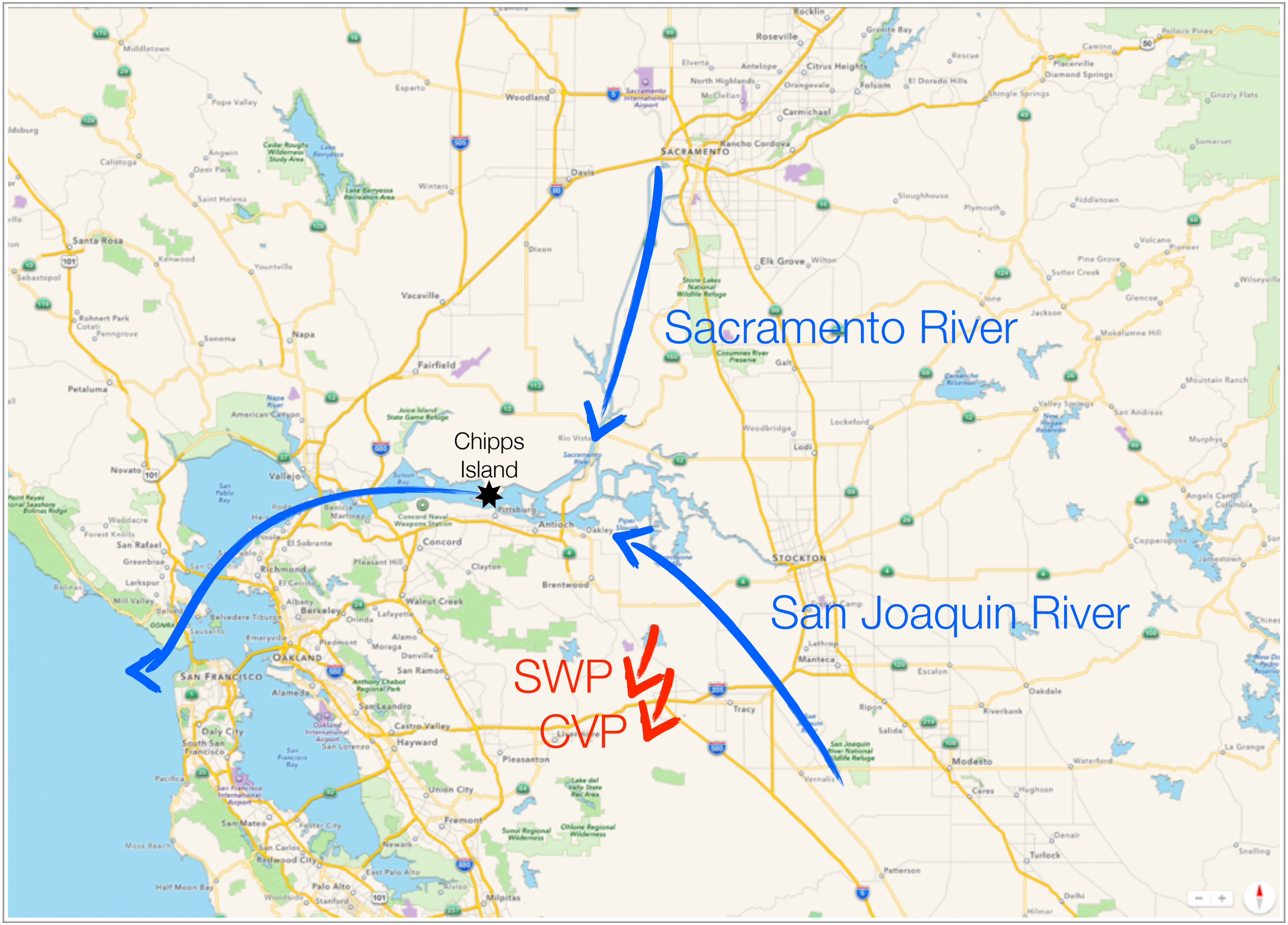
An agent-based model of Chinook smolt migration in the Sacramento-San Joaquin Delta

Doug Jackson (NOAA Southwest Fisheries Science Center)
Russell Perry (USGS Western Fisheries Research Center)
Steve Lindley (NOAA Southwest Fisheries Science Center)
17-Apr–14

Introduction


Sacramento River
Chipps Island
San Joaquin River
SWP
CVP
SACRAMENTO
STOCKTON
OAKLAND
SAN FRANCISCO
Sacramento International Airport
Oakland International Airport
San Francisco International Airport
Stone Lakes National Wildlife Refuge
Cosumnes River Preserve
Joice Island State Game Refuge
Concord Naval Weapons Station
Lake Berryessa
Cedar Roughs Wilderness Study Area
Lake Berryessa Recreation Area
Napa River
Anthony Chabot Regional Park
Lake del Valle State Rec Area
Sunol Regional Wilderness
Ohlone Regional Wilderness
San Joaquin River National Wildlife Refuge
Pittsburg
Antioch
Oakley
Rio Vista
Sacramento River
Suisun Bay
San Pablo Bay
San Francisco Bay
Woodland
Davis
Dixon
Vacaville
Fairfield
Napa
Vallejo
Benicia
Martinez
Concord
Walnut Creek
Berkeley
Richmond
Alameda
San Leandro
Hayward
Fremont
Union City
Pleasanton
Livermore
Tracy
Manteca
Lathrop
Lodi
Stockton
Modesto
Turlock
Ceres
Galt
Elk Grove
Rancho Cordova
Roseville
Rocklin
Folsom
Carmichael
Citrus Heights
Placerville
Sonoma
Petaluma
Santa Rosa
Novato
San Rafael
Daly City
San Mateo
Redwood City
Palo Alto
Milpitas
Patterson
Ripon
Escalon
Oakdale
Riverbank
Salida
Vernalis
Woodbridge
Lockeford
Valley Springs
San Andreas
Jackson
Sutter Creek
Pine Grove
Volcano
Pioneer
Ione
Glencoe
Mokelumne Hill
Mountain Ranch
Murphys
Angels Camp
Columbia
Copperopolis
Jamestown
Waterford
Hughson
Denair
Delhi
Hilmar
Snelling
La Grange
Sloughhouse
Plymouth
Fiddletown
Somerset
Grizzly Flats
Shingle Springs
El Dorado Hills
Rescue
Granite Bay
Pollock Pines
Camino
Elverta
Antelope
North Highlands
McClellan
Orangevale
Esparto
Winters
Middletown
Pope Valley
Calistoga
Angwin
Deer Park
Saint Helena
Kenwood
Yountville
Sebastopol
Rohnert Park
Cotati
Penngrove
Cloverdale
Healdsburg
Woodacre
Forest Knolls
Greenbrae
Larkspur
Mill Valley
Belvedere Tiburon
Sausalito
Emeryville
Piedmont
Orinda
Lafayette
Moraga
Alamo
Danville
San Ramon
Castro Valley
San Lorenzo
South San Francisco
Pacifica
Moss Beach
Half Moon Bay
Woodside
Stanford
Foster City
San Carlos
Newark
East Palo Alto
Alviso
Brentwood
Clayton
Pleasant Hill
El Cerrito
Albany
Belmont
Point Reyes National Seashore
Bolinas Ridge
Bolinas
GGNRA
Rio Vista
Hercules
Rodeo
Pinole
El Sobrante
Ione
Escalon
Oakdale
Riverbank
Waterford
Hughson
Ceres
Denair
Turlock
Delhi
Hilmar
Snelling
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Vernalis
Manteca
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Winters
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Stockton
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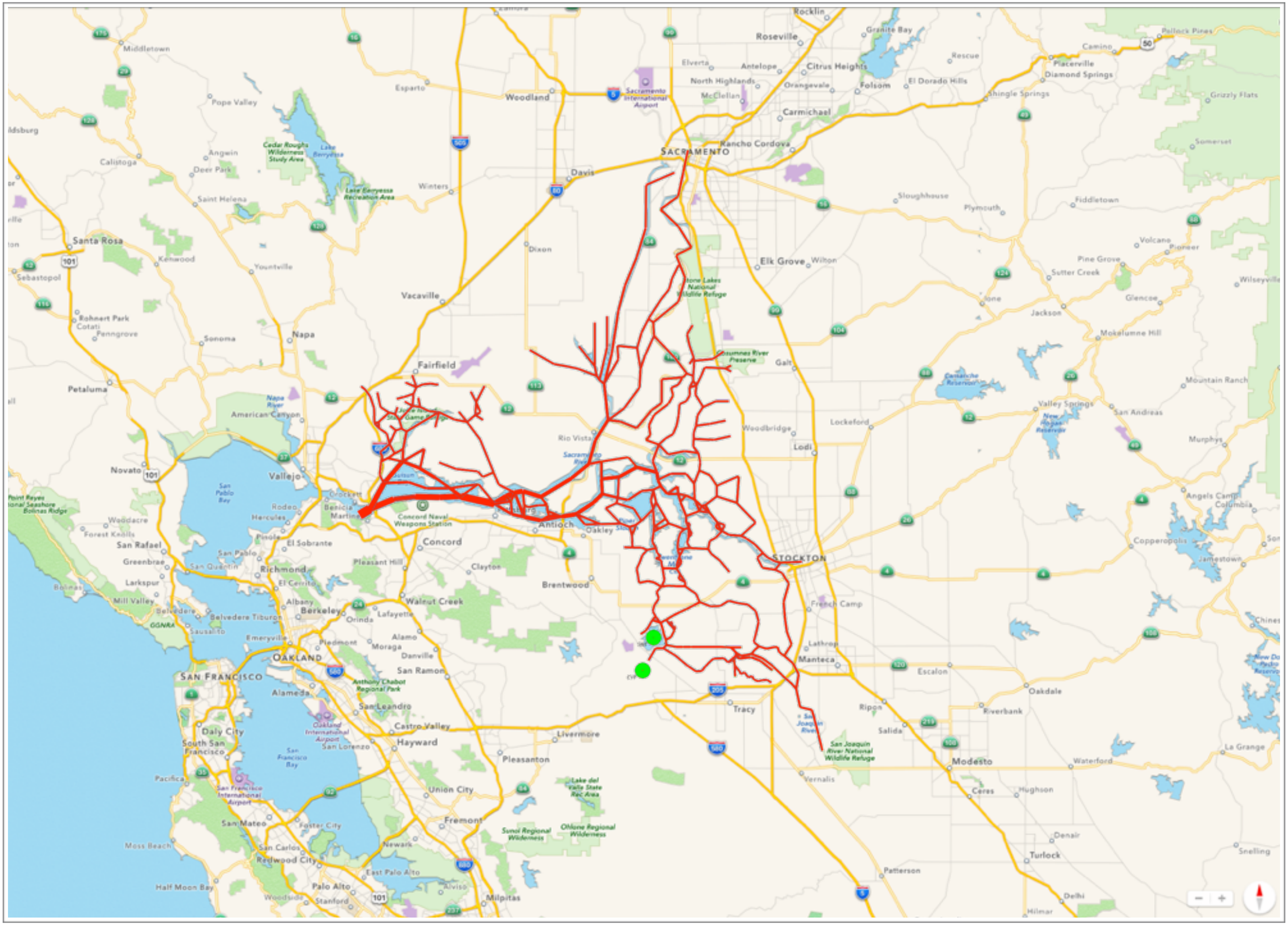
Sacramento


Middletown
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Esparto
Woodland
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Rocklin
Granite Bay
Elverta
Antelope
Citrus Heights
North Highlands
Orangevale
Folsom
El Dorado Hills
Rescue
Placerville
Diamond Springs
Camino
Pollock Pines
Shingle Springs
Grizzly Flats
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Carmichael
Rancho Cordova
SACRAMENTO
Somerset
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Sutter Creek
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Sonoma
Napa
Fairfield
Galt
Petaluma
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Rio Vista
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San Rafael
Greenbrae
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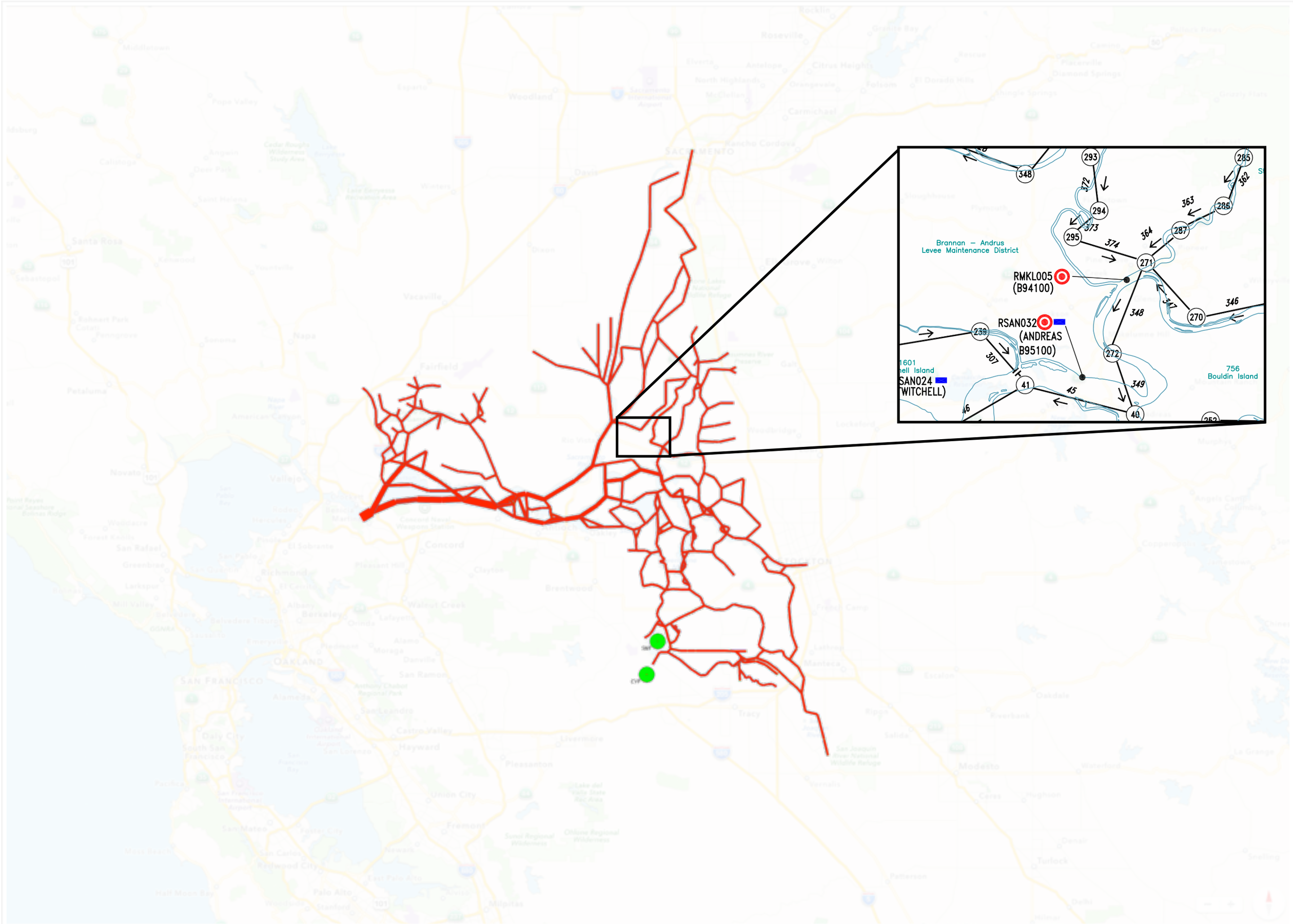
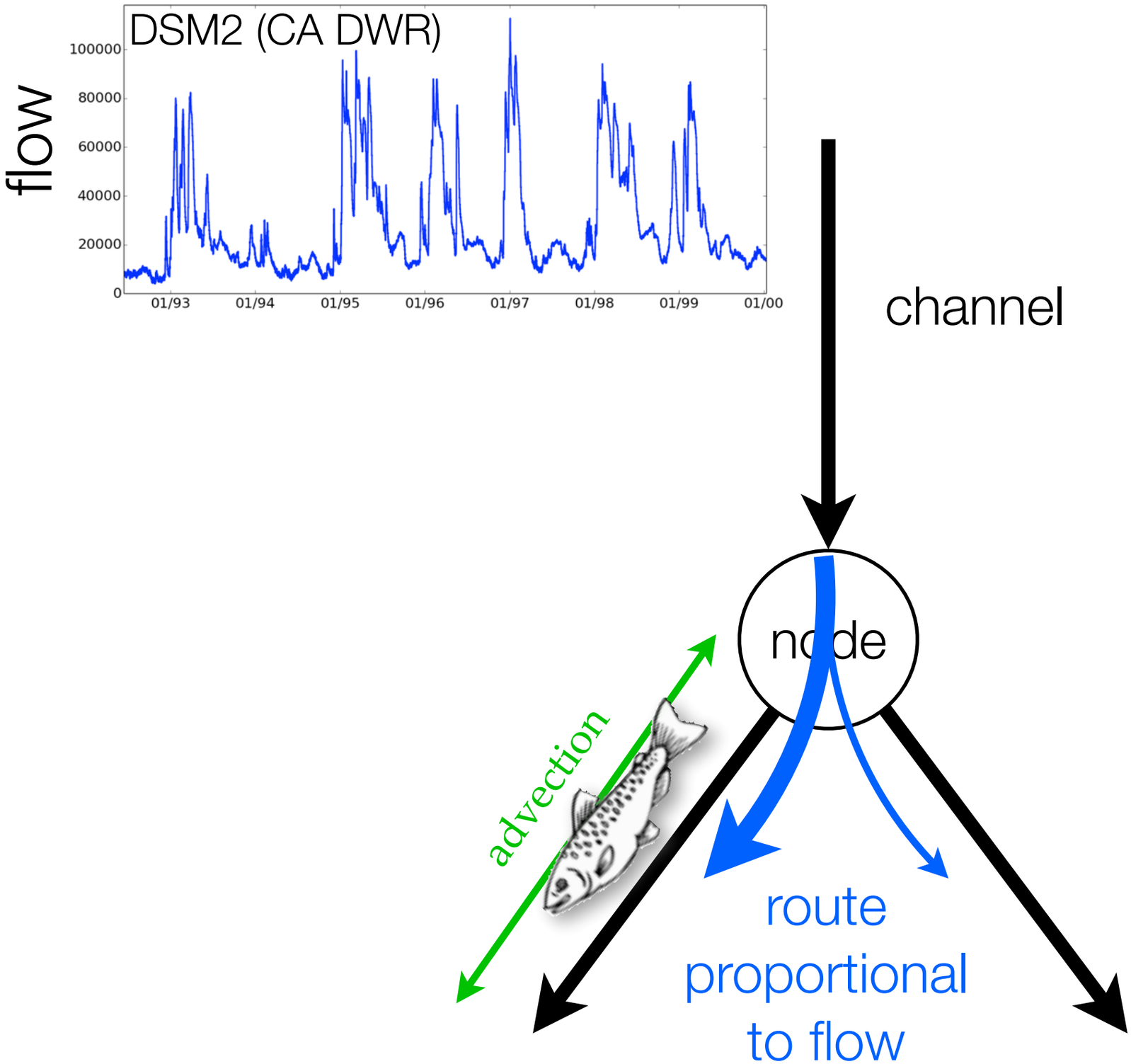
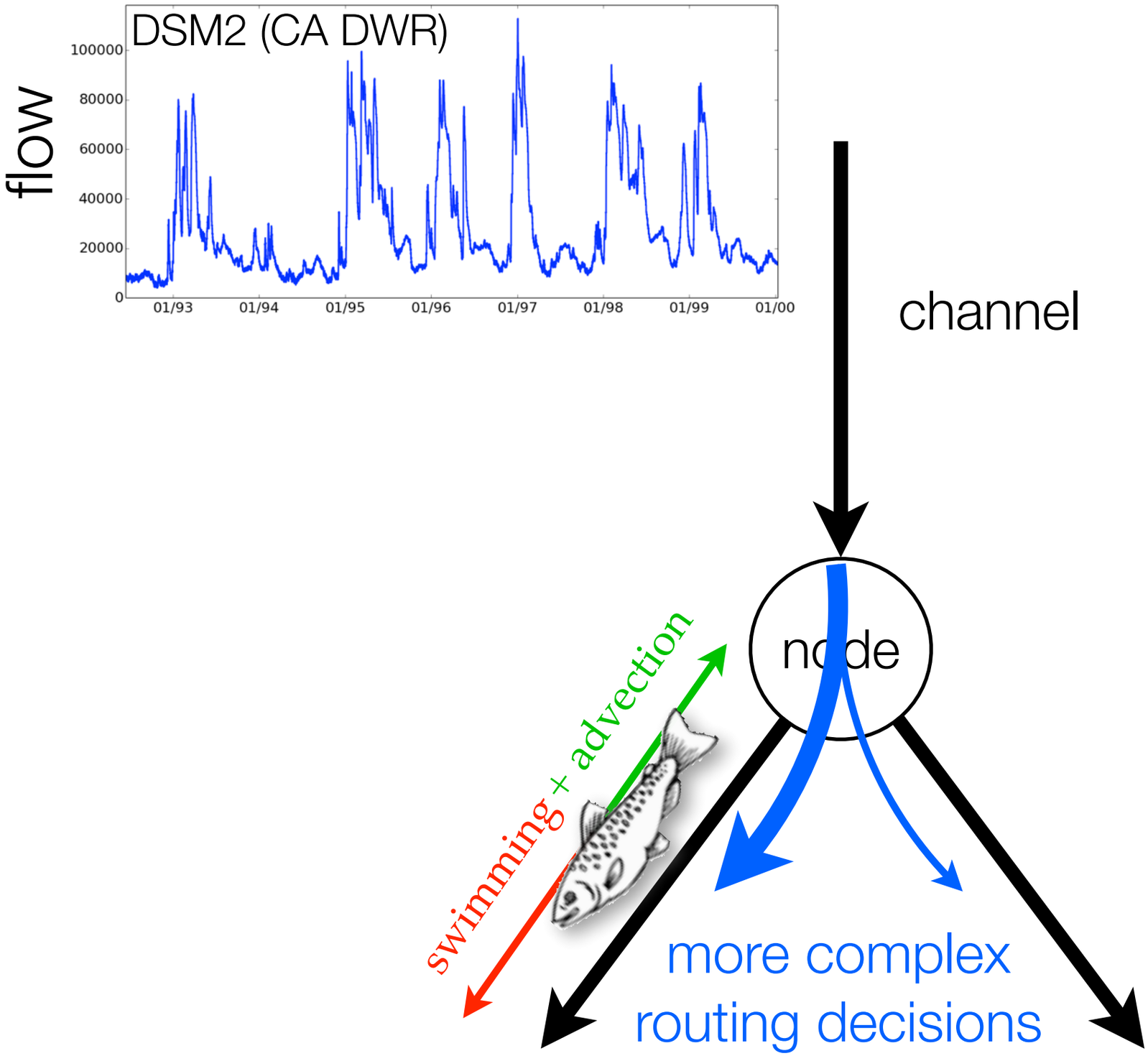


Brannan – Andrus
Levee Maintenance District
RMKL005
(B94100)
RSAN032
(ANDREAS
B95100)
SAN024
(WITCHELL)
756
Bouldin Island


DSM2 (CA DWR)
flow
100000
80000
60000
40000
20000
0
01/93
01/94
01/95
01/96
01/97
01/98
01/99
01/00
channel
node
advection
route
proportional
to flow


DSM2 (CA DWR)
flow
100000
80000
60000
40000
20000
0
01/93
01/94
01/95
01/96
01/97
01/98
01/99
01/00
channel
node
swimming + advection
more complex
routing decisions

Behaviors

Behavior	Description
1	null model: neutrally buoyant
2	always swim towards ocean
3	swim with downstream flow drift with upstream flow
4	swim with downstream flow hold otherwise
5	swim with falling tide drift otherwise
6	swim with falling tide hold otherwise
7	swim towards increasing salinity
8	diurnal swimming: swim at specified time hold otherwise

Behaviors

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Mortality: XT model

survival

distance traveled

travel time

$$S = exp\left(-\frac{1}{\lambda}\sqrt{x^2 + \omega^2 t^2}\right)$$

distance between predator encounters

random movement

Anderson et al. (2005)

Mortality: XT model

$$S = exp\left(-\frac{1}{\lambda}\sqrt{x^2 + \omega^2 t^2}\right)$$

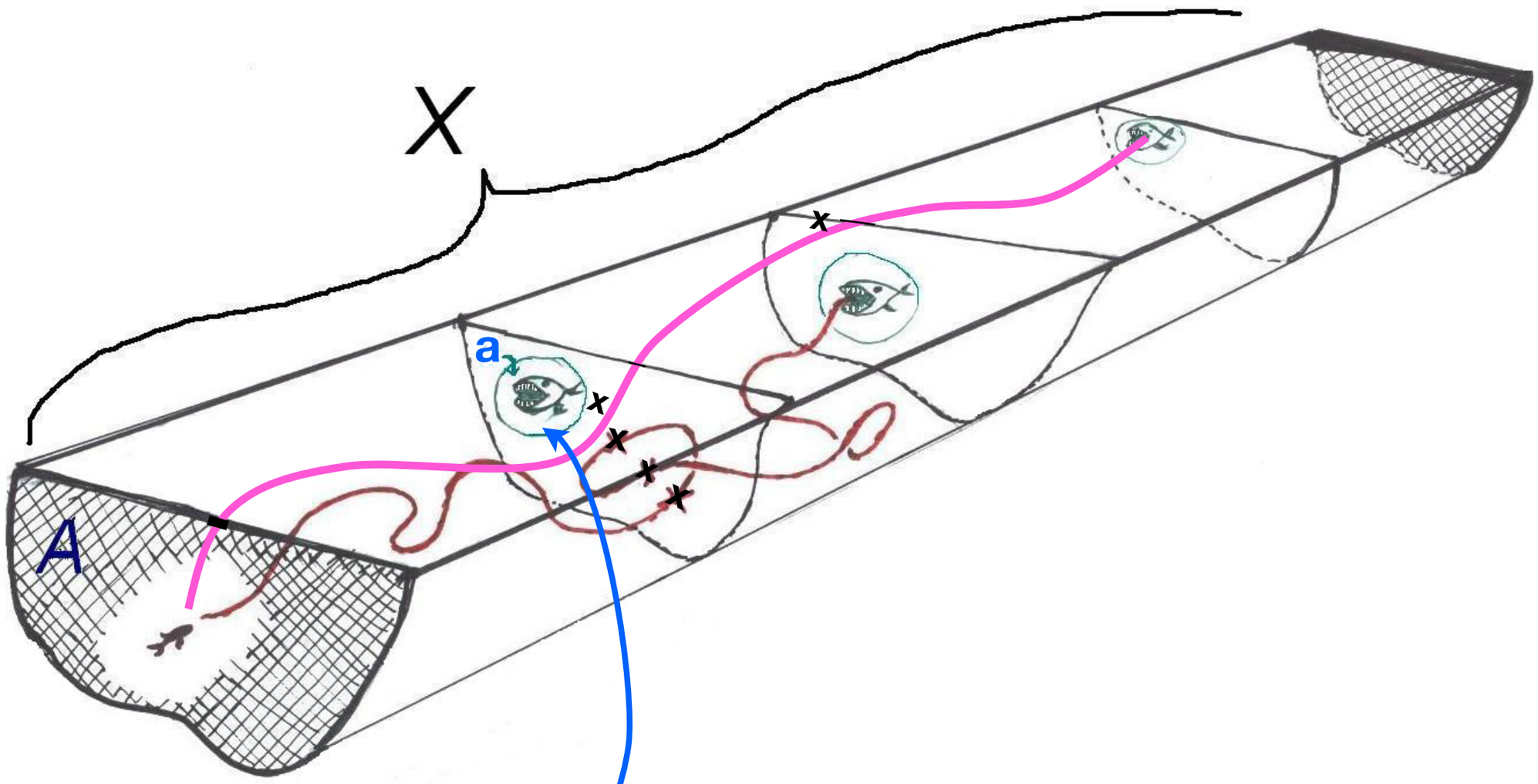
$$\lambda = \frac{1}{\rho \pi r^2}$$

predator density

predator's reaction distance

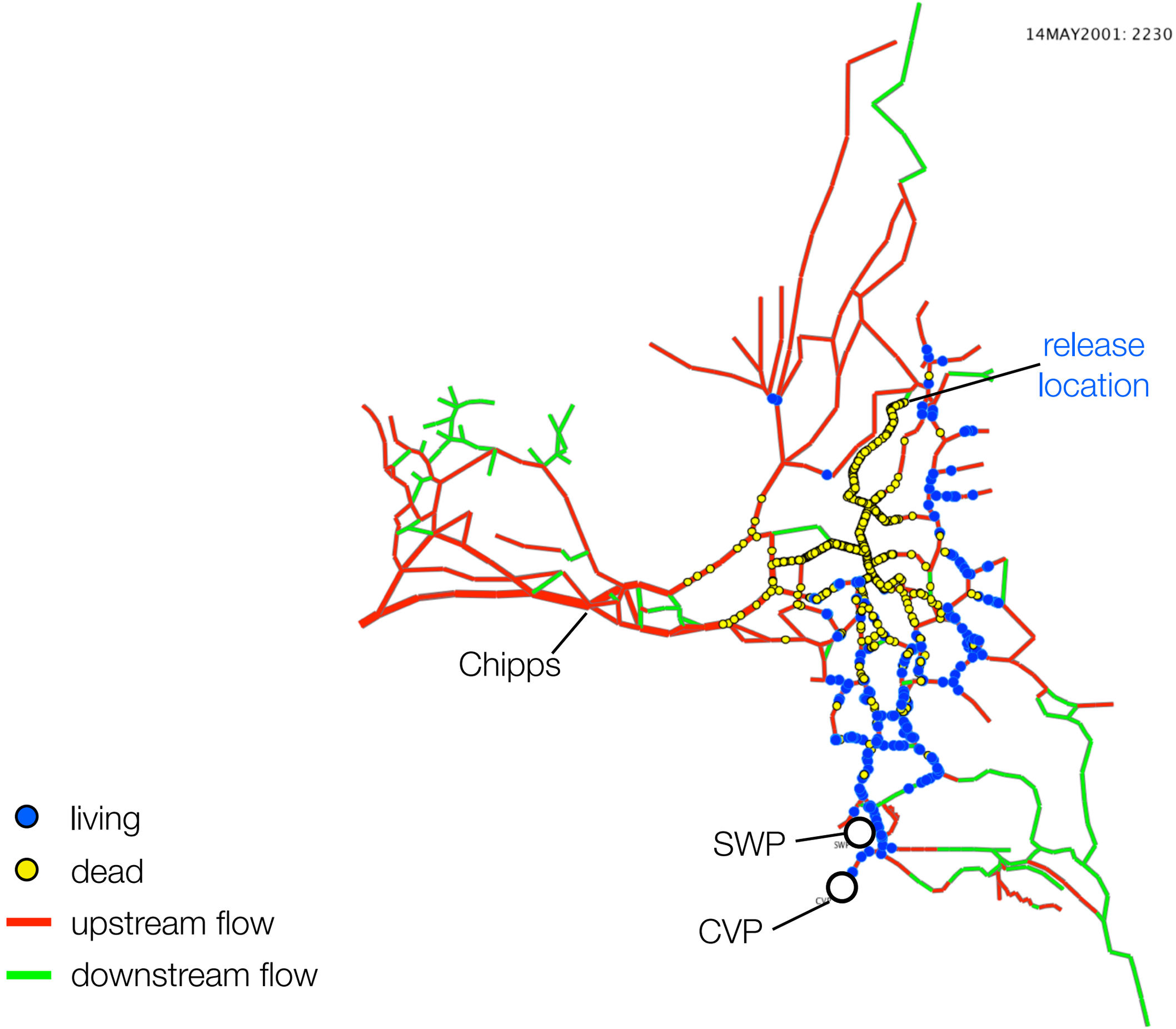
Anderson et al. (2005)

Mortality: XT model



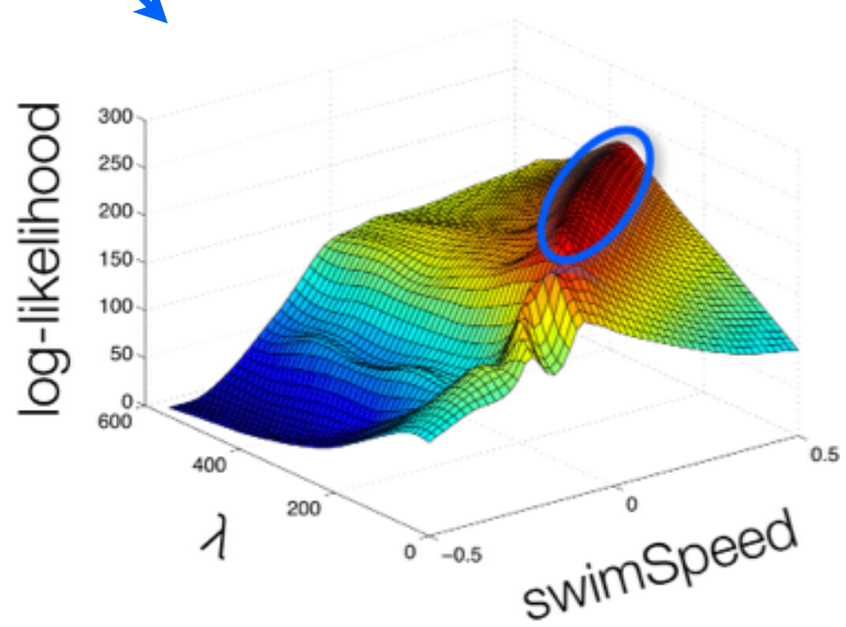
$$S = exp\left(-\frac{1}{\lambda}\sqrt{x^2+\omega^2 t^2}\right); \quad \lambda = \frac{1}{\rho\pi r^2}$$

Gurarie (2008)


14MAY2001: 2230
release location
Chipps
SWP
CVP
living
dead
upstream flow
downstream flow

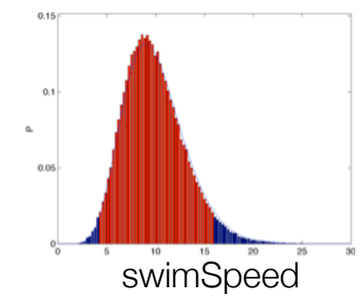
Model calibration

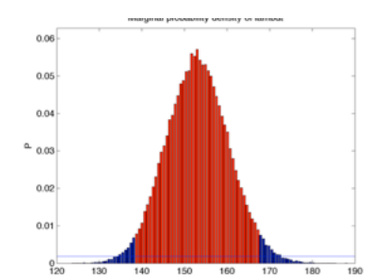
PTM
λ, ω, swimSpeed

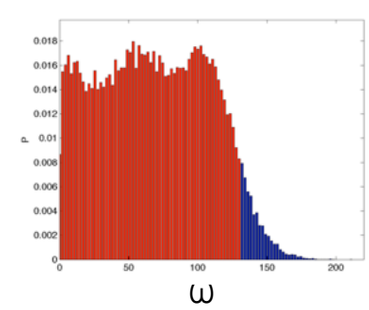


coded
wire tag
data

MCMC
calibration
model selection

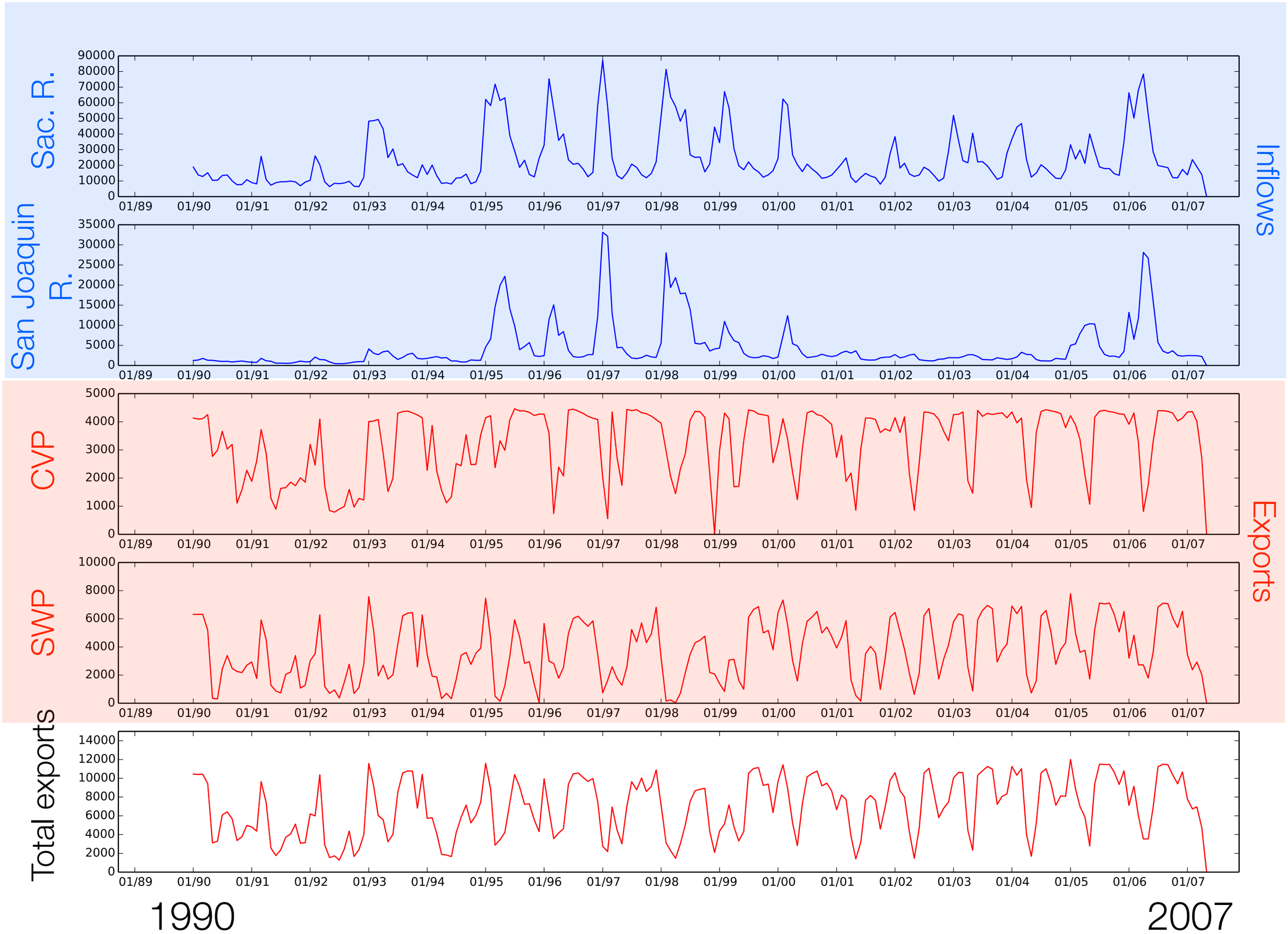


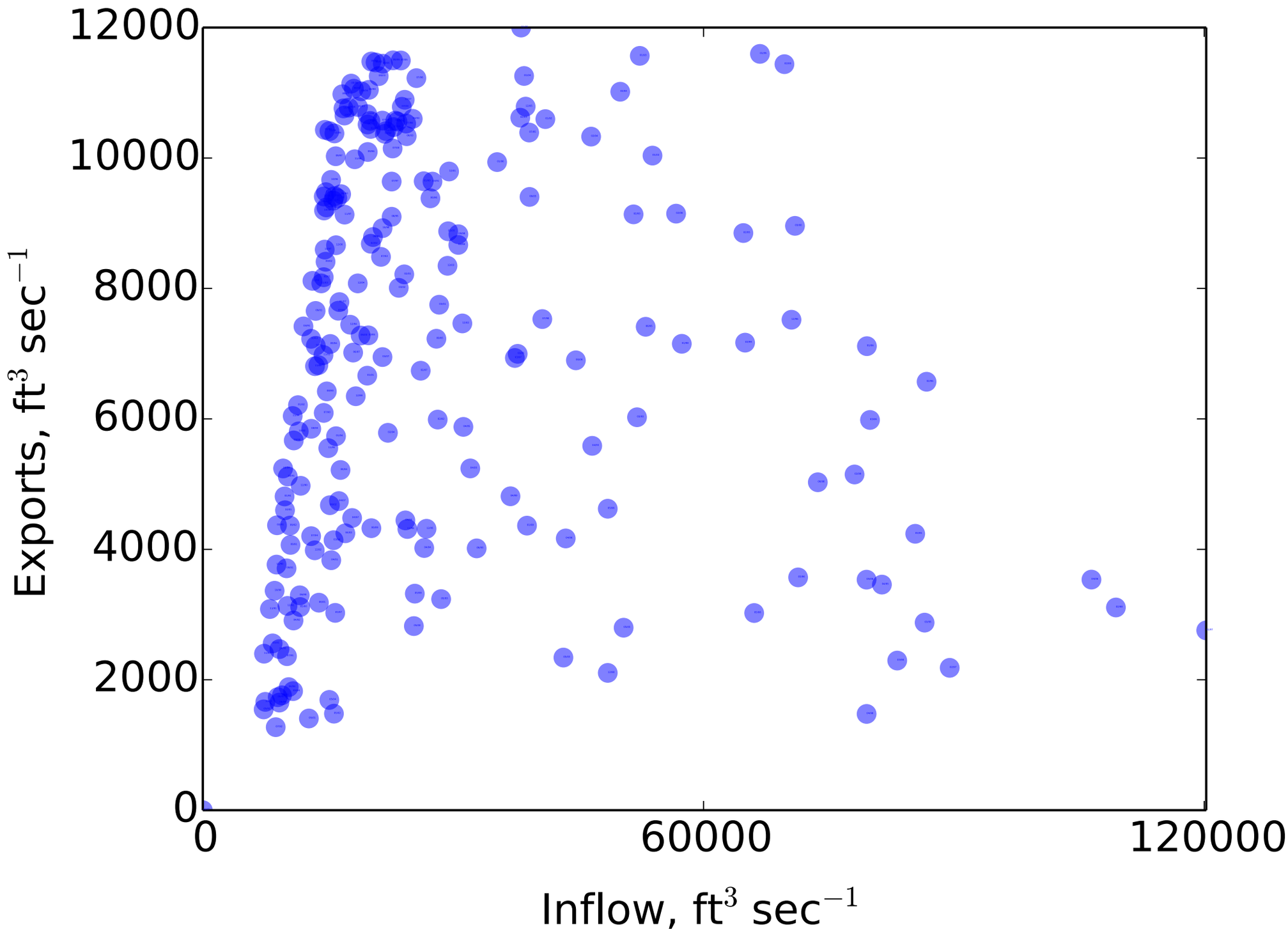


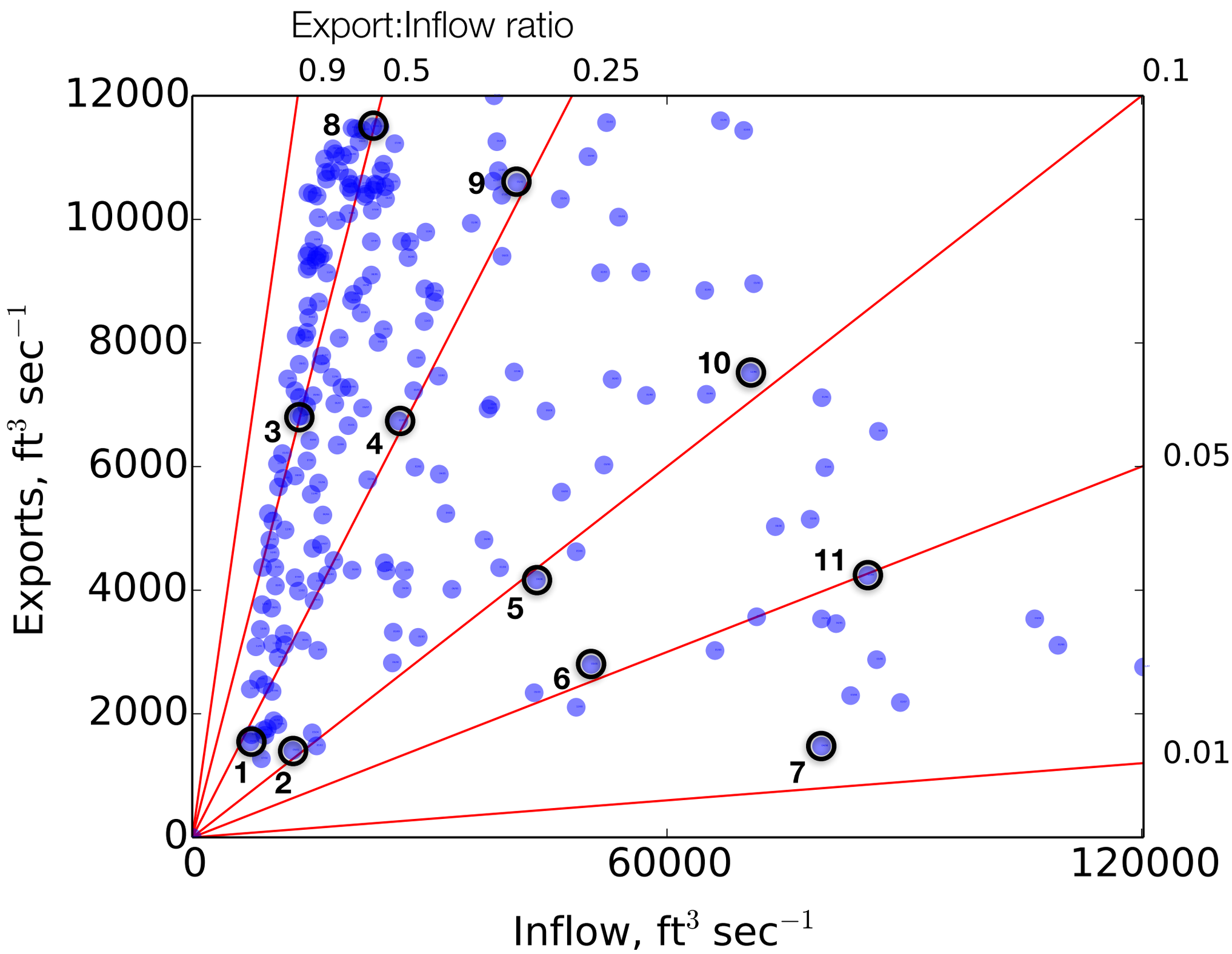


posterior
distributions

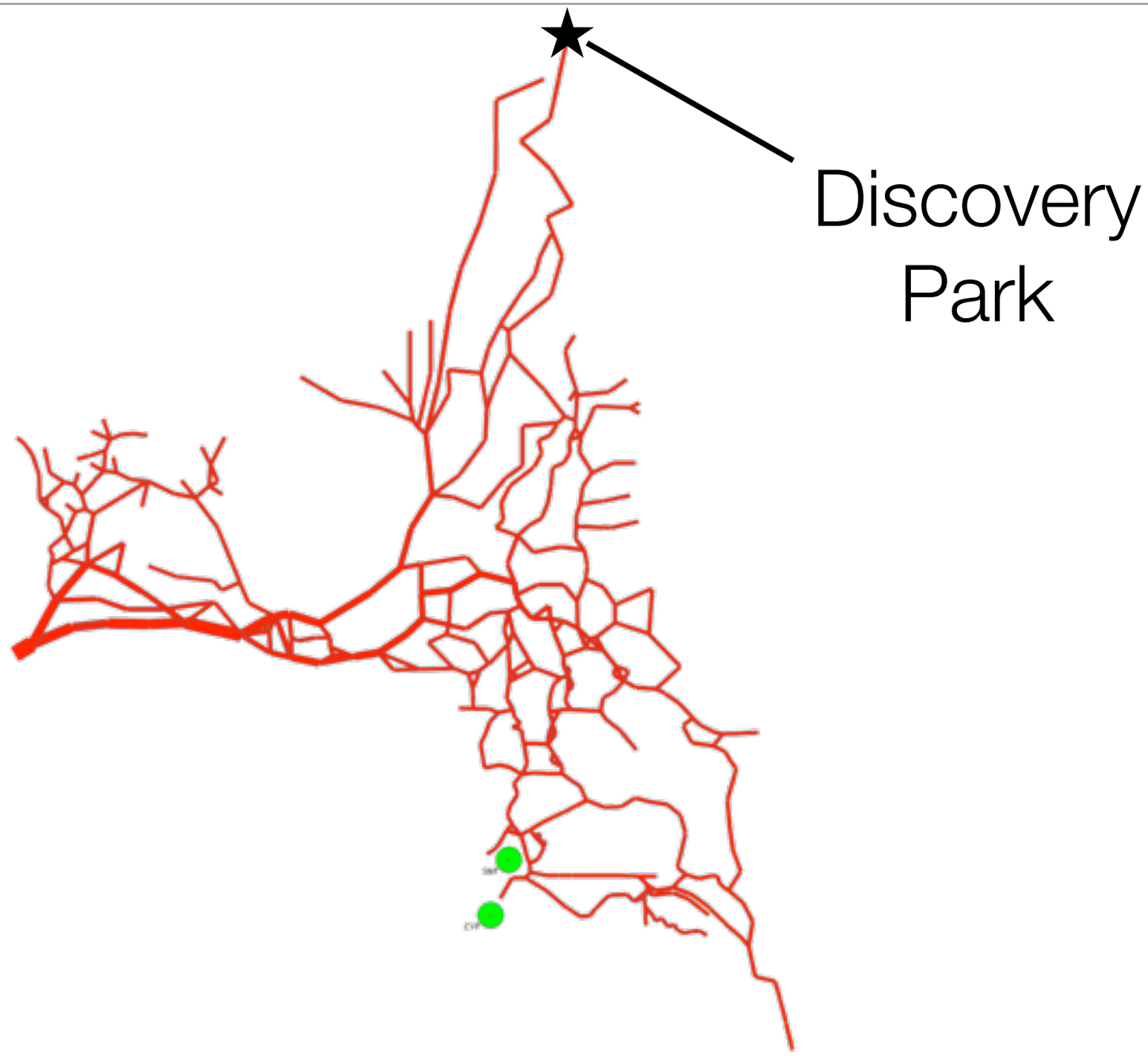
Flow scenarios


Sac. R.
San Joaquin R.
Inflows
CVP
SWP
Total exports
Exports
1990
2007

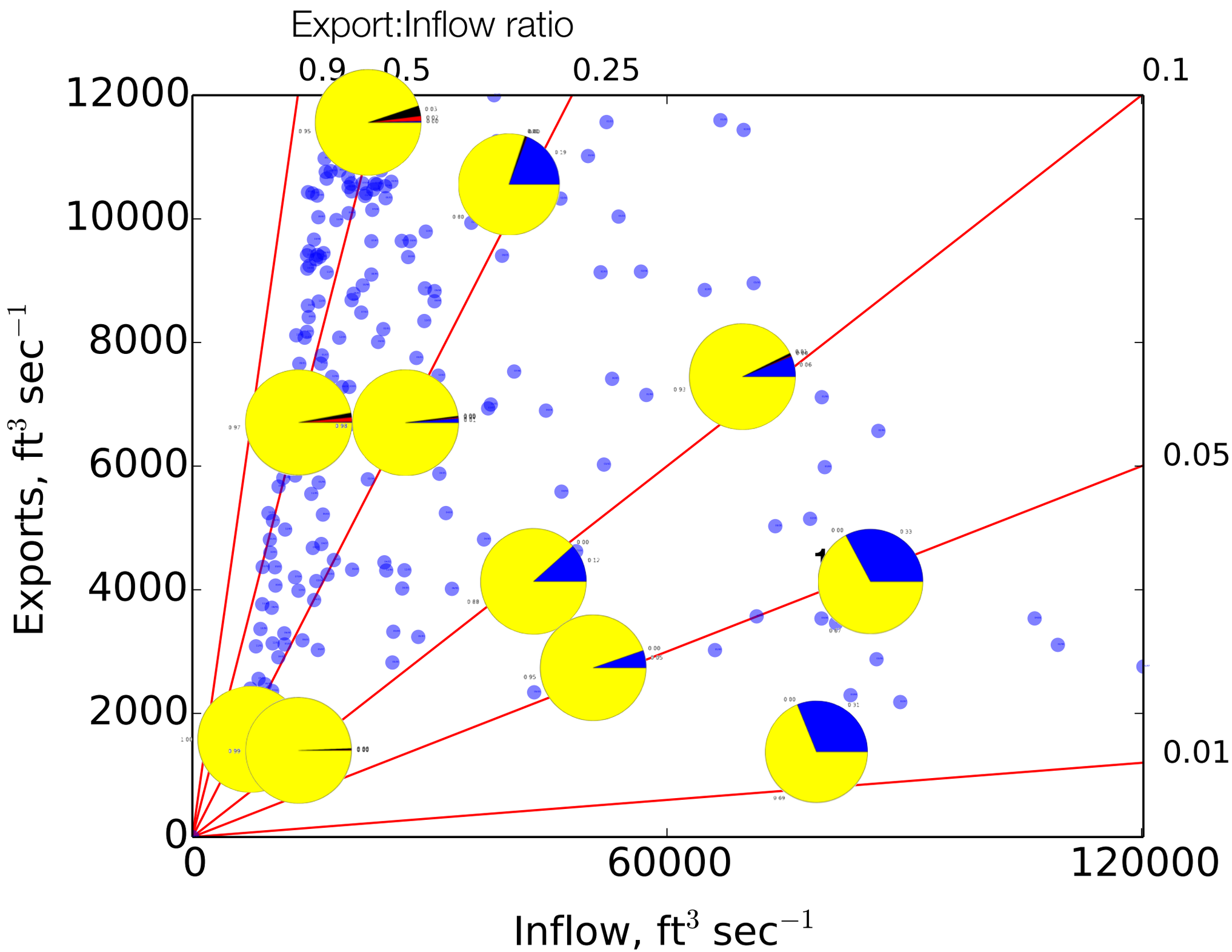

12000
10000
8000
6000
4000
2000
0
Exports, ft^3 sec^{-1}
0
60000
120000
Inflow, ft^3 sec^{-1}


Export:Inflow ratio
0.9
0.5
0.25
0.1
0.05
0.01
12000
10000
8000
6000
4000
2000
0
0
60000
120000
Exports, ft^3 sec^{-1}
Inflow, ft^3 sec^{-1}
1
2
3
4
5
6
7
8
9
10
11

Release location 1

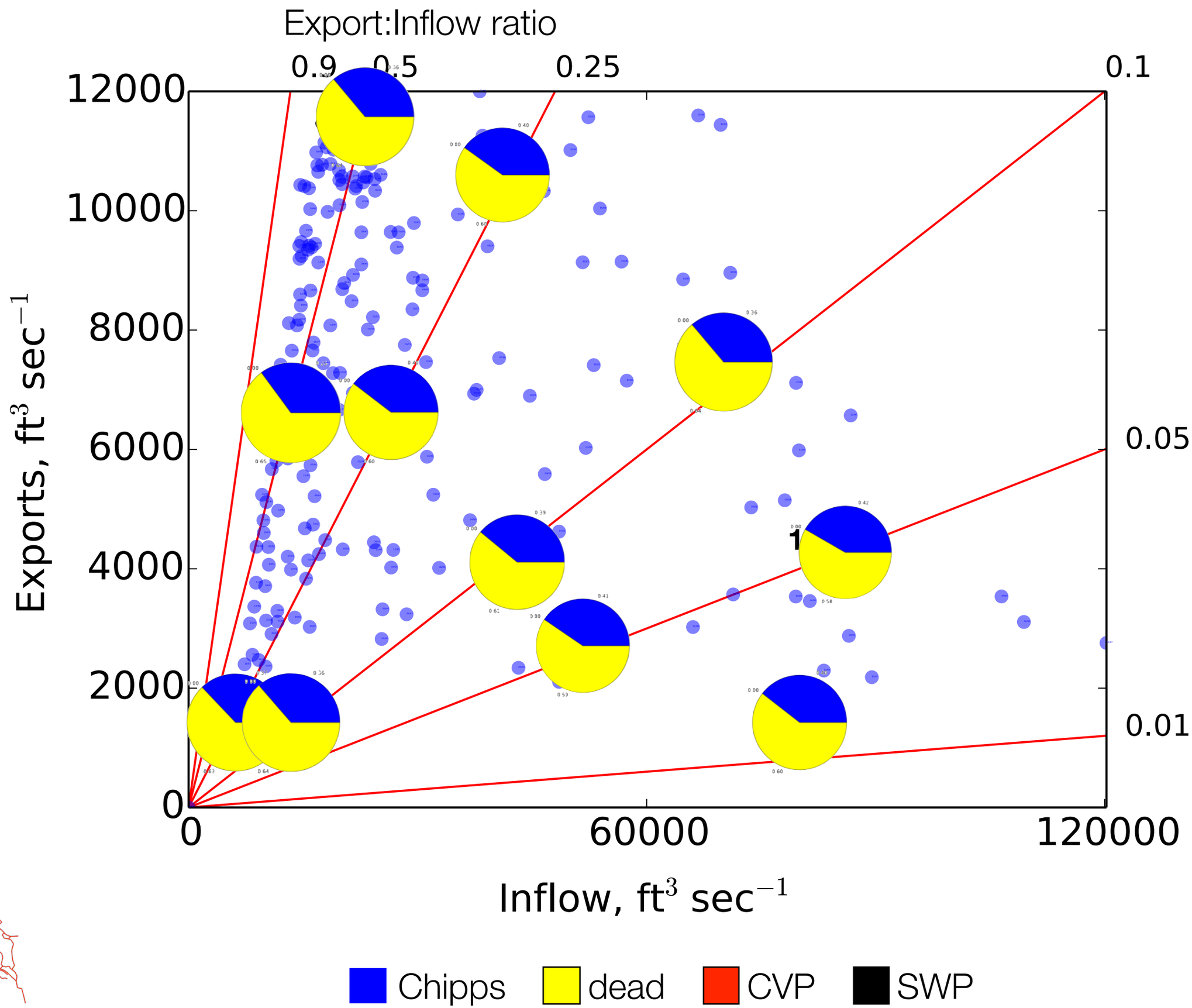


null model

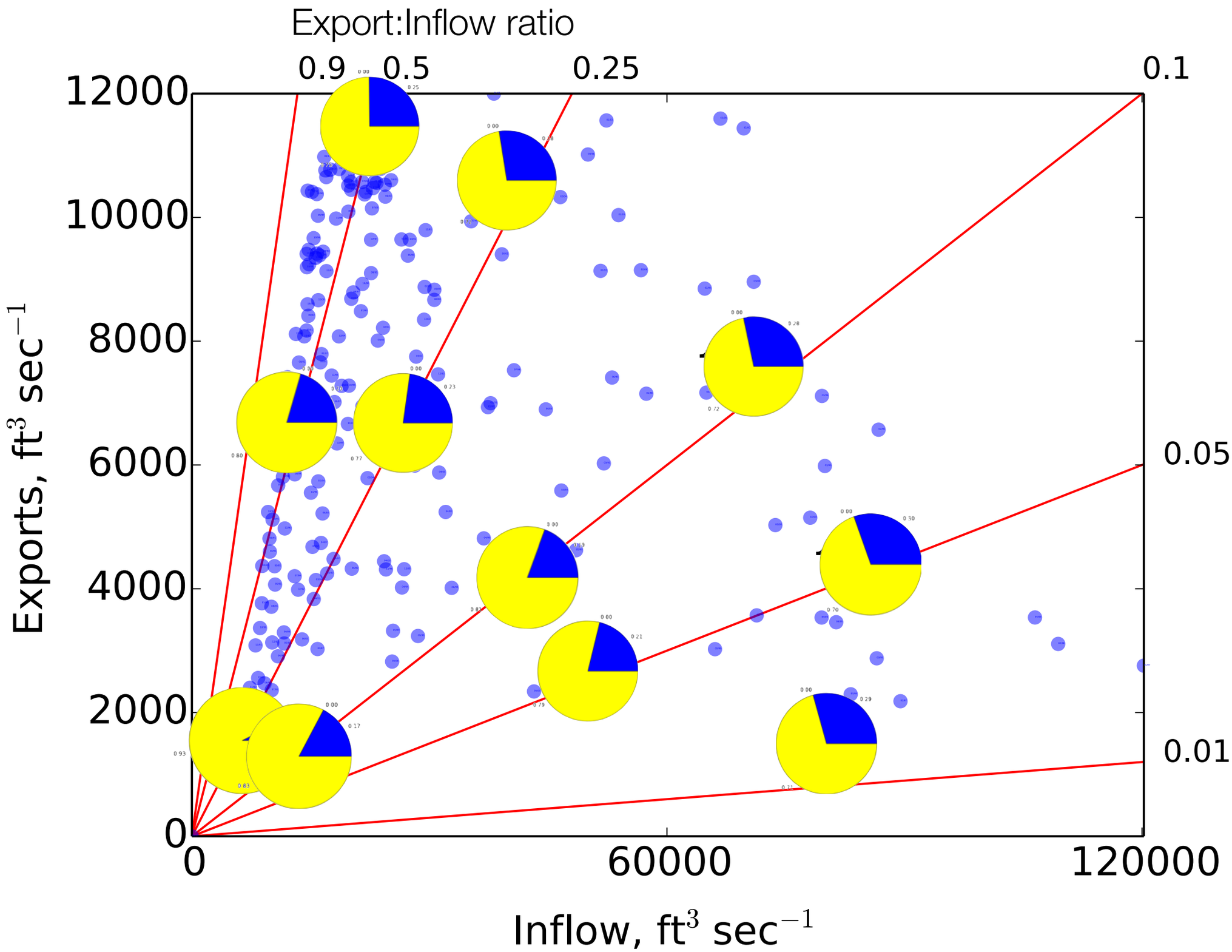


Chipps dead CVP SWP

swim with downstream flow
hold otherwise



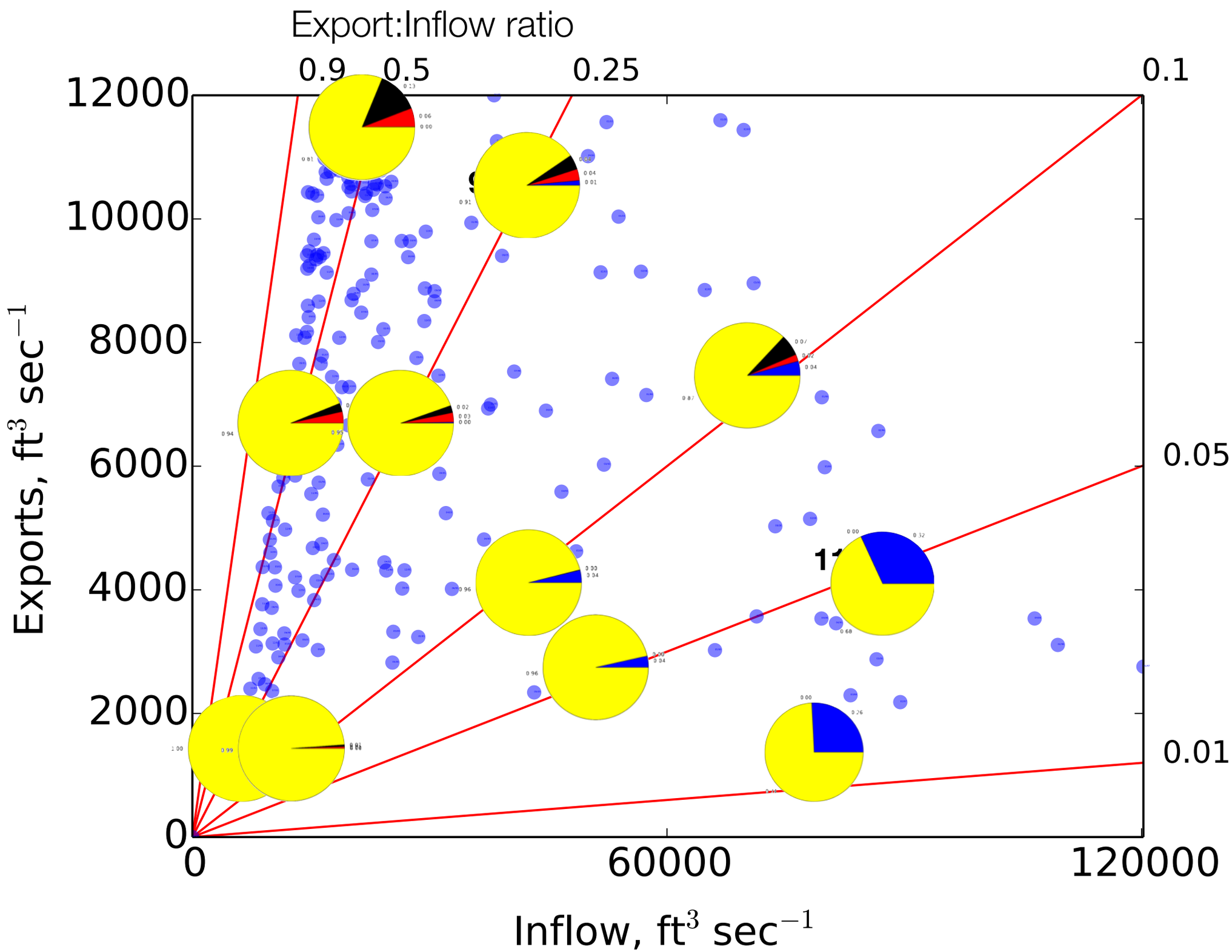
swim at night
hold otherwise



Chipps dead CVP SWP

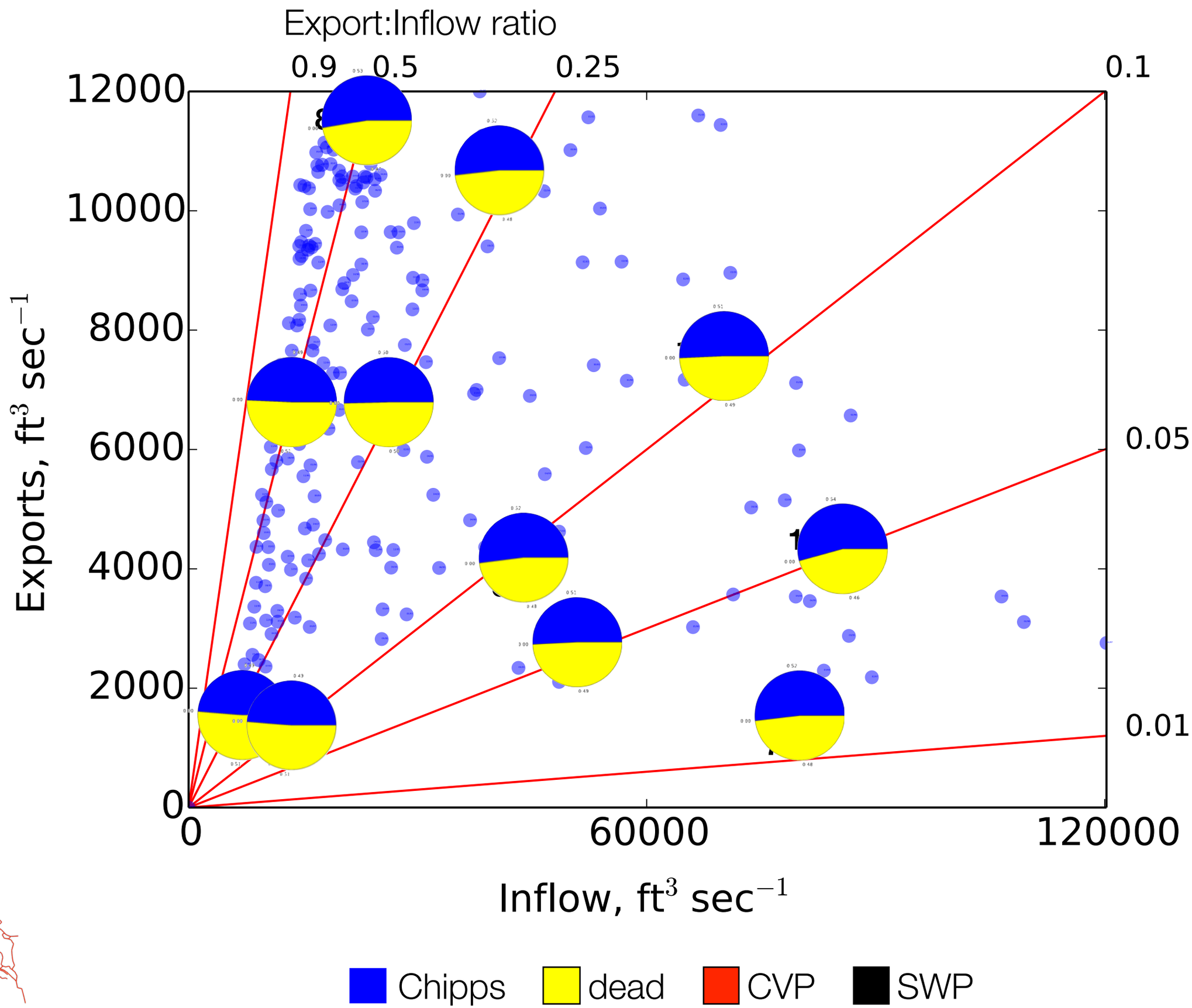
Release location 2

null model

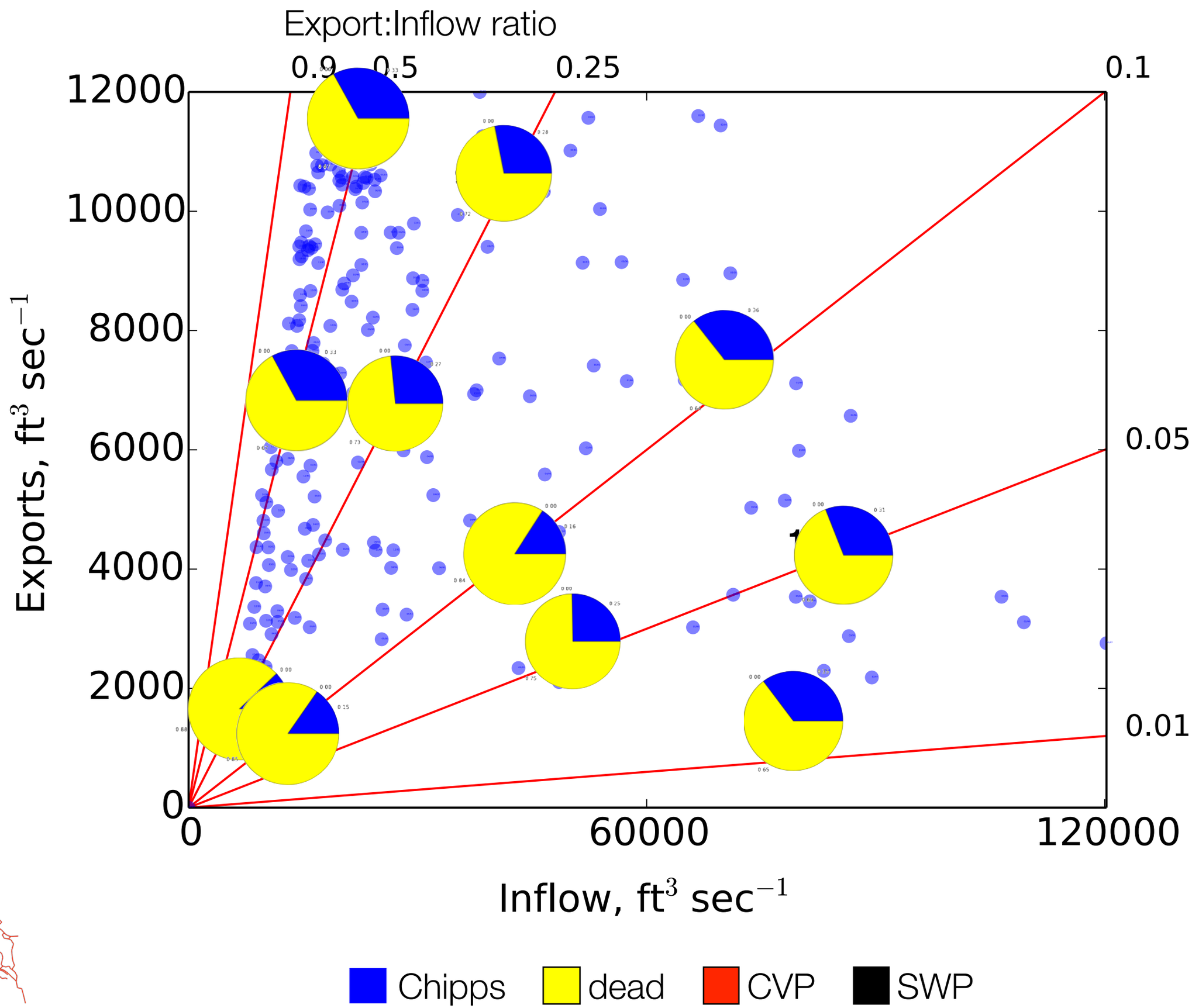


Chipps dead CVP SWP

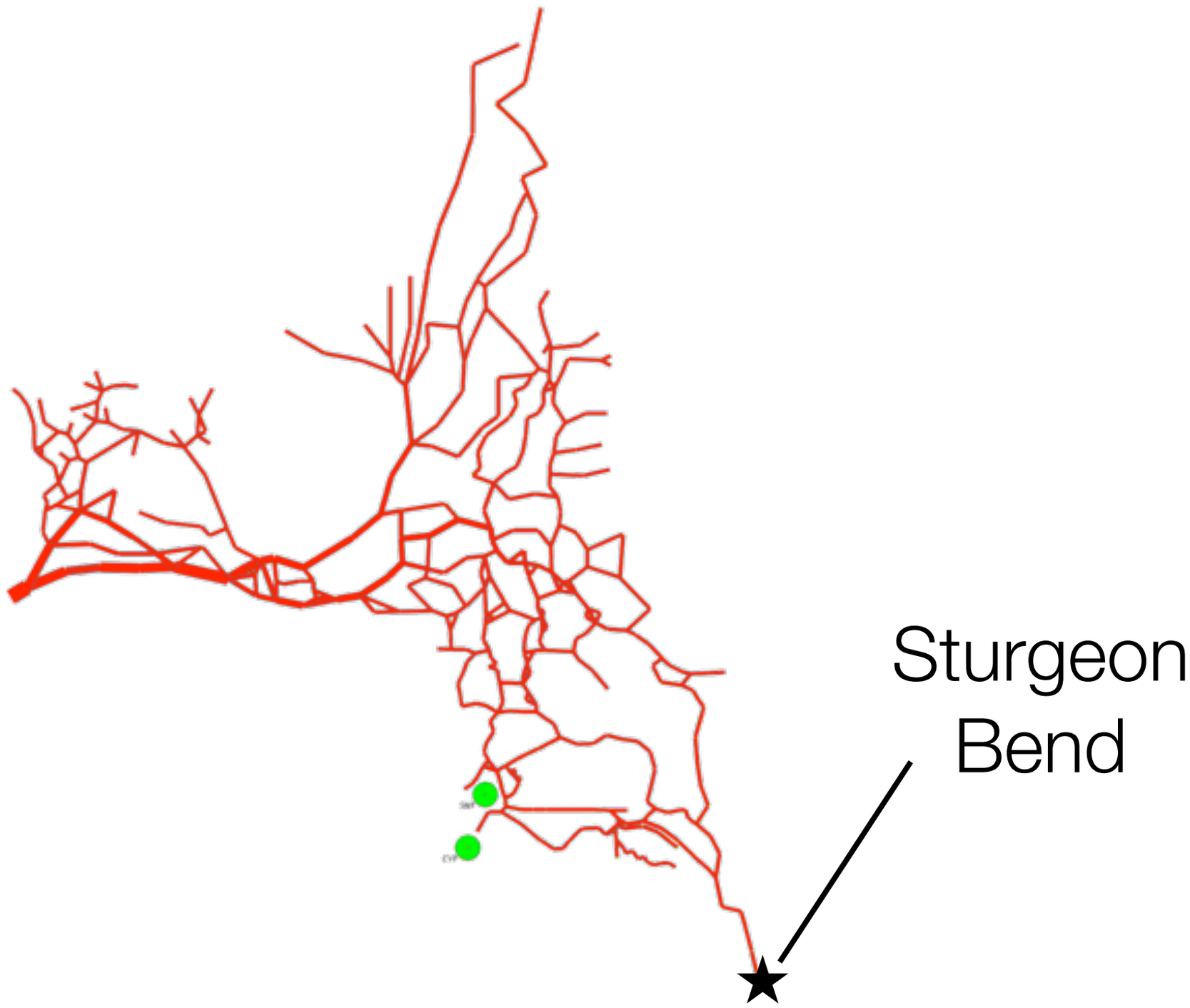
swim with downstream flow
hold otherwise



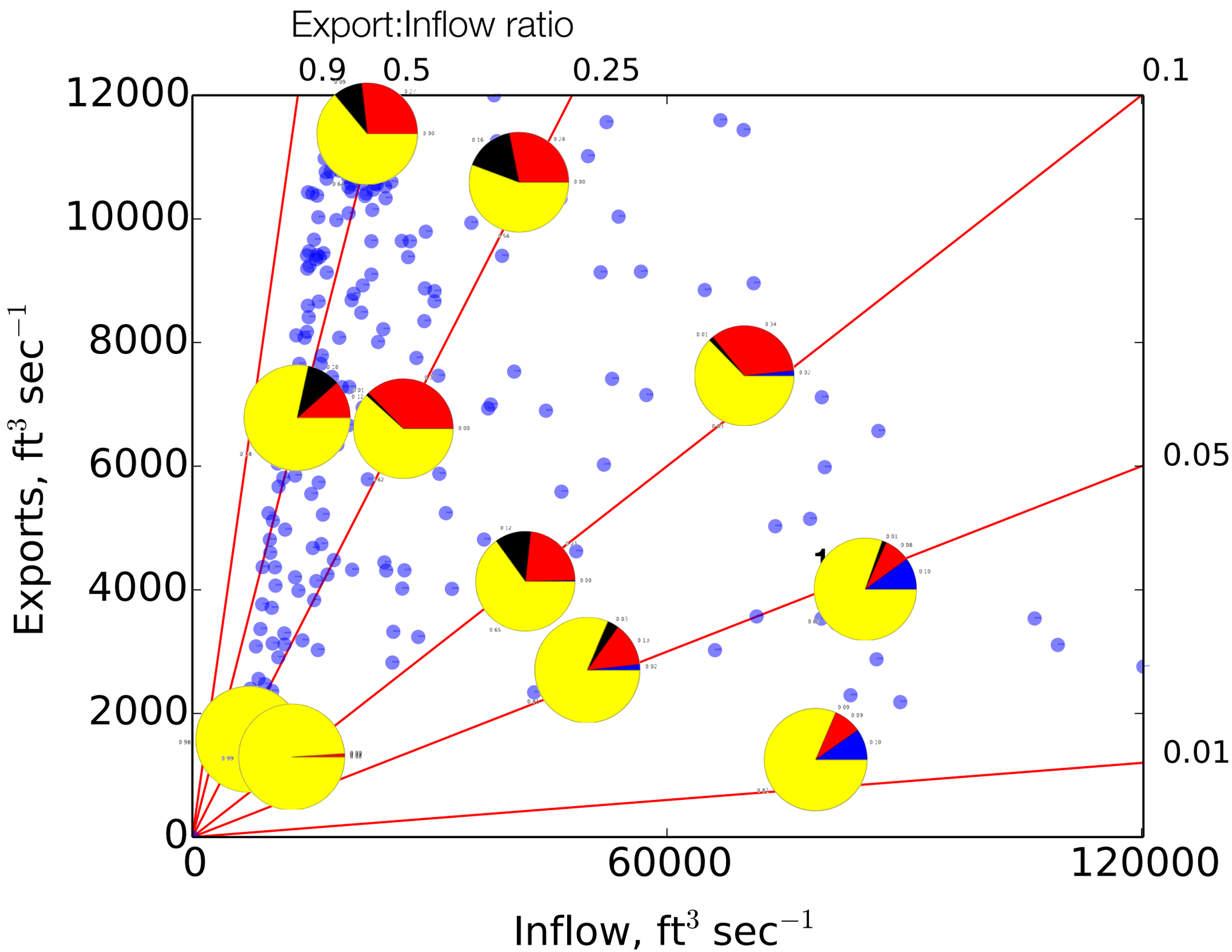
swim at night
hold otherwise



Release location 3

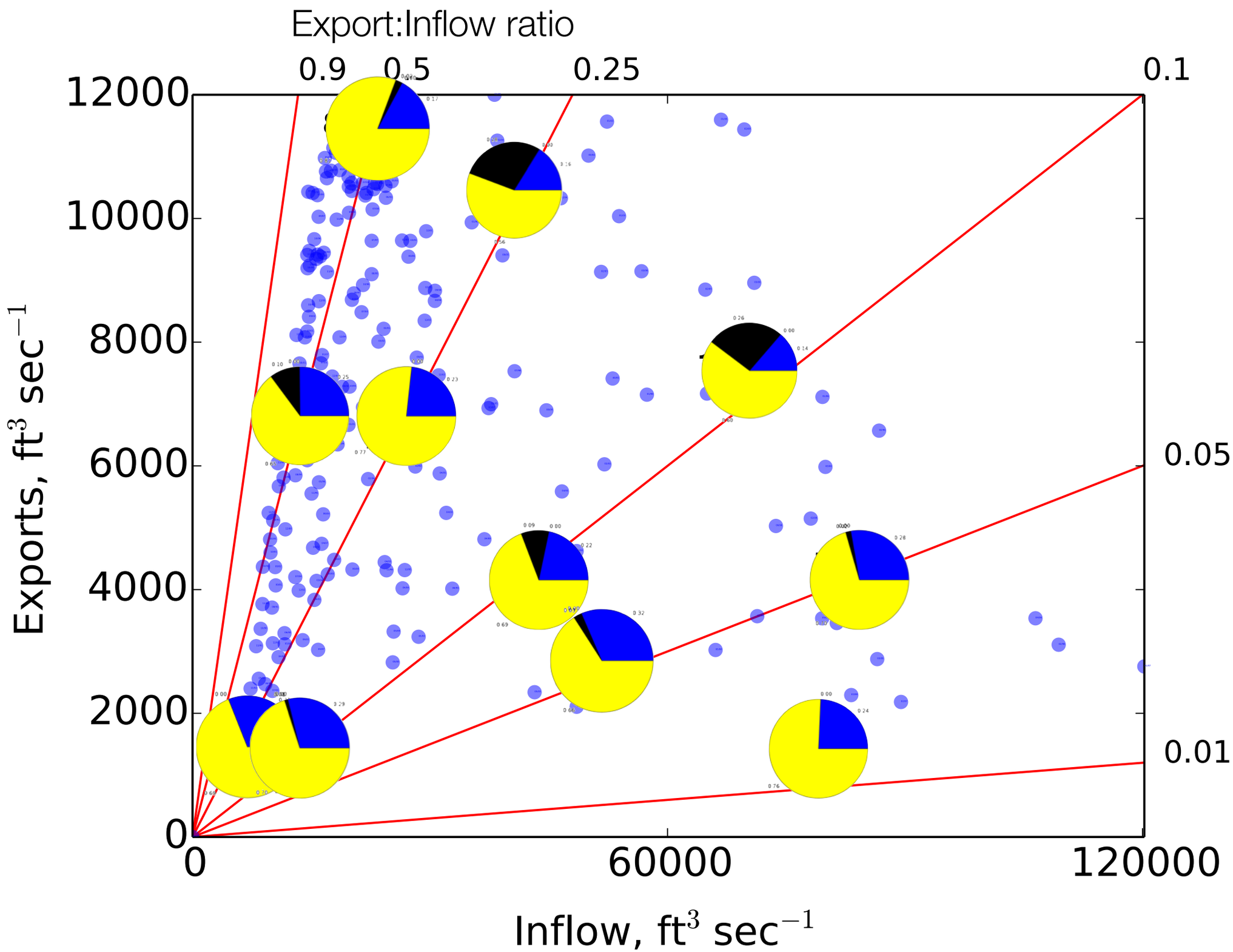


null model



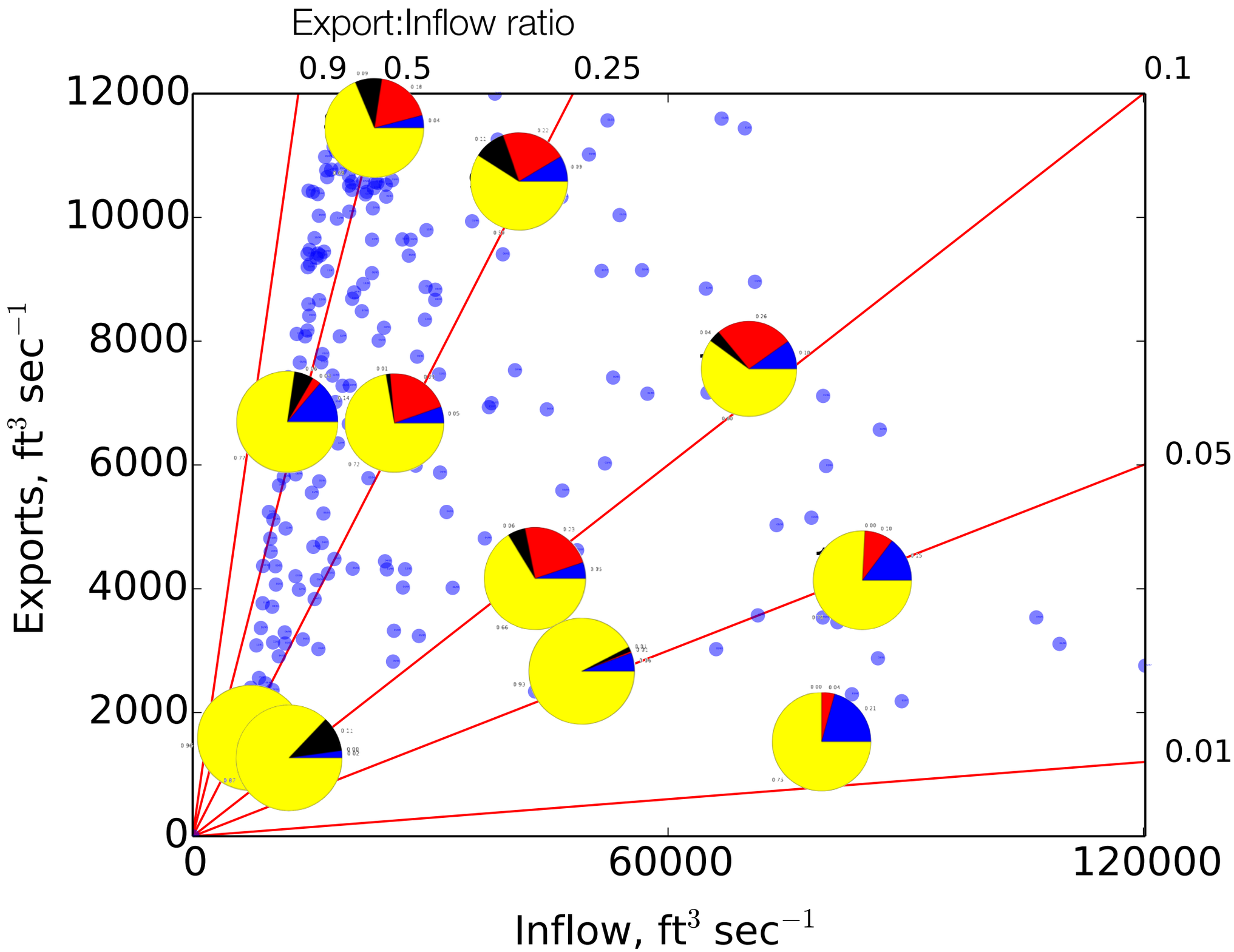
Chipps dead CVP SWP

swim with downstream flow
hold otherwise



Chipps dead CVP SWP

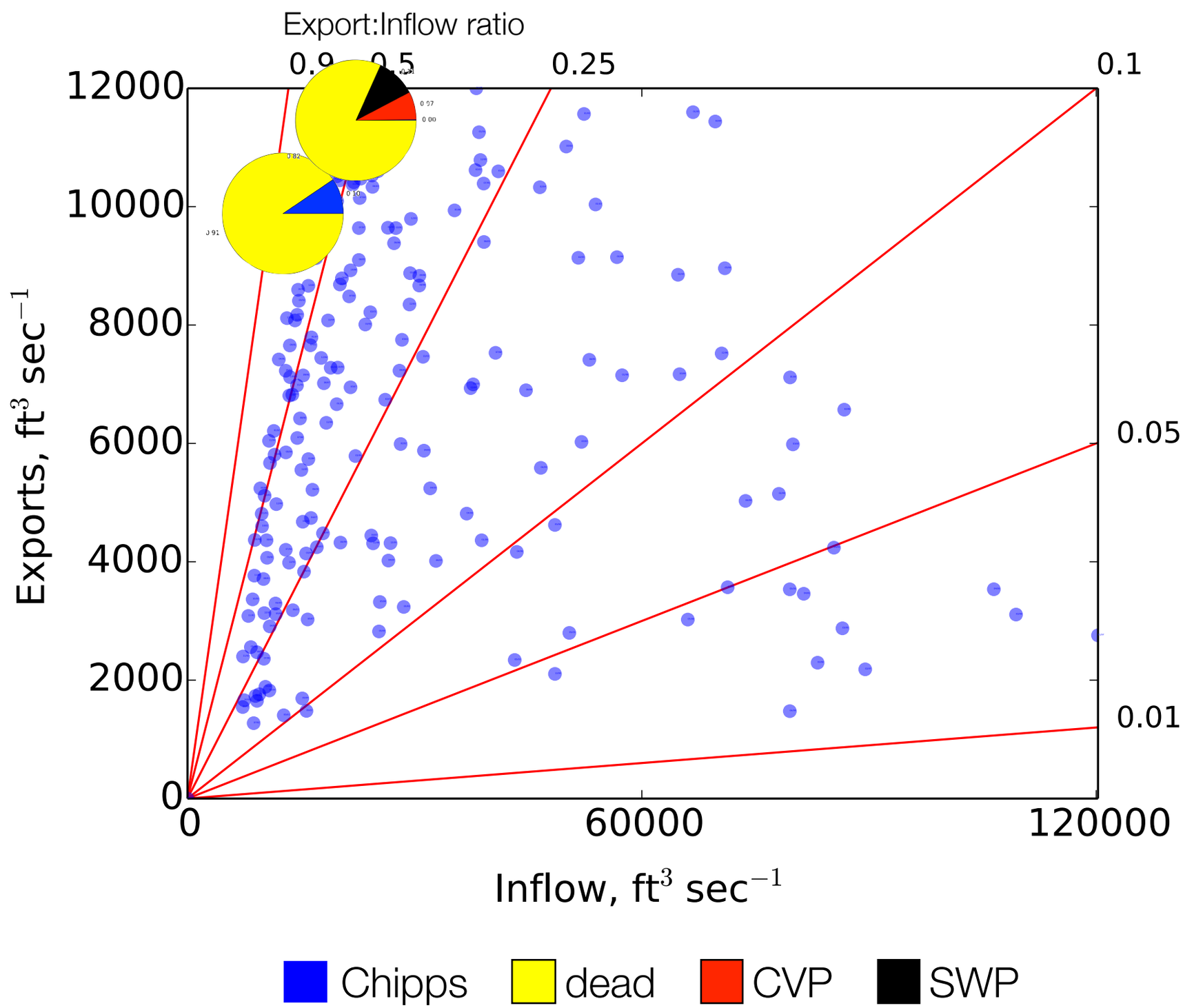
swim at night
hold otherwise

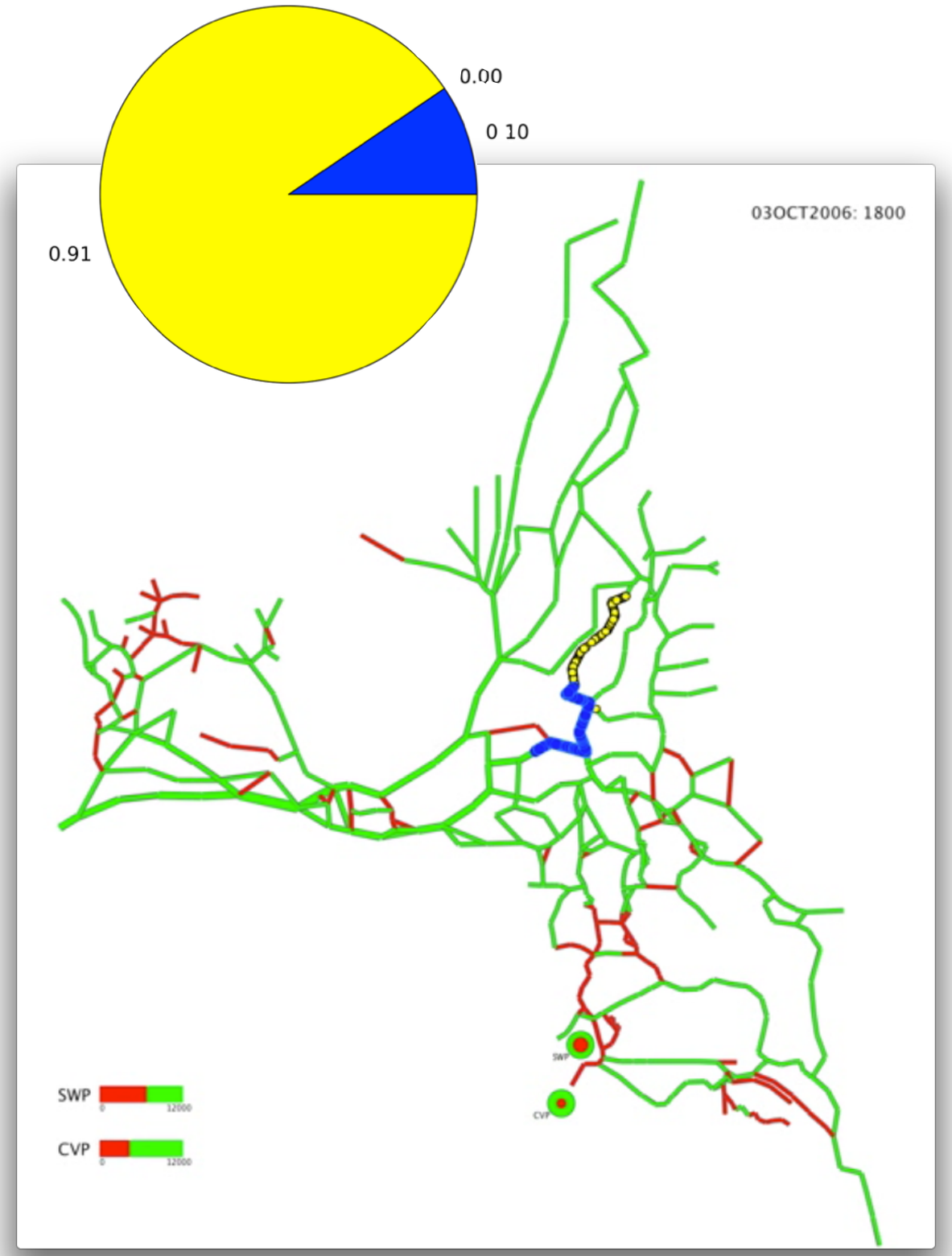


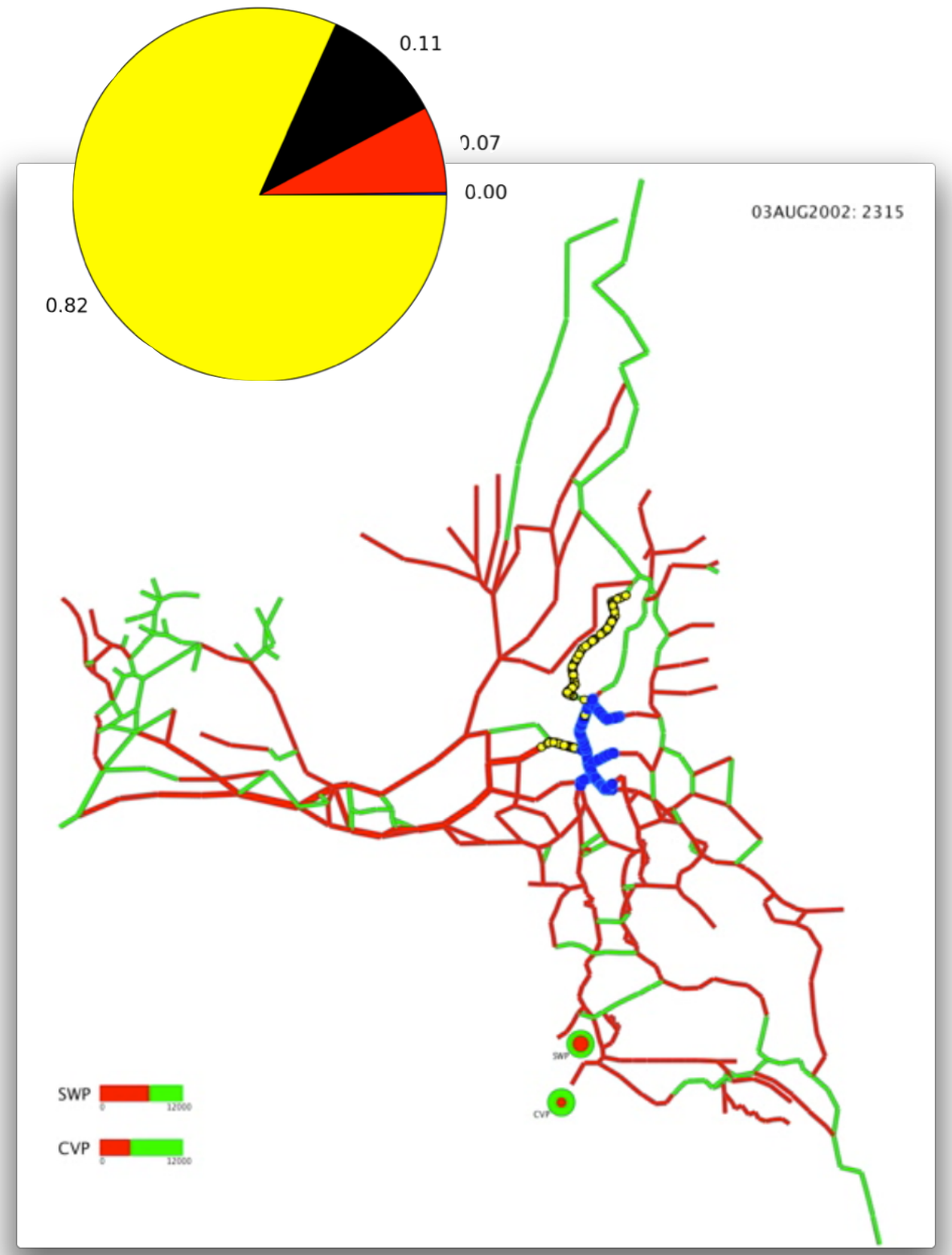
Chipps dead CVP SWP

Some benefits of a mechanistic approach

Benefit of a mechanistic model: capturing nonlinearities

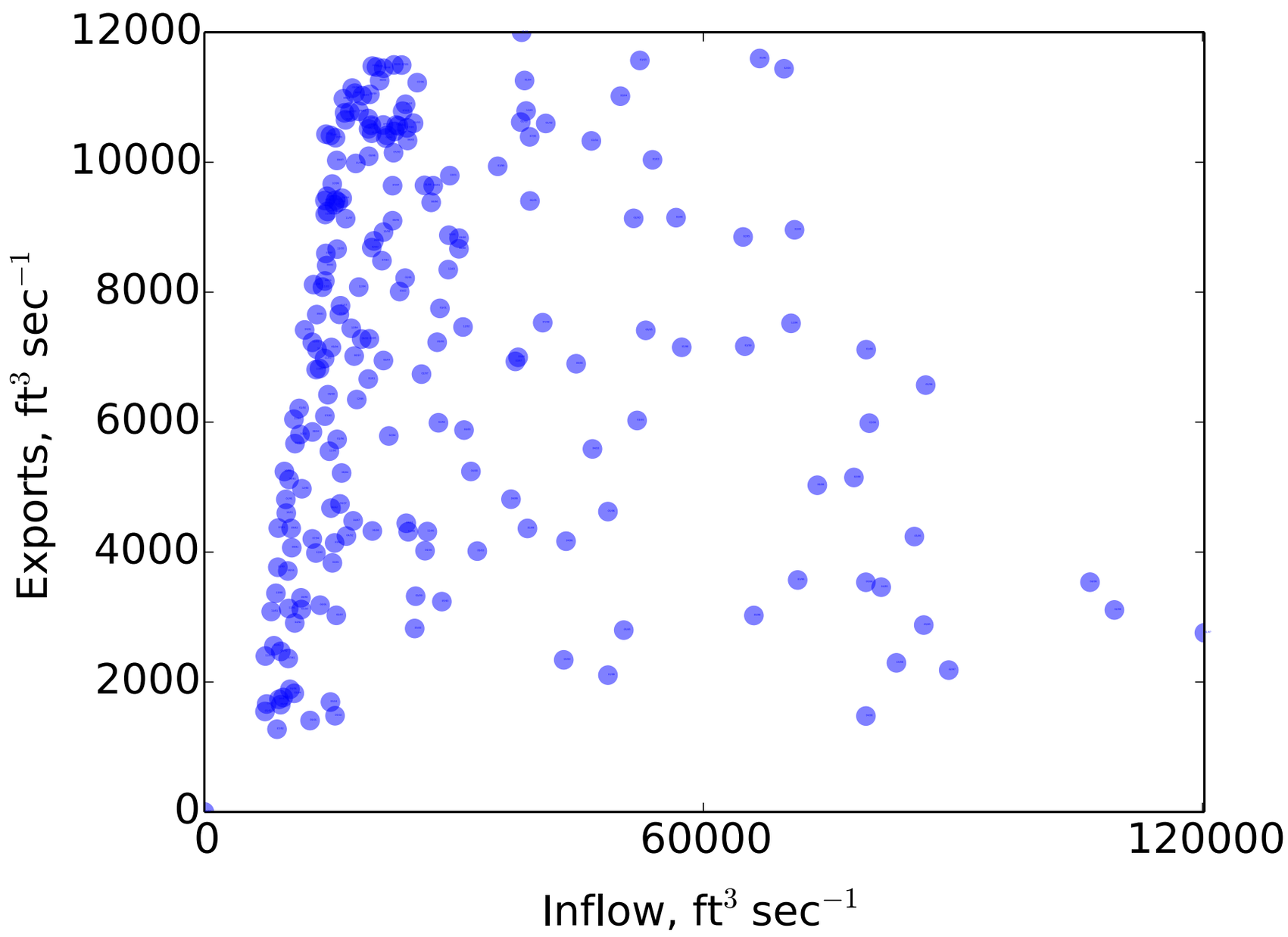




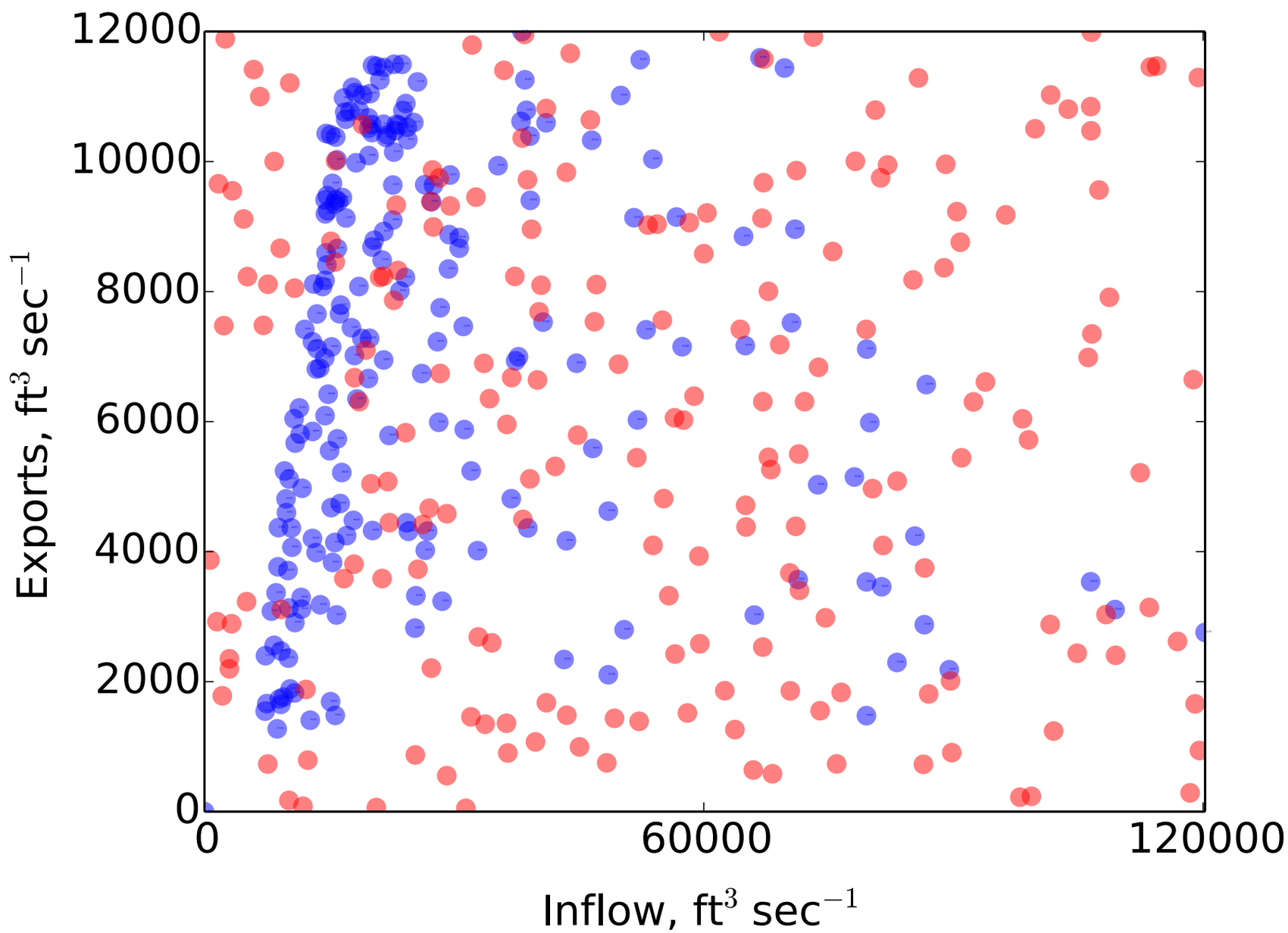


Chipps dead CVP SWP

Benefit of a mechanistic model: exploration of novel scenarios

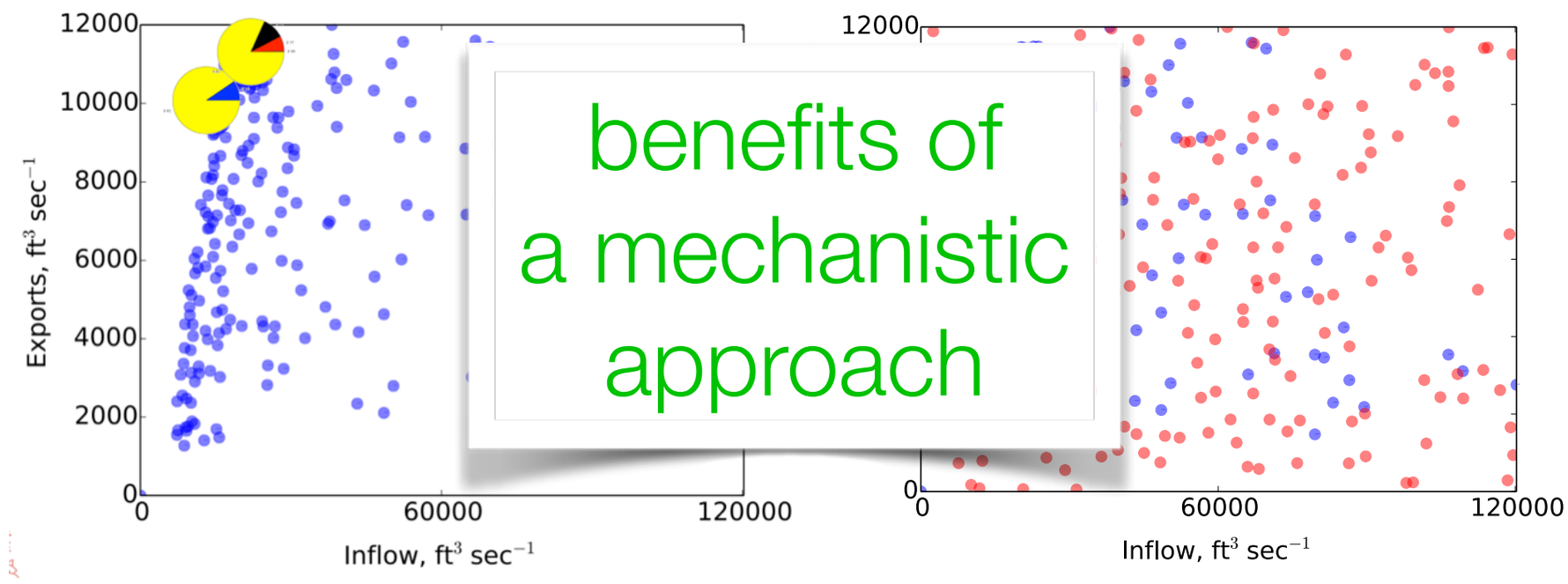


Benefit of a mechanistic model: exploration of novel scenarios



Conclusions

flow matters



Acknowledgements

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- Jonathan Speegle (USFWS)