Rio Grande Silvery Minnow Population Monitoring
(1993–2022)

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Hybognathus amarus (Cyprinidae)

(Rio Grande Silvery Minnow [Girard, 1856])

Photo by Tom Kennedy

Native Distribution

(Hybognathus amarus)

Base map from en.wikipedia.org/wiki/Rio_Grande

Rio Grande Reproductive Guild:

Rio Grande Silvery Minnow *Hybognathus amarus*

Speckled Chub *Macrhybopsis aestivalis*

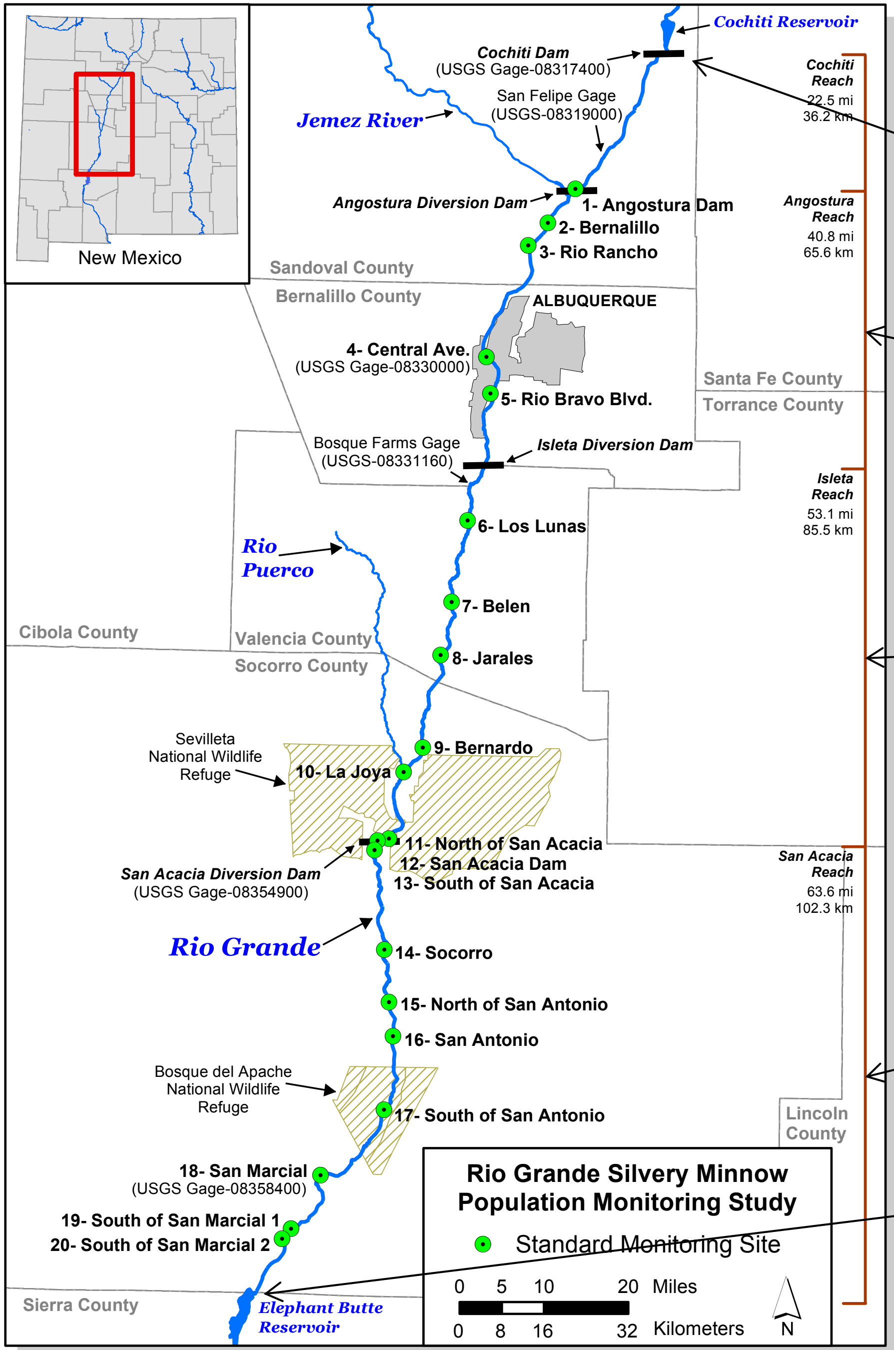
Rio Grande Shiner *Notropis jemezanus*

Phantom Shiner *N. orca*

Pecos Bluntnose Shiner *N. simus pecosensis*

Rio Grande Bluntnose Shiner *N. s. simus*

Study Area



Cochiti Dam

Angostura Reach

Isleta Reach

San Acacia Reach

Elephant Butte Reservoir

Cochiti Dam

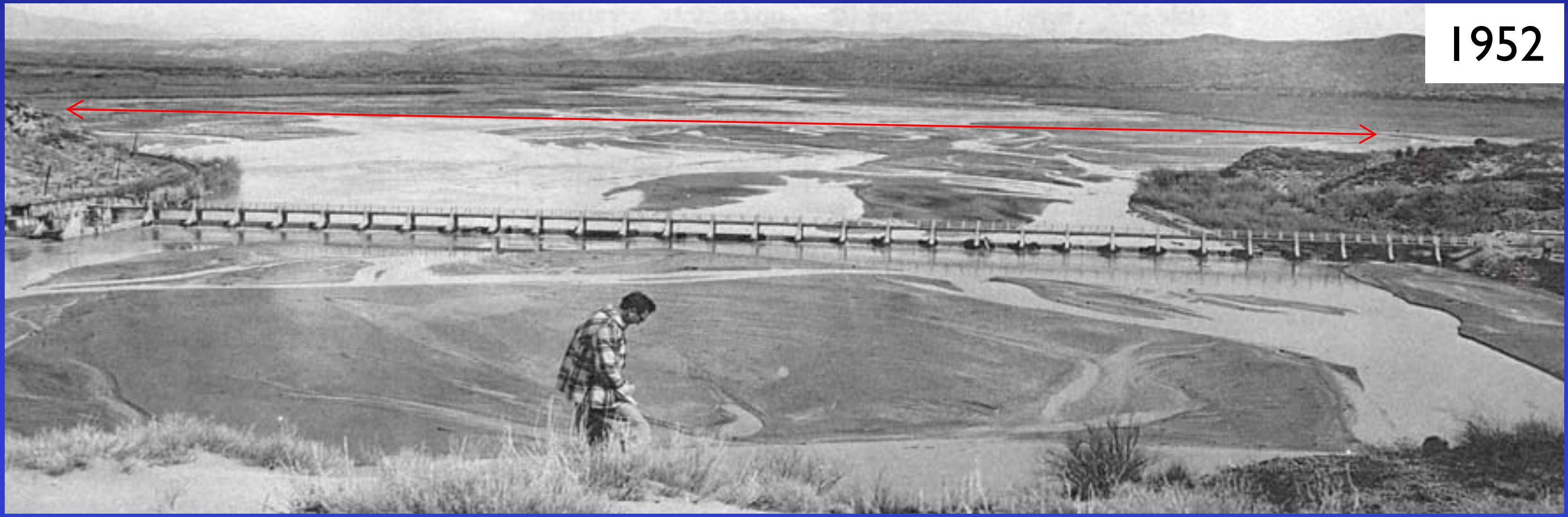
Angostura Diversion Dam

Isleta Diversion Dam

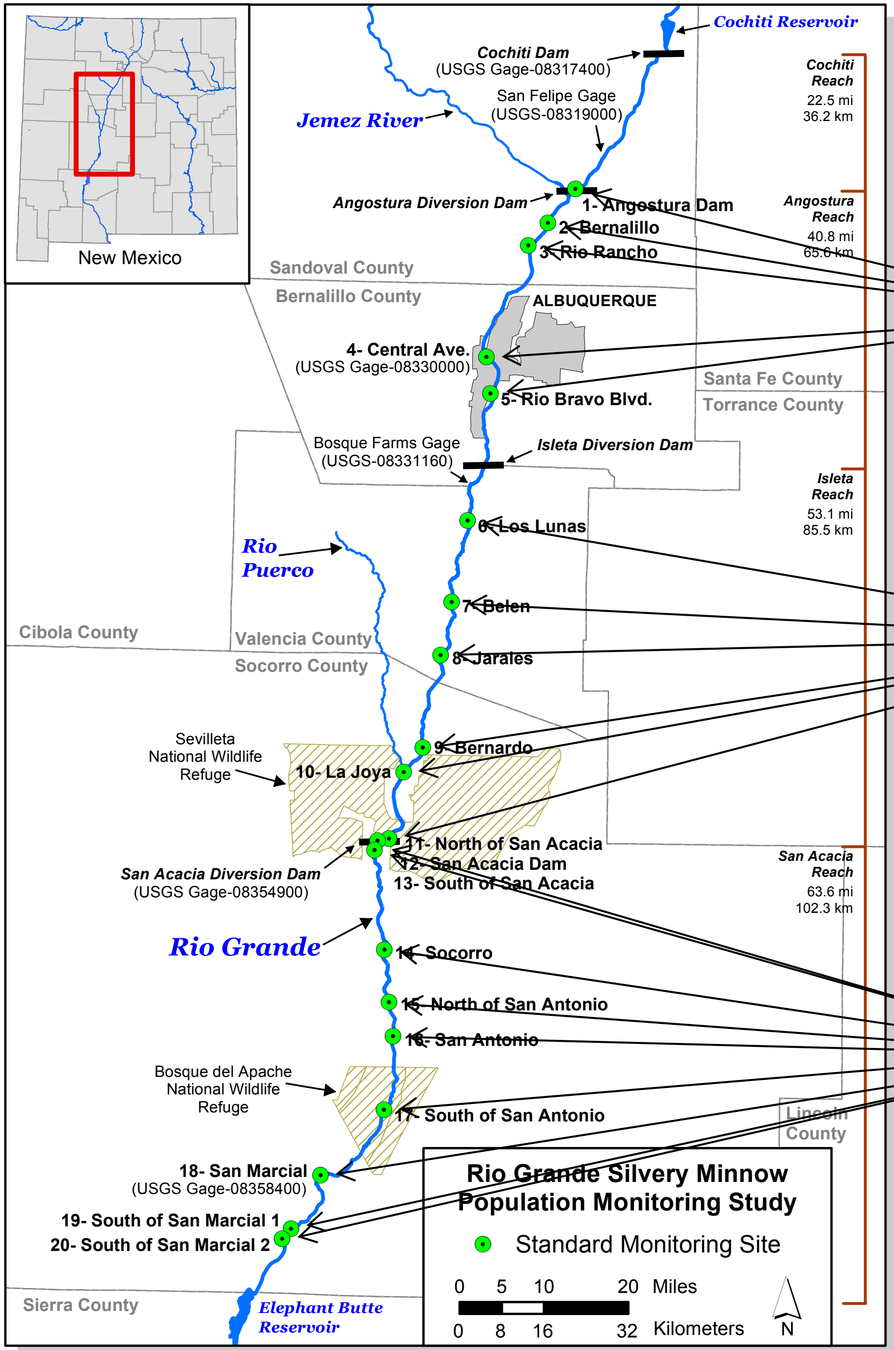
San Acacia Diversion Dam

Elephant Butte Reservoir

Historical and Recent River Channel



Sampling Sites

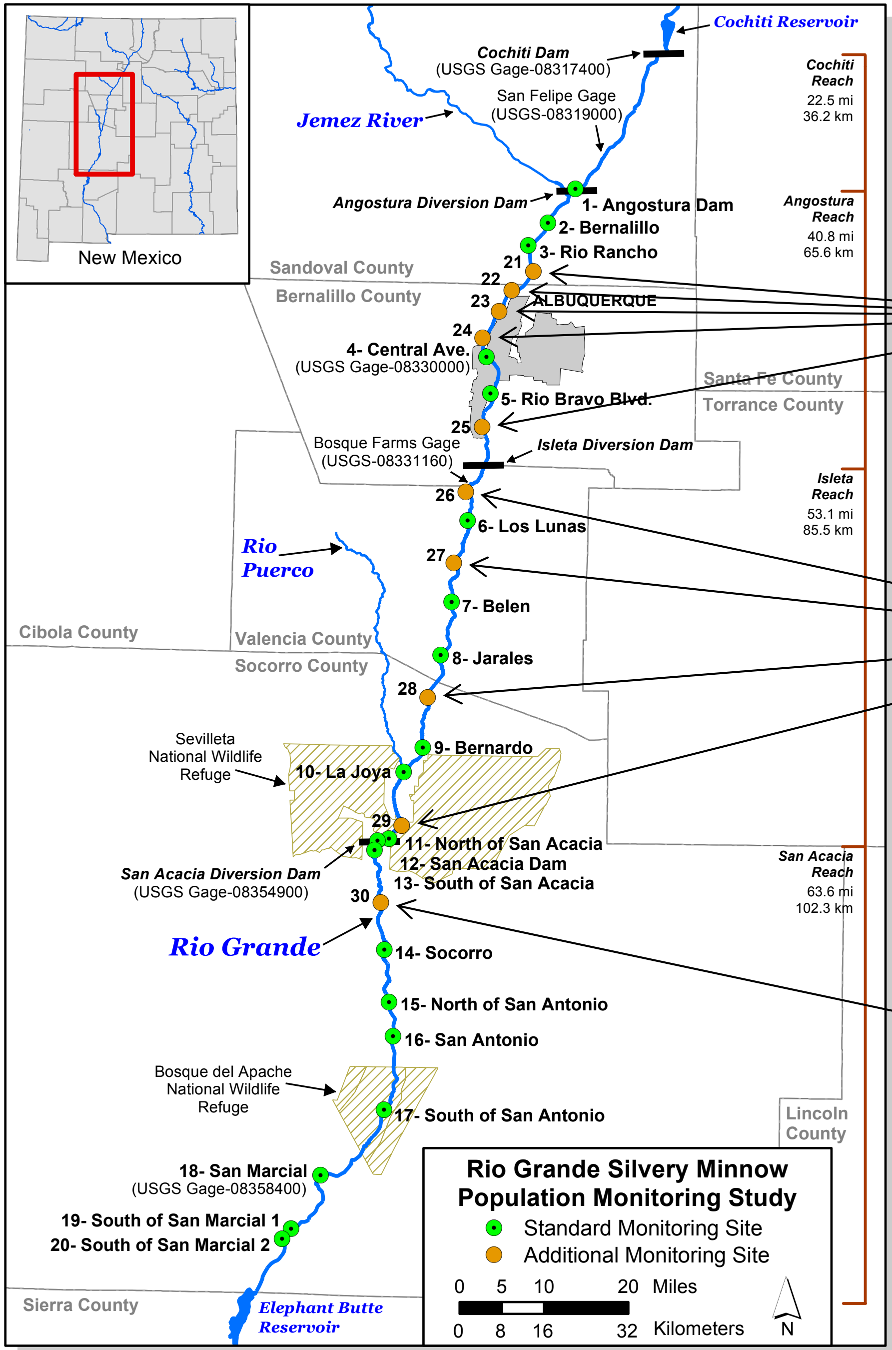


Angostura Reach sites (5)

Isleta Reach sites (6)

San Acacia Reach sites (9)

Additional Sites

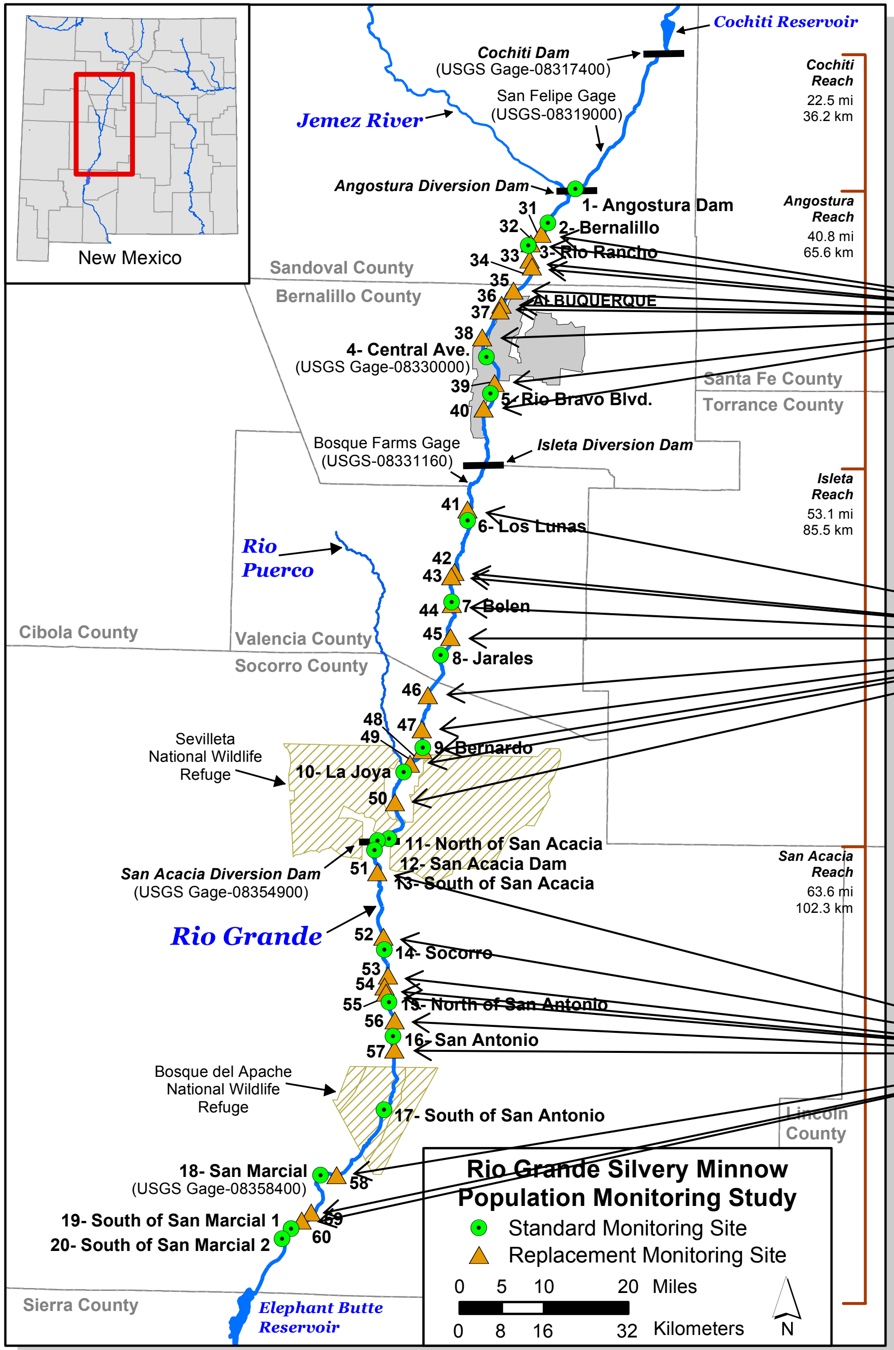


Angostura Reach sites (5)

Isleta Reach sites (4)

San Acacia Reach sites (1)

Replacement Sites

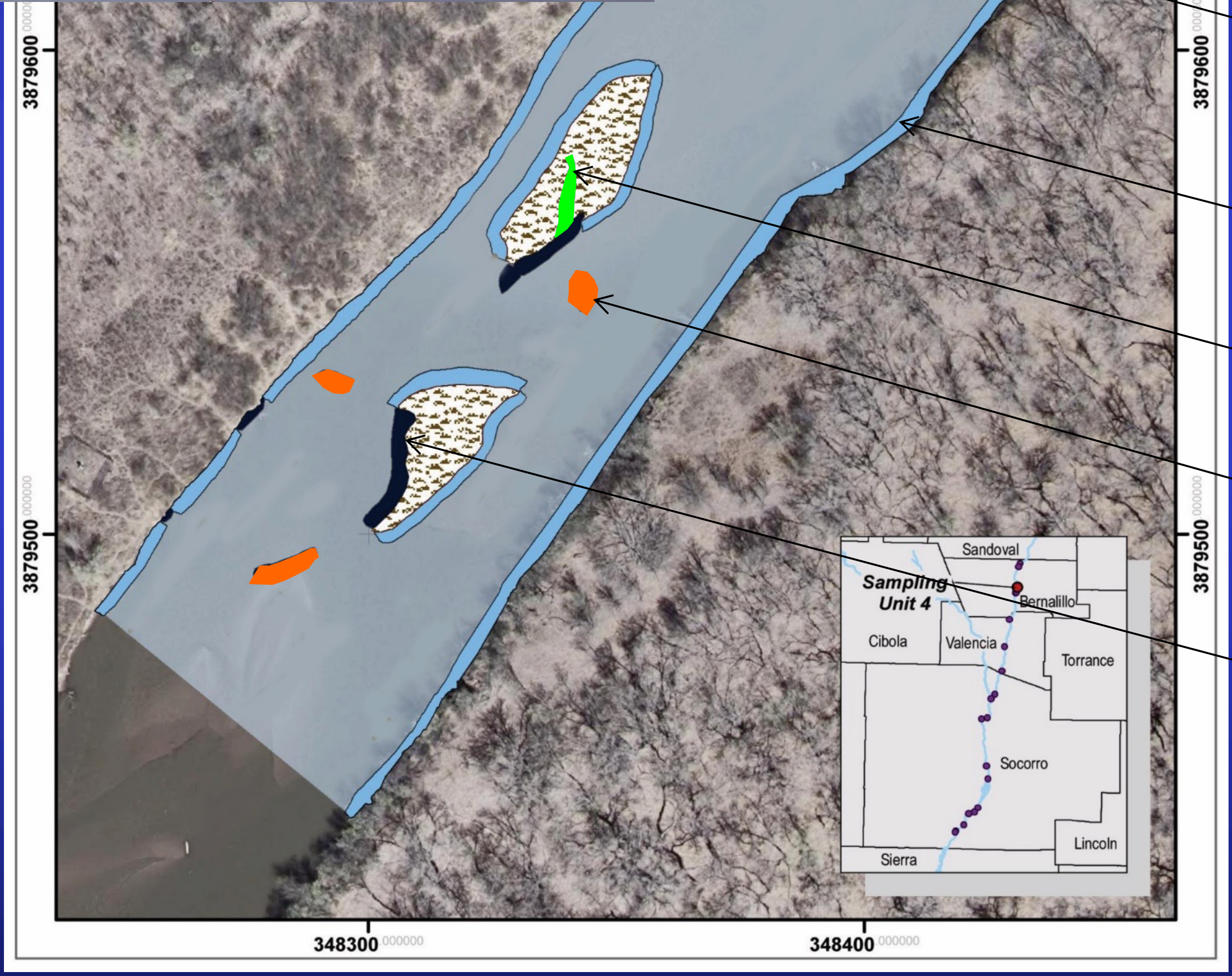


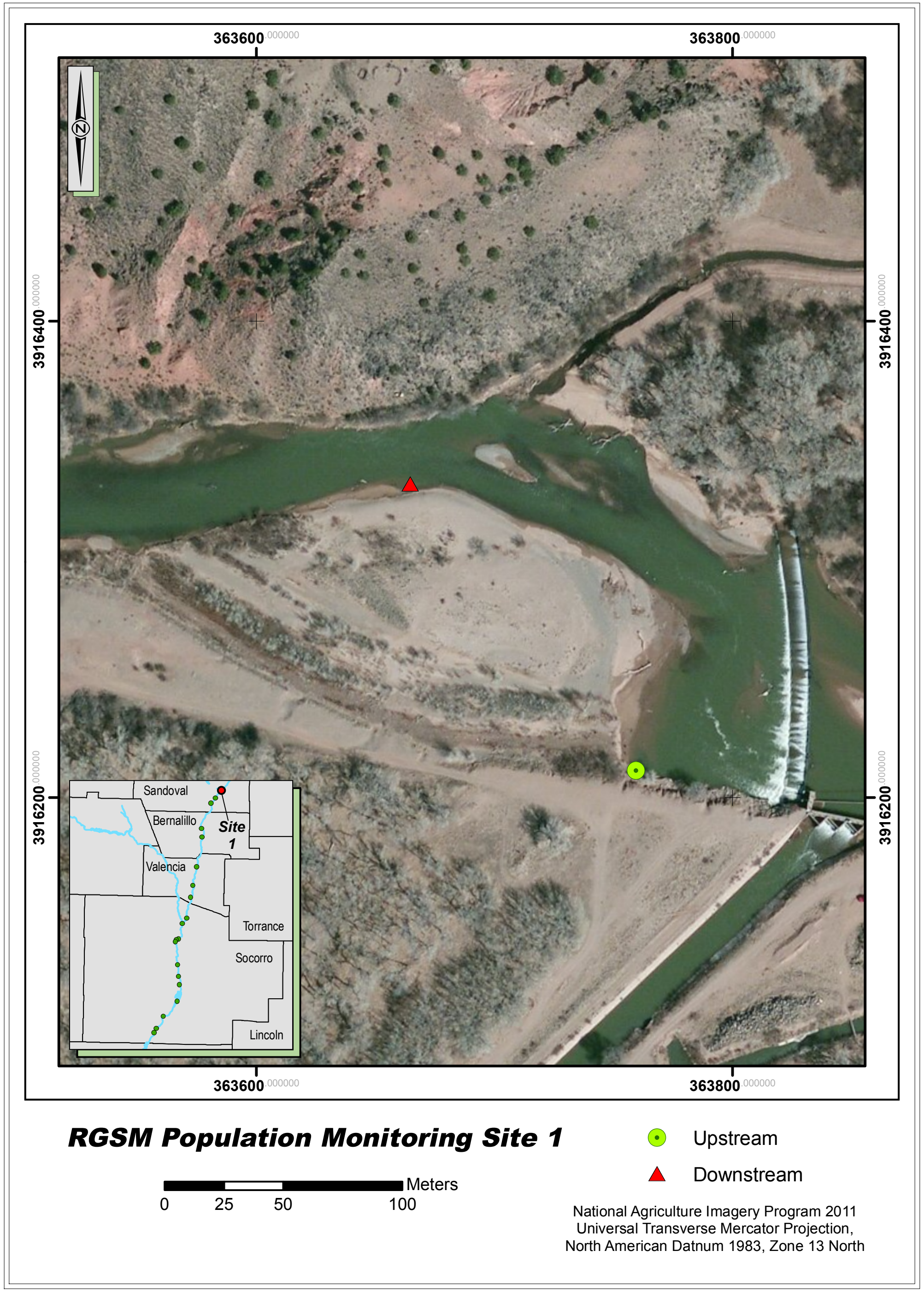
Angostura Reach sites (10)

Isleta Reach sites (10)

San Acacia Reach sites (10)

Mesohabitats





Sampling Methods

Seine hauls by mesohabitat:

- (BW/PO = 2, RU/SHPO = 4)
- (SHRU = 6–14)

Adult fish seining (18):

- (3.0 m x 1.8 m; small mesh)

Larval fish seining (2):

- (1.2 m x 1.2 m; fine mesh)

Twenty seine hauls per site:

- Mesohabitats standardized
- Sampling similar across flows
- Area sampled (ca. 500 m^2)

Evolution of Project Design

- The decline of RGSM during a prolonged drought (2000–2003), and formation of the MRGESCP, prompted increased sampling efforts (i.e., from quarterly to monthly).

- An external review, led by nationally-recognized experts, resulted in a workshop and a report (2004–2005). Most of the sampling recommendations and research studies, suggested by the experts and Population Monitoring Group (MRGESCP), were initiated in 2006.

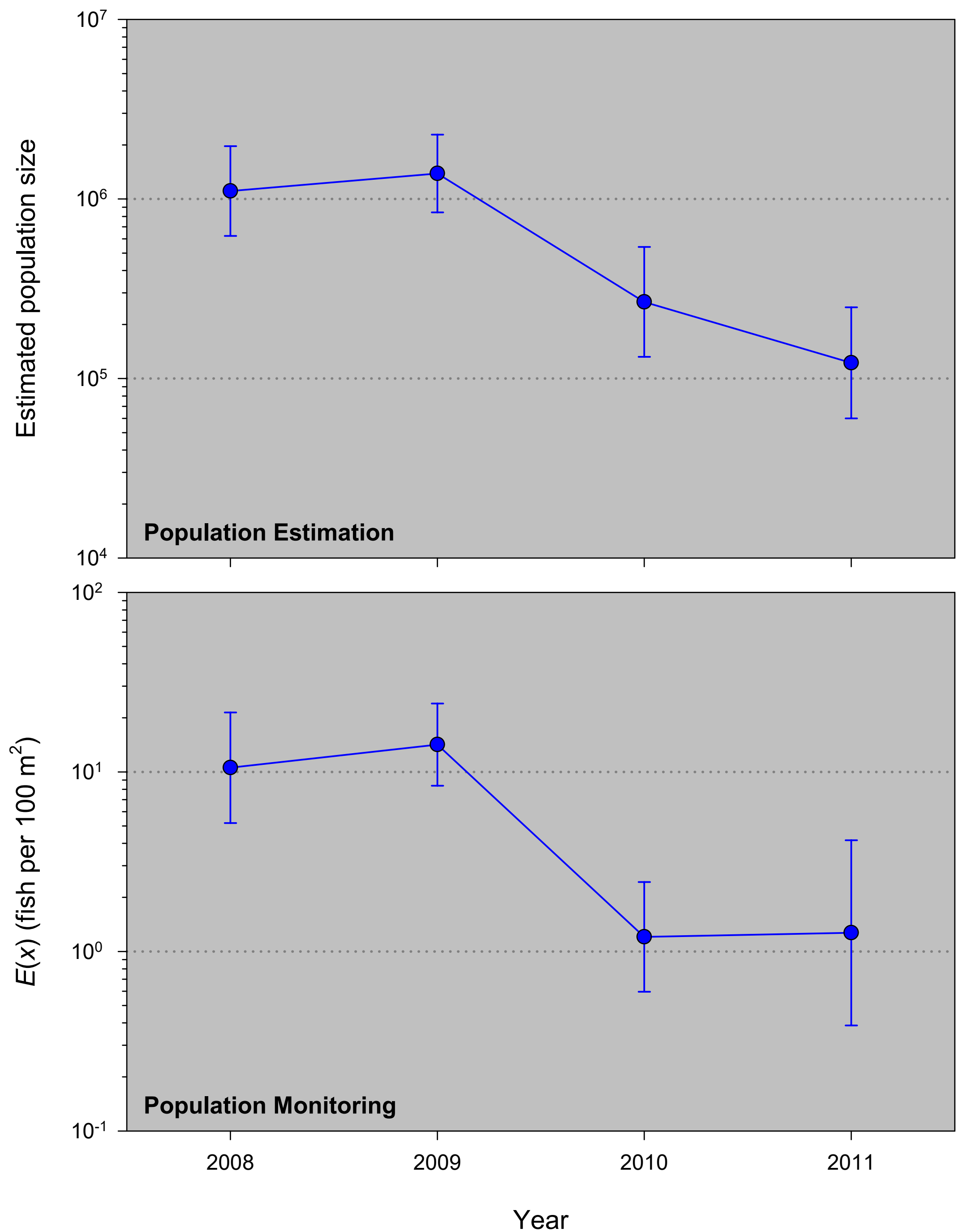
- A more recent external review, led by nationally-recognized experts, resulted in a workshop and a report (2015–2016), along with several recommendations for increased sampling efforts.

Population Trends
(Estimation vs. Monitoring)

- Similarities: Sampled in October, twenty sites, mesohabitats standardized, sampling similar across flows, area sampled (ca. 500 m^2)

- Differences: Random sites and mesohabitats, mapping of mesohabitats and samples, electrofishing removal-sampling in enclosures

- Despite notable differences in methodology and required effort, both studies indicated very similar trends over time.

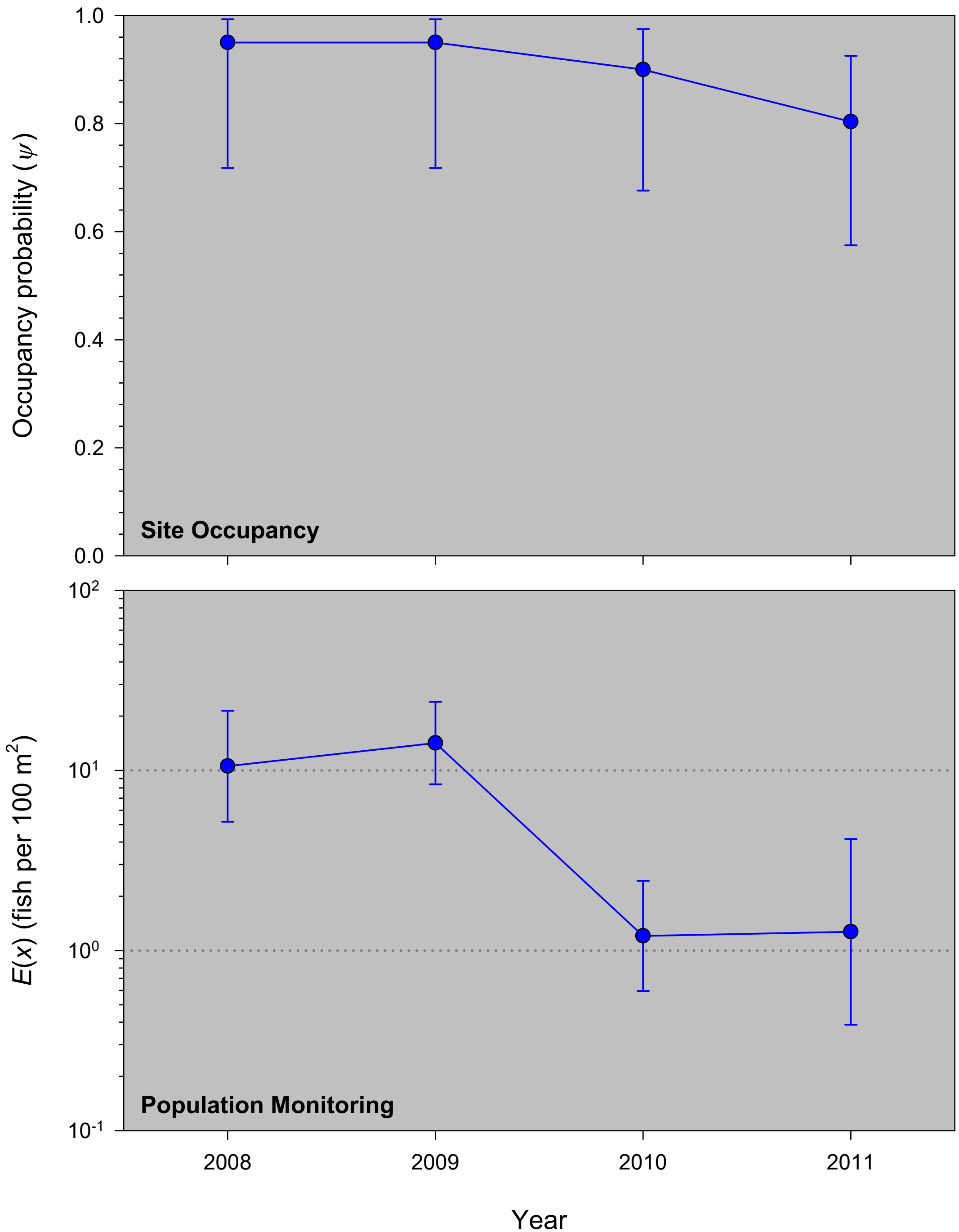


Population Trends
(Occupancy vs. Monitoring)

- Similarities: Twenty sites, mesohabitats standardized, sampling similar across flows, area sampled (ca. 500 m^2)

- Differences: Sampled in November, same mesohabitats sampled repeatedly, sites were sampled four times

- Despite notable differences in methodology and required effort, both studies indicated very similar trends over time.



Population Monitoring Program Key Objectives

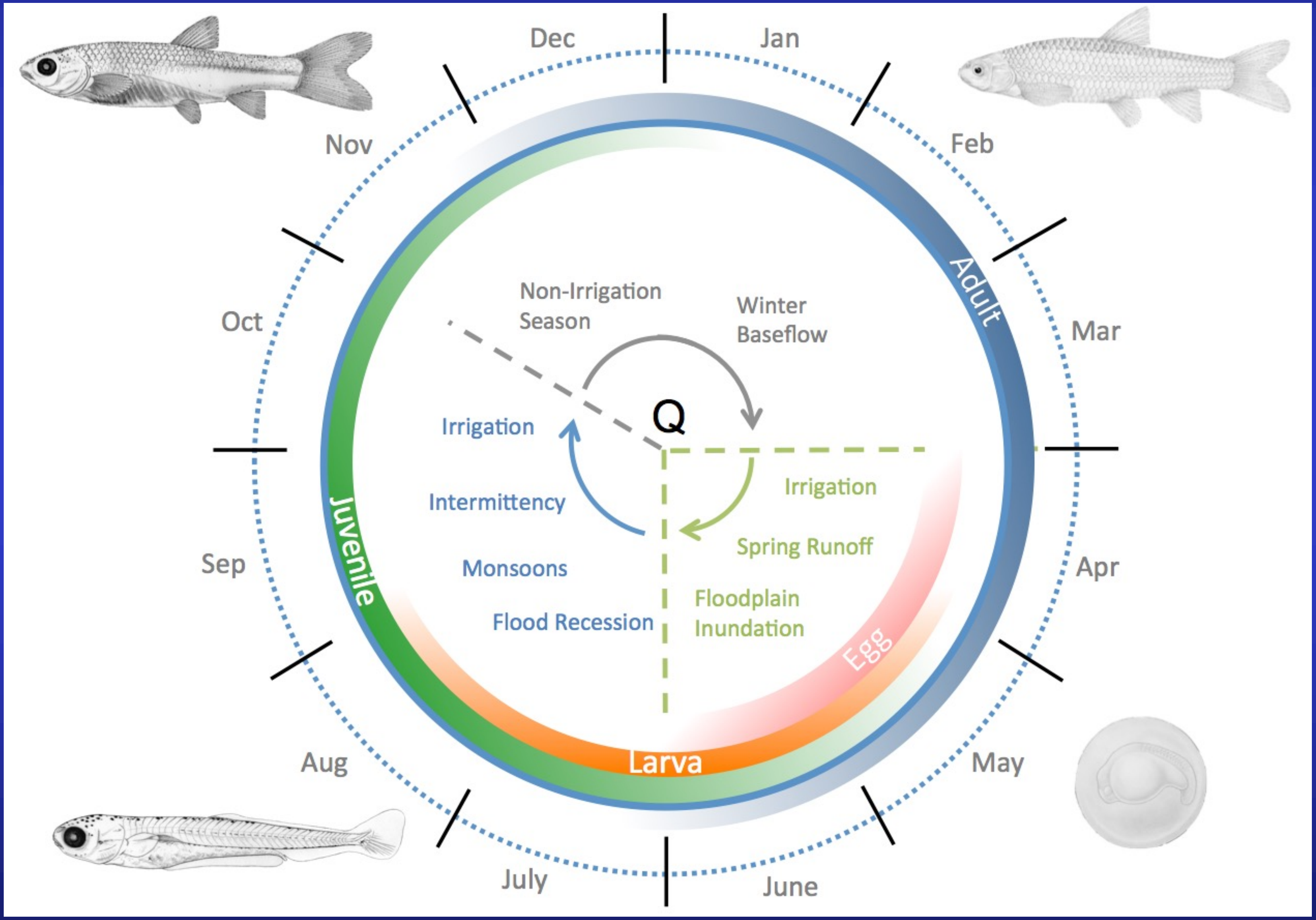
1. Compare annual and seasonal trends in the distribution and abundance of native and nonnative fishes, with a focus on Rio Grande Silvery Minnow (RGSM).

2. Evaluate the influence of discharge (e.g., timing, magnitude, and duration) on long-term RGSM population fluctuations.

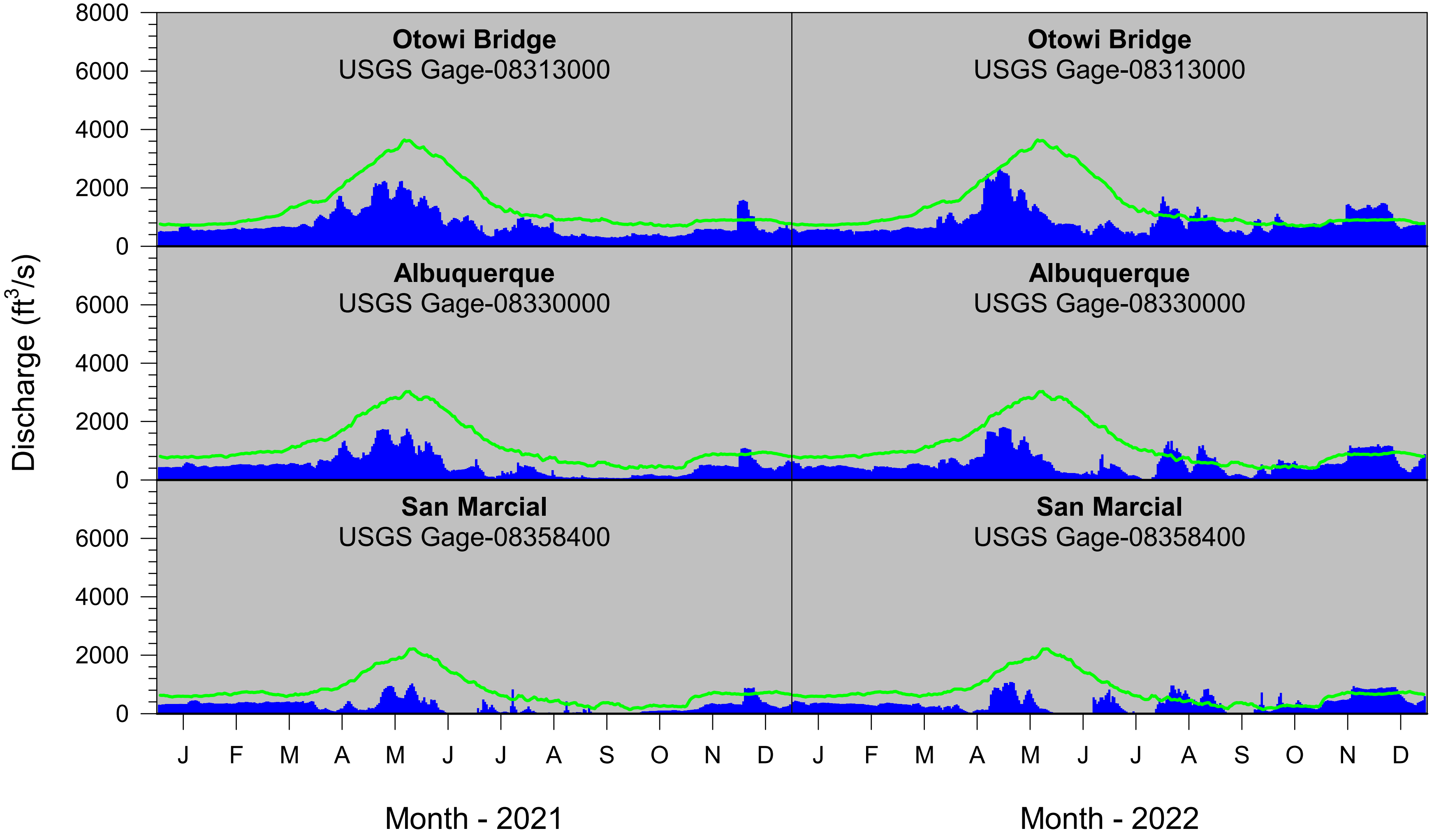
3. Assess variation of RGSM densities and estimate its site occupancy rates, based on annual repeated-sampling.

Population Monitoring and Research
(1993–2022)

Life History of Rio Grande Silvery Minnow
(Mortensen et al., 2019)

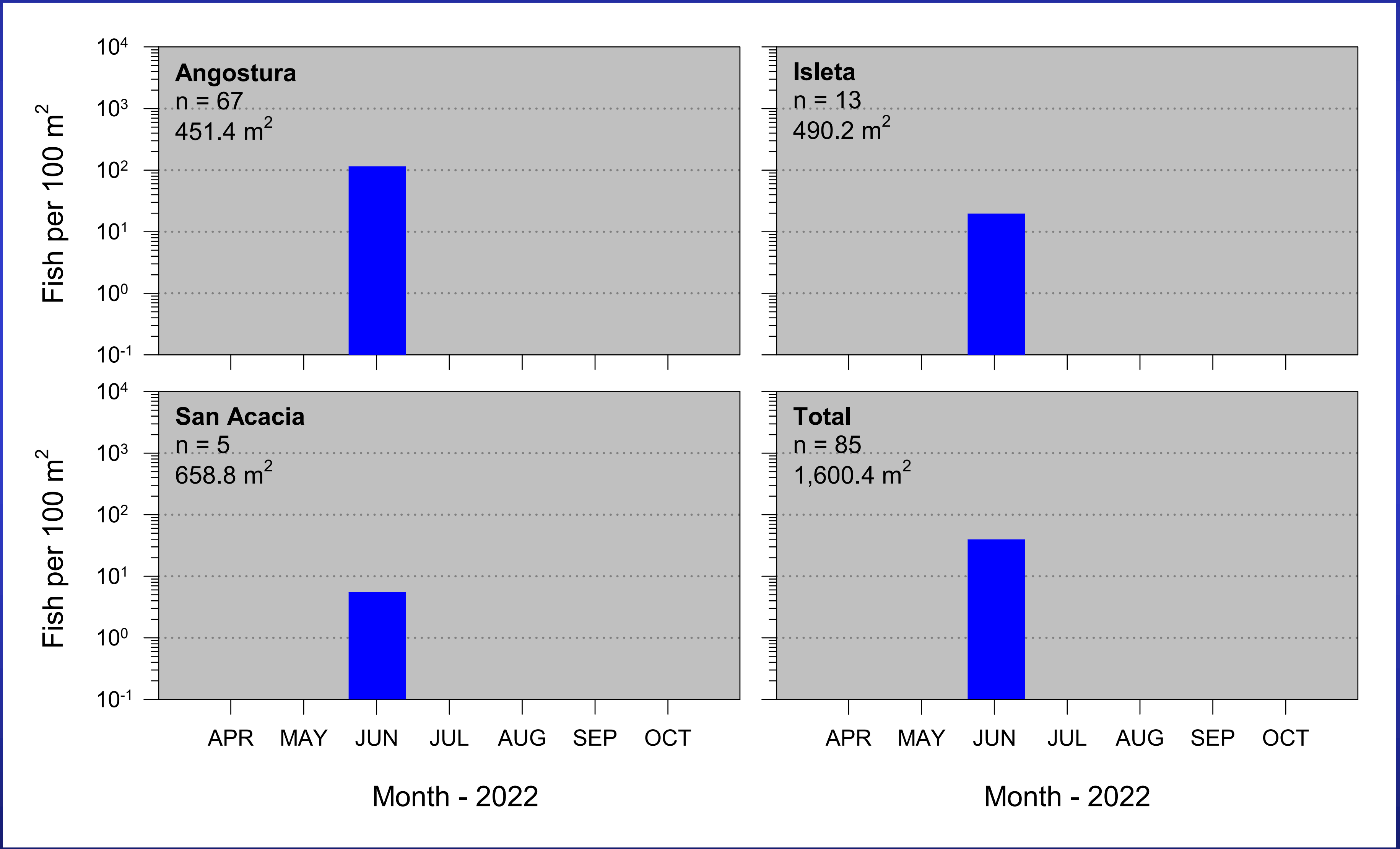


Discharge in the Middle Rio Grande
(2021–2022)



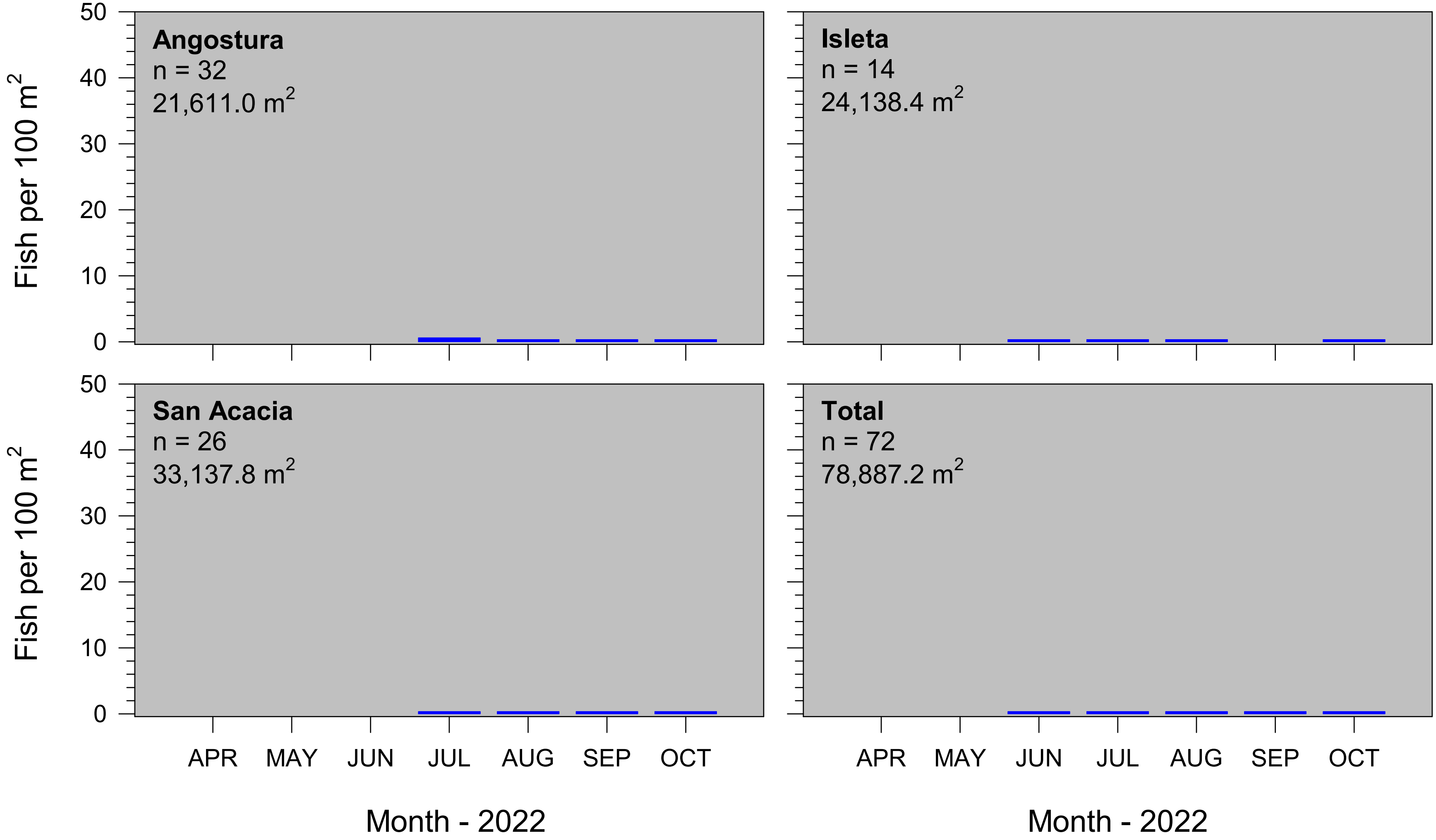
RGSM Population Trends in 2022

(Larval Fish)



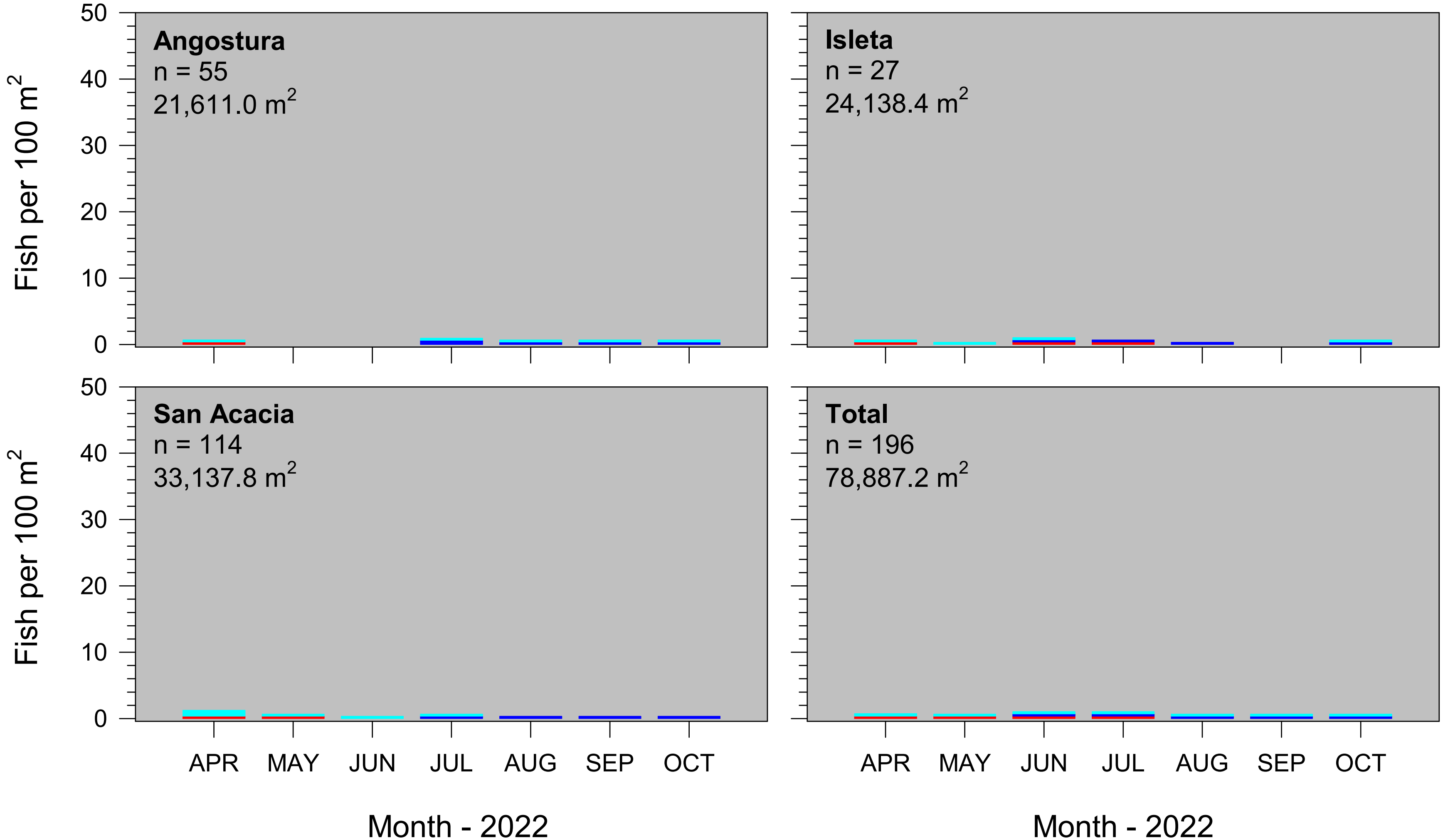
RGSM Population Trends in 2022

(Age-0 Fish)

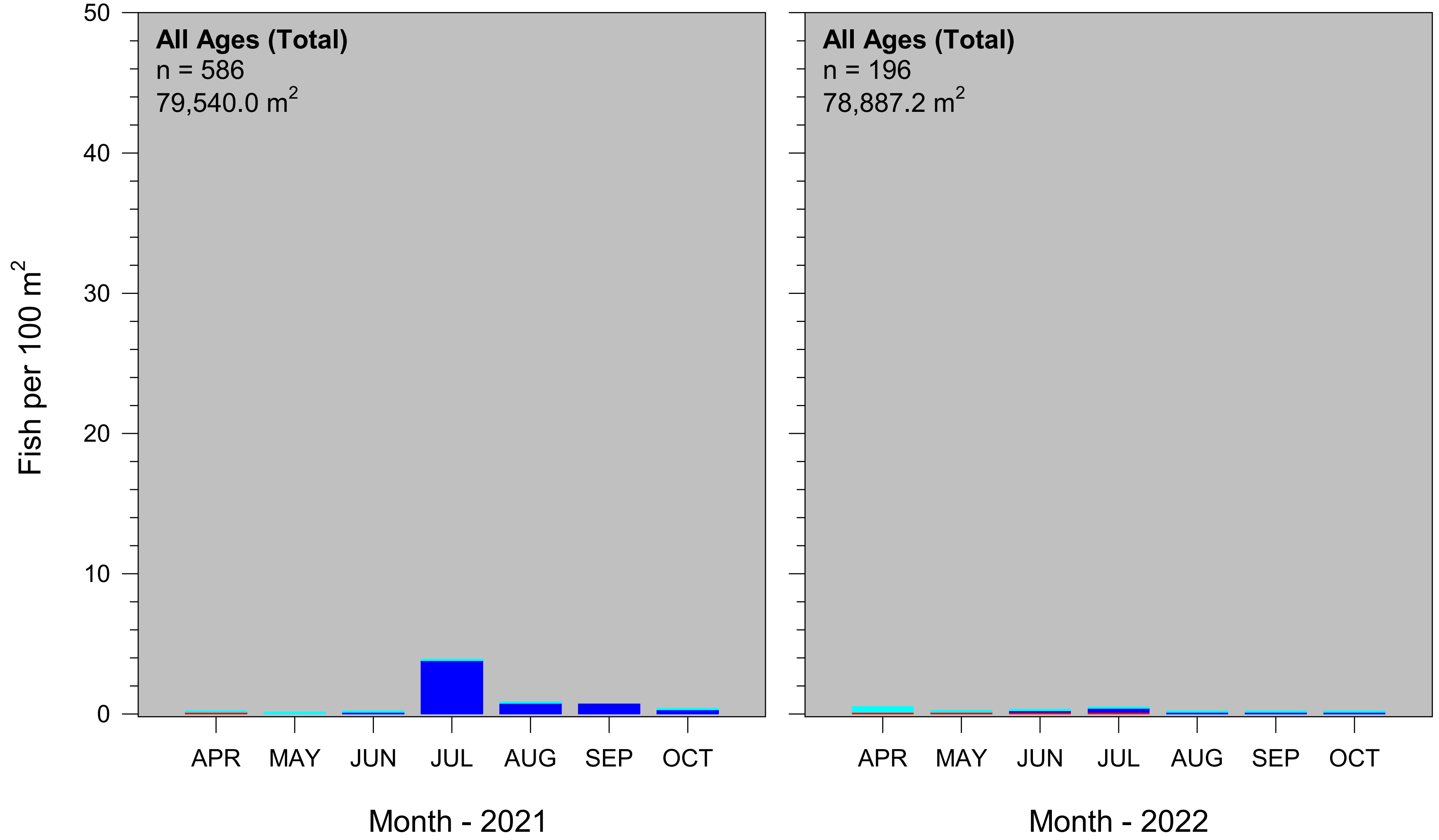


RGSM Population Trends in 2022

(All Ages)

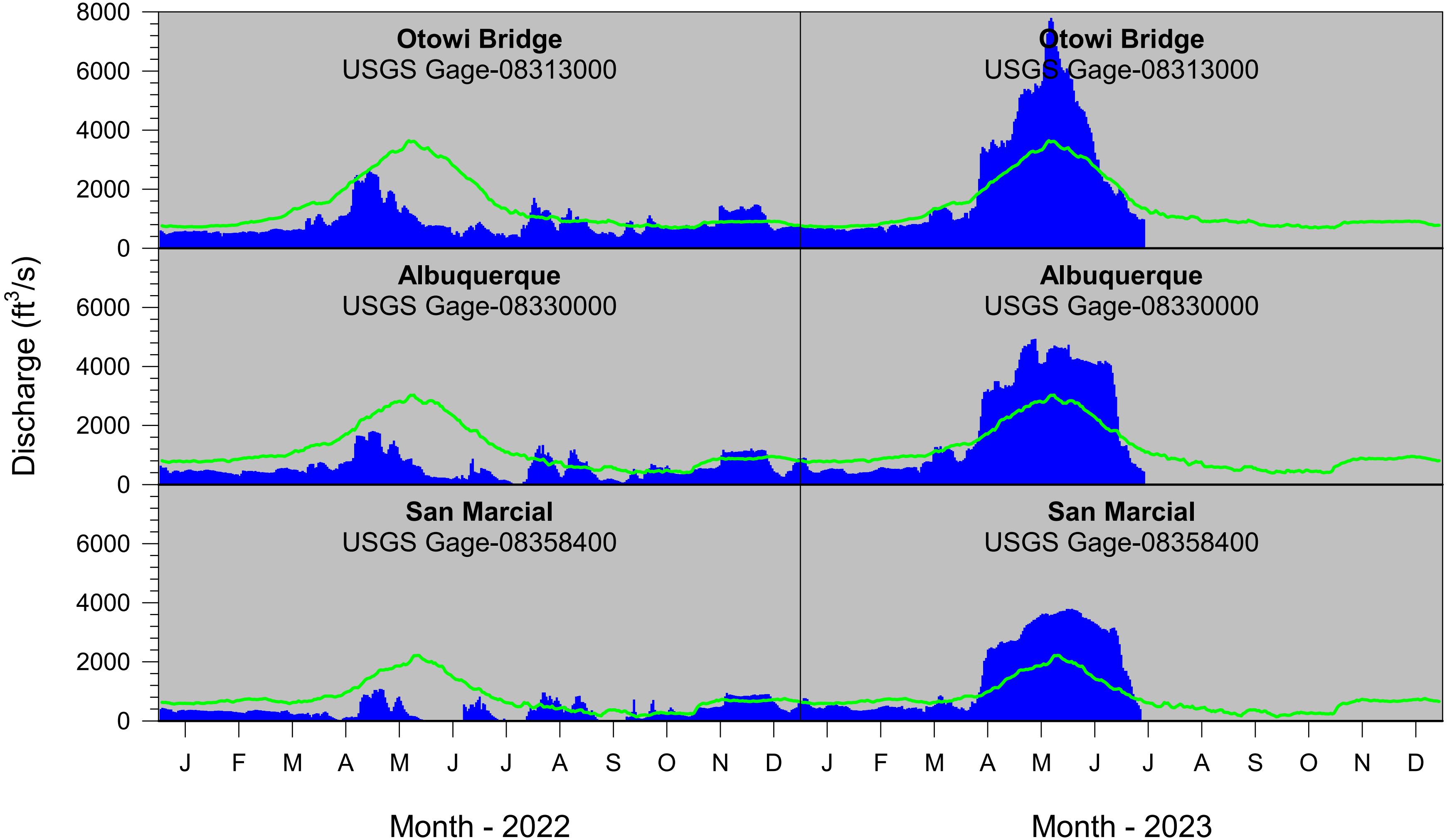


RGSM Population Trends
(2021–2022)

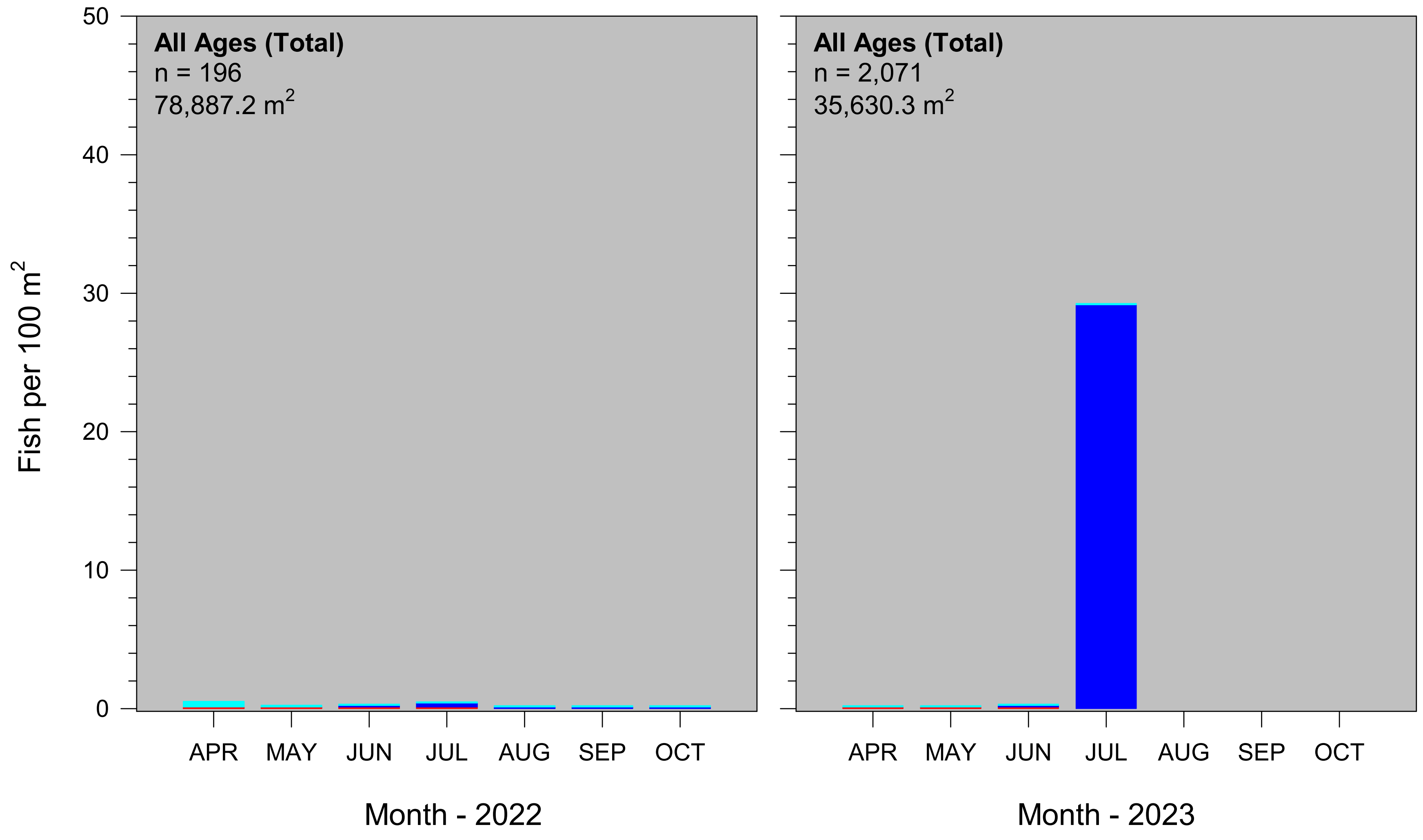


Discharge in the Middle Rio Grande

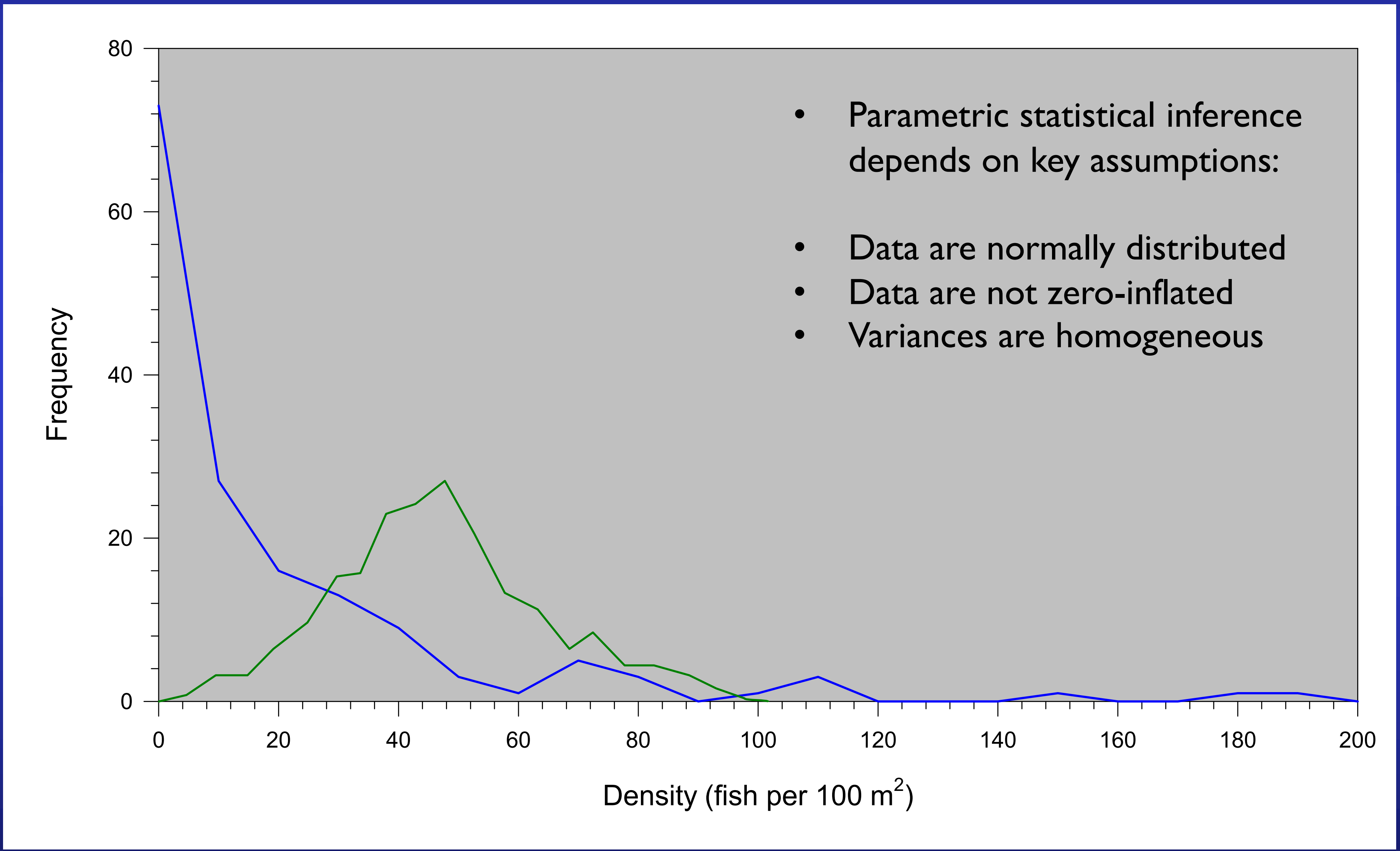
(2022–2023 [preliminary data])



RGSM Population Trends
(2022–2023 [preliminary data])

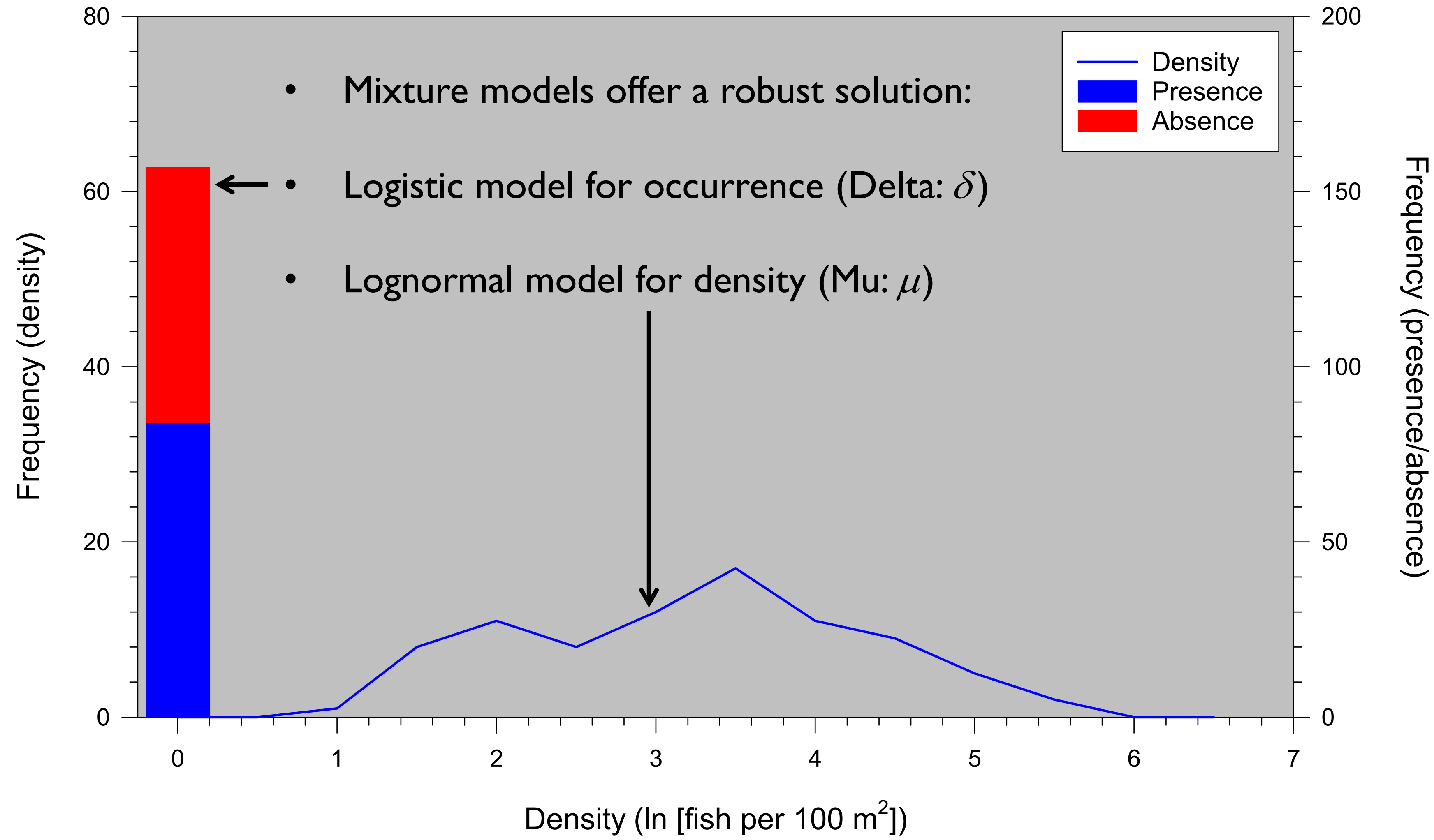


Frequency Distribution of Raw Data

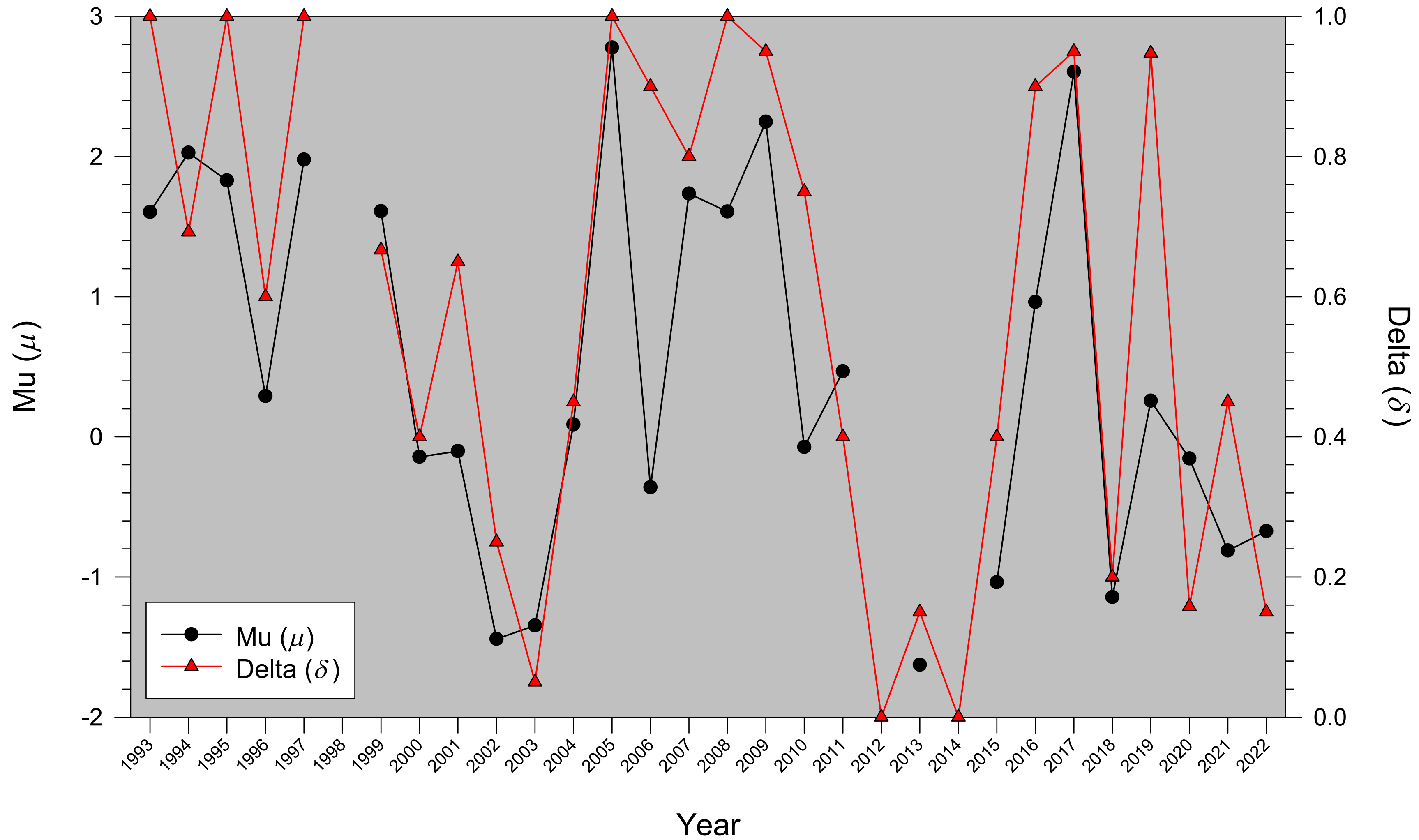


Occurrence and Density Data

- Mixture models offer a robust solution:
- Logistic model for occurrence (Delta: δ)
- Lognormal model for density (Mu: μ)



Model Estimates in October
(1993–2022)



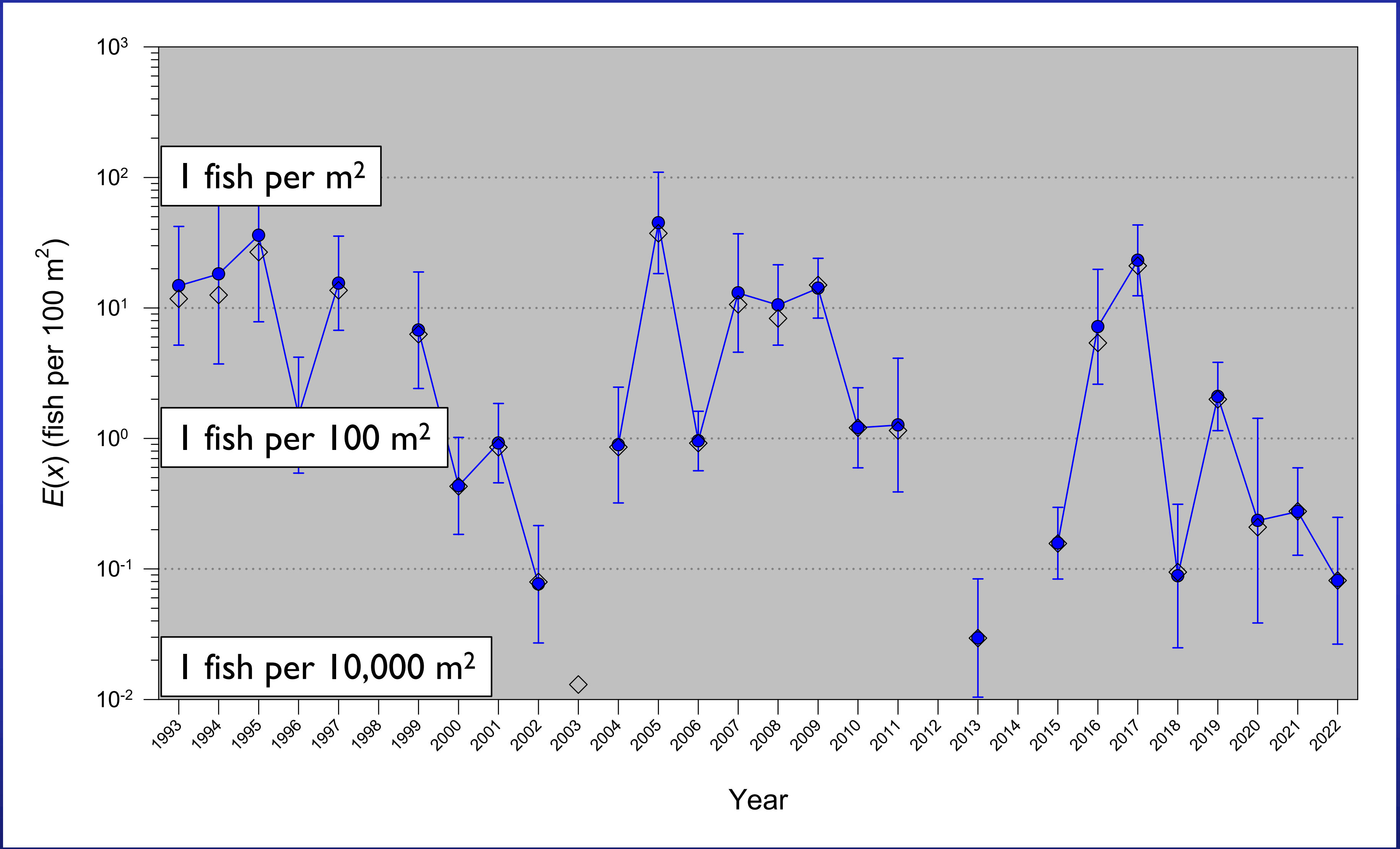
Estimated Density (fish per 100 m^2)

$$E(x) = \delta \exp\left[\mu + \frac{\sigma^2}{2}\right]$$

$$\mathrm{LCI} = \exp\left[\log\left(E(x)\right) - 1.96 \cdot \mathrm{SE}\left(E(x)\right) / E(x)\right]$$

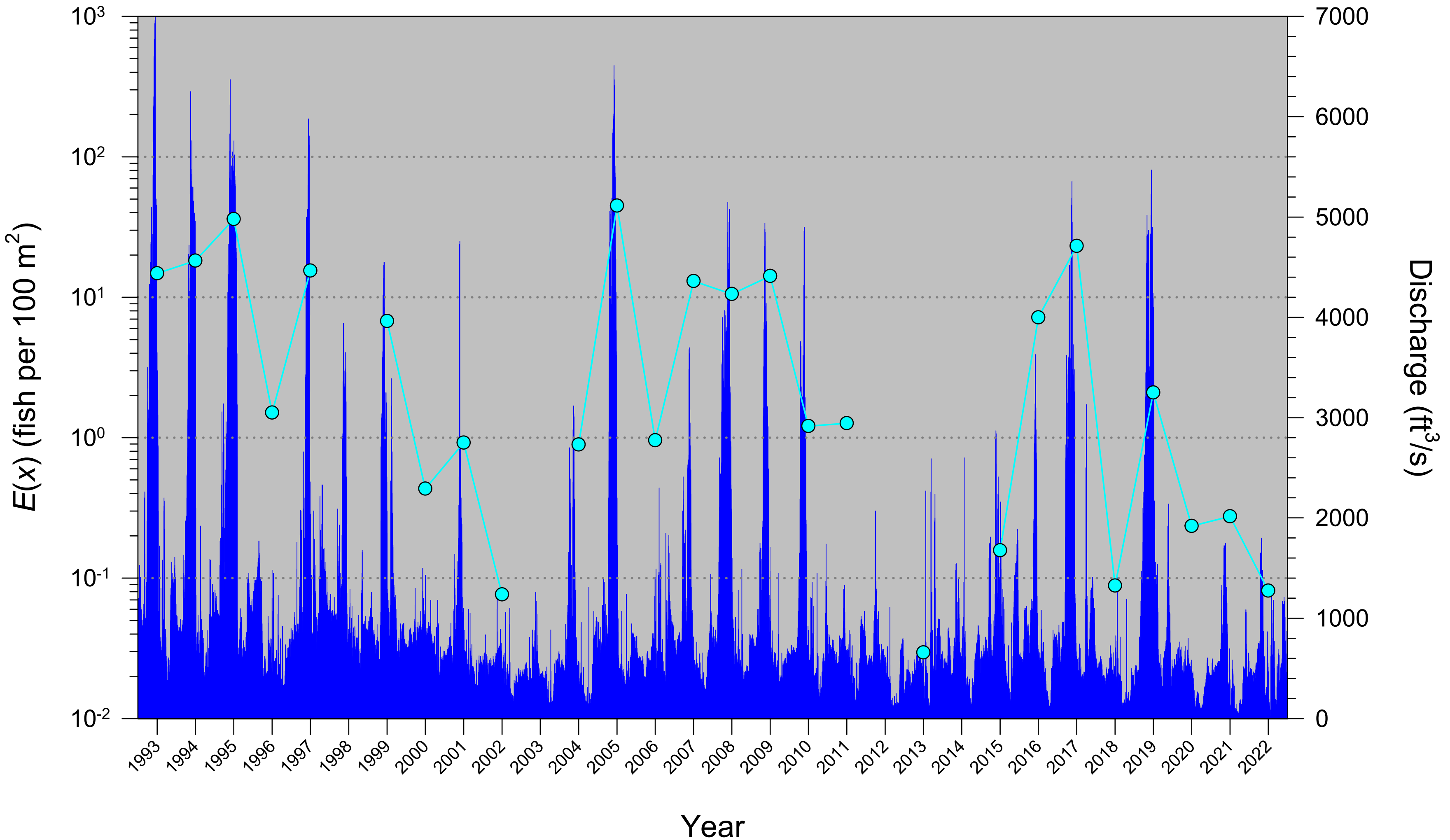
$$\mathrm{UCI} = \exp\left[\log\left(E(x)\right) + 1.96 \cdot \mathrm{SE}\left(E(x)\right) / E(x)\right]$$

Densities of RGSM in October
(1993–2022)

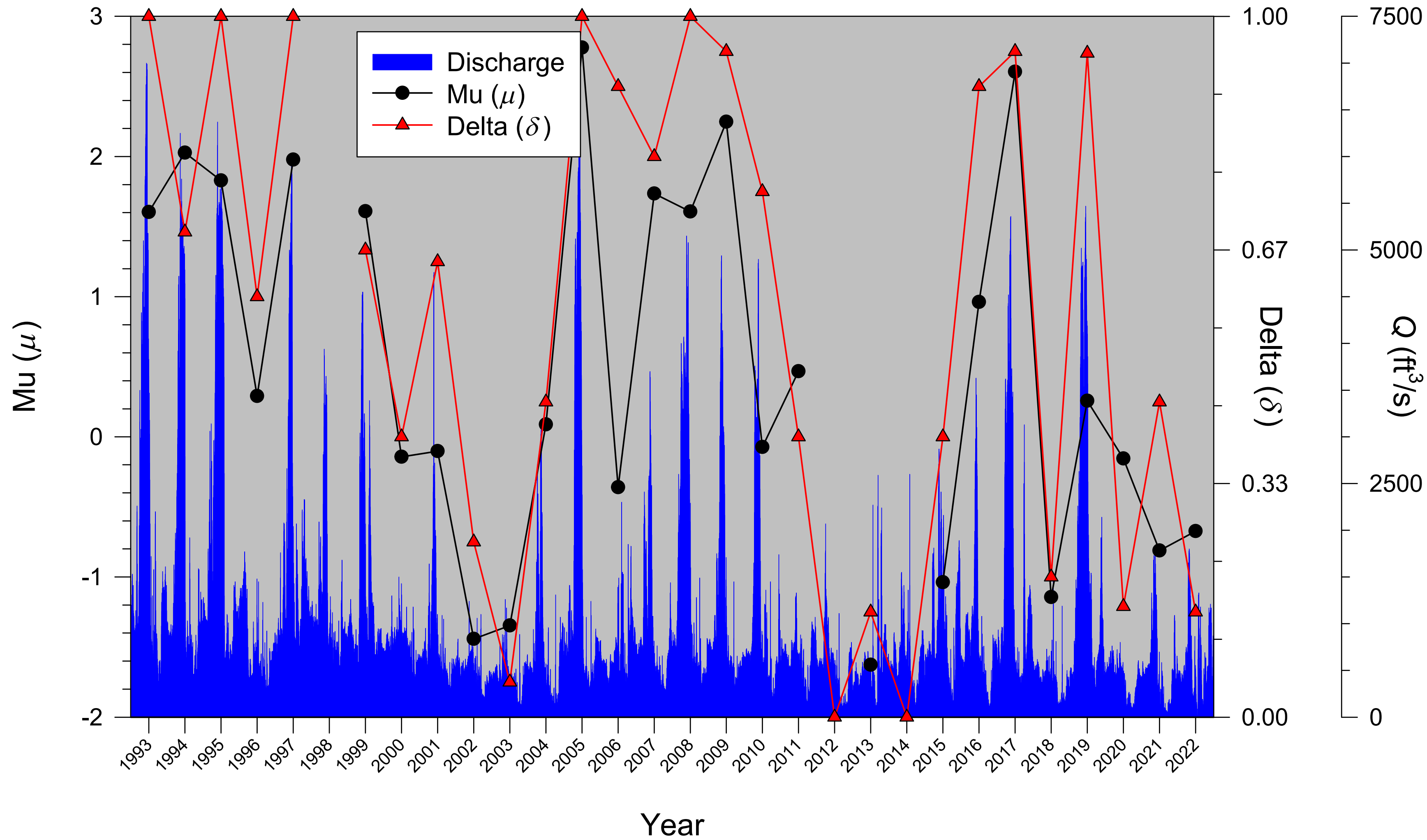


Densities of RGSM and Discharge

(1993–2022)



Parameter Estimates and Discharge
(1993–2022)



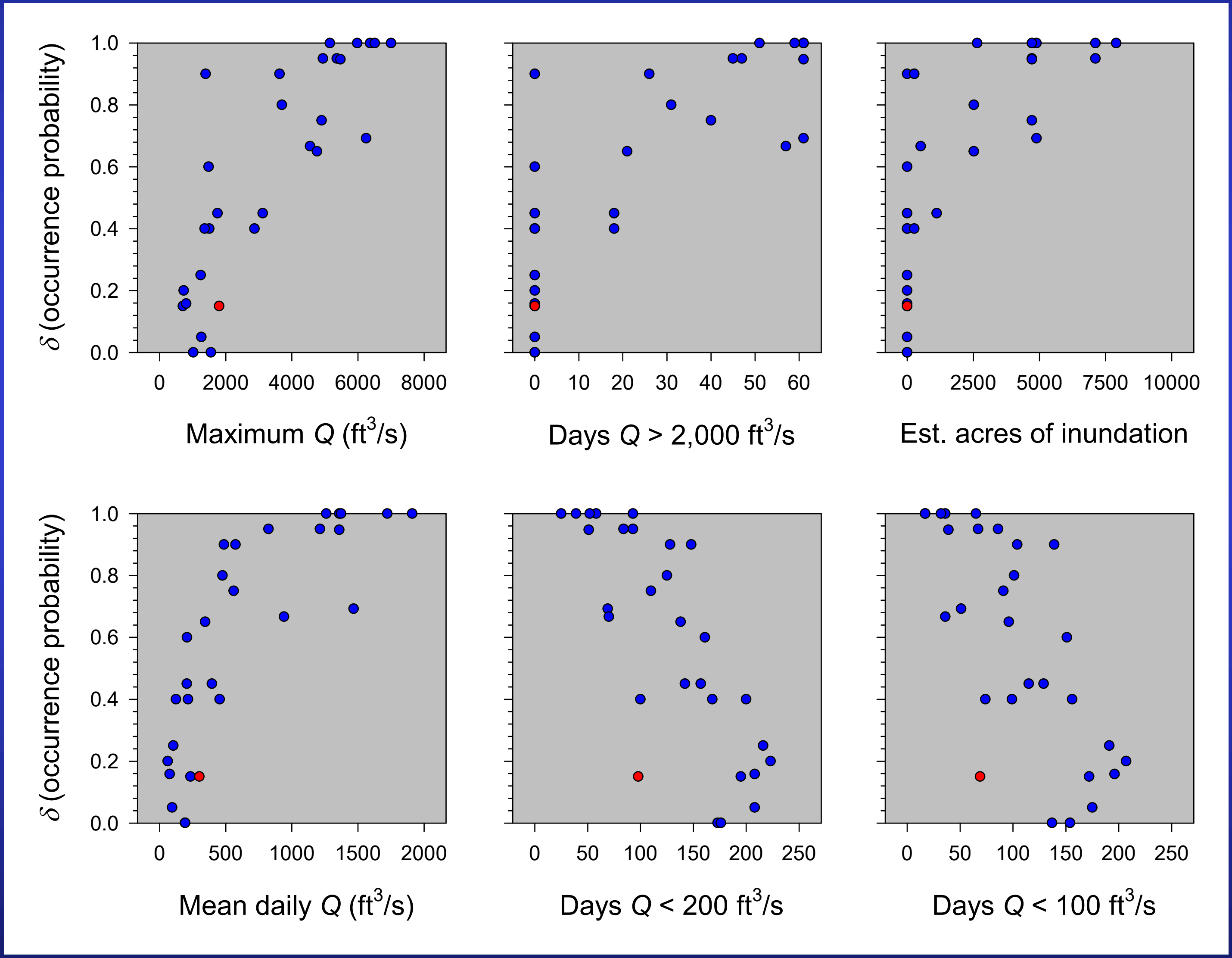
Modeling the Ecology of RGSM

- Generalized linear models (GLMs) included δ (occurrence probability) and μ (lognormal density) with a single environmental covariate (n = 9) for each estimated parameter (e.g., δ[SAN<200] μ[ABQ>3,000]).

- All covariates included both fixed effects (i.e., covariate explains variation) and random effects (i.e., random error [*R*] around covariate).

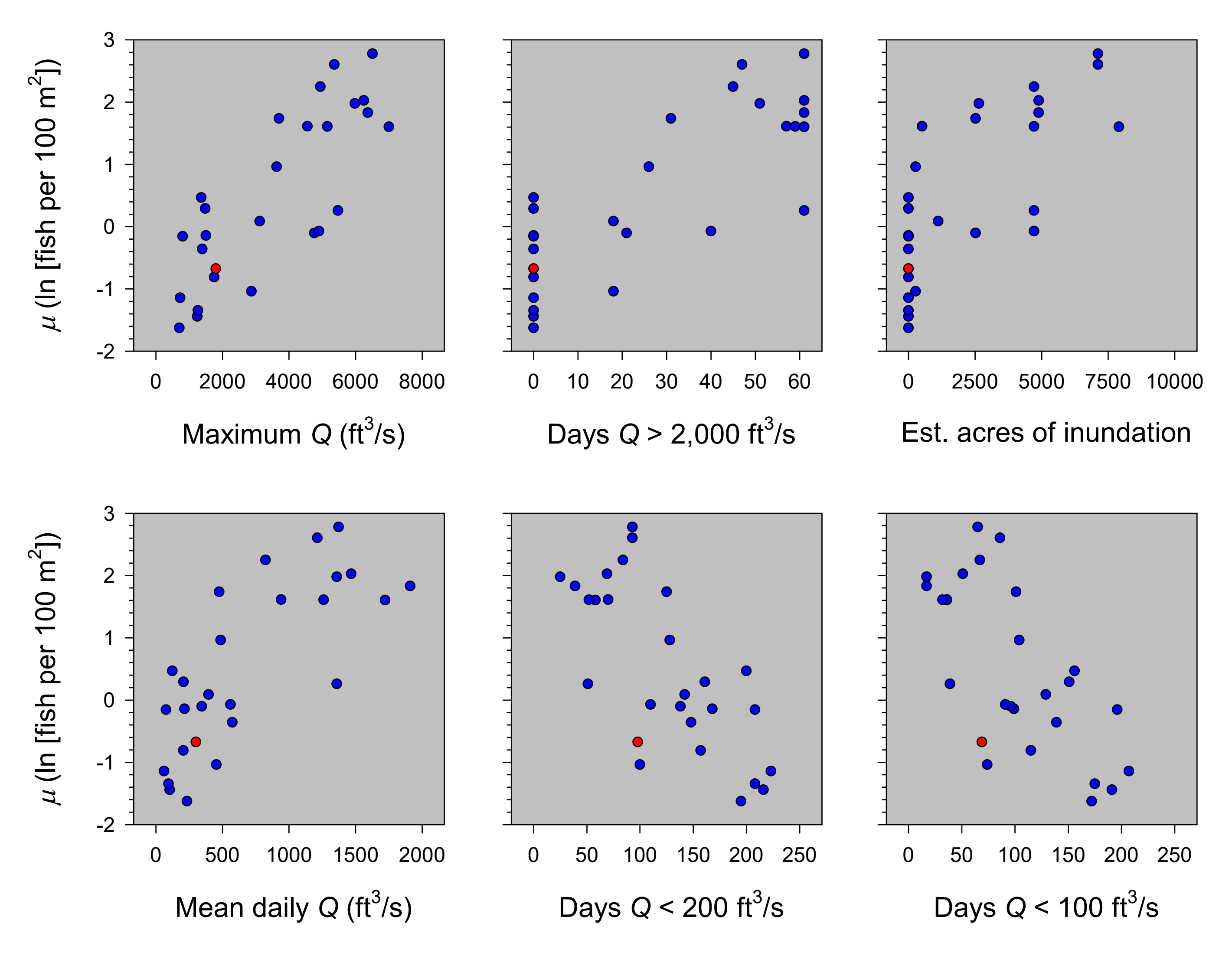
- Goodness-of-fit statistics (–2[log-likelihood] and Akaike's information criterion [AIC_c]) were used to assess the fit of data to various models.

Occurrence Probabilities vs. Discharge
(1993–2022)





Lognormal Densities vs. Discharge
(1993–2022)

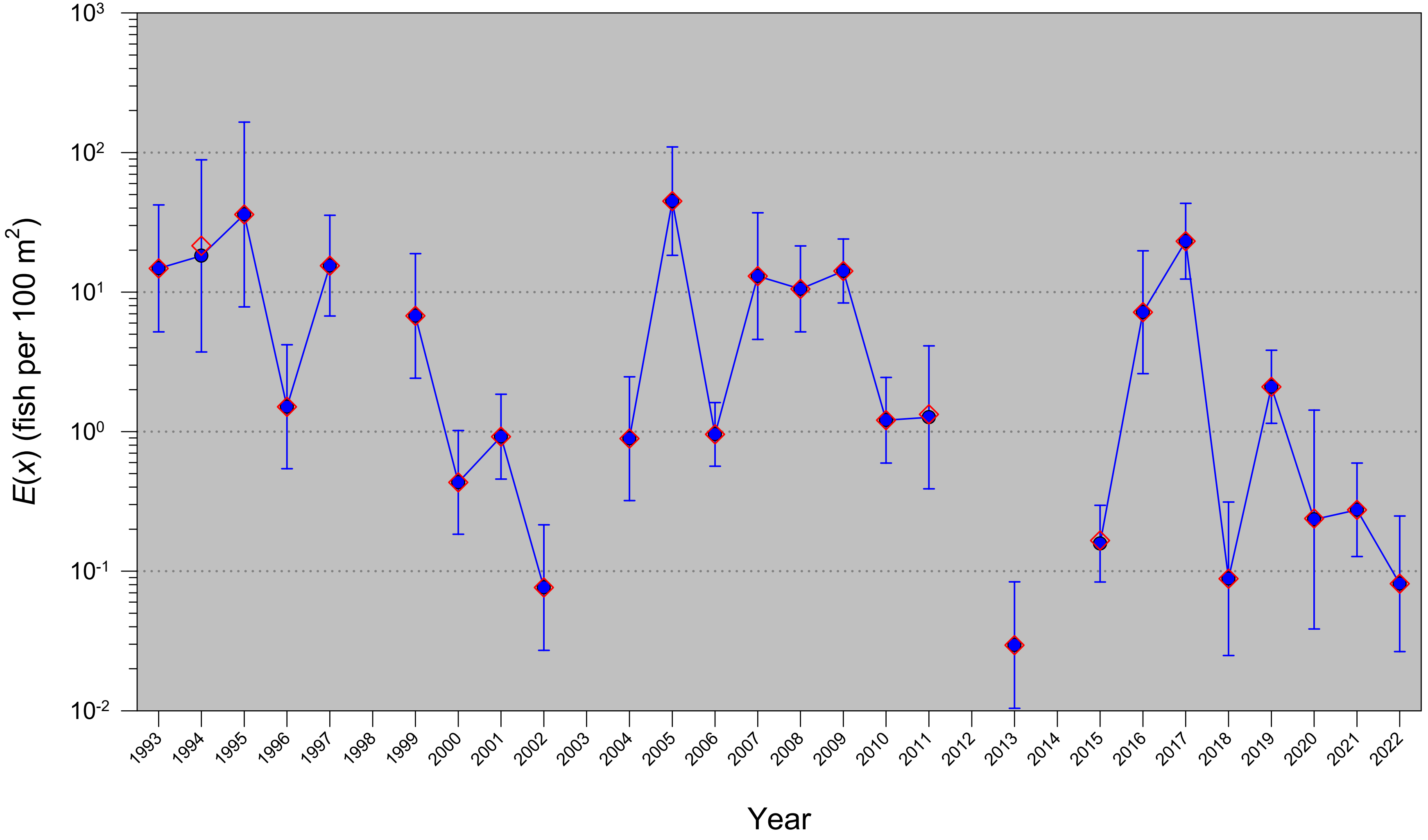


Ecological Model Results for RGSM
(1993–2022)

Model	logLike	K	AIC_c	w_i
δ(Year) μ(ABQ>2,000+*R*)	880.58	34	953.27	0.3885
δ(Year) μ(ABQmax+*R*)	880.87	34	953.55	0.3369
δ(Year) μ(ABQmean+*R*)	882.11	34	954.79	0.1812
δ(Year) μ(SANmean+*R*)	885.50	34	958.18	0.0333
δ(Year) μ(ABQ>3,000+*R*)	886.41	34	959.10	0.0210
δ(Year) μ(ABQ>1,000+*R*)	887.22	34	959.91	0.0140
δ(SANmean+*R*) μ(Year)	835.83	56	960.96	0.0083
δ(ABQmax+*R*) μ(Year)	837.63	56	962.76	0.0034
δ(SANmean+*R*) μ(ABQ>2,000+*R*)	945.30	9	963.64	0.0022
δ(ABQmean+*R*) μ(Year)	838.56	56	963.70	0.0021

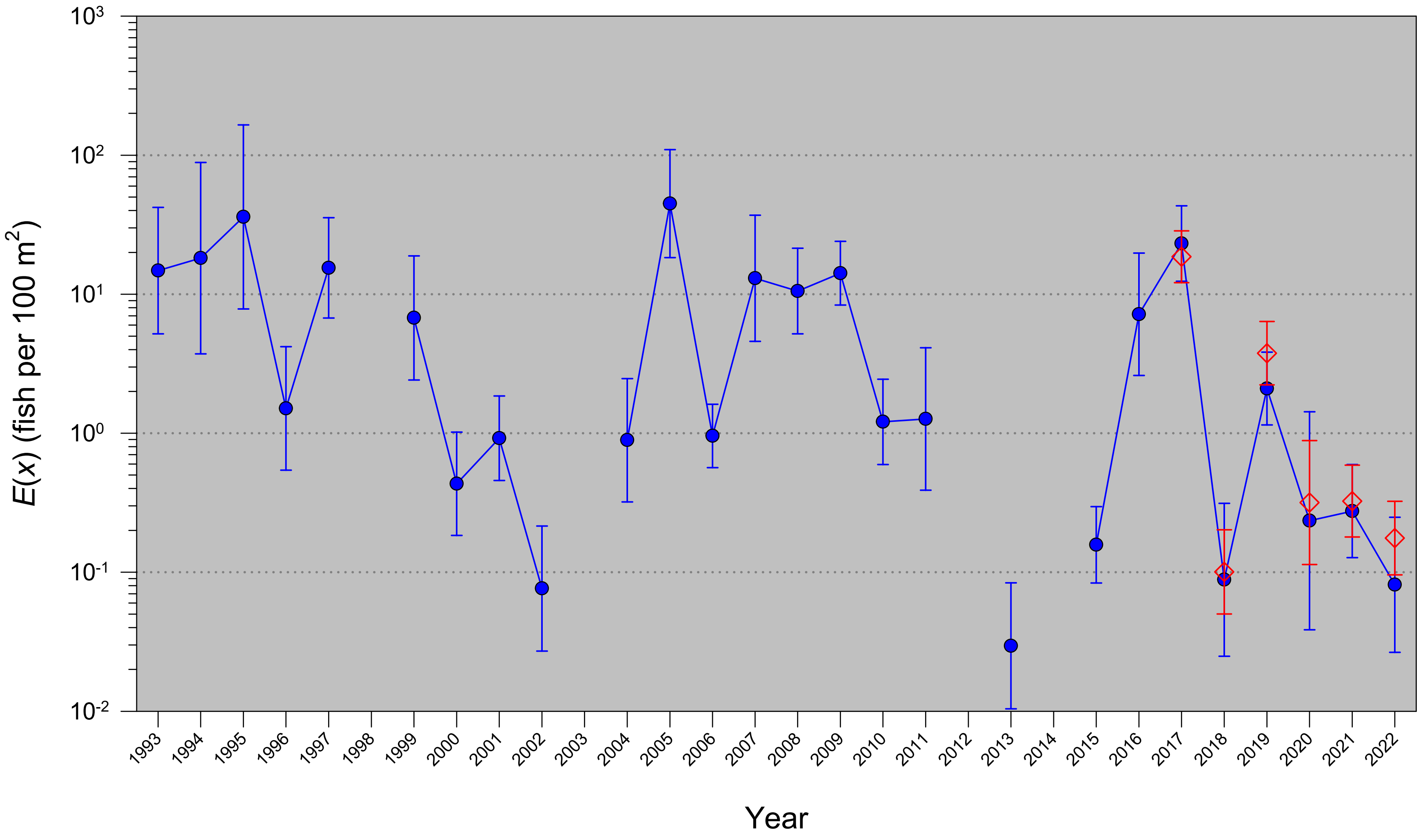
Densities of RGSM in October

(No Dry Sites)



Densities of RGSM in October

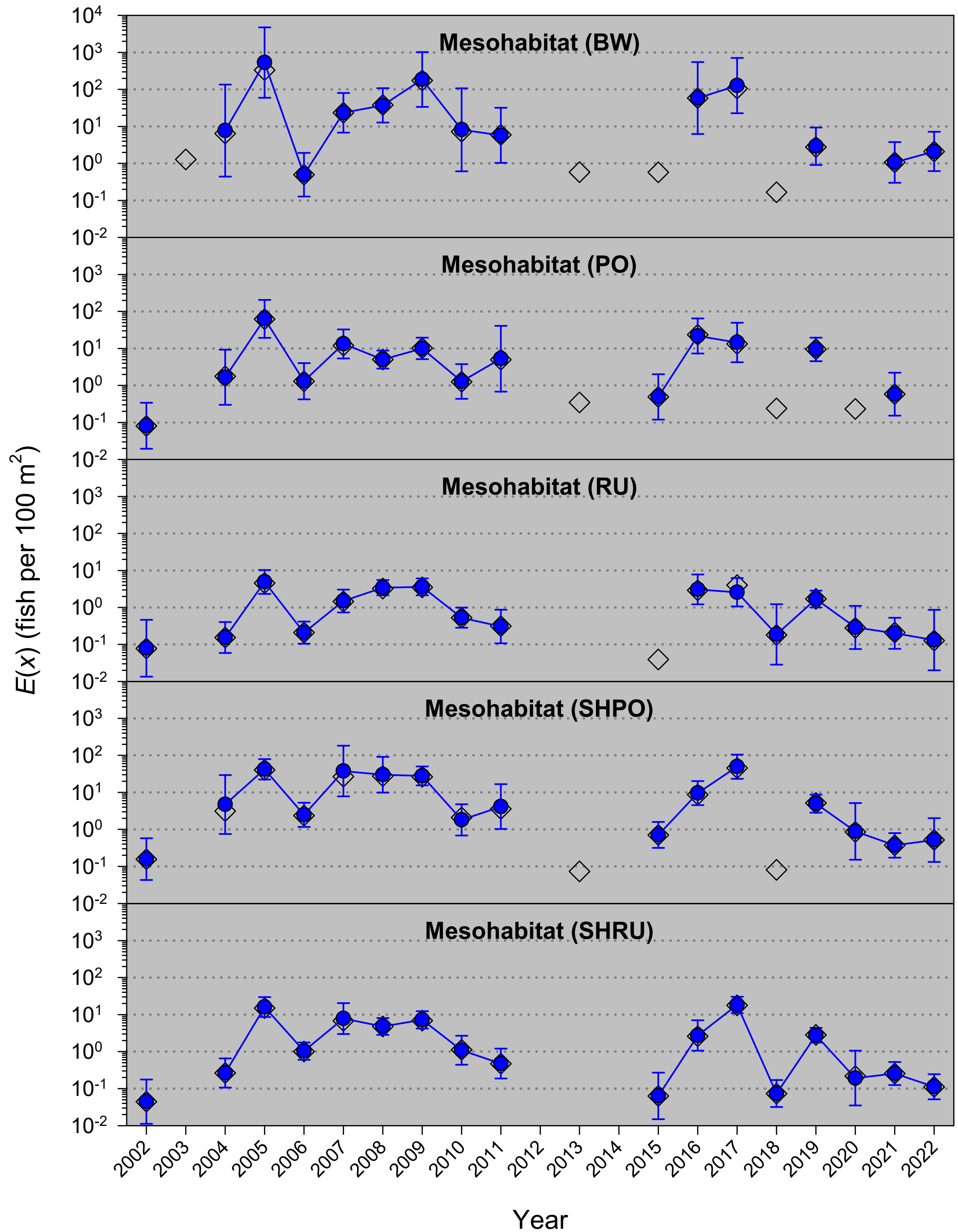
(Additional Sites)



Densities of RGSM
(October: Mesohabitats)

- Mesohabitat-specific density trends were very similar to the overall long-term trend.

- Estimated densities in BW, PO, and SHPO were generally higher and more variable, as compared to SHRU or RU.



Mesohabitat-Specific Model Results for RGSM

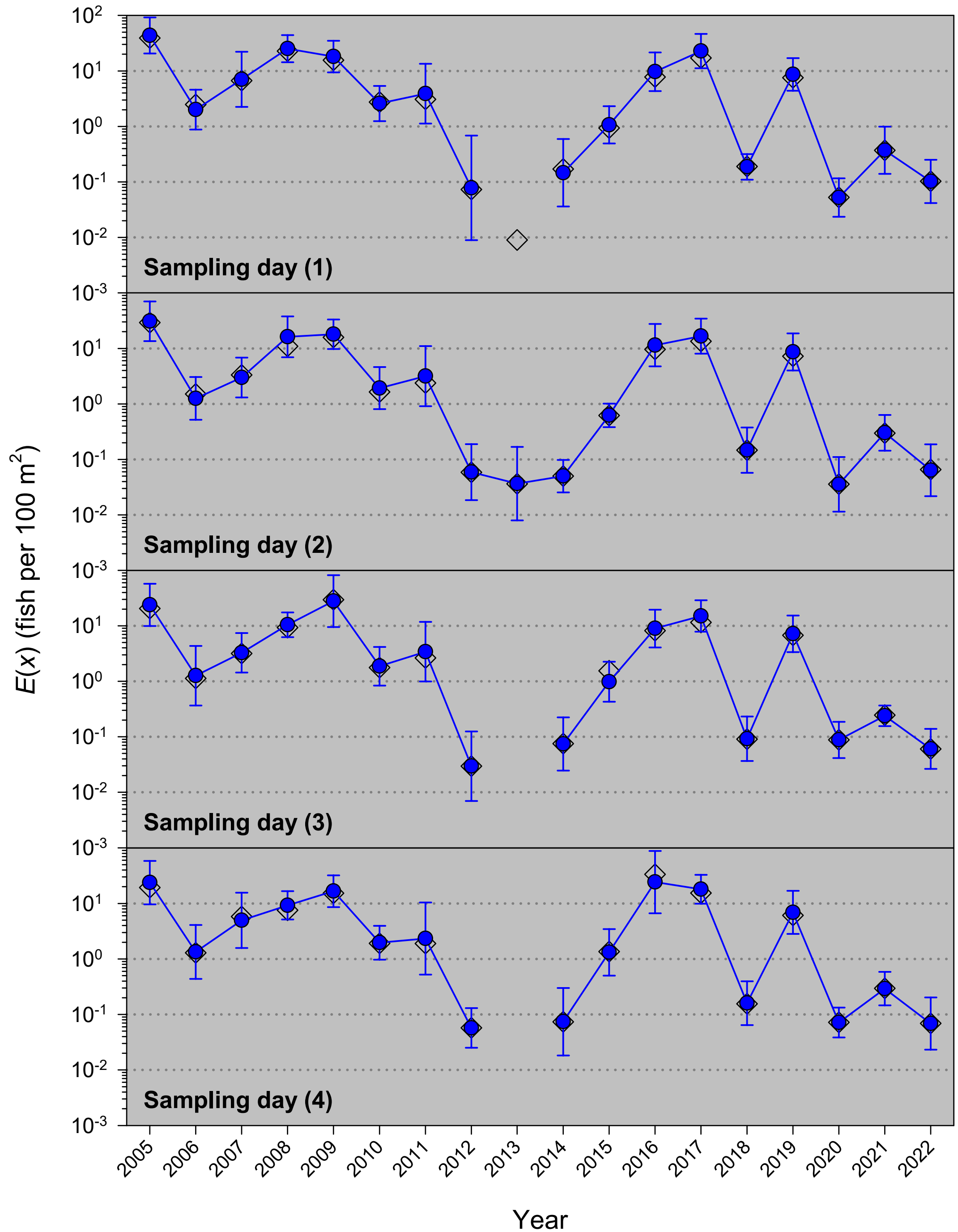
(2002–2022)

Model	logLike	K	AIC_c	w_i
δ(Year+Mesohabitat) μ(Year+Mesohabitat)	2,363.31	70	2,508.57	> 0.9999
δ(Year) μ(Year+Mesohabitat)	2,419.91	66	2,556.58	< 0.0001
δ(Year*Mesohabitat) μ(Year*Mesohabitat)	2,085.11	267	2,703.55	< 0.0001
δ(Year+Mesohabitat) μ(Mesohabitat)	2,655.56	35	2,726.86	< 0.0001
δ(Year) μ(Mesohabitat)	2,712.15	31	2,775.18	< 0.0001
δ(Year+Mesohabitat) μ(Year)	2,664.73	62	2,792.84	< 0.0001
δ(*R*) μ(Mesohabitat)	2,812.76	12	2,836.92	< 0.0001
δ(Year) μ(Year+Reach)	2,710.12	62	2,838.23	< 0.0001
δ(Year) μ(Year)	2,721.33	58	2,840.92	< 0.0001
δ(Year+Reach) μ(Year+Reach)	2,709.48	64	2,841.86	< 0.0001

Densities of RGSM
(November: Occasions)

- Repeated-sampling density trends were very similar to the overall long-term trend.

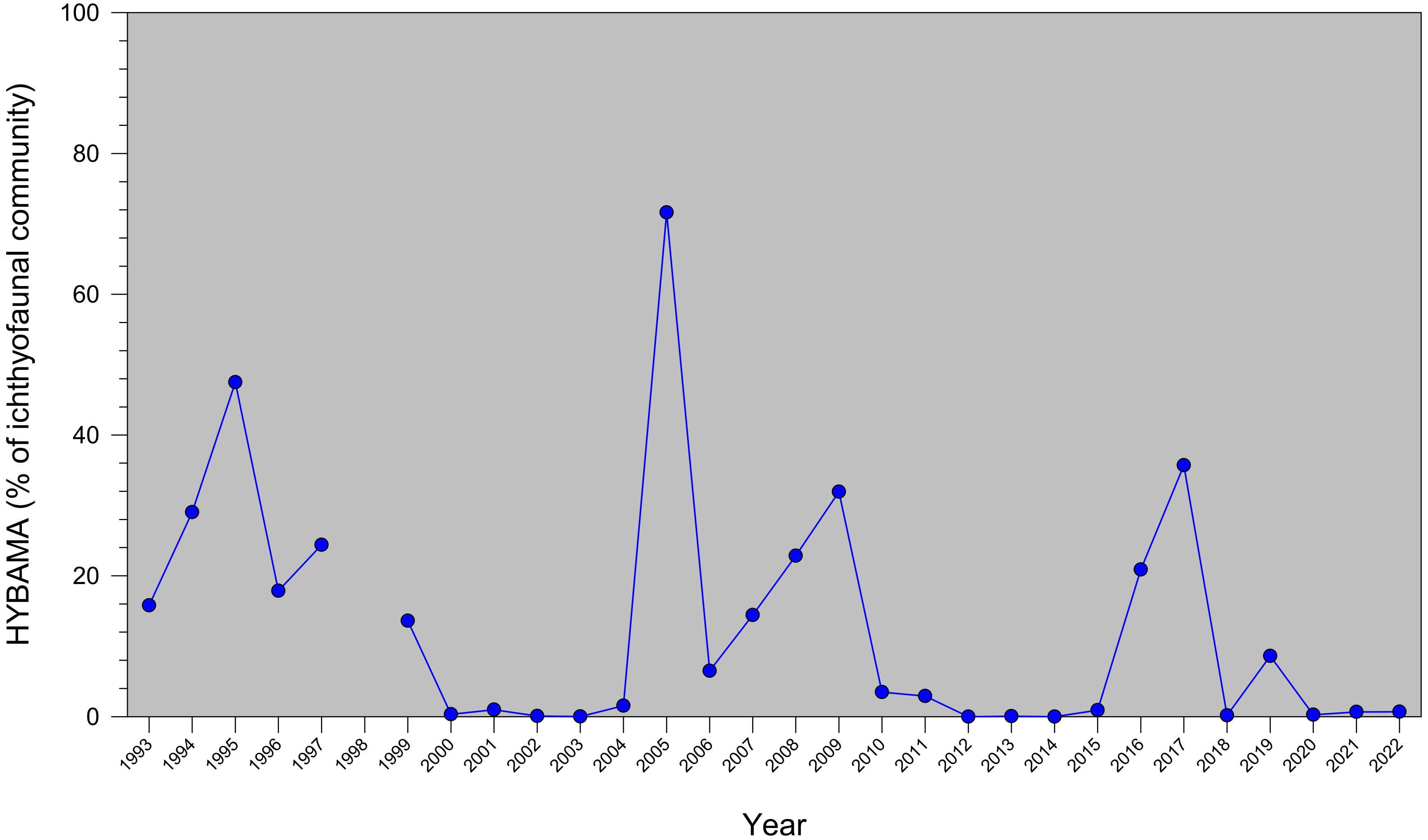
- Estimated densities were quite similar across the four sampling occasions over time.



Repeated-Sampling Model Results for RGSM
(2005–2022)

Model	logLike	K	AIC_c	w_i
δ(Year*Reach) μ(Year*Reach)	1,802.02	156	2,152.32	> 0.9999
δ(Year+Reach) μ(Year+Reach)	2,246.03	60	2,371.36	< 0.0001
δ(Year) μ(Year+Reach)	2,273.82	58	2,394.79	< 0.0001
δ(Year+Reach) μ(Year)	2,304.46	56	2,421.09	< 0.0001
δ(Year) μ(Year)	2,332.26	54	2,444.56	< 0.0001
δ(Year) μ(Year+Occasion)	2,323.78	60	2,449.10	< 0.0001
δ(Year+Occasion) μ(Year)	2,331.40	57	2,450.19	< 0.0001
δ(Year+Occasion) μ(Year+Occasion)	2,322.92	63	2,454.79	< 0.0001
δ(R) μ(Year)	2,413.68	38	2,491.80	< 0.0001
δ(Year) μ(R)	2,533.55	21	2,576.21	< 0.0001

Relative Abundance of RGSM in October
(1993–2022)



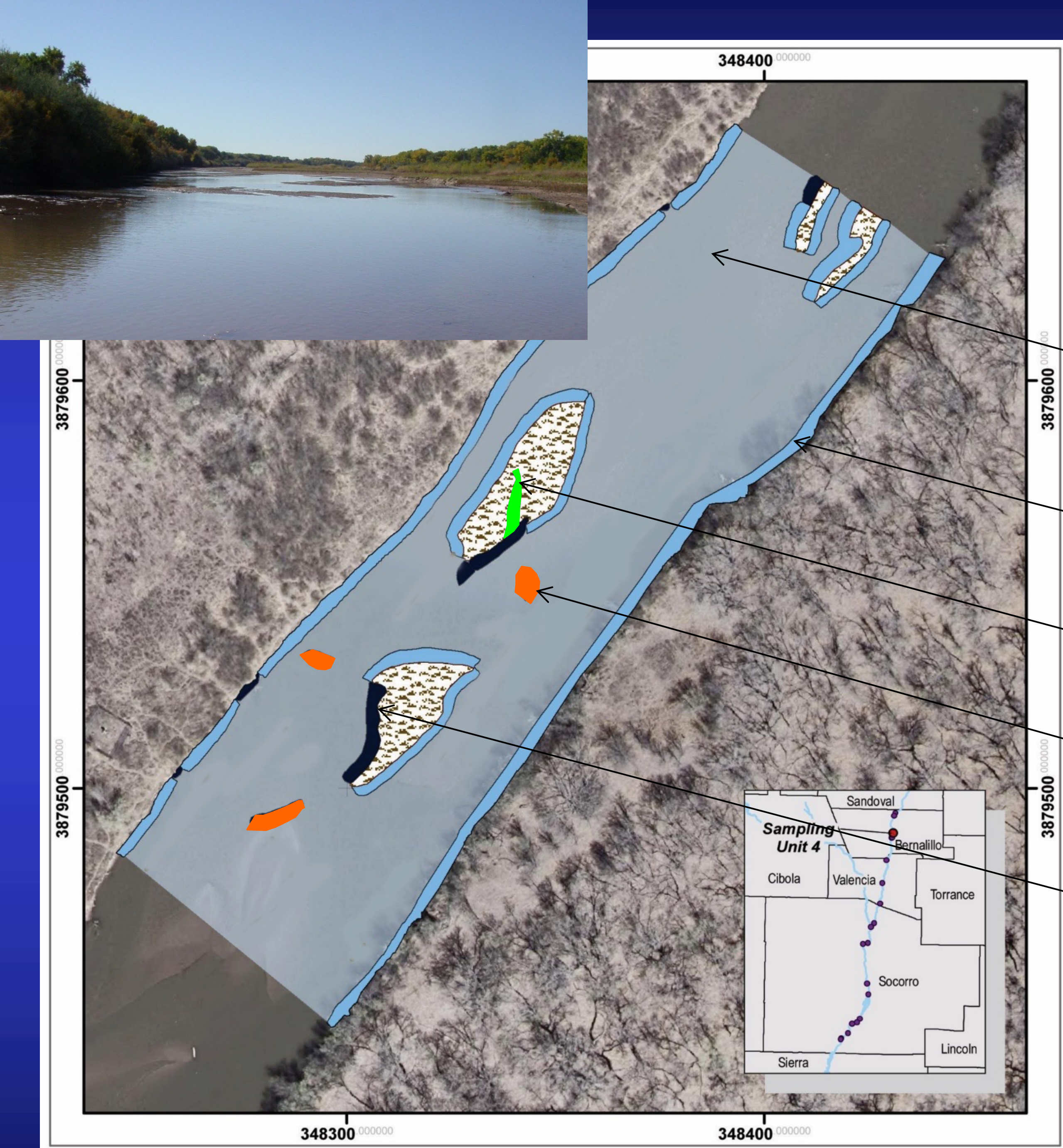
Rank Abundance of Focal Species in October
(2013–2022)

Species	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Red Shiner	1	1	1	1	2	1	1	1	1	1
Common Carp	9	8	9	7	6	8	7	10	8.5	8
Rio Grande Silvery Minnow	10	10	7	2	1	10	3	8	7	7
Fathead Minnow	4	6	6	8	8	6	8	5	6	6
Flathead Chub	6	3	3	4	5	3	4	3	3	4
Longnose Dace	3	5	5	6	7	7	6	9	4	5
River Carpsucker	8	7	8	9	10	5	10	4	8.5	9
White Sucker	7	9	10	10	9	9	9	7	10	10
Channel Catfish	5	4	4	5	3	4	5	6	5	3
Western Mosquitofish	2	2	2	3	4	2	2	2	2	2

Coefficient of concordance ($W = 0.67$) indicated consistency in species' ranks (1993–2022; $P < 0.001$).

Site Occupancy Results
(2005–2022)

Mesohabitats



Runs (RU)

Shoreline runs (SHRU)

Backwaters (BW)

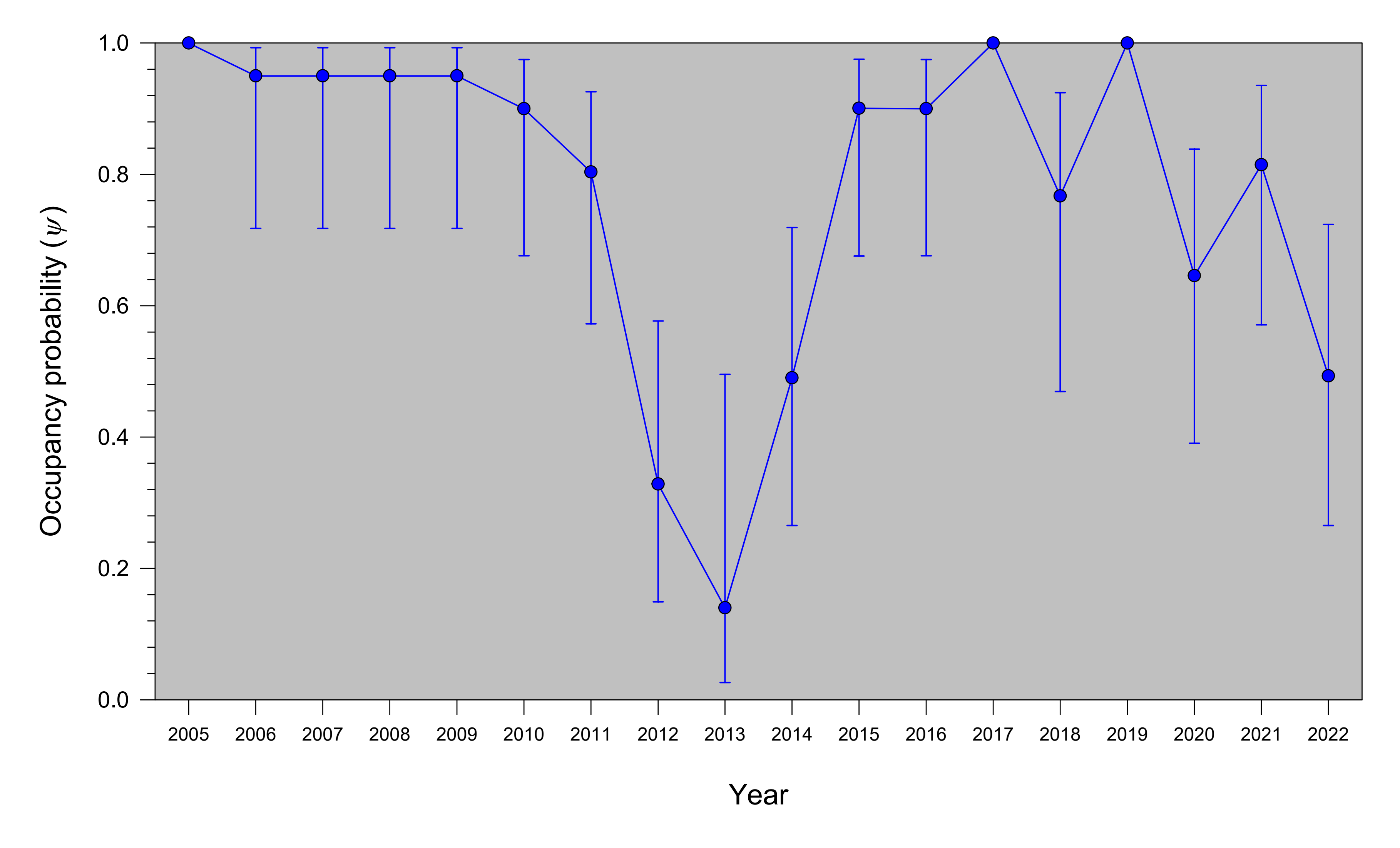
Pools (PO)

Shoreline pools (SHPO)

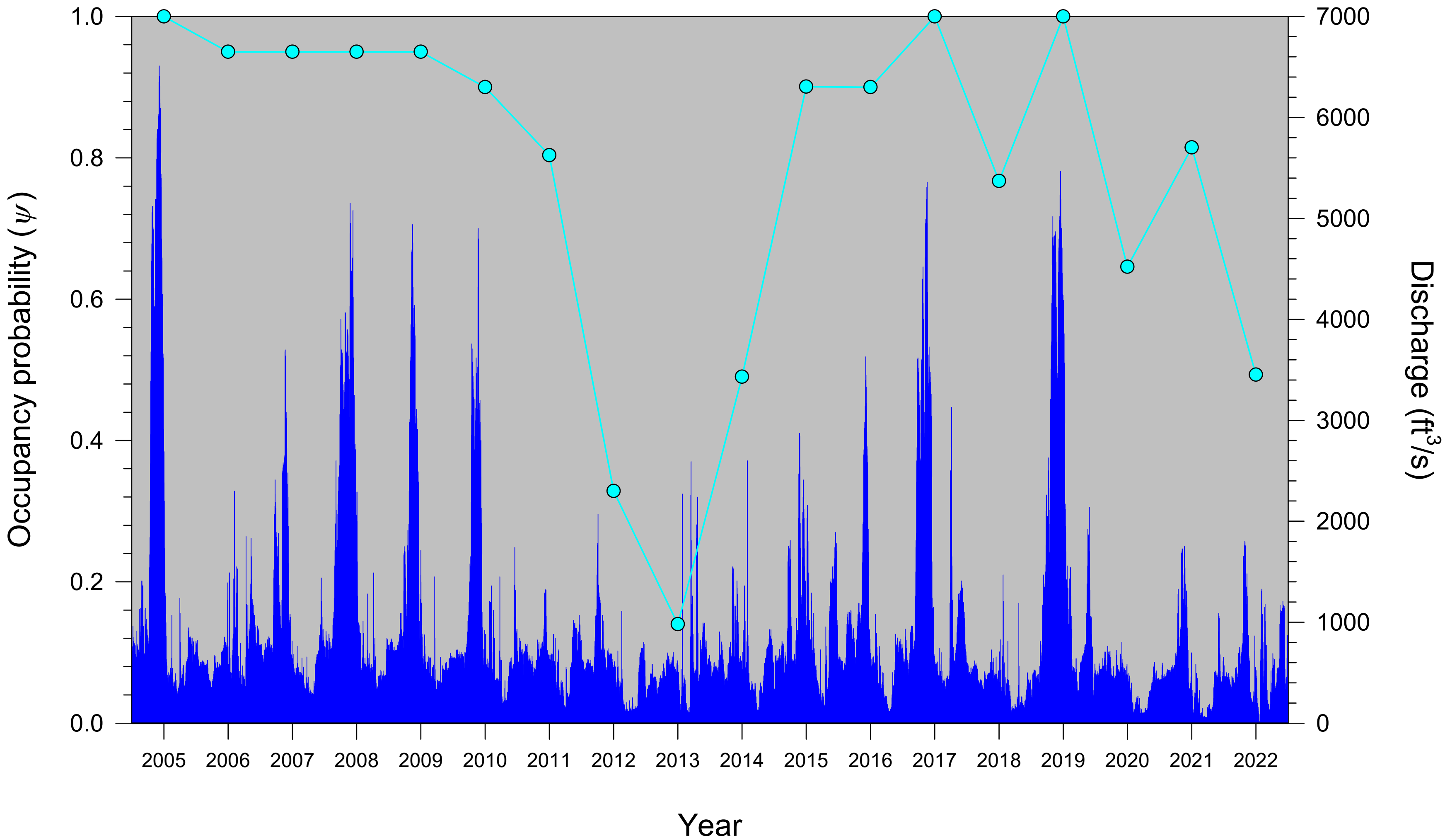
Site Occupancy Rates

- "*Few species are likely to be so evident that they will always be detected when present.*" (MacKenzie et al. 2003)
- Site occupancy analyses were based on RGSM repeated-sampling data (presence/absence) collected in November (2005–2022).
- Occupancy analyses were based on methods developed by MacKenzie et al. (2002, 2003, 2006), and Program MARK (White and Burnham, 1999) was used to compute key parameter estimates (Probability: occupancy [ψ], extinction [ε], and colonization [γ]).

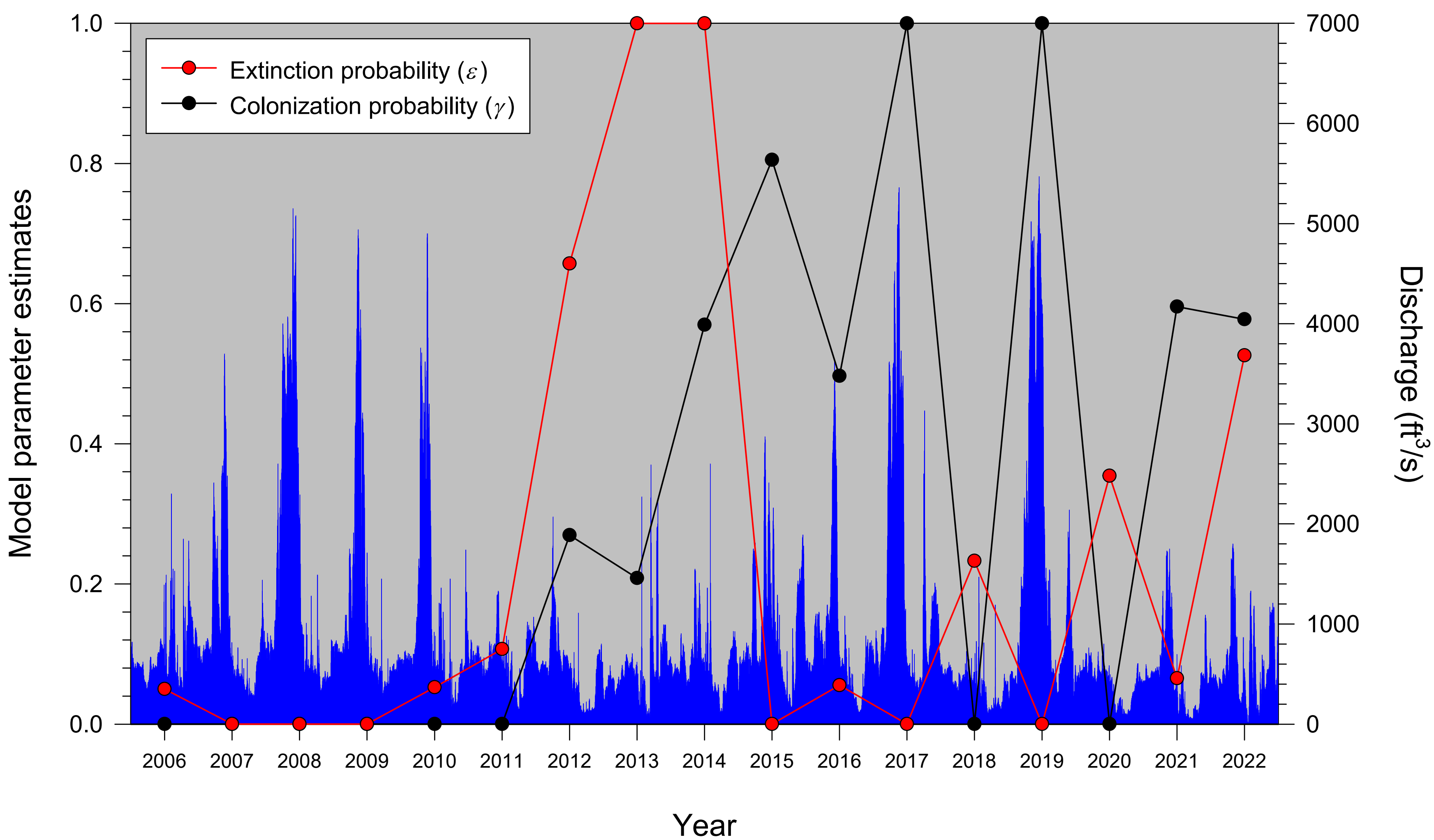
Occupancy Probabilities
(2005–2022)



Occupancy Probabilities and Discharge
(2005–2022)



Extinction/Colonization Probabilities and Discharge
(2006–2022)



Summary

- Although the estimated occurrence and density of RGSM was somewhat elevated in 2019, there was a dramatic decrease in 2020, and its occurrence and density had declined further by 2022.

- Prolonged high flows during spring were most predictive of increased density, whereas prolonged low flows during summer were most predictive of decreased occurrence.

- RGSM has been periodically lost from > 85% of its occupied sites over time. Occupancy, extinction, and colonization probabilities for RGSM (i.e., conservation status) improved slightly from 2020 to 2021 but again declined in 2022.

Implications and Opportunities

1. Ongoing efforts to restore dynamic river flows, reconnect fragmented reaches, and reestablish a functional floodplain should help to support resilient and self-sustaining populations of Rio Grande Silvery Minnow.

2. Continued efforts to provide reasonable spring spawning and summer survival conditions will be essential for securing a self-sustaining wild population of this imperiled species in the Middle Rio Grande.

3. Reestablishing resilient populations of this species at other locations within its historical range would substantially help to further ensure its long-term persistence in the wild.

4. Continued study of the factors that regulate this complex aquatic ecosystem will be essential for developing and implementing successful strategies for the long-term recovery of Rio Grande Silvery Minnow.

Acknowledgements

- **Field, Data, & Laboratory:** David Camak, Stephani Clark-Barkalow, Tyler Damron, Emily DeArmon, Michael Farrington, Jacob Mortensen, Andrea Urioste, Aaron Wedemeyer, and Soren Winter (ASIR)

- **Curation of Specimens:** Emily DeArmon and Thomas Turner (Museum of Southwestern Biology [Fishes], UNM)

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- **Technical & Contract Support:** Eric Gonzales and Mary Maestas (USBR)

- **Report Review:** Eric Gonzales (USBR)

- **Fish Sampling & Collection Permits:** The U.S. Fish and Wildlife Service authorized our handling and collection of Rio Grande Silvery Minnow (Permit TE001623-5). The N.M. Department of Game and Fish authorized our handling and collection of all other native and nonnative fishes (Permit 1896).

- **Support & Funding:** The MRGESCP has provided valuable scientific input on our research since 2000. This study was funded by USBR, and its Albuquerque Area Office and Salt Lake City Regional Office administered all funds (Contract 140R4019P0048: Requisition 0040578311).

Questions?

Site 4: Central Ave.
Summer 2022