Integrating Biophysical & Economic Values:

environmental accounting of ecosystem values

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Organization…

1. Systems of Value
2. Brief Overview of Emergy Accounting
3. Case Study: Exxon Valdez Oil Spill

Value...

...the worth, importance, or usefulness of something

...to rate something according to its perceived worth, importance, or usefulness

Value…

We find it useful to distinguish instrumental value and intrinsic values,

> instrumental value is something worth having as a means towards getting something else that is good
>
> An intrinsically valuable thing is worth having for itself, not as a means to something else.

Economic Value…

An economic value is the worth of a good or service as determined by the market

In neoclassical economics, the value of an object or service is often seen as nothing but the price it would bring in an open and competitive market.

Economic Value…

Adam Smith introduced the concepts of value in use and value in exchange,

The word VALUE... has two different meanings, and sometimes expresses the utility of some particular object, and sometimes the power of purchasing other goods which the possession of that object conveys.

...The real price of every thing, what every thing really costs to the man who wants to acquire it, is the toil and trouble of acquiring it

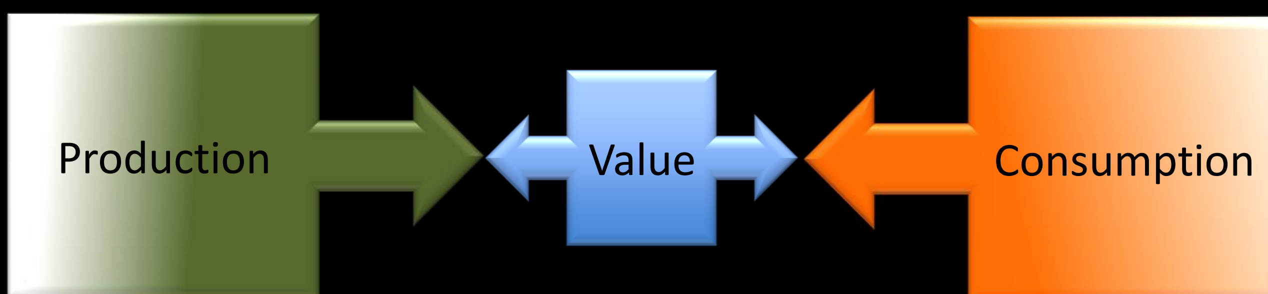
An Inquiry into the Nature and Causes of the Wealth of Nations

Two Views of Value...

1. Value is derived from what goes into something
2. Value is in the eyes of the beholder

Donor value

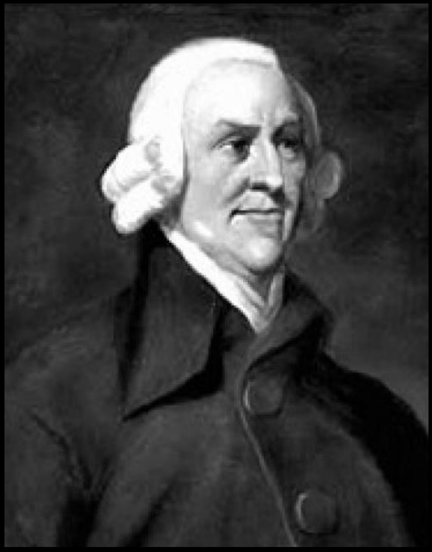
Receiver value



Cost-of-production - theory of value

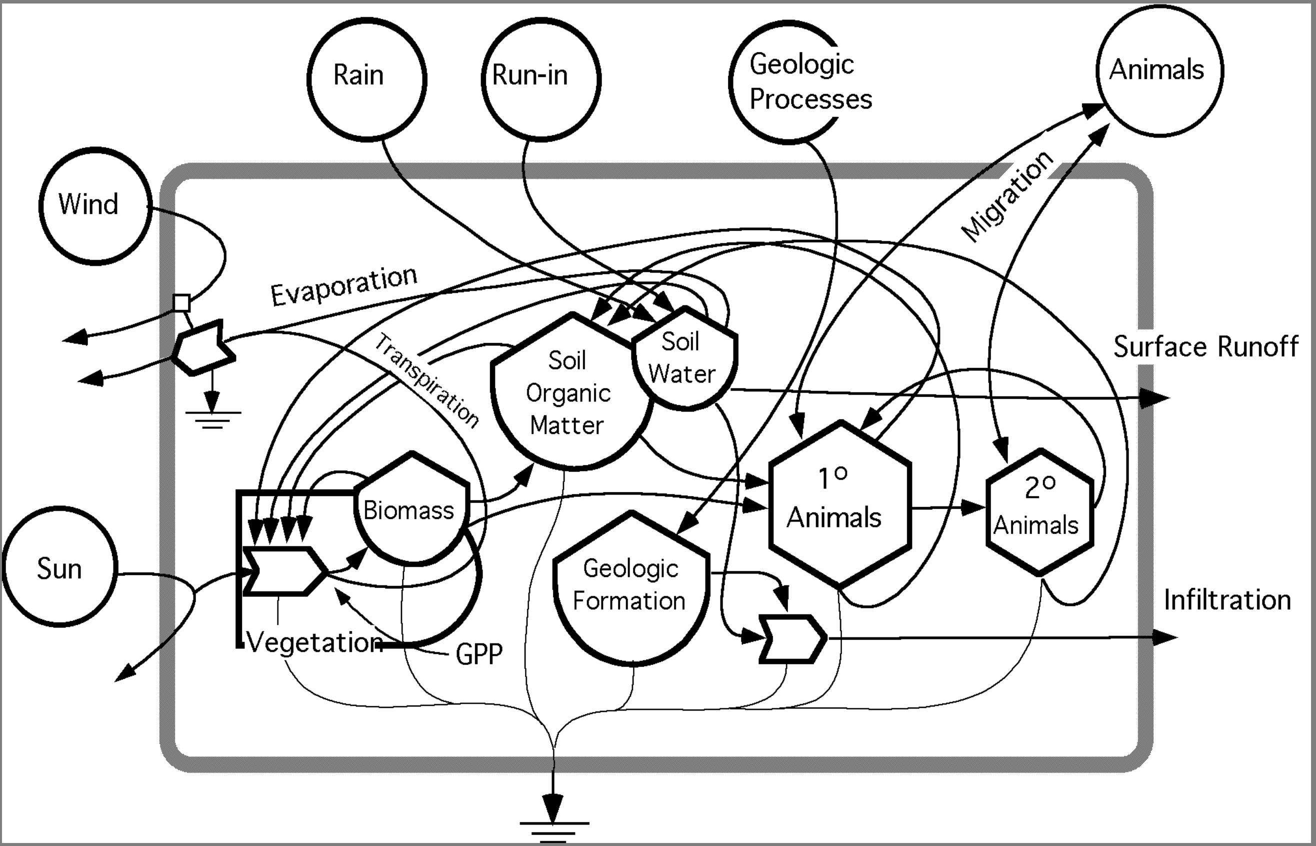
In economics, the cost-of-production theory of value is the theory that the price of an object is determined by the sum of the cost of the resources that went into making it.

Adam Smith's natural prices of commodities are the sum of the natural rates of the factors of production (wages, profits, and rent) that must be paid for inputs into production.



Ecosystem – Factors of Production

Sunlight, wind, rain, nutrients, CO_2, etc...



Ecosystem Services – Natural Prices

So...if the natural price of ecosystem services is the sum of the natural rates of the factors of production ...

all we need to do is determine the costs of producing the factors of production.

ie... Sunlight, wind, rain, nutrients, etc...

ENERGY...

The ability to cause work.

Since all energy can be converted 100% to heat, it is convenient to express energy in heat units…btu’s calories, joules.

There are many “forms” of energy….

Sunlight…

Wind…

Geopotential energy of elevated water…

Fuel…

Electricity…

Information...

Not all forms of energy are equivalent...

sunlight ≠ wind ≠ fuels ≠ electricity

While they can all be converted to heat…one cannot say that calories of one form of energy are equal to calories of another form in their ability to cause work...

EMERGY - The available energy required directly and indirectly to make something

- Expressed in energy of the same FORM … usually solar energy
- Sometimes called Energy Memory = Emergy
- Similar to Embodied Energy
- Units = solar emergy Joules = seJ

Units of EMERGY...

Solar emergy Joules…

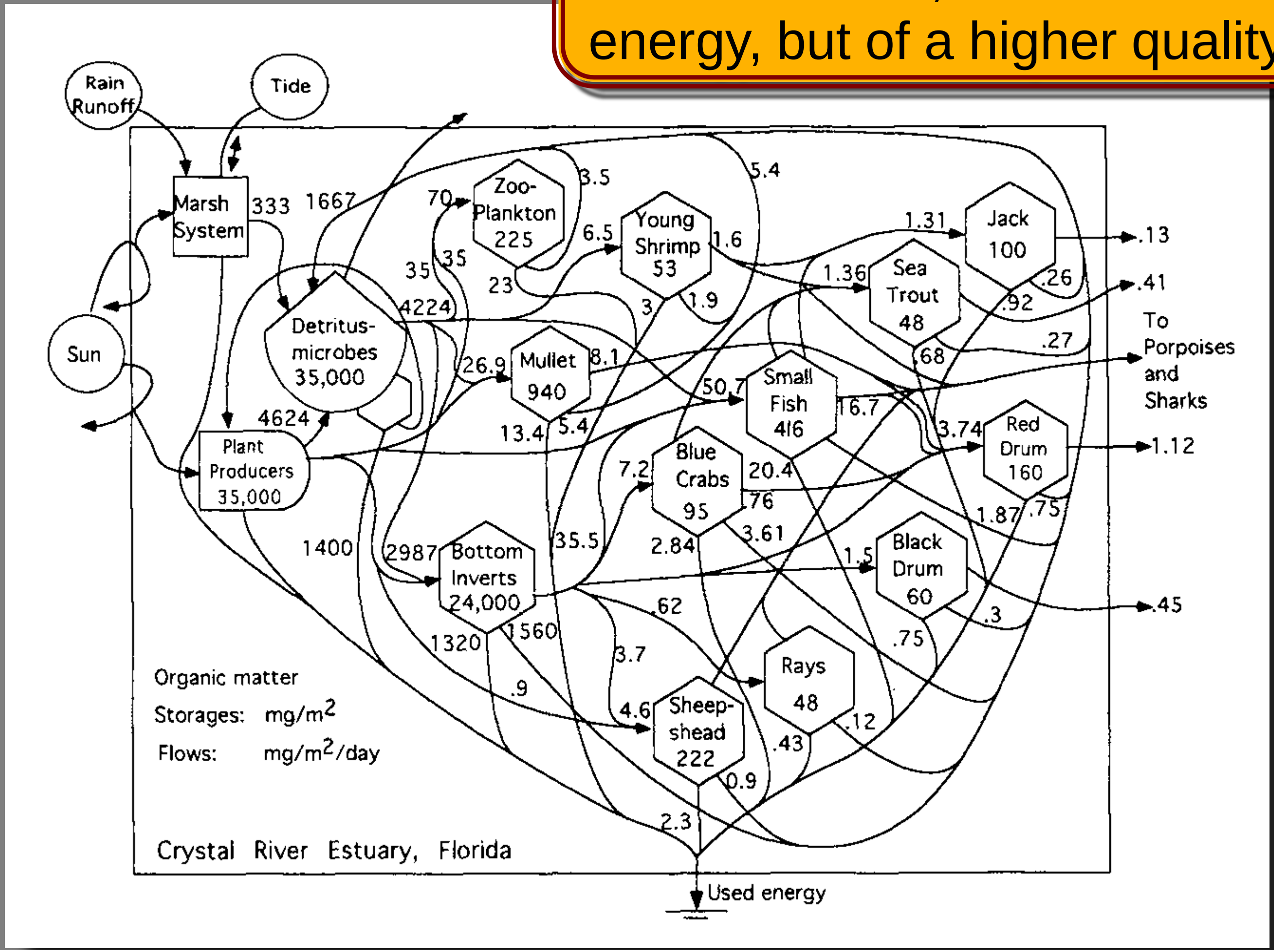
or Solar emjoules…

or "seJ"

Because Joules are so small…(it takes 4186 of them to equal 1 kilogram calorie) the units we deal with are typically 10^{12} (E12) and higher

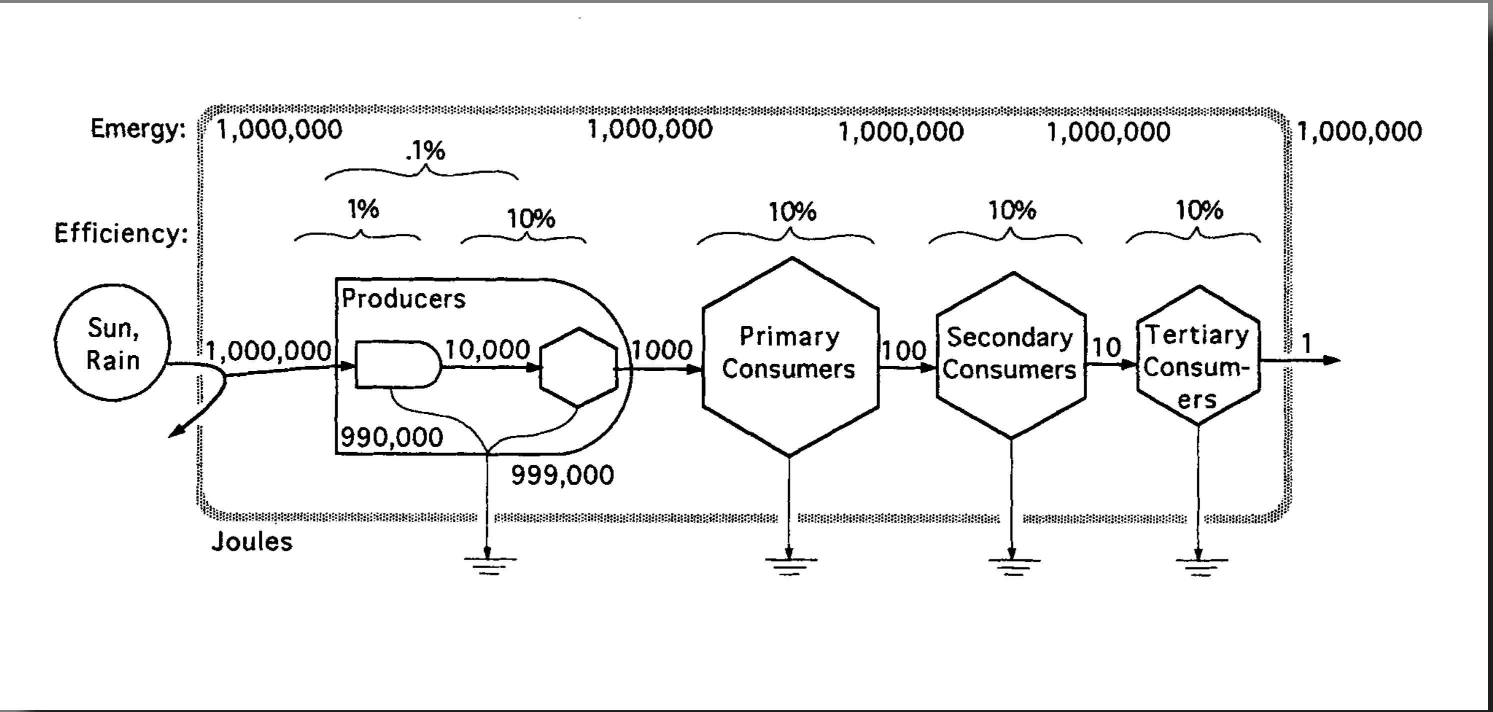
Food web

…with each successive energy transformation, there is less energy, but of a higher quality



Energy Chain

The food chain can be thought of as an energy transformation chain. At each transformation step some energy is degraded and some is passed to the next step in the chain.



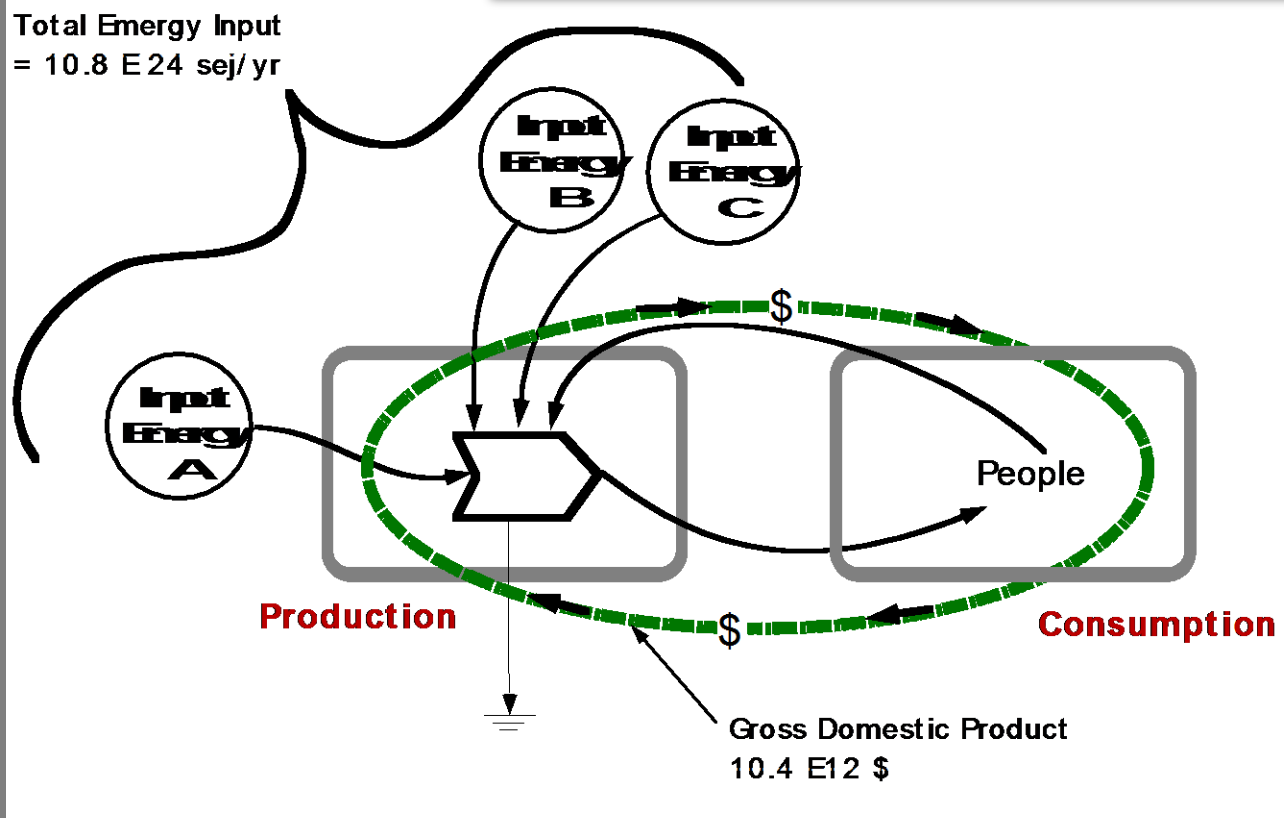
EmDollars…
the money equivalent of emergy.

By using a standard conversion factor, we can express emergy in dollar equivalents…

In the same way as we can express dollars in energy equivalents..ie gallons of gas

for instance $1 today = 0.25 gallons... or
$1 = 3.3 E7 joules of fossil fuel energy

Emergy/Money Ratio… USA



$$\frac{\text{Total Emergy}}{\text{GDP}} = \frac{10.8 \text{ E24 sej/yr}}{10.4 \text{ E12 \$/yr}} = \textbf{1.0 E12 sej/\$}$$

Emdollars of the US Economy

$$\frac{\text{Total Emergy Use}}{\text{Gross Domestic Product}} = 1.0 \text{ E12 sej/dollar}$$

So...

Every dollar spent in US economy has "embodied" in it, 1 E 12 sej of emergy

Express emergy as ^{Em}dollars for ease of recognition...

An emergy input of 3.6 E18 sej/yr…
becomes...
3.6 E6 ^{em}\$

$$\frac{3.6\ E18\ sej/yr}{1.0\ E12\ sej/\$} = 3.6\ E6\ {}^{em}\$$$

Emergy and emdollar value of **services** of the National Forest System (2005)

Note	Parameter	Emergy Value (10^{21} seJ/yr)	Emdollars* ($10^{9}\ \text{Em\$/yr}$)
Provisioning Services			
1	Fish Harvest	0.2	0.1
2	Extracted Firewood	0.4	0.2
		0.5	0.3
		5.2	2.7
		13.6	7.2
		60.7	31.9
		198.1	104.3
		6.6	3.5
		23.7	12.5
10	Clean water	19.9	10.5
Supporting Services			
11	Gross primary productivity	16.6	8.7
Cultural Services			
12	Organized recreation	24.0	12.6
13	Information produced	4.6	2.4
		Total Ecosystem Services/yr.	**196.9**

Annual NFS budget = $5.6 billion
Benefit cost ratio of
35/1

Emergy and emdollar value of **capital** of the National Forest System (2005)

Note*	Item	Units	Quantity	Emergy Intensities (seJ/unit)	Solar Emergy ($x10^{21}$seJ)	EmDollars ($x10^{9}$ Em$)
NATURAL CAPITAL						
1	Herb./Shrub Biomass	J	6.91E+18	9.79E+03	67.7	35.6
2	Surface Water	J	1.57E+18	5.04E+04	79.0	41.6
		ha	7.80E+07	1.05E+15	81.9	43.1
		J	2.80E+18	1.91E+05	535.0	281.6
		g	6.02E+13	1.72E+10	1037.9	546.3
		J	1.50E+20	1.18E+04	1771.1	932.2
		J	7.71E+19	5.04E+04	3885.8	2045.2
		g	6.23E+17	6.40E+06	3986.2	2098.0
		g	2.20E+13	3.75E+11	8243.2	4338.5
		J	9.74E+19	9.76E+04	9506.1	5003.2
		# of species	5.97E+03	2.85E+21	16984.9	8939.4
				Total Natural Capital	**46178.8**	**24304.6**
ECONOMIC CAPITAL						
12	Office Equipment	g	3.84E+10	1.13E+10	0.4	0.2
13	Machinery & tools	g	9.91E+10	1.13E+10	1.1	0.6
14	Buildings	g	1.02E+12	6.50E+09	6.6	3.5
15	Roads (paved)	g	4.81E+12	2.77E+09	13.3	7.0
16	Roads (dirt)	$	3.14E+10	1.90E+12	59.7	31.4
17	Roads (gravel)	g	7.15E+13	1.68E+09	120.1	63.2
18	Knowledge	employees	3.15E+04	1.18E+19	370.6	195.0
				Total Economic Capital	**571.9**	**301.0**

Annual NFS budget = $5.6 billion
Benefit cost ratio of

4300/1

Emergy and emdollar value of **capital** of the National Forest System (2005)

Fauna	Biomass (g)	UEV (seJ/g)	Emergy (seJ)	EmDollars ($x10^{9}$ Em$)
	1.30E+13	6.34E+09	8.24E+22	**4.3**
	2.60E+13	8.30E+09	2.16E+23	**11.4**
	1.40E+13	1.15E+10	1.61E+23	**8.5**
	4.20E+12	5.85E+10	2.46E+23	**12.9**
	3.00E+12	1.11E+11	3.33E+23	**17.5**
ass =	6.02E+13			
	Weighted UEV =	1.72E+10		
		Total emergy =	1.04E+24	**54.6**

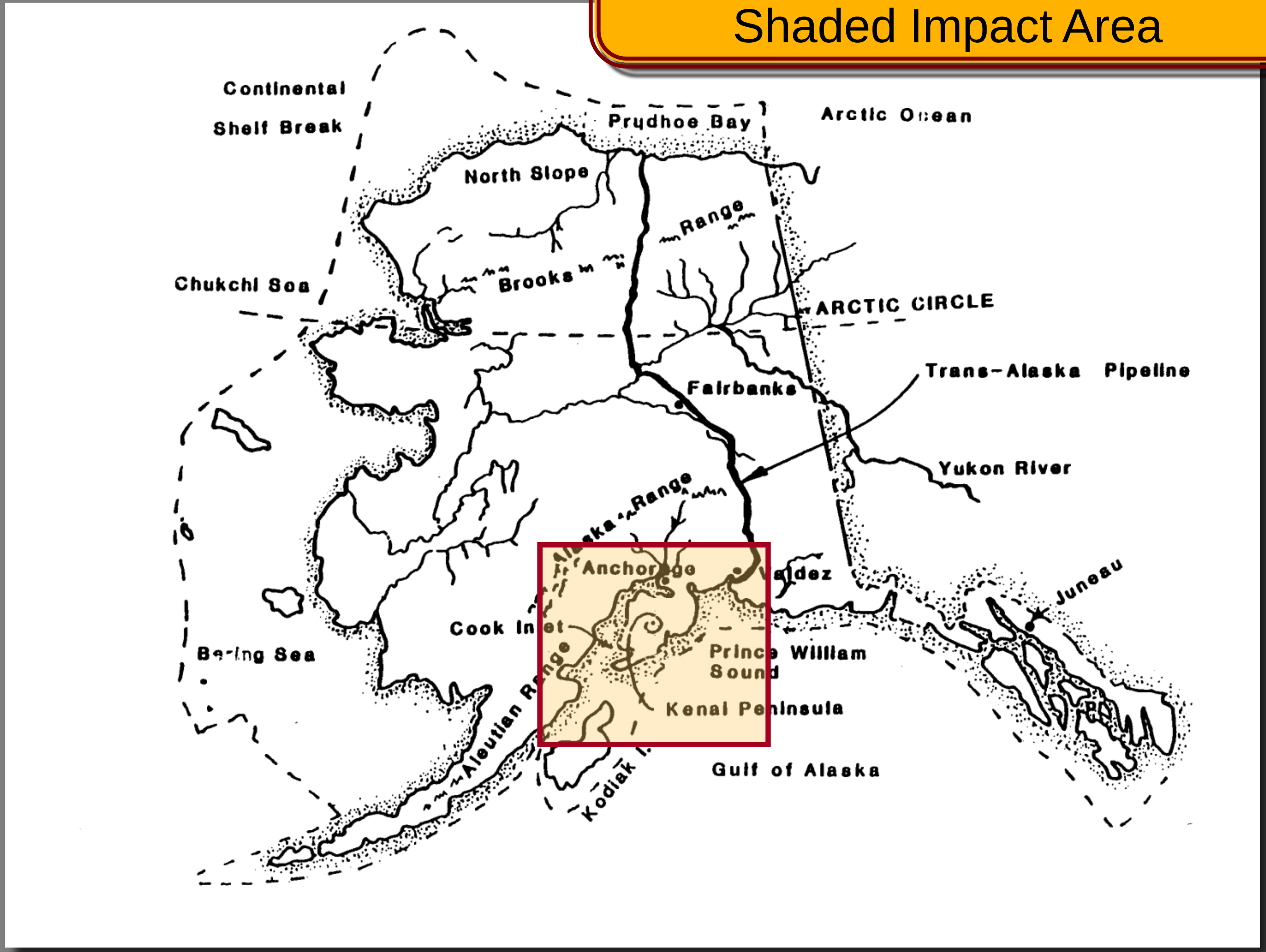
Annual NFS budget = $5.6 billion

Benefit cost ratio of

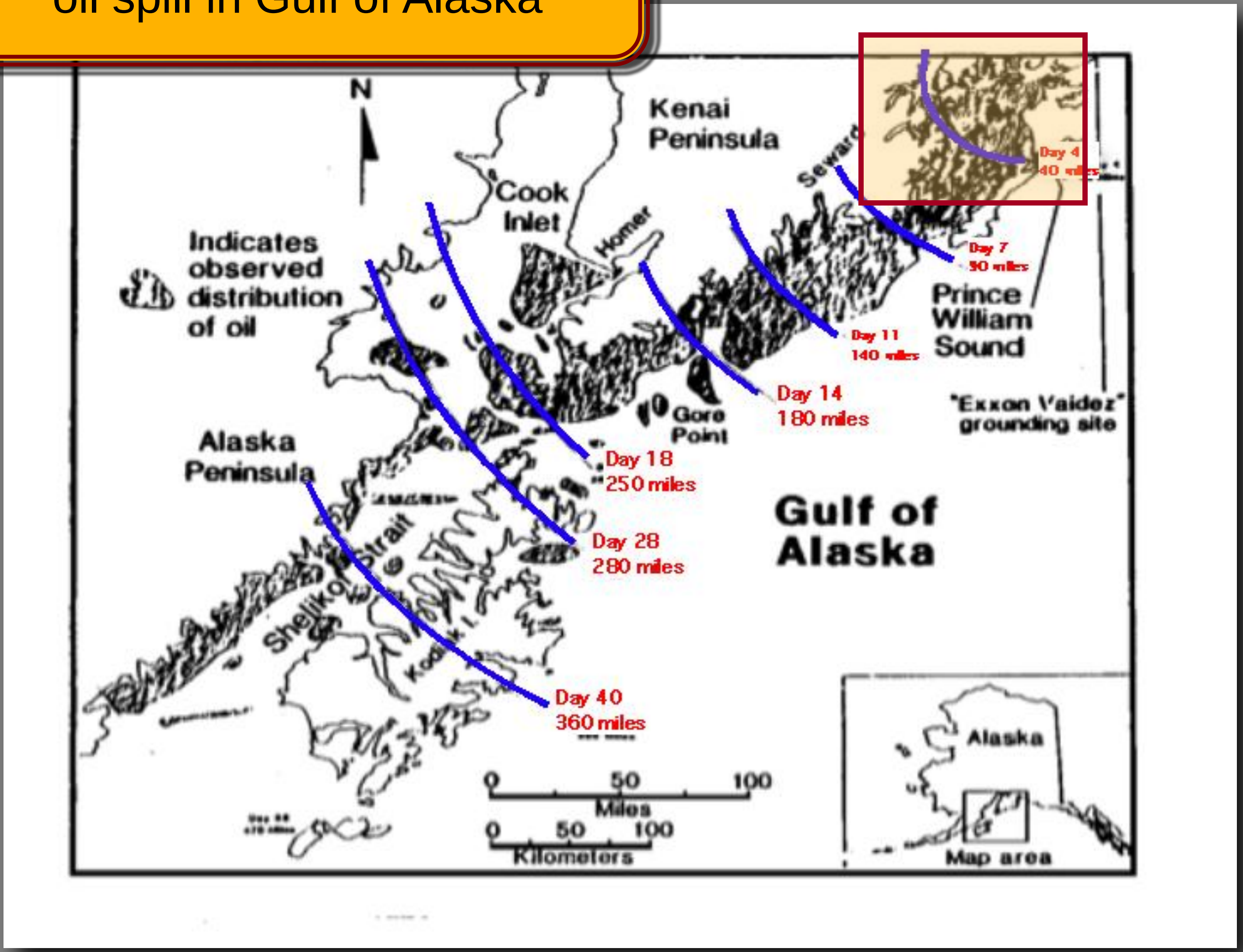
~ 10/1

Emergy Evaluation of Exxon Valdez Oil Spill

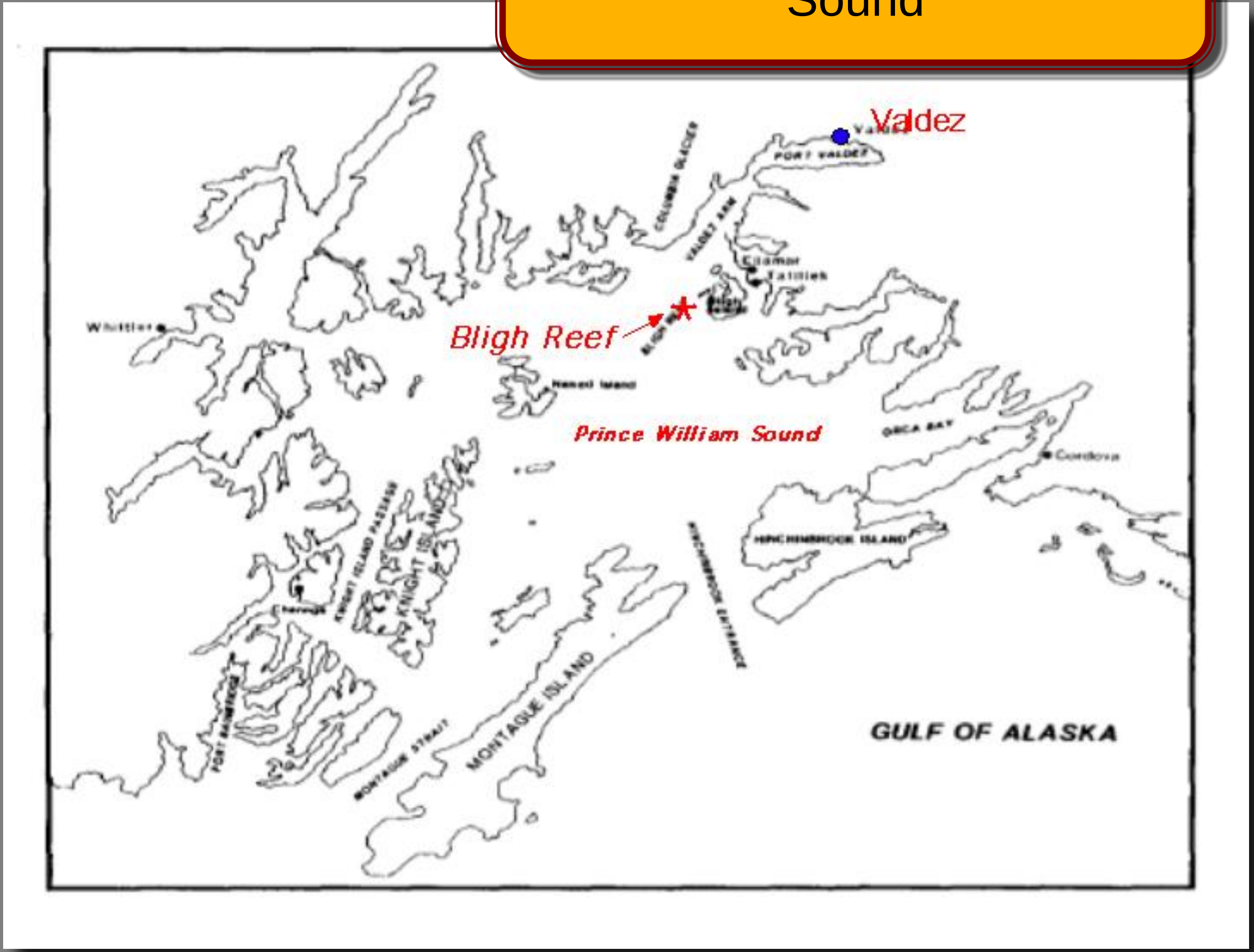
Map of Alaska showing the Trans-Alaska pipeline – Shaded Impact Area



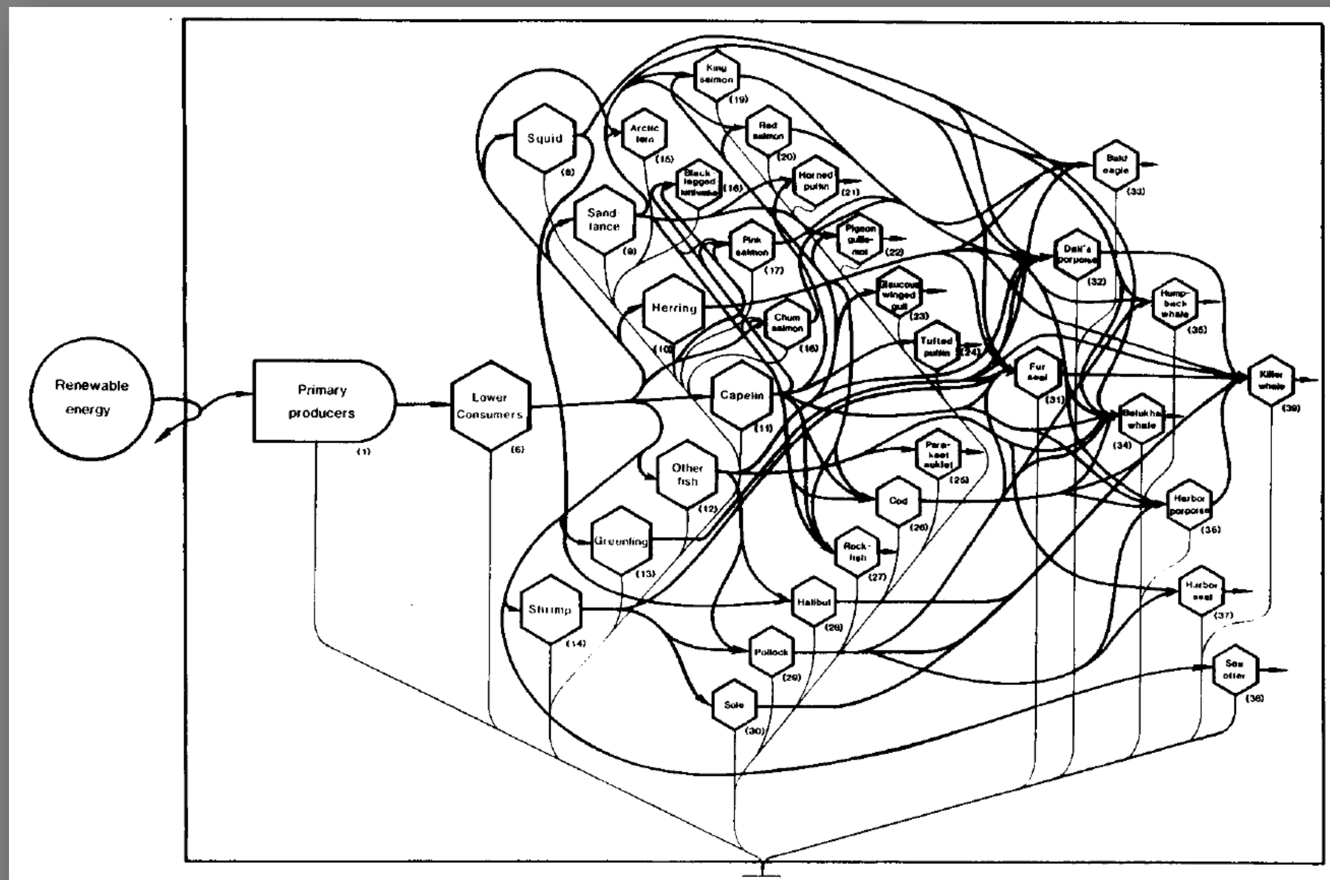
Map showing the extent of the oil spill in Gulf of Alaska



Map showing Prince William Sound



Prince William Sound Trophic Web

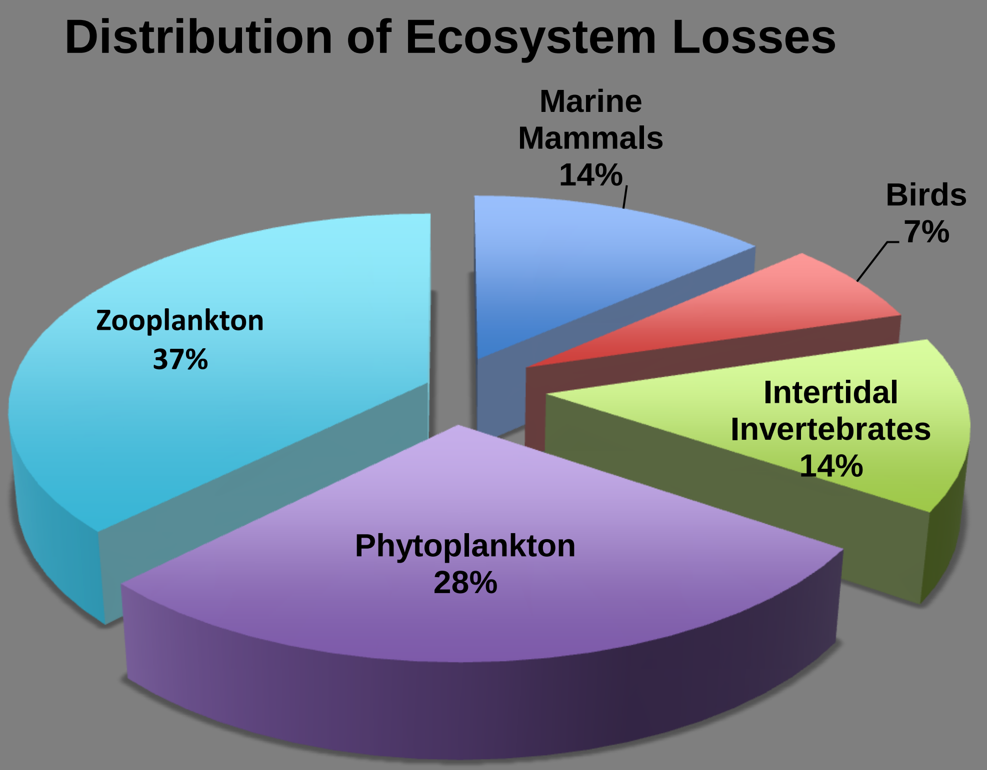


Emergy losses of the Exxon Valdez oil spill

…mergy losses (L_j, LPP_j, and M_j) of the *Exxon Valdez* oil spill. Sources and descriptions for natural resource losses are given in Appendix D.

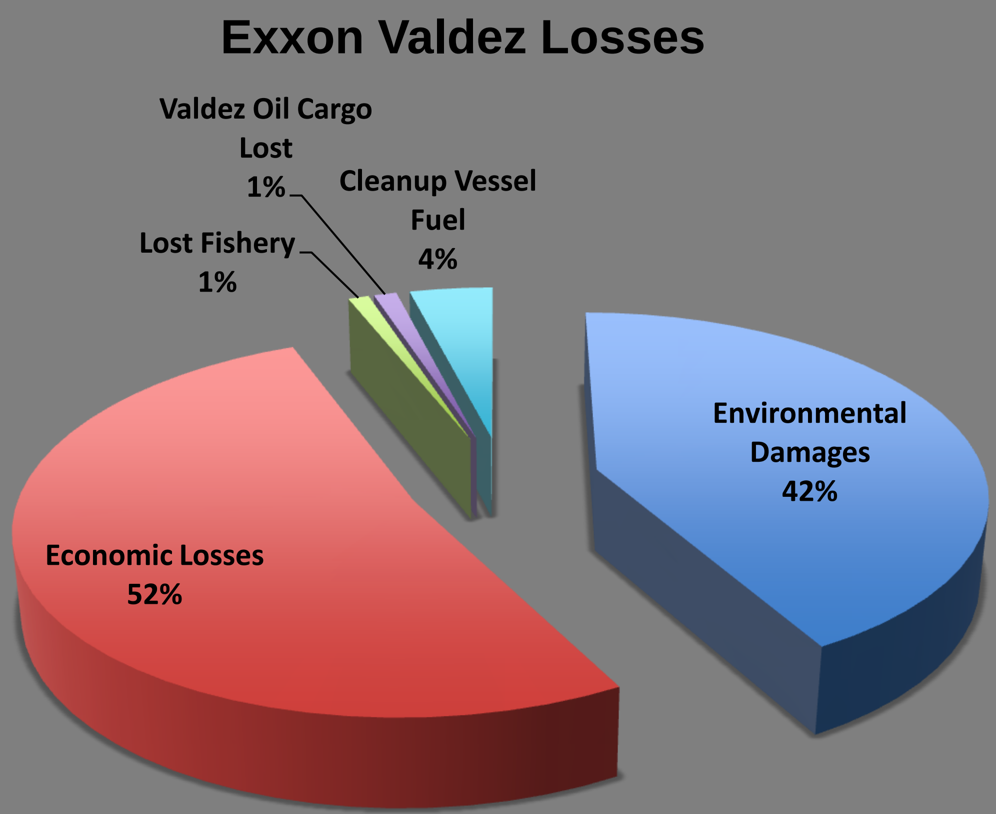
Loss	Form	Energy J	Solar Transformity sej/J	Solar Emergy 1E+19 sej	Macro-economic $ 1E+07 m$
NATURAL RESOURCE LOSSES					
M_2	Zooplankton	0.53-16E+15	1.5E+05	5.8-170.	3.6-110
M_{33}	Bald Eagles	8.0E+10	2.5E+07	0.20	0.13
M_{37}	Harbor Seals	6.0E+11	1.1E+07	0.66	0.41
M_{38}	Sea Otters	5.3-8.4E+11	9.2E+07	4.9-7.6	3.1-4.8
M_{39}	Killer Whales	0-5.3E+11	1.7E+08	0.0-8.9	0.0-5.6
M_{40}	Phytoplankton biomass	0-2.9E+16	1.1E+04	0.0-32.	0.0-20.
LPP_{40}	Phytoplankton production	0-3.7E+15	1.1E+04	0.0-4.1	0.0-2.6
M_{41}	Intertidal Producer biomass	5.2-15E+15	1.1E+04	5.6-17.	3.5-11.
LPP_{41}	Intertidal Producer production	1.4-7.5E+14	1.1E+04	0.14-0.83	0.09-0.52
M_{43}	Intertidal Herbivores	2.7-5.3E+13	1.1E+05	0.30-0.58	0.19-0.36
M_{44}	Intertidal Mieo- & Microfauna & Microflora	0-2.3E+14	2.9E+05	0.0-6.8	0.0-4.3
M_{45}	Intertidal Macrofauna	0-1.3E+14	8.1E+05	0.0-11.	0.0-6.9
$M_{46}+M_{46a}$	Murres	1.5-1.7E+12	4.7E+07	7.2-8.1	4.5-5.1
M_{47}	Procellarids	1.6-1.8E+11	2.3E+07	0.36-0.41	0.23-0.26
ECONOMIC SYSTEM LOSSES					
L_{10}	Herring Fishery Harvest	7.5E+13	1.1E+06	8.3	5.2
L_{AKNS}	AK North Slope Oil Production Loss	7.8E+16	5.3E+04	410.	260.
L_{fuel}	Fuel	5.9E+15	5.3E+04	31.	19.
L_{oil}	*Exxon Valdez* cargo	1.6E+15	5.3E+04	8.5	5.3
		person-y	sej/person-y		
L_{people}	Social Disruption	1.6E+04	1.9E+17	30.	19.
		$	sej/$		
$L_{services}$	Human Labor In Cleanup	2.7E+09	1.6E+12	430.	270.
EMERGY LOSS TOTALS					
	Primary Producers			5.6-53.	3.5-33.
	Intertidal Invertebrates			0.30-18.	0.19-11.
	Zooplankton			5.8-170.	3.6-110.
	Vertebrates			13.-19.	8.1-12.
VNRL	Natural Resource Losses:			25.-260.	16.-160.
VESL	Economic System Losses (excluding L_{AKNS})			508.	320.
	Total Loss (excluding L_{AKNS})			533.-768.	330.-480.

Ecosystem Losses



Total losses (1990 USD)= em$1.2 E9

Economic & Ecosystem Losses



Total losses (1990 USD)= ^{em}\$2.86 E9

(Oil flow interrupted = ^{em}\$2.4 E9)

Economic facts of life...

Exxon spent an estimated $2 billion cleaning up the spill and $1 billion to settle related civil and criminal charges

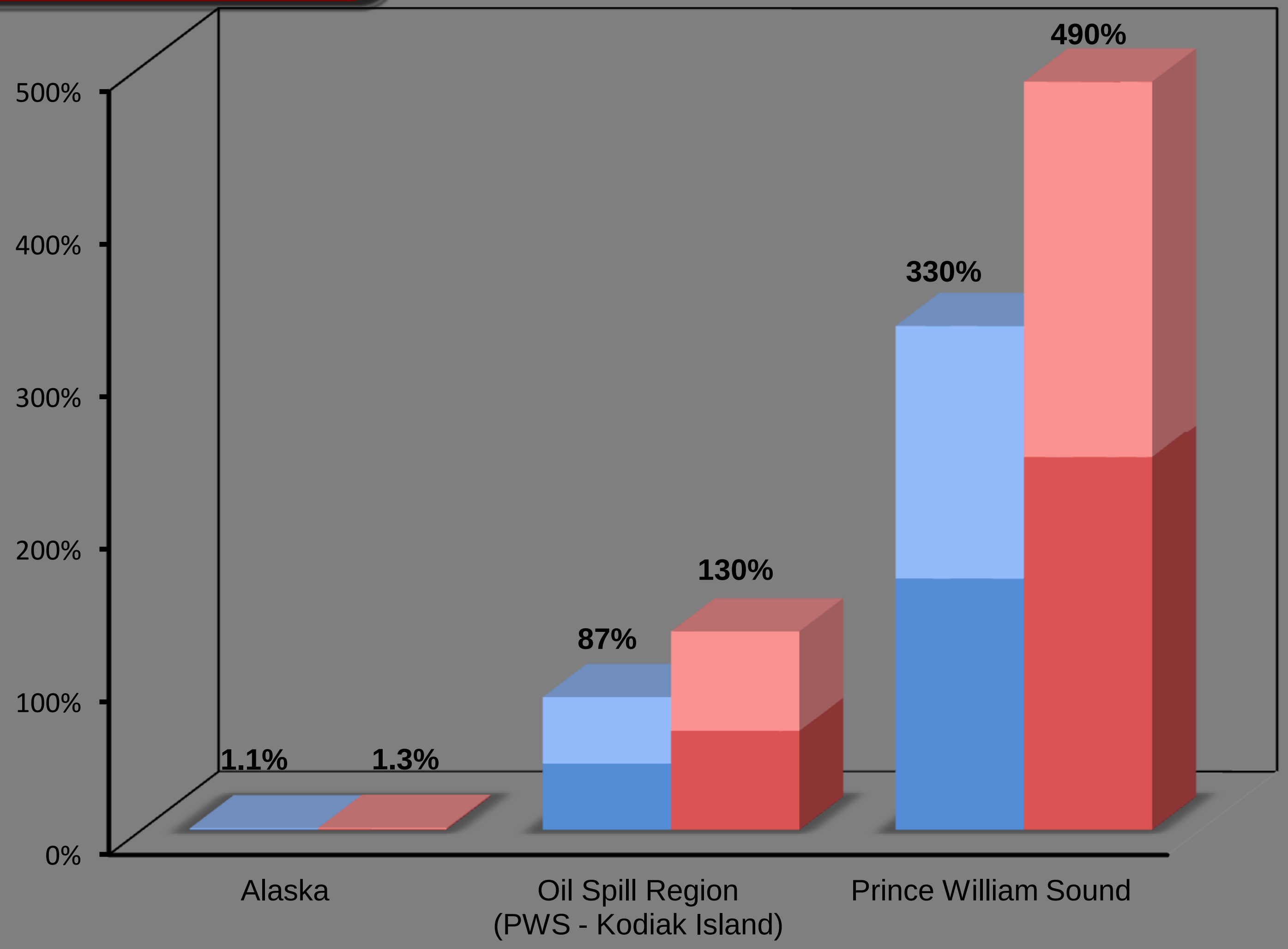
In the case of Baker v. Exxon, an Anchorage jury awarded $287 million for actual damages and $5 billion for punitive damages.

Which was reduced to $4 billion on appeal (2002)

Which was reduced to $2.5 billion on appeal (2006)

Which was reduced to “no more than $507.5 million by the Supreme Court (2008)

Total Losses as Percent of Region's Annual Emergy Support



Cost-Benefit Diagram

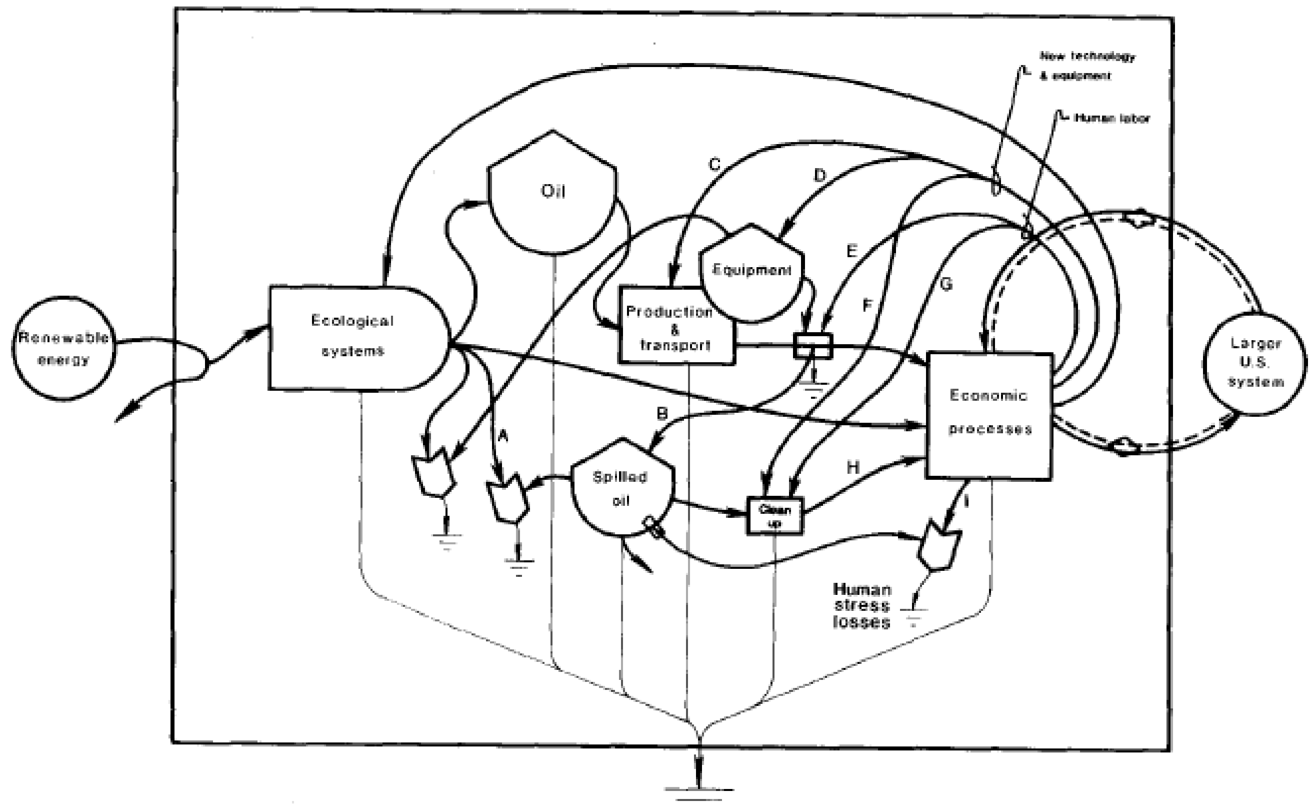
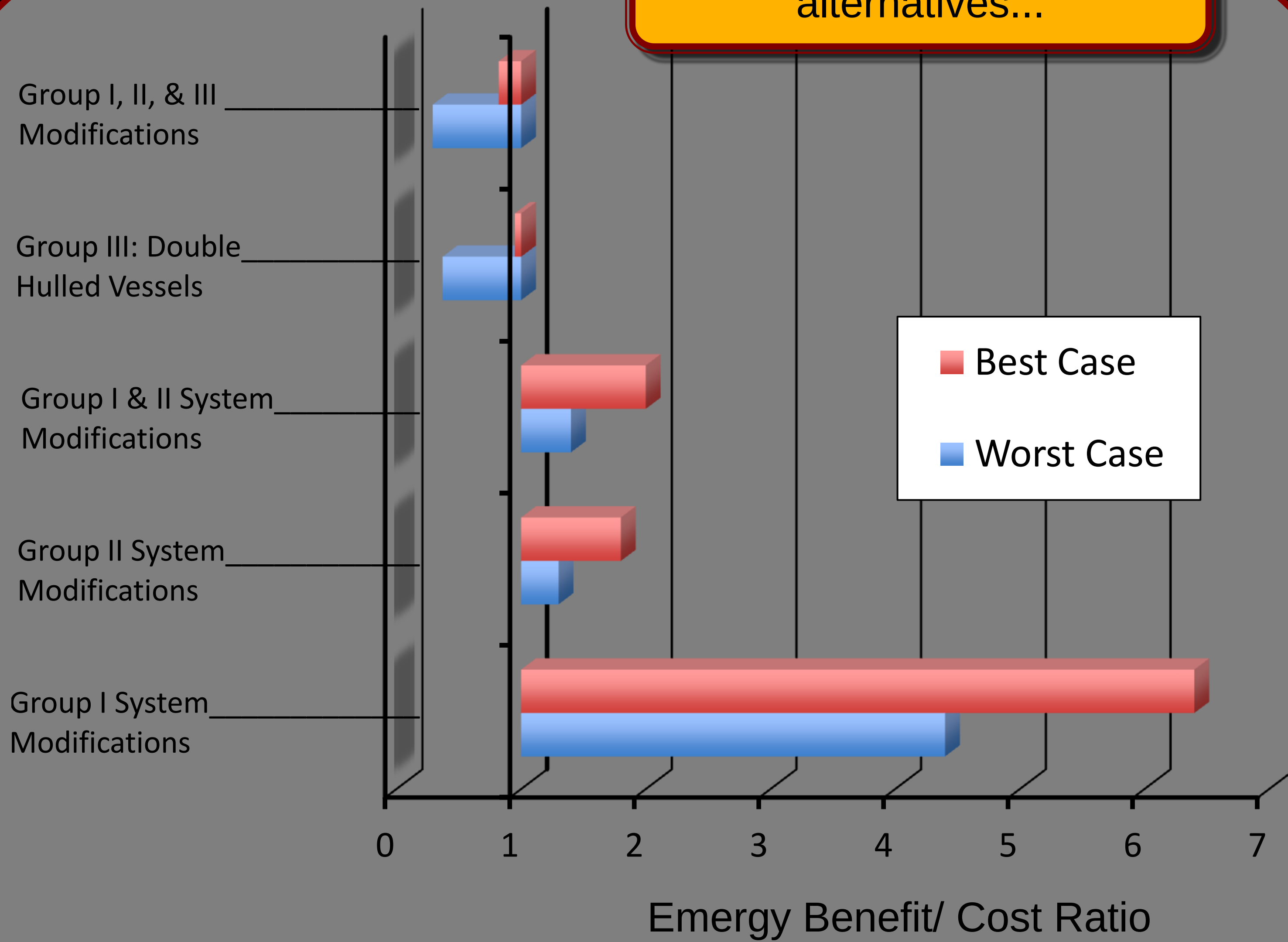
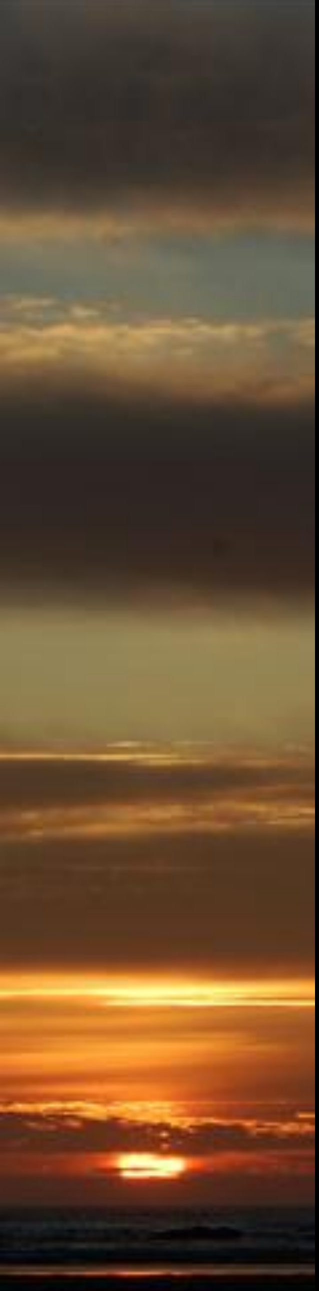


Figure II.4. A model of the costs and benefits of oil spill damage and oil spill prevention methods for the U.S. oil transportation system. the total loss from an oil spill is defined as: A + B + F + G + I - H, and the investment required to implement a prevention alternative is defined as: C + D + E, where, A = natural resource damage resulting from the oil spill, B = spilled oil, C = new technology invested in transport systems, D = new equipment invested in transport systems, E = additional human labor invested in transport systems, F = equipment and technology used in oil spill cleanup, G = human labor used in oil spill cleanup, H = spilled oil recovered during cleanup, I = human productivity losses due to stress as a result of the oil spill

Net benefits from prevention alternatives...





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Richard Murphy, project manager

Thank You…

Questions?