Teaching problem solving skills to the next generation of natural resource professionals: a proposed framework

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Critical thinking

"Efforts to develop critical thinking falter in practice because too many professors still lecture to passive audiences instead of challenging students to apply what they have learned to new questions".-Derek Bok

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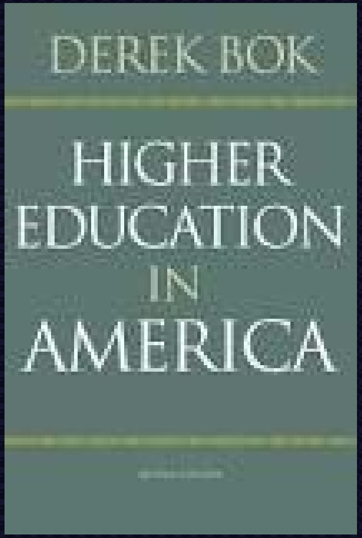
Challenge

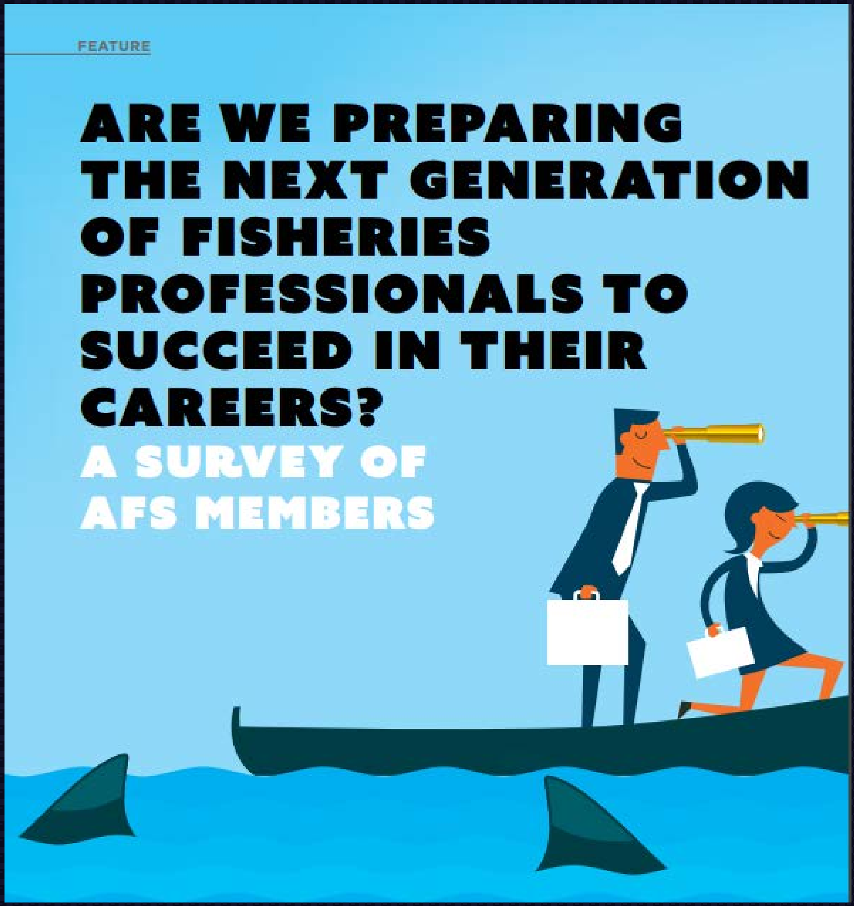
"Colleges and universities, for all the benefits they bring, accomplish far less for their students than they should…

Many students graduate without being able to write well enough to satisfy their employers... reason clearly or perform competently in analyzing complex, non-technical problems".-Derek Bok



Educating the next generation

- Natural resources educators have debated curricula for decades.
- Despite the need for writing and speaking skills, it has been recognized that those skills are lacking in in our graduates.



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What do employers desire?

- Critical thinking skills
- Oral communication
- Writing skills
- Team work
- Non-technical communication skills

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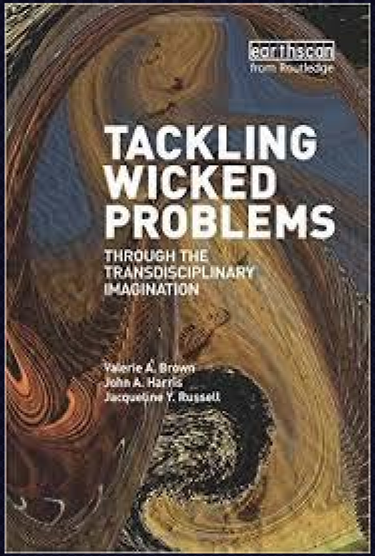
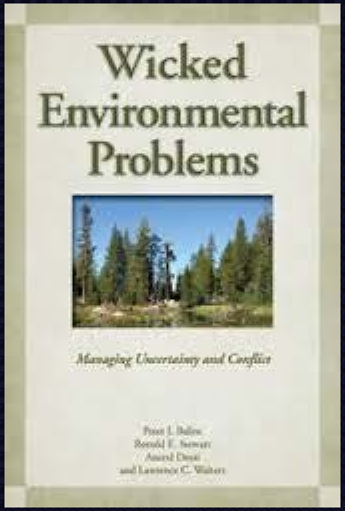
Decision Making in Natural Resources

- Multiple stakeholders
- Conflict
- Uncertainty
- Persistent
- Complex
- Large scale

- = "Wicked" Problems



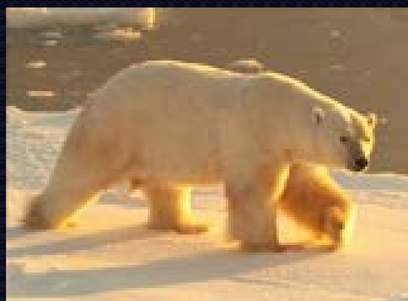


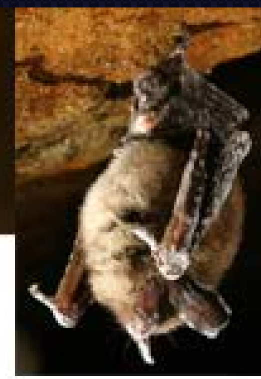
Structured Decision Making

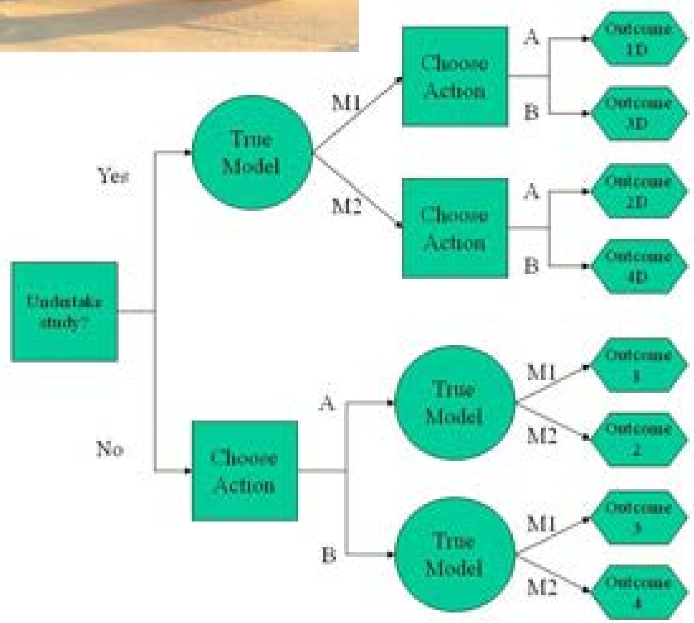
"A formal application of common sense for situations too complex for the informal use of common sense."

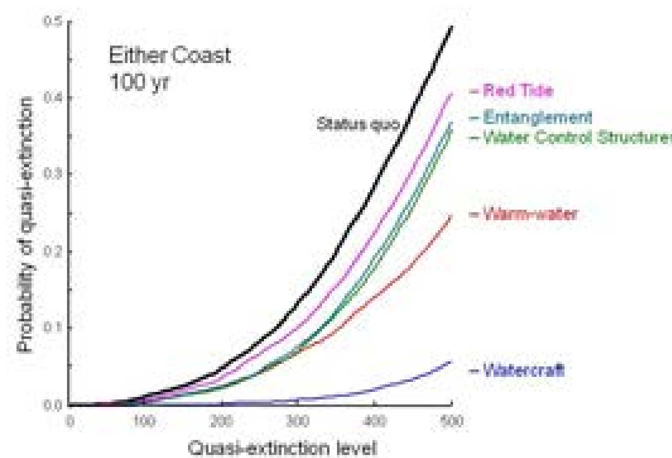
R. Keeney

SDM examples Natural Resources









Triggers

- Discussions with ADCNR about preparing their future employees.
- Experience with workshops that delivered positive results on multiple problems.

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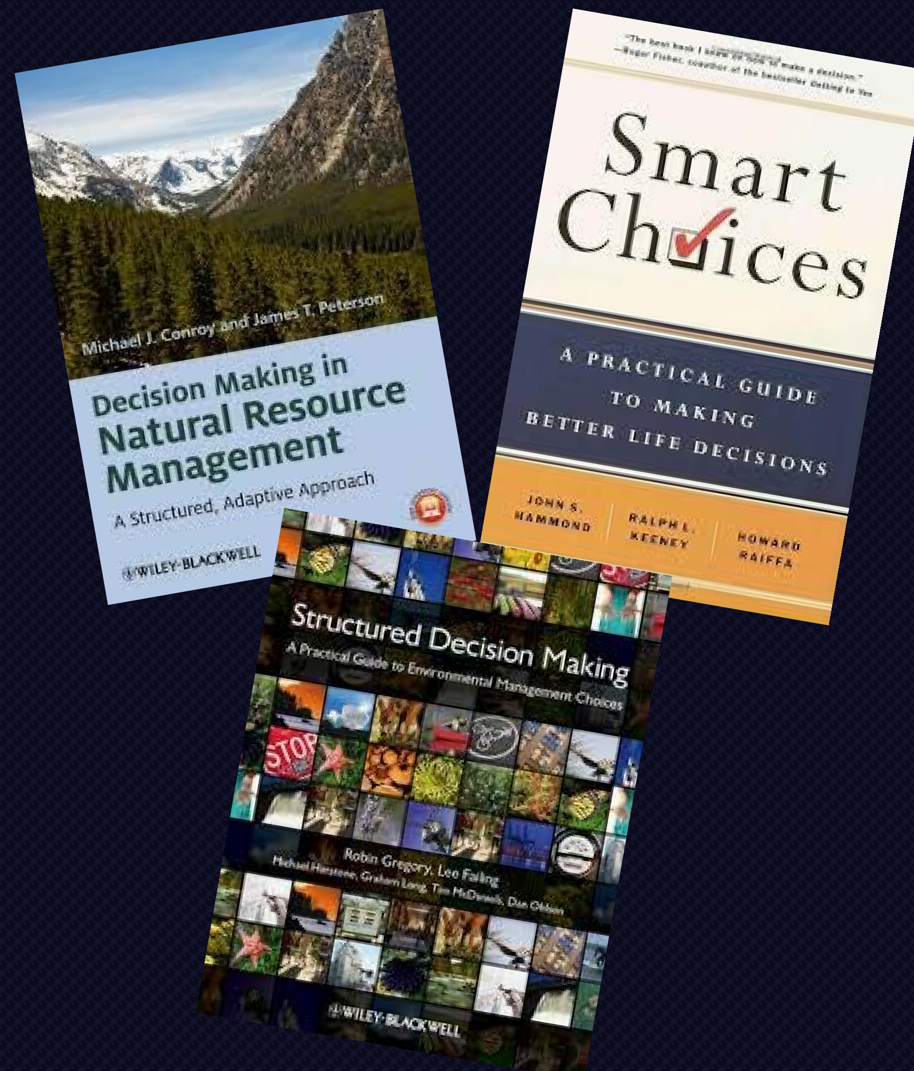
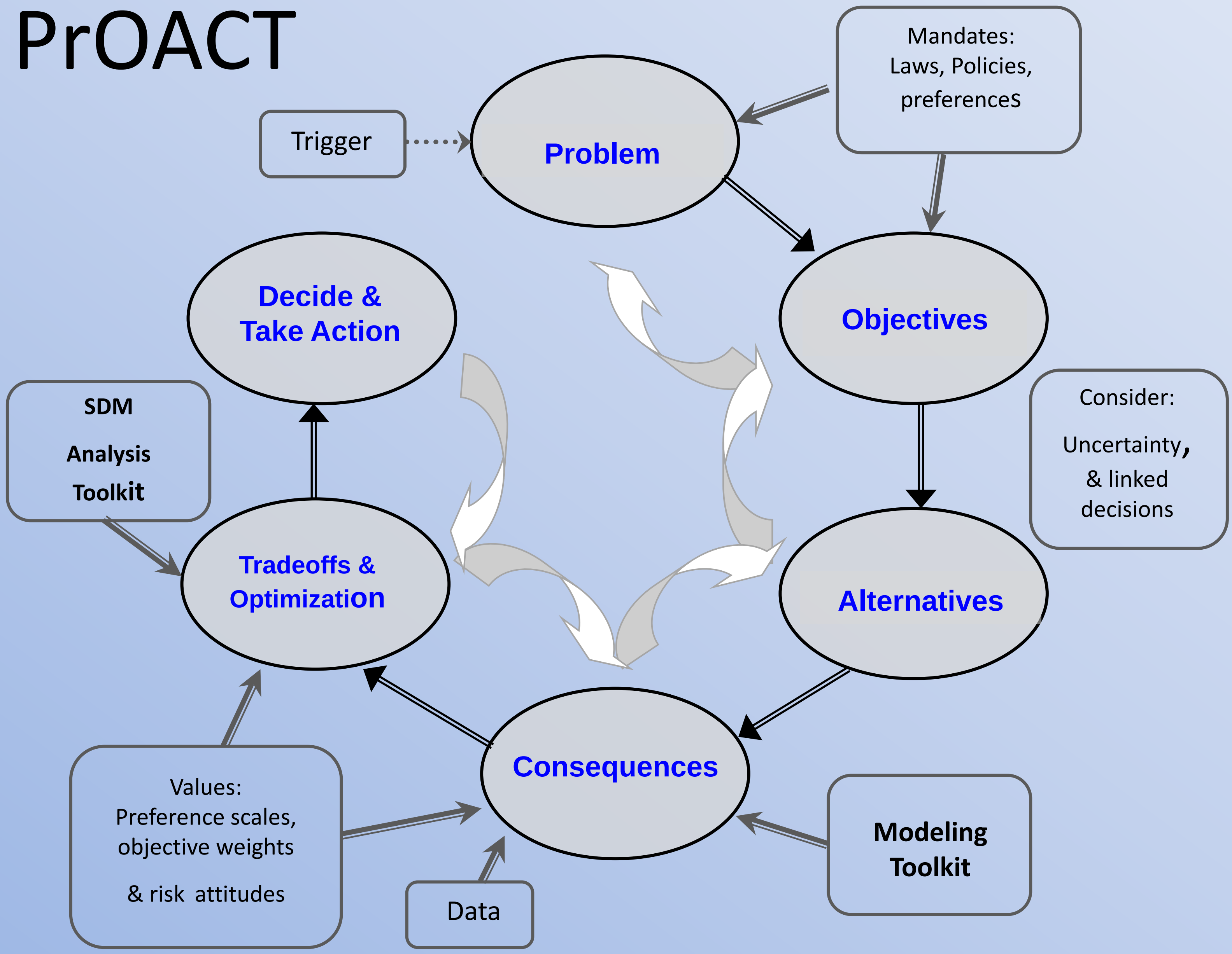
Implementation

- FISH2100 is summer course offered to rising Juniors.
- Introduces students to the different tracts in fisheries.
- Experiential learning through field trips and guest lectures.
- Added the SDM component to meet needs of employers

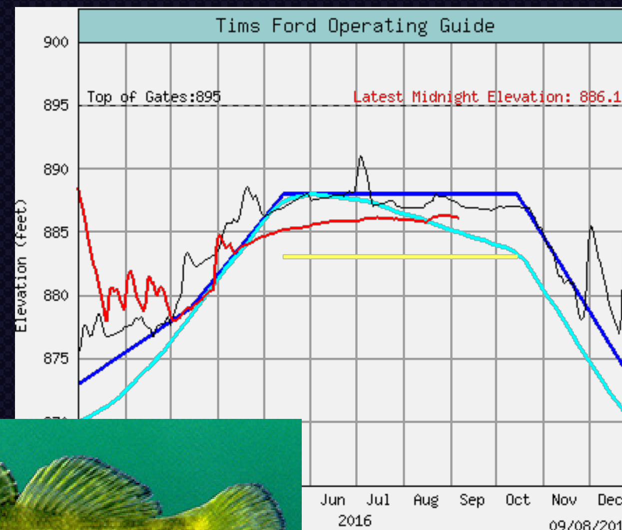


PrOACT



Mandates:
Laws, Policies,
preferences
Trigger
Problem
Objectives
Decide &
Take Action
Consider:
Uncertainty,
& linked
decisions
SDM
Analysis
Toolkit
Tradeoffs &
Optimization
Alternatives
Consequences
Values:
Preference scales,
objective weights
& risk attitudes
Modeling
Toolkit
Data

Problems are opportunities-to learn



Problem

Problem Example	Description
Lionfish invasion	Lionfish are an invasive marine species with no known predators. Solutions are needed to minimize impacts on fisheries.
State Lakes Program evaluation	The State of Alabama Department of Conservation is interested in evaluation of strategies to maximize the program that provides affordable fishing for the public.
Elk River Boulder Darter conservation	Boulder Darters are an Endangered Species that is extant in a regulated river. A trout fishery is also present creating conflict between conservation objectives and angling objectives.
Red Snapper management in the Gulf of Mexico	Red Snapper fisheries are highly regulated in the Gulf of Mexico. What management strategies are available to maximize angling satisfaction while protecting spawning stocks.

Problem Framing

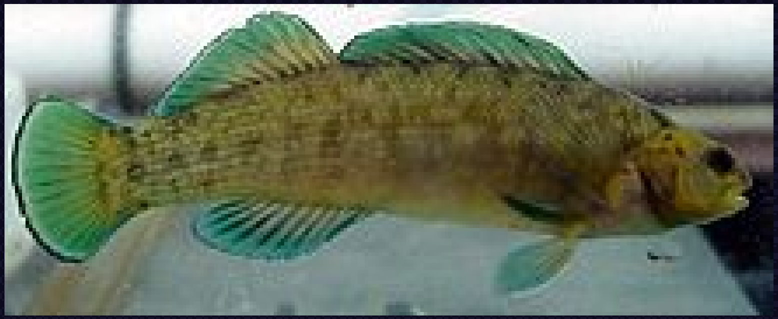
- Who is the decision maker?
- What are the legal and regulatory contexts?
- Identify the decision's essential elements
  - Scope and scale
  - Timing and frequency
- Understand what other decisions are linked to this one. Iterative?

Problem statement

"The Tennessee Valley Authority works with the US Fish and Wildlife Service and other governmental agencies when determining how to regulate flow downstream of dams. Tim's Ford Dam is located on the Elk River and has permanently changed the flow patterns of the Elk River at ERM 133. The Elk River has a federally listed endangered species called the Boulder Darter Etheostoma wapiti that is endemic to the Elk River. The cold water releases from the dam have created a stretch of stream that is too cold for Boulder Darters to grow and reproduce. In accordance with the ESA the TVA must work to maintain suitable habitat for the endangered species to ensure its survival. The coldwater release from the dam can be regulated so that temperature is kept at normal warm water stream levels. The area in the cold tailwater of Tim's Ford Dam has become a stocked trout fishery. The trout fishery is stocked with Brown Trout Salmo trutta and Rainbow Trout Oncorhynchus mykiss. The trout fishery is valued at 48 million dollars and is very important to the local economy. Any decision made should use adaptive management taking into account the need to ensure the survival of the Boulder Darter and do everything possible to protect the economic value of the trout fishery. The decision made will set the precedent for how to proceed but the dam will have to be monitored every day to ensure that the flows are regulated and within the allowable limits."

Objectives

- What do we really care about?
- Values based-Get there by asking questions
  - Why is that important?
  - How do we get there?
- Most difficult part of the process
- Basis for good decision making



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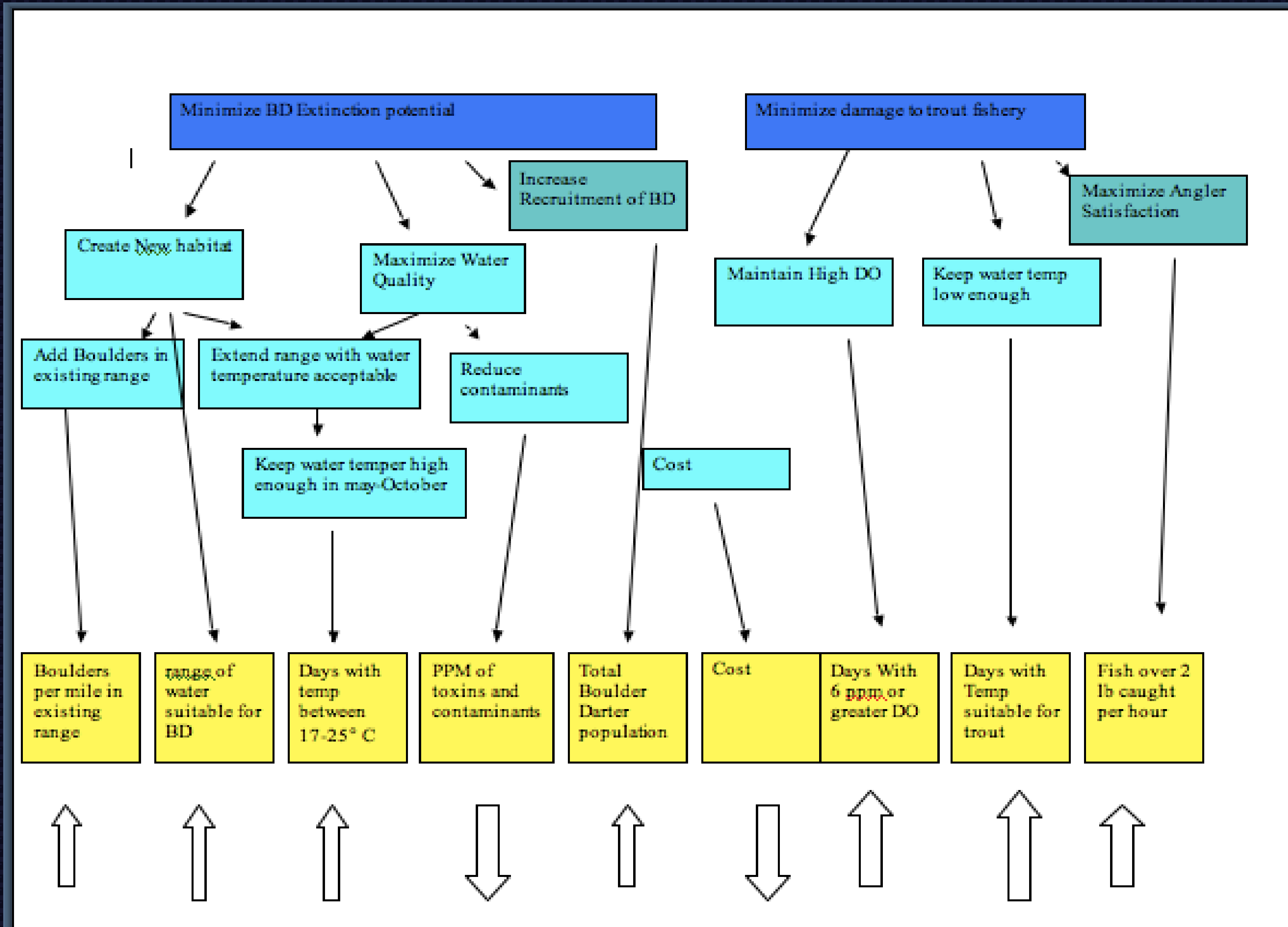

Minimize BD Extinction potential
Minimize damage to trout fishery
Increase Recruitment of BD
Maximize Angler Satisfaction
Create New habitat
Maximize Water Quality
Maintain High DO
Keep water temp low enough
Add Boulders in existing range
Extend range with water temperature acceptable
Reduce contaminants
Keep water temper high enough in may-October
Cost
Boulders per mile in existing range
range of water suitable for BD
Days with temp between 17-25° C
PPM of toxins and contaminants
Total Boulder Darter population
Cost
Days With 6 ppm or greater DO
Days with Temp suitable for trout
Fish over 2 lb caught per hour

Alternatives

- Are the things that we do toward achieving our objectives.
- Paralysis can occur here…
  - Get out of the box…
  - Alternatives that worked other places in similar systems can't work "here"
  - Management options for imperiled species are too severe or risky (or expensive)

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Consequences

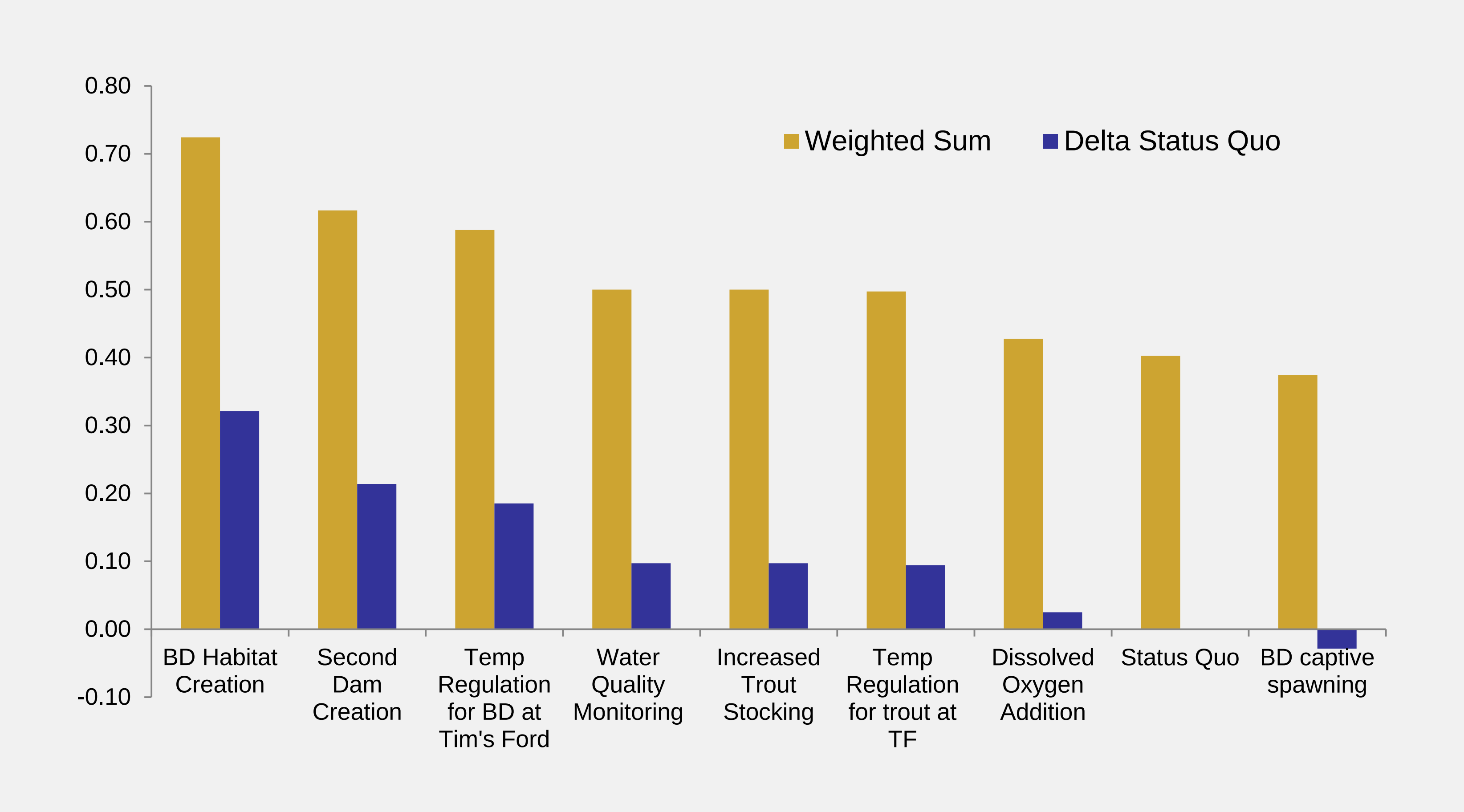
"decision making is a forward-looking process….And if decision making is the attempt to achieve a desired future, then any such attempt must include, implicitly or explicitly, a vision of what that future will look like."

– Sarewitz et al. (2000). Prediction: Science, Decision Making, and the Future of Nature. Island Press.

Consequences

	Objective	Boulder Darter Extinction Potential	BD Range	Angler Satisfaction	Cost	Economic Value Conservation
	Criteria	Boulder Darter Population	Elk River miles suitible for BD	Population of Trout	Dollars Spent	% of Economic Value Conserved
	Measurable Attribute	BD captured per hour electrofishing	# of ERM	# of trout caught per hour	$ (1= Lowest and 5=Highest)	% of $40 million remaining
	Desired Direction	Maximize	Maximize	Maximize	Minimize	Maximize
		0.25	0.25	0.20	0.20	0.10
Status Quo		0.00	0.00	0.63	1.00	0.78
Temp Regulation for BD at Tim's Ford		0.67	1.00	0.00	0.86	0.00
Temp Regulation for trout at TF		0.00	0.17	0.83	1.00	0.89
BD Habitat Creation		1.00	0.50	0.50	0.86	0.78
Water Quality Monitering		0.33	0.00	0.67	1.00	0.83
Second Dam Creation		0.67	1.00	0.67	0.00	0.67
Dissolved Oxygen Addition		0.00	0.00	0.75	1.00	0.78
Increased Trout Stocking		0.00	0.00	1.00	1.00	1.00
BD captive spawning		0.00	0.00	0.63	0.86	0.78

Trade-offs



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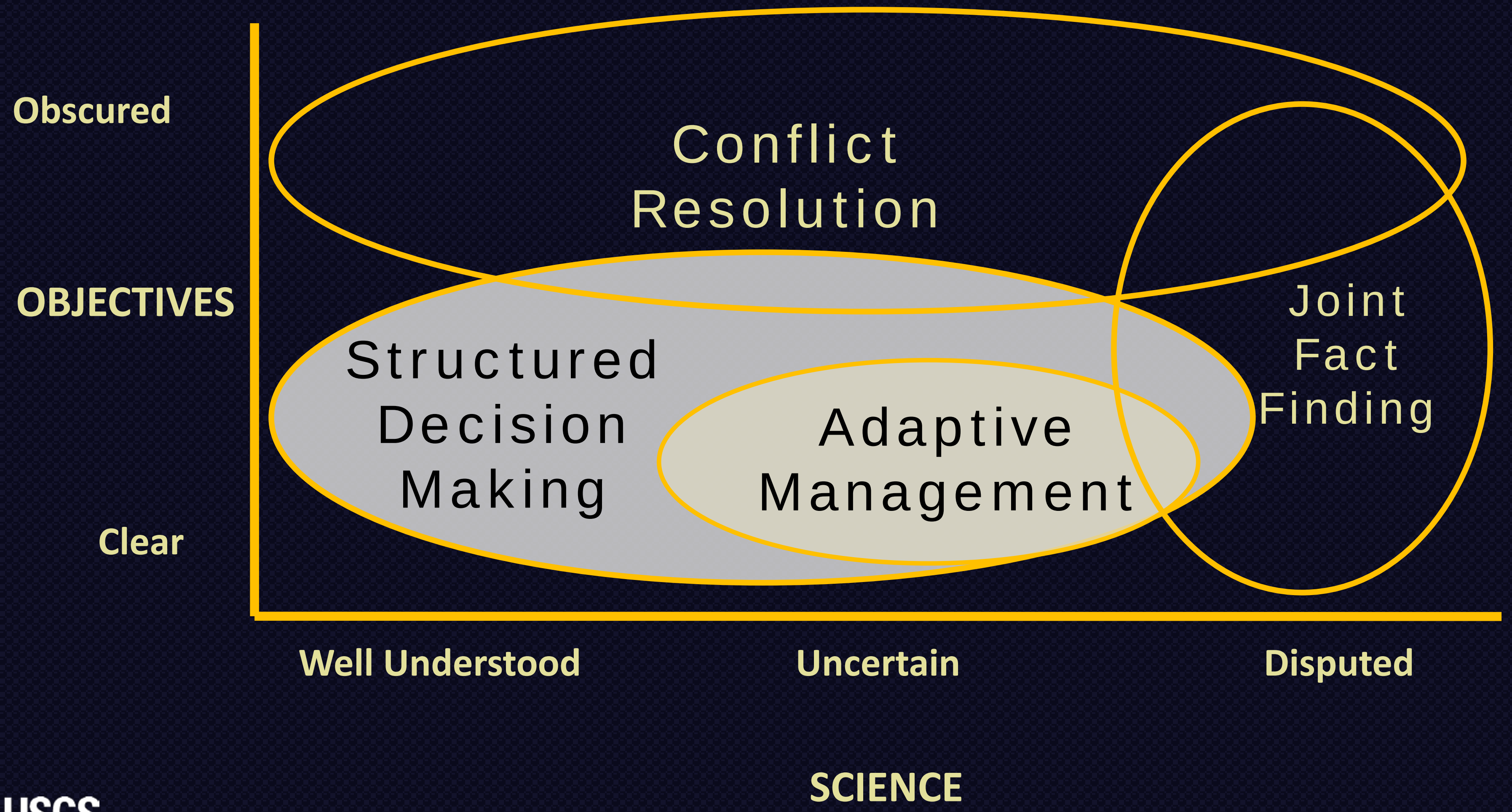
When is SDM appropriate?



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Learning objectives

- ✓ Critical thinking skills
- ✓ Oral communication
- ✓ Writing skills
- ✓ Team work
- Non-technical communication skills

What is missing?

- Quality decision making in multiple-use systems requires all stakeholders.
- Management happens on a local scale---we can not control broad-scale processes (geology, climate).
- Diverse stakeholders lead to higher-quality management decisions.
- Groups are better at making decisions when they use structured processes.

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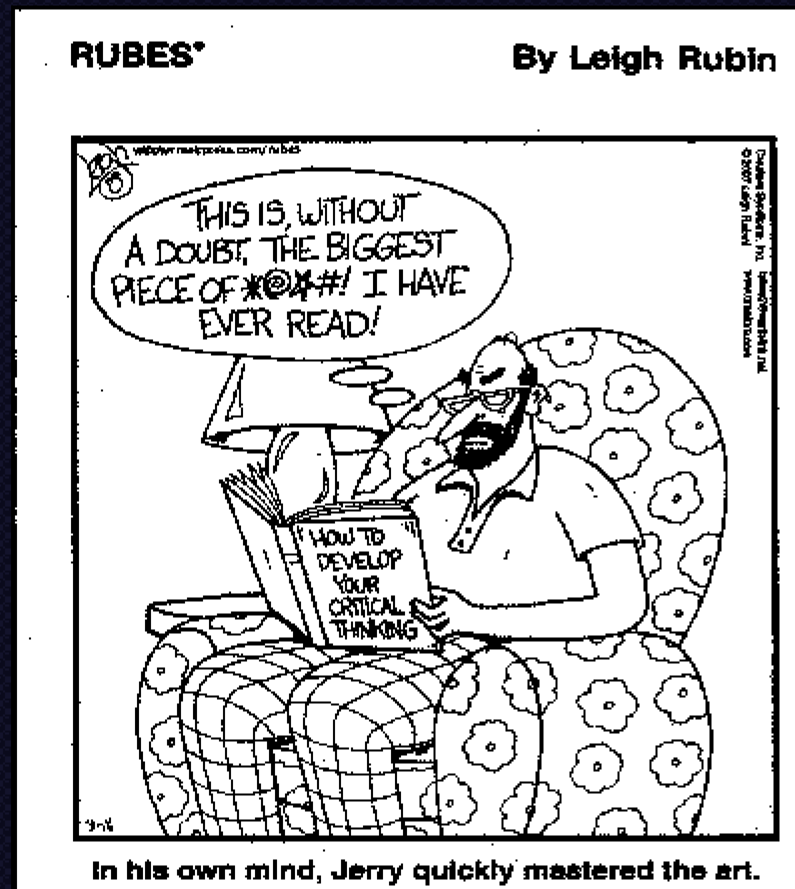
Evaluation

- High ratings by most, some don't get it.



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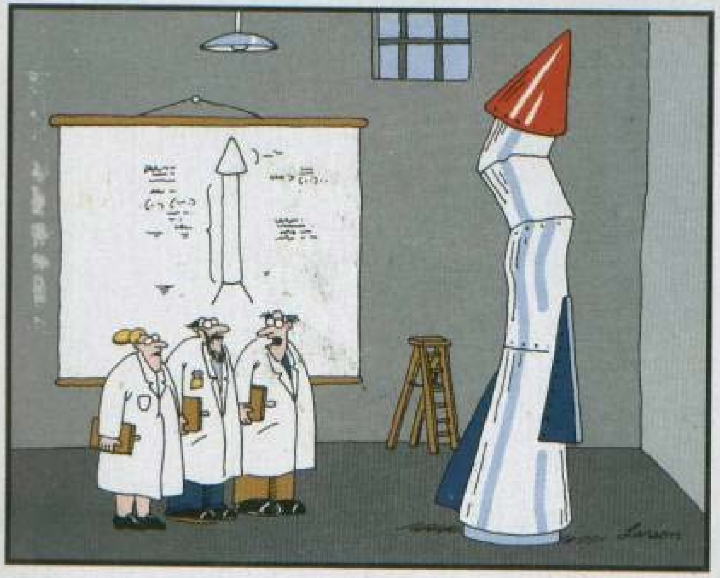
It isn't rocket science….

$$\ddot{x} = \frac{1}{M-mt}\{mc_e + F_n(p - p_{atm_s} e^{-(k/H)(\sqrt{(x^2+y^2+z^2)}-R)})\} \cos\alpha(t) - g_0 R^2 \frac{x}{(x^2+y^2+z^2)^{3/2}} +$$
$$- \frac{c_w(\sqrt{(\dot{x}^2+\dot{y}^2+\dot{z}^2)}, \chi)}{M-mt} \rho_0 e^{-(1/H)(\sqrt{(x^2+y^2+z^2)}-R)} F\dot{x}\sqrt{(\dot{x}^2+\dot{y}^2+\dot{z})} +$$
$$+ \frac{c_a(\sqrt{(\dot{x}^2+\dot{y}^2+\dot{z}^2)}, \chi)}{M-mt} \rho_0 e^{-(1/H)(\sqrt{(x^2+y^2+z^2)}-R)} F \times$$
$$\times \frac{\dot{z}\{\dot{z}\cos\alpha(t) - \dot{x}\cos\gamma(t)\} - \dot{y}\{\dot{x}\cos\beta(t) - \dot{y}\cos\alpha(t)\}\sqrt{(\dot{x}^2+\dot{y}^2+\dot{z}^2)}}{\sqrt{[\{\dot{y}\cos\gamma(t) - \dot{z}\cos\beta(t)\}^2 + \{\dot{z}\cos\alpha(t) - \dot{x}\cos\gamma(t)\}^2 + \{\dot{x}\cos\beta(t) - \dot{y}\cos\alpha(t)\}^2]}} + 2\dot{y}\omega + \omega^2 x$$

$$\ddot{y} = \frac{1}{M-mt}\{mc_e + F_n(p - p_{atm_s} e^{-(k/H)(\sqrt{(x^2+y^2+z^2)}-R)})\} \cos\beta(t) - g_0 R^2 \frac{y}{(x^2+y^2+z^2)^{3/2}} +$$
$$- \frac{c_w(\sqrt{(\dot{x}^2+\dot{y}^2+\dot{z}^2)}, \chi)}{M-mt} \rho_0 e^{-(1/H)(\sqrt{(x^2+y^2+z^2)}-R)} F\dot{y}\sqrt{(\dot{x}^2+\dot{y}^2+\dot{z}^2)} +$$
$$+ \frac{c_a(\sqrt{(\dot{x}^2+\dot{y}^2+\dot{z}^2)}, \chi)}{M-mt} \rho_0 e^{-(1/H)(\sqrt{(x^2+y^2+z^2)}-R)} F \times$$
$$\times \frac{\dot{x}\{\dot{x}\cos\beta(t) - \dot{y}\cos\alpha(t)\} - \dot{z}\{\dot{y}\cos\gamma(t) - \dot{z}\cos\beta(t)\}\sqrt{(\dot{x}^2+\dot{y}^2+\dot{z}^2)}}{\sqrt{[\{\dot{y}\cos\gamma(t) - \dot{z}\cos\beta(t)\}^2 + \{\dot{z}\cos\alpha(t) - \dot{x}\cos\gamma(t)\}^2 + \{\dot{x}\cos\beta(t) - \dot{y}\cos\alpha(t)\}^2]}} - 2\dot{x}\omega + \omega^2 y$$

$$\ddot{z} = \frac{1}{M-mt}\{mc_e + F_n(p - p_{atm_s} e^{-(k/H)(\sqrt{(x^2+y^2+z^2)}-R)})\} \cos\gamma(t) - g_0 R^2 \frac{z}{(x^2+y^2+z^2)^{3/2}} +$$
$$- \frac{c_w(\sqrt{(\dot{x}^2+\dot{y}^2+\dot{z}^2)}, \chi)}{M-mt} \rho_0 e^{-(1/H)(\sqrt{(x^2+y^2+z^2)}-R)} F\dot{z}\sqrt{(\dot{x}^2+\dot{y}^2+\dot{z}^2)} + \frac{c_a(\sqrt{(\dot{x}^2+\dot{y}^2+\dot{z}^2)}, \chi)}{M-mt} \rho_0 \times$$
$$\times e^{-(1/H)(\sqrt{(x^2+y^2+z^2)}-R)} F \frac{\dot{y}\{\dot{y}\cos\gamma(t) - \dot{z}\cos\beta(t)\} - \dot{x}\{\dot{z}\cos\alpha(t) - \dot{x}\cos\gamma(t)\}\sqrt{(\dot{x}^2+\dot{y}^2+\dot{z}^2)}}{\sqrt{[\{\dot{y}\cos\gamma(t) - \dot{z}\cos\beta(t)\}^2 + \{\dot{z}\cos\alpha(t) - \dot{x}\cos\gamma(t)\}^2 + \{\dot{x}\cos\beta(t) - \dot{y}\cos\alpha(t)\}^2]}}$$

in which: $\chi = \arccos \frac{\dot{x}\cos\alpha(t) + \dot{y}\cos\beta(t) + \dot{z}\cos\gamma(t)}{\sqrt{(\dot{x}^2+\dot{y}^2+\dot{z}^2)}}$


"It's time we face reality, my friends. … We're not exactly rocket scientists."

"powered flight of rocket through terrestrial atmosphere with prescribed thrust direction as a function of time, considered as a system of reference rotating with the earth"

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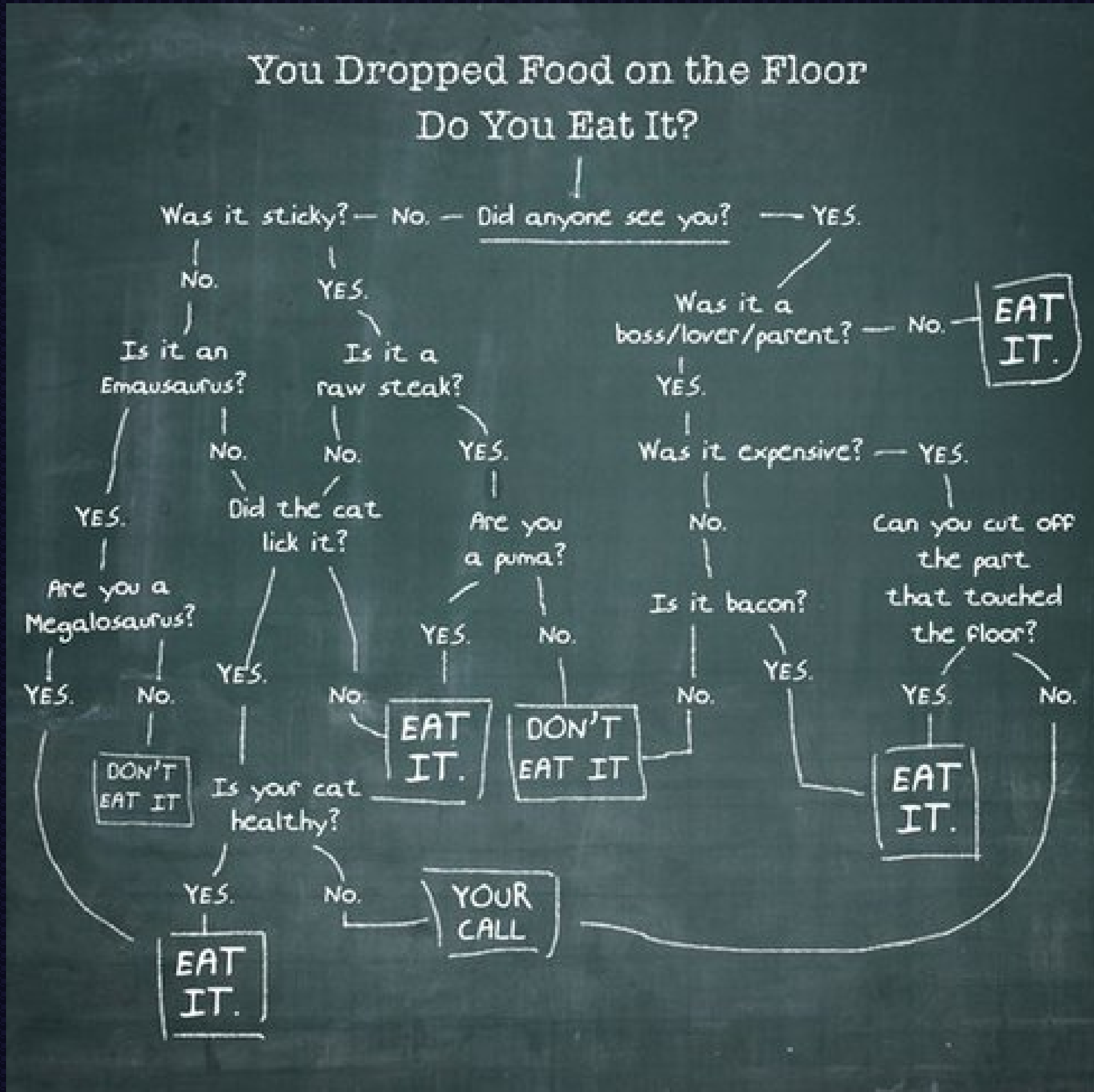

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