Lemhi River Effectiveness Monitoring (ISEMP/CHaMP)

Using Fish and Habitat data in the ISEMP Watershed Model to evaluate the Lemhi Conservation Plan

Funding:

BPA/PCSRF/NOAA

ISEMP Watershed Model

Goal = relate watershed restoration efforts to fish **population** changes (response measure for "Bi-op")

- We need to measure the success of our Restoration Actions at a population scale
- Use the monitoring data to plan future restoration actions (i.e. adaptive management)
- Have a tool that translates habitat into fish
  - Identify what is limiting fish population growth
- BUT, very difficult to disentangle ocean and mainstem migration conditions from freshwater habitat conditions
  - "Black box" problem; highly complex

Lemhi River Effectiveness Monitoring

- Measure that part of the anadromous life-cycle which is directly influenced by tributary habitat
  - *Productivity* = migrants/spawner
  - Abundance = population growth
- Freshwater productivity as a function of habitat quantity/quality – in life-cycle context.
  - identify upper limit for improvement in FW productivity
  - identify life-stage(s) with greatest/least potential for change (and interaction)

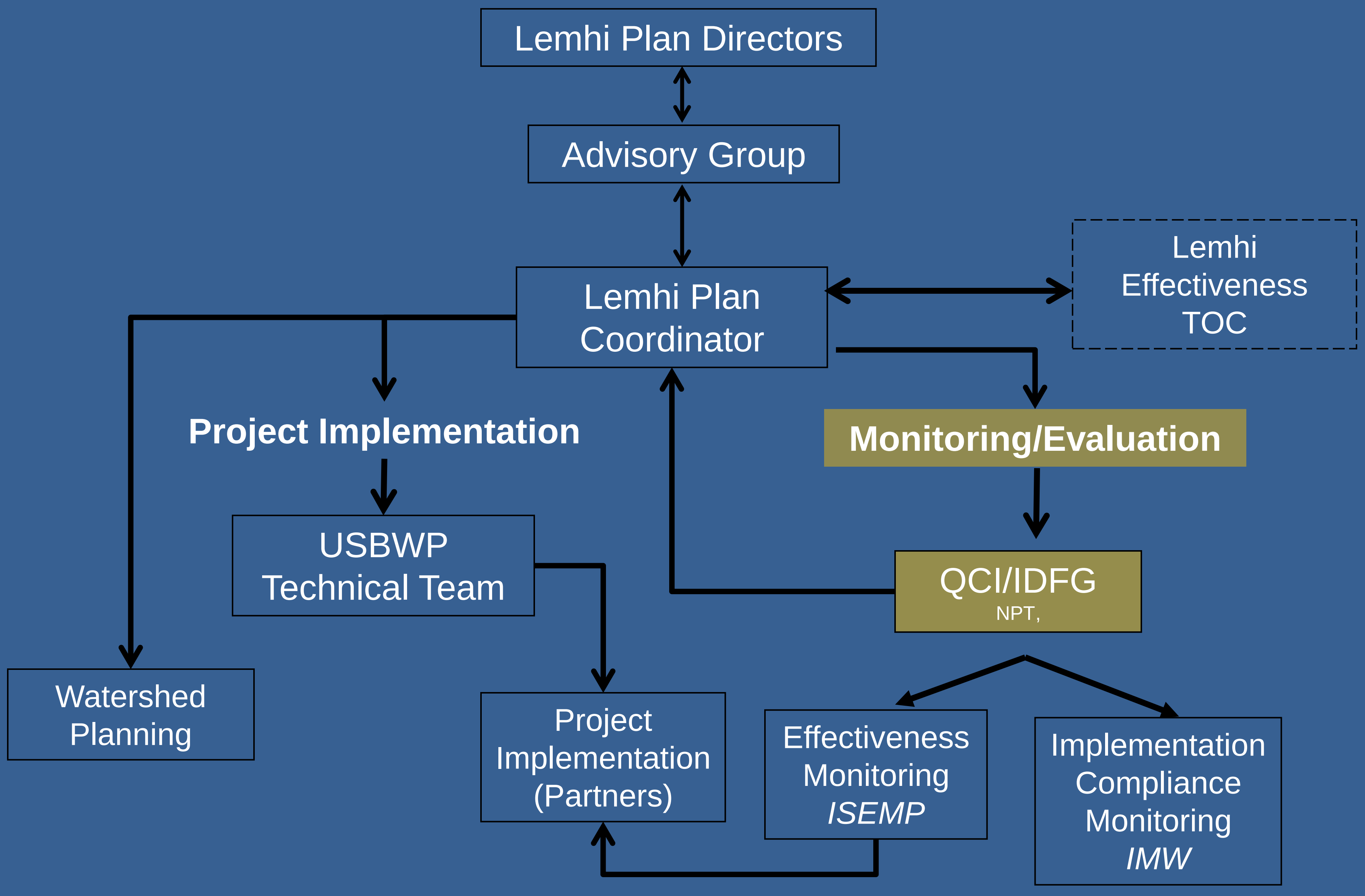
Today = merging CHaMP and ISEMP Data to evaluate a fish population

ISEMP Watershed Model

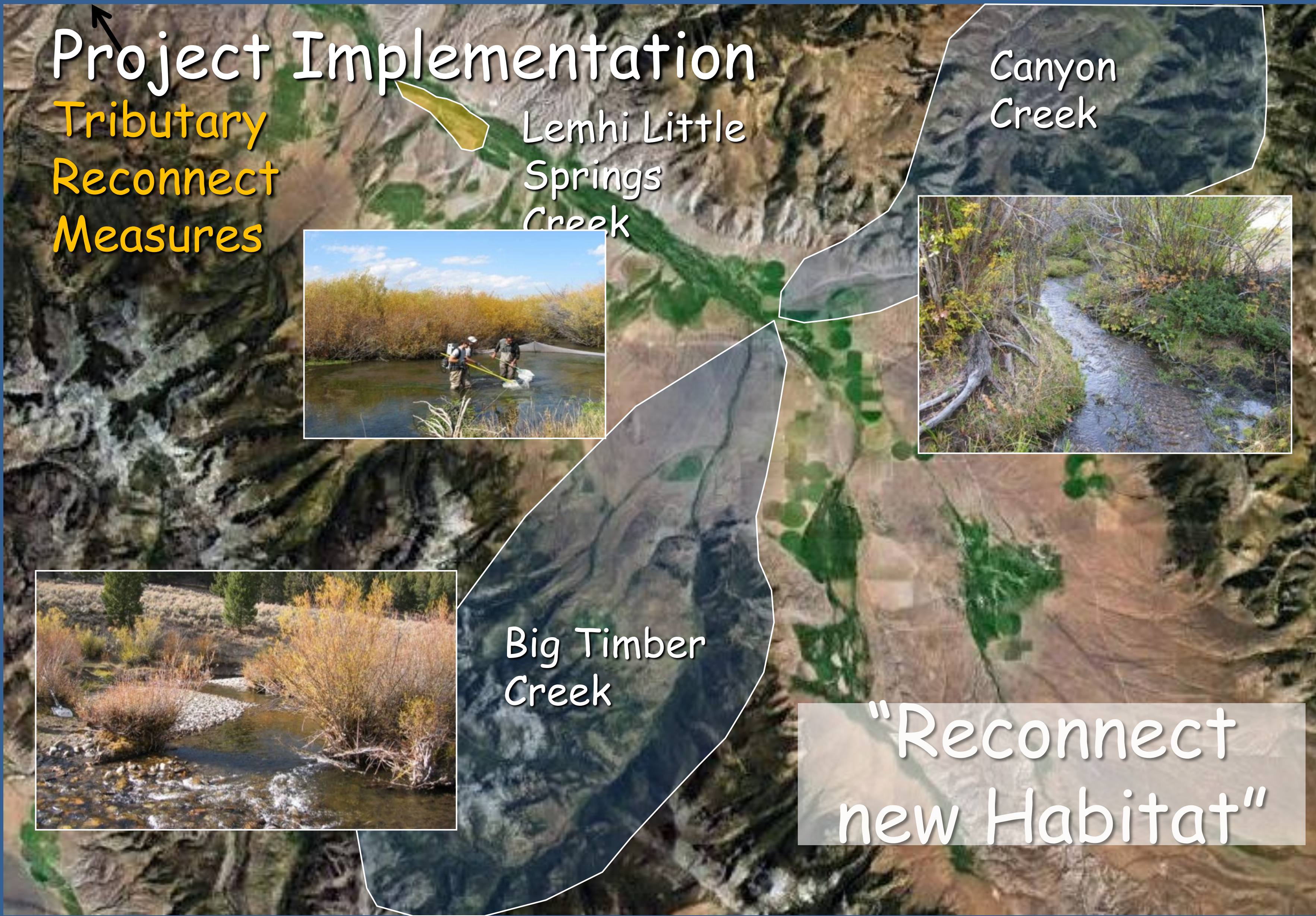
Lemhi Watershed (Brief Background)

- Successful & active watershed council
  - significant private cooperation
  - federal/state/local agency cooperation
- A single population of Steelhead
- A single population of spring Chinook Salmon
  - Historically, one the largest Snake River spawning populations
- Extensive Restoration actions occurring in the watershed both historically and planned
  - Action determined by
    - Expert Panel Process
    - Adaptive management using **Monitoring Data**

Monitoring and Evaluation/Adaptive Management/Restoration



Habitat restoration actions ISEMP is evaluating in the Lemhi Watershed



Lemhi Little Springs Creek Reconnect

Lemhi Little Springs Creek Reconnect

Habitat Restoration

Lemhi River Flow Limiting Factors and Habitat Actions

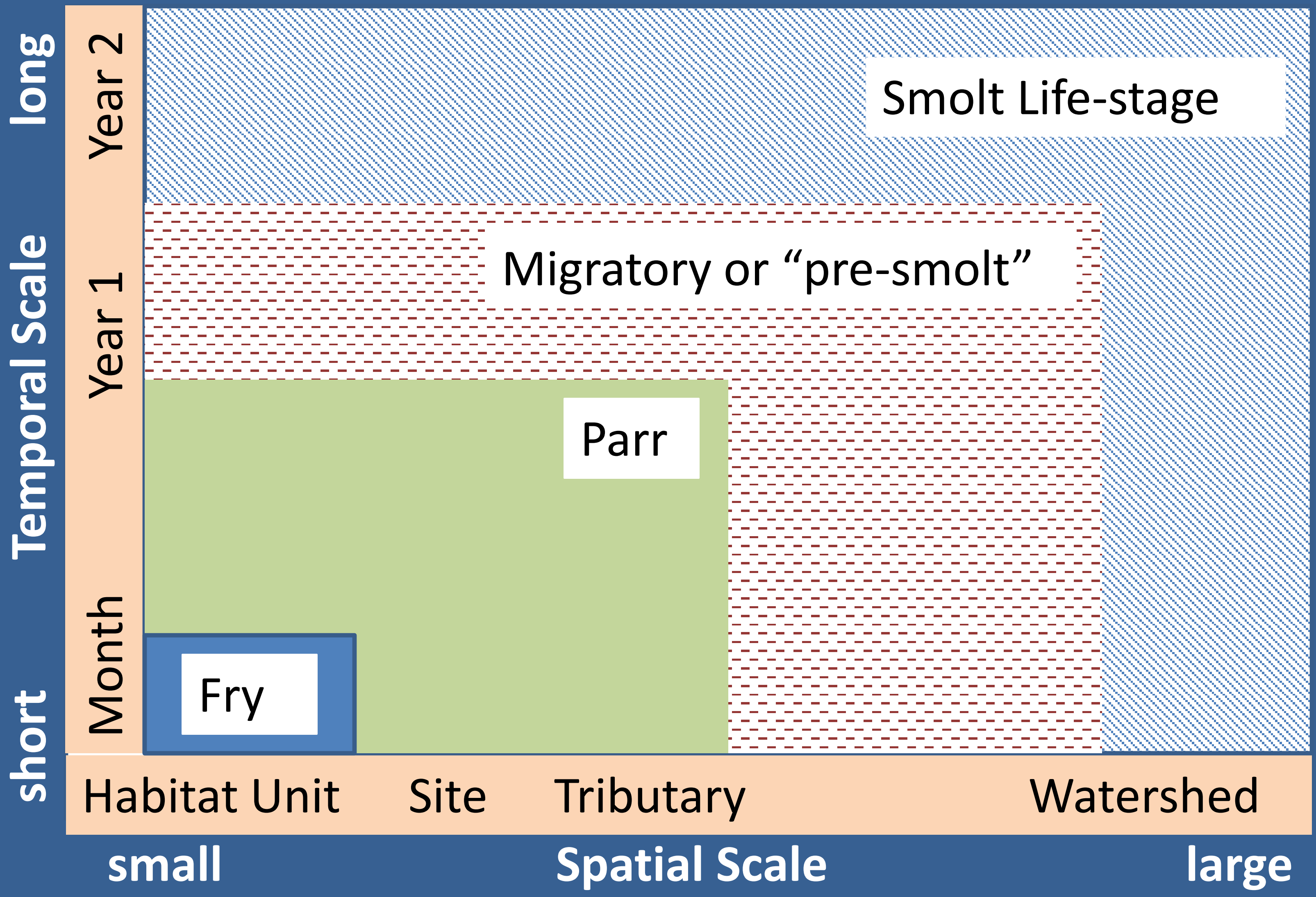
USGS	Date	Flow (cfs)
13304450	08/24/2011	14.6
13304450	08/25/2011	14.5
13304450	08/26/2011	14.5
13304450	08/27/2011	14.5
13304450	08/28/2011	14.5
13304450	08/29/2011	14.3
13304450	08/30/2011	14.0
13304450	08/31/2011	14.1

ISEMP Watershed Model

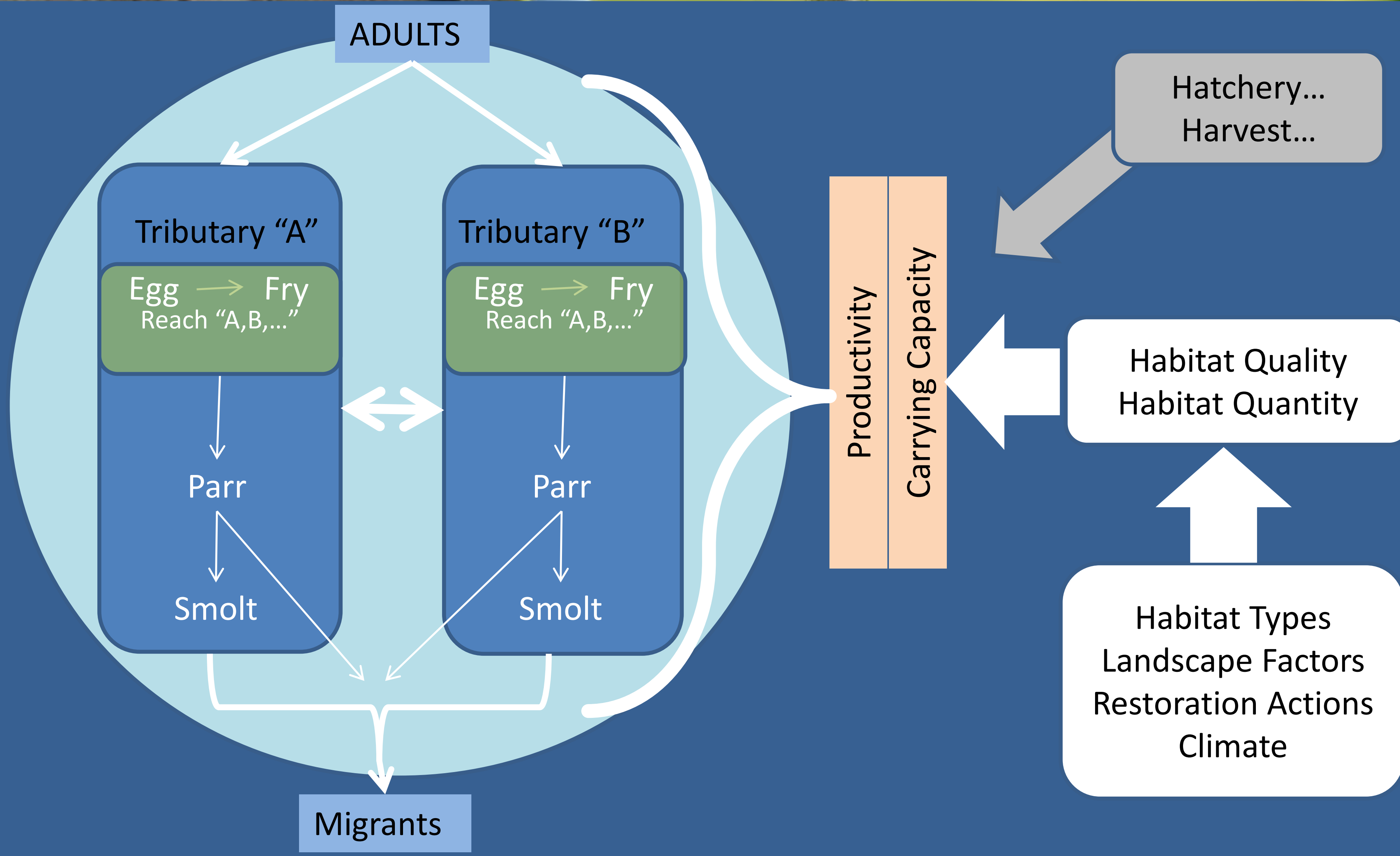
- Why a life-stage, habitat based model?
  - Life-stage response occur at a variety of scales
    - Spatial: Fry = site, Parr = tributary , Smolt = watershed
    - Temporal: Seasonal use – spring, summer, fall
  - Restoration actions (“habitat changes”) influence life-stages disproportionally
  - Stream restoration actions change habitat types at different temporal/spatial changes (e.g. cumulative effects, channel-types, etc.)
  - Population dynamics are influenced by more than habitat changes (e.g. hatcheries, harvest)

General Anadromous Life-Stage Hab. Use

Spatial/temporal scale complexity



ISEMP Watershed Model
-Habitat/Fish Interactions



ISEMP Watershed Model

-Multi-Stage Beverton-Holt

$$R_{t+1} = \frac{aS_t}{b + S_t}$$

$$N_{i+1,t+1} = \frac{N_{i,t}}{\frac{1}{p_{i,t}} + \frac{1}{c_{i,t}} N_{i,t}}$$

where

- $N_{i,t}$ = number of fish at life stage (i), time (t)
- $N_{i+1, t+1}$ = number of fish in next life-stage (i+1) and time (t+1)
- $p_{i,t}$ = **productivity**, or maximum survival rate for life-stage (i)
- $c_{i,t}$ = **carrying capacity**, or maximum numbers that survive life-stage (i)
- Moussalli & Hilborn (1986)

How to relate to habitat?

ISEMP Watershed Model

- productivity (p)

- Productivity = maximum survival from one life stage to the next

$$p_i = S_i$$

  - **<u>OR,</u>** Habitat influence on productivity = quality of habitat is related to multiple factors (e.g. land-use)
    - Or, one part of the watershed has a better survival than another
- So, add a "scalar" (*E*) to adjust survival by land-use type (*l*)
  (OR *channel-type or other geomorphic characteristic)*

$$p_i = S_i * E_l$$

- But, we are interested predicting restoration effect and where they occur, we adapt the equation for
  - *t* = temporal periods (e.g. year, season, etc.)
  - *k* = spatial context (e.g. watershed, tributary, et

$$p_{i,t} = S_i \times \frac{\sum_{q=1}^{n} [E_{i,q}] \times [L_{q,k}]_t}{\sum_{q=1}^{n} [L_{q,k}]_t}$$

ISEMP Watershed Model

- carrying capacity (c)

- Carrying Capacity = **max**. number of fish that survive life-stage
  - **OR** in a habitat context = numbers of fish by life-stage *i* in a specific habitat type *j*
    - D = density of fish
    - H = (e.g. pools) or reach type (e.g. plane-bed)

$$c_i = \sum_{j=1}^{n} \left[H_j \right] \times \left[D_{j,i} \right]$$

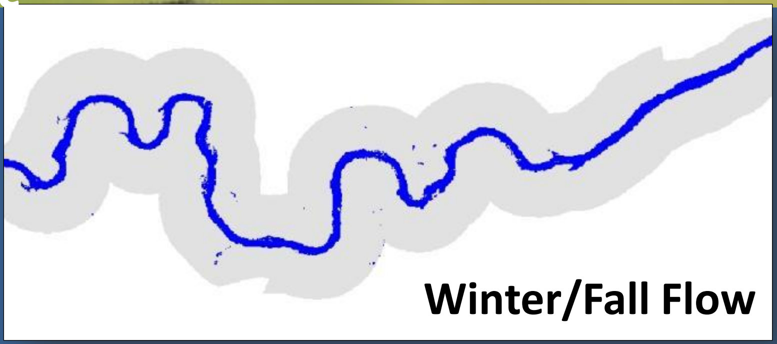
- But, we are interested predicting restoration effect and where they occur we adapt the equation for
  - *t* = temporal periods (e.g. year, **seasonal**, etc.)
  - *k* = spatial context (e.g. watershed, tributary, etc.)
- where
  - A = areal extent (or other spatial measure)
  - L = Land use type (or other characteristic)

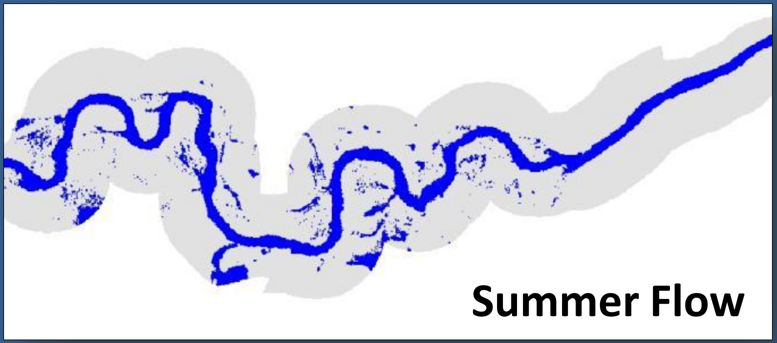
$$c_{k,i,t} = A_k \times \sum_{j=1}^{n} \left[\left[\sum_{q=1}^{n} \left[H_{j,q} \right] \times \left[L_{q,k} \right]_t \right] \times \left[D_{j,i} \right] \right]$$

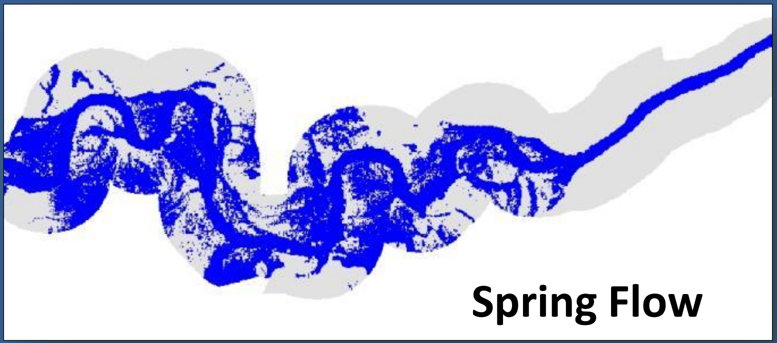
ISEMP Watershed Model
- Seasonality component

Carrying Capacity

- Problem = Habitat sampled once/yearly
- Solution = utilize the information in the Digital Elevation Model to determine seasonal habitat availability
- ISEMP/CHaMP developed River Bathymetric Toolkit (RBT)
  - Predictive modeling of habitat types







ISEMP Watershed Model

-Sharma et al (2005)

Estimated Number of Parr

Predicted Number of Migrants

$$N_{i+1,t+1} = \frac{N_{i,t}}{\frac{1}{p_{i,t}} + \frac{1}{c_{i,t}} N_{i,t}}$$

Max Fish Survival

Stream Area

Max Fish Density

The Basic Watershed M

$$N_{k,i+1_t} = \frac{N_{k,i_t}}{\frac{1}{Sr_i \times \frac{\sum_{q=1}^{n} [E_{i,q}] \times [L_{q,k}]_t}{\sum_{q=1}^{n} [L_{q,k}]_t}} + \frac{1}{A_k \times \sum_{j=1}^{n} \left[\left[\sum_{q=1}^{n} [M_{j,q}] \times [L_{q,k}]_t \right] \times [D_{j,i}] \right]} N_{k,i_t}}$$

Lemhi River Effectiveness Monitoring (ISEMP)

What do we measure?

- **FISH IN** = Adult Salmon and Steelhead ***SPAWNERS*** Returns
  - Abundance (PIT Arrays)
  - Redds
- fish

TODAY – my example data

  - Stream Surveys (stream population ***ABUNDANCE***)
  - Screw traps (***SURVIVAL*** & ***MIGRATION***)
  - PIT tag arrays (***SURVIVAL*** & ***MOVEMENTS***)
  - Downstream Dams (***SURVIVAL***)
- **HABITAT** – ISEMP/CHaMP surveys
  - 160 ground surveys 2009-Present
  - ***QUANTITY and QUALITY***

Lemhi River Sampling Design

Single Populations of:

1) Spring Chinook Salmon
2) Steelhead

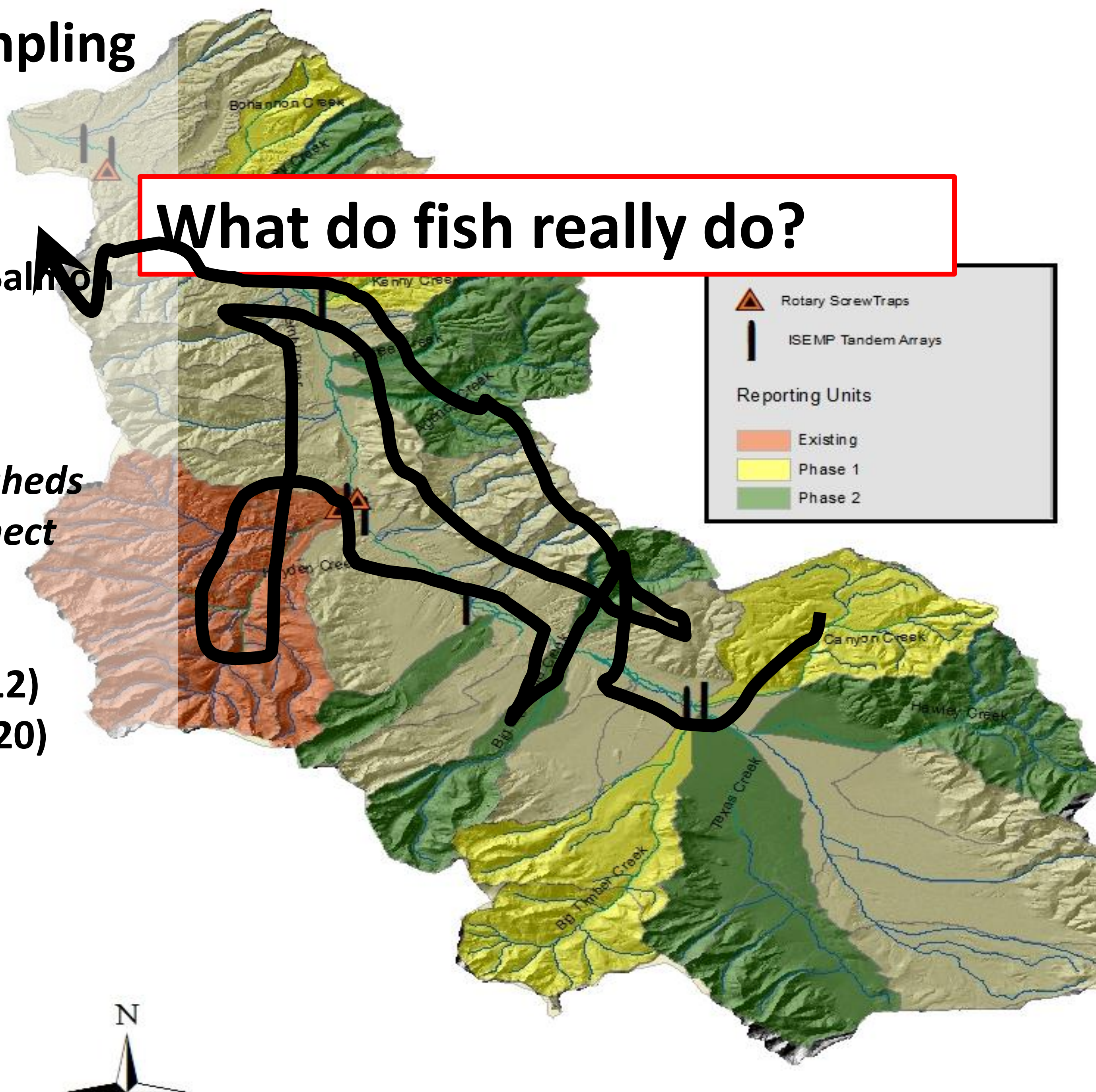
Stratification:

First Level = ***16 Watersheds***

Second Level = ***Reconnect Schedule***

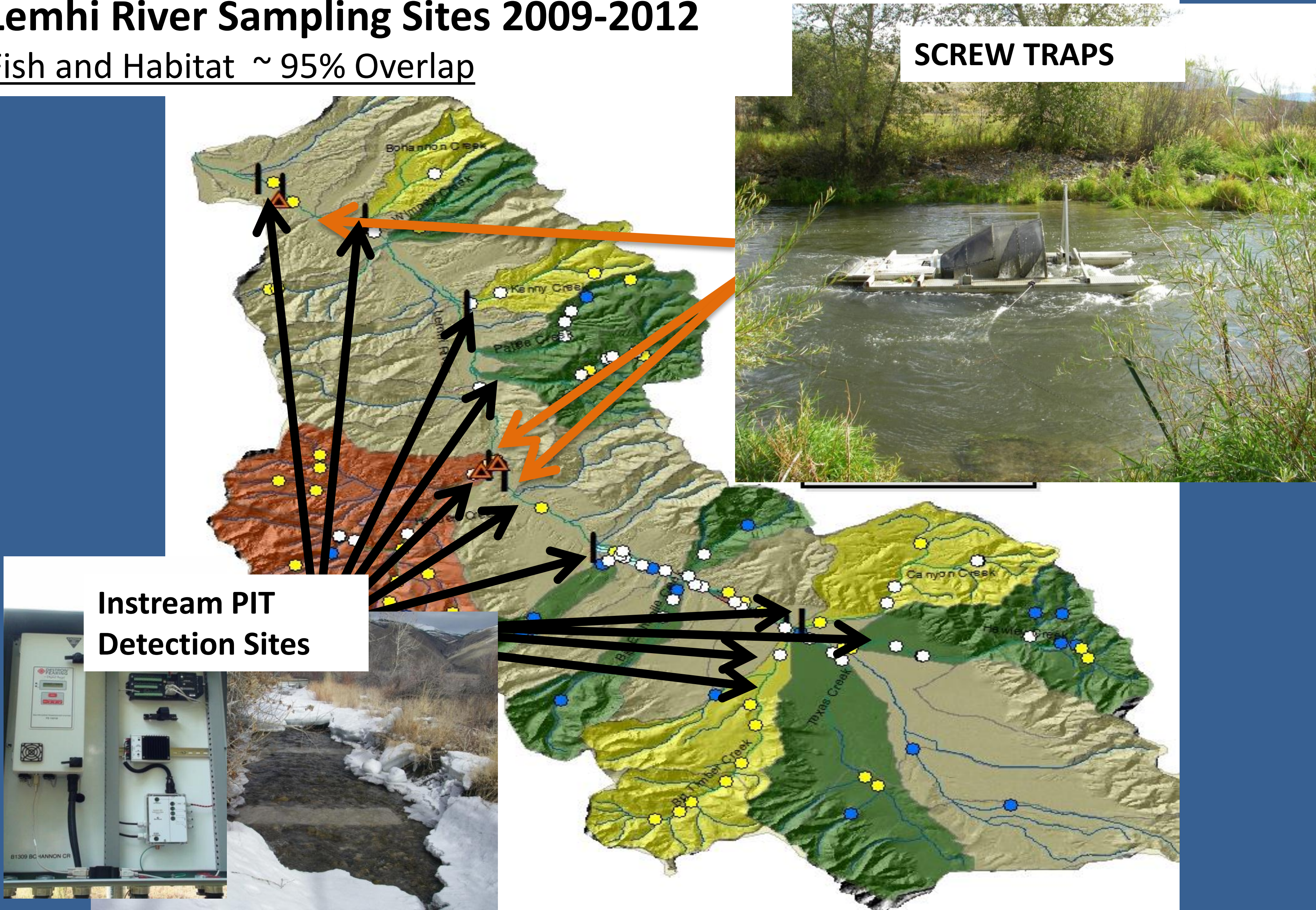
1) Existing
2) Phase 1 (2008-2012)
3) Phase 2 (2012–2020)

What do fish really do?



Lemhi River Sampling Sites 2009-2012

Fish and Habitat ~ 95% Overlap



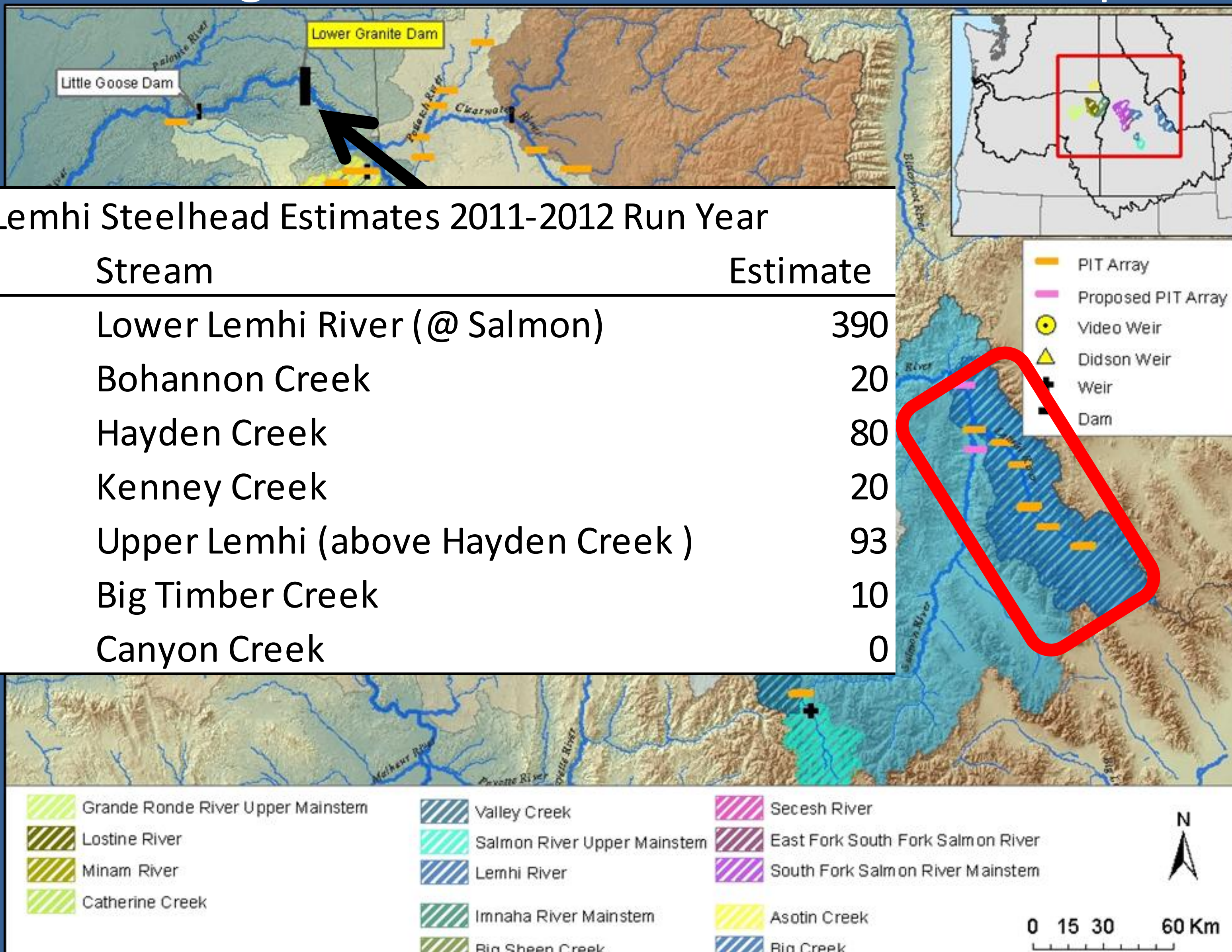
ISEMP Watershed Model

- Example Watershed (Lemhi)

- FISH – IN
  - How we get the “Adult Females” for the Productivity Parameter
    - “migrants/ female spawner”

FISH IN = Adult Spawner Abundance – PIT Arrays

Estimating Steelhead and Chinook Adult Escapement



QCI Lemhi Steelhead Estimates 2011-2012 Run Year

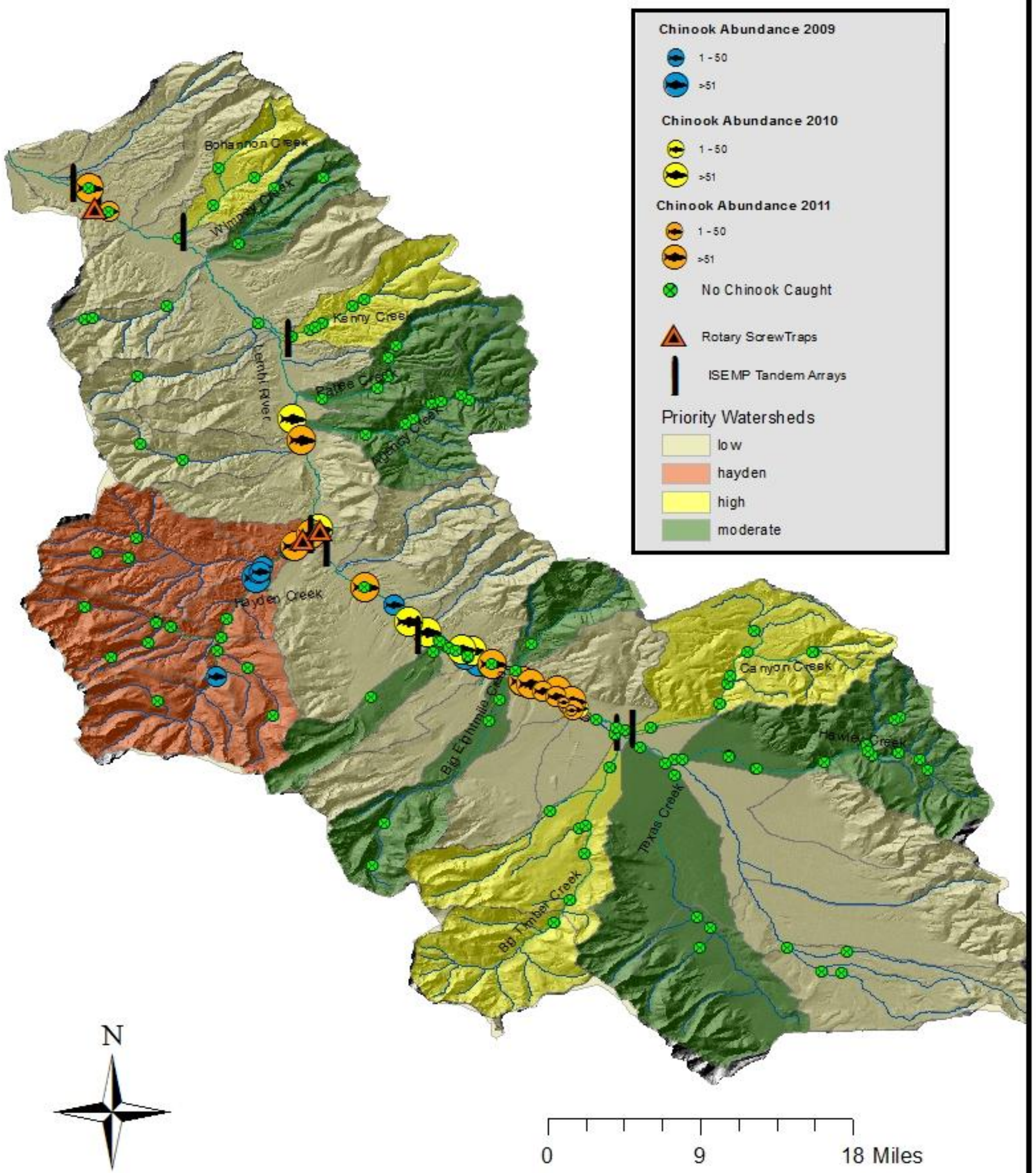
Site	Stream	Estimate
LLR	Lower Lemhi River (@ Salmon)	390
BHC	Bohannon Creek	20
HYC	Hayden Creek	80
KEN	Kenney Creek	20
LRW	Upper Lemhi (above Hayden Creek)	93
BTC	Big Timber Creek	10
CAC	Canyon Creek	0

ISEMP Watershed Model

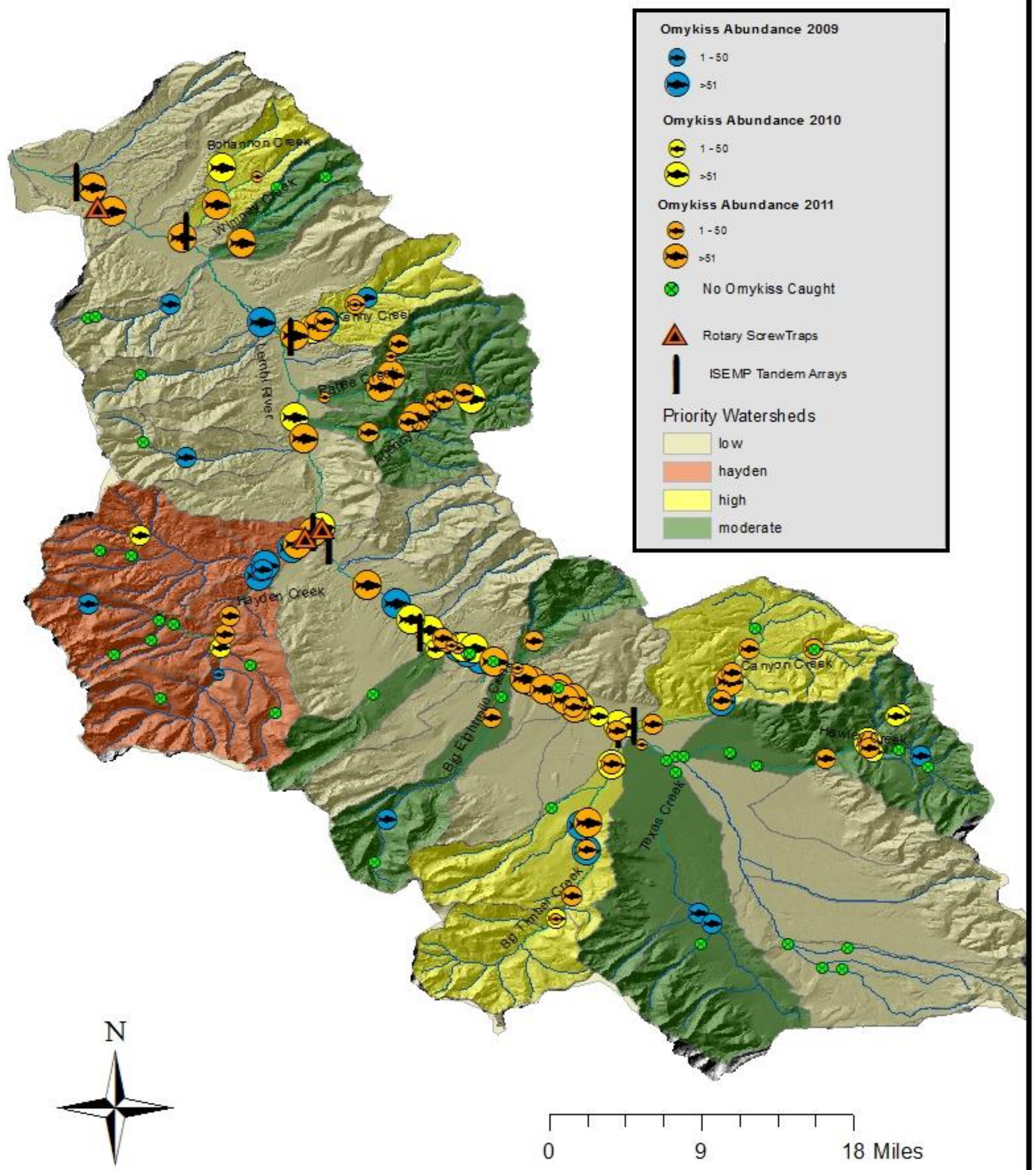
- Example Watershed (Lemhi)

- FISH – "OUT"
  - Life Stage ("egg", "fry", "parr", "smolt", etc.)
  - Standing Crop (Indicator = total fish)
    - By watershed and tributary (multiple spatial and temporal scales)
    - Different than habitat
      - Fish populations have huge yearly variability
    - Estimated each year
      - objective was to sample all sites in all habitat panels per year.
      - abundance estimate at each site

ISEMP Lemhi Chinook Numbers 2009-2011



ISEMP Lemhi Omykiss Numbers 2009-2011



ISEMP Watershed Model -Estimating Watershed Juvenile Abundance (GRTS)

Lemhi River Chinook Salmon

Year	Area	Number Sampled	Estimate (Total)	Lower 95% C.I.	Upper 95% C.I.
2009	All.Sites	59	**2,792**	40	5,544
2010	All.Sites	80	**108,569**	42,756	174,383
2011	All.Sites	72	**64,770**	35,527	94,012
2012	All.Sites	73	**96,016**	49,189	142,843

ISEMP Watershed Model
-Estimating Tributary Juvenile Abundance

Lemhi Strata Estimates = Chinook Salmon

Year	Area	Number Sampled	Estimate (Total)	Lower 95% C.I.	Upper 95% C.I.
2011	All.Sites	72	**64,770**	35,527	94,012
2011	Existing	22	**64,714**	38,744	90,684
2011	Hayden	7	**16,065**	(1,116)	33,246
2011	Lemhi	10	**47,786**	26,556	69,015
2011	Little Eightmile	2	**-**	-	-
2011	Agency	6	**-**	-	-
2011	Big Eightmile	2	**-**	-	-
2011	Big Springs	5	**864**	200	1,528
2011	Big Timber	6	**-**	-	-
2011	Bohannon	5	**-**	-	-
2011	Canyon	6	**56**	(34)	145
2011	Hawley	5	**-**	-	-
2011	Kenney	5	**-**	-	-
2011	Little Springs	2	**-**	-	-
2011	Pattee	5	**-**	-	-
2011	Texas	4	**-**	-	-

ISEMP Watershed Model -Estimating Tributary Juvenile Abundance (GRTS)

Lemhi Hayden Creek Chinook Salmon

Year	Area	Number Sampled	Estimate (Total)	Lower 95% C.I.	Upper 95% C.I.
2009	Hayden	13	**2,256**	(569)	5,081
2010	Hayden	13	**26,909**	(16,671)	70,488
2011	Hayden	7	**16,065**	(1,116)	33,246
2012	Hayden	7	**11,080**	(2,770)	24,930

Year	Age 0	Age 1	Age 2
2011	**91.6%**	**8.0%**	**0.4%**

ISEMP Watershed Model

- Estimate Quantity of Habitat (GRTS)

- From 2011-2012 Lemhi GRTS sites
  - Not complete, will use all 3 years of sites to determine habitat “Status”
  - Assume that habitat variability is small between years
  - Note: we already have a 2009-2010 sample
    - (did not use for this analysis)
- Indicator
  - Habitat Type Volume (pool, fast turbulent , fast non-turbulent)
    - Total Estimate by Watershed and Tributaries

ISEMP Watershed Model
-Estimating Watershed Habitat Capacity (GRTS) 2011-2012 data

TOTAL VOLUME (m^3)– Lemhi River

Indicator	Area	Number Sampled	Estimate (Total)	Lower 95% C.I.	Upper 95% C.I.
Wetted Volume	All	62	**113,633**	90,767	136,498
Pool Volume	All	62	**55,301**	38,796	71,806
Fast Turbulent	All	62	**32,948**	19,299	46,598
Fast Non-Turbulent	All	62	**25,085**	18,274	31,896

ISEMP Watershed Model

-Estimating Watershed Habitat Capacity (GRTS)

TOTAL POOL VOLUME (m^3)

Tributary	Number Sampled	Estimate (Total)	Lower 95% C.I.	Upper 95% C.I.
Agency Creek	5	**1,325**	915	1,735
Big Eightmile	4	**156**	54	257
Big Timber Creek	5	**1,611**	390	2,832
Bohannon Creek	3	**192**	70	315
Canyon Creek	5	**855**	533	1,177
Hawley Creek	2	**189**	(78)	456
Hayden Creek	5	**3,305**	1,687	4,924
Kenney Creek	5	**358**	198	517
Lemhi River	10	**46,346**	29,987	62,705
Little Eightmile	3	**77**	20	134
Little Spring	2	**158**	(151)	467
Mill Creek	2	**2**	(2)	5
Pattee Creek	6	**145**	67	223
Texas Creek	5	**581**	140	1,023

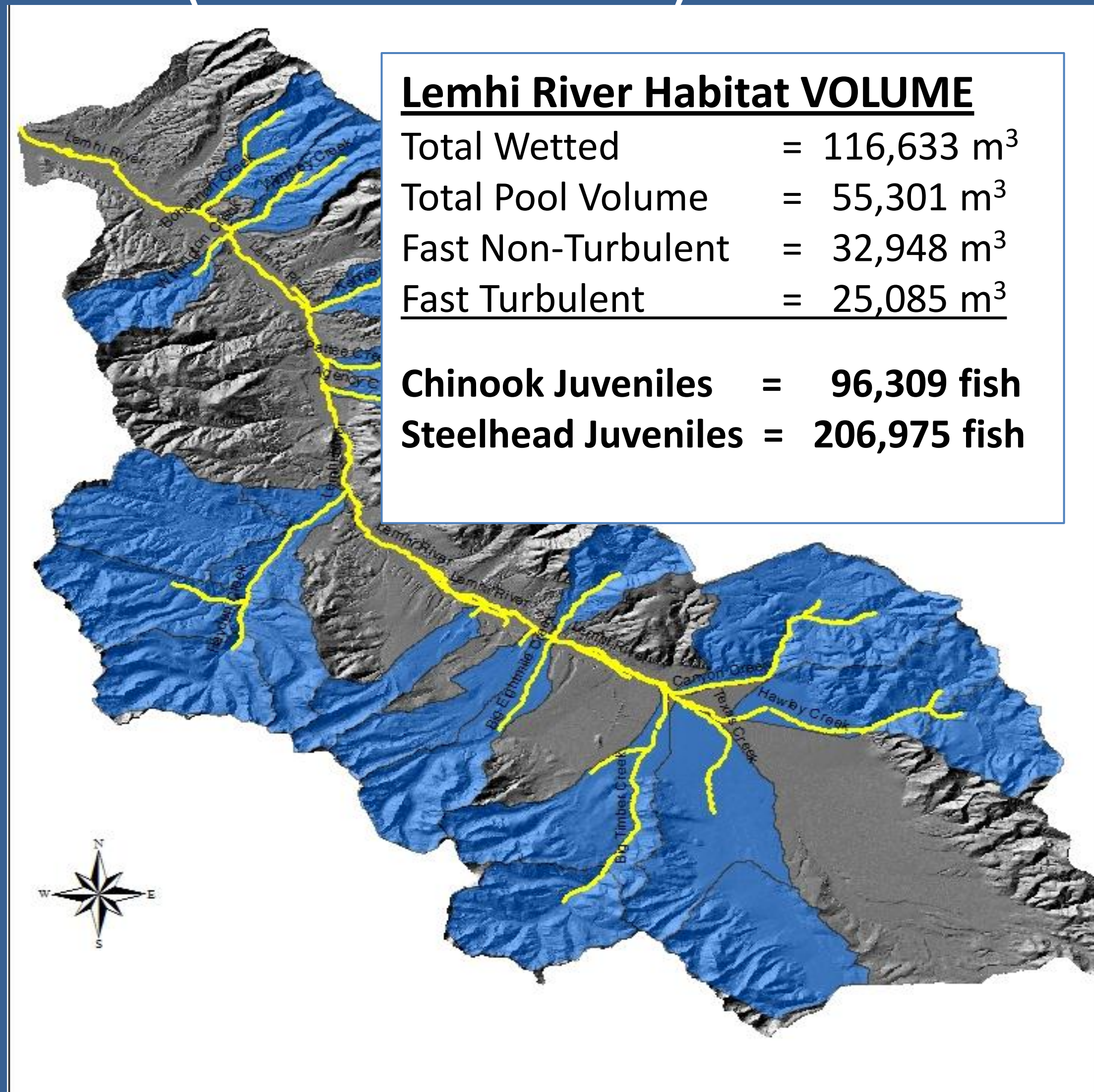
ISEMP Watershed Model

- Watershed (Lemhi)

- Combining habitat and fish data into “useful management spatial scales”
- Indicators
  - Carrying Capacity (Habitat Volume)
    - From RBT by habitat type
  - Fish Population Size

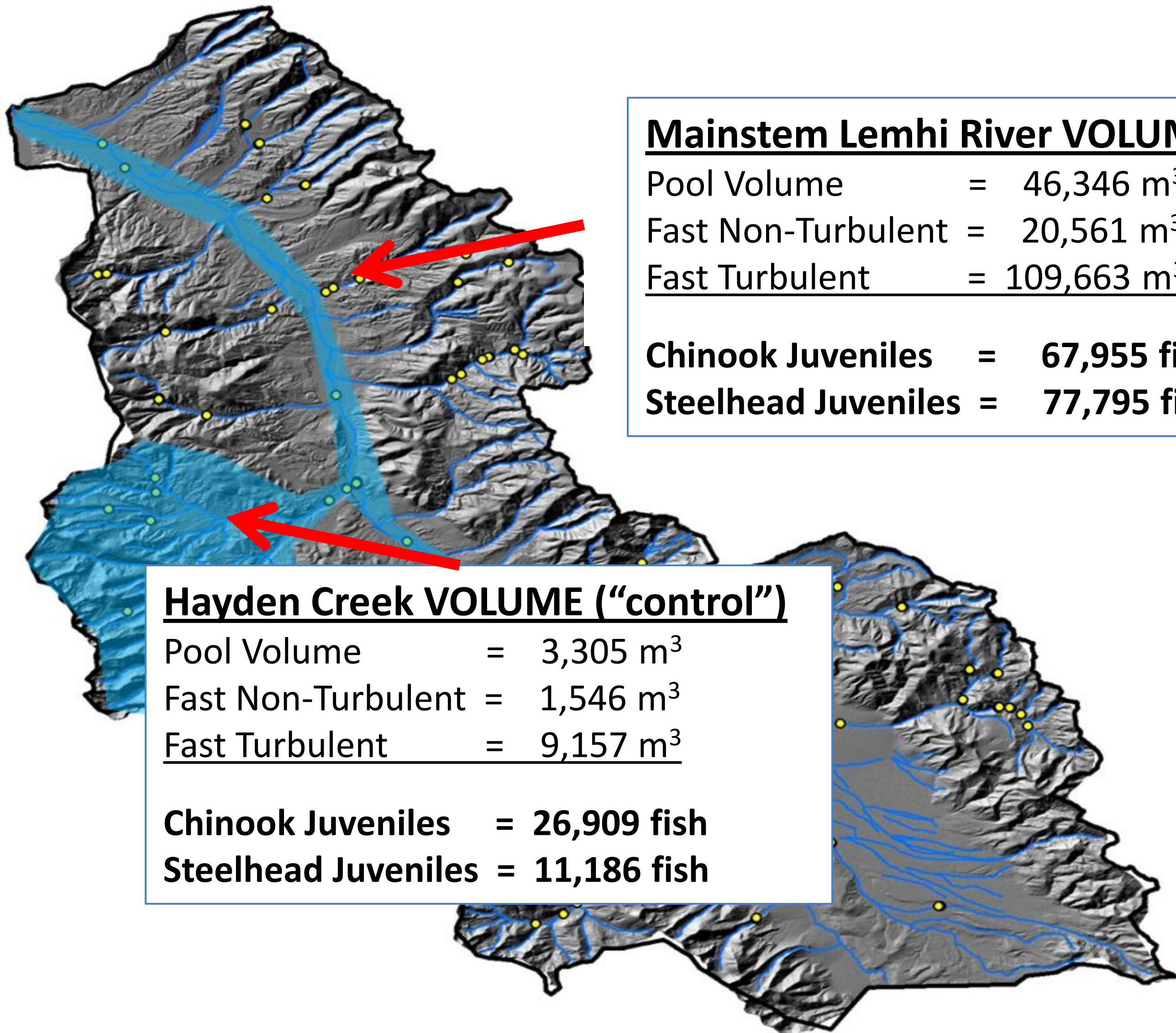
ISEMP Watershed Model

- Habitat Volume, 2012 Fish Population Estimate
- Lemhi Watershed (Habitat Volume)



ISEMP Watershed Model

- Original “Anadromous” Habitat in Lemhi Watershed
- Habitat Volume, 2012 Fish Population Estimate



<u>Mainstem Lemhi River VOLUME</u>

Pool Volume = 46,346 m^3
Fast Non-Turbulent = 20,561 m^3
Fast Turbulent = 109,663 m^3

Chinook Juveniles = 67,955 fish
Steelhead Juveniles = 77,795 fish

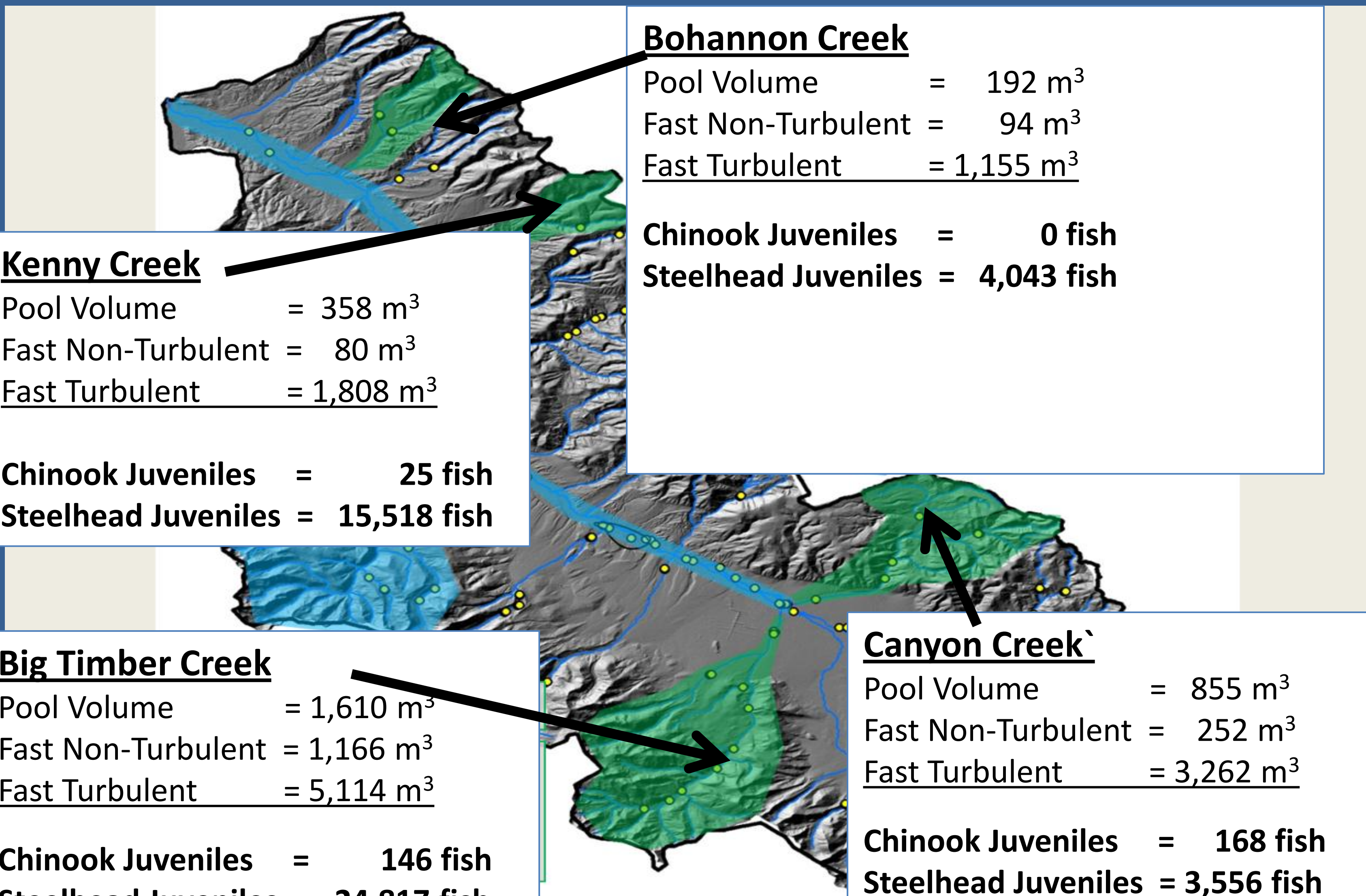
<u>Hayden Creek VOLUME (“control”)</u>

Pool Volume = 3,305 m^3
Fast Non-Turbulent = 1,546 m^3
Fast Turbulent = 9,157 m^3

Chinook Juveniles = 26,909 fish
Steelhead Juveniles = 11,186 fish

ISEMP Watershed Model

- Streams Reconnected 2008-2012
- Habitat Volume, 2012 Fish Population Estimate



Bohannon Creek

Pool Volume = 192 m^3
Fast Non-Turbulent = 94 m^3
Fast Turbulent = 1,155 m^3

Chinook Juveniles = 0 fish
Steelhead Juveniles = 4,043 fish

Kenny Creek

Pool Volume = 358 m^3
Fast Non-Turbulent = 80 m^3
Fast Turbulent = 1,808 m^3

Chinook Juveniles = 25 fish
Steelhead Juveniles = 15,518 fish

Big Timber Creek

Pool Volume = 1,610 m^3
Fast Non-Turbulent = 1,166 m^3
Fast Turbulent = 5,114 m^3

Chinook Juveniles = 146 fish
Steelhead Juveniles = 24,817 fish

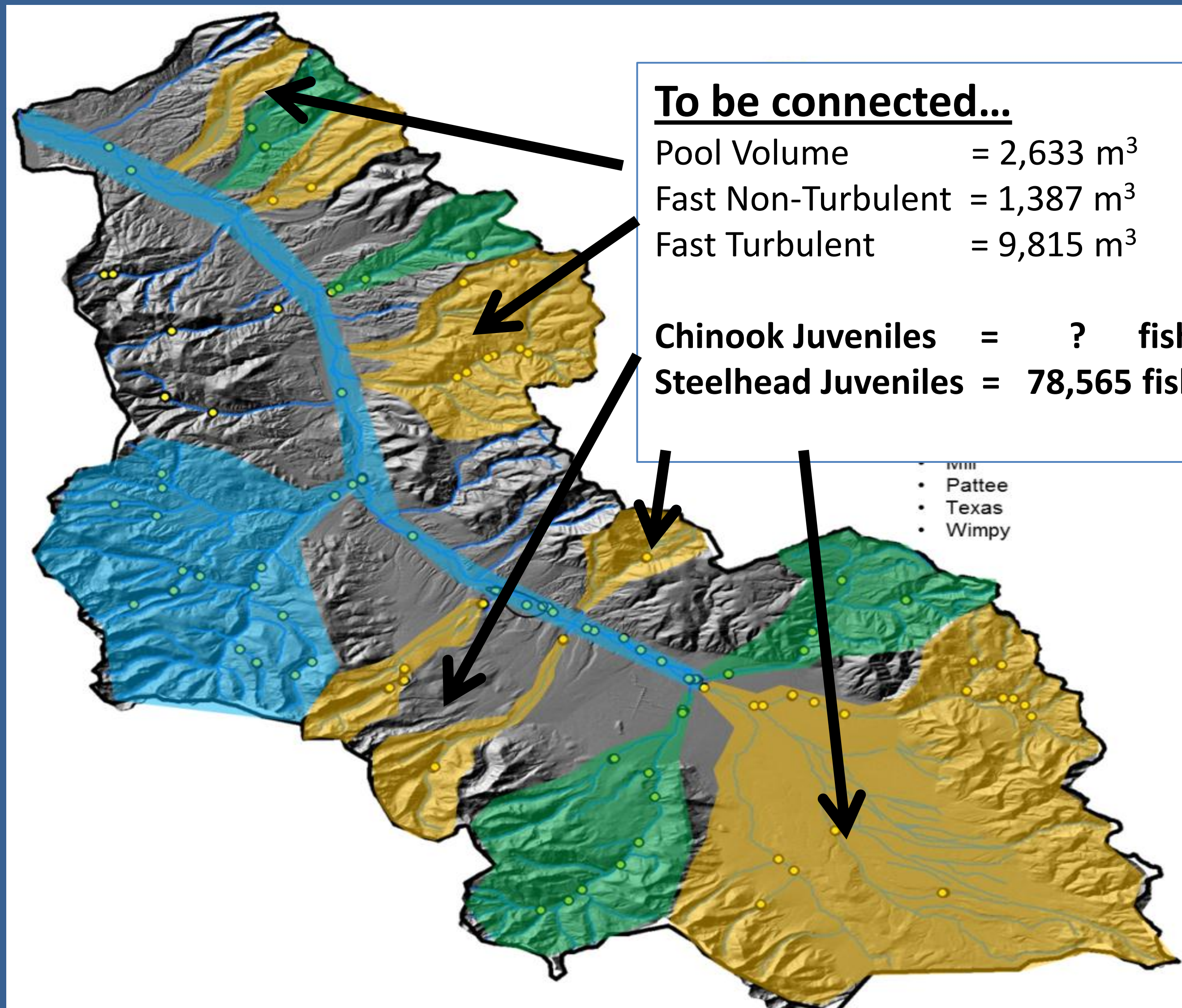
Canyon Creek`

Pool Volume = 855 m^3
Fast Non-Turbulent = 252 m^3
Fast Turbulent = 3,262 m^3

Chinook Juveniles = 168 fish
Steelhead Juveniles = 3,556 fish

ISEMP Watershed Model

- Streams To be Reconnected 2012 – 2020
- Habitat Volume, 2012 Fish Population Estimate



To be connected…

Pool Volume = 2,633 m^3
Fast Non-Turbulent = 1,387 m^3
Fast Turbulent = 9,815 m^3

Chinook Juveniles = ? fish
Steelhead Juveniles = 78,565 fish

ISEMP Watershed Model

- Watershed (Lemhi)

How to use the data to direct restoration efforts

- What are the limiting factors controlling the Lemhi River Spring Chinook Population?
- **What tributaries contain the most habitat for Lemhi River Spring Chinook Population**
  - Or which should be add first?
  - Solution = model the influence each tributary or tributaries have most influence on population growth

ISEMP Watershed Model

- Example Watershed (Lemhi)

	Habitat Increase (%)				
Scenario	**Pool**	**Rapids**	**Runs**	**Riffles**	**Total Area**
Existing + Kenney Cr.	2%	6%	3%	3%	3%
Existing + Big Timber Cr.	14%	30%	13%	15%	15%
Existing + Kenney and Hawley Cr.	8%	20%	11%	10%	10%
Existing + Kenney, Hawley, and Texas Cr.	20%	32%	21%	19%	21%
Exiting + Kenney, Hawley, Texas, and Big Timber Cr.	34%	62%	34%	34%	36%

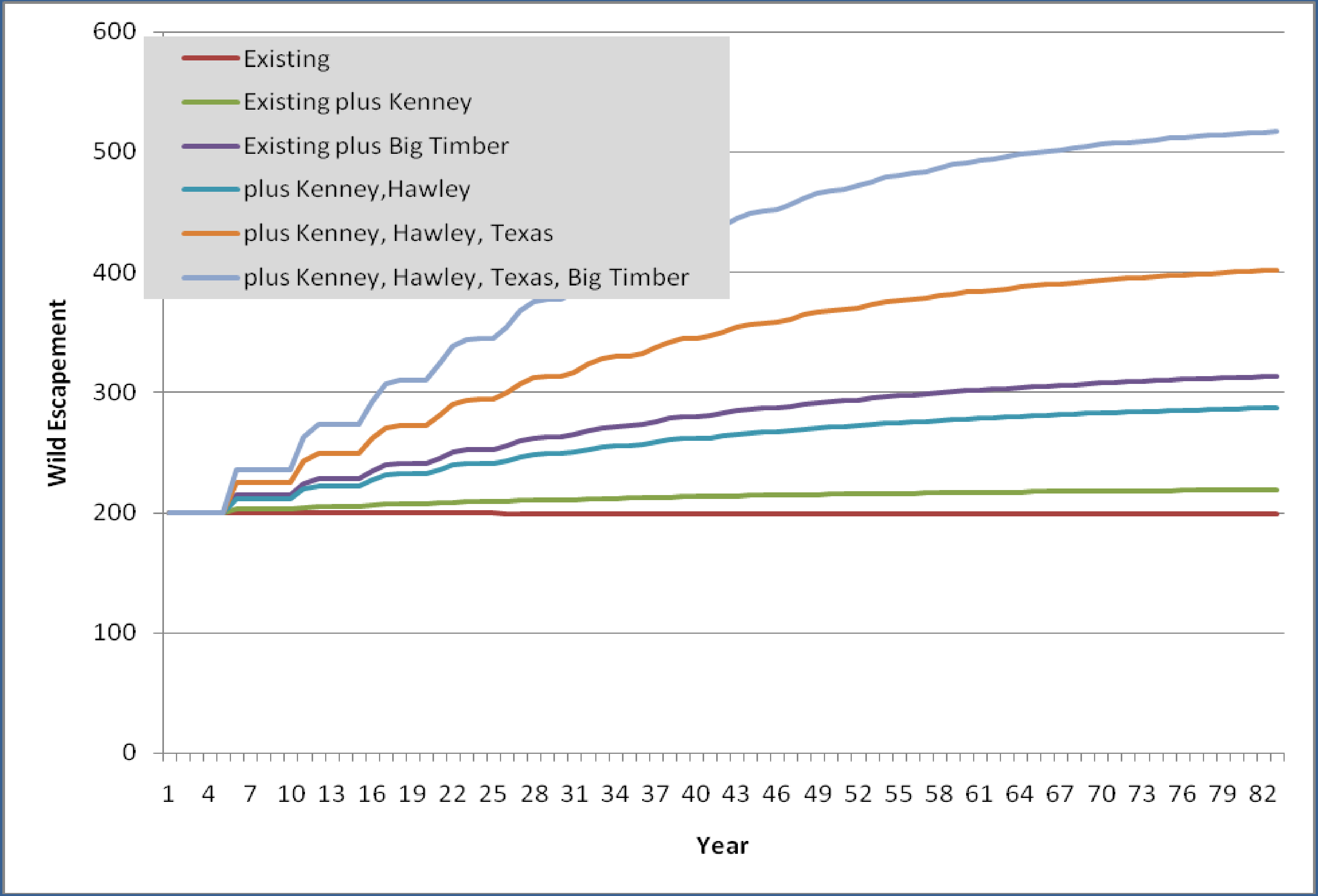
ISEMP Watershed Model

- Example Watershed (Lemhi) CHINOOK SALMON

Scenario	CC	% Increase	Productivity	% Increase
Existing (Lemhi River and Hayden Creek)	**91,947**		**124**	
Existing + Kenney Cr.	94,441	2.7%	126	1.6%
Existing + Big Timber Cr.	105,958	15.2%	132	6.5%
Existing + Kenney and Hawley Cr.	100,905	9.7%	131	5.6%
Existing + Kenney, Hawley, and Texas Cr.	112,623	22.5%	138	11.3%
All	126,606	37.7%	144	16.1%

ISEMP Watershed Model

- Example Watershed (Lemhi) CHINOOK SALMON



ISEMP Watershed Model

- Flexible modeling environment that informs freshwater productivity as a function of:
  - Management actions
  - Habitat conditions
  - Fish population characteristics

- Informs management/restoration actions (i.e. Lemhi tributary reconnections)
  - Work in the Lemhi emulates other management/restoration actions in other
  - “Exportable”
  - Identify the life-stage(s) that limit fish productivity