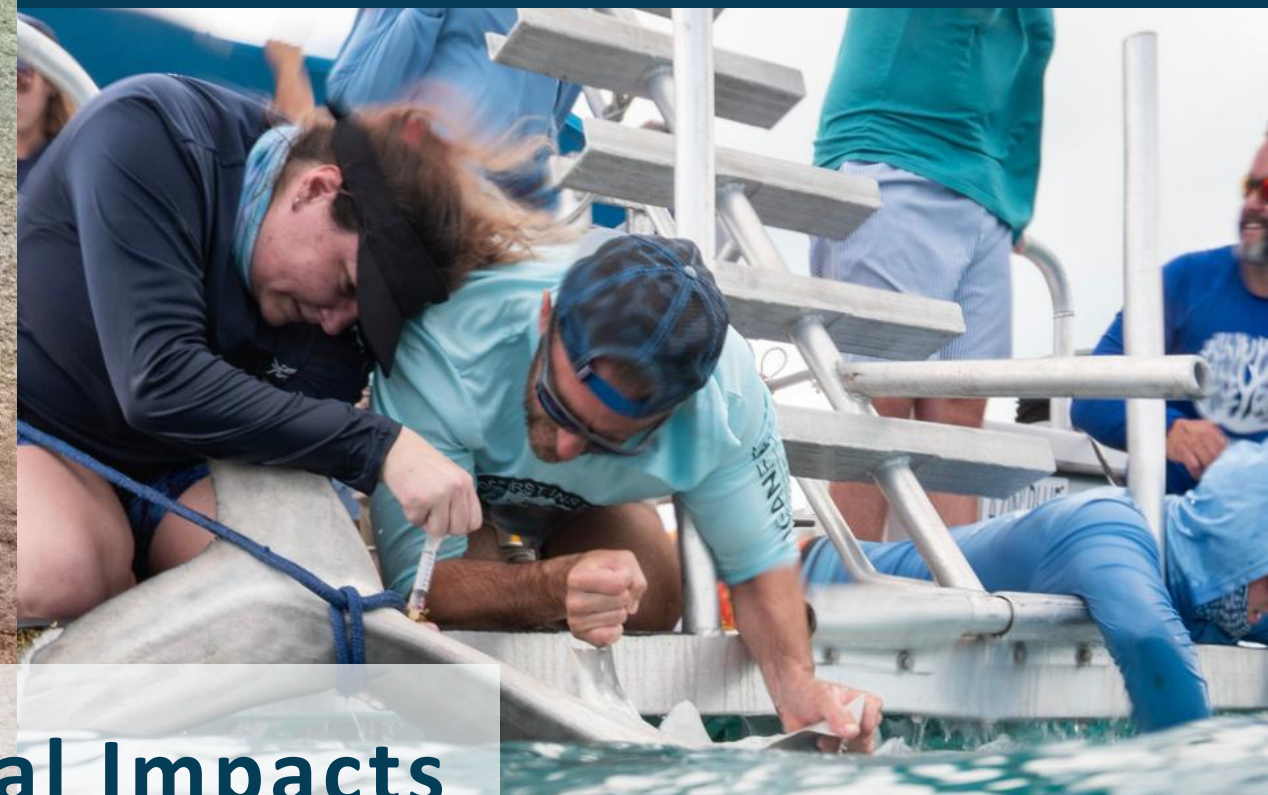


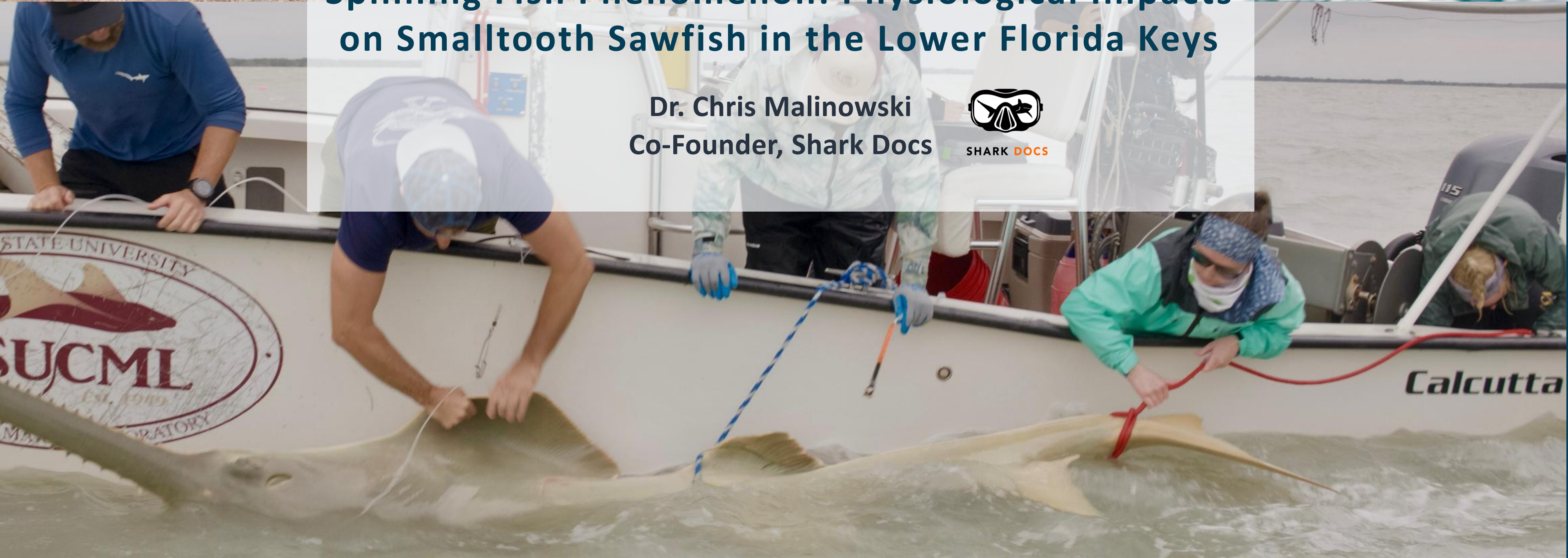


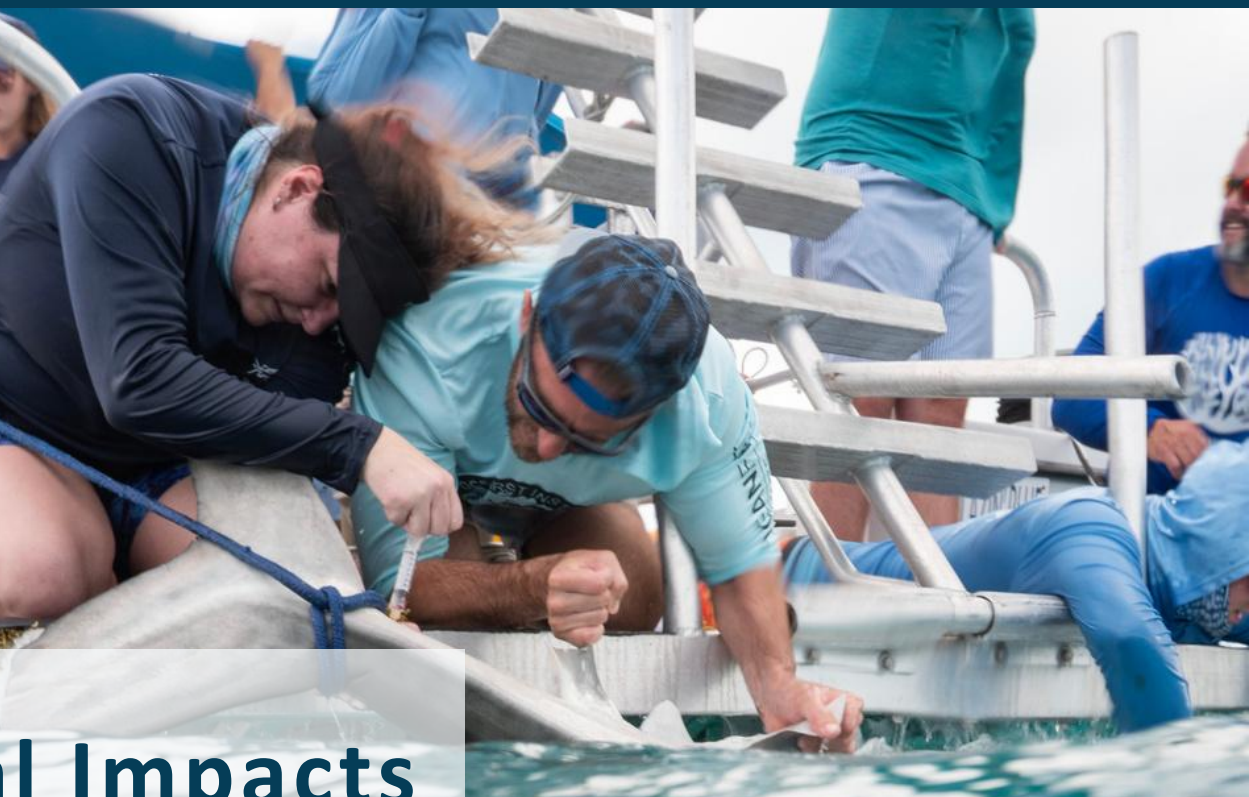
Spinning Fish Phenomenon: Physiological Impacts on Smalltooth Sawfish in the Lower Florida Keys

Dr. Chris Malinowski
Co-Founder, Shark Docs



SHARK DOCS

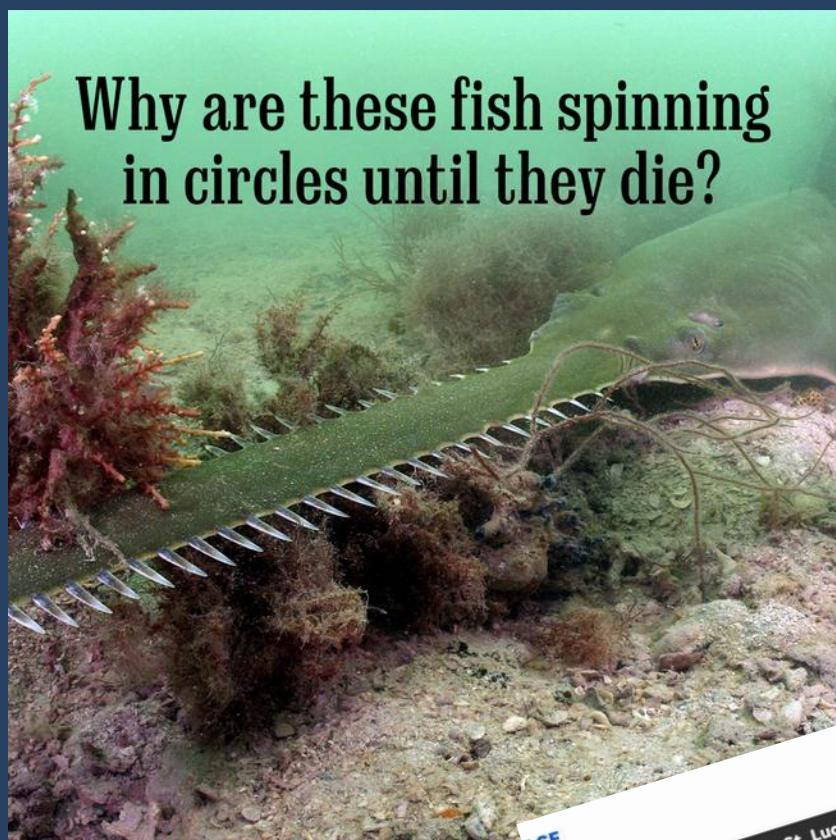




Spinning Fish Phenomenon: Physiological Impacts on Smalltooth Sawfish in the Lower Florida Keys

Chris Malinowski* Shark Docs LLC, Miami, FL	Carolyn Cray University of Miami, Miami, FL
Gregg Poulakis Florida Fish and Wildlife Conservation Commission, Port Charlotte, FL	Jeny Soto University of Miami, Miami, FL
Dean Grubbs Florida State University Coastal and Marine Laboratory, St Teresa, FL	Ally Draime Bimini Biological Field Station, Hollywood, FL
Matthew Smukall Bimini Biological Field Station, Hollywood, FL	Mikki McComb-Kobza Ocean First Institute, Key Largo, FL
Ashley Dawdy Florida State University Coastal and Marine Laboratory, St Teresa, FL	Jennifer Wyffels University of Delaware, Newark, DE





Why are these fish spinning in circles until they die?

TCPalm.
eNewspaper Legals
Indian River Martin St. Lucie Sports Advertise Obits

What is killing the fish?

Theories ask what the culprit could be. Ciguatera? Red tide? A bloom of some unknown algae? A proliferation of a parasite?

Need a break? Play the USA TODAY Daily crossword Puzzle.

...taking place. Samples everyone is in ... it's got

The sawfish was caught during an an co-taught by researches at Florida S and the University of Florida. Cour Florida Museum Of Natural Histor

Advertisement

Scientists race to save Florida's spinning, dying fish

As the mysterious event that causes fish to spin and die continues, experts are taking an unprecedented step to protect the critically endangered ray.

Following decades of overfishing and habitat loss, smalltooth sawfish (pictured, an animal in Florida) only remain in two populations.
PHOTOGRAPH BY SARAH STEELE CABRERA



Why are Florida fish spinning and...
NBC News



Nitrogen kills Florida sawfish--&...
Animals 24-7



Fish along the Florida Keys are...
National Geographic



Florida Keys' Mysterious Spinning...
YouTube



Sawfish are spinning, and dying, in...
Fox 5 San Diego



SWFL scientists work to find out...
YouTube



Fish along the Florida Keys are...
National Geographic



Florida fish are 'spinning, whirling'...
USA Today



"Spinning fish" and endangered...
Chris Malinowski



Fish are spinning to death in the...
National Geographic



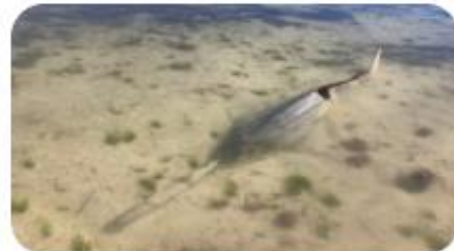
Florida Fish "Spinning Disease"...
Water Wire



Once again new accounts of...
Instagram



Report: Scientists figure out a...
WTSP



Mystery Illness Plagues Florida's...
Frost Science Museum



Smalltooth Sawfish spinning
National Geographic



Scientists Know Why Endangered...
BroBible



Fish spinning, thrashing themselves...
NewsNation



More than 30 species of fish are...
Facebook



Critically Endangered Sawfish...
The New York Times



Scientists baffled over hundreds o...
Good Morning America



Sawfish Are Endangered
Respect • Release • Report

Sawfish are protected by State and Federal laws: It is illegal to harm, harvest, or handle sawfish

You Can Help Save Smalltooth Sawfish



Florida Keys Spinning Fish & Sawfish Mortality Event

Unprecedented Sawfish mortalities beginning Fall, 2023

Impact

- 80+ species affected
- **64 Smalltooth Sawfish (*Pristis pectinata*) deaths**

Suspected Cause

- HAB toxins (i.e., *Gambierdiscus*) are the leading cause
- Multiple algal toxins found in fish tissue, still under investigation

Key Unknowns

- No definitive cause confirmed
 - Mechanism connecting detected algal toxins to neurological symptoms not yet confirmed
- Usual suspects ruled out
- Likely multifactorial
 - Record marine heatwave (>100°F, 2023), algal toxins, water quality, coastal development





Florida Keys Spinning Fish & Sawfish Mortality Event

Physiological Questions:

1. What is the impact of this “spinning fish” event on affected animals' health?
 1. Health biomarkers?
2. Once an animal is symptomatic and in care, does its physiological state recover over time — and if so, how?



Sawfish Blood Physiology- Oxidative Stress Analysis

1. What is the impact of this “spinning fish” event on affected animals' health?

- Oxidative stress = imbalance between unstable molecules (free radicals) & antioxidant defenses
- Do oxidative stress markers differ between symptomatic (n=11) and non-symptomatic (n=7) animals?
 - Collection period = 24 March 2024 – 19 June 2024

Four enzymatic/molecular markers measured from plasma:

ROS/RNS (μM)

Direct measure of oxidative load

SOD (U/mL)

First-line radical scavenger

GPX (nmol/min/mL)

Primary enzymatic antioxidant defence

GST (nmol/min/mL)

Phase II detoxification enzyme

The Antioxidant Defense Cascade



$O_2^{\bullet-}$
(superoxide)

- **Free radicals** = molecules containing unpaired electrons that cause the molecule to become highly reactive
- **ROS**, such as superoxide radical ($O_2^{\bullet-}$) and hydrogen peroxide (H_2O_2)
 - Form continuously during metabolism
 - in excess during stress, hypoxia, inflammation, or disease
 - damage lipids, proteins, and DNA

The Antioxidant Defense Cascade



- **Antioxidant enzymes** act in sequence to defuse this damage:
- **SOD** acts first on the superoxide radical

The Antioxidant Defense Cascade



- **GPx** and **GST** act downstream to neutralise the resulting peroxides

The Antioxidant Defense Cascade



- **Measuring all four together** captures both the oxidative load (**ROS**) and the body's capacity to manage it (**SOD**, **GPx**, **GST**)

Oxidative Damage

oxygen failure → oxidative burst → free radical damage → cell death

Hypoxia / Anoxia

- Stress or disease impairs gill ventilation → anaerobic metabolism activates
- Exhaustive stress and oxygen deprivation cause ROS overproduction
- Irreversible damage, release of cell death signals



Oxidative Damage

oxygen failure → oxidative burst → free radical damage → cell death

Contaminants (e.g., heavy metals)

- Generate ROS and induce antioxidant defenses
- e.g. negative GPX–THg correlation; positive ROS–GPX correlation in Goliath Grouper



Oxidative Damage

oxygen failure → oxidative burst → free radical damage → cell death

Environmental

- Temperature, salinity, and dissolved oxygen imbalances disrupt ROS production/elimination
- e.g. salinity increase → ROS↑, GPX↓ (Snook, Sheephead)

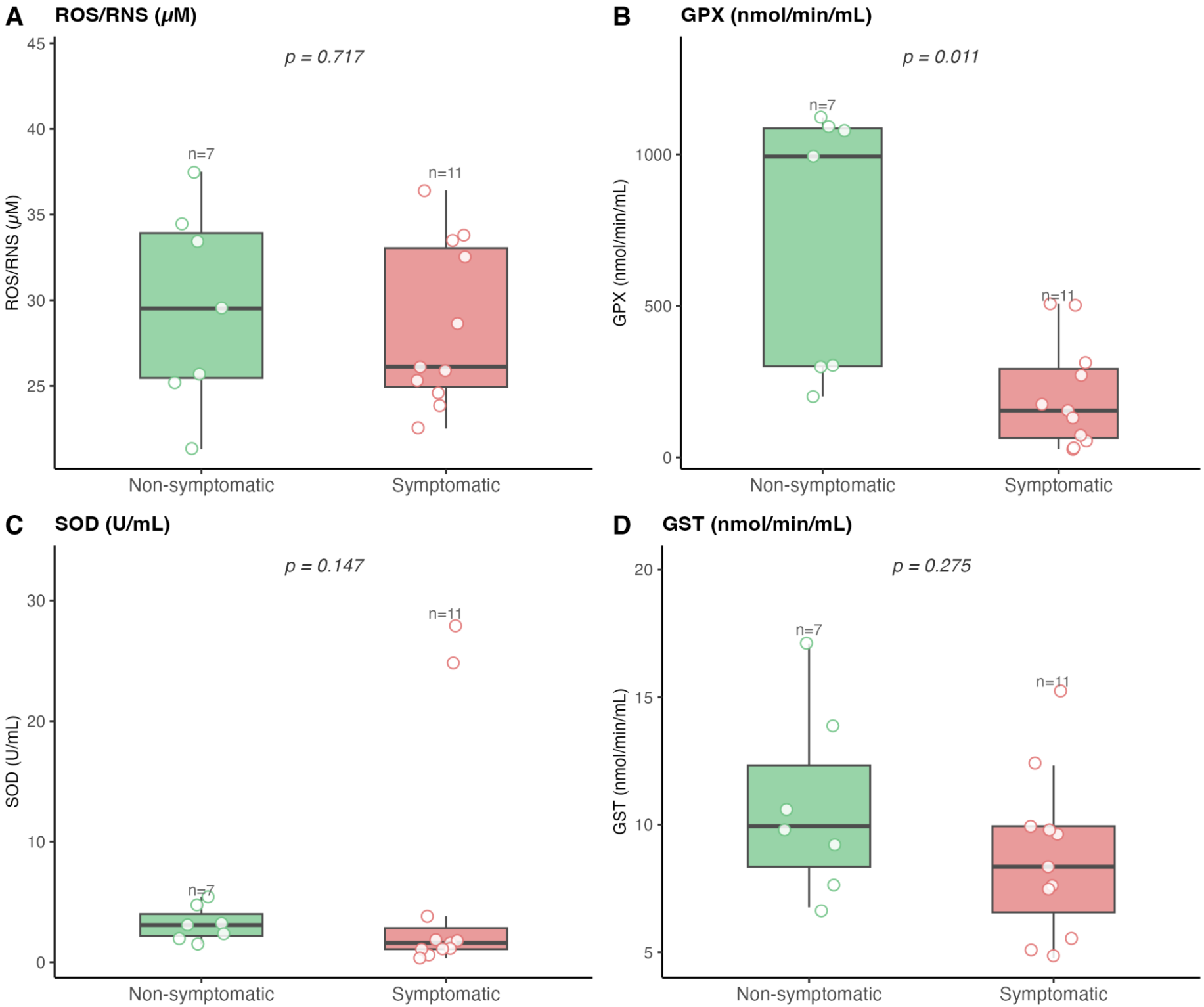


Main Results — Oxidative Stress Markers

$n = 18$ | Symptomatic ($n=11$) vs Non-symptomatic ($n=7$)



Sawfish Blood Oxidative Stress — Symptomatic vs Non-symptomatic
(Wilcoxon rank-sum; first measure only for repeated-measure individuals)



GPX — Primary Finding

993

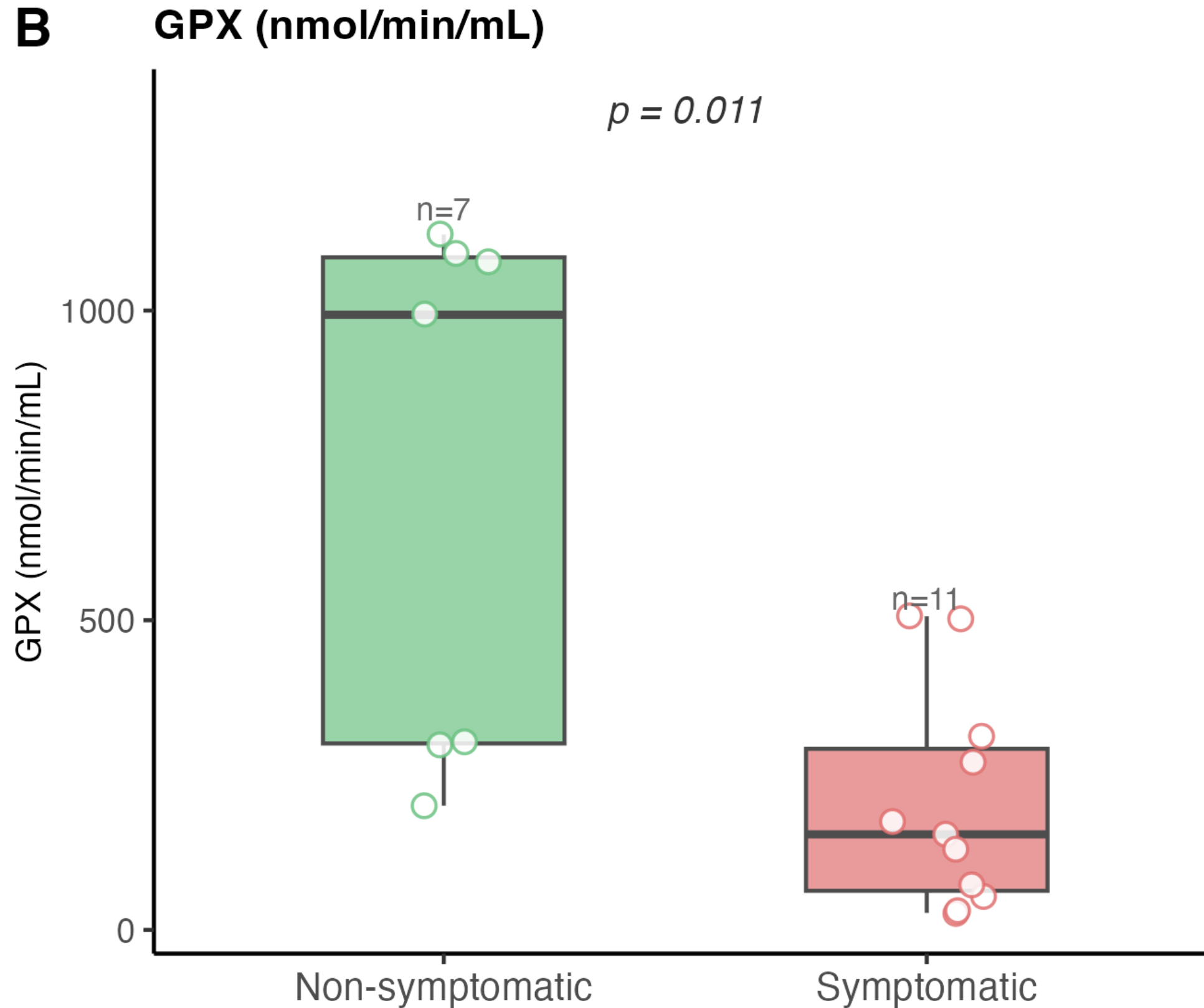


154

nmol/min/mL (medians)

Main Results — Oxidative Stress Markers

$n = 18$ | Symptomatic ($n=11$) vs Non-symptomatic ($n=7$)



GPX — Primary Finding

993



154

nmol/min/mL (medians)

Wilcoxon rank-sum

$p = 0.011$ | ~6× lower

GLM (log1p, Gaussian)

$p = 0.005$ | 40% deviance

Predictors tested

Sex, PCL, days since capture, symptomatic status

Best model selected

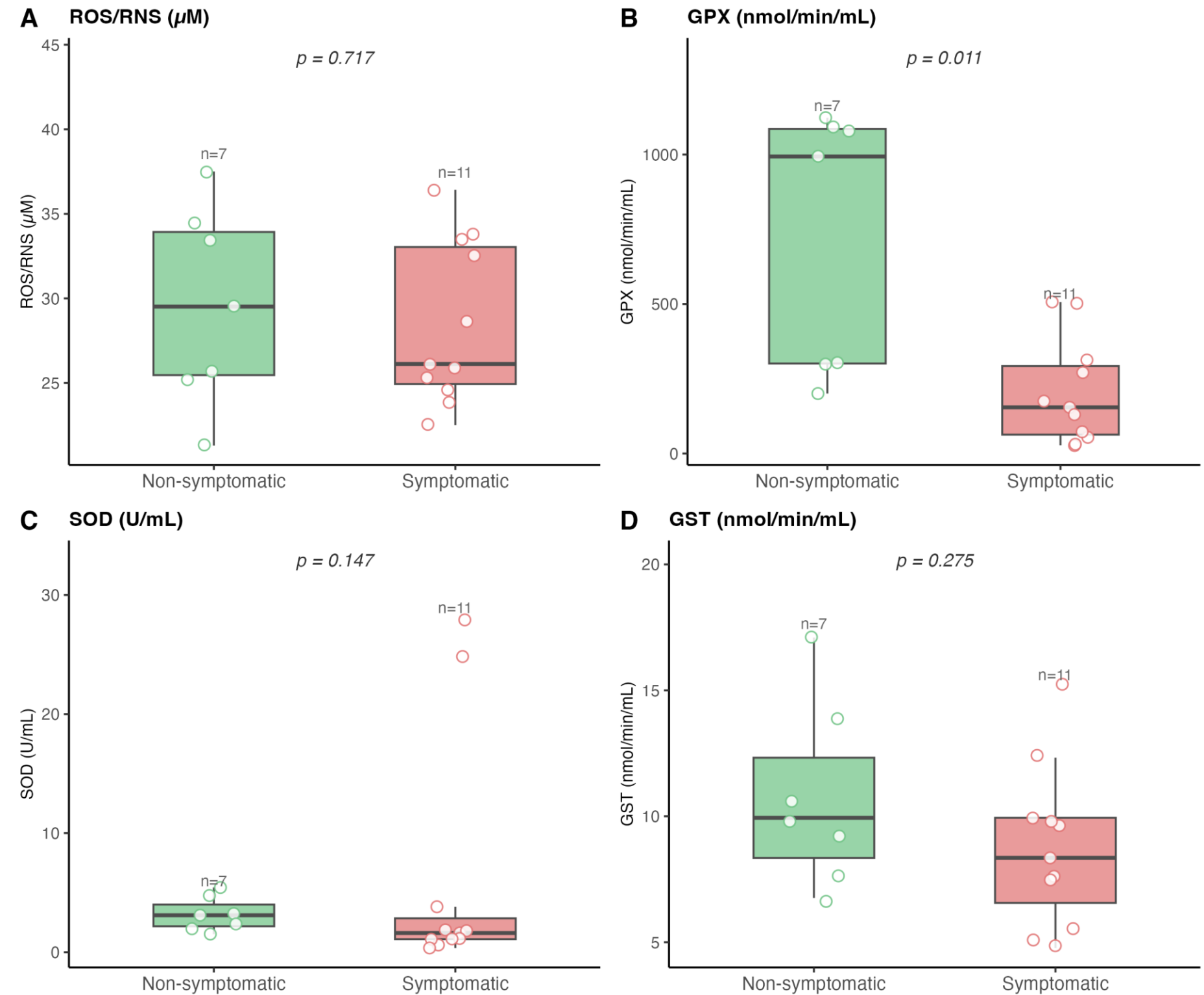
Symptomatic status only

Main Results — Oxidative Stress Markers

$n = 18$ | Symptomatic ($n=11$) vs Non-symptomatic ($n=7$)



Sawfish Blood Oxidative Stress — Symptomatic vs Non-symptomatic
(Wilcoxon rank-sum; first measure only for repeated-measure individuals)



GPX — Primary Finding

993 → 154

nmol/min/mL (medians)

Wilcoxon rank-sum

$p = 0.011$ | $\sim 6\times$ lower

GLM (log1p, Gaussian)

$p = 0.005$ | 40% deviance

Predictors tested

Sex, PCL, days since capture, symptomatic status

Best model selected

Symptomatic status only — size, sex, and date not retained

GST — calendar-time signal, not disease

GLM: days since capture only predictor (AIC wt = 0.99, $p < 0.001$) | GST rises as the event progresses from late March through May 2024 regardless of disease status.

ROS/RNS Wilcoxon $p = 0.717$ | SOD excluded (hemolysis artifact)

Discussion — What the Results Tell Us



↓ GPX depletion = systemic antioxidant failure

- The antioxidant system is overwhelmed
 - sustained high oxidative load
 - the animal can no longer neutralize ROS
- Depletion, not elevation, is the severe-stress marker
- The cause of oxidative stress in these animals is unknown
 - may reflect toxin exposure, systemic inflammation, neurological burden, or a combination

Discussion — What the Results Tell Us



↓ GPX depletion = systemic antioxidant failure

- The antioxidant system is overwhelmed
 - sustained high oxidative load
 - the animal can no longer neutralize ROS
- Depletion, not elevation, is the severe-stress marker
- The cause of oxidative stress in these animals is unknown
 - may reflect toxin exposure, systemic inflammation, neurological burden, or a combination

≈ GST tracks the event, not the individual

Rising GST across ALL animals with calendar time suggests a shared population-level exposure — independent of individual disease status

- potentially masking a disease-related signal

Discussion — What the Results Tell Us



↓ GPX depletion = systemic antioxidant failure

- The antioxidant system is overwhelmed
 - sustained high oxidative load
 - the animal can no longer neutralize ROS
- Depletion, not elevation, is the severe-stress marker
- The cause of oxidative stress in these animals is unknown
 - may reflect toxin exposure, systemic inflammation, neurological burden, or a combination

≈ GST tracks the event, not the individual

Rising GST across ALL animals with calendar time suggests a shared population-level exposure

- potentially masking a disease-related signal

? Why wasn't ROS significant?

- Half-lives of seconds - snapshot
- GPX depletion captures the downstream burden better
 - reflects cumulative load
- All individuals likely equally exposed to stressor – GPx difference based on chronic vs acute exposure?

High intra-group variability

- masks group differences
- may emerge at larger n



Florida Keys Spinning Fish & Sawfish Mortality Event

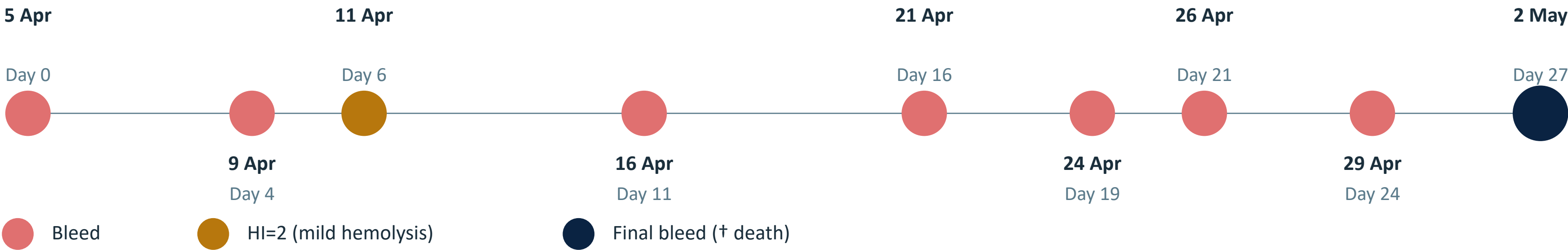
Physiological Questions:

1. What is the impact of this “spinning fish” event on affected animals' health?
2. Once an animal is symptomatic and in care, does its physiological state recover over time — and if so, how?
 - Do oxidative stress markers change over time during disease or rehabilitation?

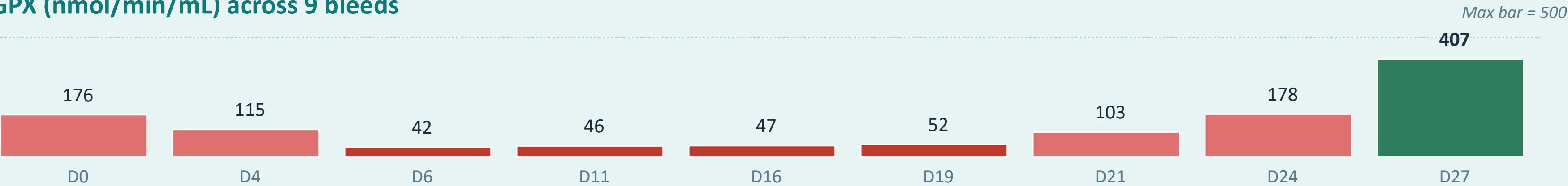
Keys-3 (MML Sawfish 5) — Serial Bleed Overview



- Keys-3 (~11' immature male) rescued after displaying the abnormal spinning behaviour characteristic of the mortality event
- Monitored in rehabilitation at Mote Marine Laboratory with serial blood samples taken across 27 days
- Despite showing signs of partial biochemical recovery, the animal died following the final (9th) bleed on 2 May 2024.



GPX (nmol/min/mL) across 9 bleeds

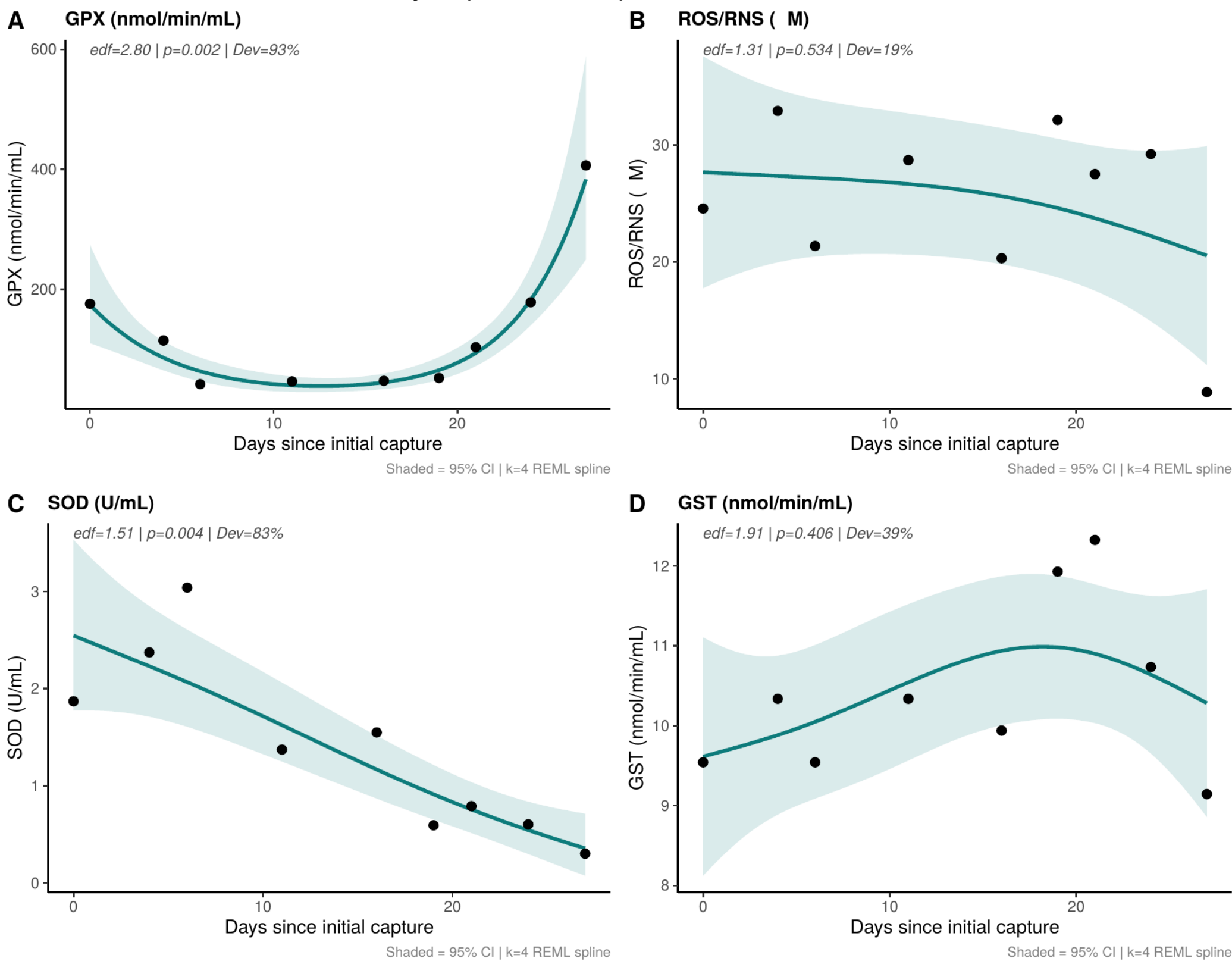


Non-symptomatic group median GPX = 993 nmol/min/mL | Keys-3 GPX never exceeded 407 across all 27 days in care, remaining well below healthy reference

Keys-3 — Statistical Trend Analysis



Keys-3 (MML Sawfish 5) – GAM Smooth Trends



GPX — Significant U-shaped trajectory

GAM

$edf=2.80$, $p=0.002$, 93% deviance

Quadratic test

day^2 $p=0.0001$ — U-shape confirmed

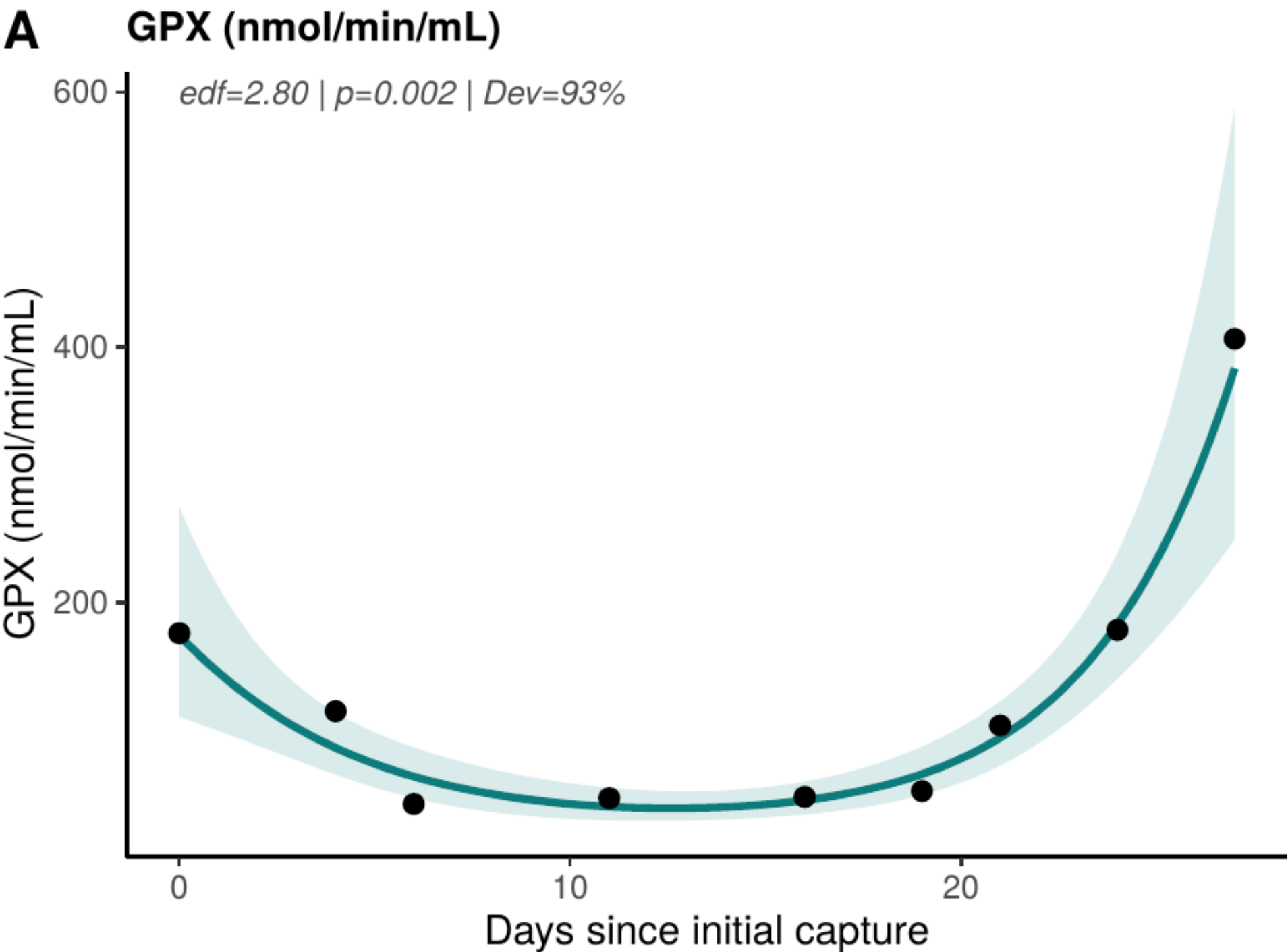
Permutation

$\rho=0.683$, $p=0.026$

Keys-3 — Statistical Trend Analysis



Keys-3 (MML Sawfish 5)



GPX — Significant U-shaped trajectory

GAM

edf=2.80, p=0.002, 93%
deviance

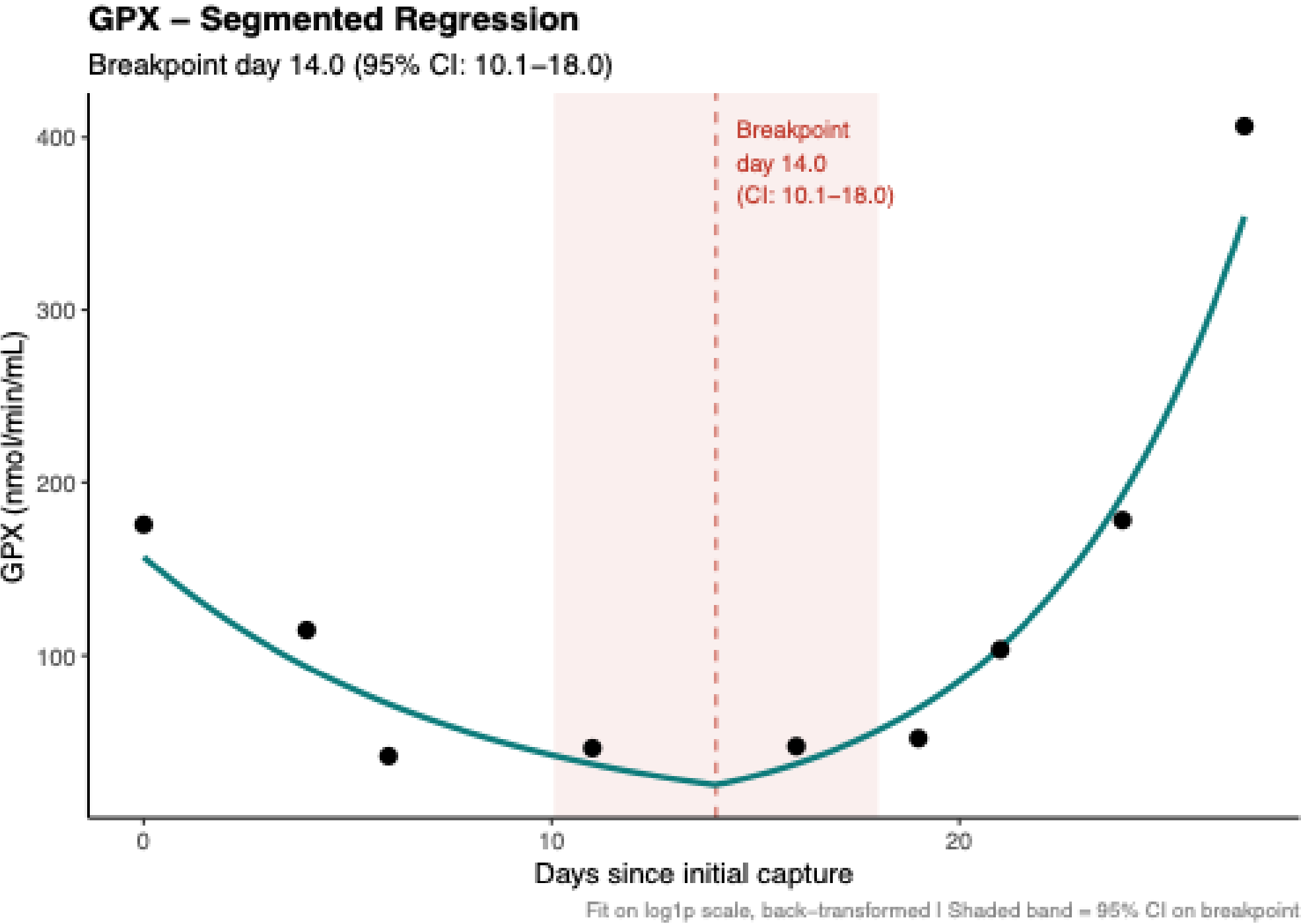
Quadratic test

day² p=0.0001 — U-shape
confirmed

Permutation

rho=0.683, p=0.026

Keys-3 — Statistical Trend Analysis



GPX — Significant U-shaped trajectory

GAM

edf=2.80, $p=0.002$, 93% deviance

Quadratic test

day² $p=0.0001$ — U-shape confirmed

Permutation

$\rho=0.683$, $p=0.026$

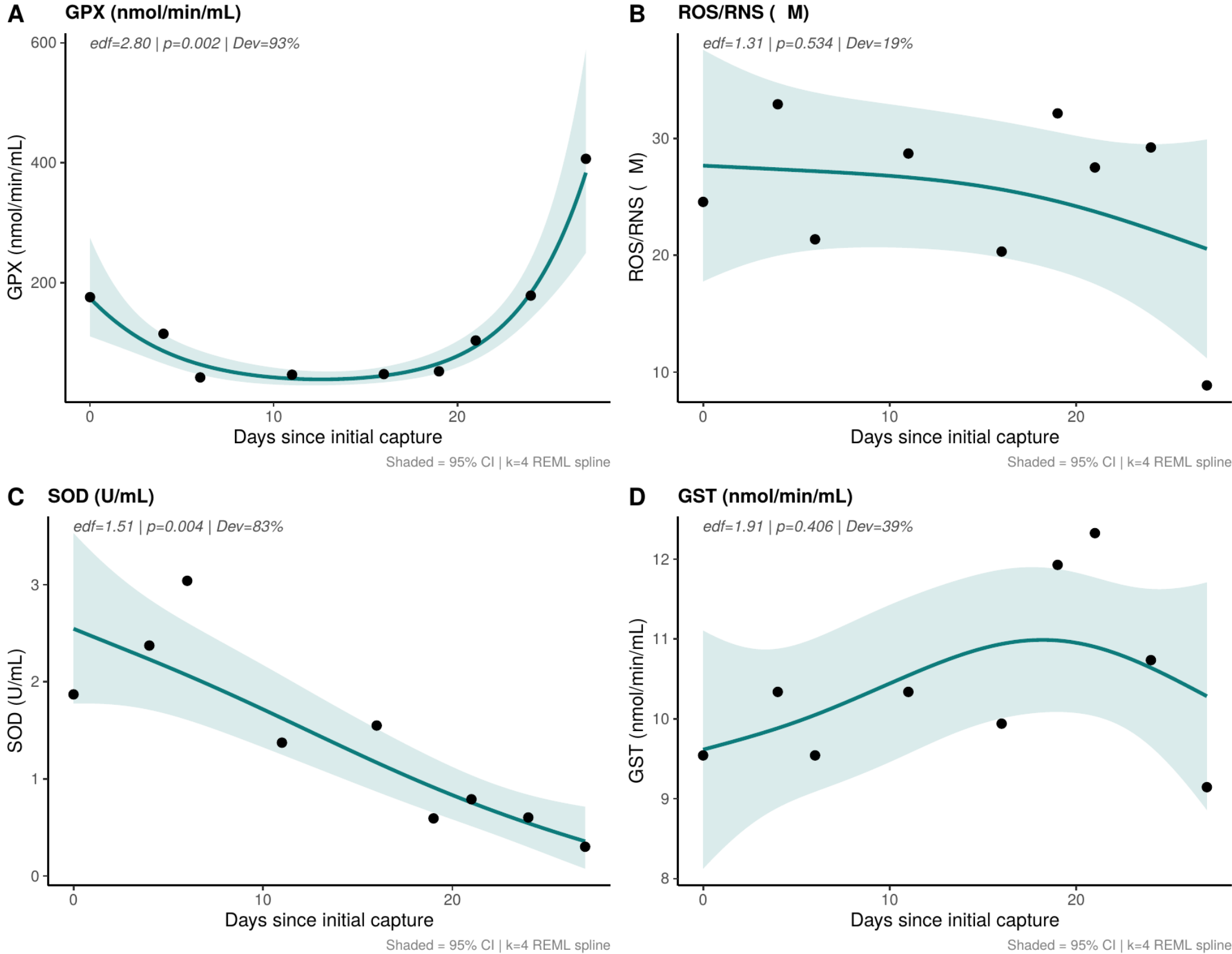
Segmented reg.

Breakpoint day 14 (CI: 10–18)

Keys-3 — Statistical Trend Analysis



Keys-3 (MML Sawfish 5) – GAM Smooth Trends



GPX — Significant U-shaped trajectory

GAM edf=2.80, p=0.002, 93% deviance

Quadratic test day² p=0.0001 — U-shape confirmed

Segmented reg. Breakpoint day 14 (CI: 10–18)

Permutation rho=0.683, p=0.026

SOD — Significant decline (artifact)

GAM p=0.004 | Peaked on HI=2 bleed (day 6) then declined — hemolysis clearance, not biology

ROS/RNS and GST — No significant trends

ROS/RNS: GAM p=0.534 | GST: GAM p=0.406 | Both non-significant

Keys-3 — Interpretation and Key Takeaways

What the serial bleed trajectory tells us | In the context of a non-surviving symptomatic animal



1 Acute depletion (days 0–6)

2 Plateau phase (days 11–21)

3 Partial recovery (days 21–27)

Key takeaways

- GPX recovery did not translate to survival — antioxidant system improvement was underway but irreversible damage had already occurred
- Plateau phase suggests the antioxidant system was overwhelmed for an extended period
 - may have allowed oxidative damage to accumulate beyond a **point of no return**
- GST rise over time is consistent with the population-level temporal signal seen in the population-level data
- Keys-3 results are statistically significant and directly consistent with the population-level finding:

Conclusions



Possible explanations for GPX depletion

- HAB neurotoxins may disrupt ion channels and mitochondrial function, generating ROS as a downstream consequence
- Sustained spinning behaviour imposes metabolic demand and may impair gill ventilation
- Systemic inflammation from any trigger could suppress GPX
- **These mechanisms are not mutually exclusive and the causative agent remains unconfirmed**

Conclusions



Possible explanations for GPX depletion

- HAB neurotoxins may disrupt ion channels and mitochondrial function, generating ROS as a downstream consequence
- Sustained spinning behaviour imposes metabolic demand and may impair gill ventilation
- Systemic inflammation from any trigger could suppress GPX
- **These mechanisms are not mutually exclusive and the causative agent remains unconfirmed**

Significance of this study

- **First blood-based antioxidant enzyme profile for any sawfish species**
- GPX depletion may serve as a biomarker of disease severity in future monitoring and rescue efforts

Conclusions



Possible explanations for GPX depletion

- HAB neurotoxins may disrupt ion channels and mitochondrial function, generating ROS as a downstream consequence
- Sustained spinning behaviour imposes metabolic demand and may impair gill ventilation
- Systemic inflammation from any trigger could suppress GPX
- **These mechanisms are not mutually exclusive and the causative agent remains unconfirmed**

Significance of this study

- **First blood-based antioxidant enzyme profile for any sawfish species**
- GPX depletion may serve as a biomarker of disease severity in future monitoring and rescue efforts

Future directions

- Reference values for healthy animals
- Higher N of symptomatic/non-symptomatic
- Sharks – before/after, inside/outside

Thank You Symposium Sponsors!



save our seas
foundation



All activities performed under
authorization and guidance of
NOAA Fisheries Emergency
Section 7 Consultation
#SERO-2024-00402

and

ESA Section 10 permits
to Gregg Poulakis,
Tonya Wiley, John Carlson, and
Colin Simpfendorfer

