Black-swan events in fisheries

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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
NEW YORK TIMES BESTSELLER

THE

BLACK SWAN

The Impact of the
HIGHLY IMPOSSIBLE

“The most prophetic voice of all.”
-GQ

Nassim Nicholas Taleb
WALL ST. IN PANIC AS STOCKS CRASH
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
Definitions
The black swan triplet:

1. Rarity
2. Extreme impact
3. Retrospective predictability
Black swans and surprise unite many fields

- Regime shifts
- Extreme climatic events (ECE)
- Mass mortality events (MME)
- Ecological surprises

Back-swan events
$##!+ HAPPENS
where

$#!+ \text{ HAPPENS}$
Salmon size

Salmon returns
Population growth vs. population mortality
Why should we expect black swans for fish and fisheries?
Marine ecosystems contain an enormous number of (potentially) non-linear interactions.
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 surprises?
Increased climate mean + increased variance = increased extremes

Adapted, e.g., from IPCC 2012
Global sea ice area by year (with 2017, 2018)

Last date: 2018-12-29

https://sites.google.com/site/arctischepinguin/home/global-sea-ice

graph by Wipneus

NSIDC NASA
The 'Warm Blob' and 'Blob 2.0'
Blob 2.0 is bad sign for Gulf of Alaska groundfish

By AARON BOLTON  •  DEC 7, 2018

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.

Pacific Cod on ice.
CREDIT PHOTO COURTESY OF HOLLAND DOTTIS & THE ALASKA MARINE CONSERVATION COUNCIL.
What is the evidence?
A survey on ecological surprise

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 Novak8
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
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
"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\textsuperscript{a,b,1,2}, Adam M. Siepielski\textsuperscript{c,1}, Sébastien Nusslé\textsuperscript{d}, Kristina Cervantes-Yoshida\textsuperscript{d}, Jason L. Hwan\textsuperscript{d}, Eric R. Huber\textsuperscript{d}, Maxfield J. Fey\textsuperscript{b}, Alessandro Catenazzi\textsuperscript{e}, and Stephanie M. Carlson\textsuperscript{d}
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
Searching for black swans in 609 animal abundance time series

Black-swan events in animal populations

Sean C. Anderson\textsuperscript{a,b,1}, Trevor A. Branch\textsuperscript{b}, Andrew B. Cooper\textsuperscript{c}, and Nicholas K. Dulvy\textsuperscript{a}

\textsuperscript{a}Earth to Ocean Research Group, Department of Biological Sciences, Simon Fraser University, Burnaby, BC V5A 1S6, Canada; \textsuperscript{b}School of Aquatic and Fishery Sciences, University of Washington, Seattle, WA 98195; and \textsuperscript{c}School of Resource and Environmental Management, Simon Fraser University, Burnaby, BC V5A 1S6, Canada
Simulated population dynamics

Normal process noise

$t$ distribution with degrees of freedom $= \infty$
Simulated population dynamics

Heavier-tailed noise

Degrees of freedom = 5
Simulated population dynamics

Very heavy-tailed noise

Degrees of freedom = 2
Simulated population dynamics

Student - t distribution

Normal

Simulated population dynamics

Black swans

log Abundance

Normal
tails

Prior

Posterior samples

Model fits

Median + IQR

Samples or probability

Heavy tails

Slightly heavy tails

Time step
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

\[
\text{Process noise log}(\sigma)
\]

\[
\log(\text{Time steps})
\]

\[
\log(\text{Lifespan})
\]

Density dependence

Productivity

\[
\text{Coefficient value (per 2 SDs of predictor)}
\]

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?

Synoptic survey biomass

Queen Charlotte Sound

2018

2017

2018

2003

2004

2005

2007

2009

2011

2013

2015

2017

Biomass estimate kg/km²

2000

1000

500

100

Are Pacific groundfish tracking local climate velocities?

Local climate velocity vectors

Local biomass changes

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

Grey heron

Anderson et al. 2017a PNAS
The multivariate t distribution for spatiotemporal extremes

A spatial extreme in time

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

**A Halibut**

- Median revenue ($1000/year)
- Estimated revenue variability
- Number of permits: 1, 2, 3
- Permit holders: 500, 1000, 1500

Adding a permit reduces revenue variability.
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)
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)
Same 2-page layout for all species
Draft available at:
github.com/pbs-assess/gfsynopsis
6.12 ALASKA SKATE

*Bathyraja parmiifera* (061)
Order: Rajiformes, Family: Arhynchobatidae. [FishBase link](#)
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
5.29 DOVER SOLE

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

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.