Optimal Harvesting

Natural resources for human use:

Nonrenewable: fossil fuel, minerals

Renewable (Forest, crops, fisheries)

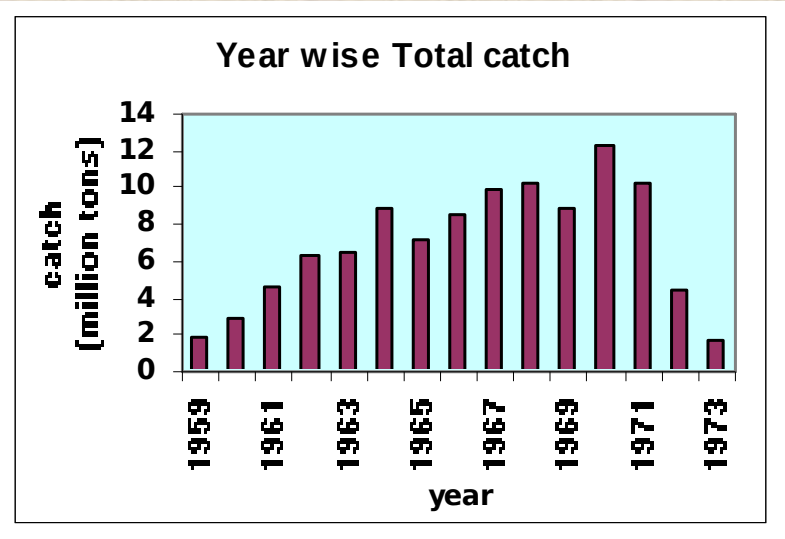
over exploitation → exhaustion/ extinction

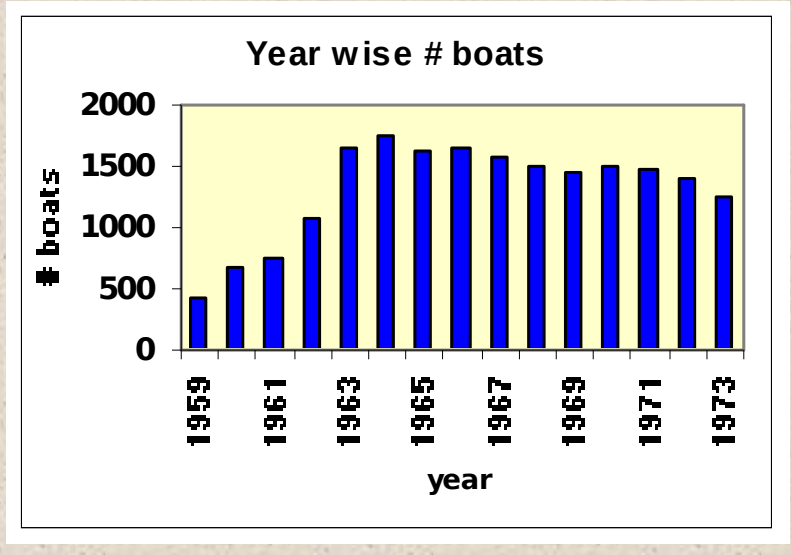
Whales, anchovies, sugar cane

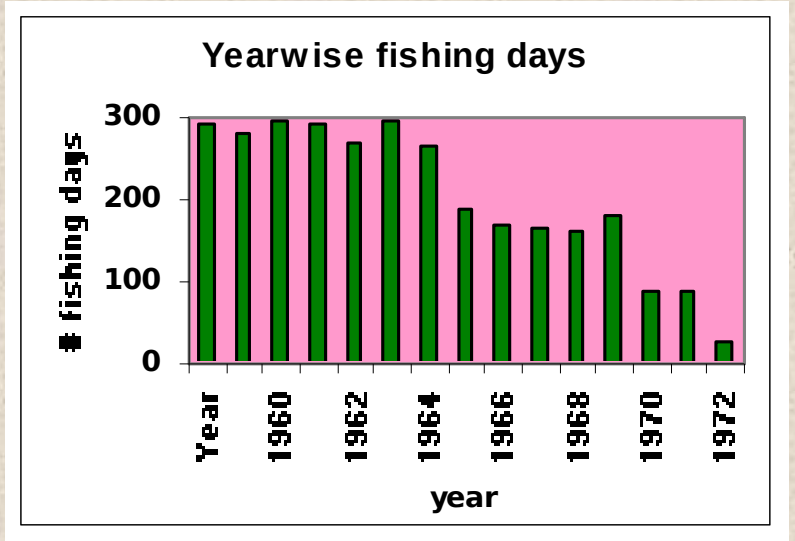
Cases of over-exploitation

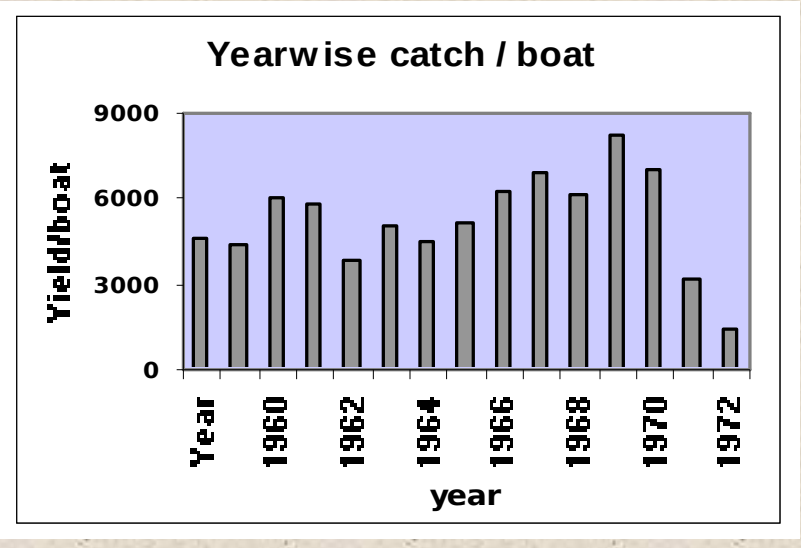
Species	Peak catch	1981 catch
Blue whale(1931)	29,000 (#)	Nil
Fin whales(1938)	27,000 (#)	Nil
Hokkaido herring(1913)	850,000 tons	Nil
California sardine (1936)	640,000 tons	Nil
North sea herring (1962)	1500,000 tons	Negligible

Peruvian Anchovy Fishery









Tuskers poached for ivory- very few left in south India.

NTFP collection by tribal groups-
decline in genetic quality of Amla fruit

Sugarcane farming
soil salinity, over supply

Prudent use essential- but how?

Tragedy of commons

Search for optimal strategy

MSY

Controversy on export of

Indian bull frog: Rana tigrina

Will It disappear?

A.P.Gore

S.A.Paranjpe

Frog-leg Export

Export to : USA, EEC, Japan

Export from : India, Bangladesh, Indonesia etc.

Export from India

Year	volume(tons)
1963	514
1970	2545
1981	4368
1983	3678

Pro-export lobby: Traders, MPEDA
(marine products export development authority)

Arguments in favor:

- Earning foreign exchange
- Employment in frog catching

Anti export lobby: SPCA, conservationist

Arguments against:

- Threat of frog extinction
- Possible explosion of rice pest population

Policy decision: EXPORT BANNED

Quantitative basis: none to our knowledge

Approach adopted in Gore & Prayag (1993)

Step 1: Estimate density – capture recapture method

Step 2: use population dynamics model with harvesting (nonlinear version) to arrive at optimal strategy

Biometrics (1975) Doubleday, (1980) Reed

Density estimation capture – recapture model

- Standard model:

Capture occasion	Before sampling		After sampling	
	Marked	unmarked	Fresh captures	recaptures
First	0	N	R	0
Second	R	N-R	u_1	$m_1=n_1 - u_1$
Third	(1-k) $(R+u_1)$	(1-k)$(N-R-u_1)$	u_2	$m_2 =n_2 - u_2$

- k – fraction of frogs removed (harvested)

Density estimation modified capture – recapture model

- Modified model: introduction of **'escapement'-e** and compensatory arrivals

Capture occasion	Before sampling		After sampling	
	Marked	**unmarked**	**Fresh captures**	**recaptures**
First	**0**	**N**	**R**	**0**
Second	**$R(1-e) = R^*$**	**$N-R^*$**	**u_1**	**$m_1 = n_1 - u_1$**
Third	**$(1-k)(R^* + u_1 - n_1 e)$**	**$(1-k)(N - R^* - u_1 + n_1 e)$**	**u_2**	**$m_2 = n_2 - u_2$**

$p_1 = R^*/N$, $p_2 = (R^* + u_1 - n_1 e)/N$: capture probabilities at 2nd and 3rd occasion

Maximum likelihood estimation

- $L(N,e \mid n_1,n_2,R) = C.\ p_1^{m1}(1-p_1)^{u1}\ p_2^{m2}(1-p_2)^{u2}$

- N,e estimated by search

Estimates in 3 villages of Maharashtra

Village	Est(N)(5ha)	Est(e)	Density/ha
Poinje	539	0.66	107.8
Kolwan	773	0.48	154.6
Kambe	461	0.47	92.2

- Est(e) quite high
- Density 100/ha used for further calculations

Assessment of sustainable harvest (Doubleday model)

- Leslie matrix approach
  - M- matrix of fecundity & survival
  - $\underline{\theta}$ - diagonal $(\theta_1, \theta_2, \ldots, \theta_{m+1})$
    $\forall \theta j$:fraction from age class j that escapes harvest
  - C – vector of age wise weights
  - V –vector of age structure

- Problem :
  - Maximize $C'(I - \theta)MV$ (yield)
  - By choosing θ such that
  - $\underline{MV} - \underline{V} \geq 0$ increasing population
  - $\forall\theta$ $\underline{MV} - \underline{V} \geq 0$ harvesting stabilizes population
    - θ to be obtained using LPP

Results

- First attempt:
  Age groups: froglets, 1 yr old, 2 yr old, ….6 yr old, above 6 yr

- Harvest policy: (I- θ) = diag(0.92, 0.02,0,0,1,1,1,1)

  Harvest all 4 yr or older frogs, 92% of froglets

  Froglets – useless, yield not worth efforts

  If not harvested- population explodes

- This solution not of much practical value

- Modification:
  - Introduce density dependence
    - E- # recruits in froglet class
    - g(E) – proportion surviving
    - $g(E) = \alpha \exp(-\beta E)$
  - A simplifying Constraint
    – all frogs above a threshold age should be harvested
- Good choice 2 years (wt 100gm or above)
- Sustained yield – about 12 Kg/ha
- Matches with field practice of traders

Effect on insects?

- Argument:
  - Frog – predator of insect
  - Frog harvest may lead to increased insect biomass

- From stomach contents food composition can be estimated

Food composition of frogs (proportion of body wt)

Frog wt (gm)	crab	insect	larvae
80	0.0134	0.0212	0.0141
125	0.0596	0.0077	0.0027
250	0.0427	0.0067	0.0019
450	0.0442	0.0037	negligible

Frog population structure

•No harvesting	(28,28,28,28,8,5,2,1)
•With harvesting (our policy)	(93,93,0,0,0,0,0,0)

Food consumption by frogs per day (kg/ha)

	crab	insects	Larvae
No harvest	1.12	0.18	0.08
harvest	0.79	0.25	0.14

- **Harvesting increases insect predation !**

Findings

- **Optimal strategy: catch frogs of 100 gm or above**

  - **Ensures sustainable yield**

- **Comment: This was the practice of exporters**

  - **Reason: smaller frogs had no demand**

- **Pest control aspect**

  frog diet- insects and other prey

  % share of insects ↓ as weight of frog ↑

  large frogs eat crabs

- **Inference: Removal of large frogs → more small frogs**

  → higher consumption of insects

  → no danger on pest control front