A Salmon's Eye View:
digital twins for salmon lives in salmon habitats

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Outline

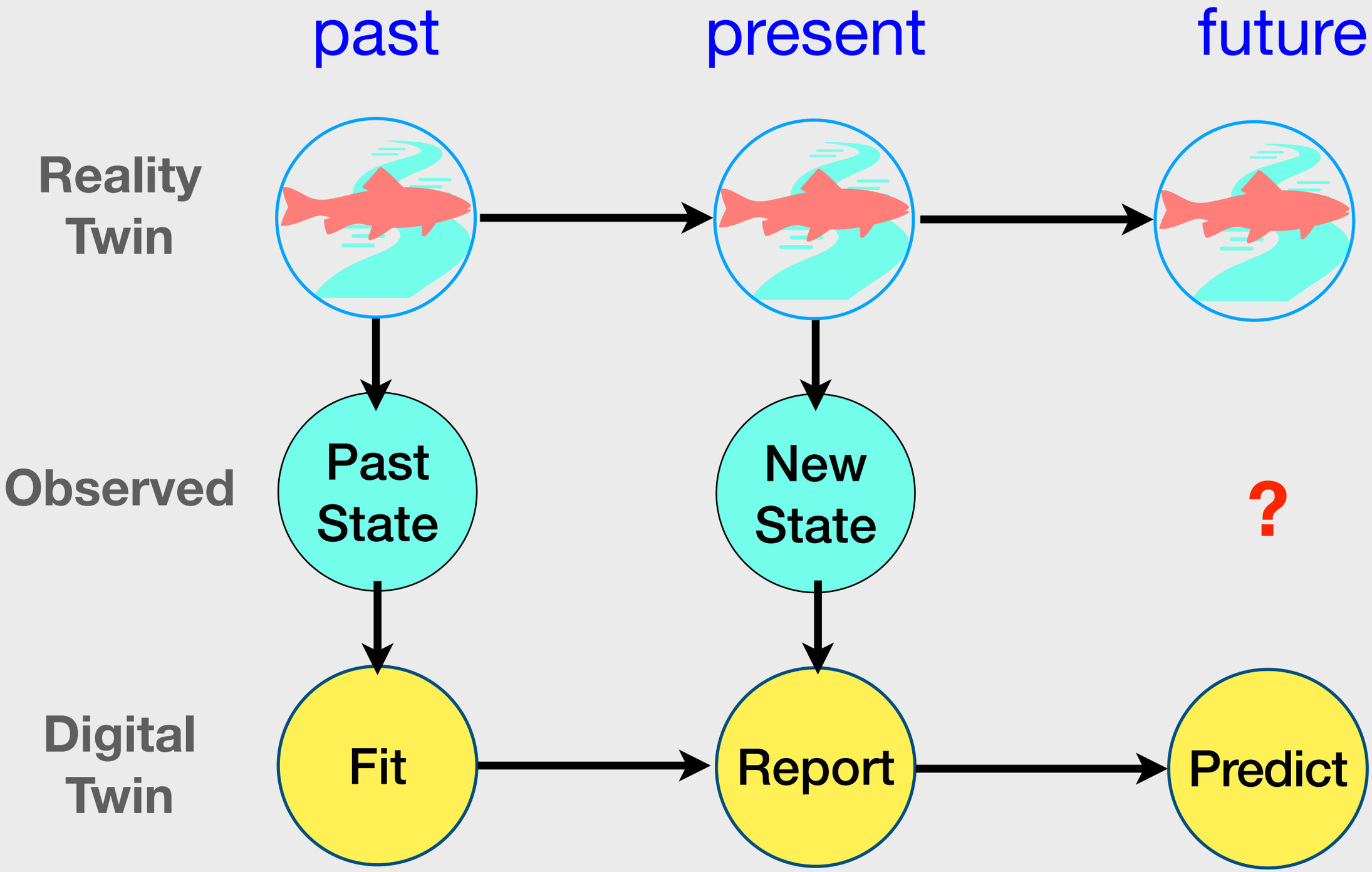
1. Digital Twin
2. Shared Steps
3. Collaboration
4. Example

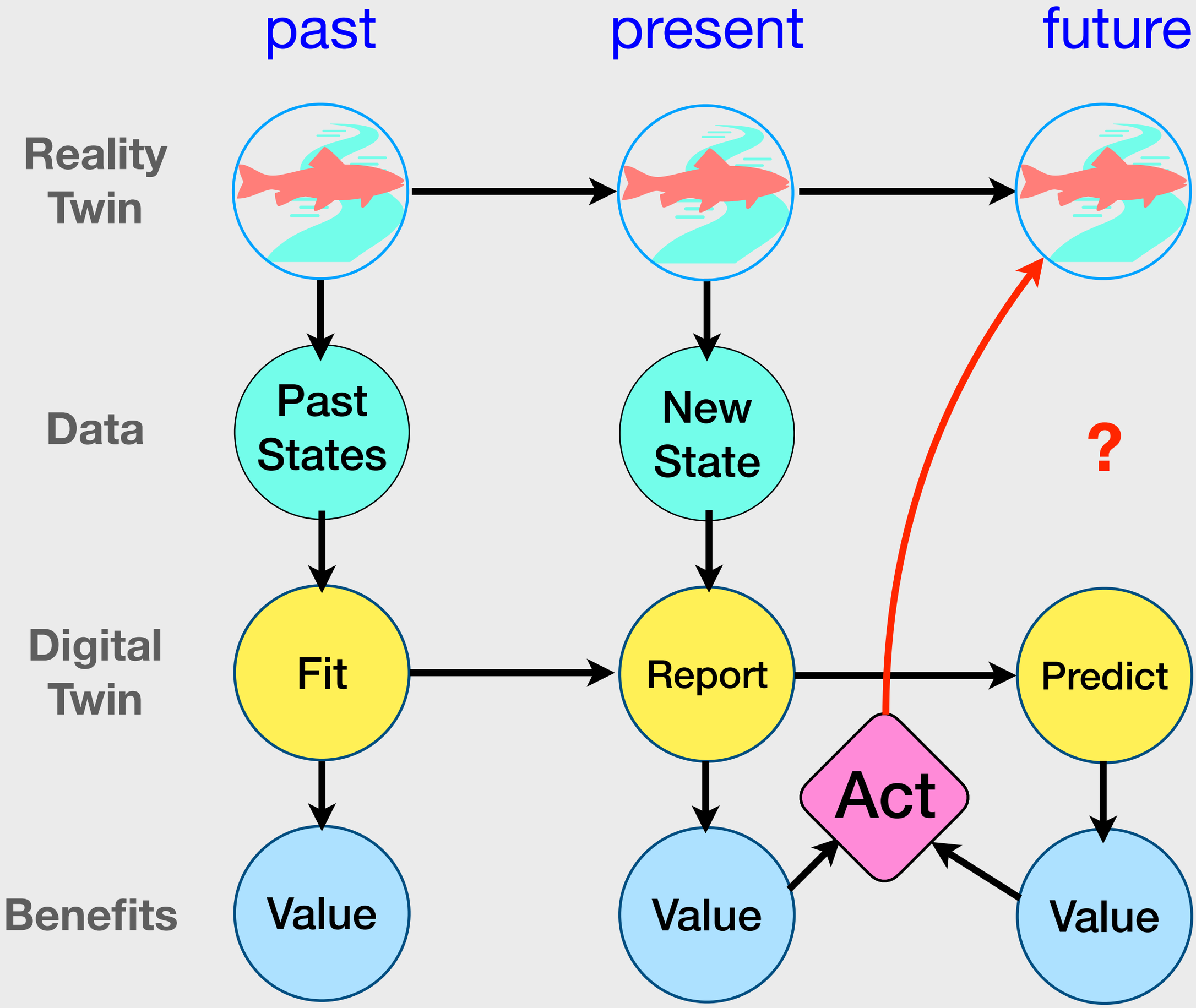


Part 1.

Salmon Digital Twin




past
present
future
Reality Twin
Observed
Past State
New State
?
Digital Twin
Fit
Report
Predict

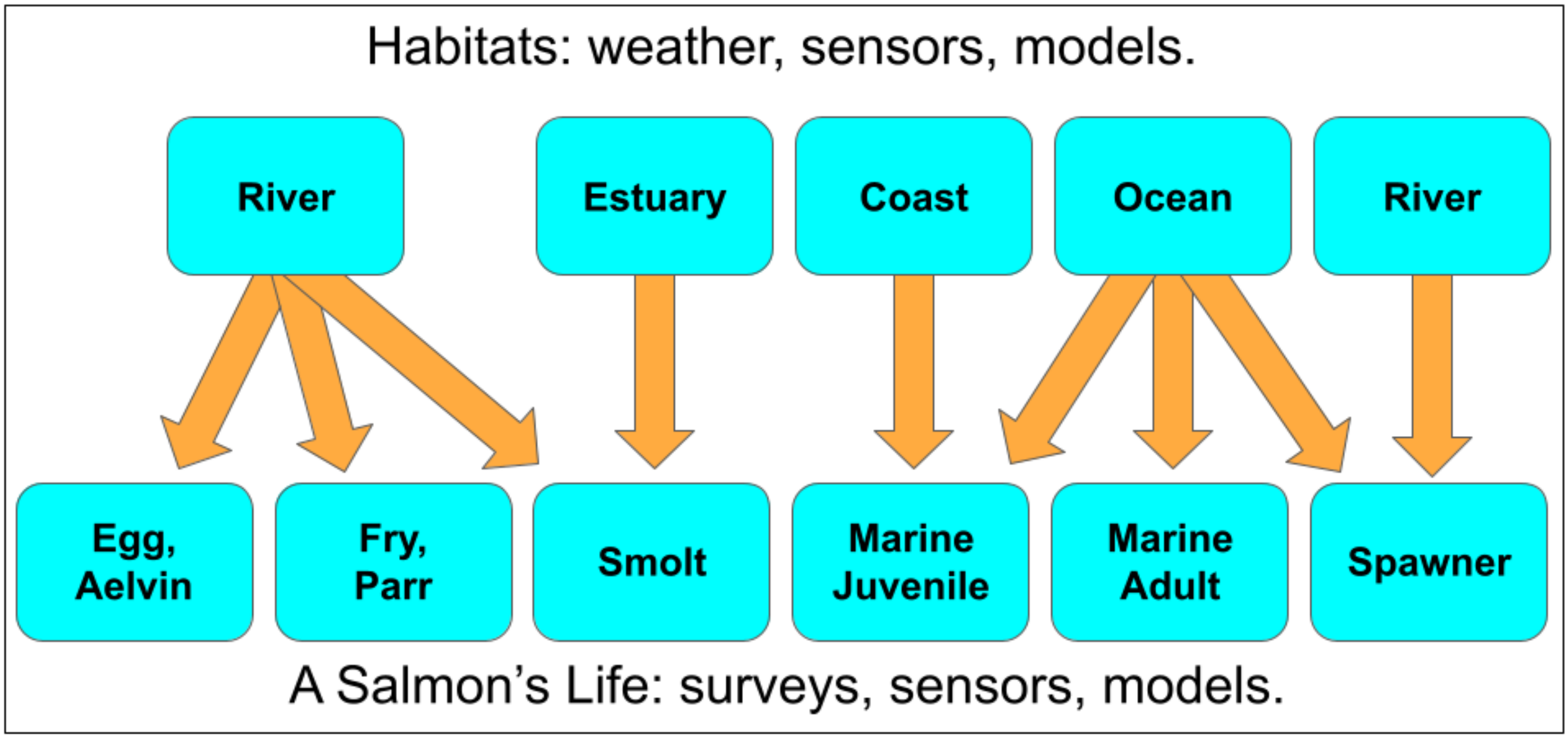

past
present
future
Reality Twin
Data
Digital Twin
Benefits
Past States
New State
?
Fit
Report
Predict
Act
Value
Value
Value

Part 2.

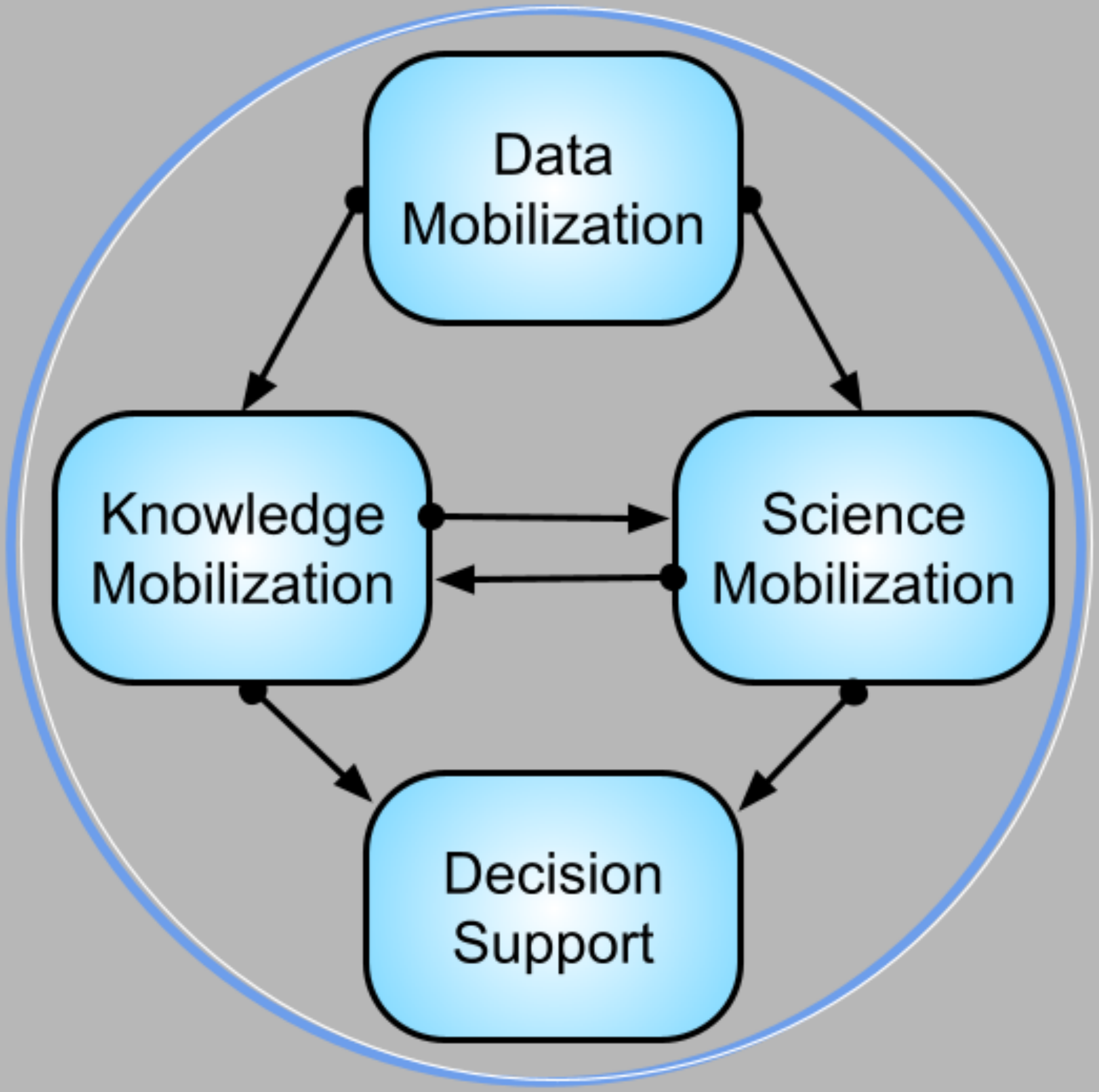
Shared Steps



Habitat twins drive life-stage twins



Shared steps in workflows


Data
Mobilization
Knowledge
Mobilization
Science
Mobilization
Decision
Support

Data Sources
- historical
- real-time

Platform
- integration
- AI learning

Models
- salmon life
- habitats

Applications
- scenarios
- status

Data Sources
- historical
- real-time

Platform
- integration
- AI learning

Models
- salmon life
- habitats

Exports
- Excel RTD
- API, REST

Applications
- scenarios
- status

Interfaces
- ecologists
- managers
- public

Reports
- documents
- Infographics

Decision Support
- trade-offs
- values

Part 3.

Collaboration



a PSC grant! (almost)

Feasibility Study for Digital Twins in PSC Decision Support

Organize:

Gottfried Pestal, Scott Akenhead

Collaborate:

Dr. Colin Bull
University of Stirling
Dr. Lene Sortland
Norwegian Institute for Nature Research
Dr. Eduardo Roberts
University of Northern British Columbia
Brett Johnson
Pacific Salmon Commission
Dr. Patrick Thompson
Fisheries and Ocean Canada
Dr. Tomas Bird
Fisheries and Ocean Canada
Dr. Charles Hannah
Fisheries and Oceans Canada

Dr. Yi Xu
Washington Dept. Fish and Wildlife
Dr. Curry Cunningham
University of Alaska Fairbanks
Dr. Jon Chamberlain
Fisheries and Oceans Canada
Dylan Glaser
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Kaitlyn Dionne
Fisheries and Oceans Canada
Dr. Brendan Connors
Fisheries and Oceans Canada
Dr. Cameron Freshwater
Fisheries and Oceans Canada

A practical question:

What are the potential benefits, and implementation challenges, for a salmon digital twin able to monitor and predict how the 2027 *Godzilla El Niño* will impact en-route and pre-spawning mortality for Sockeye and Chinook in the Fraser and Columbia watersheds?

Wide and Open Collaboration

Goals

- Experiments with models, technologies, AI, sharing.
- Twins as re-usable steps:
  - by life-stage, by habitat.
- Habitat twins ↔ Salmon twins

Workshops

- Four on-line:
  - kick-off: Nov. 2026 ?
  - wrap-up: February 2027
- Sharing: GitHub, Slack,.

Products

- Decision support
- Public awareness
- Tools for twins
- Standards and guidelines

Rewards

- Learn by sharing
- Better models and tools
- Your name on papers
- Save the salmon

Part 4.

Example: Nechako Sockeye



another PSC grant! (almost)

Migration Mortality from Thermal Stress in Nechako Sockeye: *A Digital Twins Approach*

Organize:

Scott Akenhead

Sreekant Sreedharan

Norwegian U. Science & Technology

Collaborate:

Dr. Eduardo Martins

U. Northern British Columbia

Dr. Patrick Thompson

Fisheries and Oceans Canada

Your Name

Your Agency

Nechako River Watershed



Monitoring Sites
- Active
- Decommissioned
- Rivers
- Lakes

Watershed Elevation
- 600 m ASL
- 1000 m ASL
- 1400 m ASL
- 1800 m ASL
- 2200 m ASL
- 2600 m ASL

9 13 10 29 30 24 21 28 22 18 19 12 4 17 20 6 27 16 15 14 7 26 2 25 32 31 8 11 3 23 5 1

0 50 100 150 km

a call for collaboration:

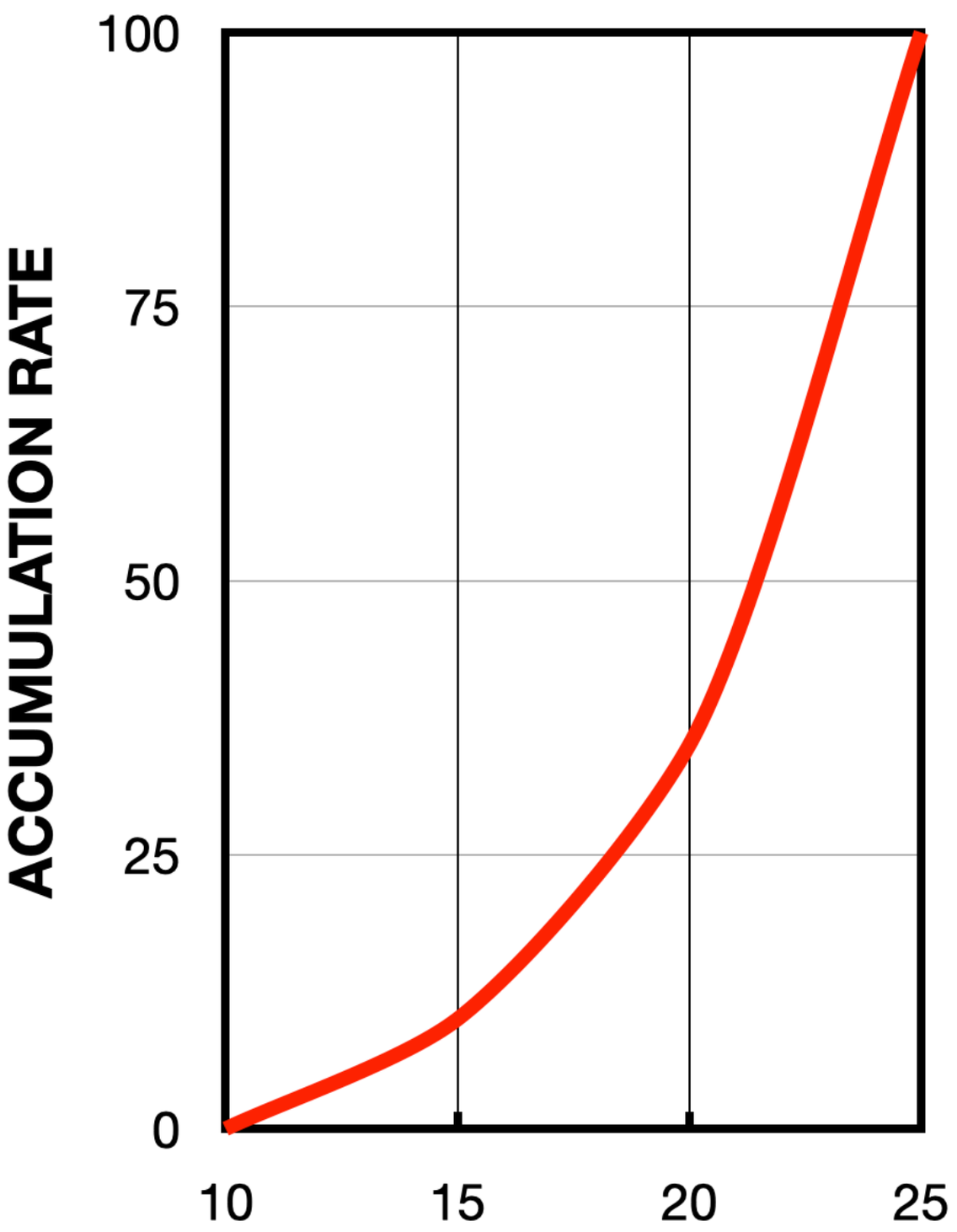
Nechako Sockeye spawners as *the illustrative example*

(1) Where, when, how, and why spawners **accumulate thermal stress** during a 1,000 km migration up the Fraser, Nechako, and Stuart Rivers.

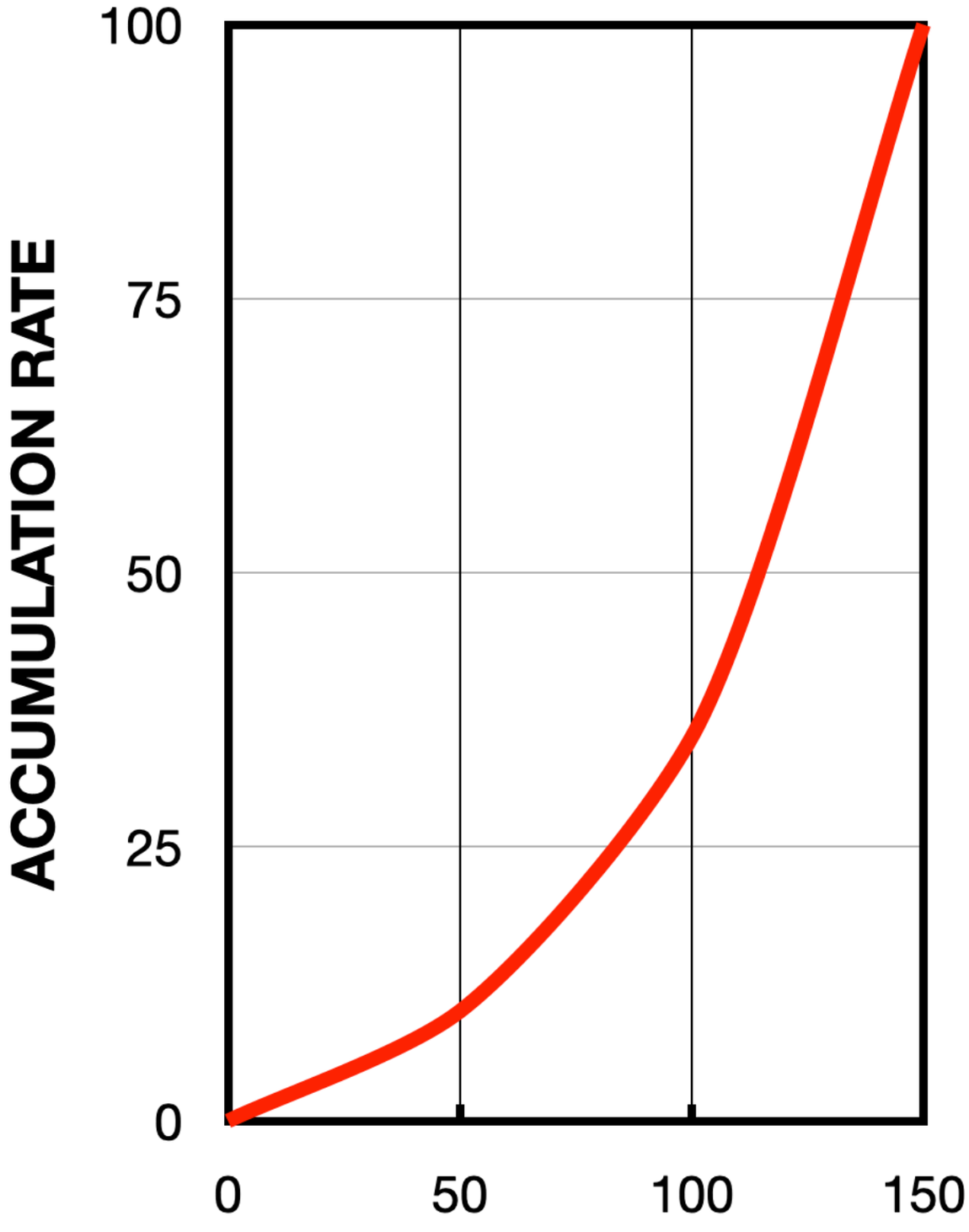
(2) Visible in near-real time (2027).

(3) Subsequent implementation.

TEMPERATURE STRESS



MORTALITY RISK



$$\text{fish_velocity} = f(L, T, F, E, \text{ATS})$$

ms^{-1}

L = Length

T = Temperature, river

F = Flow rate, proxy for river velocity

E = Energetics: lipids, maturation

ATS = Accumulated Thermal Stress

fish_phenology = f(t, T, E, ATS)

% lipid, % gonad, ATS, AMR

t = time

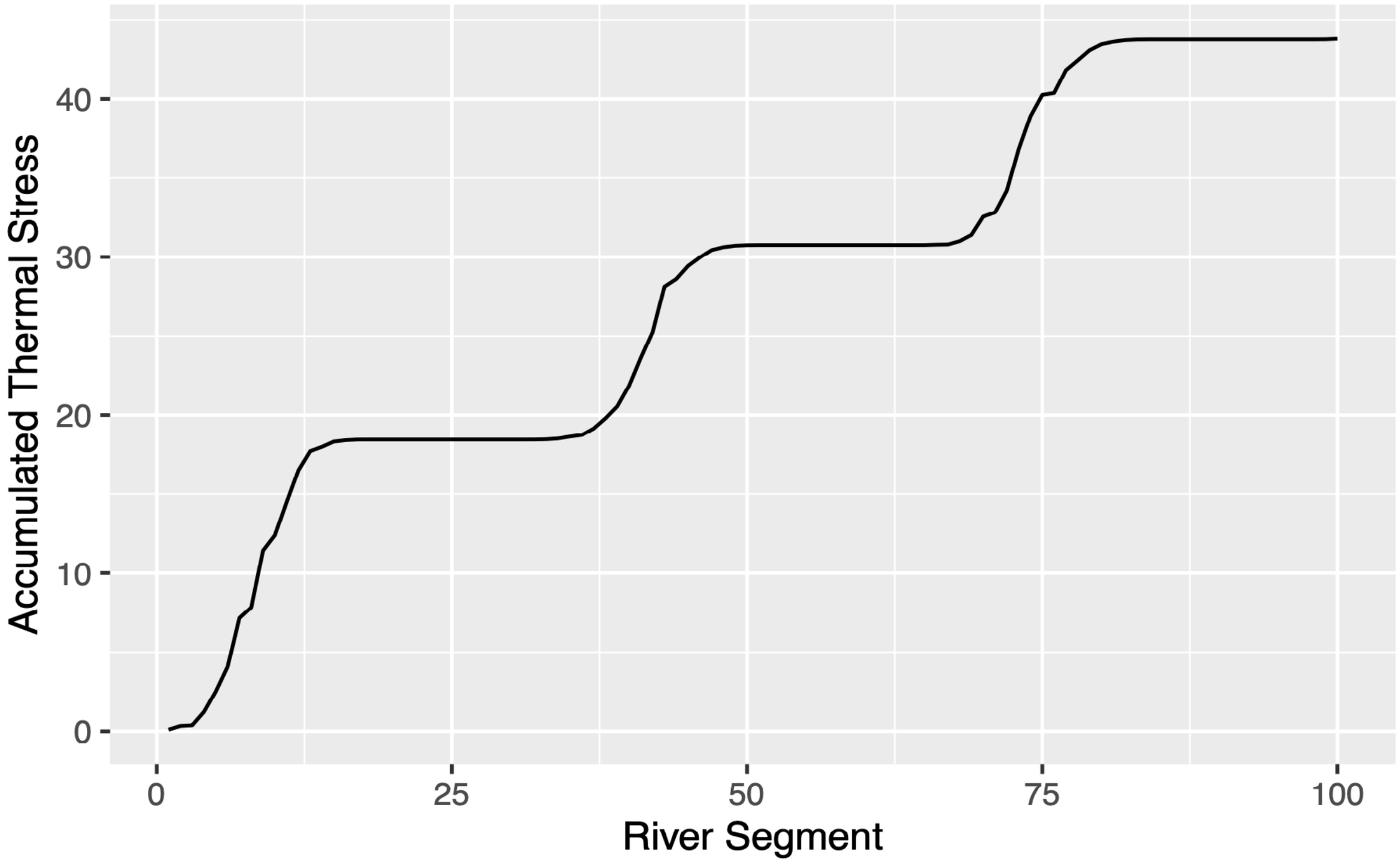
T = Temperature: metabolic rate

E = Energetics: lipids, maturation

ATS = Accumulated Thermal Stress

AMR = Accumulated Mortality Risk

Maybe the salmon don’t die where they were killed.



Questions?

Comments?

Apoplexy?




Scott@S4S.com

U.S.E.R.-friendly

Understandable

Safe

Effective

Reusable



Abstract

Digital twins for salmon populations will introduce a new paradigm for fisheries science and management: a shift from coarse-scale correlations to fine-scale mechanisms, as required in the context of climate chaos and (with informative exceptions) world-wide declines of salmon populations.
Salmon twins are data-driven simulation models that utilize
(1) conventional abundance estimates of salmon at consecutive life stages (parr, smolt, adult landings)
(2) in-situ video and sonar observations,
(3) data from remote sensing instruments carried by satellites or aerial, surface, and submerged drones, and
(4) real-time habitat information.
The simulations continuously predict how a salmon is reacting to a real-time prediction of the state of the habitat that the salmon is experiencing: a salmon's eye view.
That habitat state is, in turn, output from an ocean digital twin and from twins for coastal zones, estuaries, rivers, and lakes.
The result is visibility of the present state of a salmon population, a prediction of its future state, and predictions from what-if scenarios about habitat restoration, extreme weather events, land-use, and effects from fisheries.
Among the challenges of moving from 1950's stock-recruit models to individual-based, mechanistic models for salmon will be large-scale mobilization of data, knowledge, and science, and an attendant requirement for better collaboration and communication.
The technological foundation for this paradigm shift is facilitated by rapidly-evolving enabling technologies such as AI; how remains to be seen.
Salmon twins that use ocean twins and watershed twins will open important opportunities including:
(1) a more informed approach to reversing salmon population declines, (
(2) confronting and and prioritizing knowledge gaps,
(3) faster learning from scenarios and experience (adaptive management), and **critically**
(4) improved engagement with decision fora, co-managers, stakeholders, citizen science, and open-source collaborators.