THE EARTH’S BIOSPHERE

- Energy Flows in Ecological Systems
- Ecosystem Structure
- Productivity and Biodiversity

Energy Flows in Ecological Systems

Producers and Consumers

- Organisms with the ability to capture energy and manufacture matter are known as **autotrophs**, or **producers**
- All other organisms are known as **heterotrophs**, or **consumers**
- There are two kinds of autotrophs: **phototrophs** and **chemoautotrophs**
- **Phototrophs** get their energy from light, while **chemoautotrophs** obtain their energy from chemicals in the environment

Energy Flows in Ecological Systems

Food Chains

- Some of the energy captured by autotrophs is passed on to other organisms, the consumers, through a **food chain**
- Each level of the food chain is called a **trophic level**
- **Herbivores** eat producers and are the energy source for higher-level consumers, or **carnivores**
- **Omnivores**, such as humans, raccoons, sea anemones, and cockroaches, can get their energy from multiple trophic levels

Energy Flows in Ecological Systems

Food Chains

- **Decomposer food chains** are just as important as **grazing food chains**
- These chains are based on dead organic material called **detritus**, which is high in potential energy but difficult for typical consumer organisms to digest
- Decomposer food chains play a key role in breaking down plant and animal material into products such as carbon dioxide, water, and inorganic forms of phosphorus and nitrogen and other elements

Energy Flows in Ecological Systems

Biotic Pyramids

- he second law of thermodynamics explains how energy flows from trophic level to trophic level, with a loss of usable energy at each transformation
- **Energy efficiency:** portion of energy entering system that is transformed into useful form of energy or work
  - In natural food chains may be as low as 1%; 90% lost at each trophic level
- Some ecosystems have an inverted **biomass pyramid** (natural grasslands, oceans)

Energy Flows in Ecological Systems

Productivity

- The rate at which energy is changed into biomass; usually expressed in kilocalories per square metre /year
- **Gross primary productivity** (**GPP**) is the overall rate of biomass production
- C*ellular respiration* (R), must be subtracted from the GPP to reveal the **net primary productivity** (**NPP**); the amount of energy available to heterotrophs
- The most productive ecosystems are wetlands and tropical rainforests; the least are deserts, the Arctic and open Ocean
- Humans use 40% of all terrestrial NPP for their own use

Energy Flows in Ecological Systems

Productivity

- Measurements can also be made of **net community productivity** (NCP), including heterotrophic and autotrophic respiration
- Over time, natural systems mature towards maximization of NCP
- *Auxiliary energy flows* allow some ecosystems and sites to be very productive
  - For example, tidal energy in an estuary brings in nutrients and helps dissipate wastes

Ecosystem Structure

- The ecosphere can be broken down into smaller units
- At the smallest level is the individual **organism**
- A group of individuals of the same species is a **population**
- All the populations of all species in an environment are known as a **community**

Ecosystem Structure

- **Ecosystems** are collections of communities interacting with their physical environments
- Ecosystems are *open systems* in that they exchange material and organisms with other ecosystems
- *Ecozones* are groups of ecosystems with similar dominant vegetation and animal communities
- Many ecozones taken together and classified according to their dominant vegetation and reflecting animal adaptations to predominate climatic conditions form a **biome**

Ecosystem Structure

Abiotic Components

- **Abiotic components** play an important role in determining how the living or **biotic components** of ecosystems are distributed
- **Key abiotic factors**: light, temperature, wind, water, and soil characteristics

Ecosystem Structure

Abiotic Components

- **Range of tolerance**: the range of conditions that different organisms can tolerate and still survive
- **Optimum range:** the range of conditions that is ideal for a species
- **Zone of physiological stress**: conditions can be tolerated by certain individuals within the population, but are not optimal, so fairly few individuals can exist

Ecosystem Structure

Biotic Components

- According to the **competitive exclusion principle**, no two species can occupy the same niche in the same area
  - *Fundamental niche:* potential range of conditions a species can occupy
  - *Realized niche:* the range actually occupied
- **Specialist species** have narrow niches and are vulnerable to environmental change, e.g., Panda
- **Generalist species** may have a very broad niche, e.g., black bear, coyote

Ecosystem Structure

Biotic Components

- Competition
  - **Intraspecific competition** occurs among members of the same species; regulates population size; may lead to establishment of **territories**
  - **Interspecific competition** occurs between different species
  - **Resource partitioning:** resources are used at different times, or in different ways, by species with overlaps of fundamental niches, possibly reducing competition

Ecosystem Structure

Biotic Components

- Biotic Relationships (**Optimal foraging theory)**
  - **Parasitism**: a special type of predator–prey relationship, where the predator lives on or in its prey (host)
  - **Mutualism**: the relationship benefits both species
    - e.g., nitrogen-fixing bacteria and their host plants
  - **Commensalism:** interactions that seem to benefit only one partner but do not harm the other
    - e.g., epiphytes

Biodiversity

Biodiversity is the result of all the interactions between abiotic and biotic factors throughout evolution

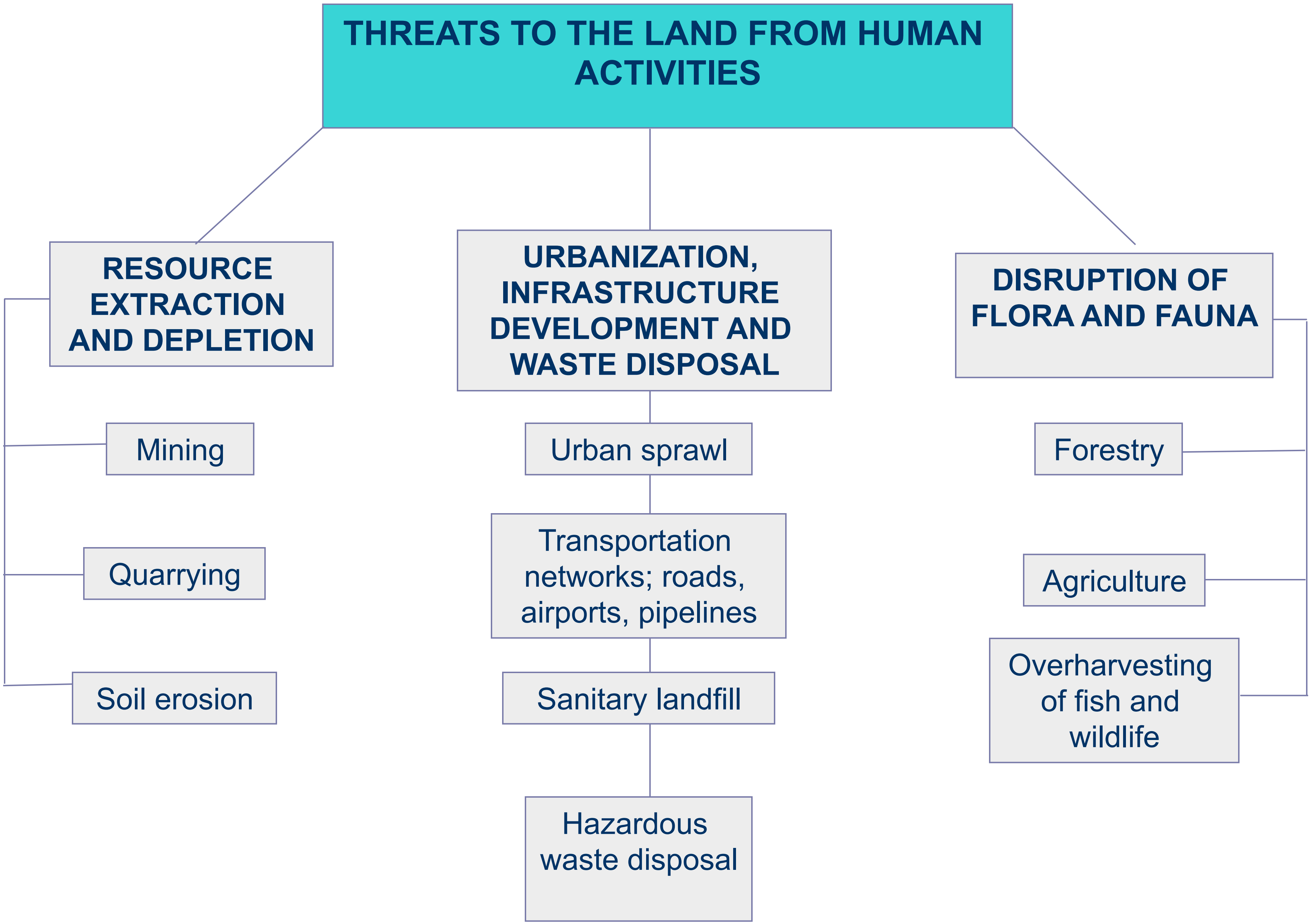
- **Genetic diversity (richness):** variability in genetic makeup among individuals of the same species; the ultimate source of biodiversity at all levels
- **Species diversity (richness):** the total number of species in an area
  - Global estimates 5 to 20 million
- **Ecosystem diversity (richness)**: the variety of ecosystems in an area.

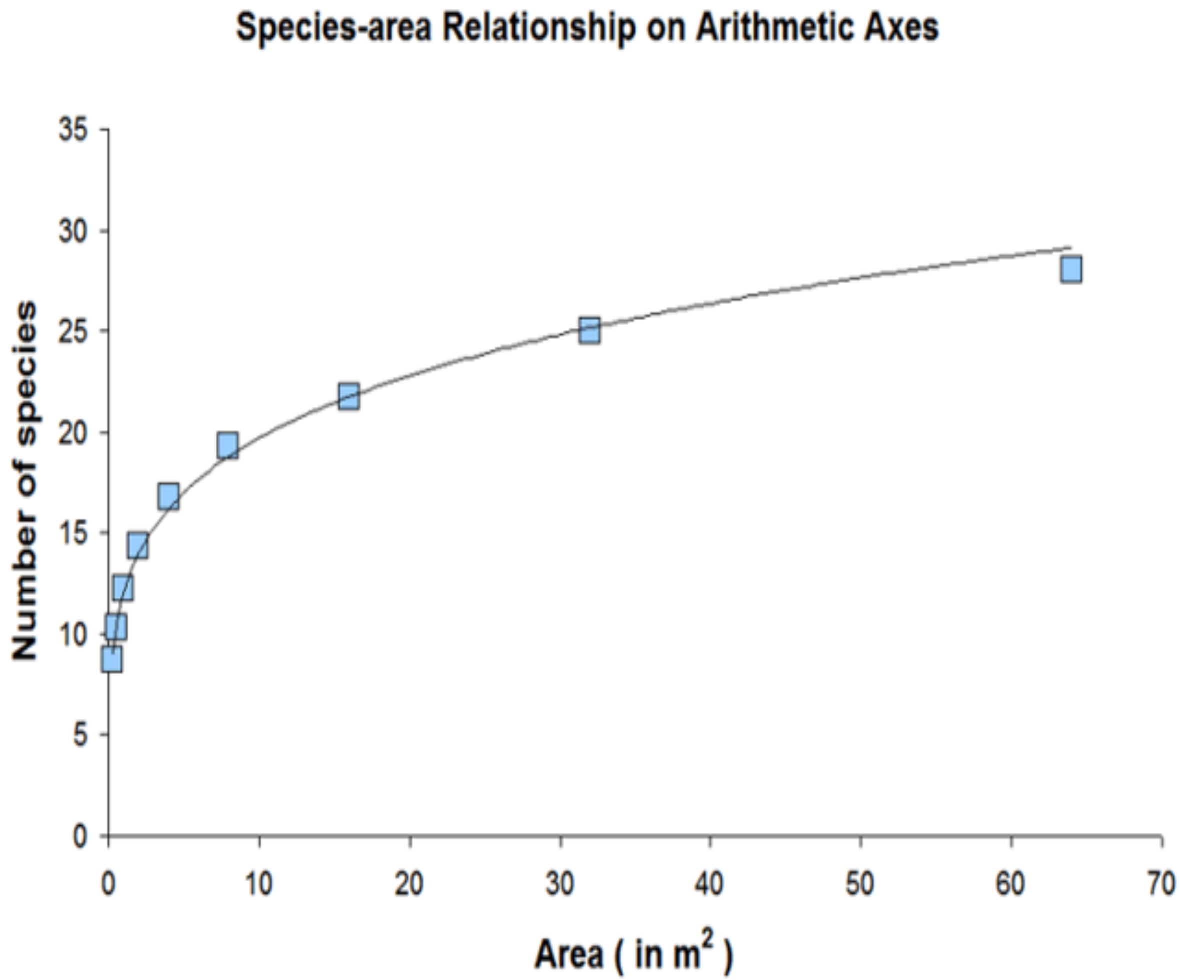
Implications

- All of the Earth's inhabitants are interlocked in environmental systems that depend on one another for survival
- Basic scientific laws dictate that society must transform itself from a throwaway society to one in which energy efficiencies are improved and matter flows reduced
- A species may have a wide range of tolerance to some factors but a very narrow range for others

Implications

- Species with the largest ranges of tolerance for all factors tend to be the most widely distributed (e.g., cockroaches and rats)
- Many weed and pest species are successful because of their large range of tolerance
- Response to growth factors is not independent
- Tolerance for different factors may vary through life cycles
- Some species can adapt to gradually changing conditions for some factors, up to a point


THREATS TO THE LAND FROM HUMAN ACTIVITIES
RESOURCE EXTRACTION AND DEPLETION
Mining
Quarrying
Soil erosion
URBANIZATION, INFRASTRUCTURE DEVELOPMENT AND WASTE DISPOSAL
Urban sprawl
Transportation networks; roads, airports, pipelines
Sanitary landfill
Hazardous waste disposal
DISRUPTION OF FLORA AND FAUNA
Forestry
Agriculture
Overharvesting of fish and wildlife

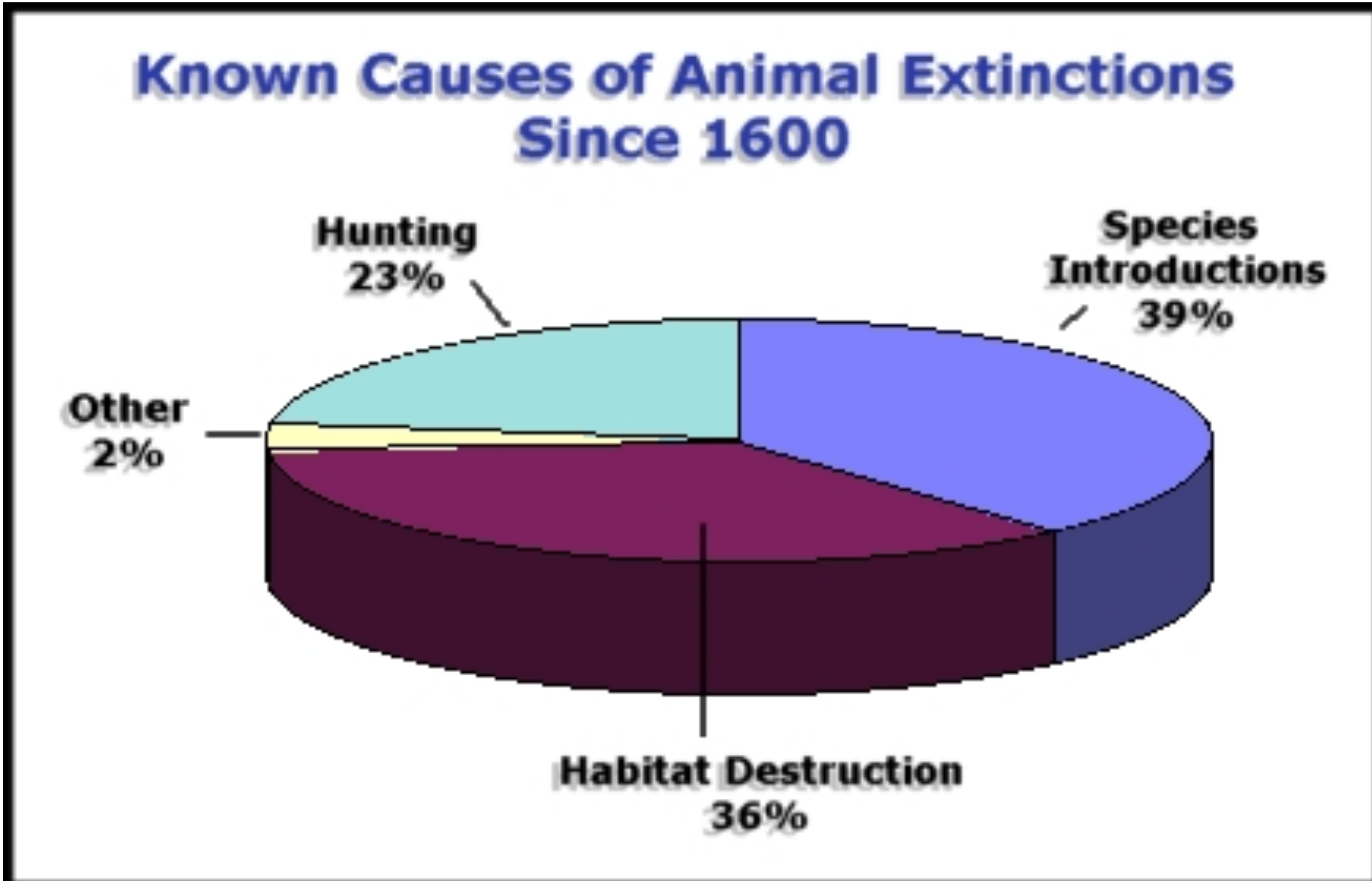


The **species-area curve** is a graph showing the number of species found in a defined area of a particular habitat or of habitats of different areas.

- Usually constructed for a single type of organism (I.e. vascular plants or a trophic level).

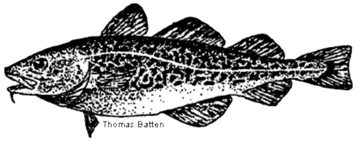
- Rarely constructed for all types of organisms

- The species-area relationship is sometimes called as *species-area theory*.

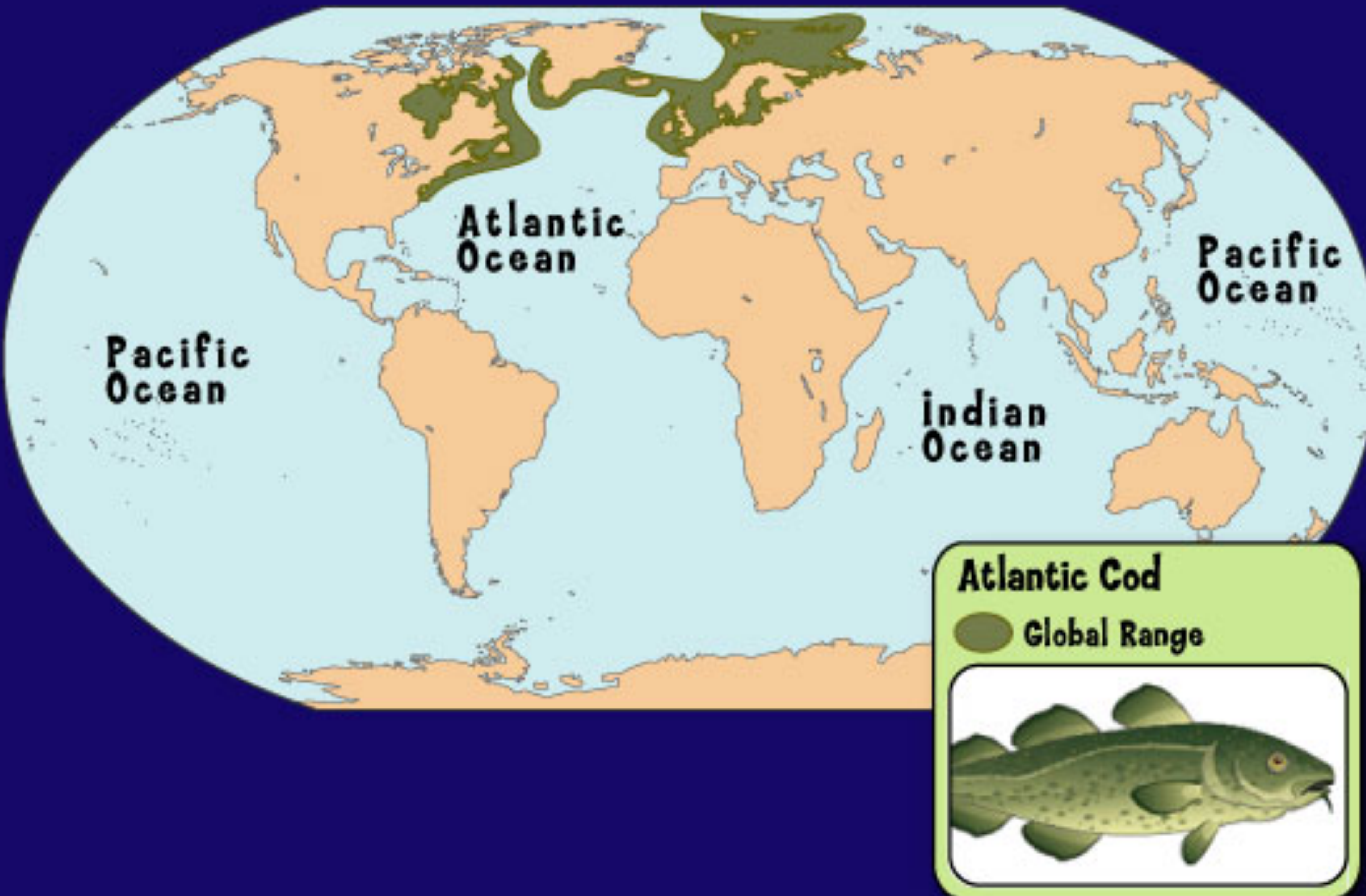

Known Causes of Animal Extinctions Since 1600
Hunting 23%
Species Introductions 39%
Other 2%
Habitat Destruction 36%

A Tragedy of the Commons:

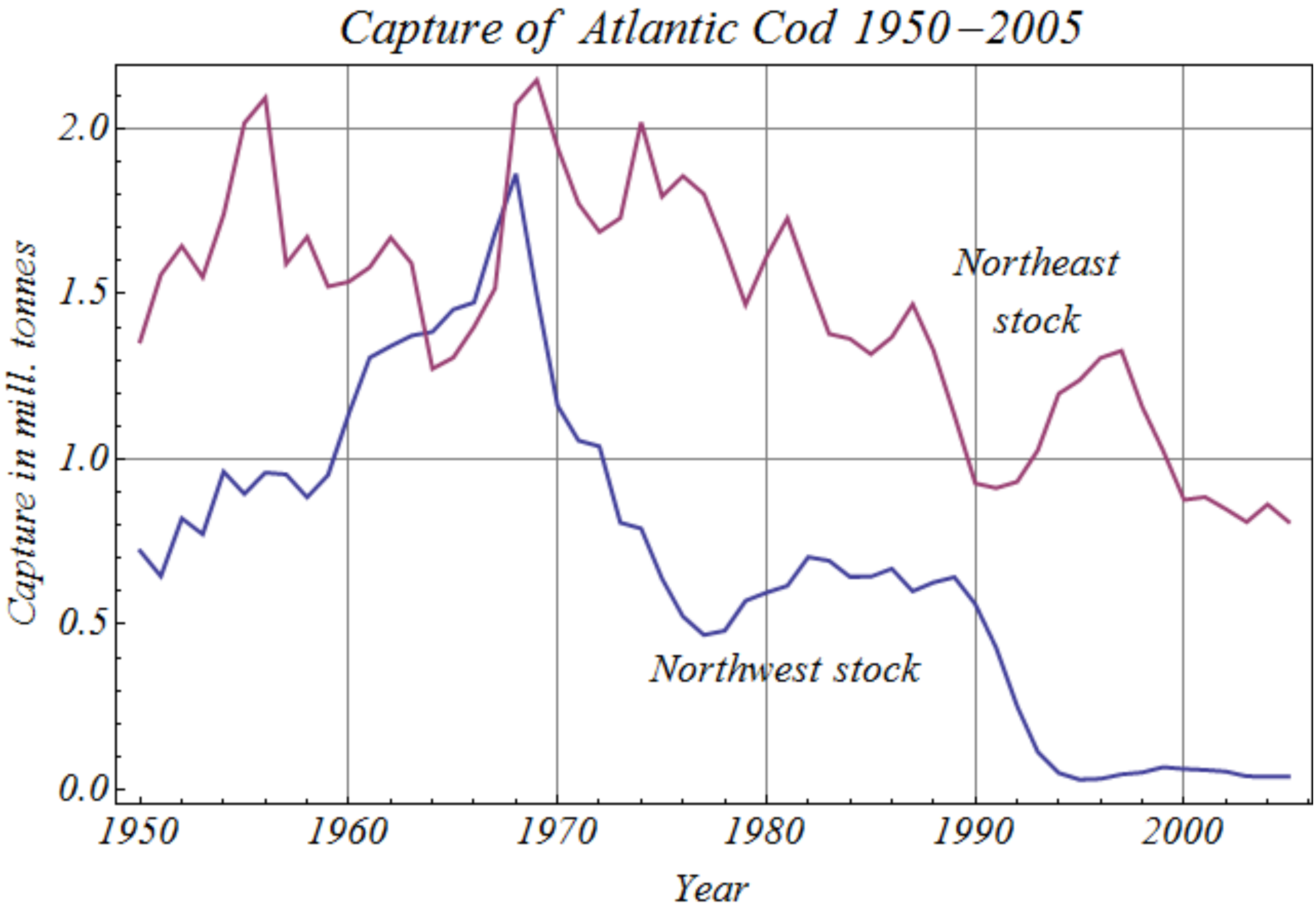
The Newfoundland Cod Fisheries



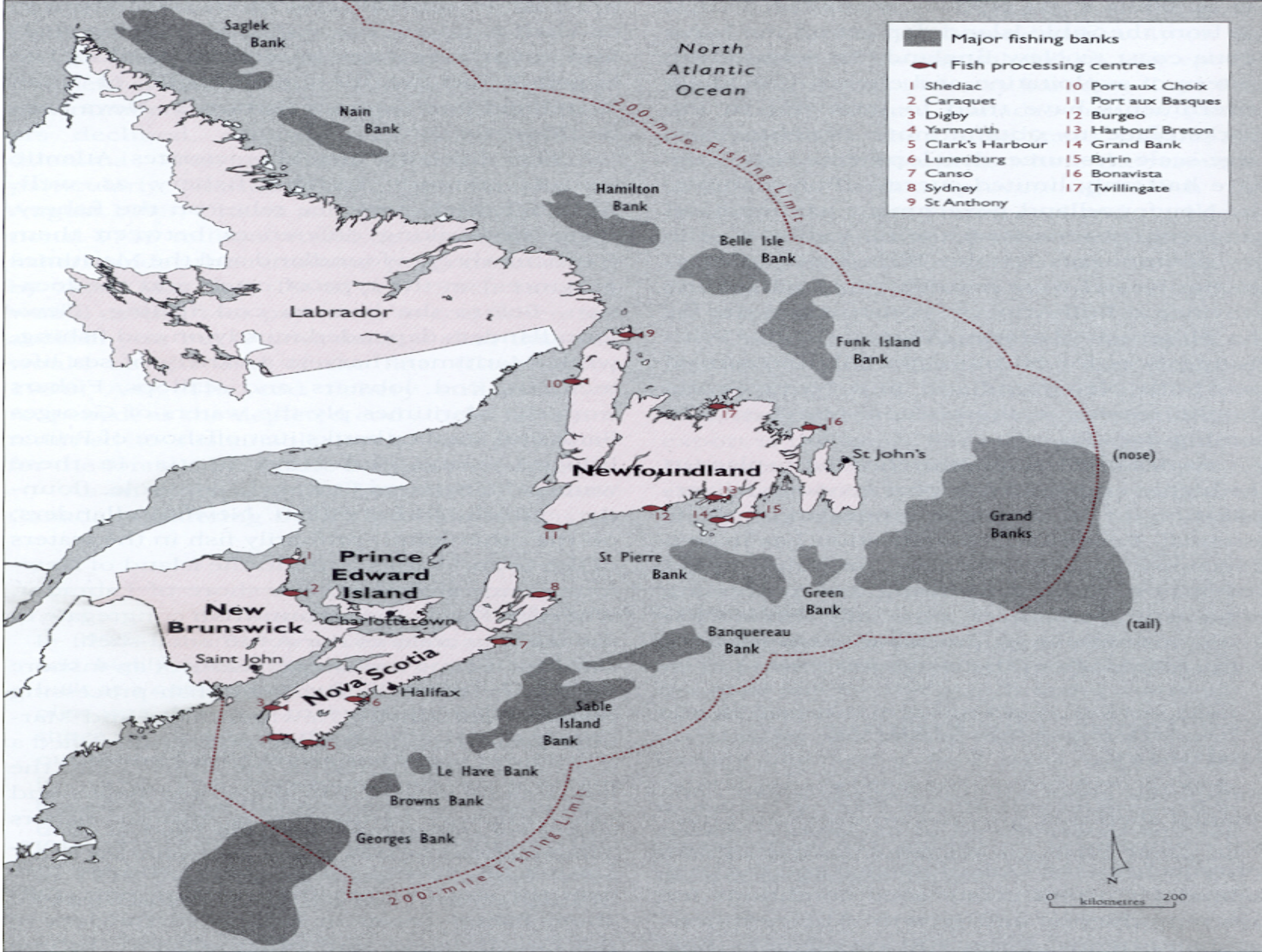
The Atlantic Cod (Gadus morhua)



Atlantic Ocean
Pacific Ocean
Pacific Ocean
Indian Ocean
Atlantic Cod
Global Range



Capture of Atlantic Cod 1950–2005
Capture in mill. tonnes
Year
Northeast stock
Northwest stock
0.0
0.5
1.0
1.5
2.0
1950
1960
1970
1980
1990
2000



Major fishing banks
Fish processing centres
1 Shediac
2 Caraquet
3 Digby
4 Yarmouth
5 Clark's Harbour
6 Lunenburg
7 Canso
8 Sydney
9 St Anthony
10 Port aux Choix
11 Port aux Basques
12 Burgeo
13 Harbour Breton
14 Grand Bank
15 Burin
16 Bonavista
17 Twillingate
North Atlantic Ocean
Saglek Bank
Nain Bank
Hamilton Bank
Belle Isle Bank
Funk Island Bank
200-mile Fishing Limit
Labrador
Newfoundland
St John's
(nose)
Grand Banks
(tail)
St Pierre Bank
Green Bank
Banquereau Bank
Sable Island Bank
Le Have Bank
Browns Bank
Georges Bank
Prince Edward Island
Charlottetown
New Brunswick
Saint John
Nova Scotia
Halifax
N
0 kilometres 200

DORY: Inland seasonal

1956-1977 inshore catch plummeted by 2/3

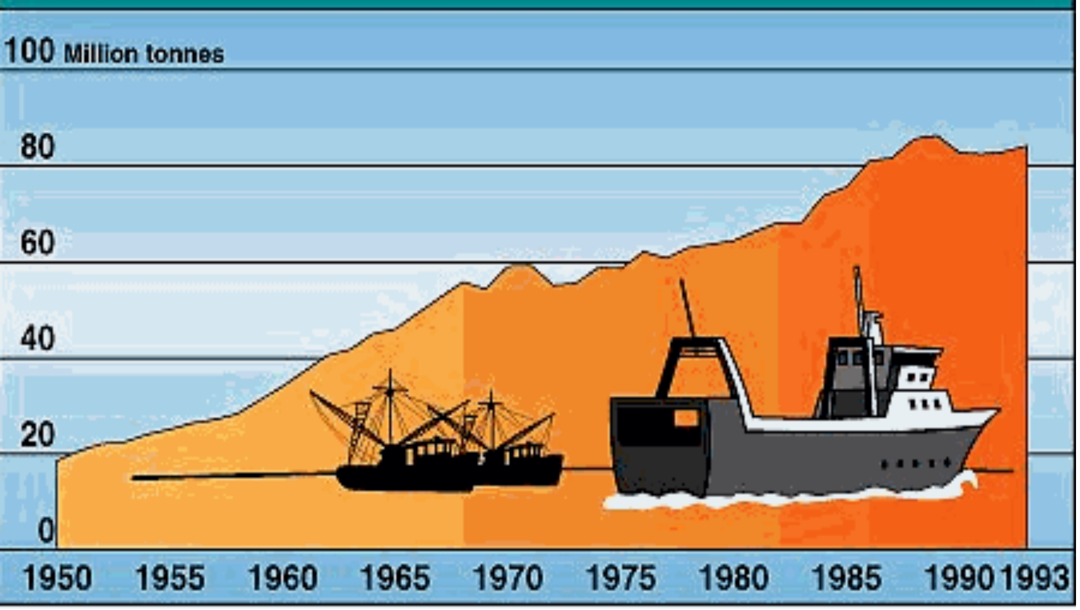
- 200 mile limit too late

Large Hydraulic Vessels:

-Offshore

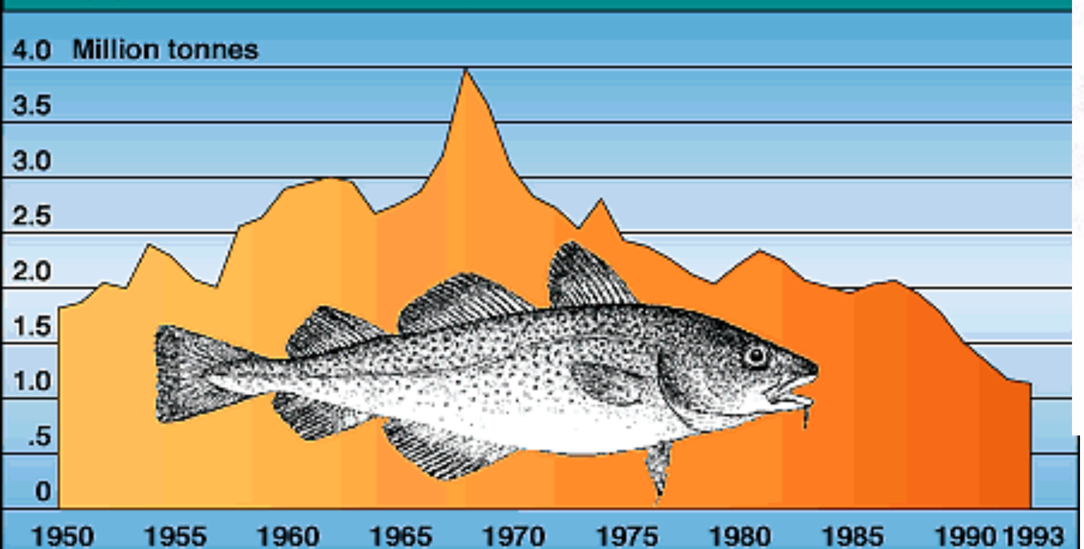
-Hundreds of tonnes of fish to fish processing

The Decline of North Atlantic Cod



Nominal catch of Atlantic cod, 1950-93

Overfishing has severely depleted cod stocks in the Atlantic. As a result, the cod catch has plummeted over the past 25 years and some fisheries have been closed entirely. FAO warns that cod and many other heavily fished stocks will recover only if catches are sharply reduced and carefully monitored for at least a decade.



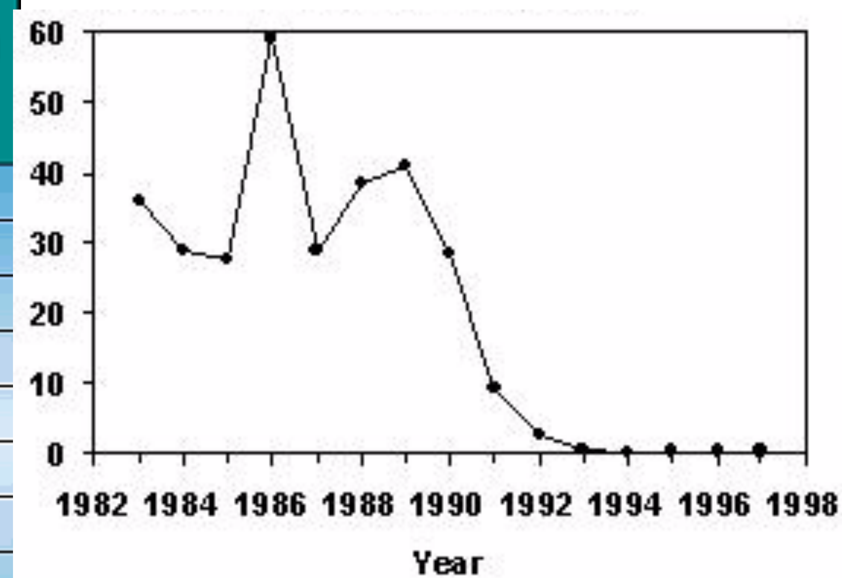


Table 9.4 **Atlantic Canada and Newfoundland Fisheries Landings, 1990–2001 (million tonnes)**

Year	Newfoundland	Atlantic Canada	Per cent Newfoundland
1990	245,896	395,266	62.2
1991	178,687	309,031	57.8
1992	75,138	187,804	40.0
1993	37,068	76,644	48.4
1994	2,292	22,719	9.8
1995	863	12,438	6.9
1996	1,147	15,541	7.4
1997	12,317	29,899	41.2
1998	22,764	37,894	60.0
1999	38,663	55,527	69.6
2000	30,216	46,177	65.4
2001	23,774	40,440	58.8

Source: Fisheries and Oceans Canada (2003).

Summary

- The overestimation and overexploitation of renewable resources can have direct consequences to social, economic and political systems that rely on the integrity of the environment

- The *Tragedy of the Commons* is a dilemma in which multiple individuals acting independently in their own self-interest can ultimately destroy a shared resource even where it is clear that it is not in anyone's long term interest for this to happen.