Robert L. Vadas, Jr.
(Robert.Vadas@dfw.wa.gov)

Washington Department of Fish & Wildlife (WDFW): Habitat > Wildlife & Fish programs

Washington Department of Ecology (WDOE)

National Park Service (NPS) & U.S. Forest Service (USFS), Olympic Region

Trout Unlimited, Olympia Chapter

10,000 Years Institute (10KYI, Forks, WA)

Other volunteers ('trout groupies')

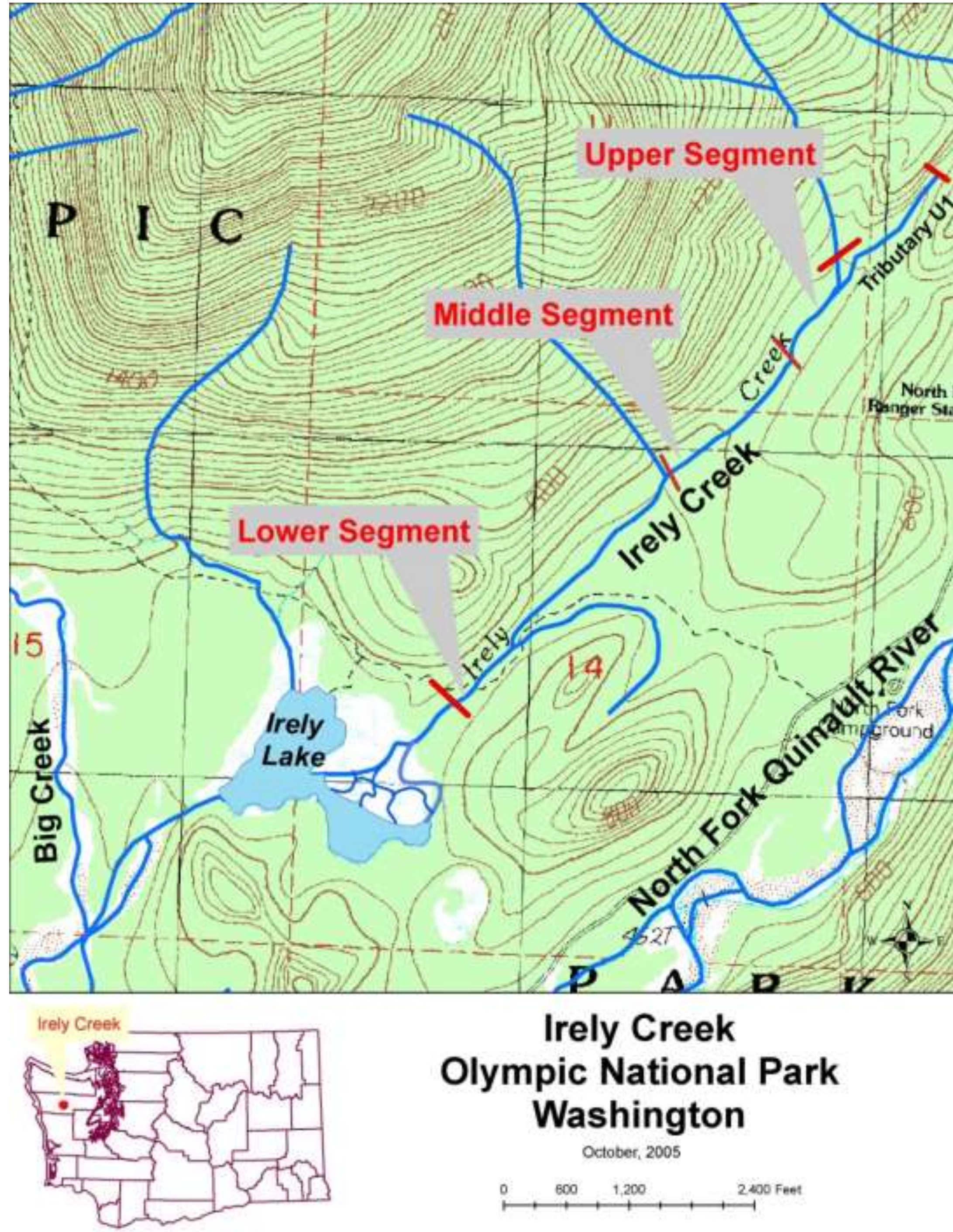
# Long-term population response of Coastal Cutthroat Trout (CCT) to environmental fluctuations in a temperate-rainforest stream: hydrology, temperature, and invasive weeds & other biotic factors

Presentation assistance:
Timothy Quinn (WDFW-Habitat), Hal A. Beecher & Joanne P. Schuett-Hames (WDFW-retired), Jill Silver (10KYI), Pat Crain (NPS), Alex D. Foster (USFS), & Dylan Glaser (U. Calgary)

# Study Area

(collaborated w/ NPS)

2 main tribs. enter <u>Irely Lk.</u> on the east (Irely Cr.) vs. NW (unnamed crk.) shores



# Can We Predict Future Trout-Run Size?

* **We began intense microhabitat-HSI work on an abundant CCT run** (in only 1 of 2 lake tribs.)
  # Unnamed trib. w/ stream order (SO) = 2 *(see photo on right)*
    - Salmonid rearing only (D/S)
  # SU/FA trout angling in Irely Lake (C&R) for *adfluvial run*
  # Main trib. Irely Creek (mouth SO = 3, headwaters = 2)
    - *Trout-run decline* after lake dry-out in 2002 (SU/FA)
    - Along w/ (since '02) *reed canarygrass (RCG)* influx D/S & in lake (bare mud then)

# Can We Predict Future Trout-Run Size?

- Also expanding *beaver dams* (which provide pool refuges for fishes)

# Developed multiple-regression models for CCT escapement based on 2001-12 data

- Using physical & biotic variables of potential importance for future-run size (*cumul. impacts?*)

# Follow-up surveys of trout redds during 2015-18 (for model testing)

# Cont'd redd surveys (future)

- CCT recovery from *RCG removal* via lake-level &/ or water-quality benefits?
- *Out-of-kind mitigation* (for hydrology) = field expt.

# Can We Predict Future Trout-Run Size?

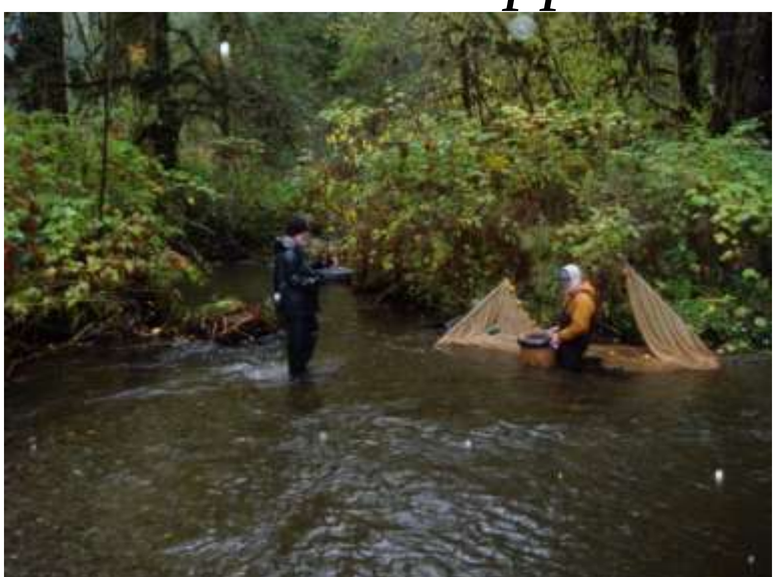
*** 2001-18 "natural expt." of CCT ecohydrology**

# Hydrologic variables assessed

- Lake level, streamflow, & Forks (WA) precip'n
- Snowpack in the Olympic Mountains

# Forage-fish sampling via stream > lake netting & snorkeling (especially during SU/FA)

- Few fish spp. in these headwaters (but *other trout spp*. in lake)



# Can We Predict Future Trout-Run Size?

* **Stream walks** to estimate salmonid escapements

- Coho carcass/adult (CAC) counts (esp. *late WI*)
  - # Mainstem & 5 larger tribs.
  - # Some yrs. w/ earlier &/or later counts (for full-escapement estimation)
- Trout-redd counts (adults rarely on nests) in SP (*Vadas et al. 2016*)
  - # L, M, & U mainstems (the latter w/ long-term *beaver dams & RCG*) & trib. U1

# Cutthroat Trout Rearing

- Dominant adult fish in Irely Lk.
- Subdominant in Irely Cr.
  - *YOY* prominent here
    - * ~2 mo. incubation
  - *Juveniles* common to age 2+
  - *Adults* uncommon
    - * Resident fish the only spawners after SU/FA drought years (natural selection)?
- *Run size uncorrelated* w/ that for sea-run coho there (in the same year) via different life histories

# Cutthroat Trout Escapement

- **Spawning in mainstem & 1 headwater trib. (U1)**
  - Field methodology *(Vadas et al. 2016)*
    - 2001-2 (full counts before lake dry-outs, but spatial extrapolation upstream); 2007 also a full count
    - 2003-12 (usu. only 2 peak-season counts in later years, w/ spatiotemporal extrapolation [via flood-caused turbidity D/S &/or incomplete walks U/S])
    - Estimated adult coho:cutthroat ratio during 2001-12 was 1.3-60.5 (median 8.9)

      * Above *expected, healthy ratio* of 4:1 for PNW streams)

# Cutthroat Trout Spawning

– Main-channel > side-channel habitats

- Late peak; early > late April (mid-late March to mid-early May spawning)
  - * Vs. WDFW's SASI report for periodicity b/c stream-specific $T_w$ matters *(Vadas et al. 2008; cf. Vadas 2006)*
  - * 0.5-1.5 mo. when $T_w$ = 4-10$^{O}$C (peak ~6$^{O}$C) for 2010-18 (coldwater-oriented)

– Less commonly seen above larger (0.9-1.5 m), temporary hydraulic drops that form in upper segment *(unlike coho)*

- Hence, such partial barriers often required spatial extra-polation *(Vadas et al. 2016)*

# Summer/Fall Ecohydrologic Dynamics

**(esp. 1-y time lag suggests adult kills; *Vadas et al. 2016*)**

- **<u>Full lake dry-out</u> (creek intermittent far D/S in both mainstem & tributary U1)**

  # 2002-3 (two years in a row) & 2009

  * Impacted 2003-4 & 2010 CCT runs
  * Then trout-run recoveries (2005 & 2011-12)

    - *Coho recovered* during 2010-11 (also + for CCT)

# Summer/Fall Ecohydrologic Dynamics

- **<u>Semi-dry</u> (lake reduced, creek low)**
  - # 2005-6 (two years in a row, w/ *full dry-out* in 2006)
    - * Impacted 2006-7 trout runs, then 2008 recovery
  - # 2010 (two years in a row, w/ *full dry-out* in 2009)
    - * Impacted 2009-10 trout runs, then some recovery (2011-12)
  - # 2000 (three years in a row, w/ *full dry-out* in 1998)
    - * Likely impacted 2001 trout run
    - * But ~K-level run of 2002
      - - Nearest to *carrying capacity (K)*

# Summer/Fall Ecohydrologic Dynamics

**- Cutthroat-run escapement (adult-run size)**

# Estimated as 2*redd count (assumes 1:1 sex ratio & that all adults spawned)

# Decreased by 3.5-8 times after lake dry-outs (midpt. 5.75)

# Increased by only 2-3 times after wetness returned (midpt. 2.5)

# Hence, a general run drop during 2001-18

* But notable recovery for 2011-15 (w/ increasingly good lake levels)

# Summer/Fall Ecohydrologic Dynamics

**- Statistical analyses (on transformed data)**

# Spearman & Pearson *correlation (also factor) analyses*

* Clustering (redundancy) of environmental variables

# Stepwise, linear, & curvilinear *regression analyses*

* Future prediction of trout-run size

# Trout-Environmental Relationships

**- Unimportant variables (NS, inconsistent effects)**

# <u>Present-year</u> physical (flow/thermal) & food (coho-abundance) conditions

* *Minor sea-run effect* for CCT (at best)

# Some <u>last-year physical conditions</u>

* *Hydraulic-drop "barriers"* in the upper mainstem (sieve-like or w/ side-channel passage)
    - Spawning habitat rarely limiting
* *Flood-scour impacts* (during & after trout spawning)
    - Flood protection in forested headwaters

# Trout-Environmental Relationships

- **Important variables (final multiple-regression model)**
  - **# Hydrology (short time lag = landlocking)**
    - * Cumulative (drought-related) impacts (- effect)
      - - Across years (even though *preceding year* was a strong effect *[cf. Vadas et al. 2016])*
  - **# Cumulative thermal (peak CCT-spawning) variable**
    - * Last > present year index (coldwater benefits) (- effect)

# Trout-Environmental Relationships

**- Important variables (cont.)**

**# Last-year biotic (density-related) variables (mostly beneficial; *minor curvilinearity*)**

* <u>Cutthroat escapement (forecast'g)</u>
  - Weaker (likely *Beverton-Holt*) density dependence (- effect)
* <u>Food abundance (coho salmon)</u>
  - *Late-winter* carcass/ adult abundance best (+ effect)
  - Via *flood scour* that moved food D/S to Irely Lk. or beyond?

# Best Multiple-Regression Models

## - Monotonic equation

# *Best lake model is CONSEC-E*

* Threshold lake level for (-) impacts on trout
    - Drier (semi-dry/dry) = +1 & wet yrs. = -1 pts.
* $TROUT = A – (B_1*CONSEC) – (B_2*TROUT1) + (B_3*CAC1)$ (adjusted $R^2$ = 89%, realistic)

## - Quadratic equations

# *"Goldilocks effect"*

* $TROUT = \pm A – (B_1*CONSEC) – (B_2*CUMUL\text{-}T_W) \pm TROUT1 \pm CAC1$ terms

# *"Best" lake model is CONSEC-C*

* Dry yrs. w/ the strongest effects
    - Dry = +1, semi-dry = +0.5, & wet yrs. = -0.5 pts.

# Best Multiple-Regression Models

**- Quadratic equations (cont.)**

* As w/ monotonic model, explains net-downward decline of trout run during 2001-2018
  - In contrast to CONSEC-B (see below)
* Adjusted $R^2$ = 97% (but underestimated in 2013)

# *Best model for CONSEC-B*

* More-symmetric dry- vs. wet-yr. effects
  - Dry = +1, semi-dry = +0.5, & wet yrs. = -1 pts.
* Adjusted $R^2$ = 89%, but run overestimated in 2013)

# Best Multiple-Regression Models

- **Quadratic equations (cont.)**

  # *Best model for CONSEC-E*

    * Threshold lake level (again)

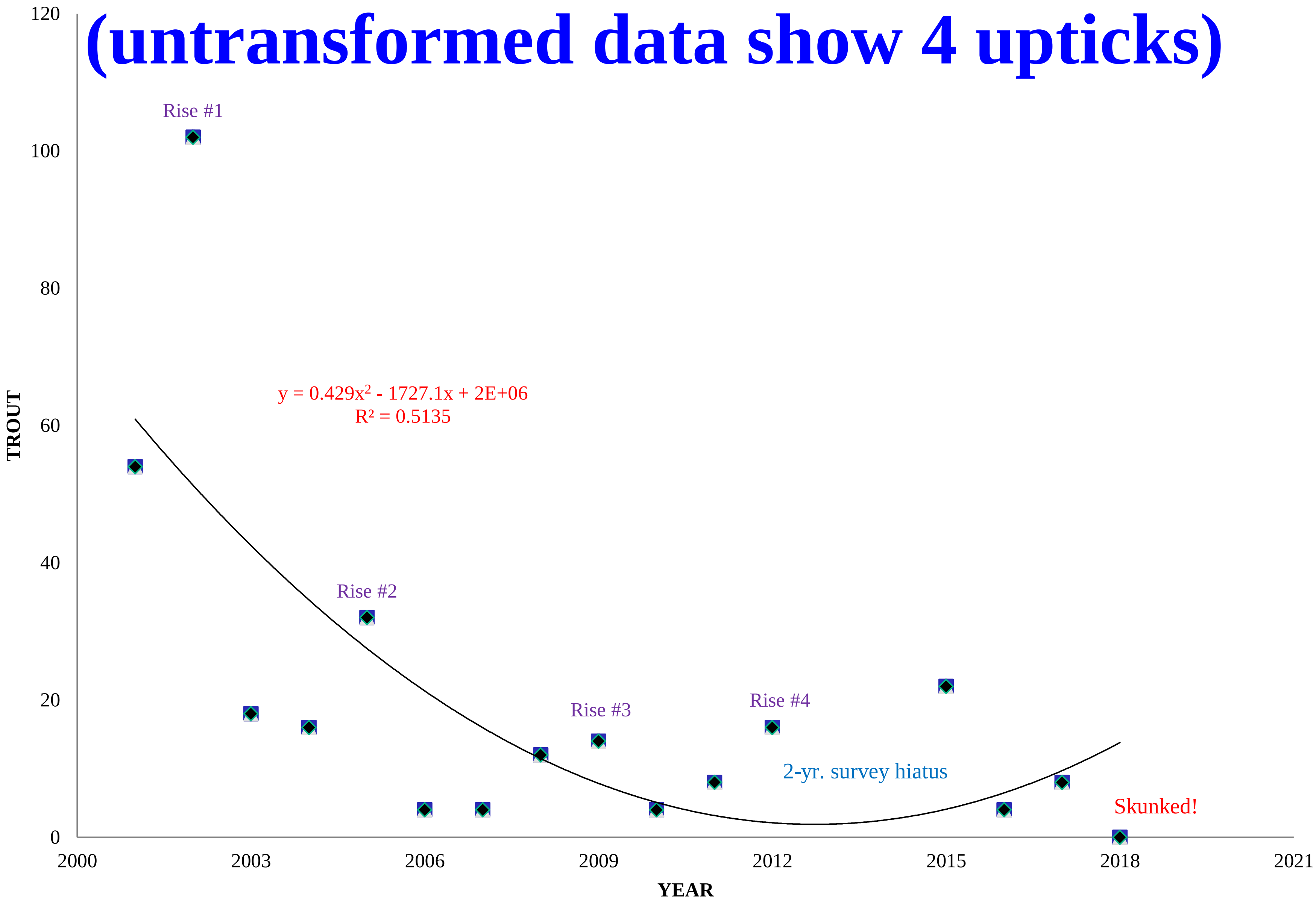
      - Drier = +1 & wet yrs. = -1 pts.

    * Adjusted $R^2$ = 91% (realistic, "warm porridge")

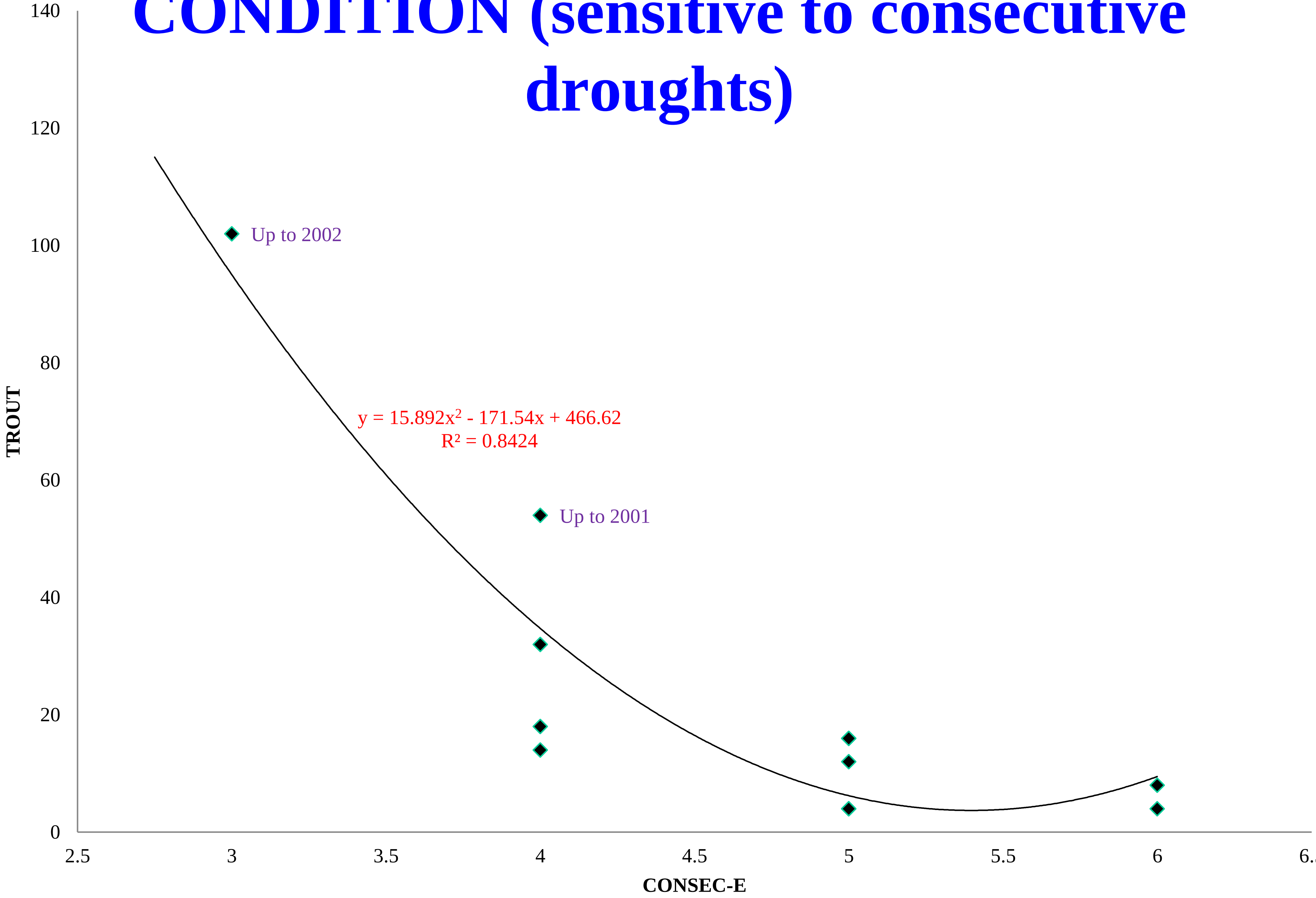
- **'Hybrid' approach (use of both CONSEC-E equations,** most accurate**)**

  # Because monotonic & quadratic eqns. slightly under- vs. overpredicted trout escapement, resp., during *drier yrs.*

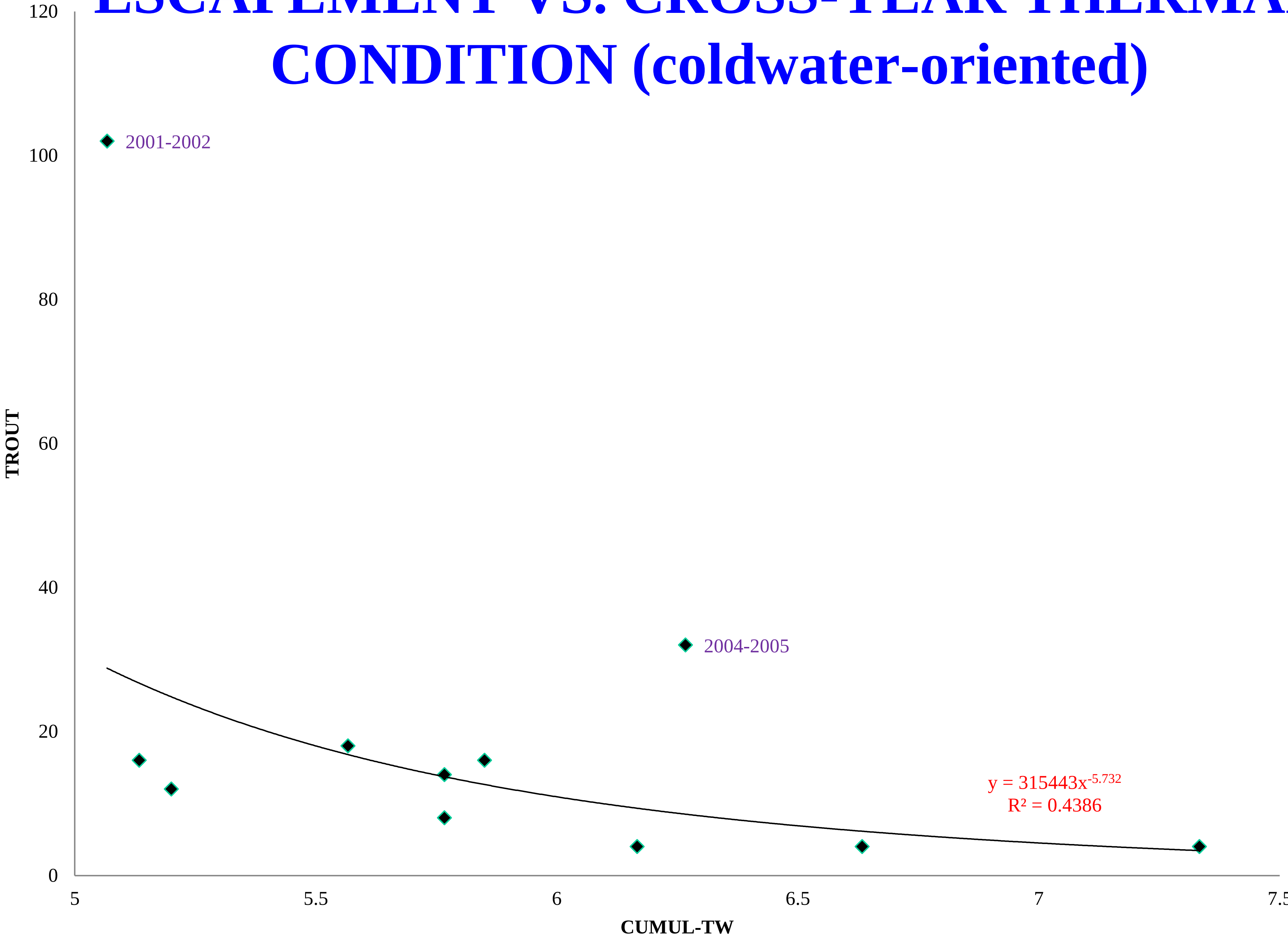
# ESCAPEMENT ACROSS YEARS (untransformed data show 4 upticks)



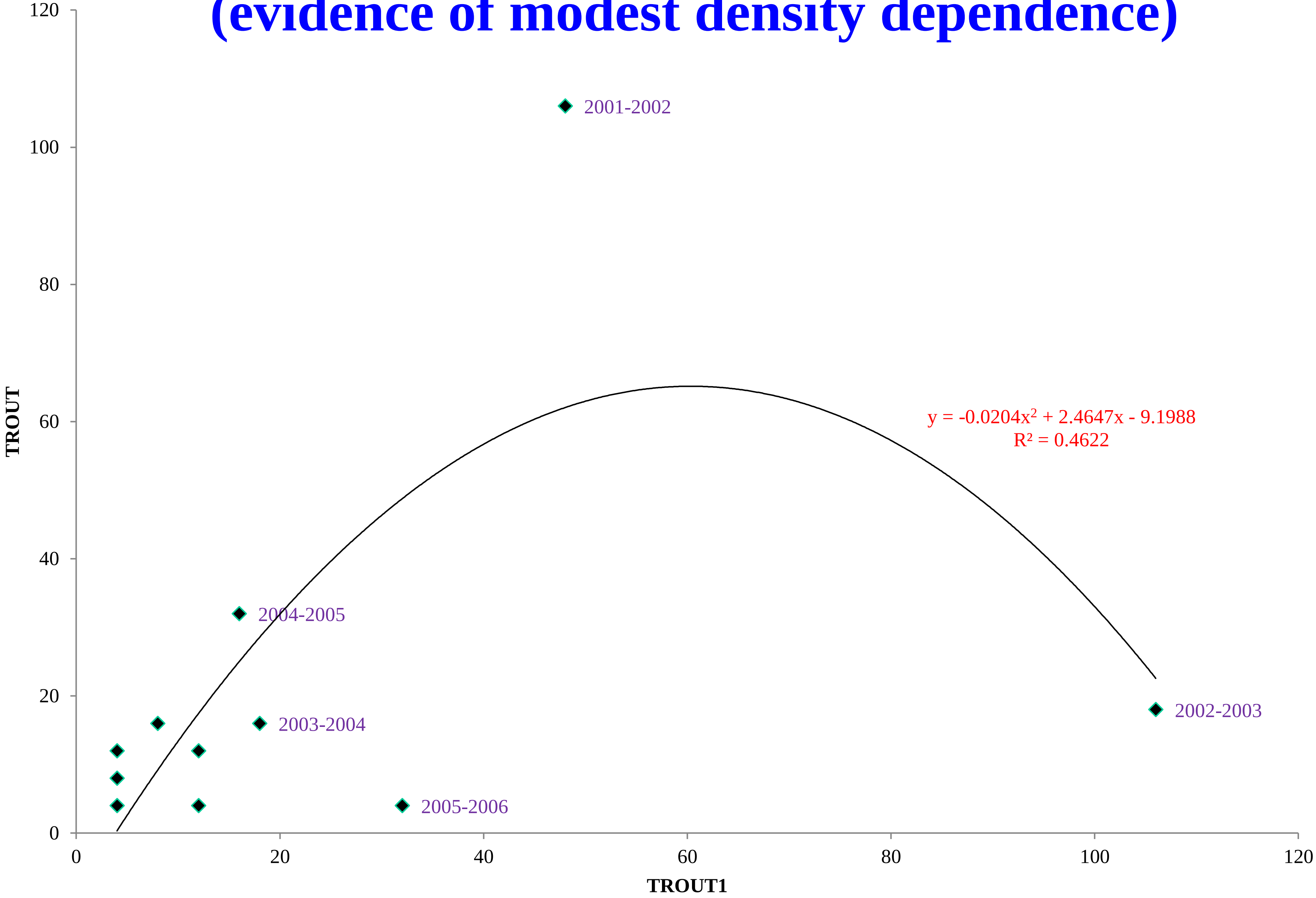
# ESCAPEMENT VS. CROSS-YEAR LAKE CONDITION (sensitive to consecutive droughts)



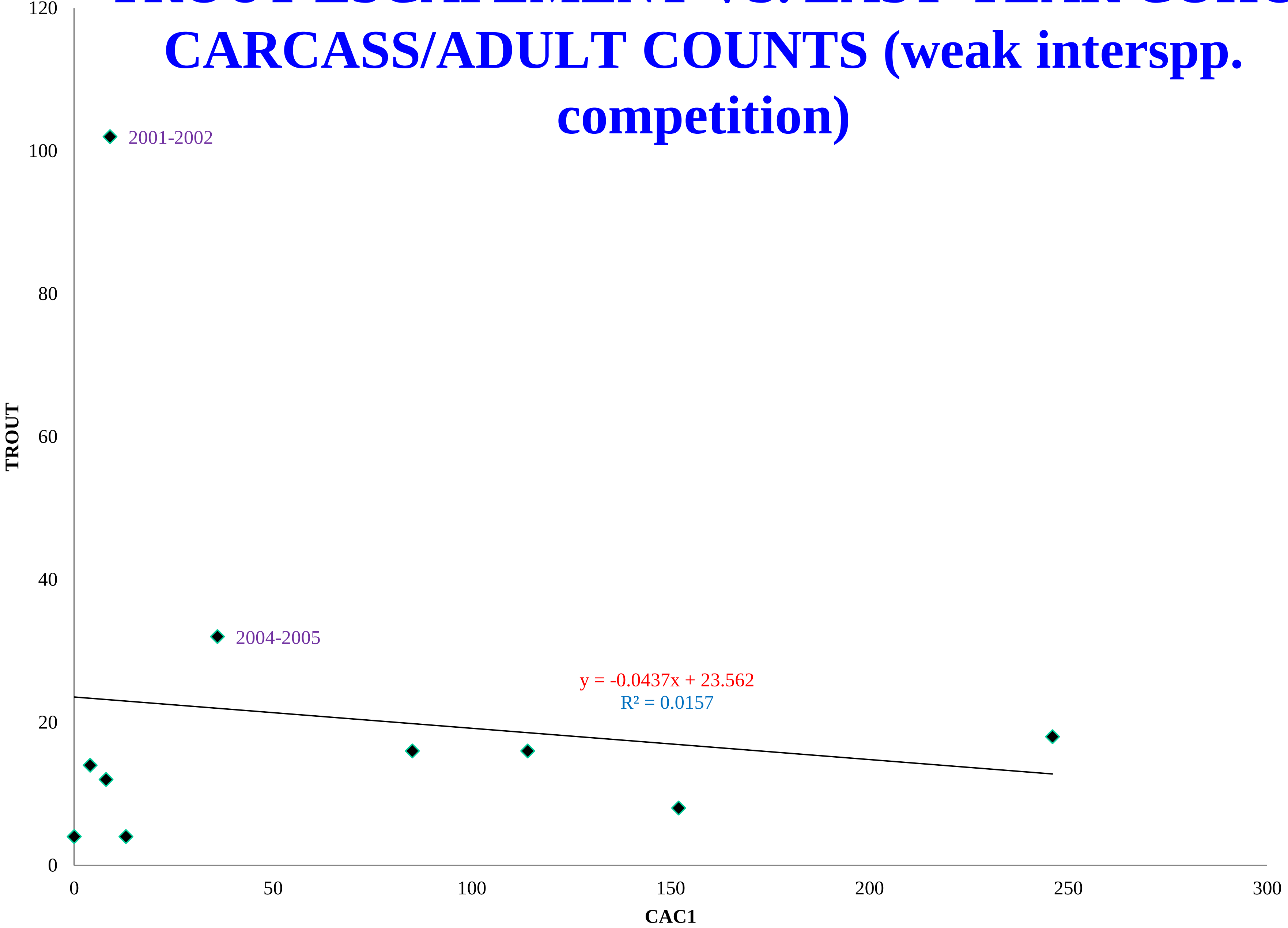
# ESCAPEMENT VS. CROSS-YEAR THERMAL CONDITION (coldwater-oriented)



# PRESENT- VS. LAST-YEAR TROUT ESCAPEMENT (evidence of modest density dependence)



# TROUT ESCAPEMENT VS. LAST-YEAR COHO CARCASS/ADULT COUNTS (weak interspp. competition)



# Effects of Warm-Weather Dry-Outs: 1998-2000, 2002-3, 2005-6, & 2009-10

**- Irely Lk. often dries out down to middle Big Cr.**

# Full dry-out has recurred over the last few decades
  * Based on remote-sensing info during 1984-2012 *(Vadas et al. 2016)*
  * Worse dry-outs since interdecadal-climate shift of 1999 *(oddly; global-warming effect?)*

# Dying sculpins, crayfishes, & dragonfly nymphs there

# Hence, cutthroat a climate-sensitive sp. *(cold-adapted)*
  * Despite its *groundwater preferences* (i.e., relatively low spawning flows)

# Effects of Warm-Weather Dry-Outs: 1998-2000, 2002-3, 2005-6, & 2009-10

**- <u>Possible large-fish refuge</u> in flatter, deeper reach near Irely Lk. (pool-dominated)**

# *Immature coho & cutthroat* of various sizes in lower mainstem of Irely Cr.

# <u>Perennially flowing</u> in most mainstem reaches (but w/ some *residual pools* D/S)

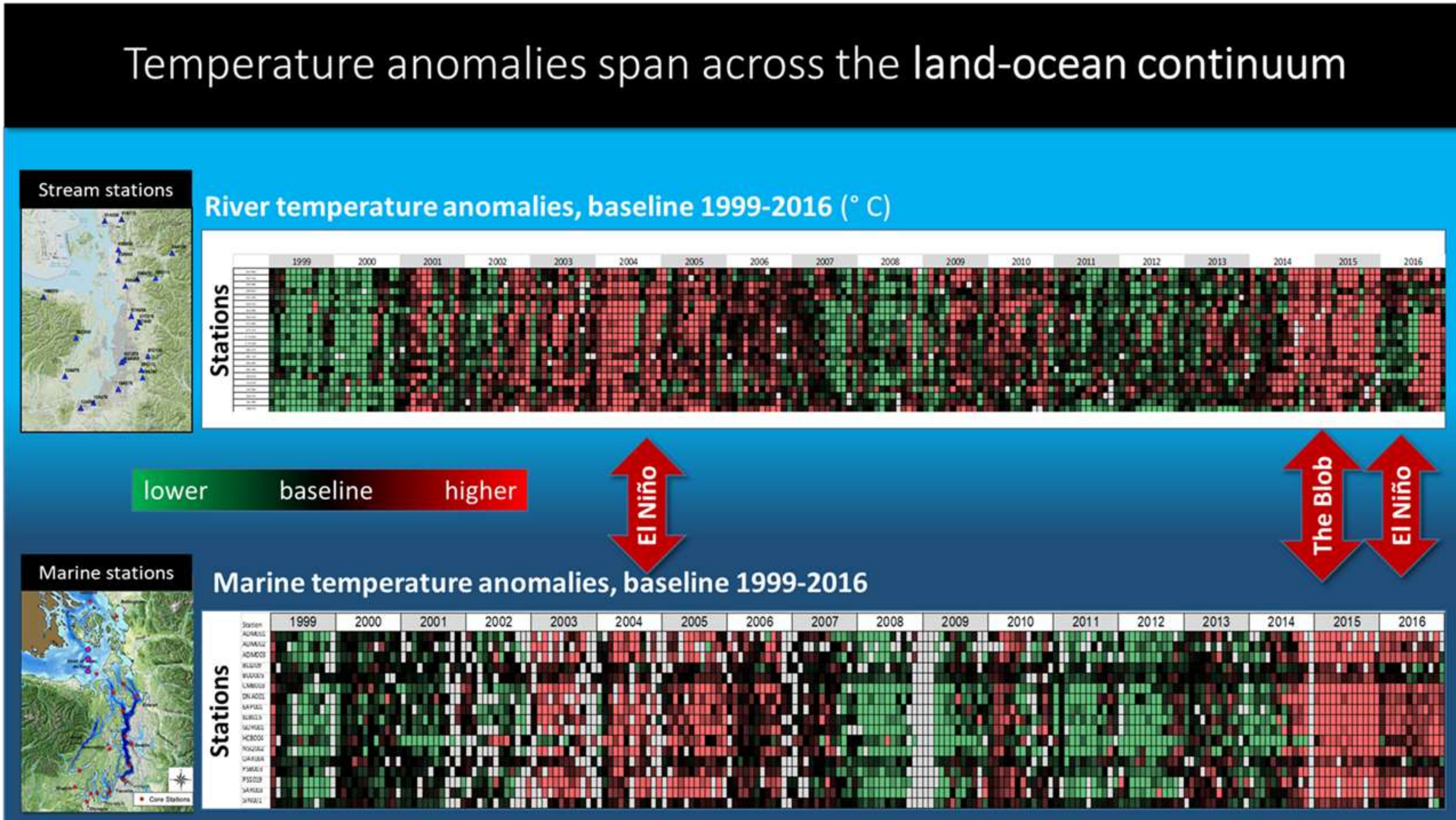
# Loss of <u>trout-fishing action</u> of 1990s

# Effects of Warm-Weather Dry-Outs: 1998-2000, 2002-3, 2005-6, & 2009-10

- **Middle Big Cr. (intermittent fish passage)**
  # Hyporheic flow during non-winter months (*flood scour*)
    * Unlikely refuge *(until now via Irely Lk. outlet sedimentation?)*
  # But 3-4 *salmon spp.* spawn in MBC (& sockeye D/S)
  # Well-forested watershed likely compensates (allowing *salmonid persistence*)

# Biophysical Conditions Since 2015

**(major drought via El Niño/blob impacts, as portrayed by WDOE thermal data for Puget Sound, c/o Dr. Christopher Krembs)**



# Irely Lake - 2015 Drought

**(Aug. > dry, showing bare & weedy [esp. RCG] areas that reflect depth trends)**

# Irely Lake - 2015 After Rain

**(Sep. full, showing exposed native plants > RCG)**

# Irely Lake - 2017 Post-Blob

## (Aug. < full, showing exposed RCG along shores)

# Biophysical Conditions Since Major Drought of 2015-16

- **Moderate trout escapement in 2015**
  # Somewhat better than for last survey of 2012
    * Likely better lake levels for <u>sampling hiatus </u>of 2013-14
- **Irely Lk. w/ full dry-outs during 2015-16**
  # So escapement has generally dropped since 2015, but w/ some trout recovery in 2017
    * Will estimate missing CARC data for coho (perhaps via late-winter flows for inmigration)

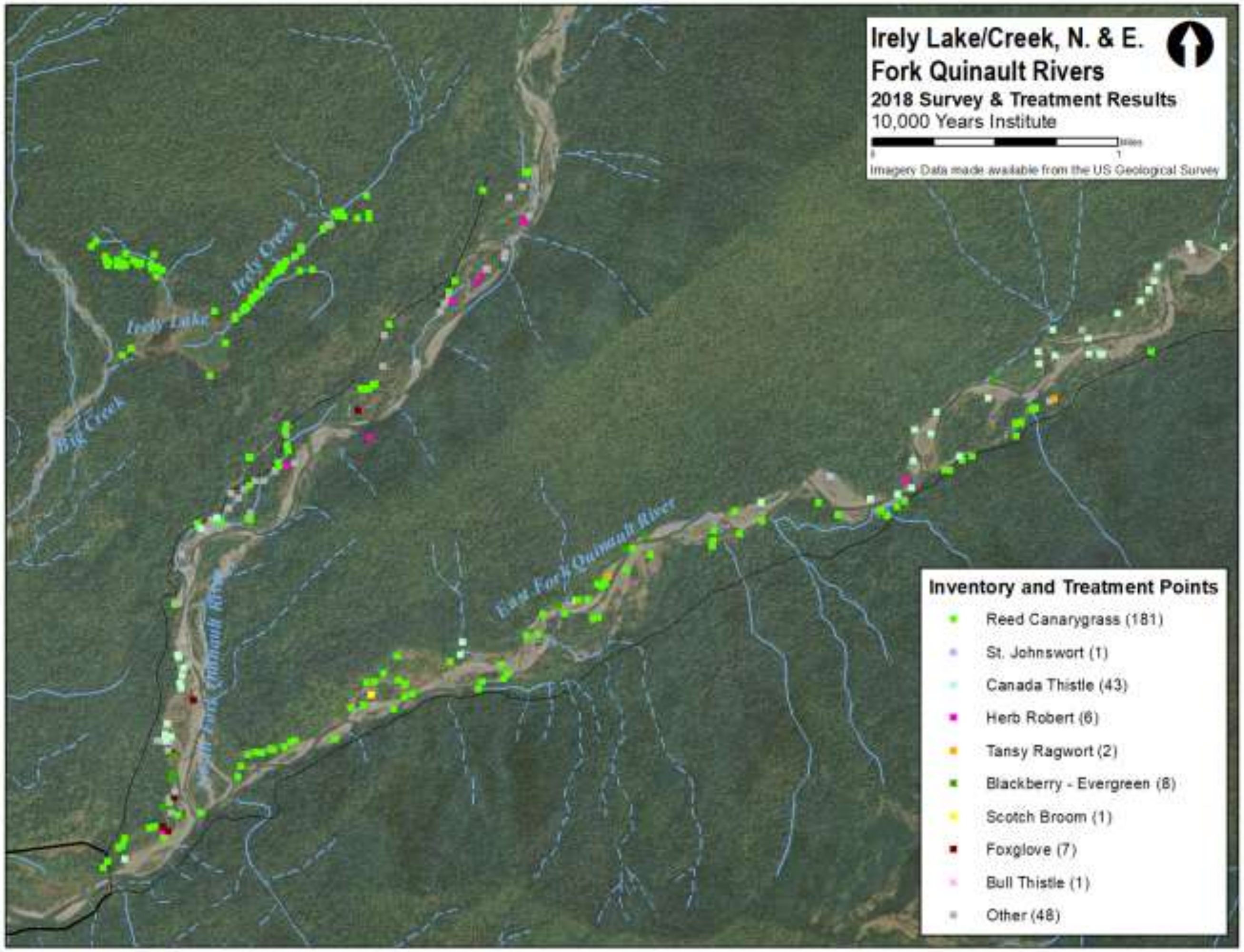
# Biophysical Conditions Since Major Drought of 2015-16

- **Escapement nil (for 1st time) in 2018**
  - # Was incentive to start lake/crk. RCG removals (manual/herbicidal) in 2018 *(NPS & 10KYI)*
  - # ENSO effects in 2019, so lake might dry out again
    - Food (late-WI coho carcasses) also at low levels
- **Continued RCG-removal & trout-redd work in 2019, etc.**
  - # Tougher now w/ more storm-downed snags
  - # Including air/crk. thermographs

# Semi-dry Conditions during 2018

**(suggests <u>poor trout escapement</u> next spring; note the native sedges & sweetgale nr. the Irely Cr. outlet)**

# SU/FA 2018 - Start of Invasive-Plant (e.g., RCG) Removal Efforts




**There & in N. & E. forks of the Quinault R.**

# Potential RCG impacts

**(spring 2018 photos show a very full lake, but need summer/fall rains, too)**

**Channel (lake/creek) filling & heating**

- **Creek flow & sediment transport**
- **Prey production**
- **Riparian succession**

# Conclusions

- Loss of iteroparous (repeat) spawning, so long-term decline of trout run
- - Reproduction has now failed, so 3 consecutive-drought yrs. could extirpate it
- Despite old-growth, temperate-rainforest conditions w/ high rainfall, existing <u>water was limiting</u> for CCT in the Irely Lake watershed (cobble/ boulder sieve & RCG effects)

  - Additional water use from <u>developed, headwater streams</u> typically impacts salmonid-population viability

# Conclusions

- **Salmonid instream-flow needs quantified in lower Irely Creek via *PHABSIM studies* in 2 reaches of this protected stream**
- **Joint riparian (e.g., RCG) & instream-flow management important for Pacific-salmonid protection in more-developed watersheds (e.g., Central/South Puget Sound)**