Fisheries and Oceans Canada | Pêches et Océans Canada

Black-swan events in fisheries

Sean C. Anderson

sean.anderson@dfo-mpo.gc.ca | @sean_anderson

PICES | October 2019

Trump has a better chance of cameoing in another "Home Alone" movie with Macaulay Culkin — or playing in the NBA Finals — than winning the Republican nomination.

-Harry Enten
June 2015

FiveThirtyEight

SECOND EDITION

WITH A NEW SECTION: "ON ROBUSTNESS & FRAGILITY"

NEW YORK TIMES BESTSELLER

THE BLACK SWAN

The Impact of the HIGHLY IMPROBABLE

"The most prophetic voice of all."
—*GQ*

Nassim Nicholas Taleb

Fair, slightly cooler tonight. Friday fair. Fresh south-west to west winds.

BROOKLYN DAILY EAGLE

And Complete Long Island News

LATE NEWS

WALL STREET 1:15 PRICES ★★

89th YEAR—No. 295. ★ NEW YORK CITY, THURSDAY, OCTOBER 24, 1929. ★ 32 PAGES THREE CENTS

WALL ST. IN PANIC AS STOCKS CRASH

Attempt Made to Kill Italy's Crown Prince

ASSASSIN CAUGHT IN BRUSSELS MOB; PRINCE UNHURT

Royal Suitor Was About to Lay Wreath on Unknown Soldiers' Tomb.

Princess, Deeply Moved, Falls Into Fiance's Arms and Kisses Him

ATTEMPT MADE ON LIFE

Crown Prince Humbert.

Hollywood Fire Destroys Films Worth Millions

Consolidated Studios Are Swept by Flames Fatal to One—Master Pictures Burned Include Many New Talkie Productions.

Please Turn to Page 2

FEAR 52 PERISHED IN LAKE MICHIGAN; FERRY IS MISSING

Wreckage Picked Up Indicates Craft Went Down With All Aboard.

PIECE OF PLANE LIKE DITEMAN'S IS FOUND AT SEA

Black and Orange Wreckage Indicates Daring Flier Went to Death.

High Duty Group Gave $700,000 to Coolidge Drive

Grundy Agrees Rates Went Up Due to His Activities as Propagandist. Favors More Lobbying to 'Carry Out Voters' Wish.'

FOR MORE LOBBYISTS

By HENRY SUYDAM.

Please Turn to Page 2

STOCKS CRASH IN RUSH TO SELL; BILLIONS LOST

Morgan, Mitchell Buying Stocks in Effort to Check Rush to Unload

CARNEGIE CHARGE OF PAID ATHLETES ROUSES COLLEGES

HOOVER'S TRAIN HALTED BY AUTO PLACED ON RAILS

WARDER SOUGHT TO KEEP SEA TRIP

SOMERS NAMED AS HEAD OF NEW

A small number of black swans explain almost everything in our world.

-Nicholas Taleb, The Black Swan

Northern cod collapse, Newfoundland, 1992

Pyrosome blooms, Eastern Pacific, 2017

Big Bar Landslide, BC, 2019

Province of BC

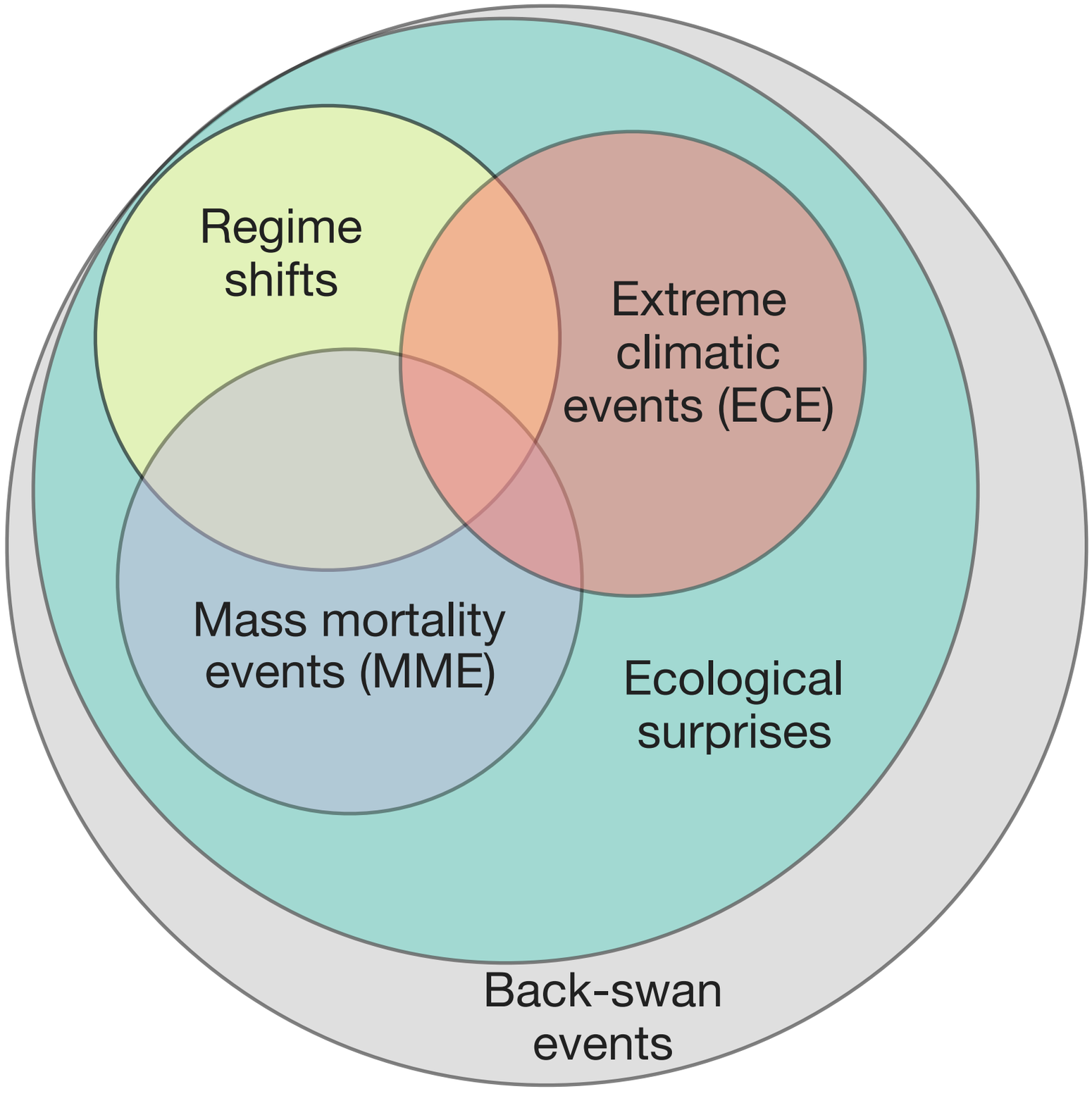
Definitions

The black swan triplet:

1. **Rarity**
2. **Extreme impact**
3. **Retrospective predictability**

Adapted from Taleb 2007

Black swans and surprise unite many fields



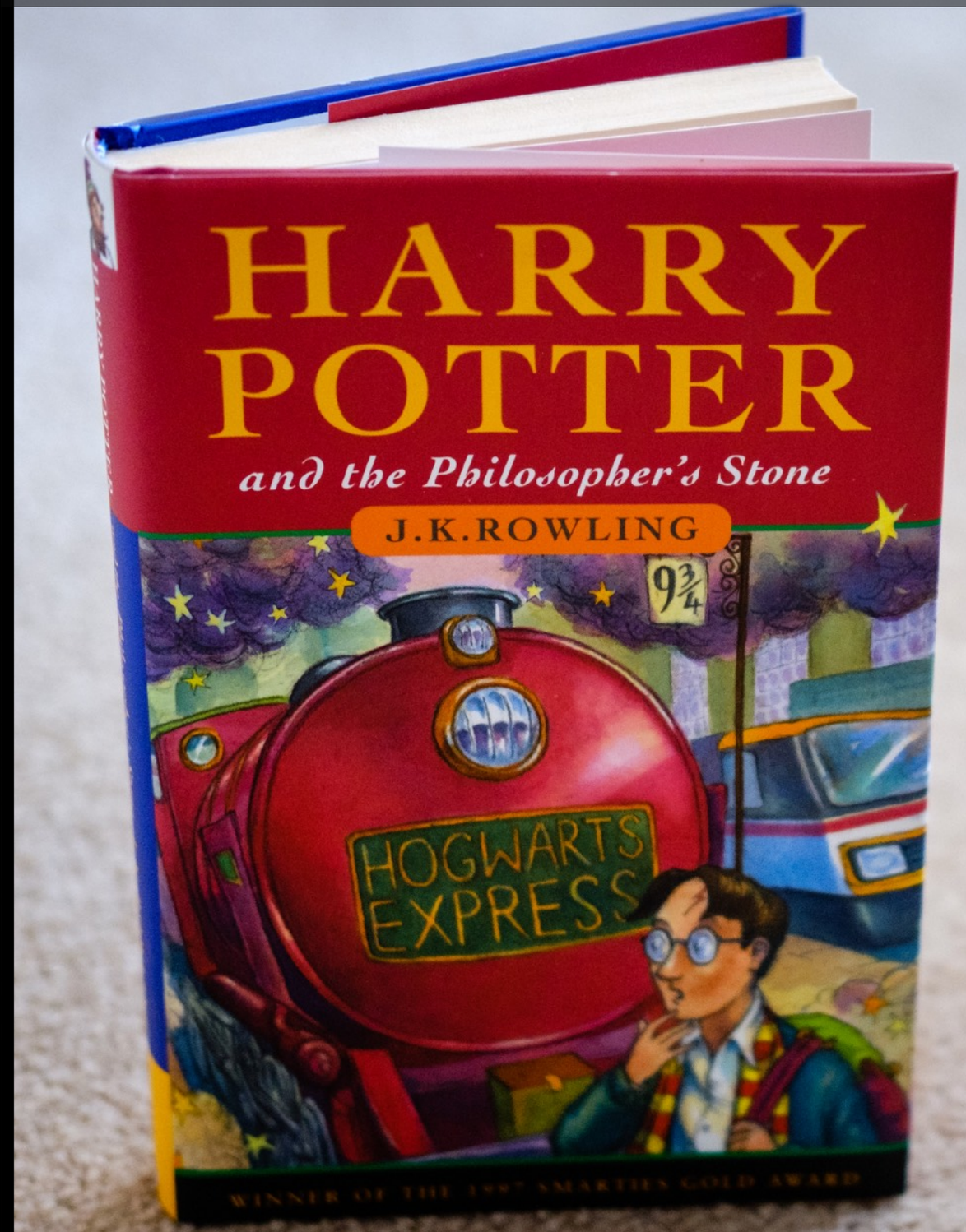
$#!+ HAPPENS

where

$#!+ HAPPENS

Non-scalable

Scalable



Salmon size

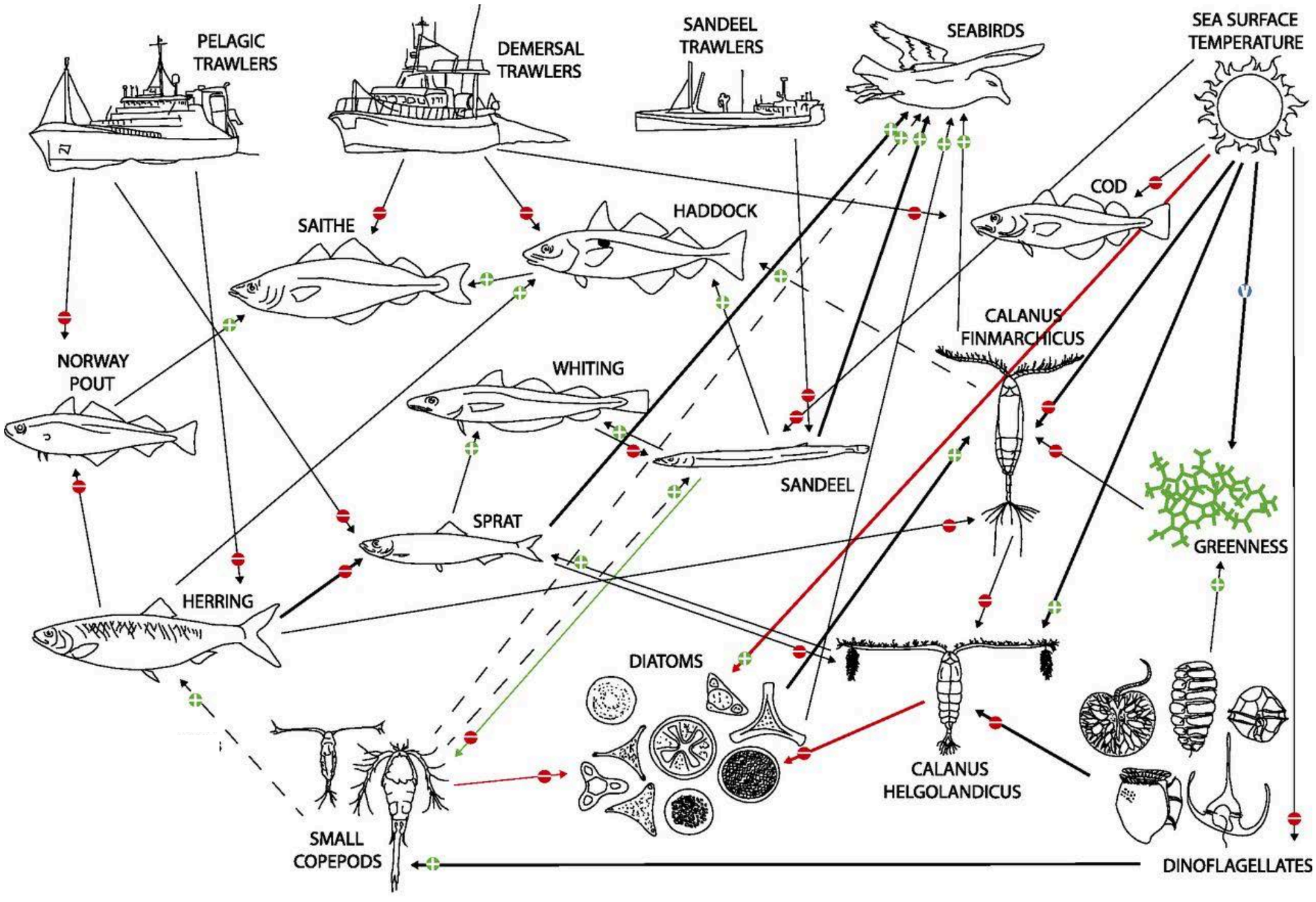
Salmon returns

Population growth

Population mortality

Why should we expect black swans for fish and fisheries?

Marine ecosystems contain an enormous number of (potentially) non-linear interactions

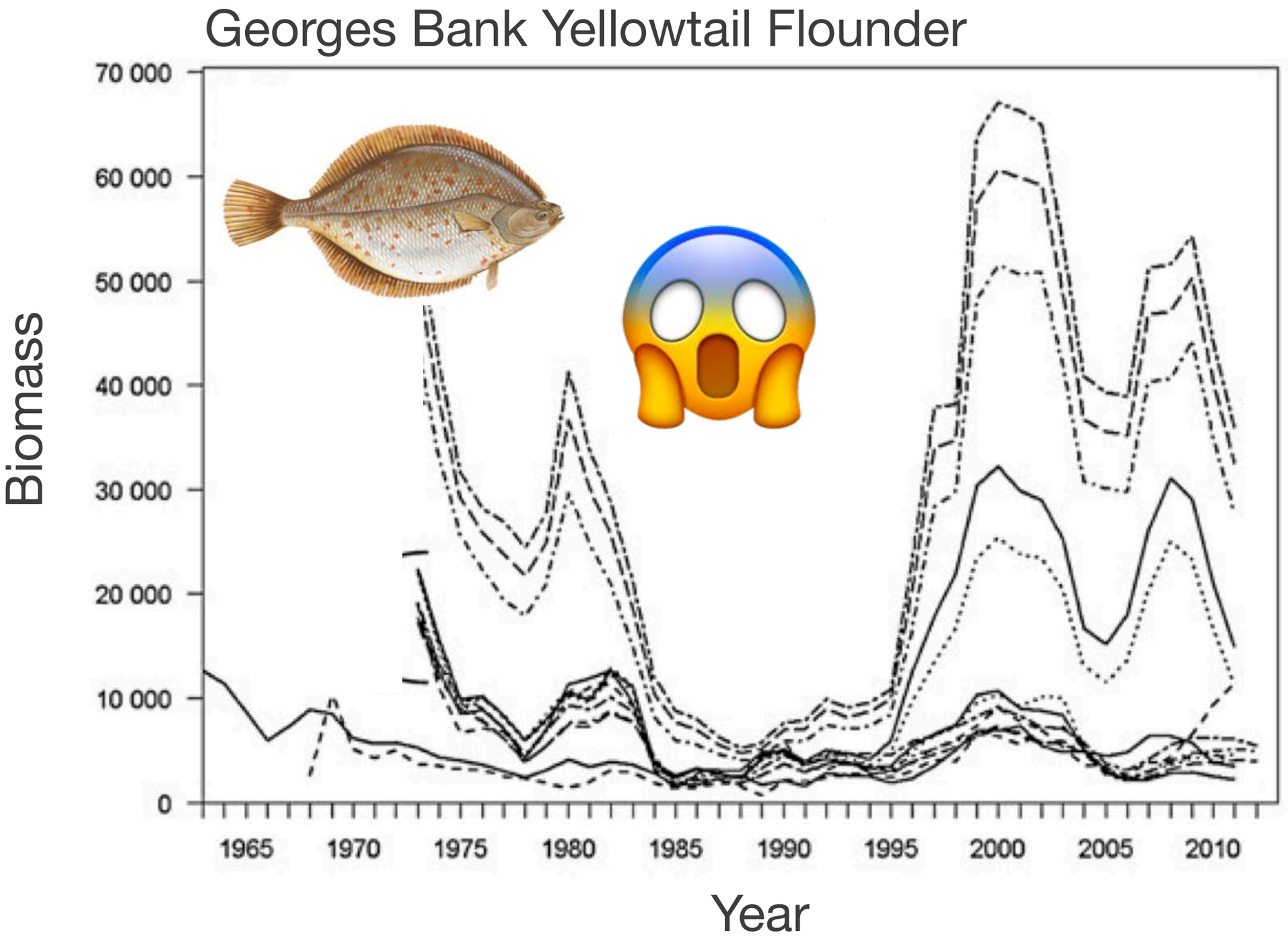


Lynam et al. 2017 PNAS

Humans magnify the consequences

Most fish populations are hard to count.
And they move.

It's easy to place too much confidence in our models



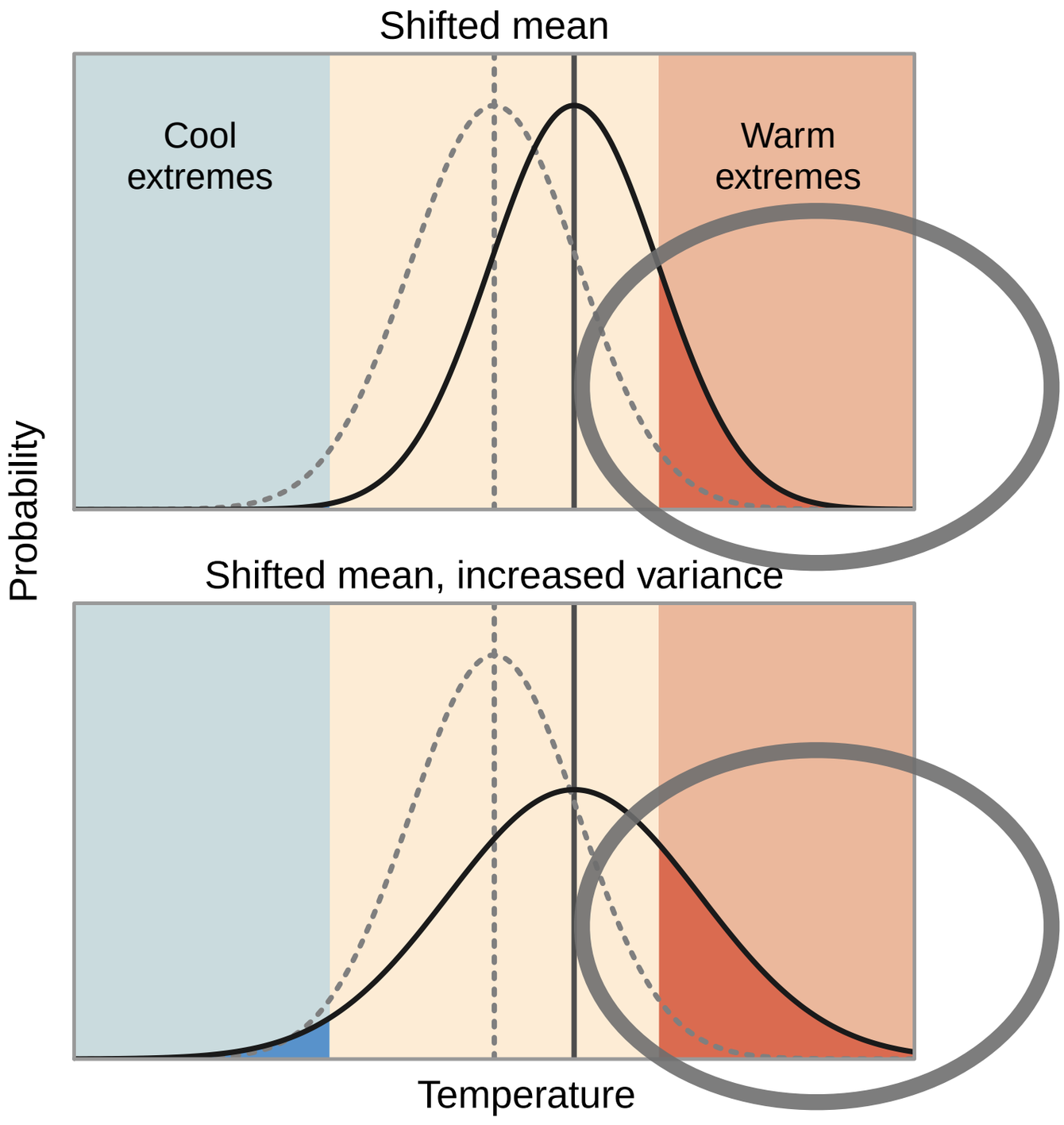
Deroba et al. 2015 ICES J. Mar. Sci.

"Ecologists study extraordinarily complex systems, they base their expectations on limited data that are frequently of short duration, and they are, after all, only human."

Doak et al. Ecology 2008

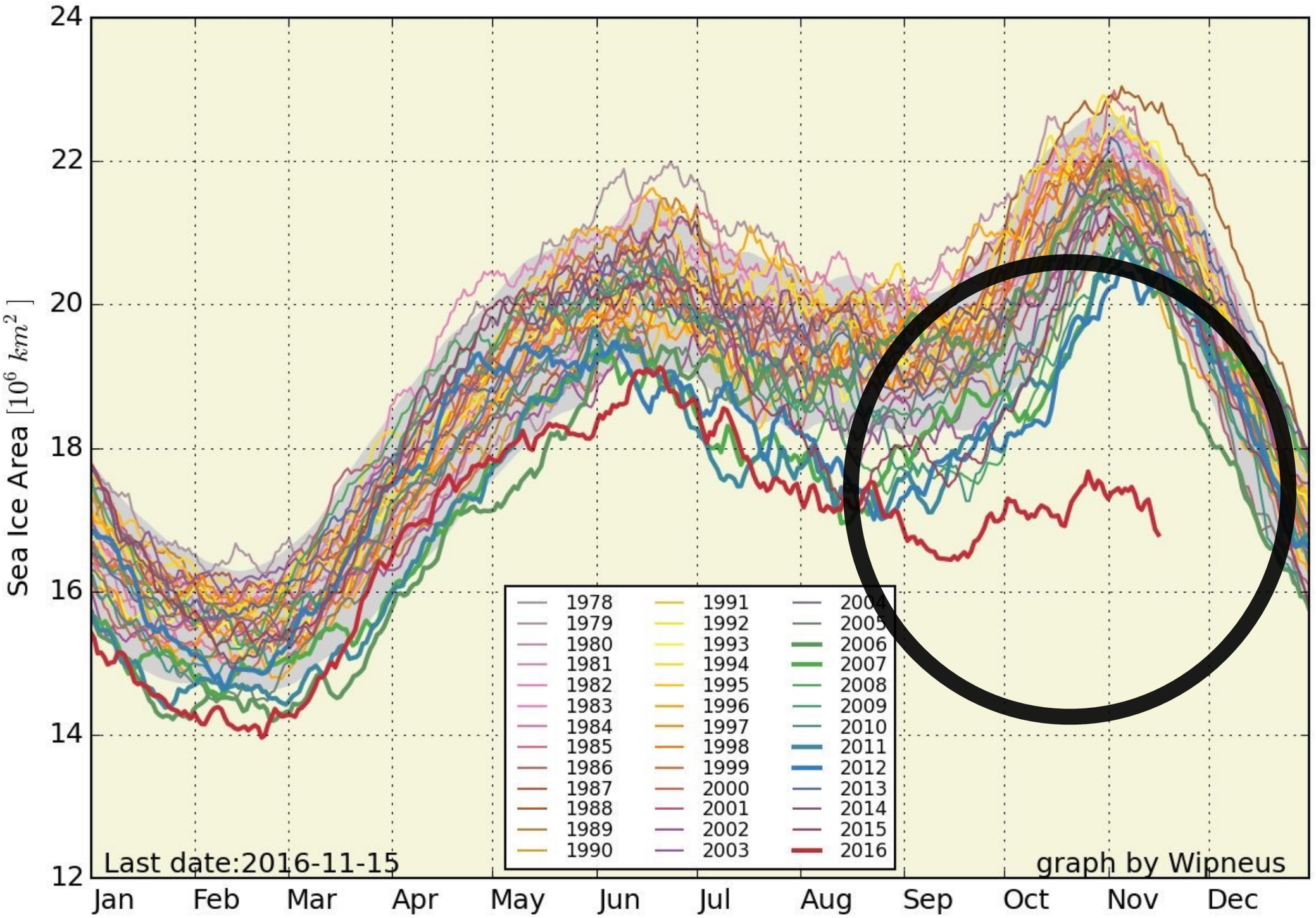
Why expect MORE surprises?

Increased climate mean + increased variance = increased extremes



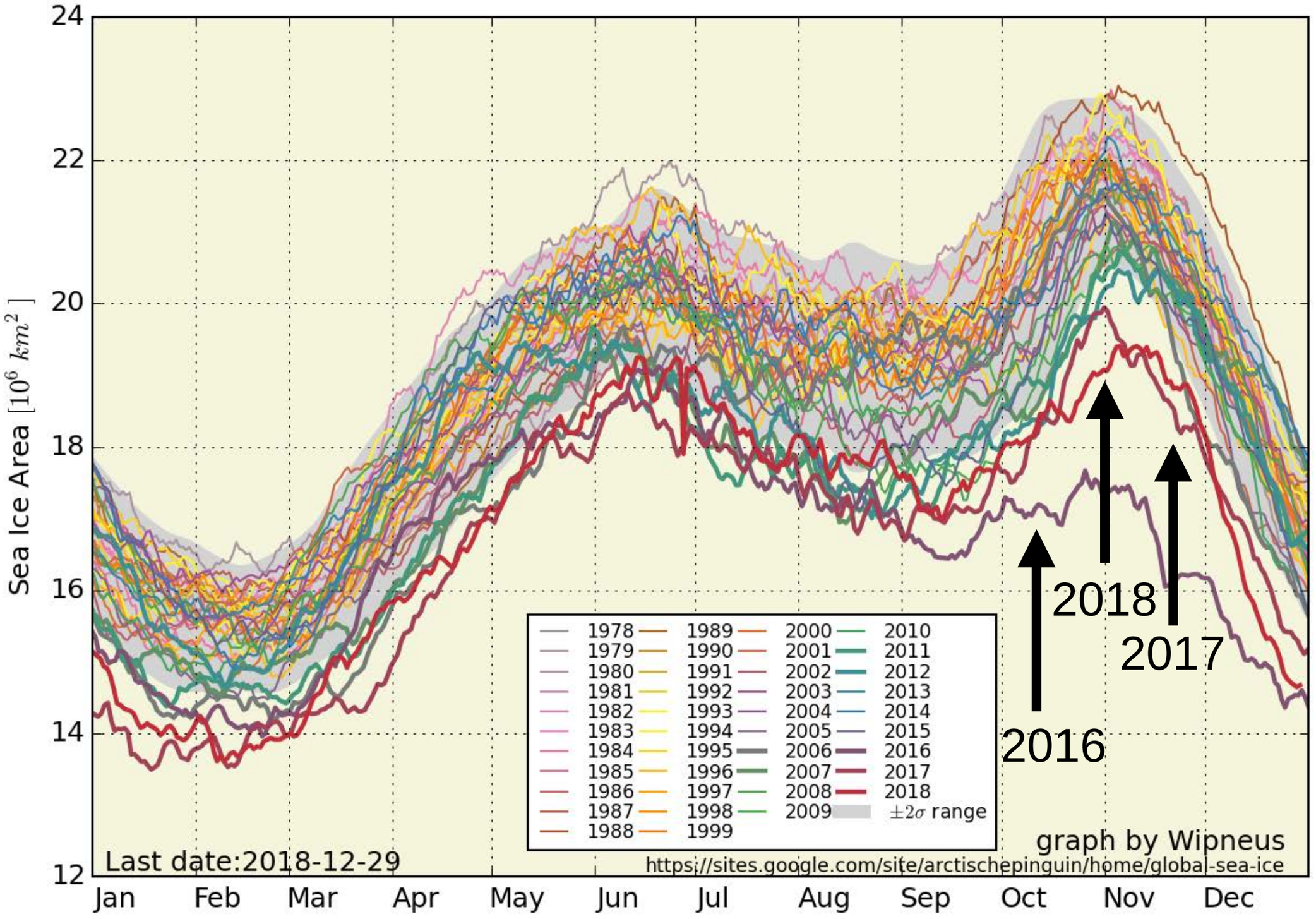
Adapted, e.g., from IPCC 2012

Global sea ice area by year: 2016



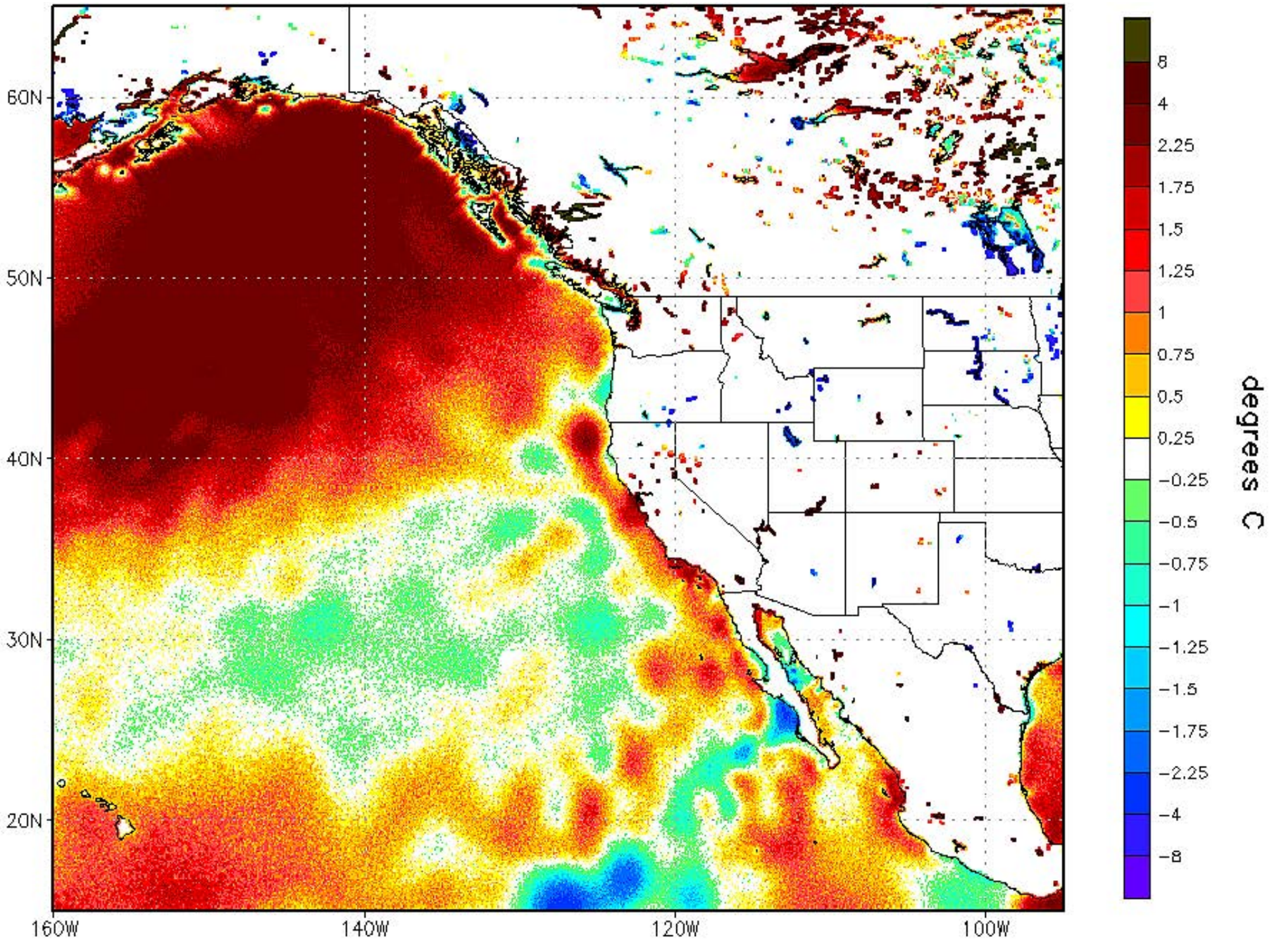
NSIDC NASA

Global sea ice area by year (with 2017, 2018)



NSIDC NASA

The 'Warm Blob' and 'Blob 2.0'



NOAA/NWS/NEP/EMC Marine Modeling and Analysis Branch

Blob 2.0 is bad sign for Gulf of Alaska groundfish

By AARON BOLTON • DEC 7, 2018

Pacific Cod on ice.

CREDIT PHOTO COURTESY OF HOLLAND DOTTS & THE ALASKA MARINE CONSERVATION COUNCIL.

Fish heavily impacted by a three-year marine heatwave in the Gulf of Alaska may be headed for round two. Commonly referred to as the blob, warmer waters between 2014 and 2017 were blamed for a dramatic decline in Pacific cod and are thought to have negatively impacted other species such as pollock.

https://www.kbbi.org/post/blob-20-bad-sign-gulf-alaska-groundfish

What is the evidence?

A survey on ecological surprise

Ecology, 89(4), 2008, pp. 952–961

UNDERSTANDING AND PREDICTING ECOLOGICAL DYNAMICS: ARE MAJOR SURPRISES INEVITABLE?

DANIEL F. DOAK,[1,11] JAMES A. ESTES,[2] BENJAMIN S. HALPERN,[3] UTE JACOB,[4] DAVID R. LINDBERG,[5] JAMES LOVVORN,[1] DANIEL H. MONSON,[6] M. TIMOTHY TINKER,[7] TERRIE M. WILLIAMS,[7] J. TIMOTHY WOOTTON,[8] IAN CARROLL,[9] MARK EMMERSON,[4] FIORENZA MICHELI,[10] AND MARK NOVAK[8]

Doak et al. 2008 Ecology

1. Have you encountered one or more “surprises” in the course of your field studies? We are defining a “surprise” as a substantial [...] change in the abundance of one or more species resulting from a previously unknown or unanticipated process of any kind...

52/58: Yes

Doak et al. 2008 Ecology

2. If so, were you able to make a [...] determination of (or at least formulate a compelling hypothesis for) the cause of the surprise?

46/58: Yes

Doak et al. 2008 Ecology

"This suggests that the factors responsible for surprises are easy to see but seldom anticipated."

Doak et al. Ecology 2008

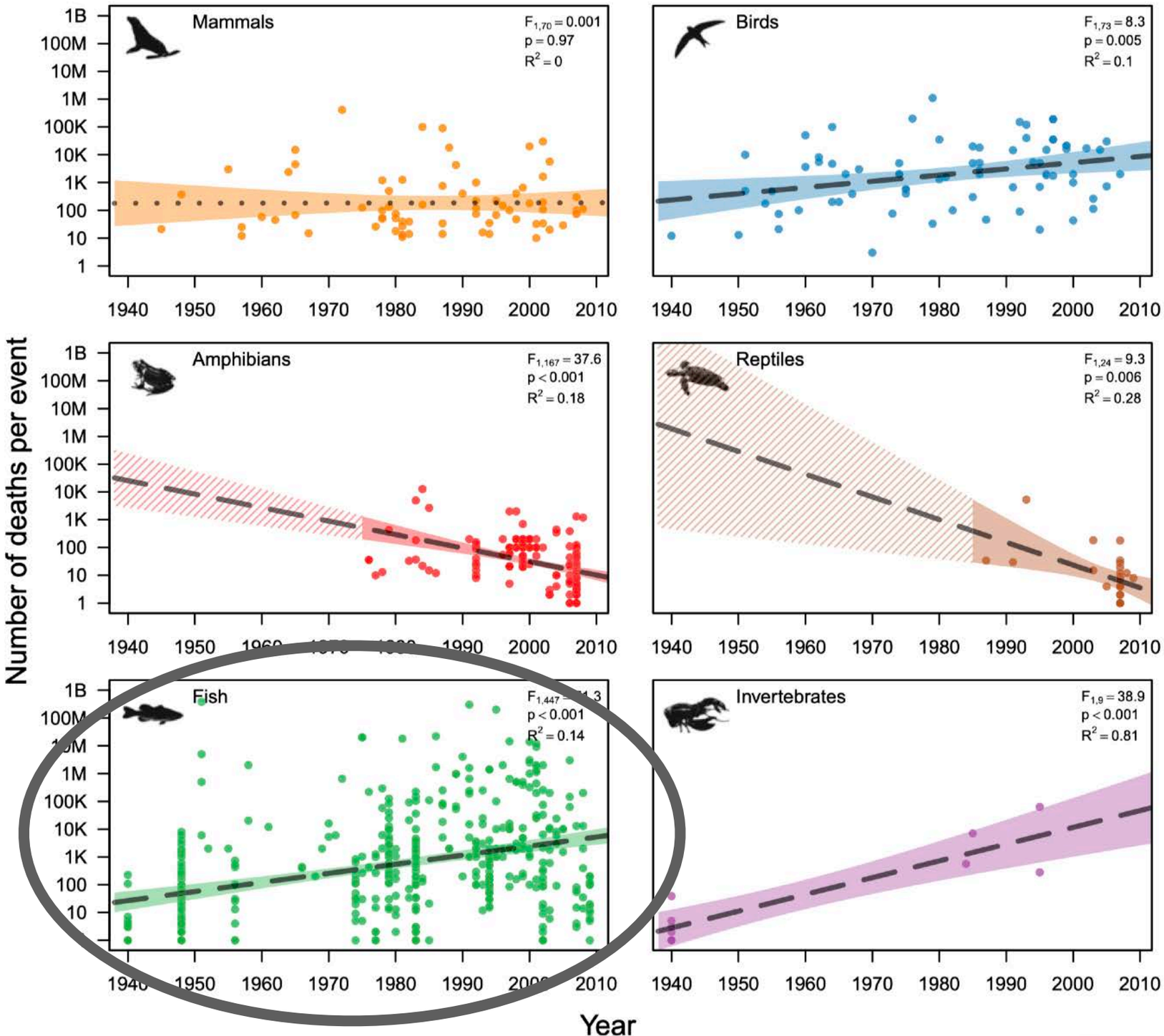
727 published accounts of mass mortality events

Recent shifts in the occurrence, cause, and magnitude of animal mass mortality events

Samuel B. Fey[a,b,1,2], Adam M. Siepielski[c,1], Sébastien Nusslé[d], Kristina Cervantes-Yoshida[d], Jason L. Hwan[d], Eric R. Huber[d], Maxfield J. Fey[b], Alessandro Catenazzi[e], and Stephanie M. Carlson[d]

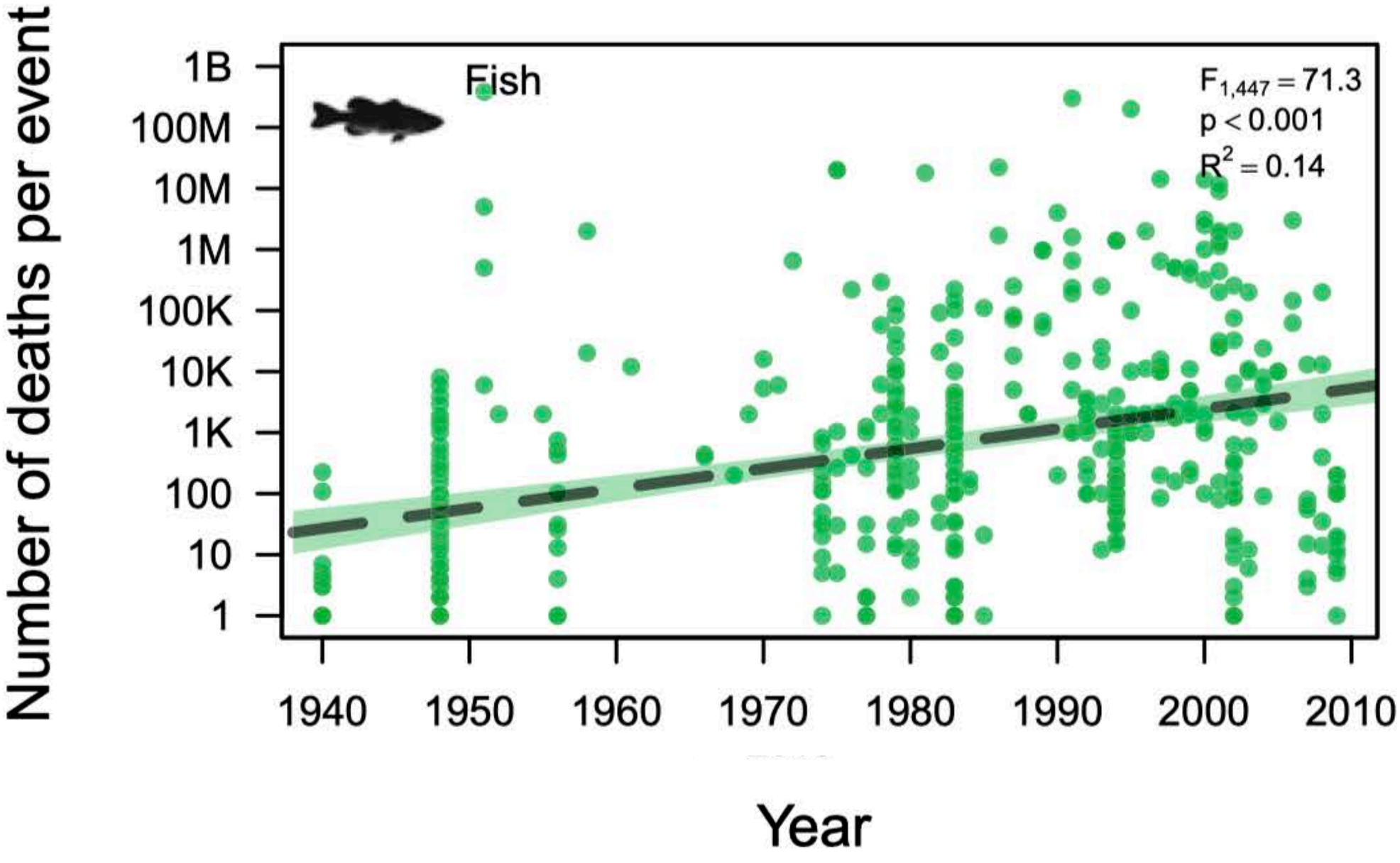
Fey et al. 2015 PNAS

There are more published fish mass mortality events than for other taxa



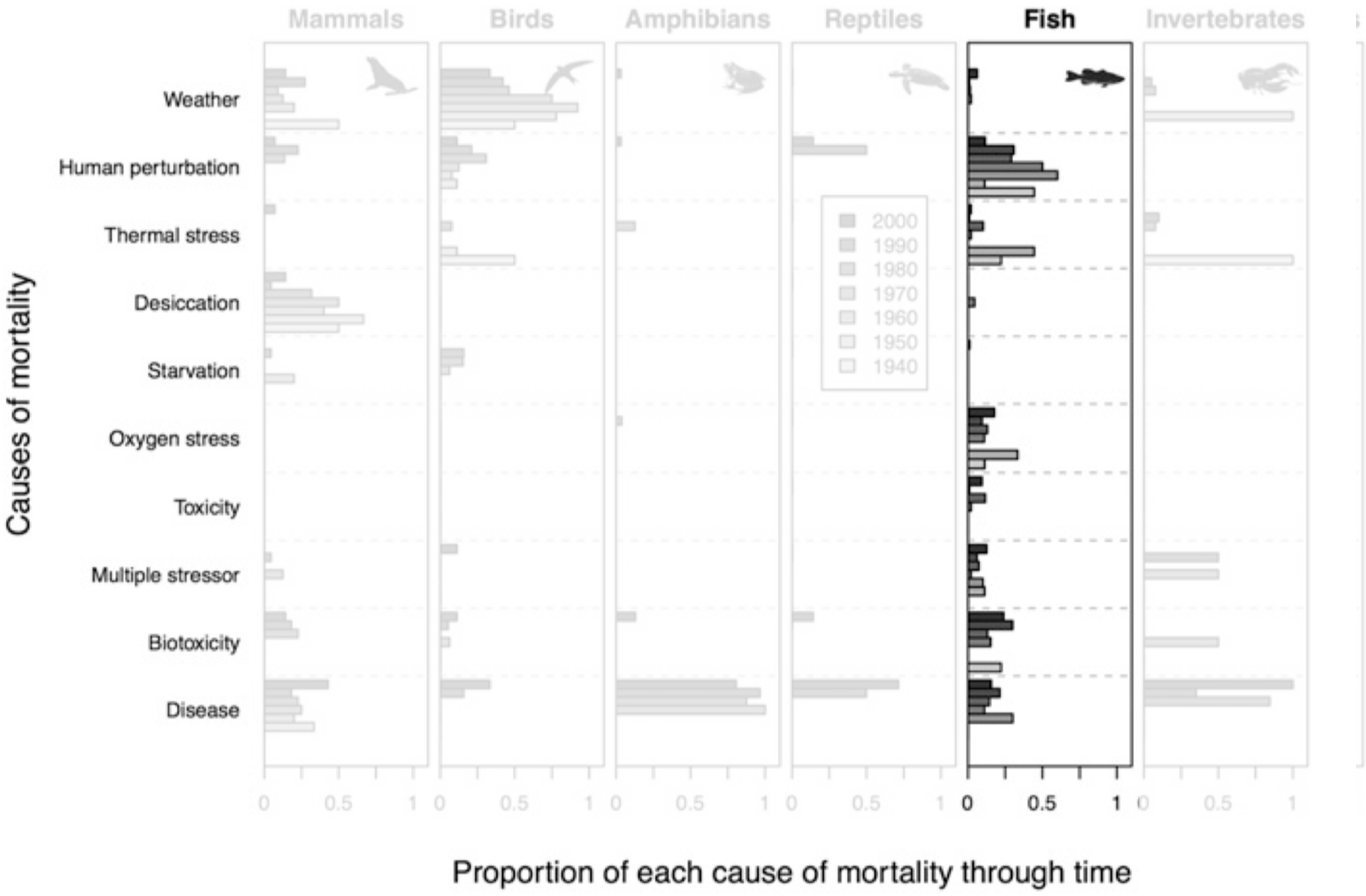
Fey et al. 2015 PNAS

The severity of fish mass mortality events may be increasing



Fey et al. 2015 PNAS

And they have many causes



Fey et al. 2015 PNAS

Searching for black swans in 609 animal abundance time series

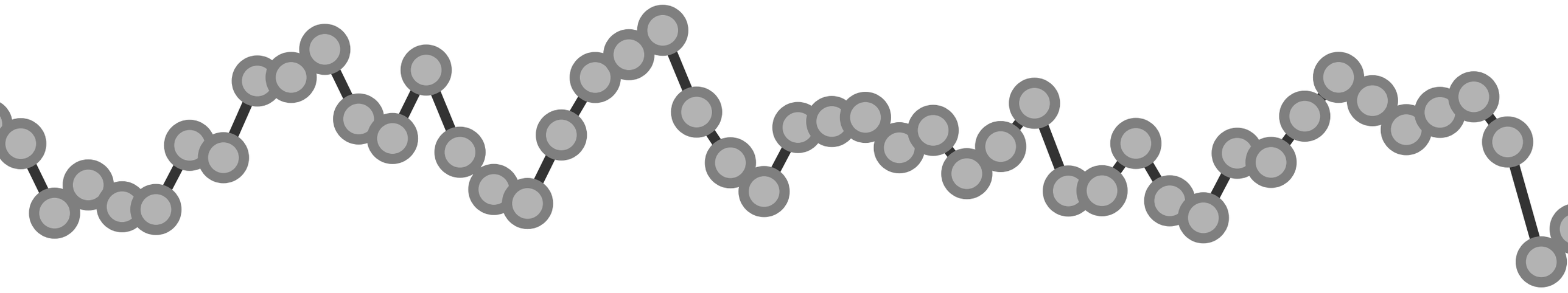
Black-swan events in animal populations

Sean C. Anderson[a,b,1], Trevor A. Branch[b], Andrew B. Cooper[c], and Nicholas K. Dulvy[a]

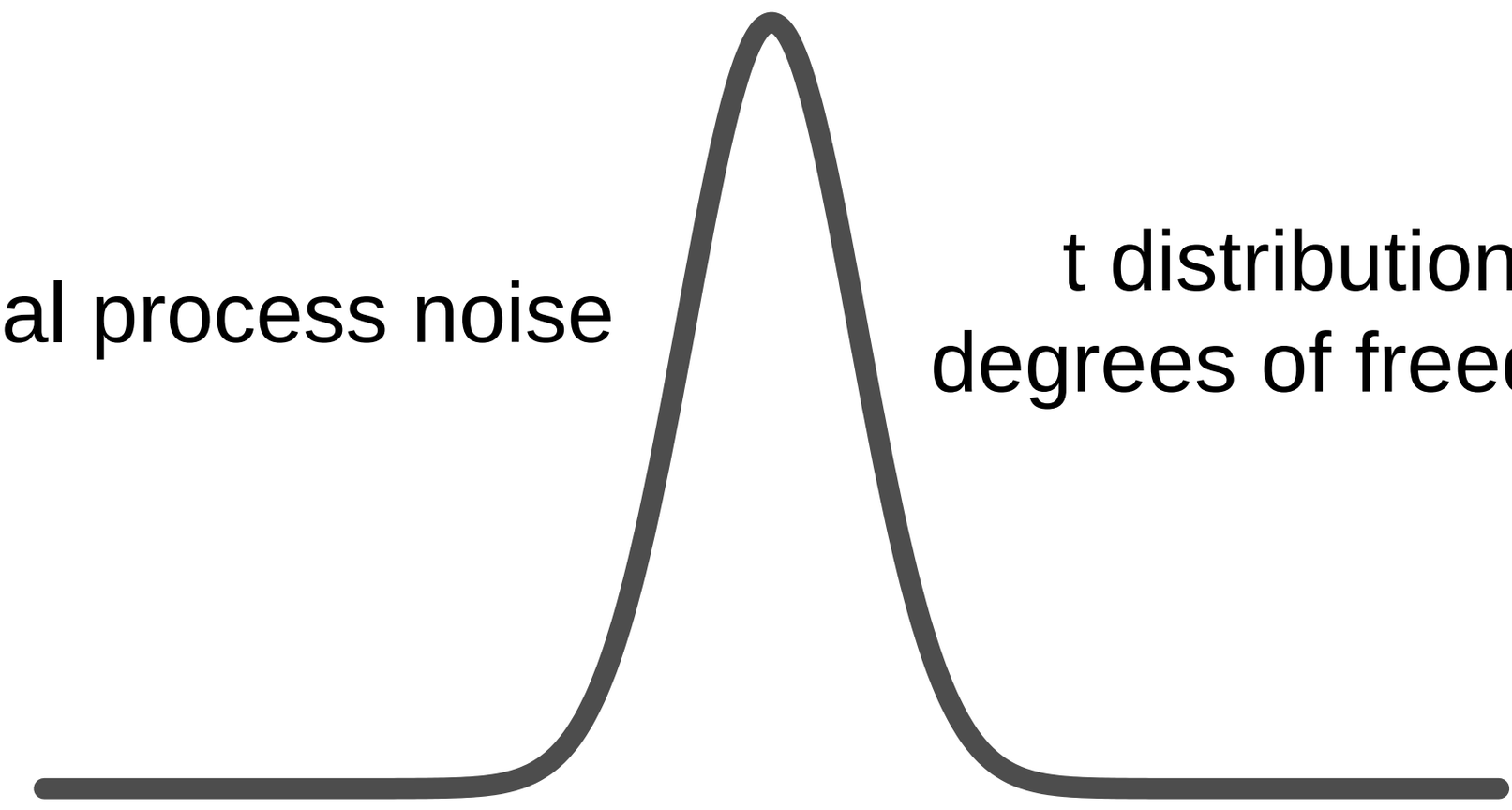
[a]Earth to Ocean Research Group, Department of Biological Sciences, Simon Fraser University, Burnaby, BC V5A 1S6, Canada; [b]School of Aquatic and Fishery Sciences, University of Washington, Seattle, WA 98195; and [c]School of Resource and Environmental Management, Simon Fraser University, Burnaby, BC V5A 1S6, Canada

Anderson et al. 2017a PNAS

Simulated population dynamics

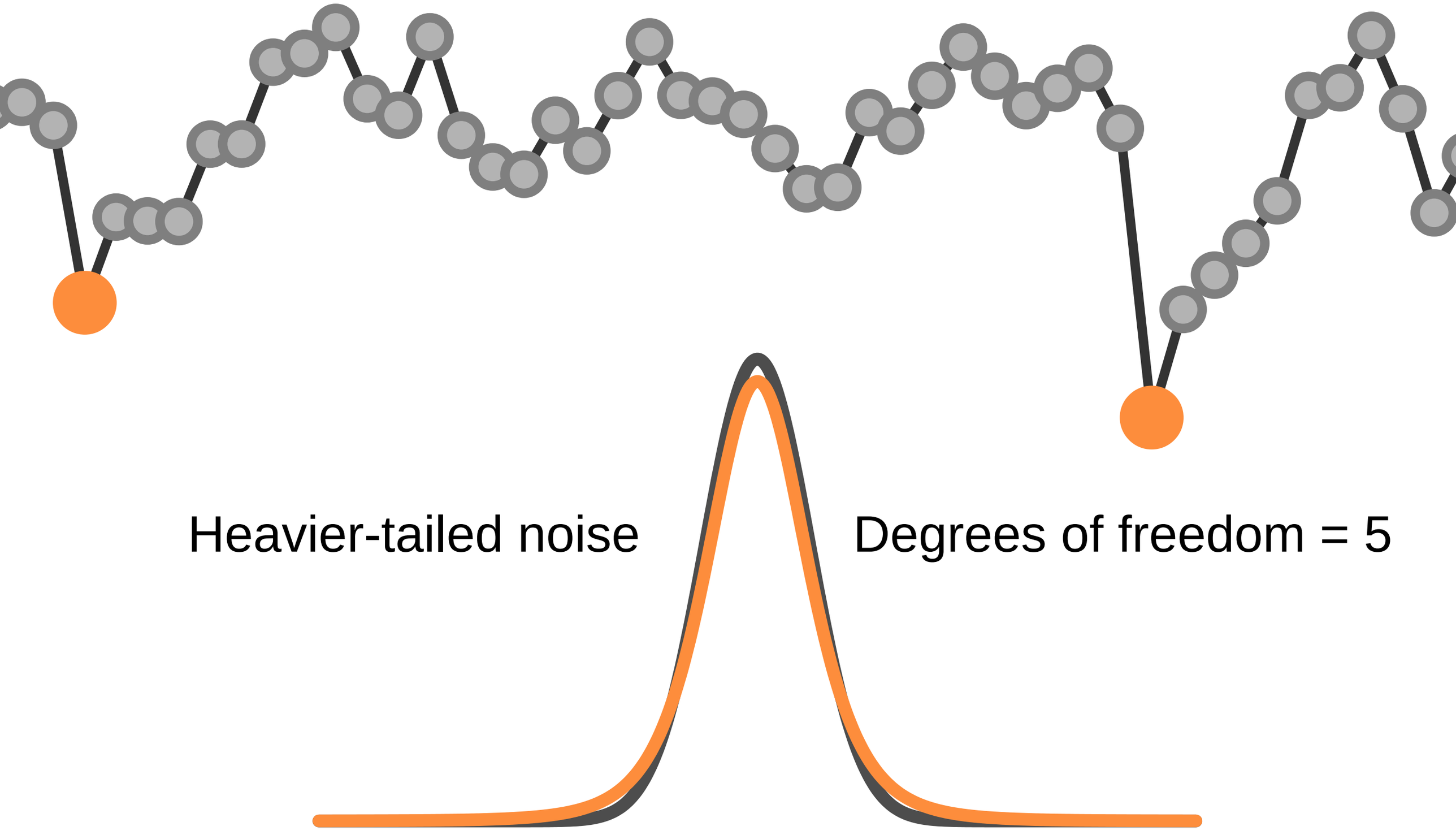


Normal process noise



t distribution with
degrees of freedom = ∞

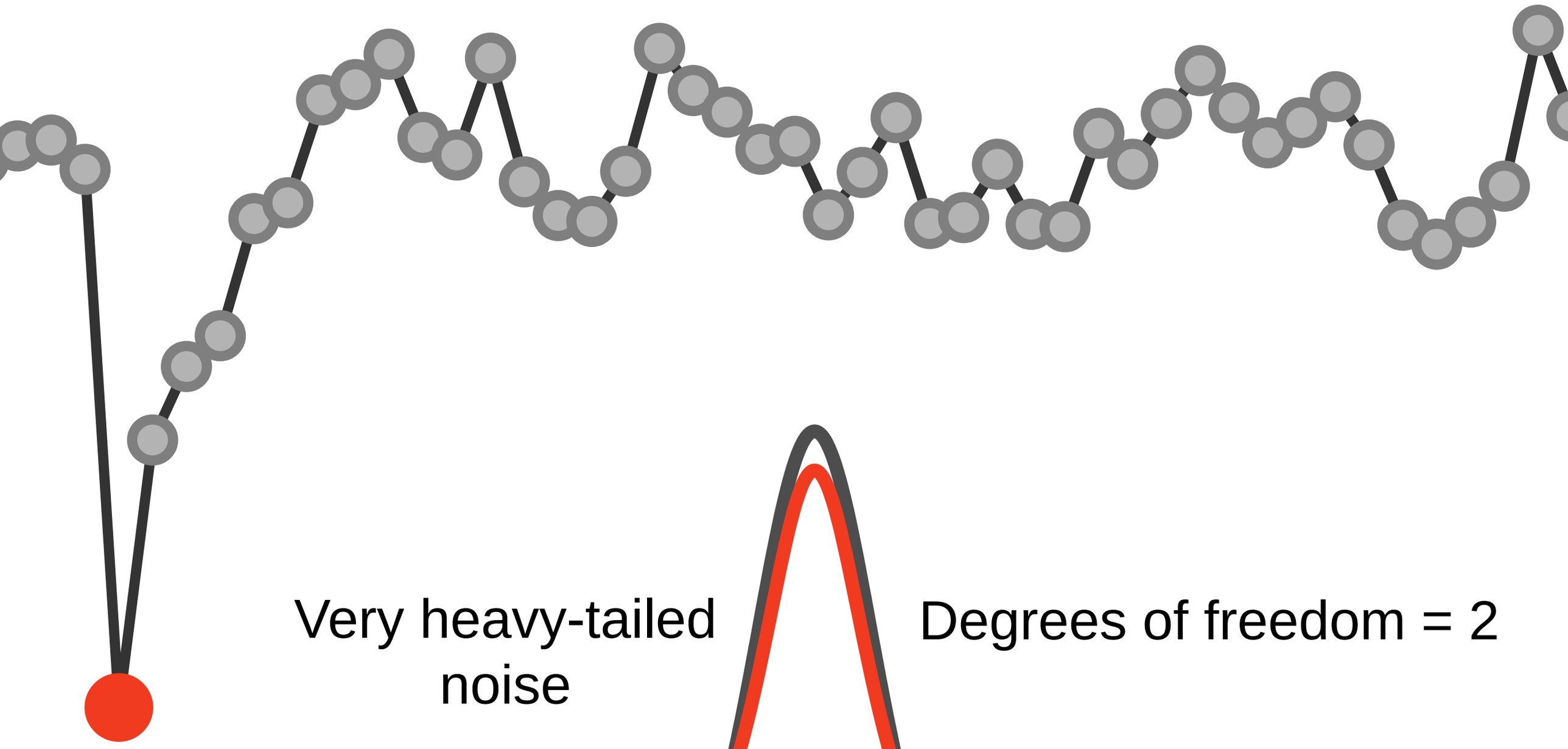
Simulated population dynamics



Heavier-tailed noise

Degrees of freedom = 5

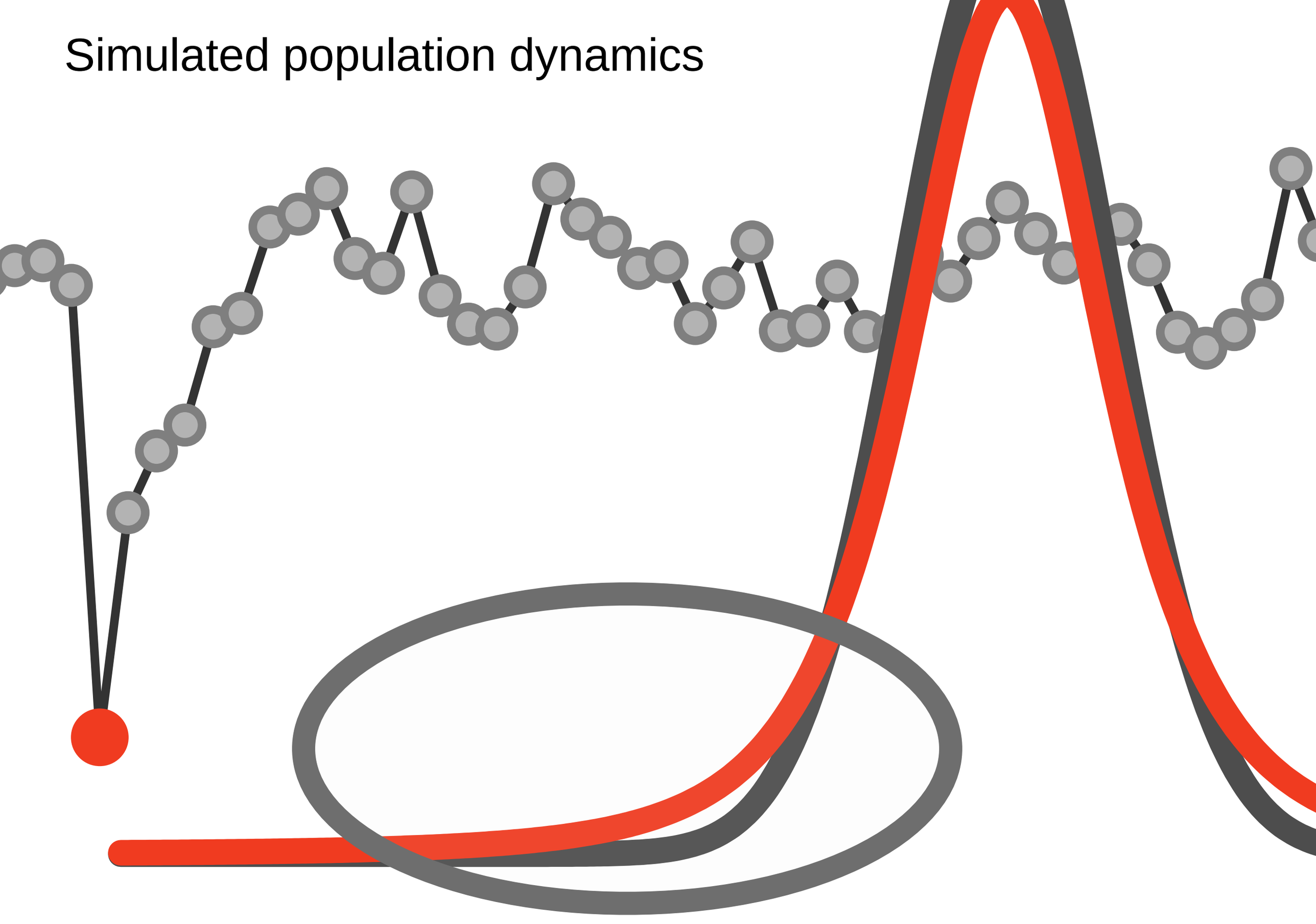
Simulated population dynamics



Very heavy-tailed noise

Degrees of freedom = 2

Simulated population dynamics



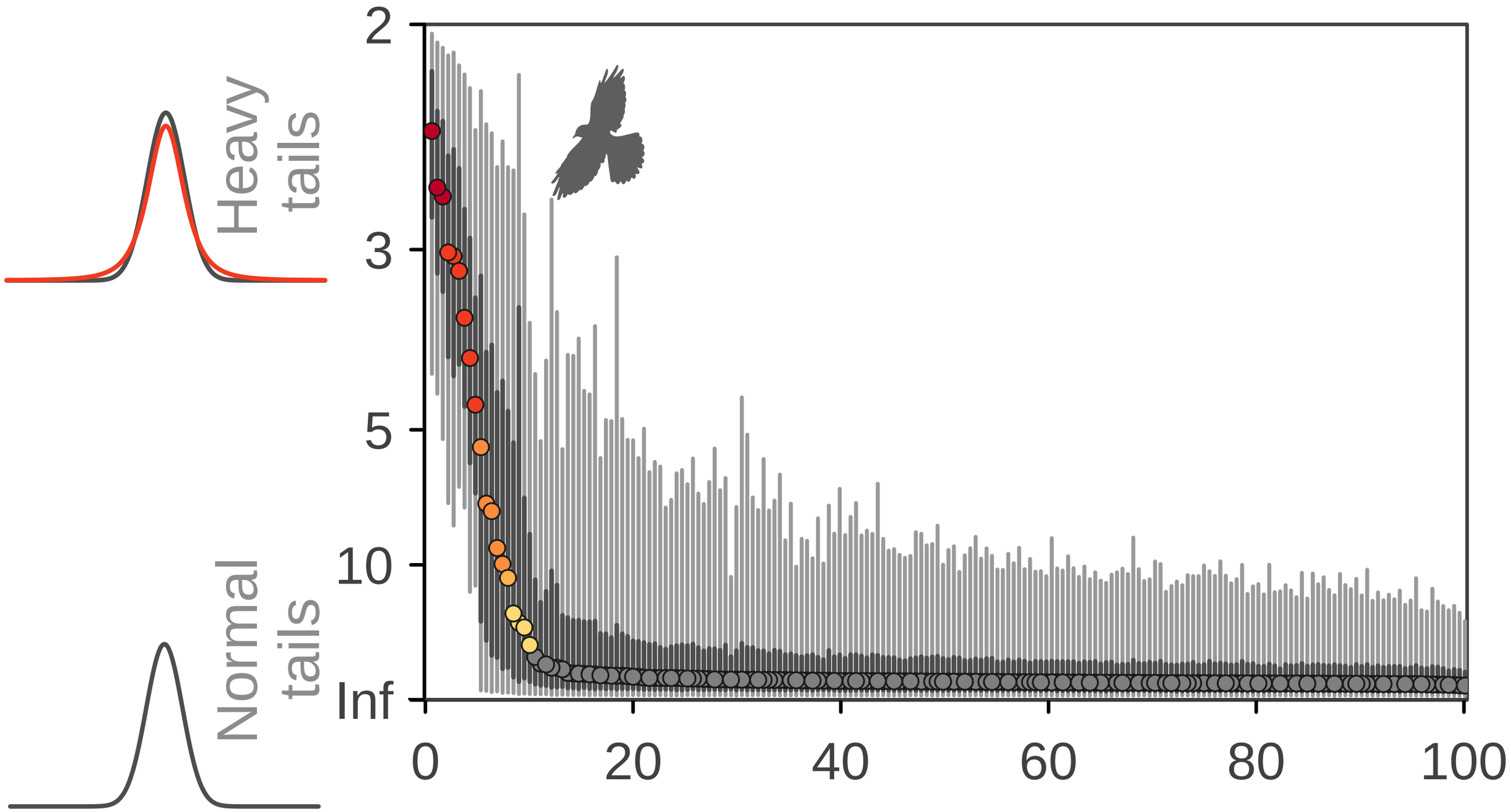
1 in 30 million years

1 in 30 million years

vs.

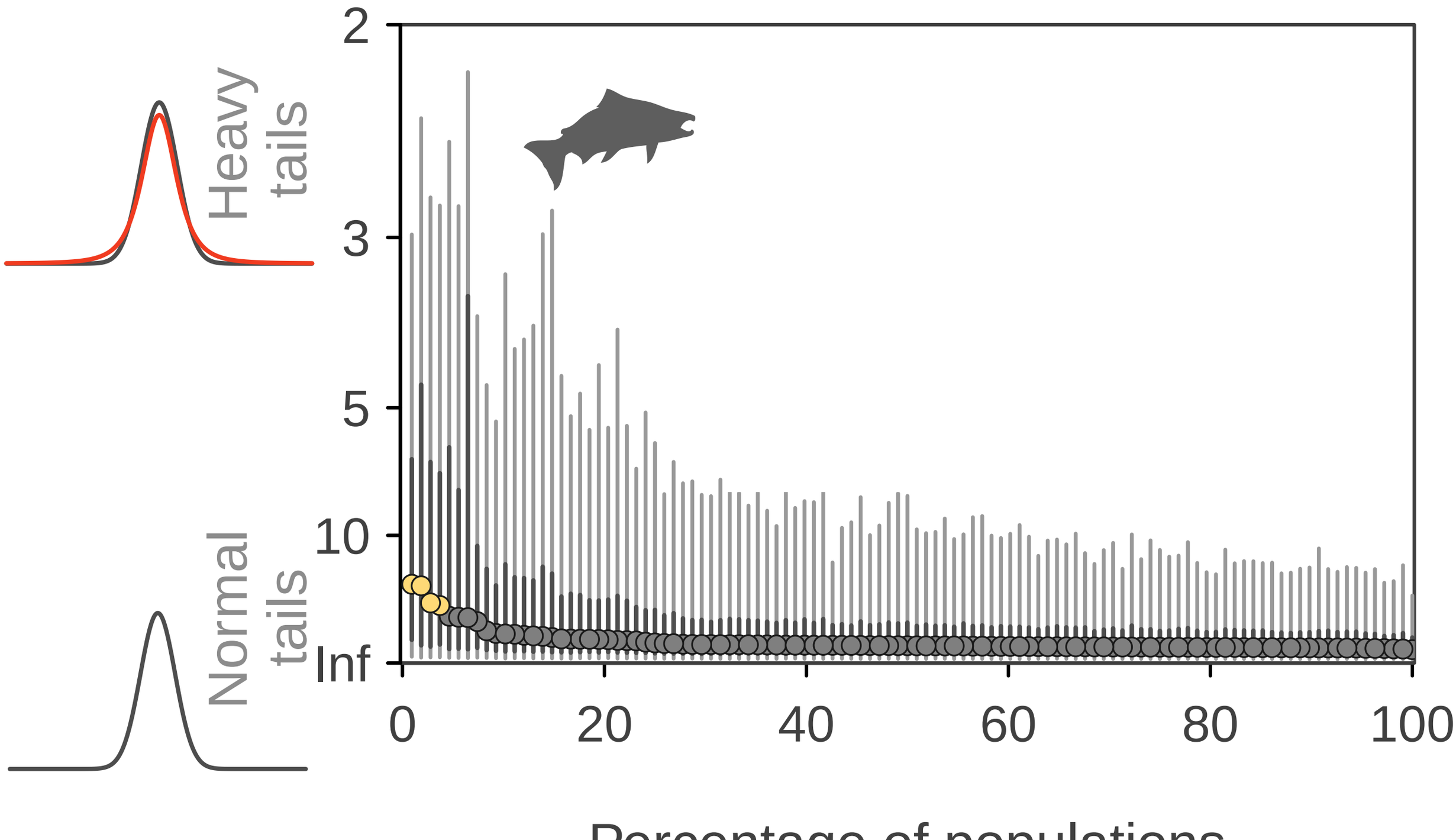
1 in 50 years

Evidence of black swans by population



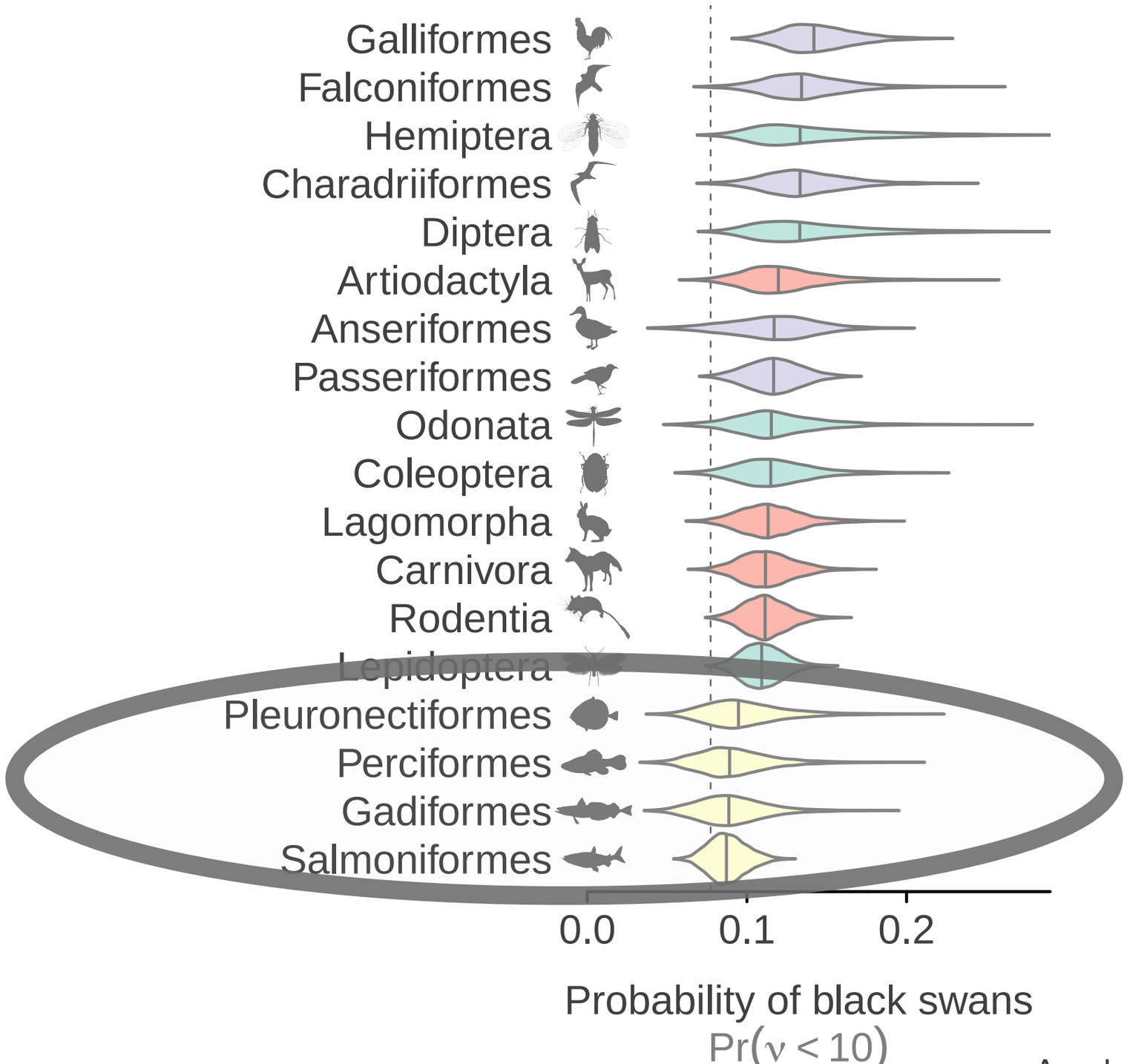
Anderson et al. 2017a PNAS

Evidence of black swans by population



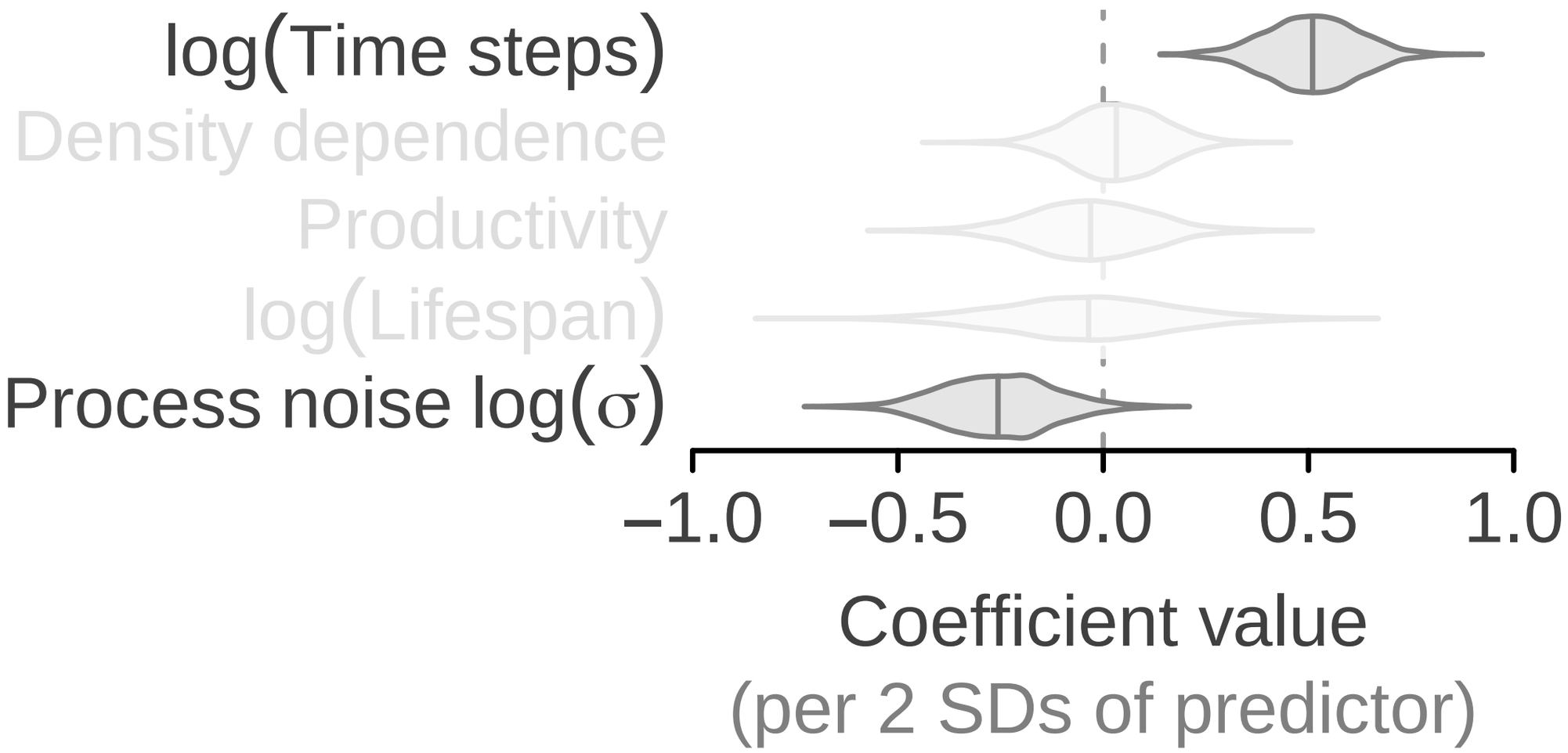
Anderson et al. 2017a PNAS

Black swans are widespread... but not for fish?



Anderson et al. 2017a PNAS

Noise and short time series = Challenging hunt for the black swan



Anderson et al. 2017a PNAS

The hunt for the black swan in many common fisheries time series is unlikely to bare fruit.

Instead, we should aim to be robust to surprises.

Challenges and solutions

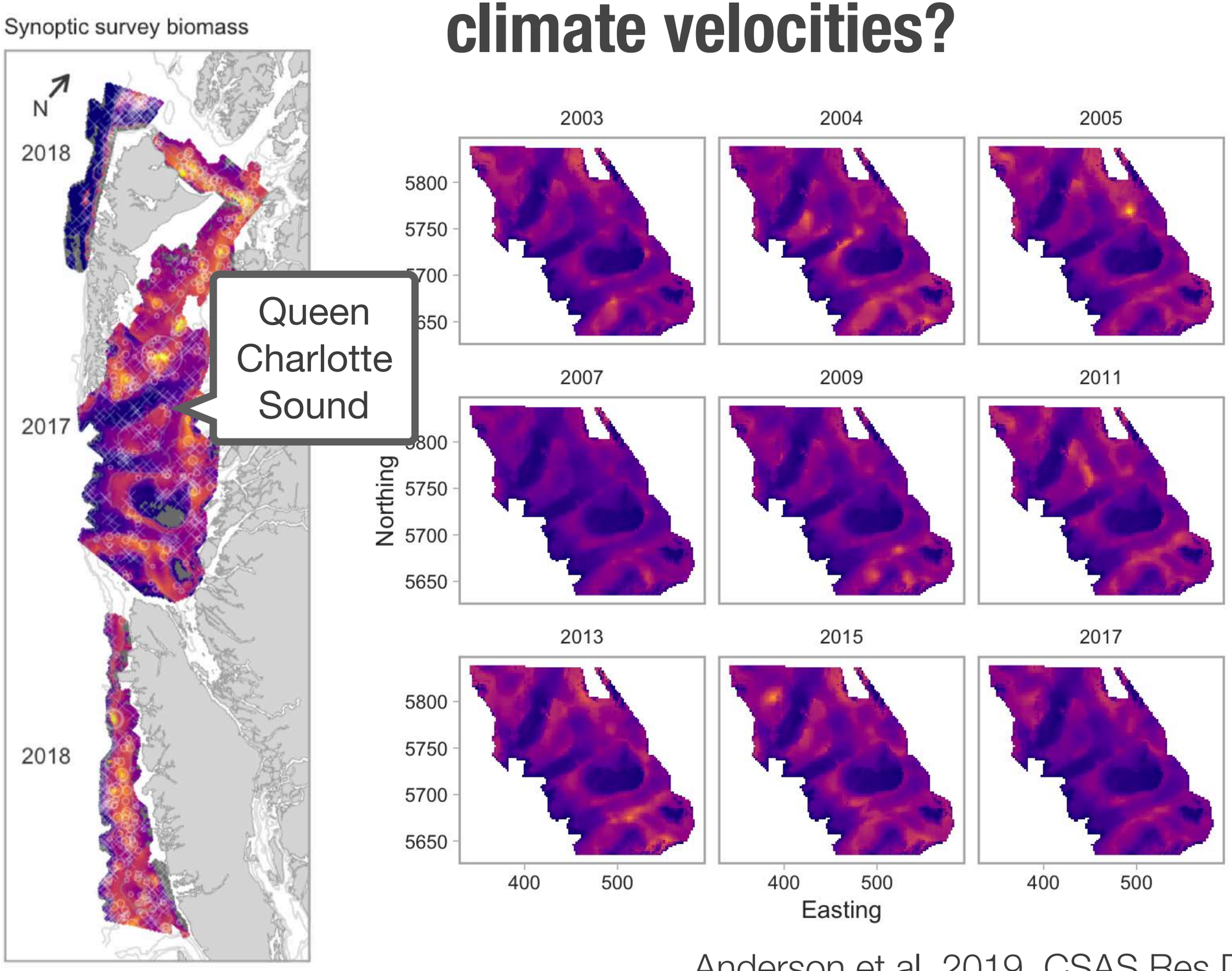
Challenges:

0. (Try to) avoid surprise
1. Embed surprise into models
2. Make systems robust to surprise
3. Detect and react quickly to surprise

Challenge 0:

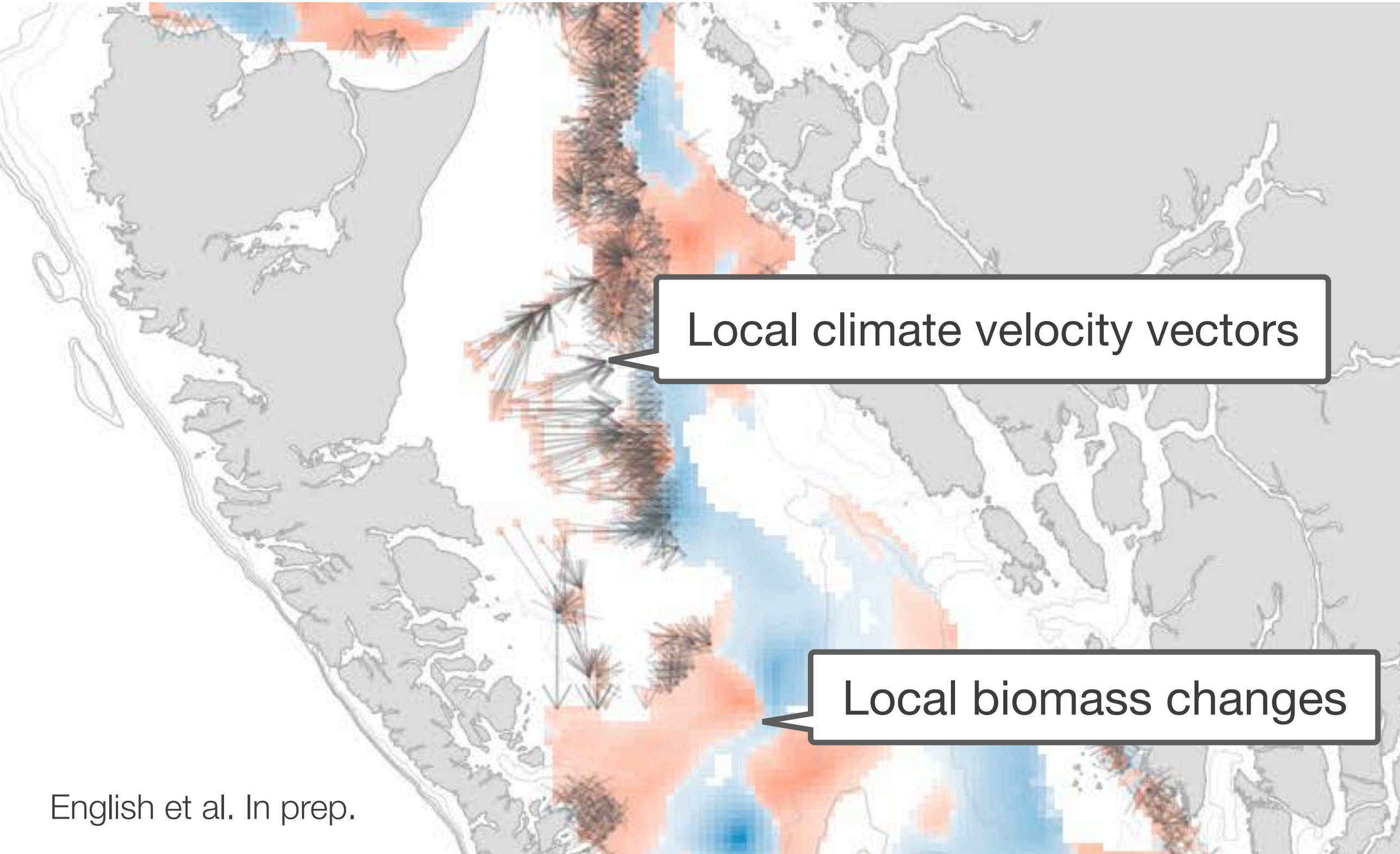
(Try to) avoid surprise.

Are Pacific groundfish tracking local climate velocities?



Anderson et al. 2019. CSAS Res Doc. In press.

Are Pacific groundfish tracking local climate velocities?



English et al. In prep.

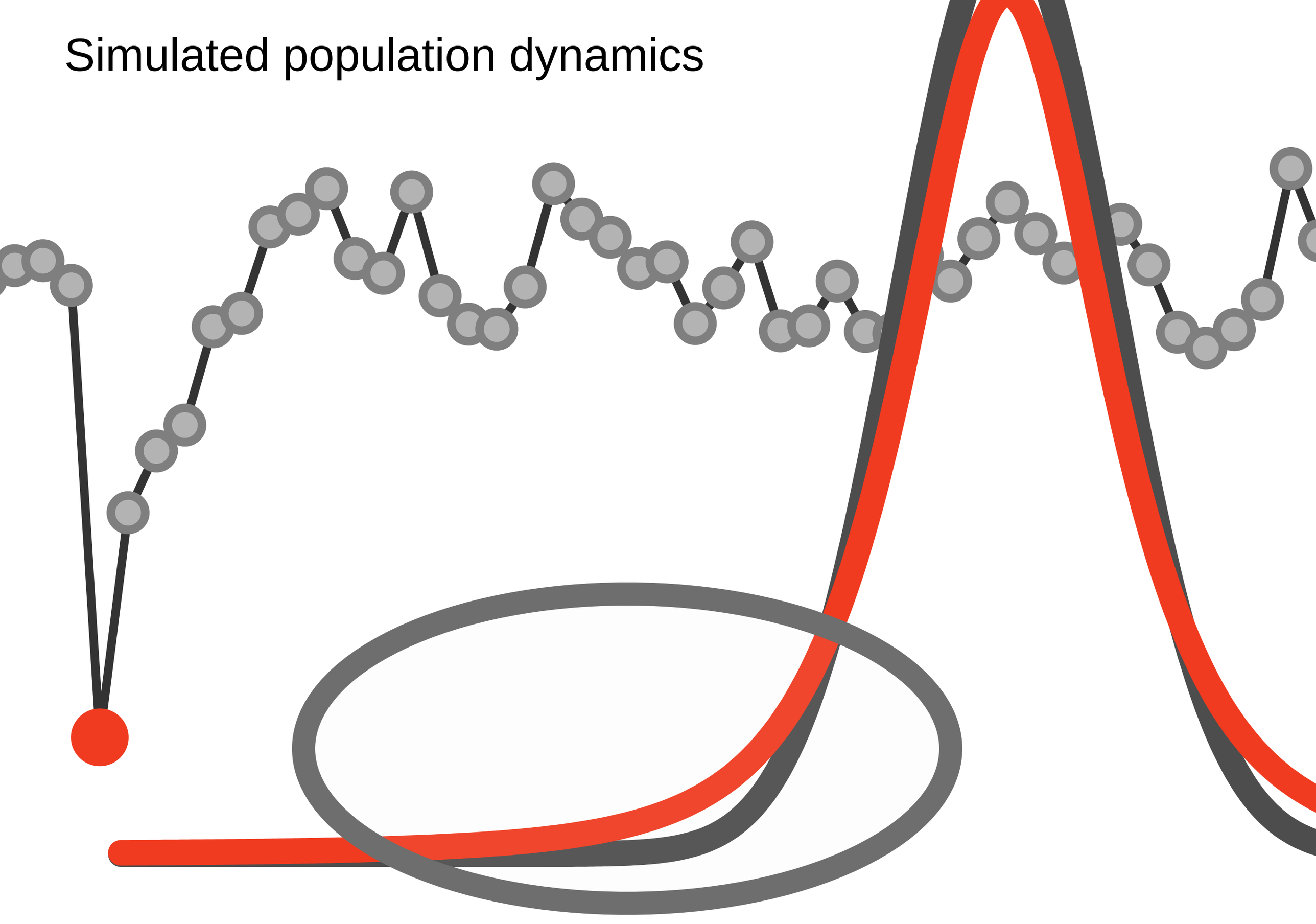
Challenge 1:

Embed surprise into models

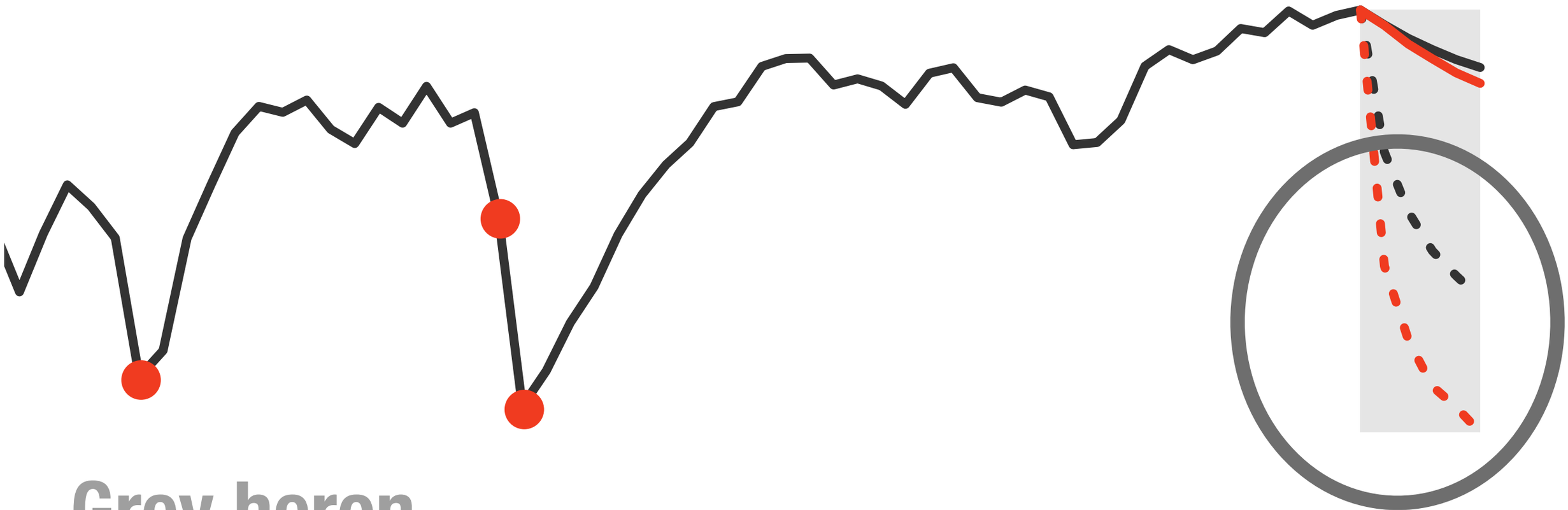
1. Embed surprise into models

Heavy tails

Simulated population dynamics

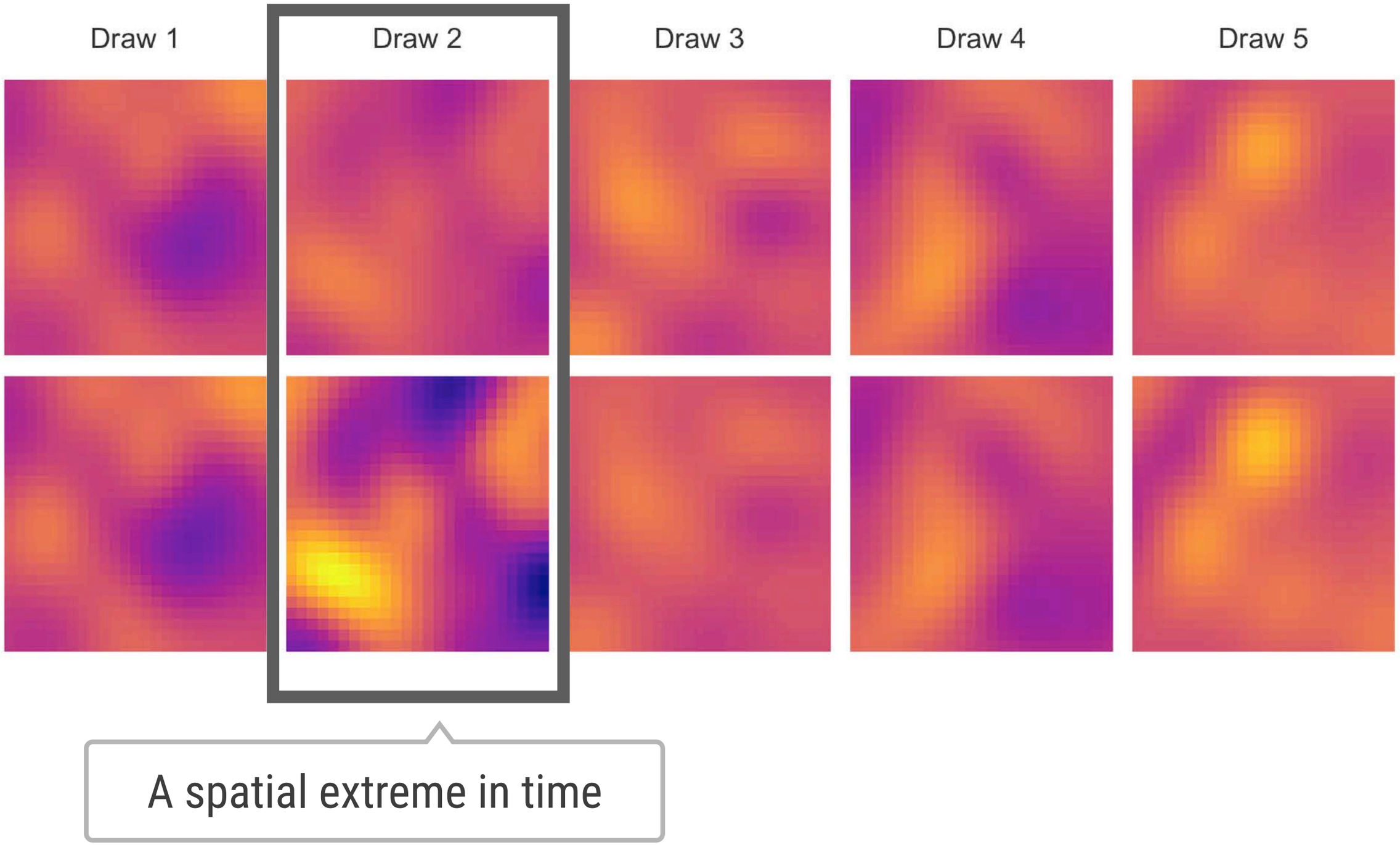


Ignoring black swans underestimates risk



Anderson et al. 2017a PNAS

The multivariate t distribution for spatiotemporal extremes



Anderson and Ward 2018 Ecology

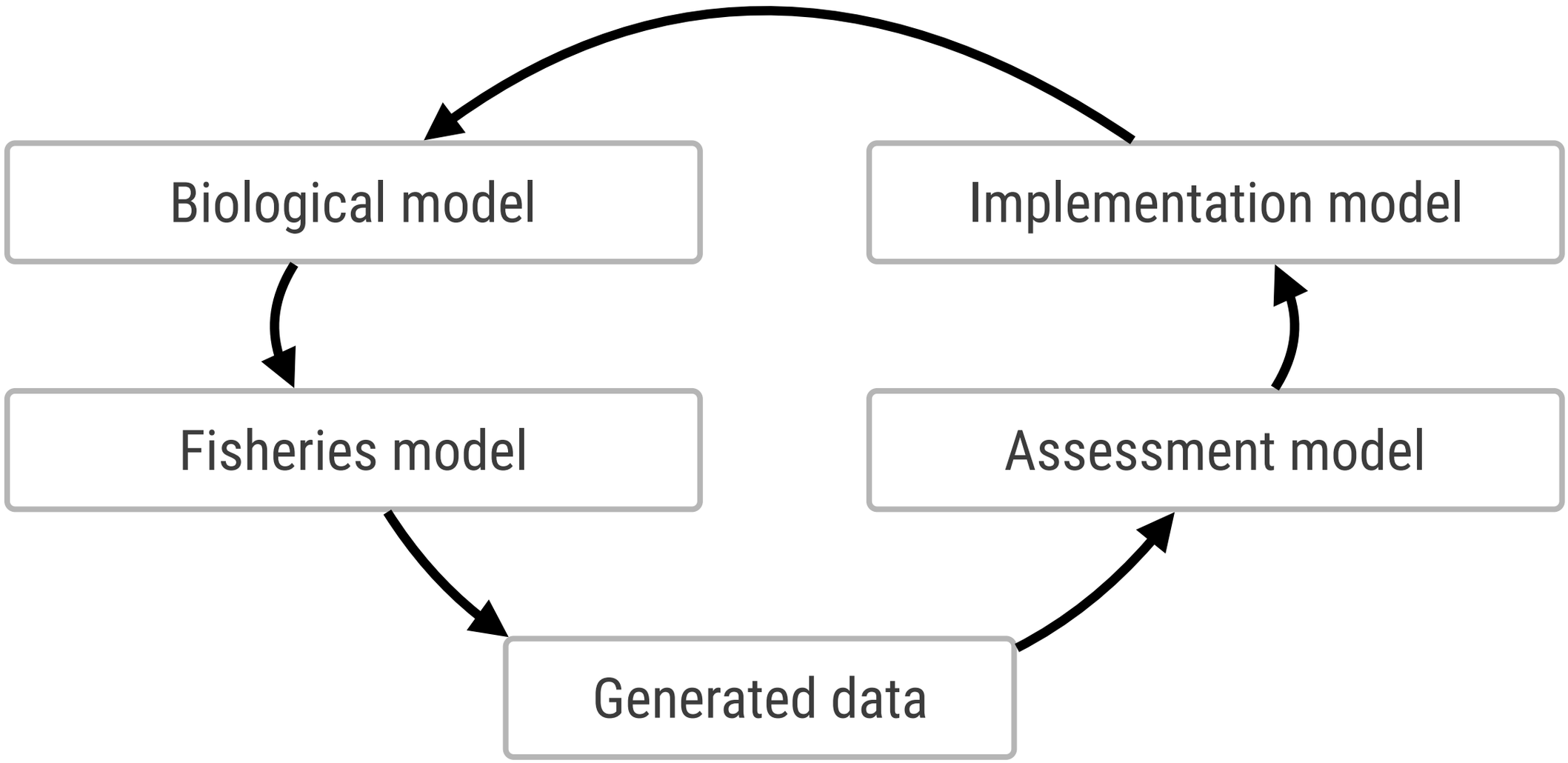
Challenge 2:

Make the system robust to surprise

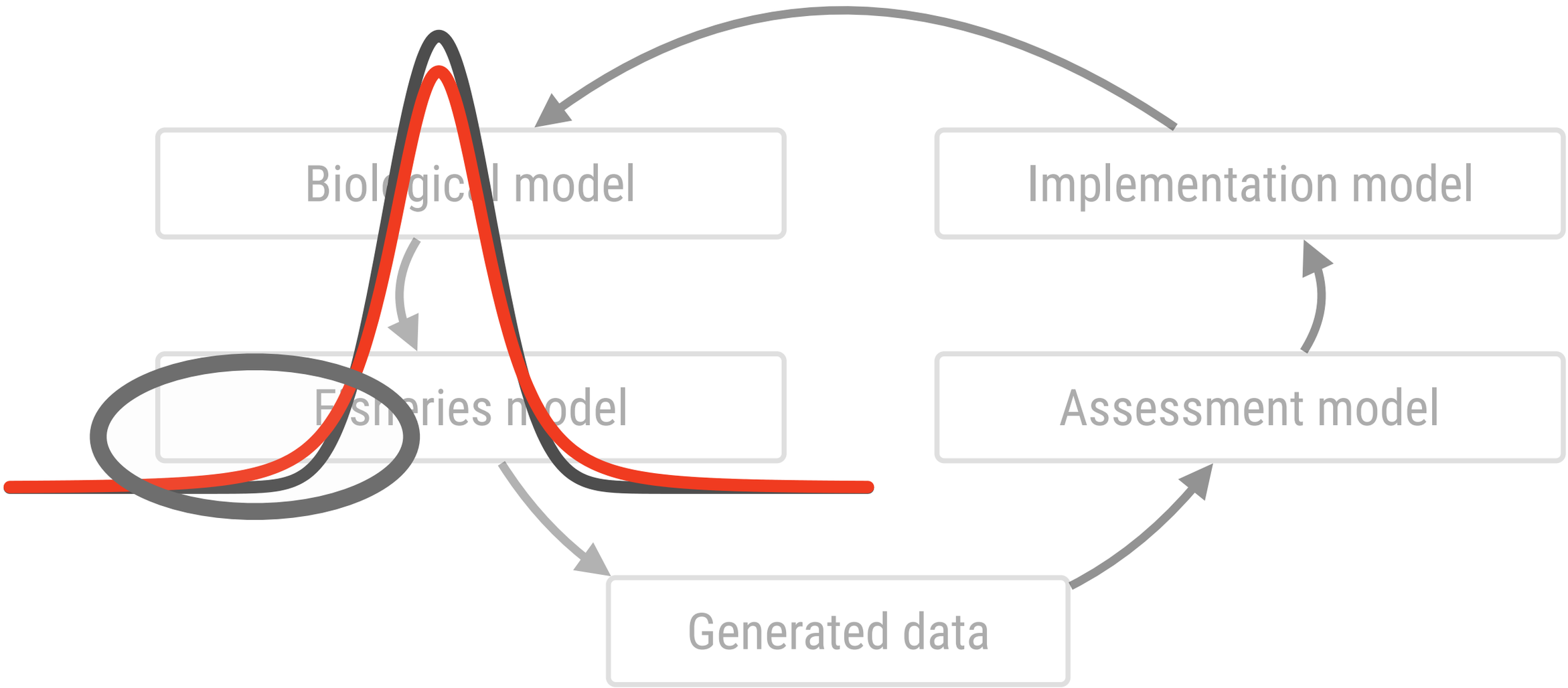
2. Make the system robust to surprise

Closed-loop simulation

Closed-loop simulation can help find management approaches that are robust to extremes



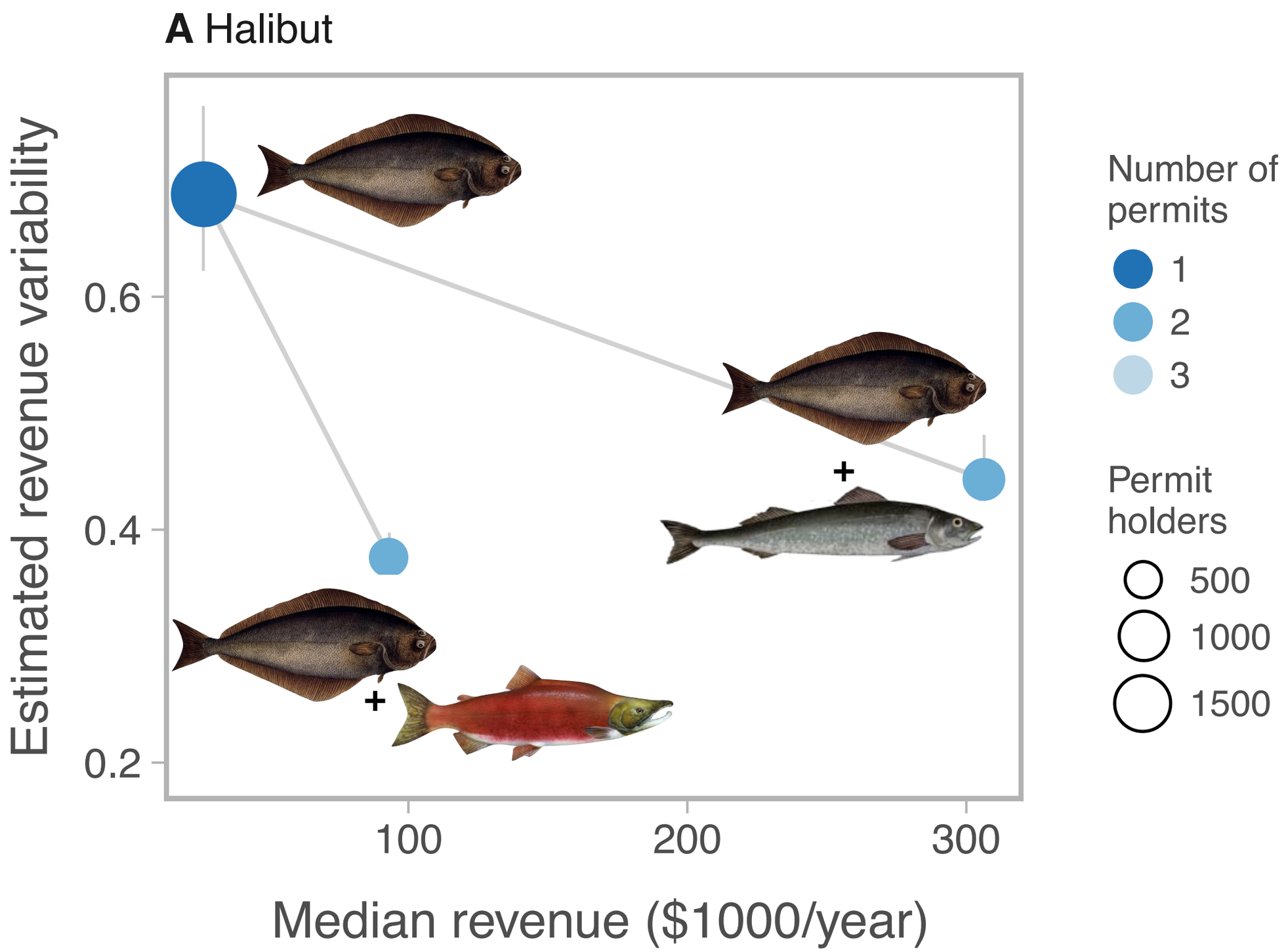
Closed-loop simulation can help find management approaches that are robust to extremes



2. Make the system robust to surprise

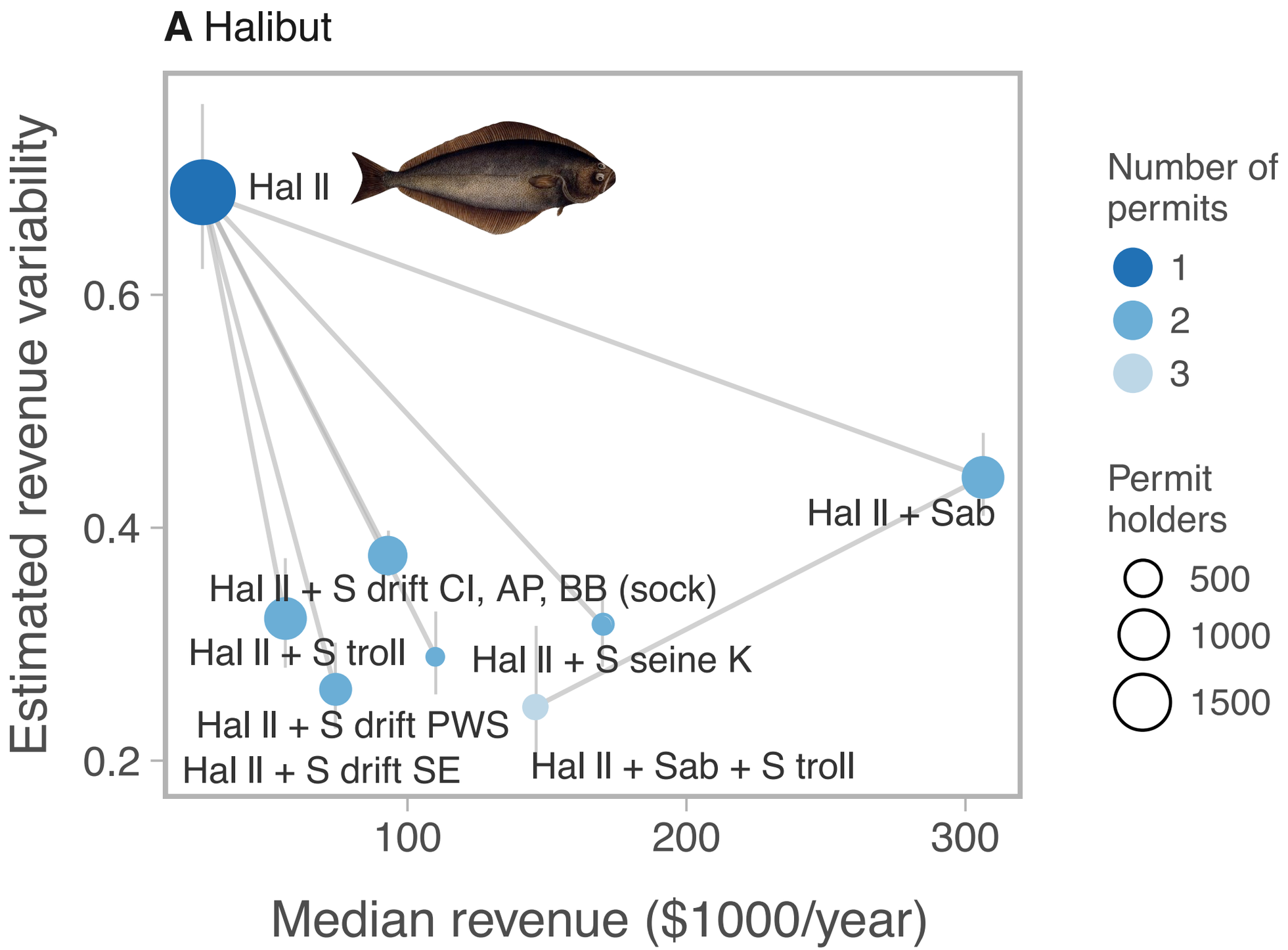
Promote diversification

Adding a permit reduces revenue variability



Anderson et al. 2017b PNAS

Adding a permit reduces revenue variability



Anderson et al. 2017b PNAS

Challenge 3:

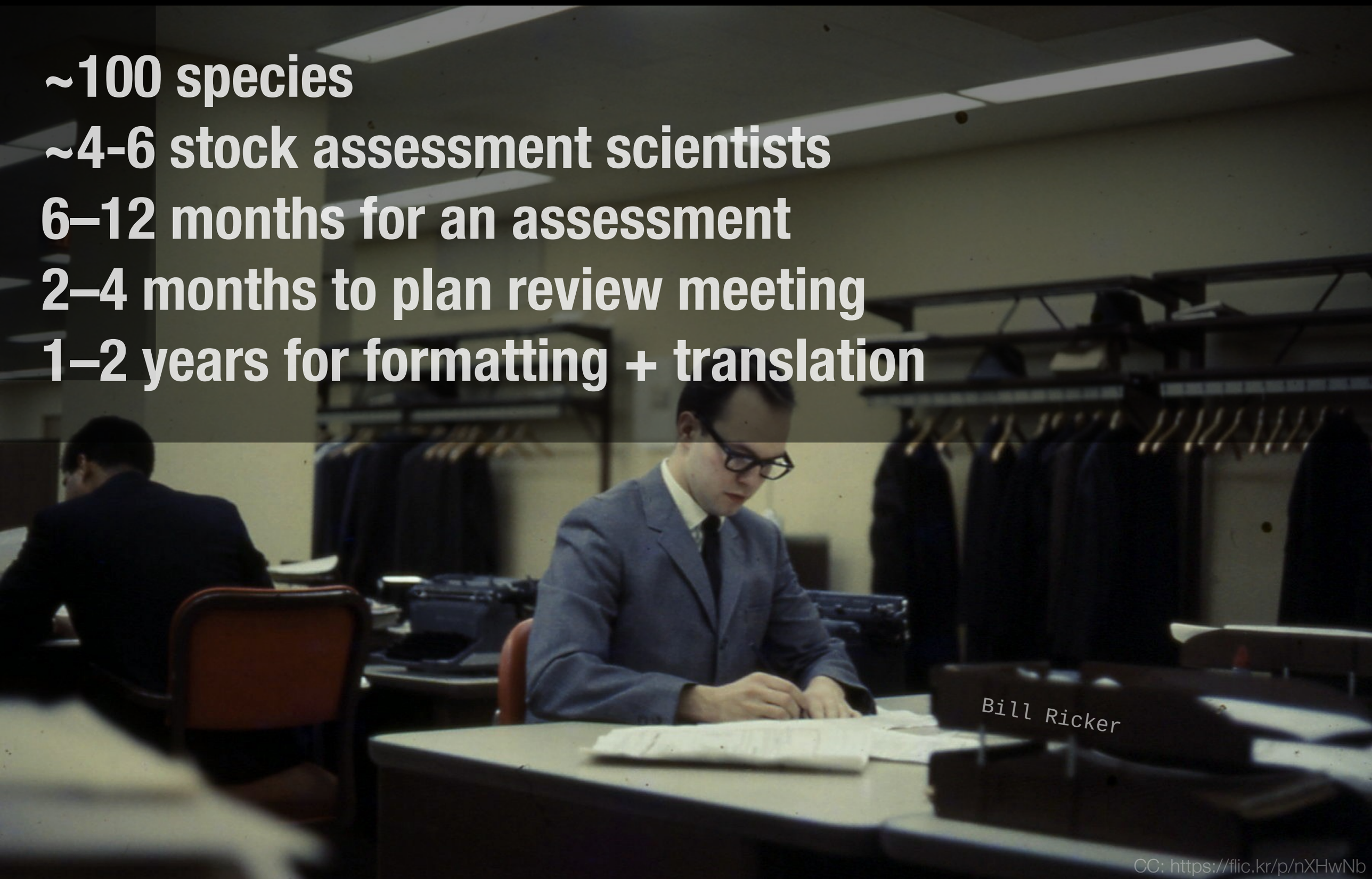
Detect and react quickly to surprise

3. React quickly to surprise

Adaptive management

For British Columbia Groundfish:

~100 species
~4-6 stock assessment scientists
6–12 months for an assessment
2–4 months to plan review meeting
1–2 years for formatting + translation



3. React quickly to surprise

Automated reporting + visualization

Visualization can surprise you, but it doesn't scale.

Modelling scales, but it can't surprise you.

-Hadley Wickham (paraphrased)

Plot the data.

Plot the data.

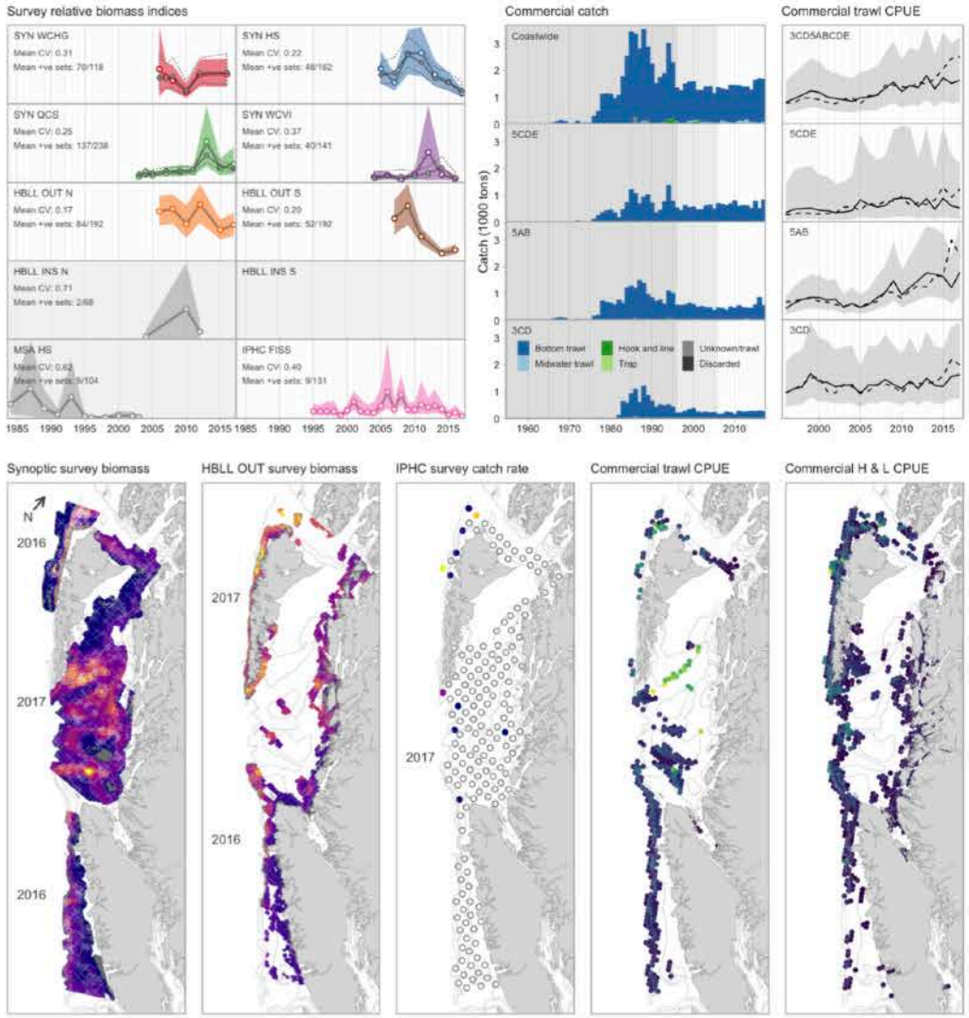
Plot the data.

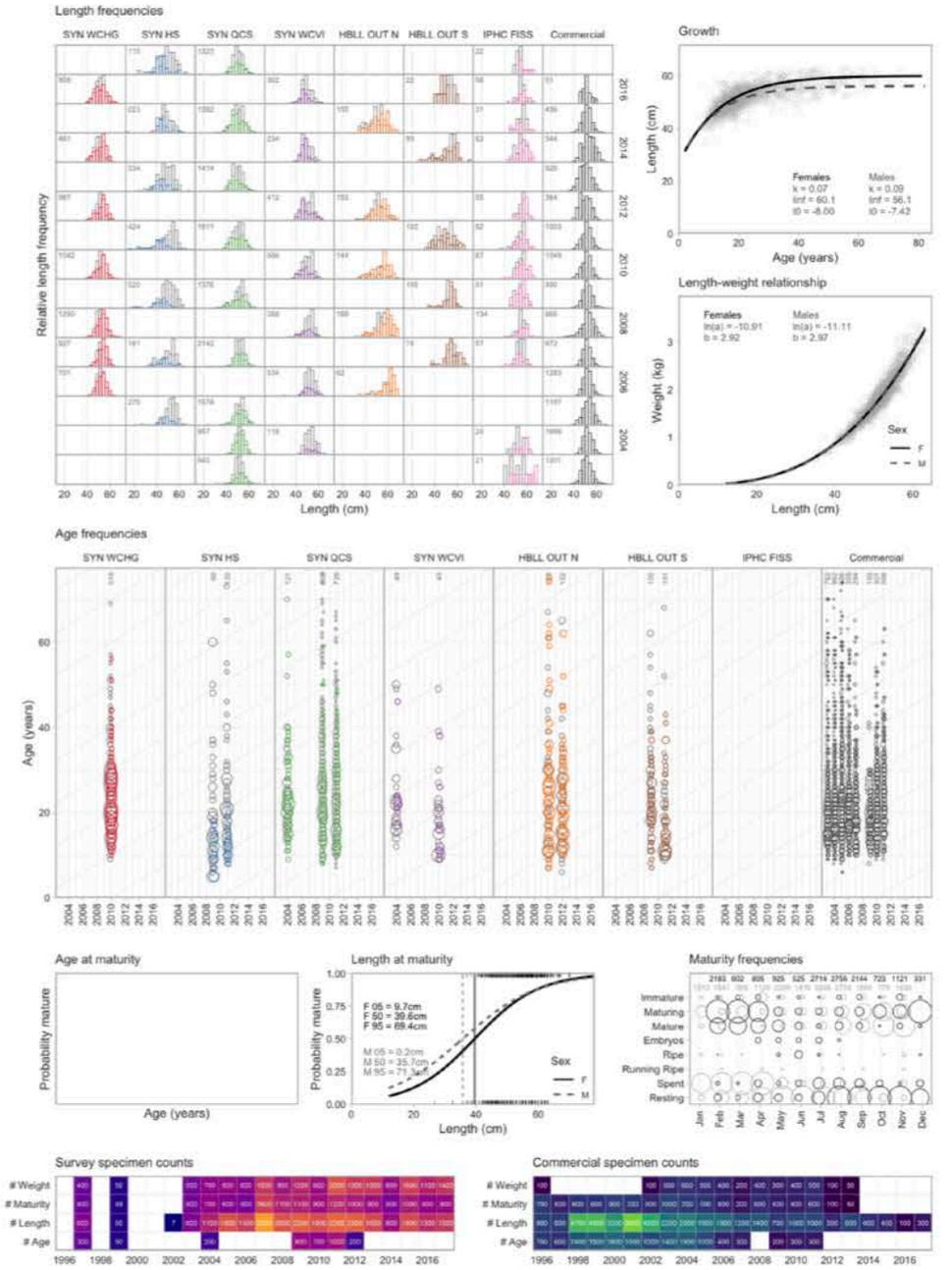
-Ransom Myers

Could we:
Plot all the data.
For every species.
On 2 pages per species.
Automated.
Every year?

5.10 SILVERGRAY ROCKFISH

Sebastes brevispinis (405)
Order: Scorpaeniformes, Family: Scorpaenidae, FishBase link
Last Research Document: Starr et al. (2016)
Last Science Advisory Report: Fisheries and Oceans Canada (2014b)





Anderson et al. 2019 CSAS Res Doc. In press.

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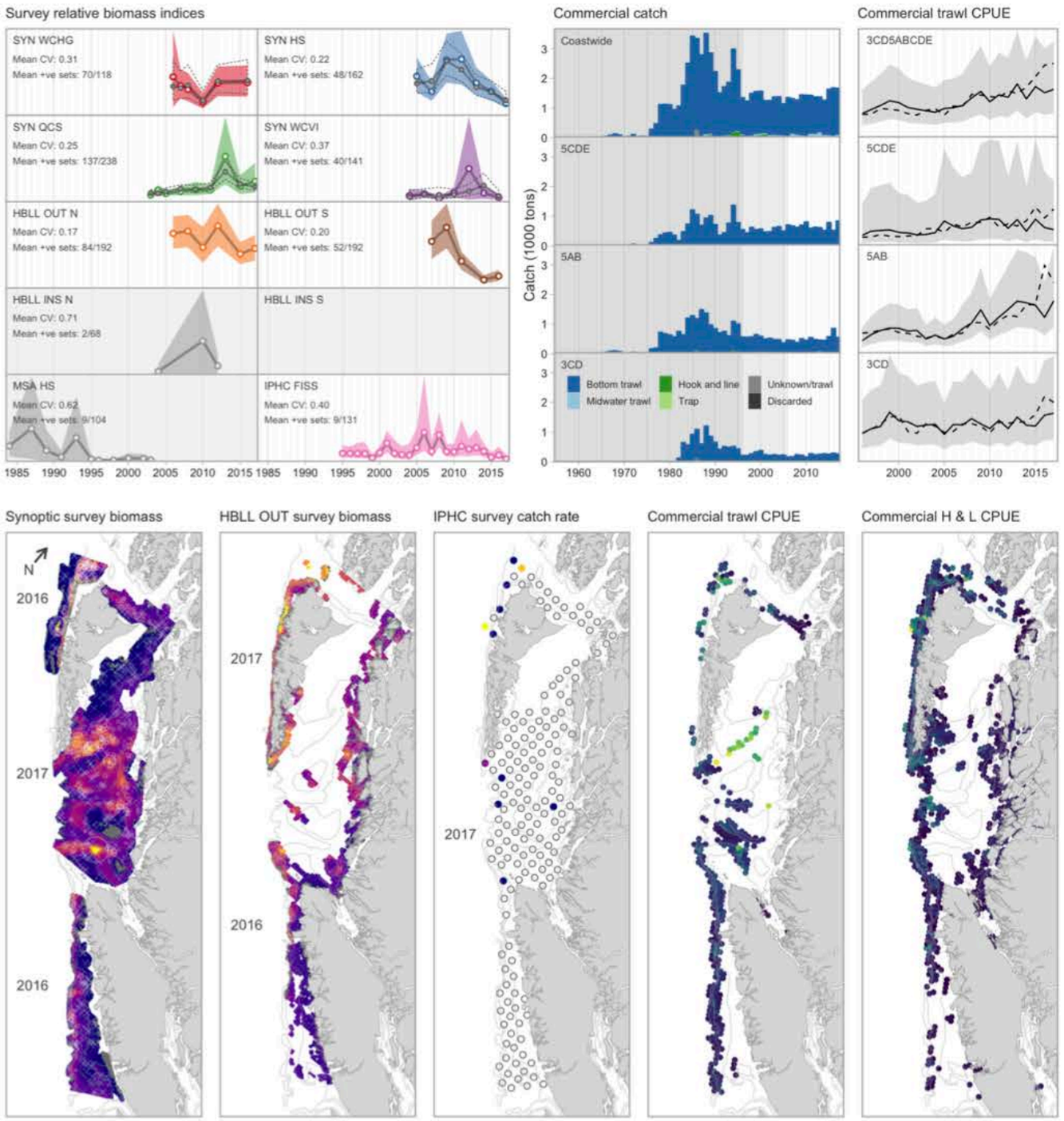
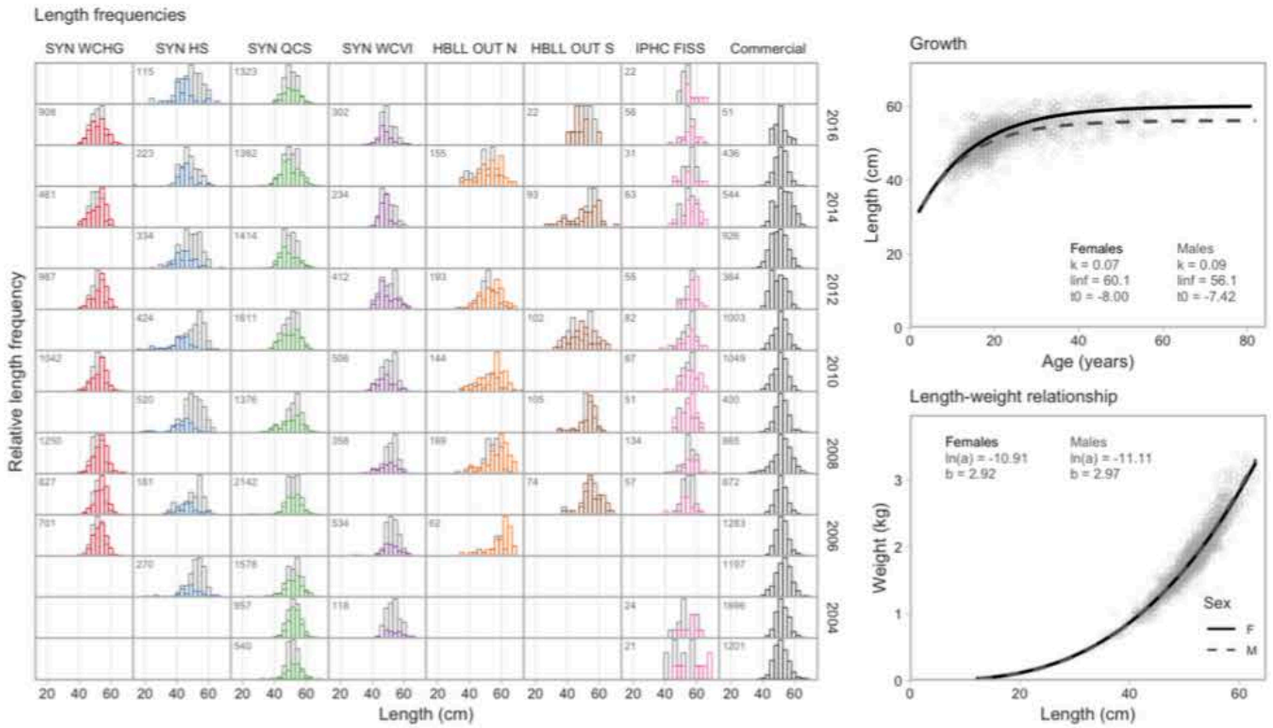



Length frequencies
SYN WCHG
SYN HS
SYN QCS
SYN WCVI
HBLL OUT N
HBLL OUT S
IPHC FISS
Commercial
Relative length frequency
Length (cm)
Growth
Length (cm)
Age (years)
Females
k = 0.07
linf = 60.1
t0 = -8.00
Males
k = 0.09
linf = 56.1
t0 = -7.42
Length-weight relationship
Weight (kg)
Females
ln(a) = -10.91
b = 2.92
Males
ln(a) = -11.11
b = 2.97
Sex
F
M
Age frequencies
Age (years)
Age at maturity
Probability mature
Age (years)
Length at maturity
F 05 = 9.7cm
F 50 = 39.6cm
F 95 = 69.4cm
M 05 = 0.2cm
M 50 = 35.7cm
M 95 = 71.3cm
Maturity frequencies
Immature
Maturing
Mature
Embryos
Ripe
Running Ripe
Spent
Resting
Survey specimen counts
Weight
Maturity
Length
Age
Commercial specimen counts

Same 2-page layout for all species

19 20 21 26

27 28 29 30 31 32 33 34

35 36 37 38 39 40 41 42

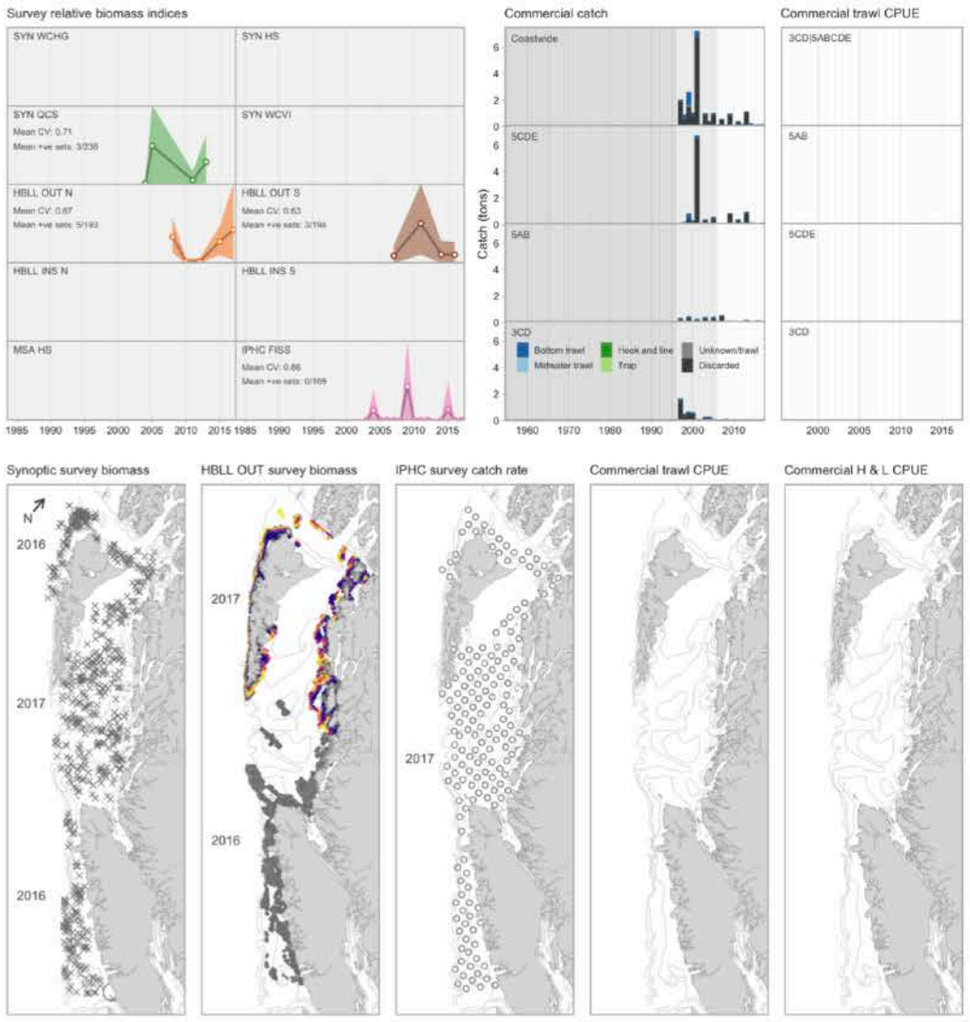
Draft available at:

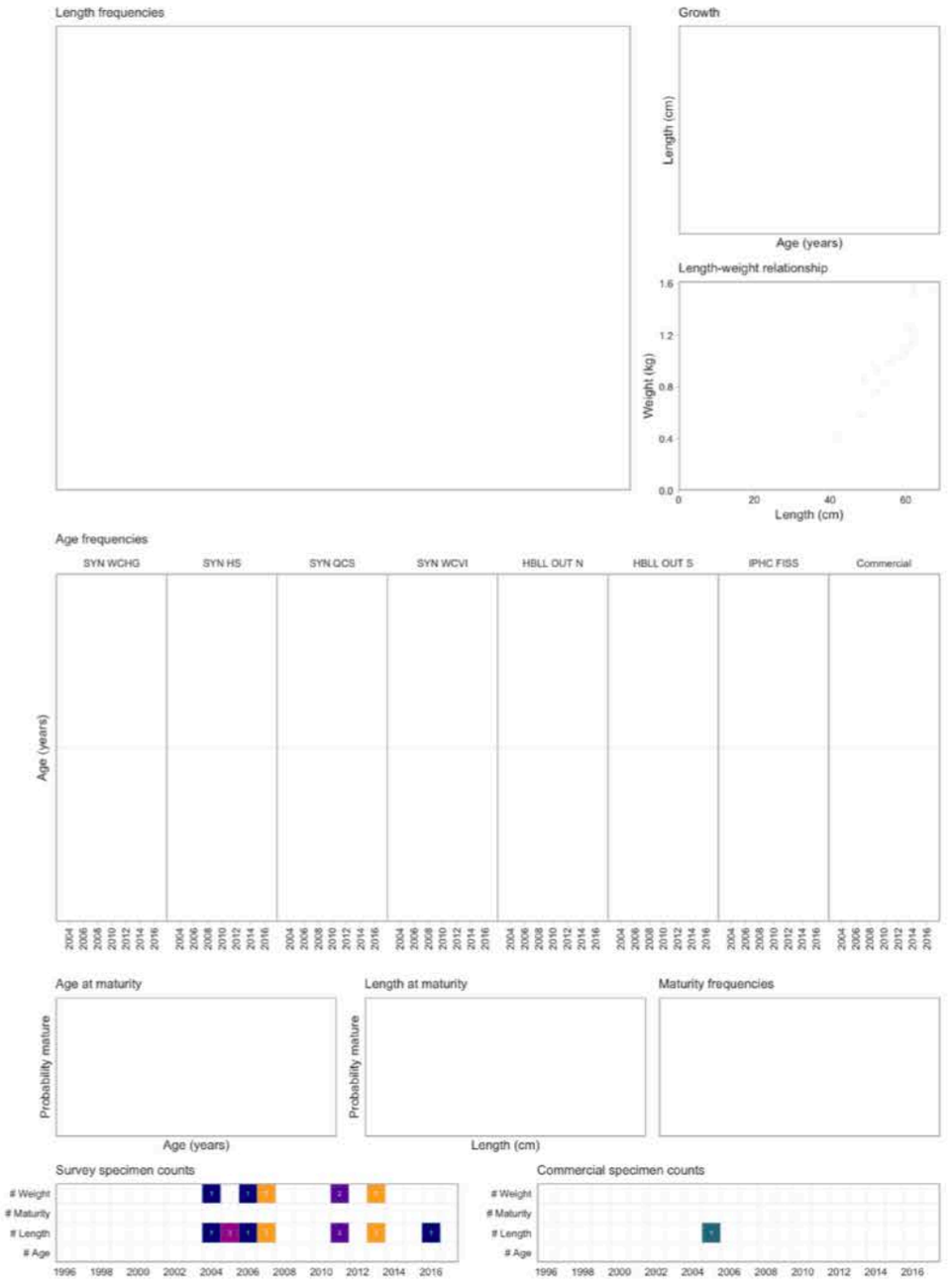
github.com/pbs-assess/gfsynopsis

github.com/pbs-assess/gfsynopsis

6.12 ALASKA SKATE

Bathyraja parmifera (061)
Order: Rajiformes, Family: Arhynchobatidae, FishBase link



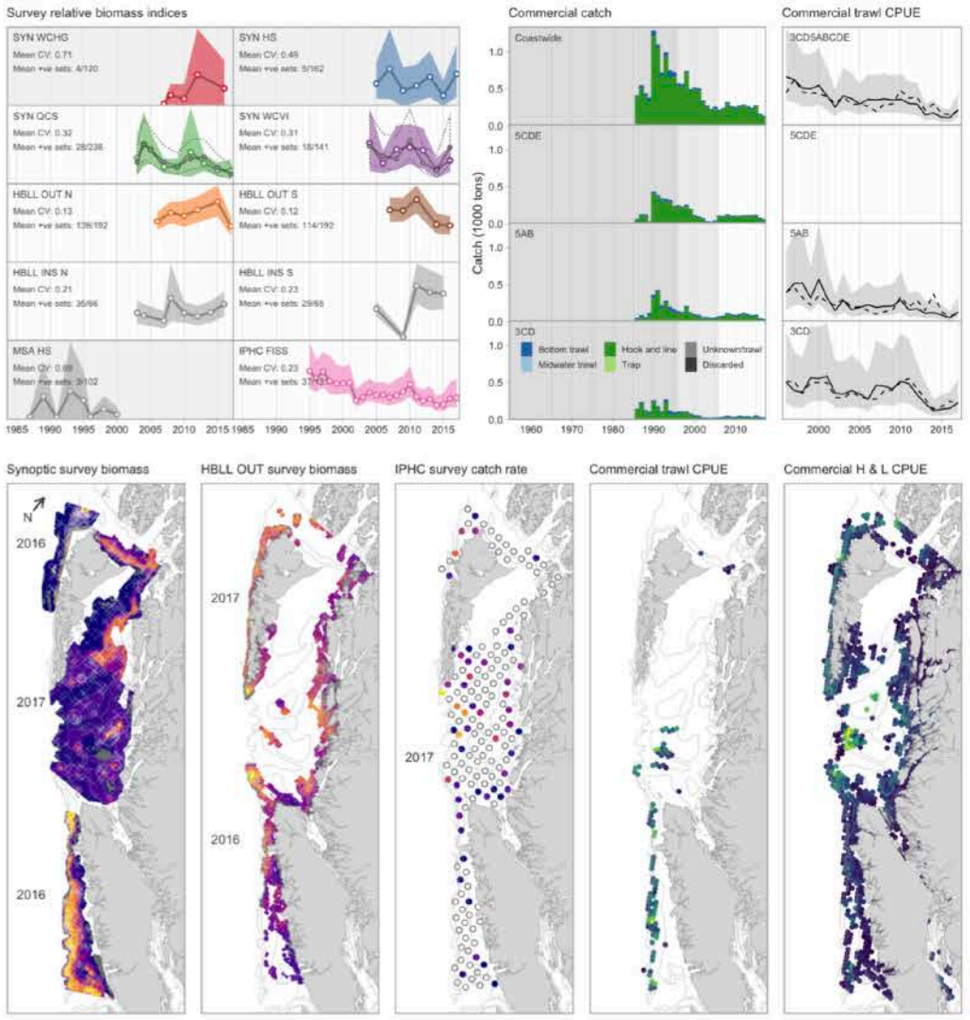


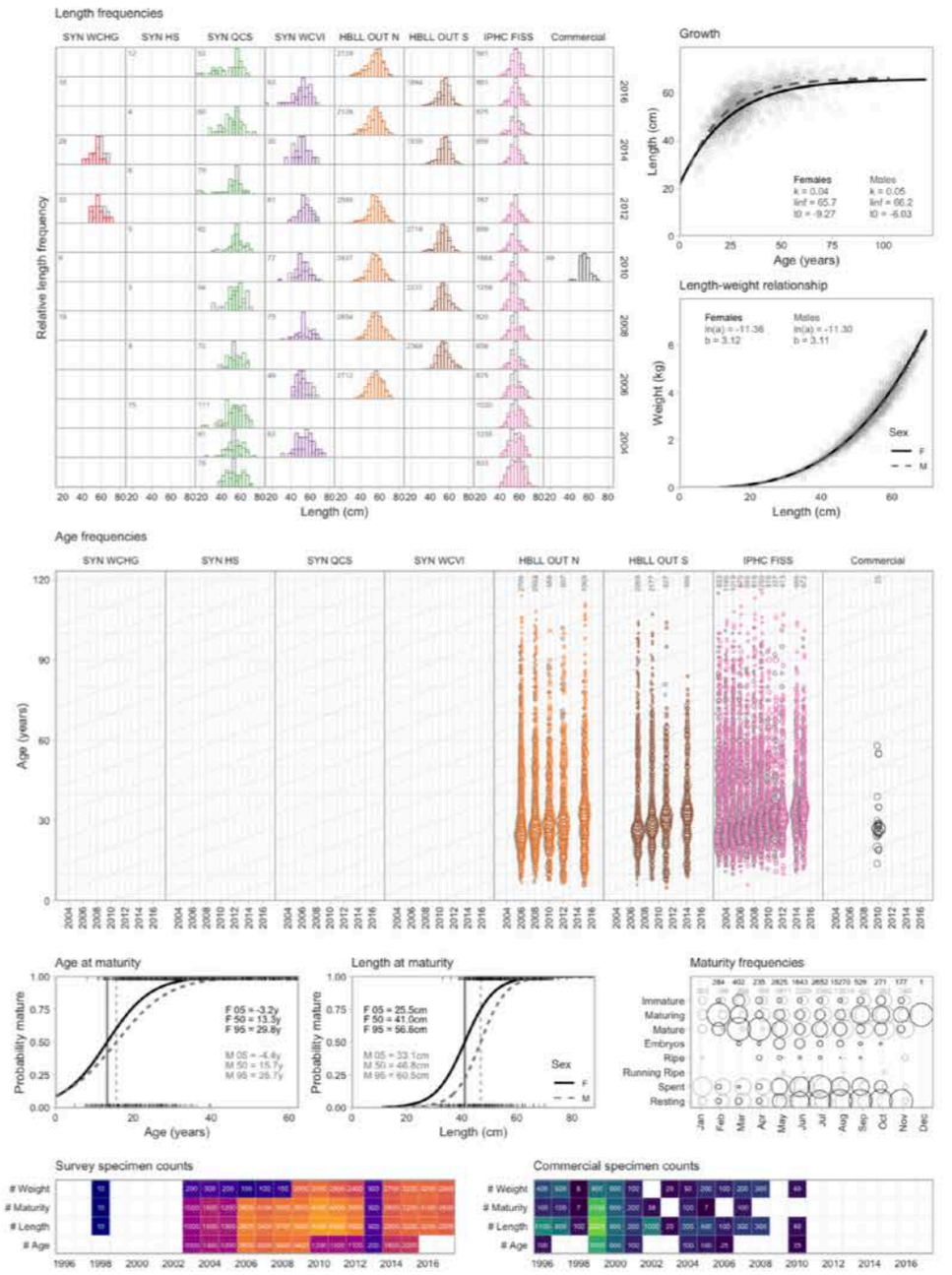
Anderson et al. 2019 CSAS Res Doc. In press.

github.com/pbs-assess/gfsynopsis

5.20 YELLOWEYE ROCKFISH

Sebastes ruberrimus (442)
Order: Scorpaeniformes, Family: Scorpaenidae, FishBase link
Last Research Documents: Yamanaka et al. (2011b), Yamanaka et al. (2018)
Last Science Advisory Reports: Fisheries and Oceans Canada (2011c), Fisheries and Oceans Canada (2015d)
Pre-COSEWIC Review: Keppel and Olsen (In press)
COSEWIC status report: COSEWIC (2008)
COSEWIC status: Special Concern, SARA status: Special Concern



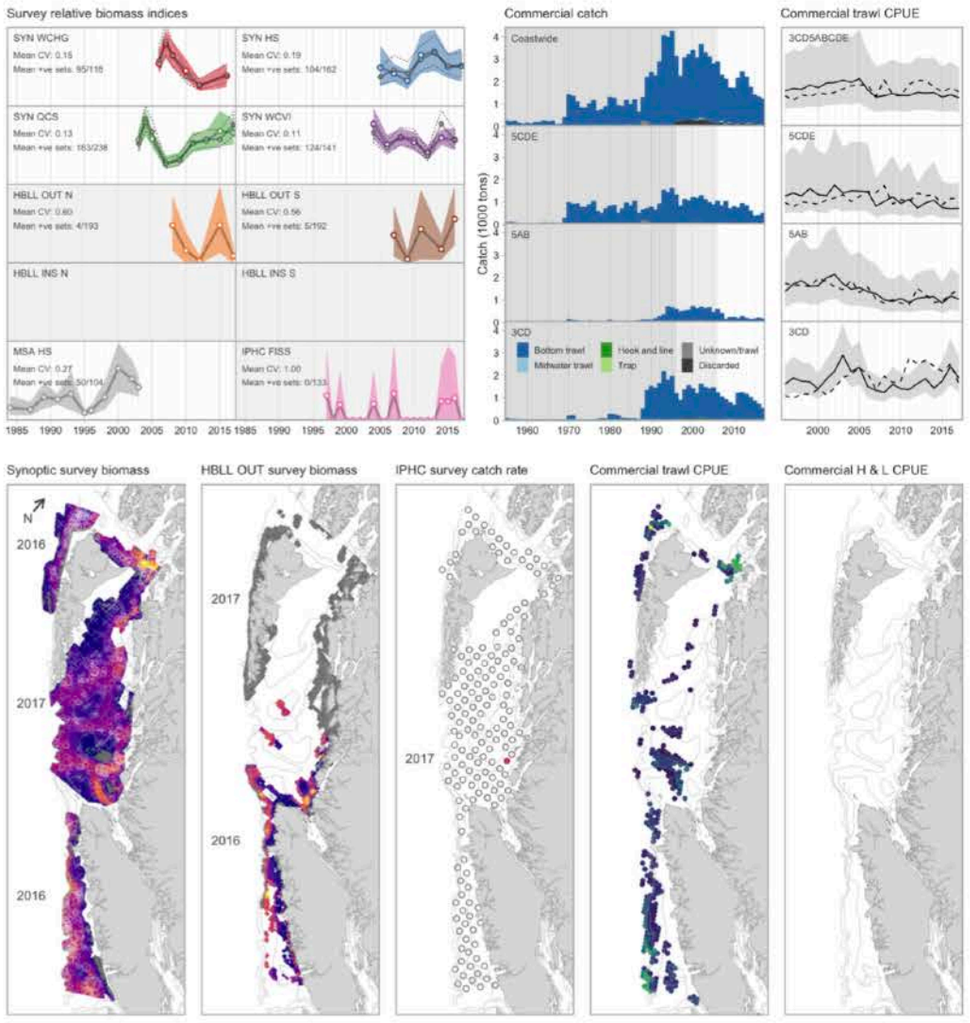


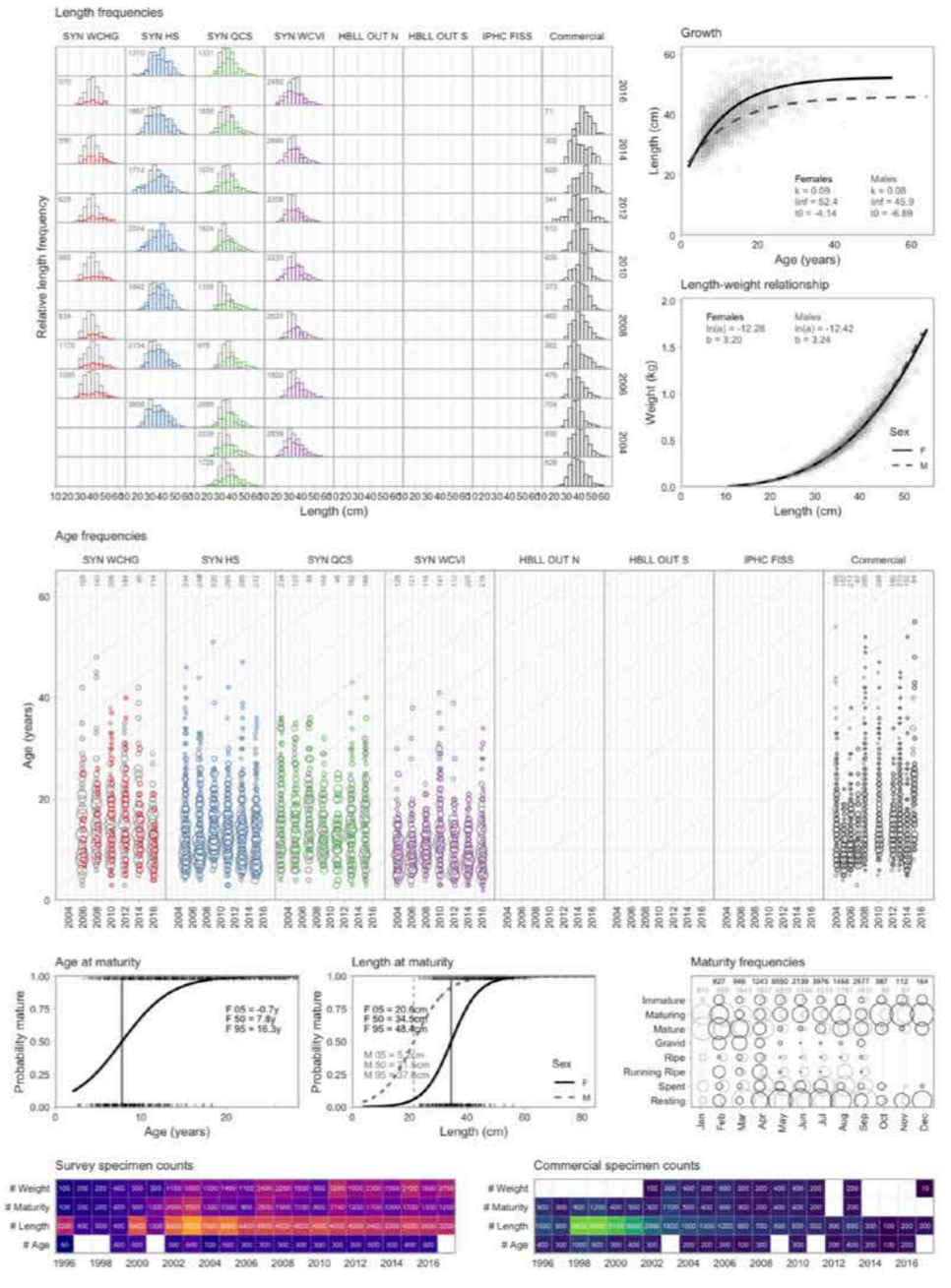
Anderson et al. 2019 CSAS Res Doc. In press.

github.com/pbs-assess/gfsynopsis

5.29 DOVER SOLE

Microstomus pacificus (626)
Order: Pleuronectiformes, Family: Pleuronectidae, FishBase link
Last Science Advisory Report: Fisheries and Oceans Canada (1999f)



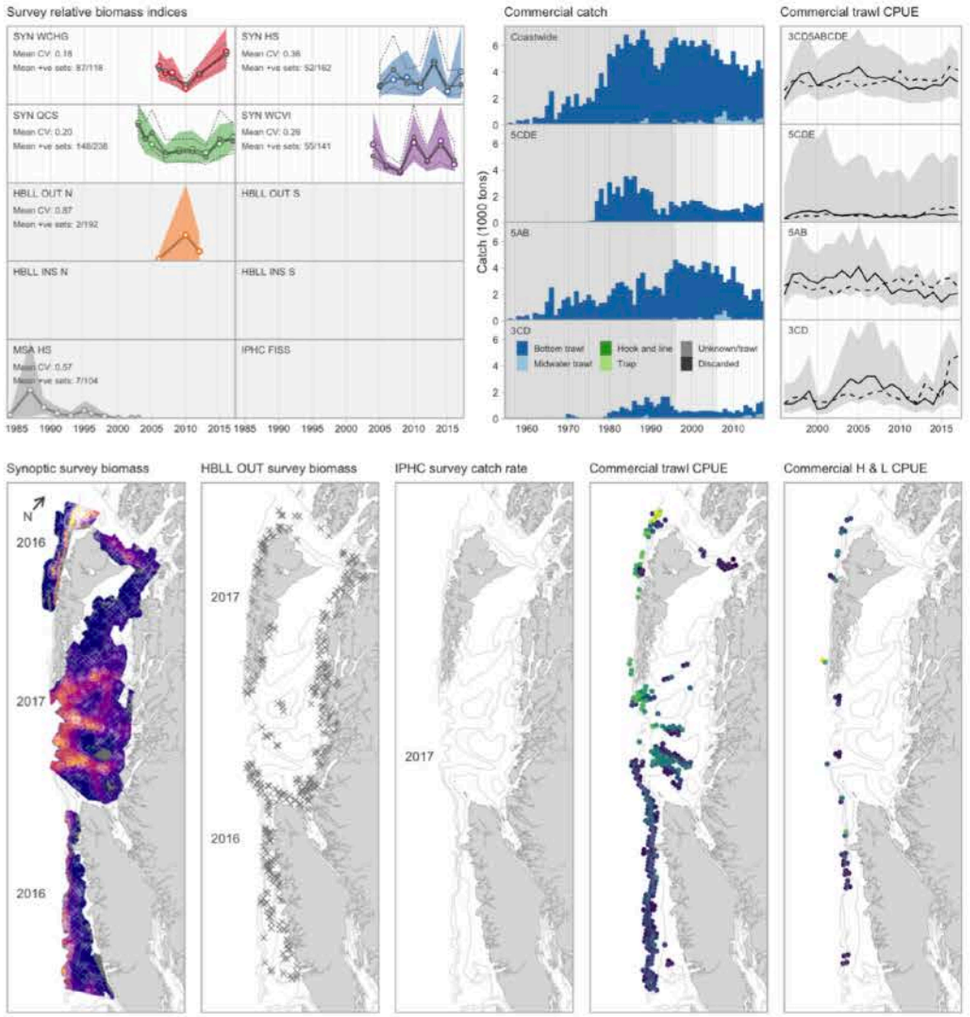


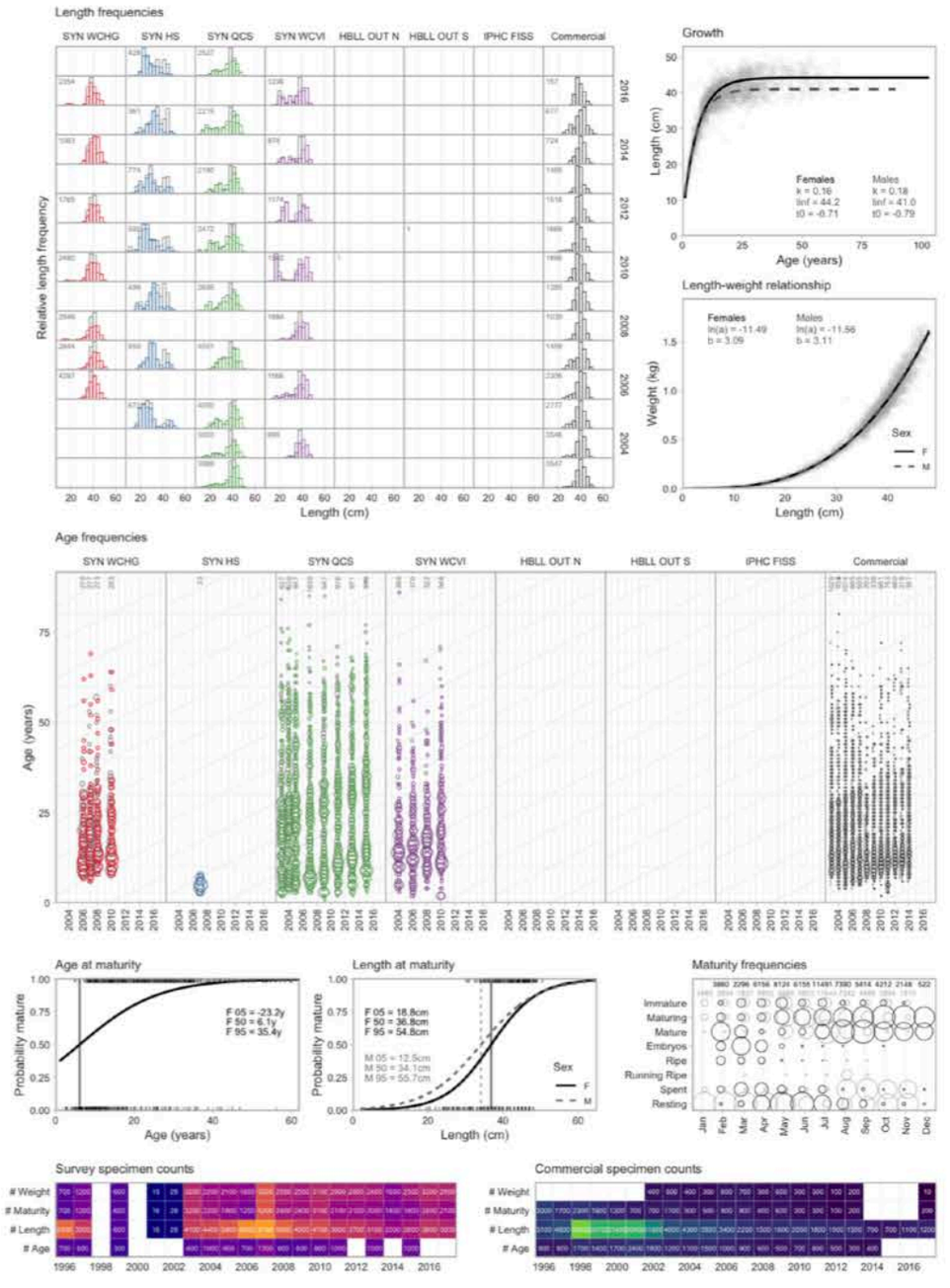
Anderson et al. 2019 CSAS Res Doc. In press.

github.com/pbs-assess/gfsynopsis

5.7 PACIFIC OCEAN PERCH

Sebastes alutus (396)
Order: Scorpaeniformes, Family: Scorpaenidae, FishBase link
Last Research Documents: Edwards et al. (2013), Edwards et al. (2014), Haigh et al. (In press)
Last Science Advisory Reports: Fisheries and Oceans Canada (2013), Fisheries and Oceans Canada (2017a)





Anderson et al. 2019 CSAS Res Doc. In press.

Communication

Prioritization

Faster assessments

Broad monitoring

In conclusion

"Individual surprise events are, by definition, very rare, but it is quite possible that surprise itself [...] is common enough to be an important factor in the daily lives of managers."

Hilborn 1987 North Am. J. Fish. Manag.

Surprises happen.

Surprises with fish and fisheries happen.

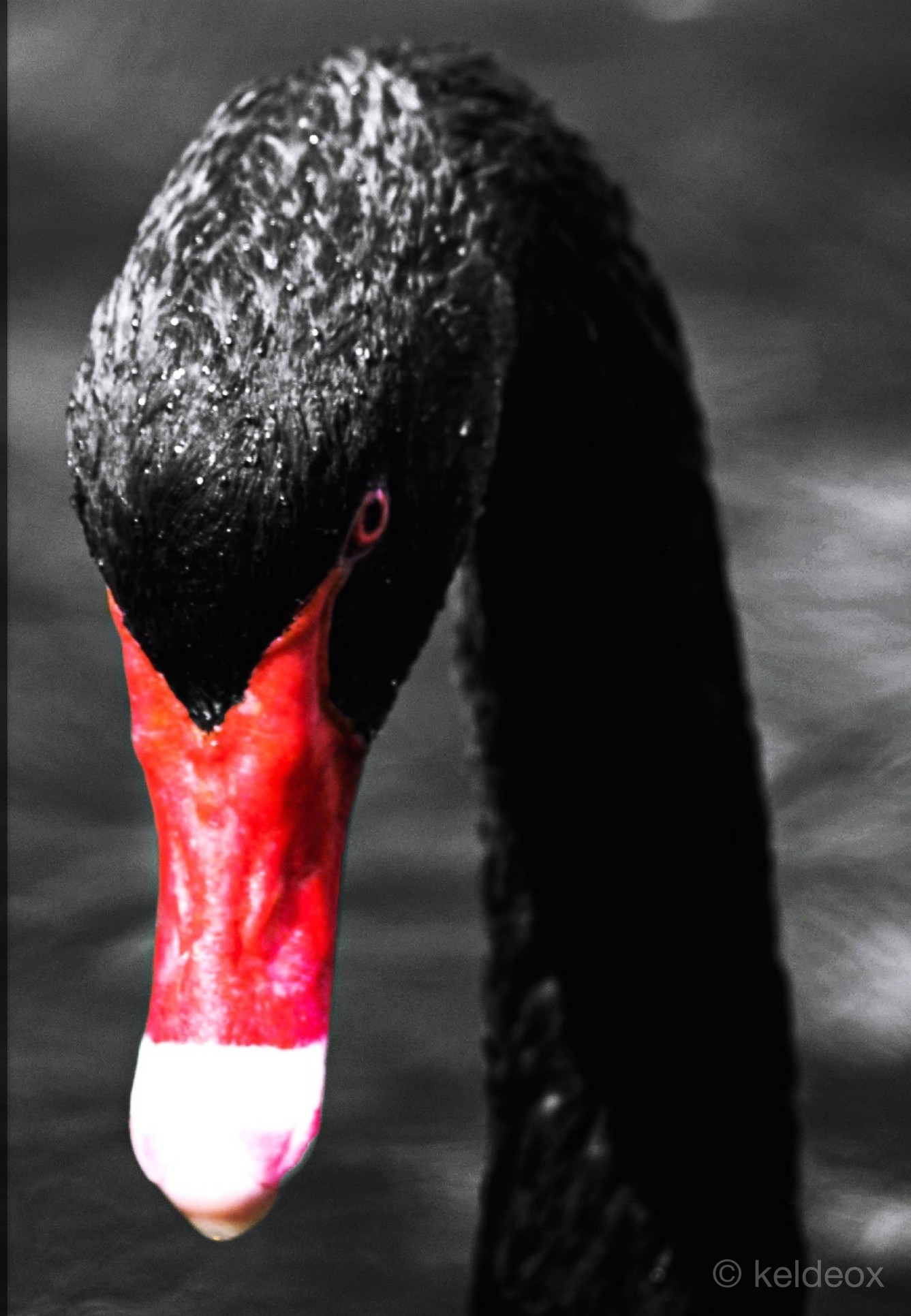
Surprises with fish and fisheries will probably become more common.

Black swans and surprise:

We can integrate them into our models.

We can make our fisheries management systems robust to them.

We can work to detect and react to them quickly.



Sean C. Anderson
sean.anderson@dfo-mpo.gc.ca
seananderson.ca
@sean_anderson

Fisheries and Oceans Canada

Co-authors:
Trevor A. Branch
Nicholas K. Dulvy
Eric J. Ward
Philina A. English
Elise A. Keppel
Andrew M. Edwards

github.com/pbs-assess/gfsynopsis