

#### **Future Oceans**

#### Meeting the Challenges of Securing Aquatic Food Resources

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#### Aquatic Food Resources

- Key source of animal protein for a large fraction of humankind
- Many economies and communities, in particular in developing nations and coastal regions, depend on fisheries
- Rampant overfishing on open-access ocean fisheries is causing serious problems
- Impacts of catches on freshwater systems are still underestimated



#### Seafood is the primary source of animal protein for more than

## 1 billion people



Food and Agriculture Organization of the UN



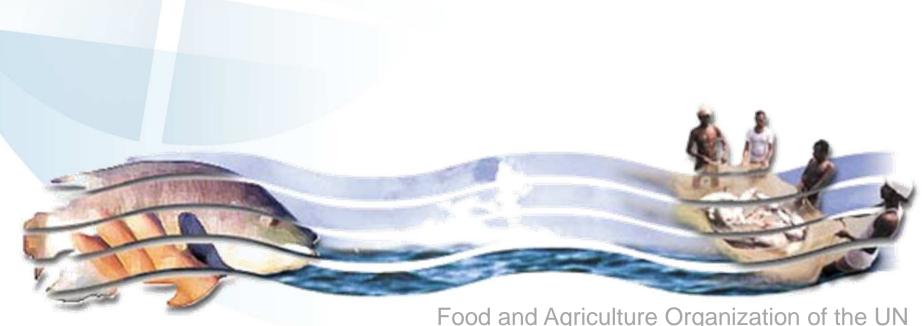
# Fishing, aquaculture, and related industries support the livelihoods of 700 million people





## Only 2%

of motorized fishing boats are of industrial size



Food and Agriculture Organization of the UN



### Total annual revenue

## US\$225 billion





## Total annual production 155 million tonnes





#### Average annual per capita fish supply

## 19 KG



Food and Agriculture Organization of the UN



#### Production growth in past 50 years

480%

"Conquering the blue continent"





#### Today, aquaculture supplies

40%

of total production; in China even

65%

Food and Agriculture Organization of the UN



## During the past 30 years capture production has plateaued, while aquaculture production has risen

## 12-fold





#### Of our oceans' fish stocks,

50% are fully exploited

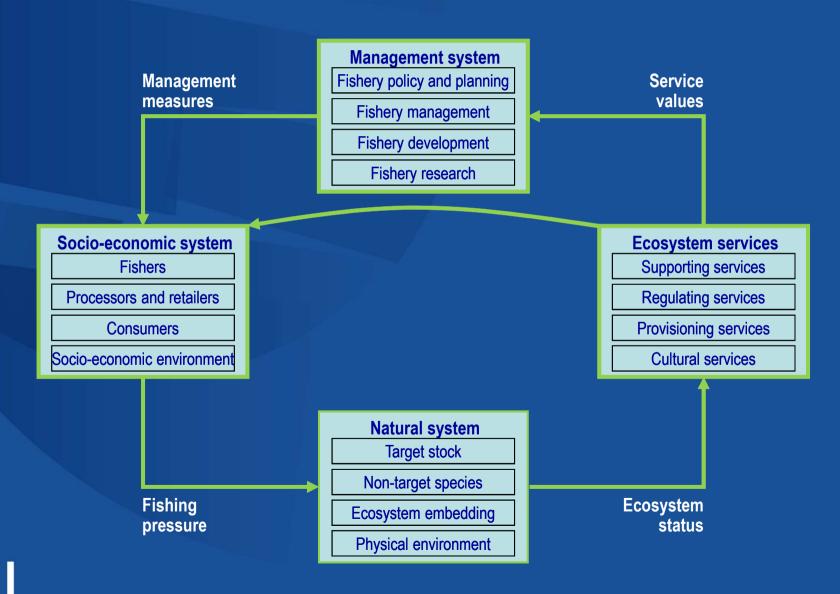
25% are overexploited







#### Fishery Systems





#### **IIASA's Main Contributions**

Process-based models
 Needed for coping with uncertainties, nonlinearities, and regime shifts

Fisheries-induced evolution
 Needed for overcoming a blind spot of contemporary fisheries management

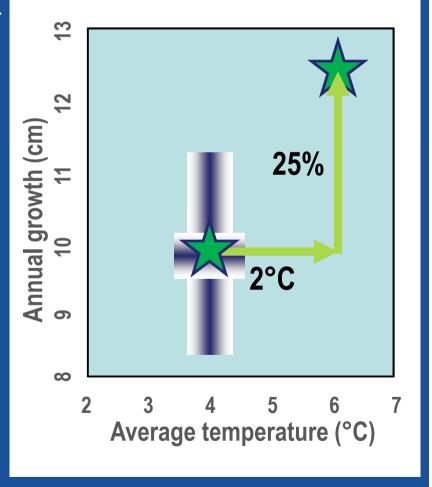
Integrative assessments

Needed for facilitating transparent stakeholder reconciliation through quantitative socioeconomic analyses



## Example 1: Process-Based Models Growth of Northeast Arctic Cod

- Very valuable European stock
- Standard statistical models are problematic when used for extrapolation
- Standard age-based models are not suitable when growth is variable
- Growth turns out to vary with temperature and stock size
- A 2°C rise in temperature is expected to cause a 25% rise in growth

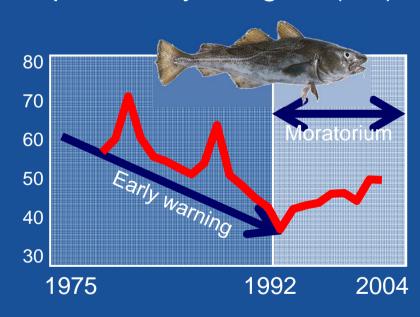




### Example 2: Fisheries-Induced Evolution Collapse of Northern Cod

- Stock collapsed in 1992 and has not recovered since
- Heavy exploitation favors earlier maturation at smaller size
- We have documented a 15% drop in age at maturation and a 30% drop in size at maturation
- Such evolutionary impacts of fishing are very slow and difficult to reverse

Size at 50% maturation probability at age 5 (cm)

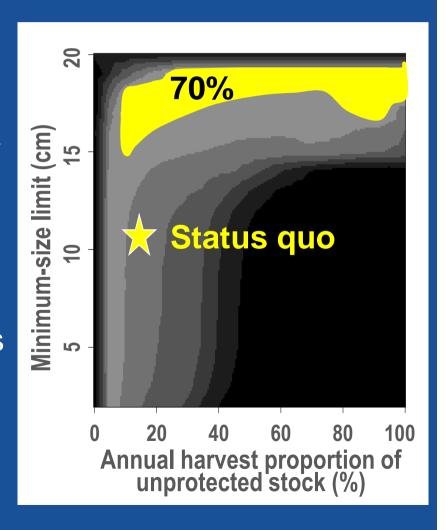


Nature 428:932



### Example 3: Integrative Assessments: Management of Barents Sea Capelin

- Largest capelin stock in the world; was largest Norwegian fishery; collapsed in 1986
- Our assessment accounts for yields, profits, employment, and ecological impact
- Our assessment also accounts for differential preferences among five types of stakeholders
- Maximum joint satisfaction is high, and is best achieved through minimum-size limits





#### Improving Fishing Policies

- International expert group on "Fisheries-induced Evolution"
- Part of the scientific advice by the International Council for the Exploration of the Sea (ICES)
- New tool: Evolutionary Impact Assessments (EvolA)
- Monitoring maturation evolution has become a binding EU requirement
- At IIASA, further integration of process-based, evolutionary, and socioeconomic perspectives

#### **POLICY**FORUM

#### **Managing Evolving Fish Stocks**

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ocess of innovation and adaptation op of natural selection, human-induced selecion pressures can also cause rapid evolution. Sometimes such evolution has undesirable consequences, one example being the spreadng resistance to antibiotics and pesticides, hich causes suffering and billion-dollar osses annually (1). A comparable anthroogenic selection pressure originates from ishing, which has become the main source of nortality in many fish stocks, and may exceed

vinian evolution is the driving natural mortality by more than 400% (2). This has, however, been largely ignored, even ss the world's biota. Acting on though studies based on fisheries data and controlled experiments have provided strong empirical evidence for fisheries-induced evolution over a range of species and regions (see table, page 1248). These evolutionary changes are unfolding on decadal time scales-much faster than previously thought.

Life-history theory predicts that increased

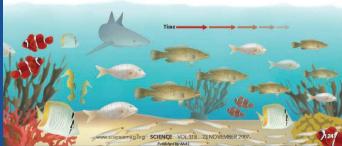
mortality generally favors evolution toward earlier sexual maturation at smaller size and selective with respect to size, maturity status, behavior, or morphology causes further evolutionary pressures (3) Evidence that harvesting can bring about genetic changes comes from breeding programs in aquaculture. which have shown heritable genetic variation in numerous traits (4), and from experiments explained by environmental influences alone (table S2). Although alternative causal hypo-theses can be difficult to rule out, fisheriesinduced evolution consistently arises as the most parsimonious explanation after environmental factors have been accounted for. The features. This may reduce the body size of the fish.

for quantificing the effects of harvest induced evolution on the utility generated by fish stocks.

occur, but how fast fishing practices bring about evolutionary changes and what the conequences will be

Life-history traits are among the primary determinants of population dynamics, and biomass, demography, and economic yield (5, 6). Fisheries-induced evolution may also be slow to reverse or even irreversible (5), with implications for recruitment and reco elevated reproductive effort. Fishing that is ics competitive interactions, relative species ships will systematically change over time become less resilient or may be erroneously assessed as being within safe biological lim its. Some evolutionary trait changes will showing harvest-induced evolution in just a even have the notential to cause nonlinea few generations (table S1). Furthermore, analyses of fisheries data spanning a few outcomes (8). Fisheries-induced evolution decades have detected widespread changes in maturity schedules that are unlikely to be single-species management.

An evolutionarily enlightened manage



Science 318:1247 **Science** 320:48

