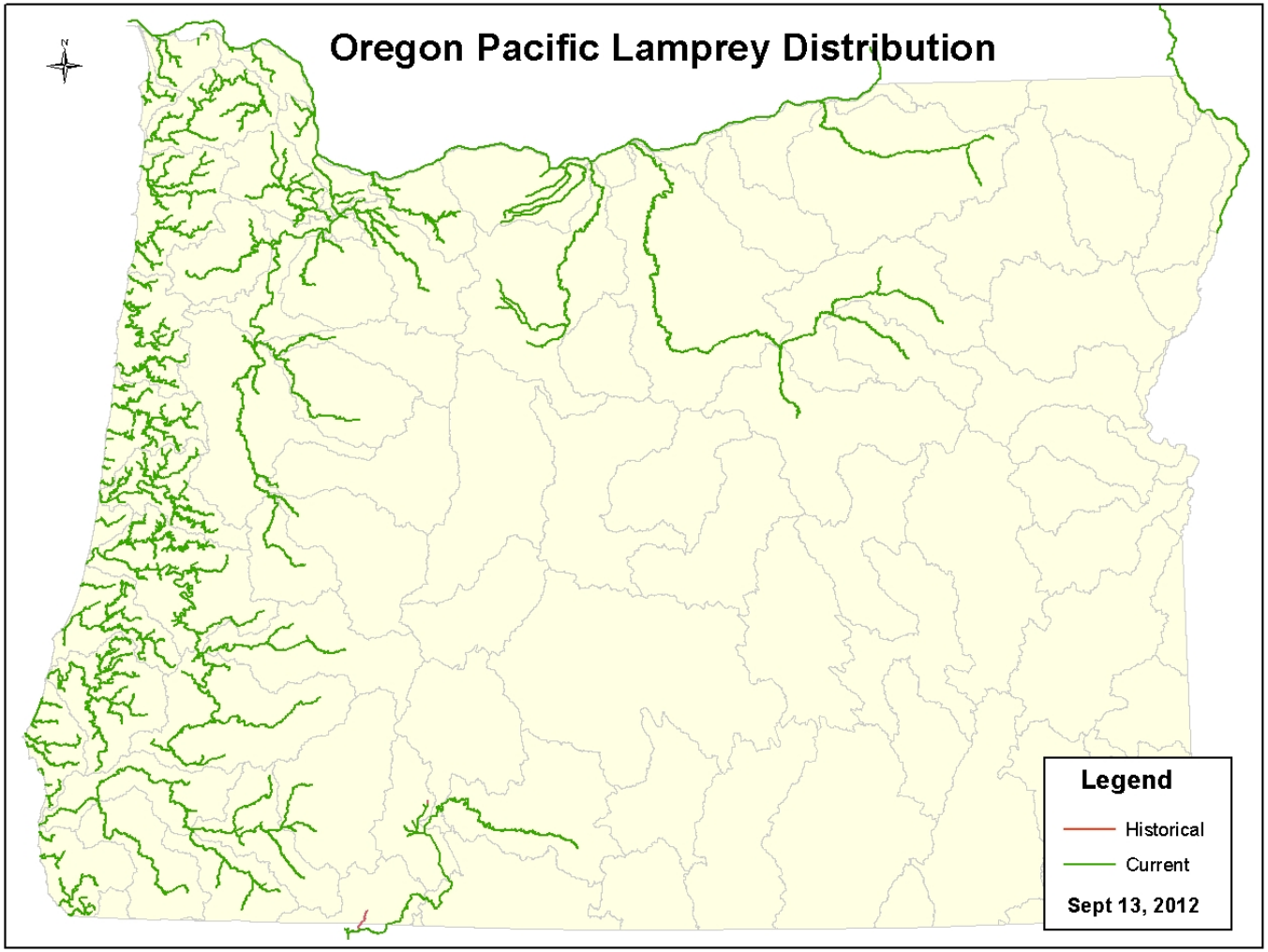
- NatureServe risk assessment (HUC 4 level)
- Regional management units
- Draft PL distribution (linear stream segments)
- Draft PL observations (point locations)
- Other existing layers or future desired layers??

Current Data Contributors

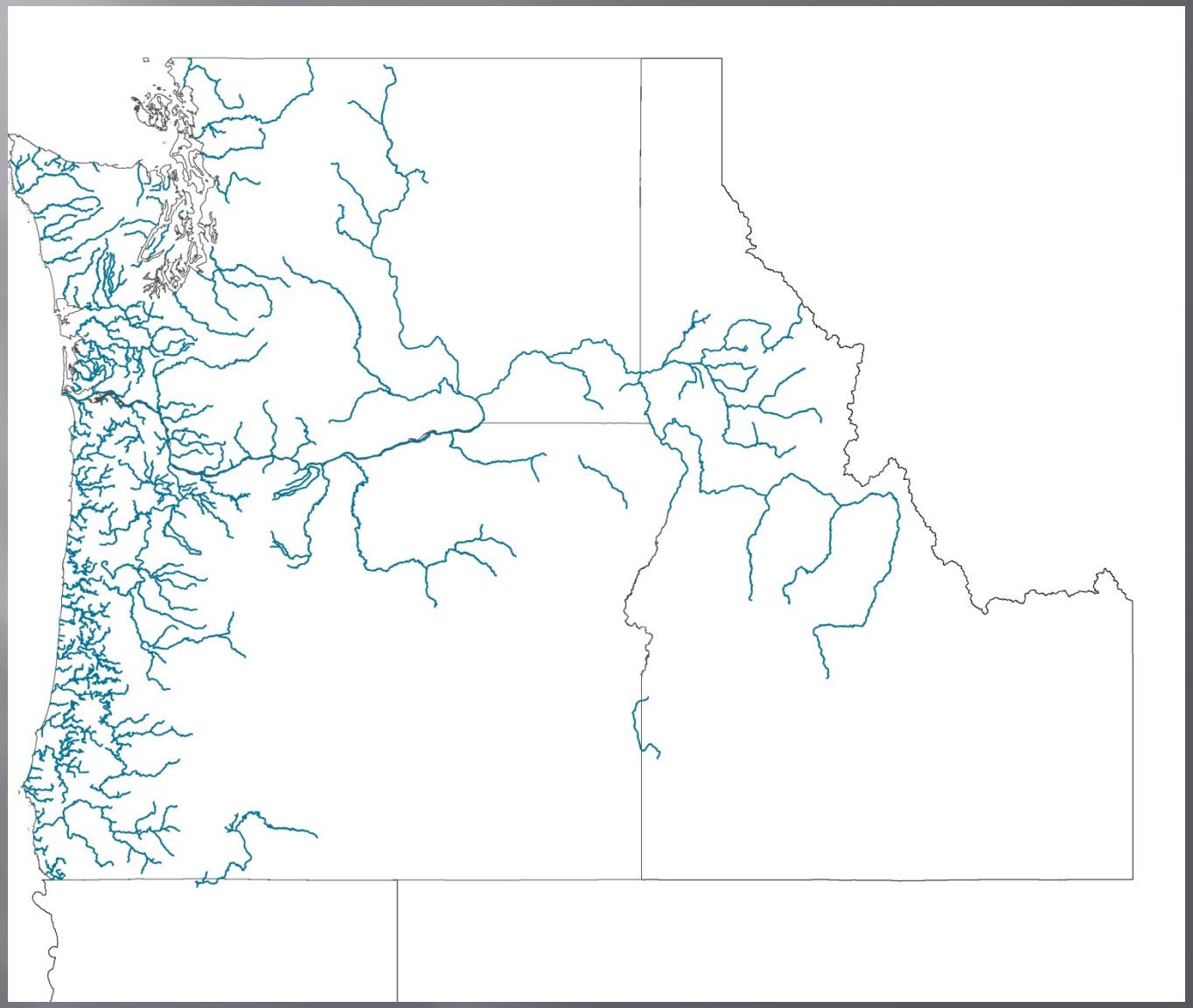
- Siletz, Grande Ronde, Umpqua tribes (OR)
- Yakima, Umatilla, and Warm Springs Tribes
- Oregon Department of Fish and Wildlife
- Washington Department of Fish and Wildlife
- Idaho Fish and Game
- US Fish & Wildlife Service
- US Bureau of Land Management (OR)
- US Forest Service (OR)
- Oregon State University

ODFW Distribution data set

https://nrimp.dfw.state.or.us/DataClearinghouse/default.aspx?p=202&XMLname=997.xml

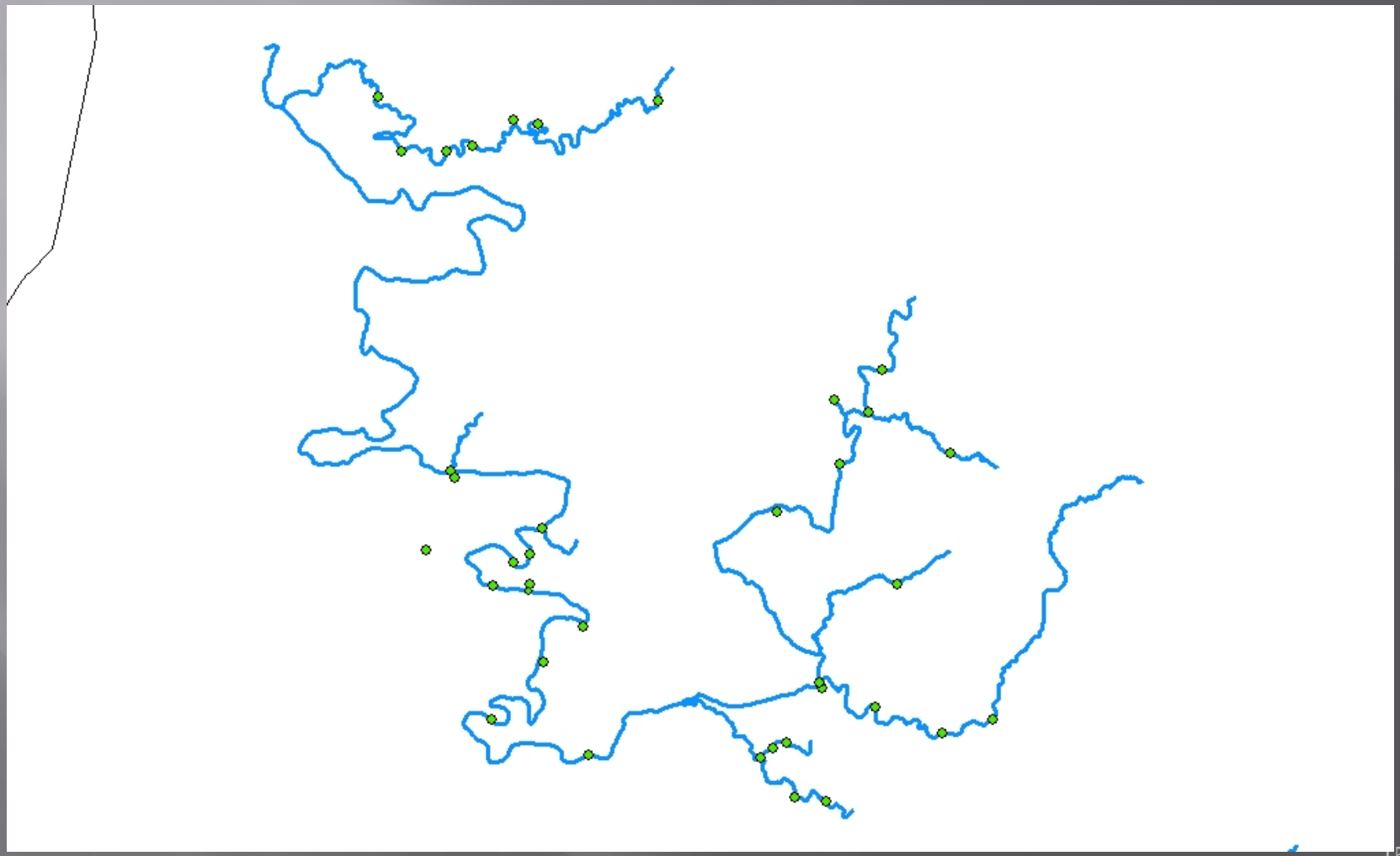


USFS Distribution data set



How observations inform distribution

Cut of the linear distribution at the highest upstream point



Observations database design

Database schema

Take home message

Lamprey distribution covers a large area

The only way to cover such a large area is through fostering close partnerships and sharing information