A Simple Example

of How System Dynamics Modeling Can Clarify and Improve Discussion and Modification of Model Structure

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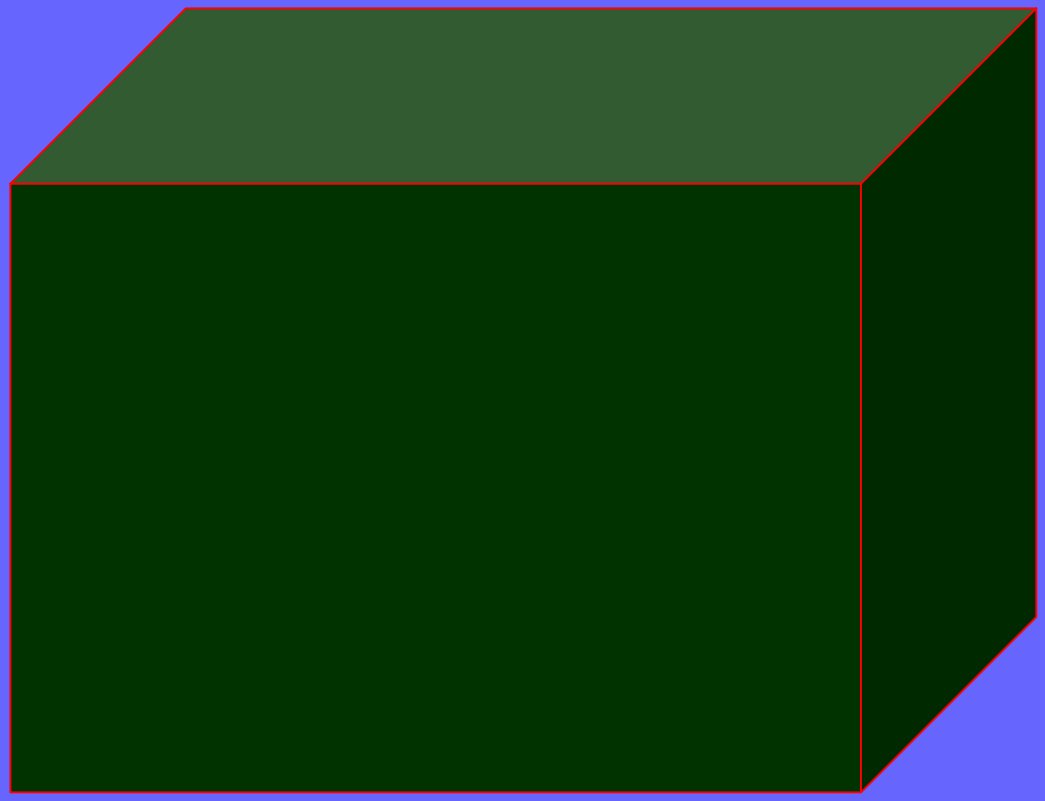
System Dynamics Modeling:

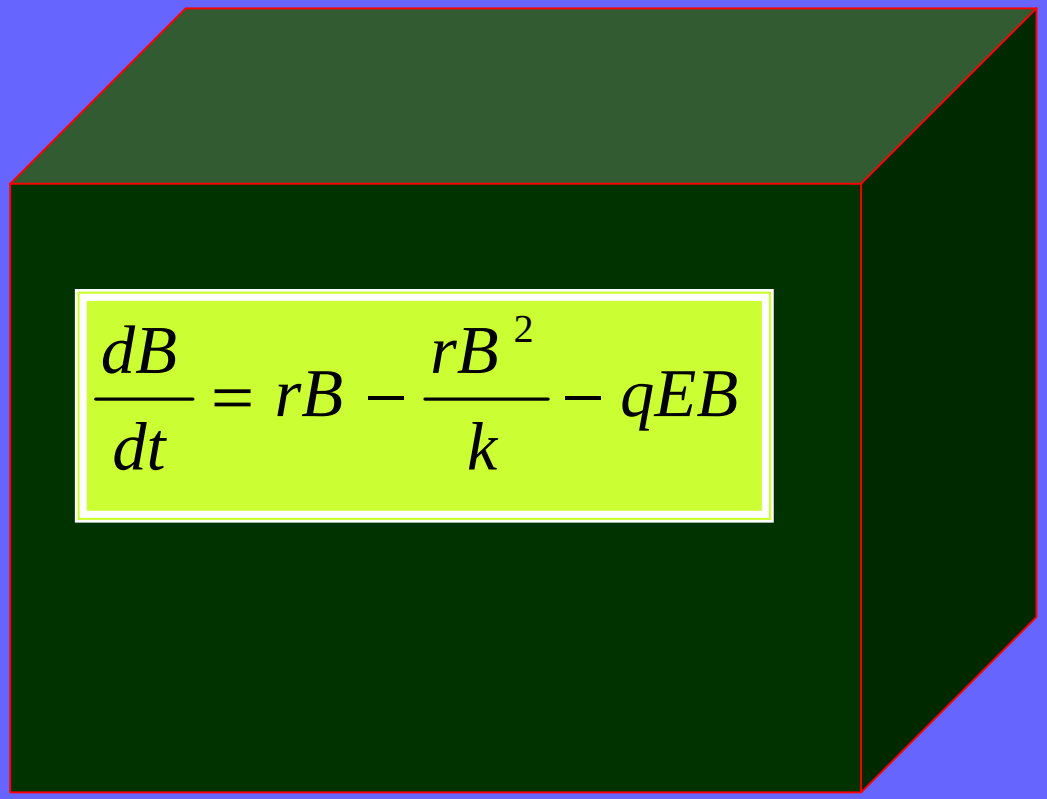
- Uses stock and flow modeling.
- Emphasizes feedback loops.
- Most useful for studying system behavior over time.
- Calculates numerical, rather than analytical, solutions to the system of equations developed.
- Allows complex systems to be modeled

This Is Our Model:



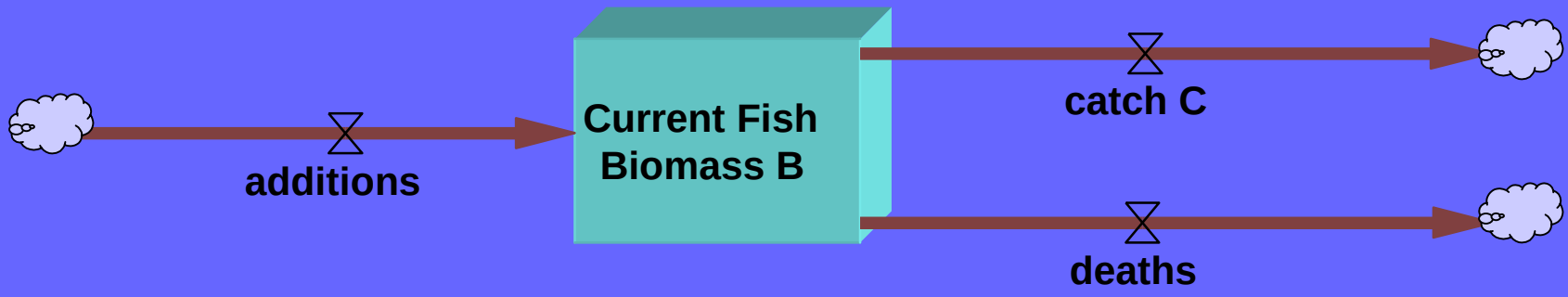
Any comments or suggestions?

This Is Our Model:



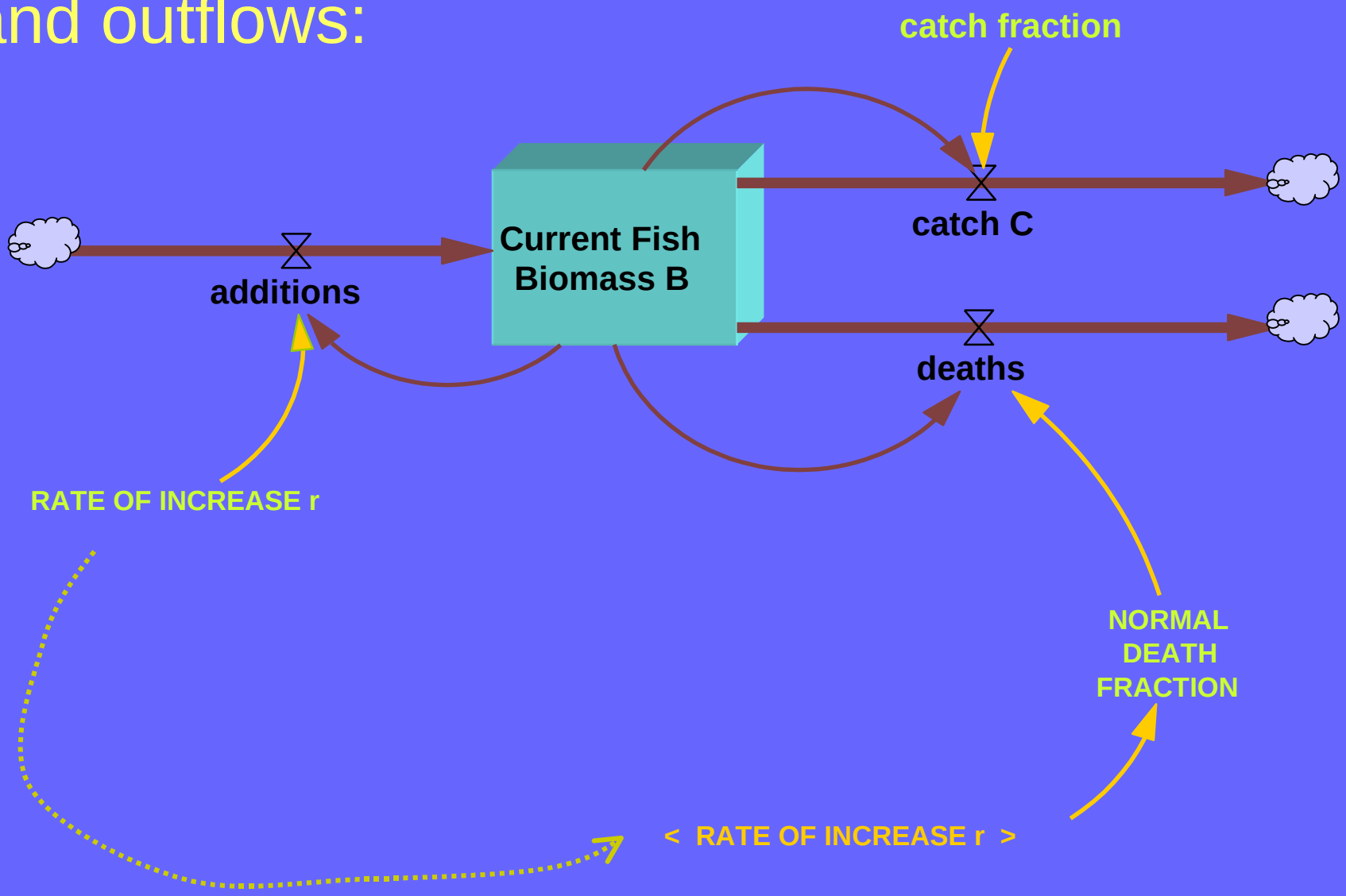
Any comments or suggestions?

This is the basis of our model:

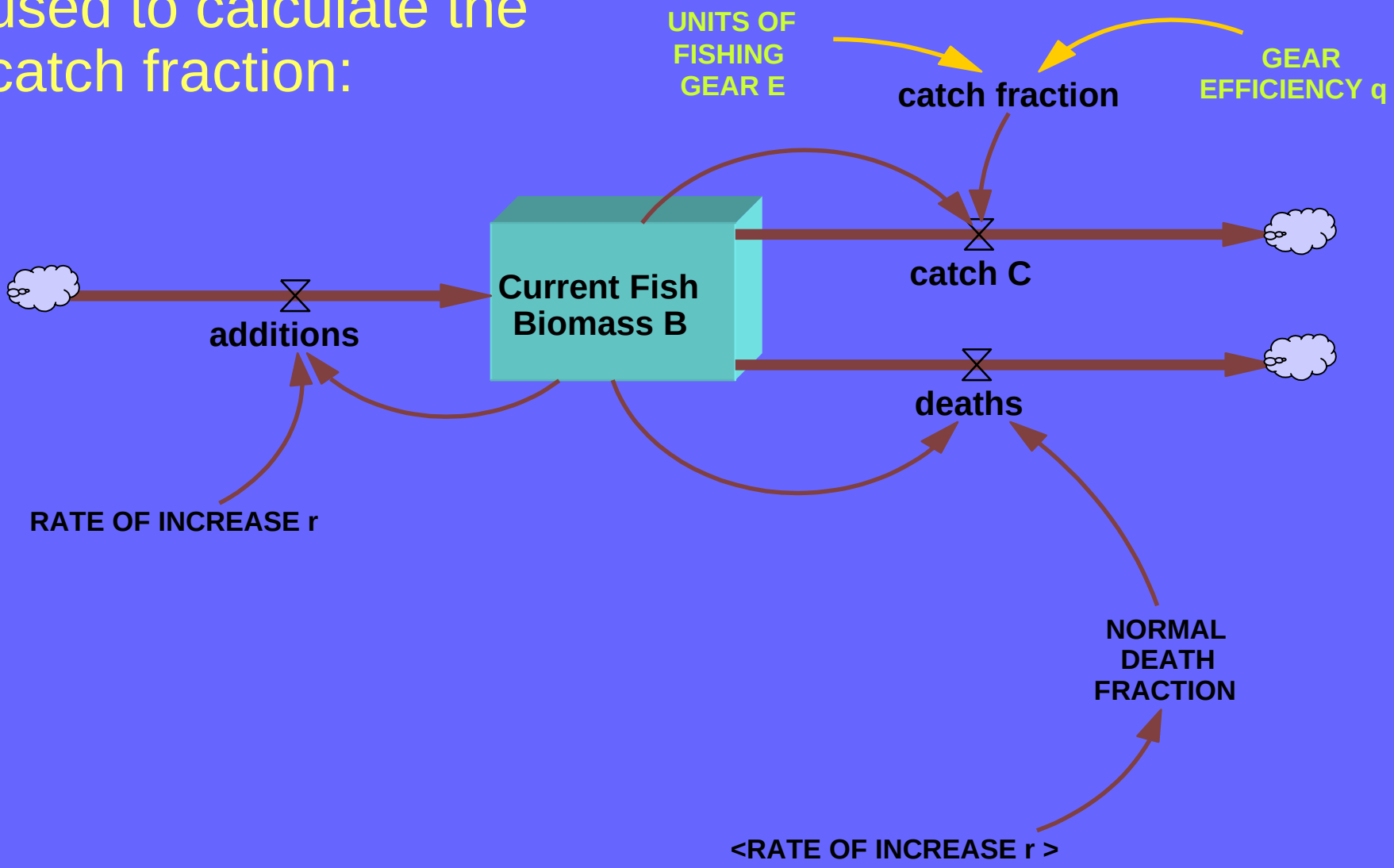


It has the following additions…..

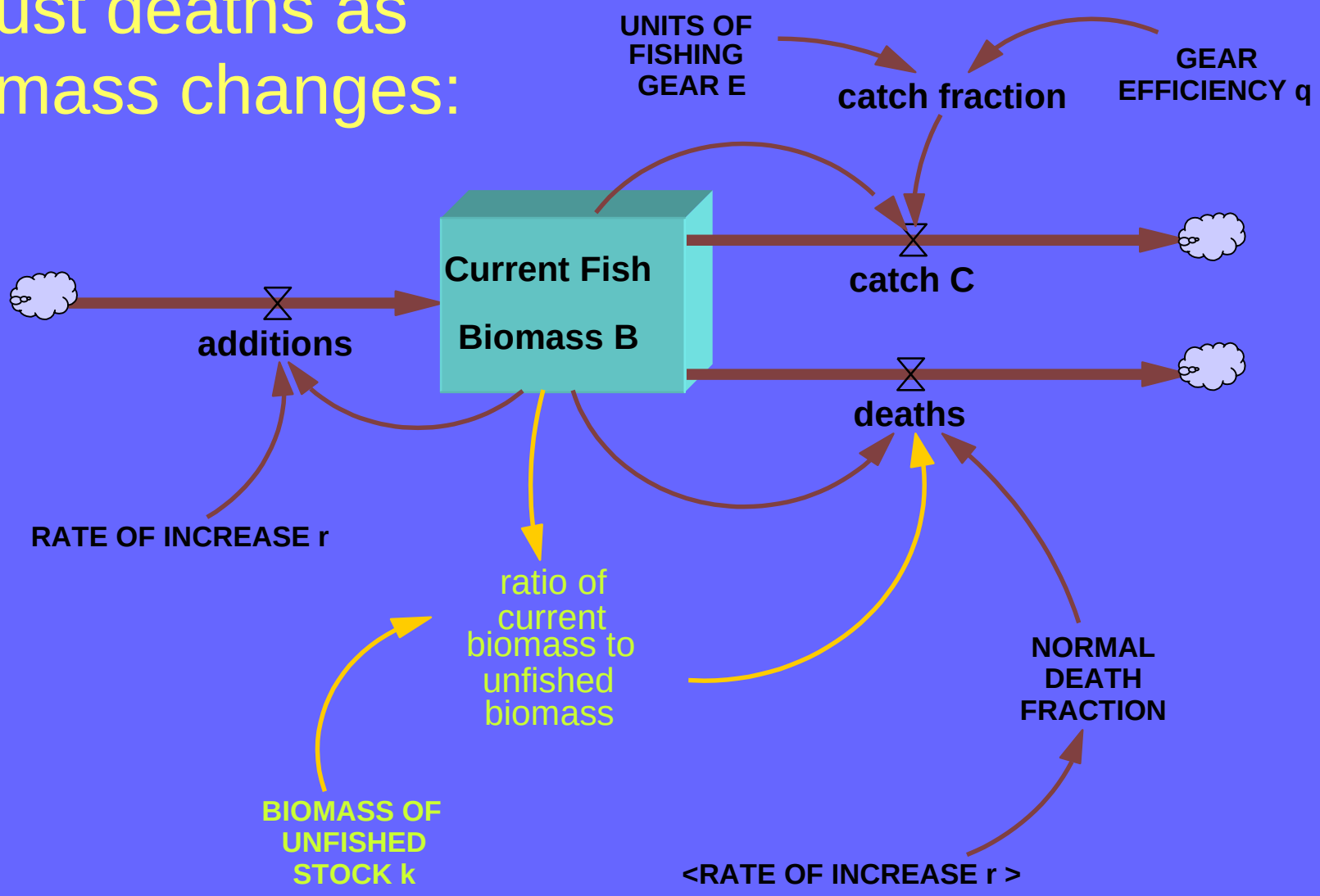
These additions help calculate the inflow and outflows:



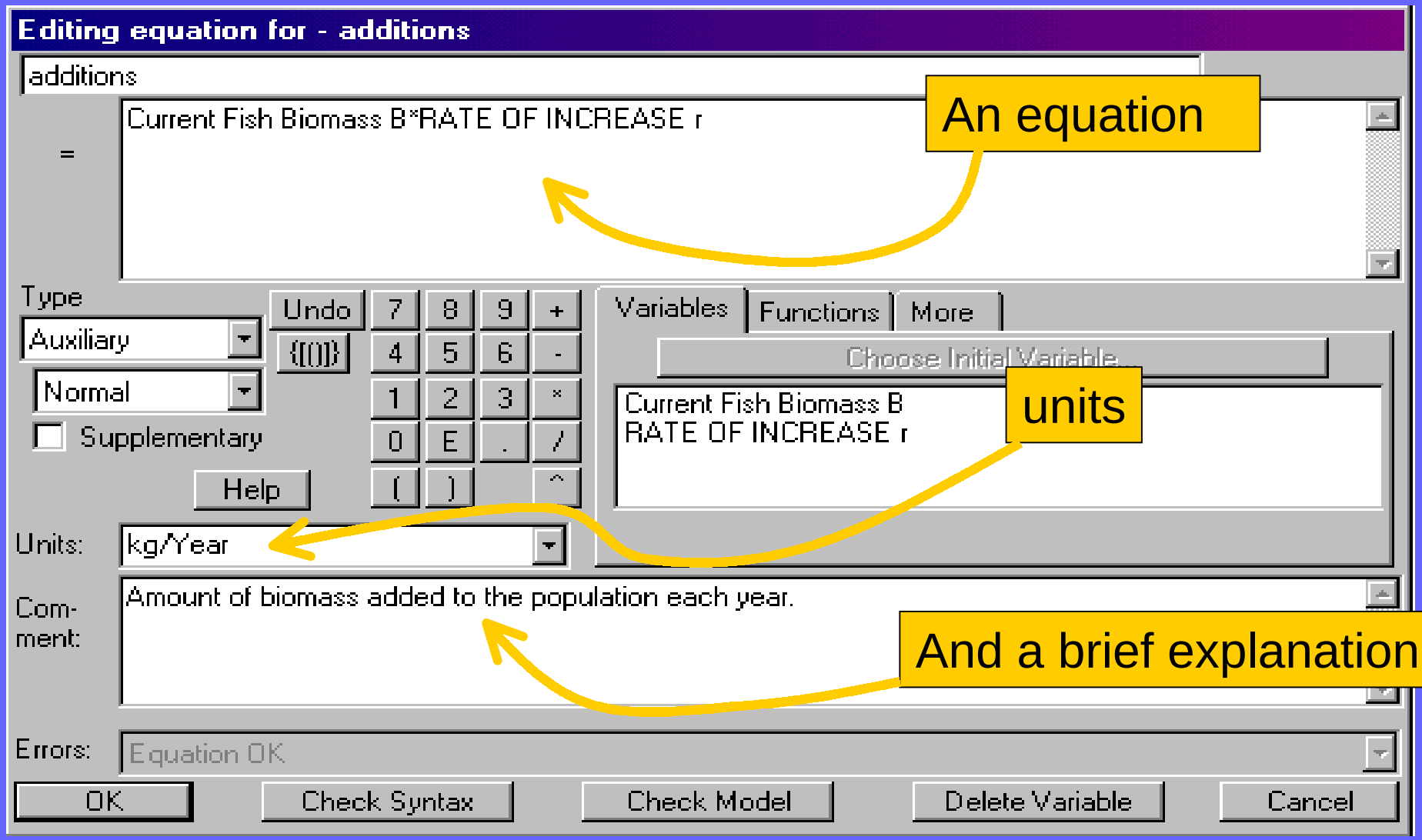
These additions are used to calculate the catch fraction:



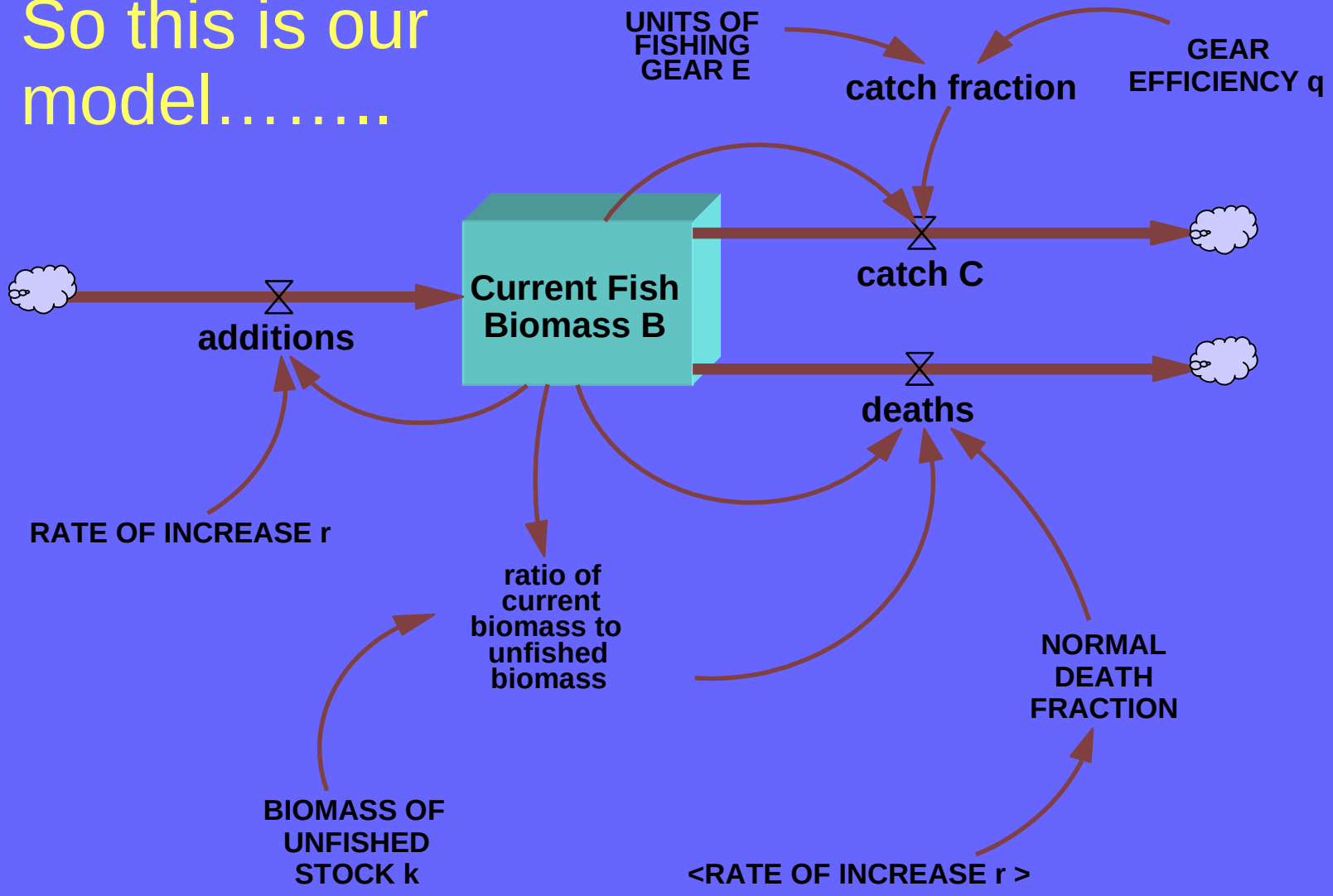
These additions adjust deaths as biomass changes:



Each Model Component Contains:

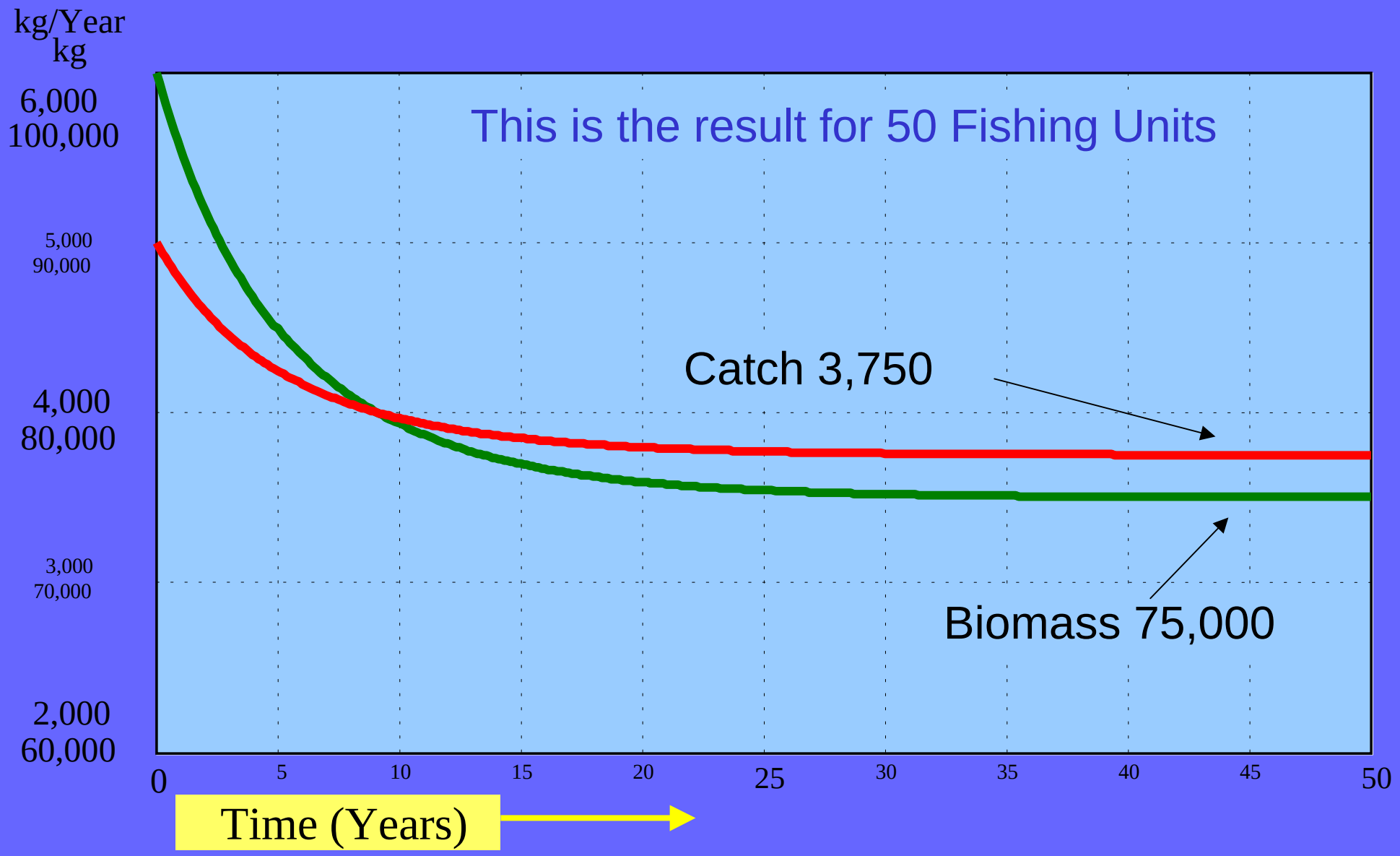


So this is our model……..

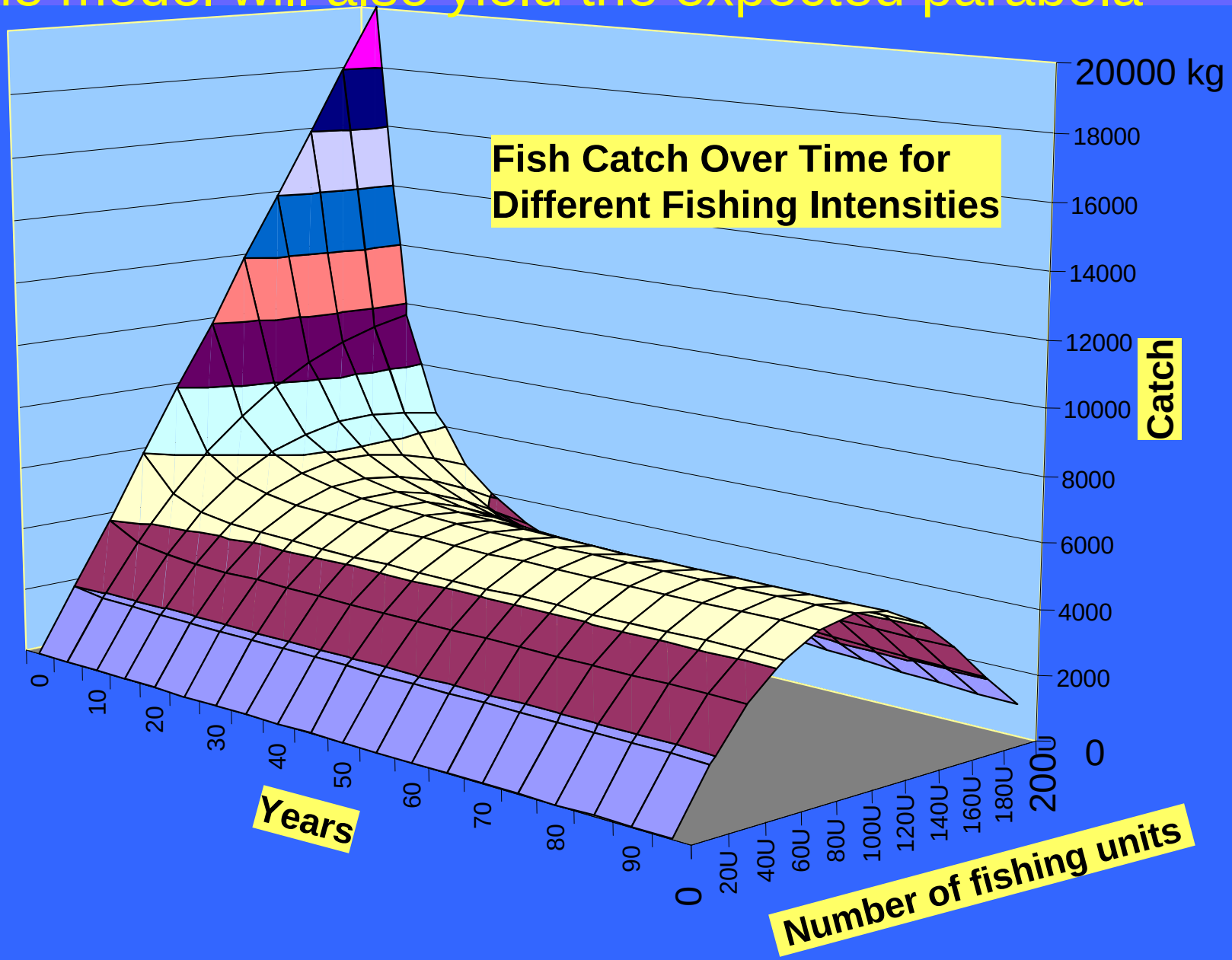


Any comments or suggestions?

Typical SD output follows variables over time:



The model will also yield the expected parabola



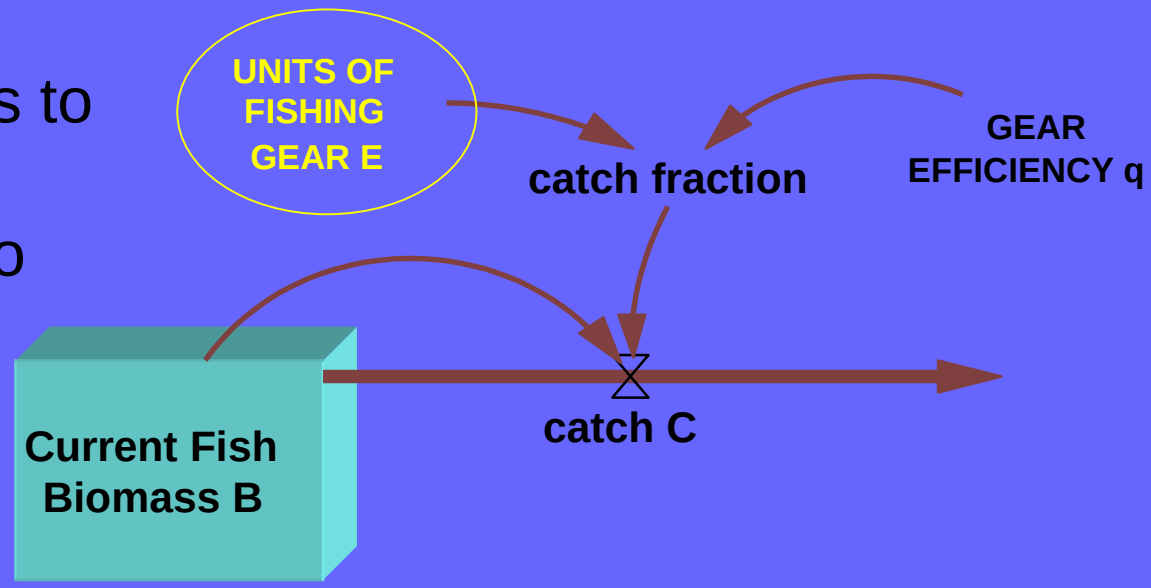
This Approach Creates Models that

- consist of understandable components,
- have a clear description of each component,
- have a relatively simple equation for each component,
- are thus open to discussion,
- can be easily examined and modified.

One Value of SD Approach is:

- The ease with which model structure can be modified

For example we can add model components to change fishing gear numbers in response to management needs.

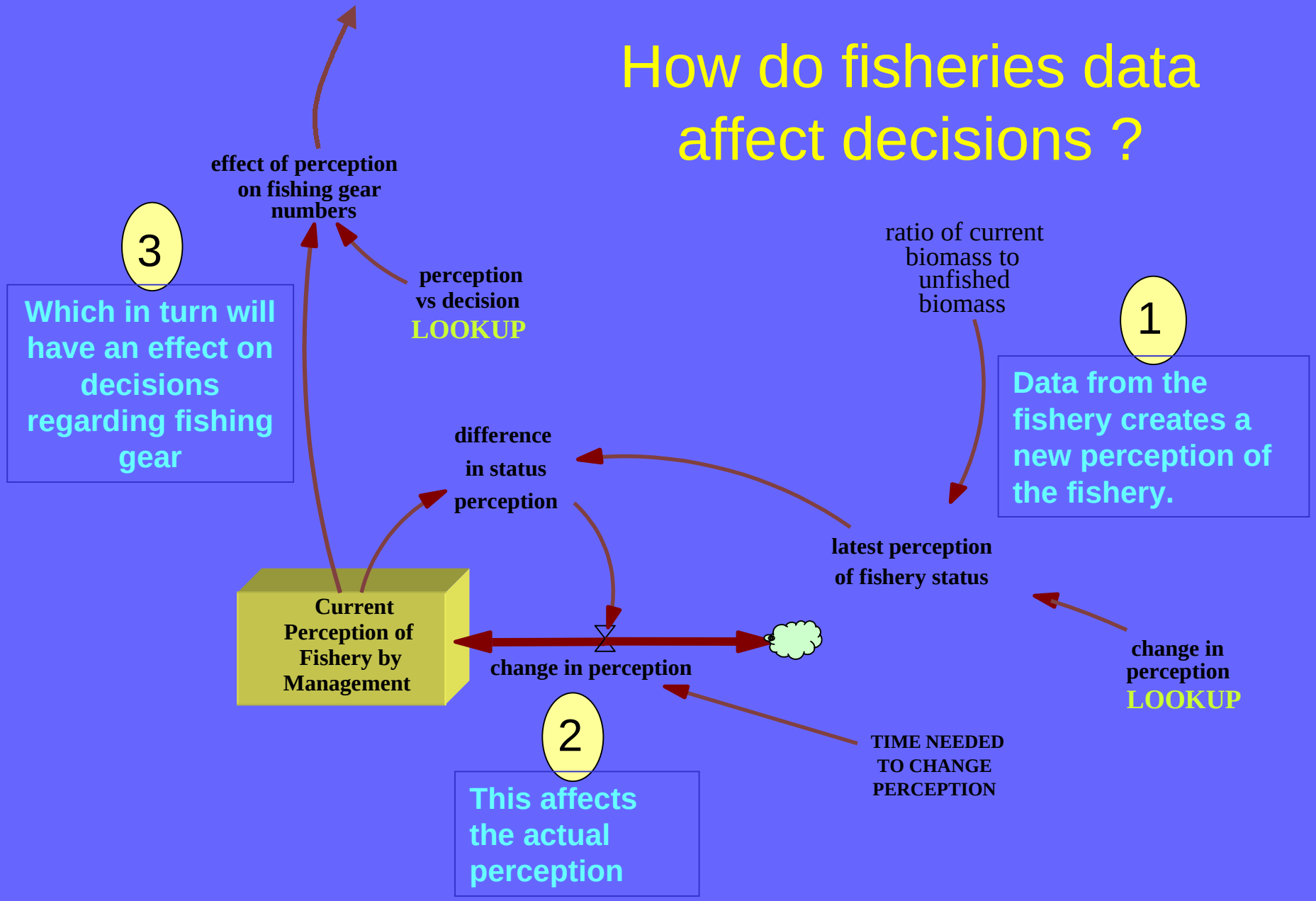


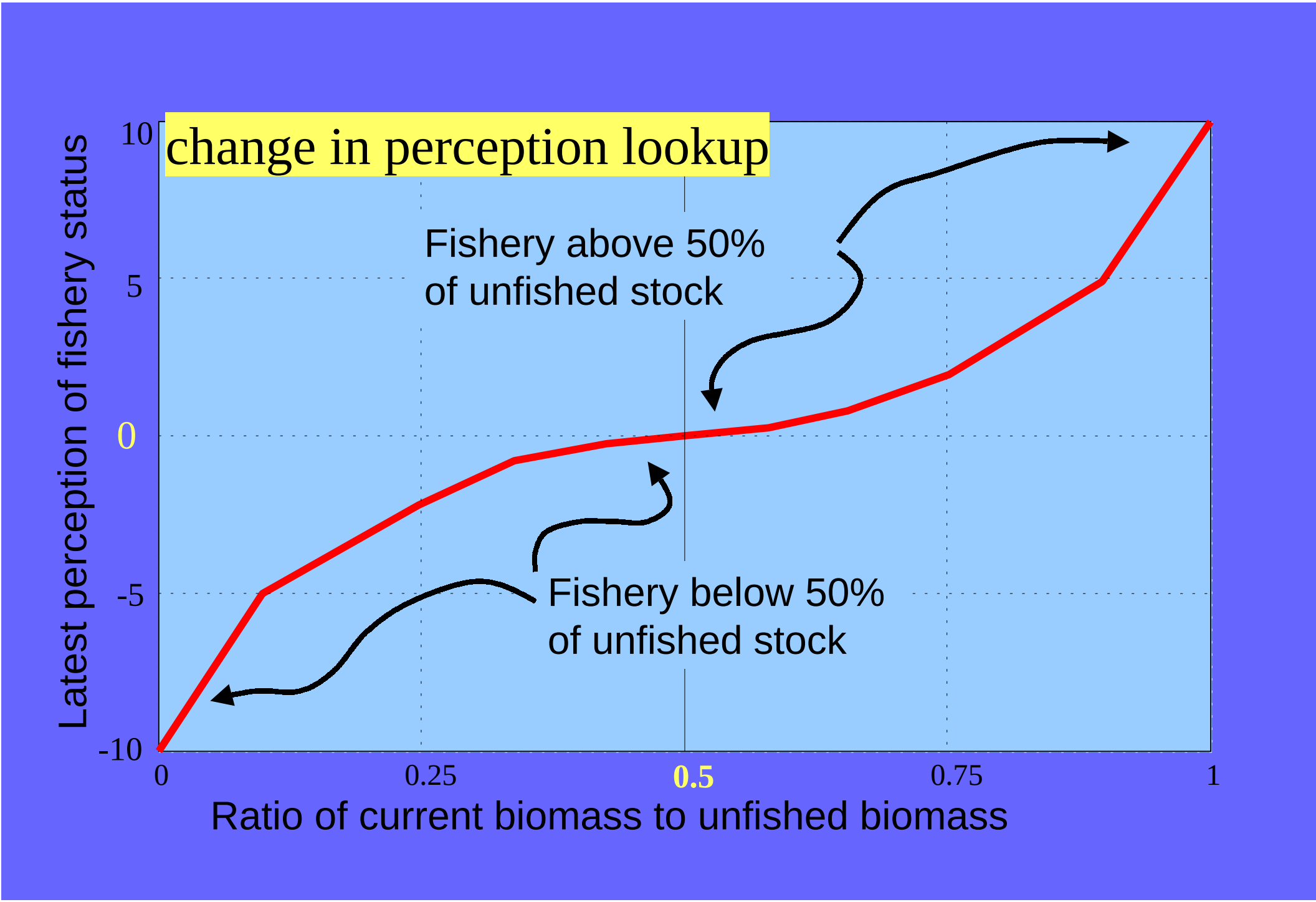
Suppose We Have a Fishery Fully Controlled by Management:

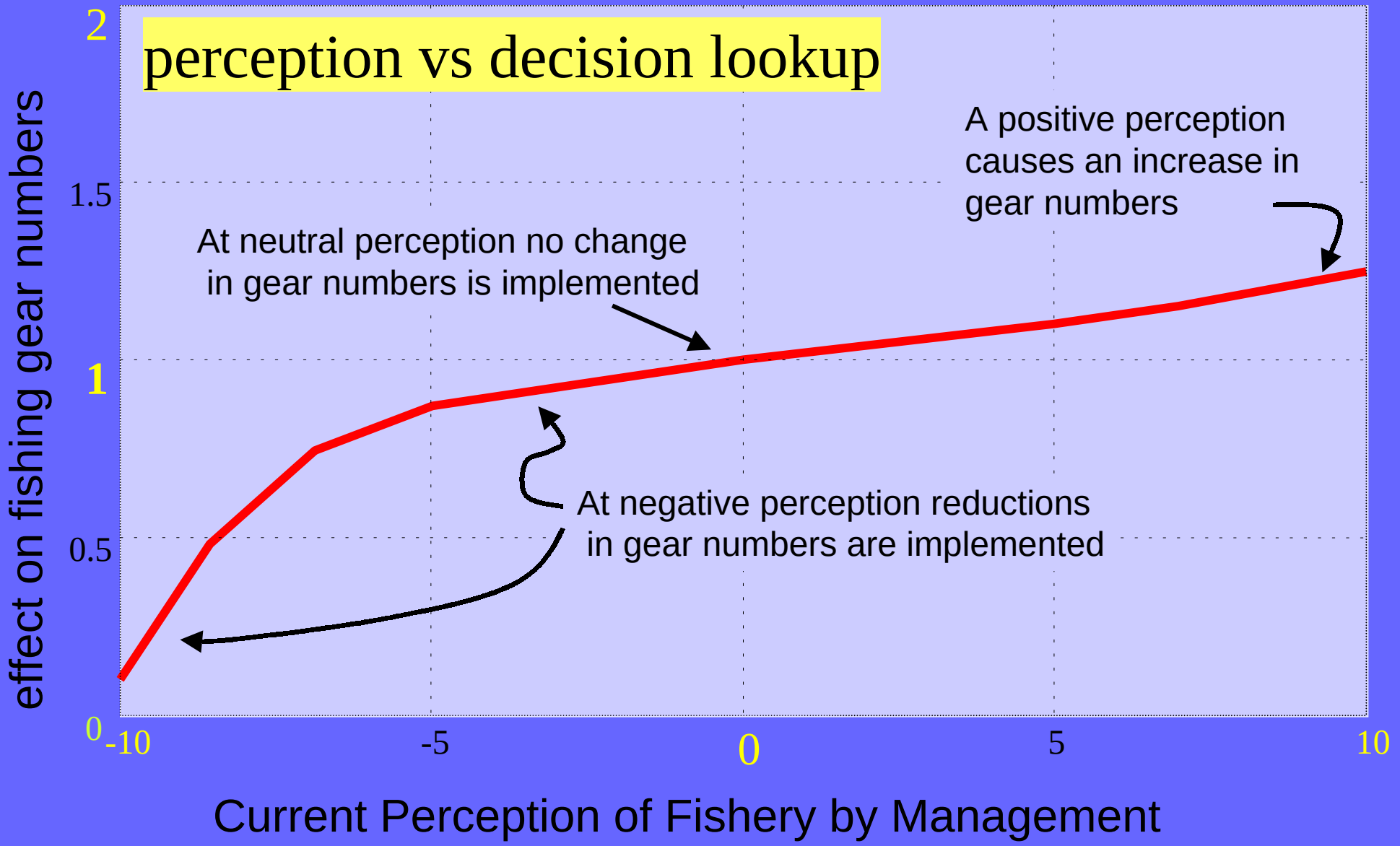
- ✔ Management personnel examine the fish population on a regular basis.
- ✔ Consideration of new data changes their perception of the fishery.
- ✔ They realize that a change in gear numbers is needed.
- ✔ After an implementation delay new fishing gear numbers are put into use.

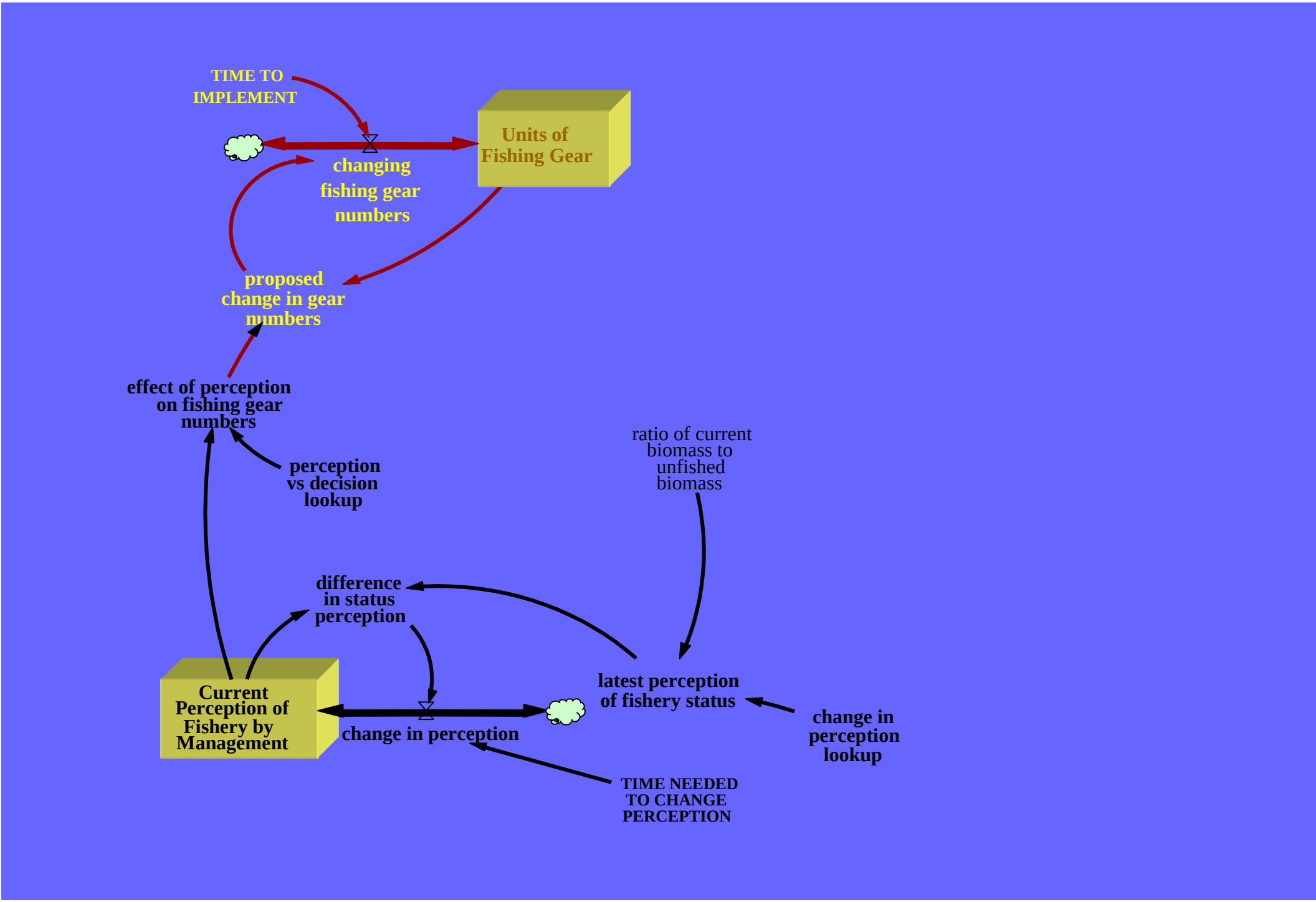
➤ This might be modeled as follows……

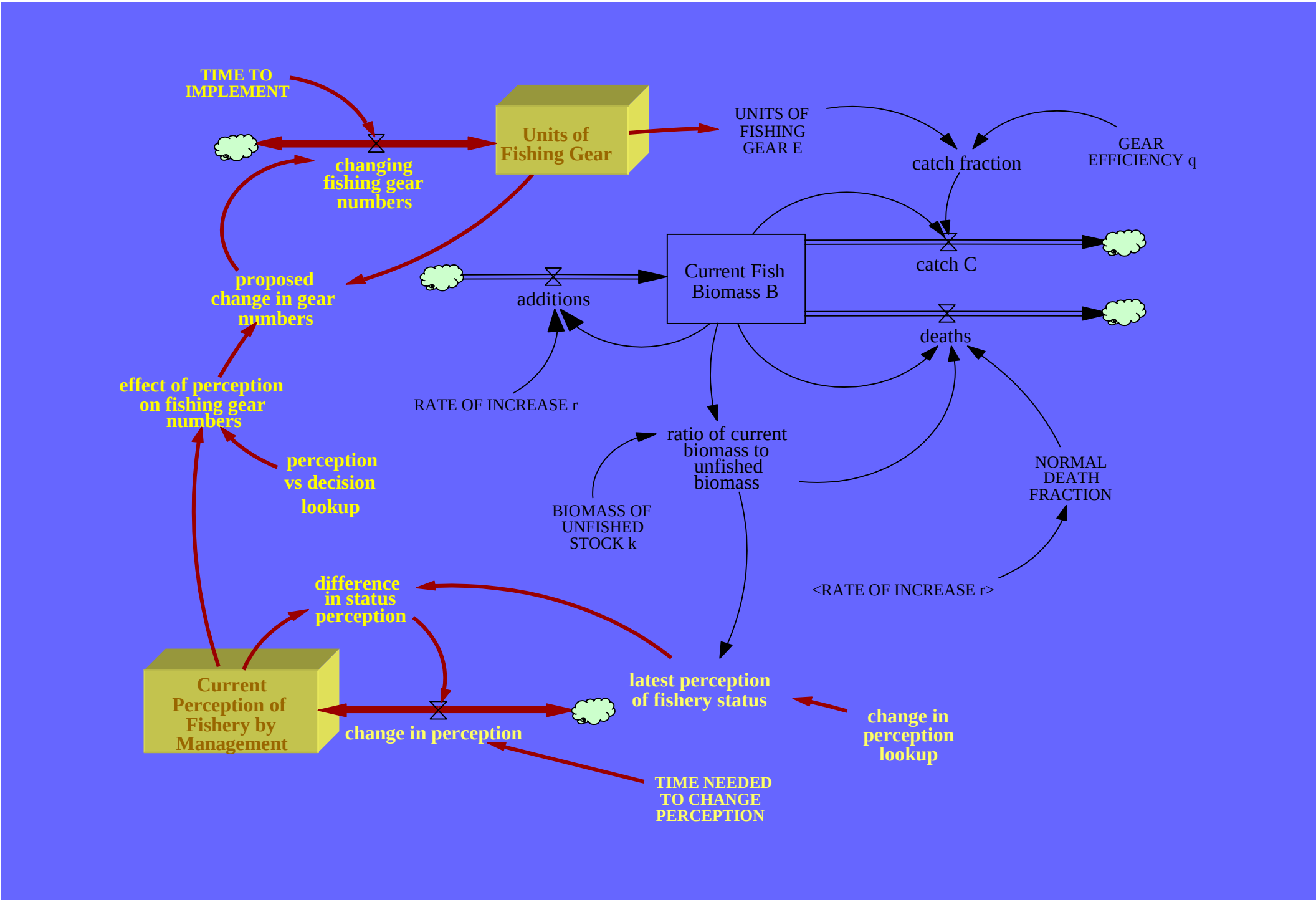
How do fisheries data affect decisions ?

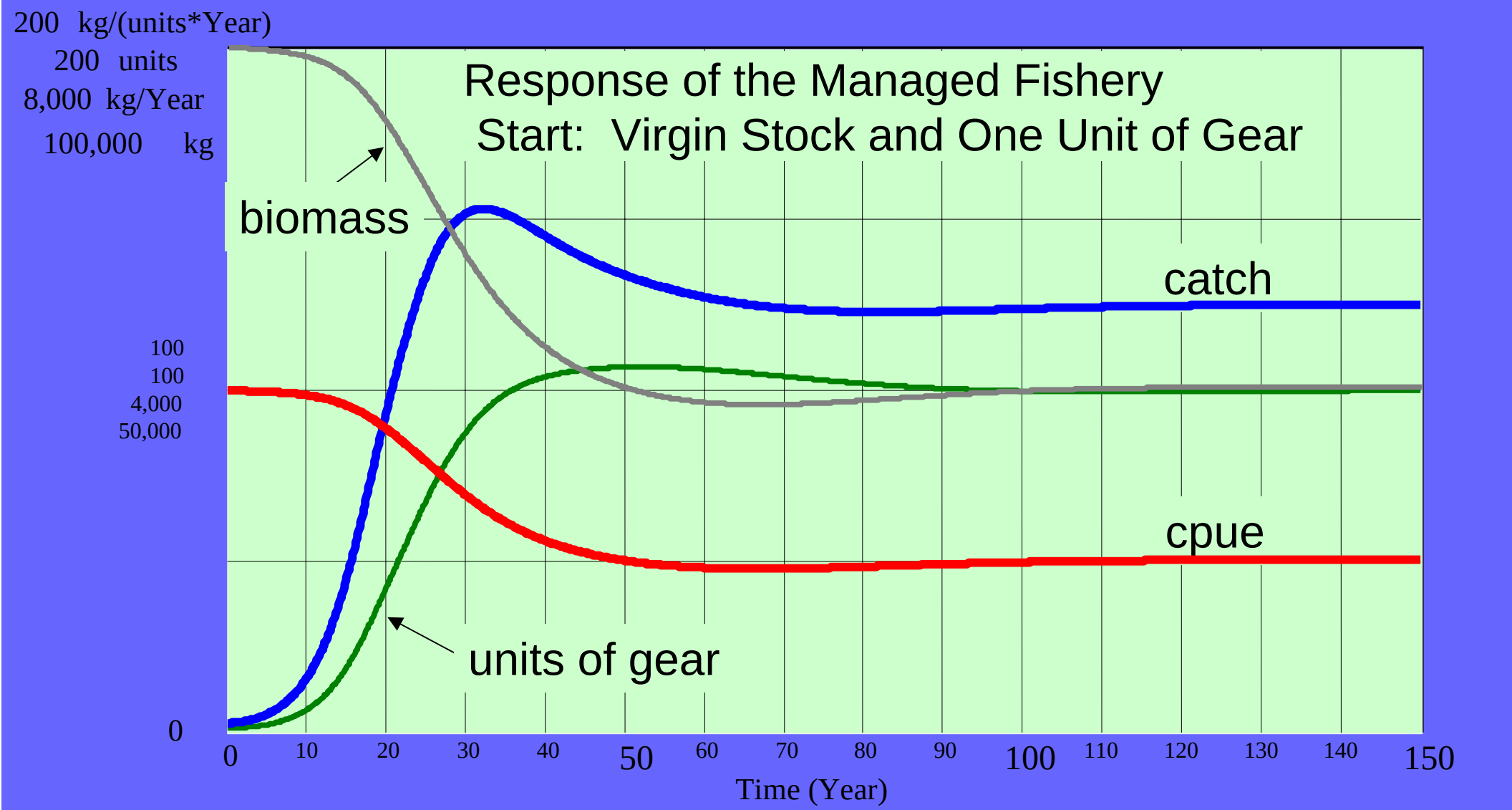



change in perception lookup
Latest perception of fishery status
10
5
0
-5
-10
Fishery above 50%
of unfished stock
Fishery below 50%
of unfished stock
0
0.25
0.5
0.75
1
Ratio of current biomass to unfished biomass


perception vs decision lookup
A positive perception causes an increase in gear numbers
At neutral perception no change in gear numbers is implemented
At negative perception reductions in gear numbers are implemented
effect on fishing gear numbers
2
1.5
1
0.5
0
-10
-5
0
5
10
Current Perception of Fishery by Management


TIME TO IMPLEMENT
Units of Fishing Gear
changing fishing gear numbers
proposed change in gear numbers
effect of perception on fishing gear numbers
perception vs decision lookup
ratio of current biomass to unfished biomass
difference in status perception
Current Perception of Fishery by Management
change in perception
latest perception of fishery status
change in perception lookup
TIME NEEDED TO CHANGE PERCEPTION

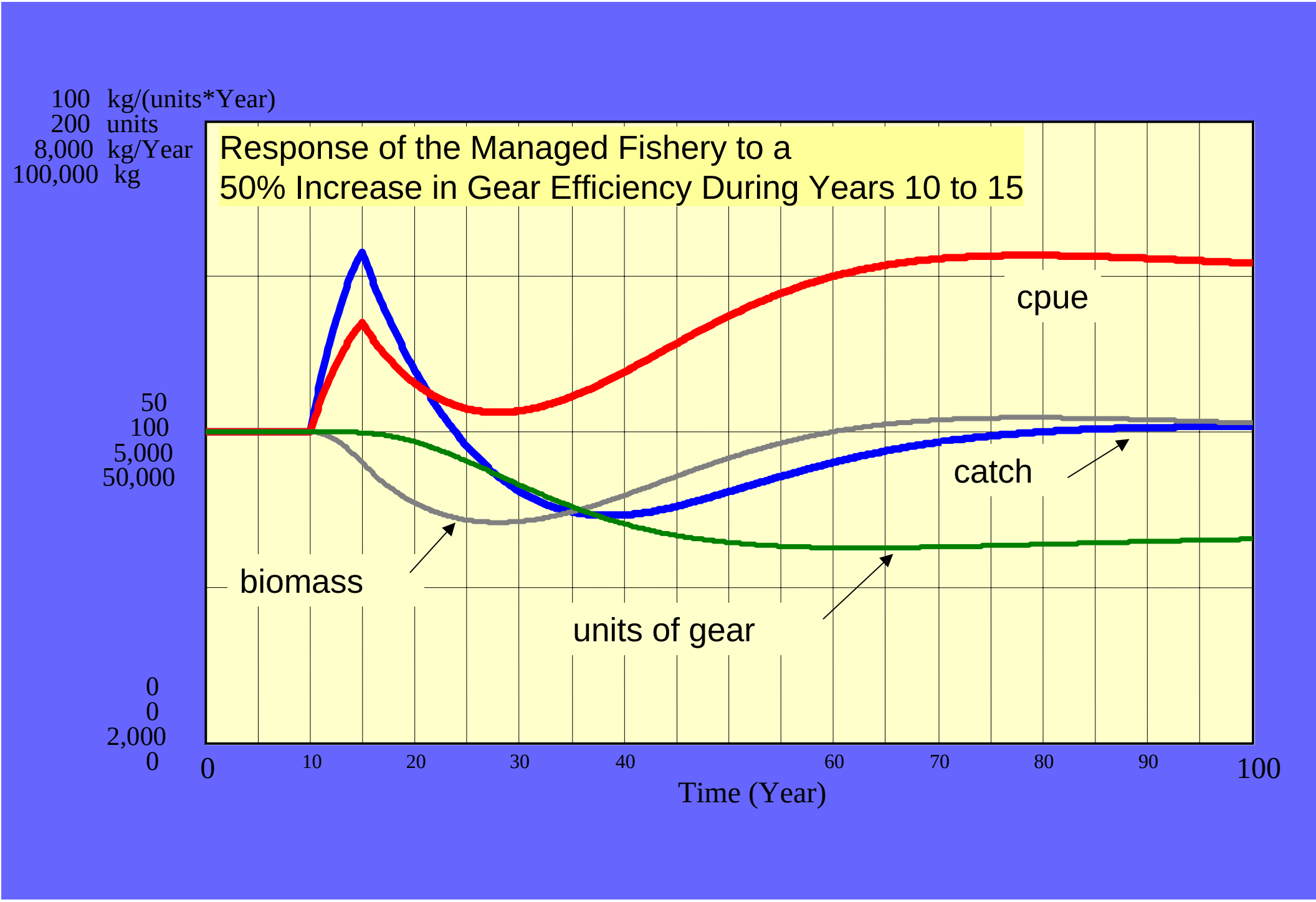

TIME TO IMPLEMENT
changing fishing gear numbers
Units of Fishing Gear
UNITS OF FISHING GEAR E
catch fraction
GEAR EFFICIENCY q
proposed change in gear numbers
additions
Current Fish Biomass B
catch C
deaths
effect of perception on fishing gear numbers
RATE OF INCREASE r
ratio of current biomass to unfished biomass
NORMAL DEATH FRACTION
perception vs decision lookup
BIOMASS OF UNFISHED STOCK k
<RATE OF INCREASE r>
difference in status perception
Current Perception of Fishery by Management
latest perception of fishery status
change in perception
change in perception lookup
TIME NEEDED TO CHANGE PERCEPTION

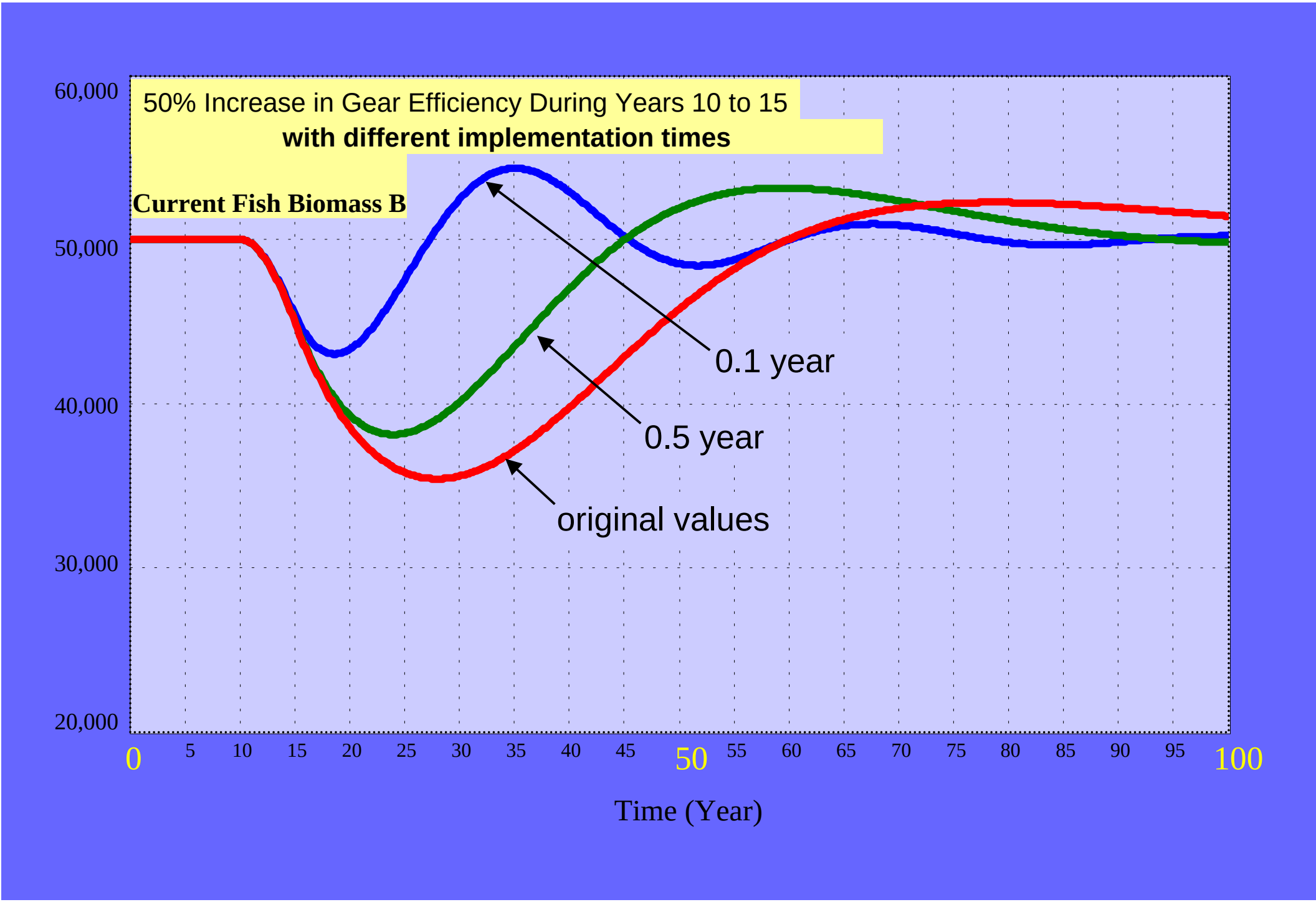

200 kg/(units*Year)
200 units
8,000 kg/Year
100,000 kg
Response of the Managed Fishery
Start: Virgin Stock and One Unit of Gear
biomass
catch
cpue
units of gear
100
100
4,000
50,000
0
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
Time (Year)

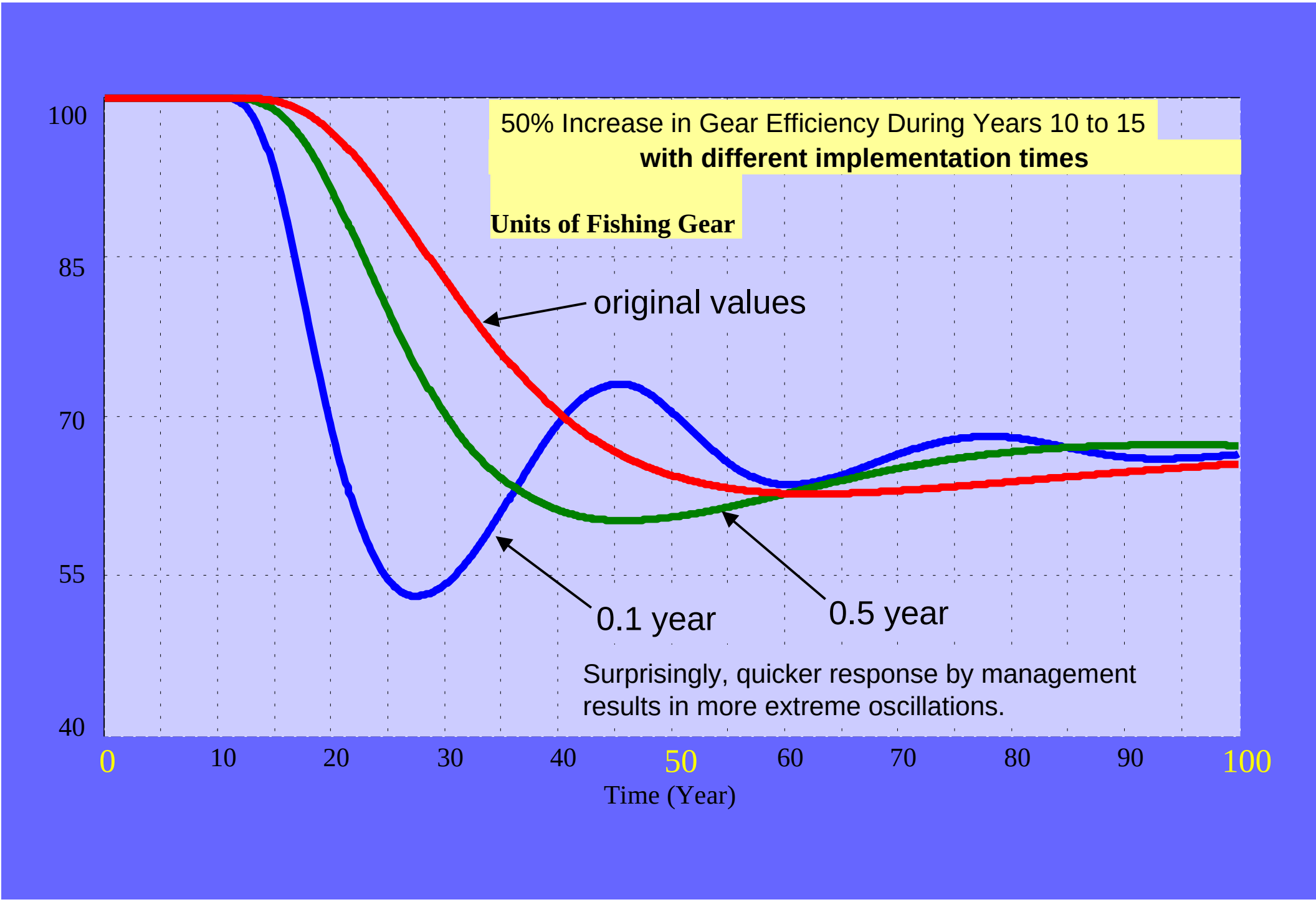
Suppose Fishing Gear Efficiency Increases:

- By 50% between years 10 and 15
- In other words: fishers improve their ability to catch fish with each unit of gear

How will the model react?…….


100 kg/(units*Year)
200 units
8,000 kg/Year
100,000 kg
Response of the Managed Fishery to a
50% Increase in Gear Efficiency During Years 10 to 15
cpue
catch
biomass
units of gear
50
100
5,000
50,000
0
0
2,000
0
0
10
20
30
40
60
70
80
90
100
Time (Year)


50% Increase in Gear Efficiency During Years 10 to 15
with different implementation times
Current Fish Biomass B
0.1 year
0.5 year
original values
60,000
50,000
40,000
30,000
20,000
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
Time (Year)


50% Increase in Gear Efficiency During Years 10 to 15
with different implementation times
Units of Fishing Gear
100
85
70
55
40
0
10
20
30
40
50
60
70
80
90
100
Time (Year)
original values
0.1 year
0.5 year
Surprisingly, quicker response by management
results in more extreme oscillations.

System Dynamics modeling:

- creates an interconnected system of straightforward equations, which
- clearly presents model structure
- permitting open discussion and modification.
- This makes it more likely that the model will include critical information from all stakeholders.