

# Fisheries Biology

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- Reading: Chapter 1
- Review basic definitions
- Introduce aspects of management issues
  - objectives
  - strategies
  - regulations



# Fisheries biology

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- Applied ecology
  - Effects of harvesting on natural communities on a large scale
- Emphasis on Population Dynamics
  - Sustaining a maximum yield
- Fisheries management
  - Fish biology vs. human behavior
  - Social, economic, and political factors
  - fishers and fisheries systems conflict often

# Fisheries biology

- Why is this important/relevant?
- Increasing importance to 'everyday' life.
  - Evidenced by increased media coverage



# Science

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## Détente in the Fisheries War

After a controversial projection that wild-caught fish will disappear, top researchers buried the hatchet to examine the status of fisheries—and what to do about it



Doomsday will come to fishes across the world's oceans by 2048. That was the startling implication of findings published in 2006 by marine ecologist Boris Worm of Dalhousie University in Halifax, Canada, and several colleagues. The projection was merely a side note in a paper in *Science* about the relationship between biodiversity and ecosystem services in the oceans, which concluded that the world's oceans were in bad shape, in part because of overfishing. Then, in the next-to-last paragraph, the authors extrapolated from the percentage of fisheries that have already collapsed and predicted that in 32 years no more fish would be caught in the ocean. That point, not their larger conclusions on the role of biodiversity in ecosystem functions, was highlighted in press releases and then garnered headlines around the world.

Many fisheries scientists were appalled. Trained in quantitative techniques for determining the abundance of fish stocks, they questioned the methods used in Worm's global assessment, such as a reliance on the mass of fish reported caught. They also blasted the paper for ignoring fisheries that are doing well, like those in the northeastern Pacific and New Zealand, and those that are

now recovering from decades of overfishing. One particularly prominent critic was Ray Hilborn of the University of Washington, Seattle. In media interviews, he called the analysis "incredibly sloppy" and the projection "mind-boggling[ly] stupid." Worm and his colleagues defended their analyses in responses in *Science* and elsewhere. The conflict continued a charged and long-simmering debate between marine ecologists and fisheries scientists about the status of the world's ocean ecosystems.

Yet less than a year later, Hilborn and Worm began meeting on neutral ground to hammer out their differences—to the amazement of some observers. "There were such extreme attacks on the [Worm *et al.* paper] that it was a little hard to imagine that they would have a constructive dialog," says ecologist Larry Crowder of Duke University in Durham, North Carolina. Working under the auspices of the National Center for Ecological Analysis and Synthesis (NCEAS) in Santa Barbara, California, a

All gone? A controversial projection of exhausted fisheries led to a new look at the oceans.

grant-funded center run by the University of California to facilitate collaboration among ecologists, Hilborn and Worm have brought together some 20 scientists from their respective disciplines as well as dozens of graduate students who they hope will also learn to think more broadly. "This is the most interesting thing I've been involved in in a long time," Hilborn says.

The goal was to figure out why their different data or methods yield such divergent impressions of ocean ecosystems—and in the process create better databases that both camps deem reliable and informative. Perhaps more importantly, they have used the new databases to develop a common vision of how to balance fishing and conservation most effectively. Joint publications are expected to start appearing later this year. "I have high expectations that

they'll come back with useful outcomes," says Steven Murawski, chief scientist of the National Oceanic and Atmospheric Administration (NOAA) Fisheries Service in Silver Spring, Maryland, who participated in the first meeting.

### Head to head

In large part, the Worm-Hilborn clash reflects the different worldviews of the two disciplines. Fisheries scientists see marine ecosystems as a resource to be used, whereas marine ecologists usually envision pristine, unfished habitats as the ideal.

The two fields also tend to rely on different types of data. In their 2006 *Science* paper, Worm and his co-authors were trying to look at the global impacts of marine biodiversity loss. For that, they had to rely on the most comprehensive kind of data available: the tonnages that countries report are caught. Fisheries scientists, by contrast, tend to look at individual stocks of fish and typically use sparser data gathered

*"There are a lot of problems, but things may not be as bad as ecologists have thought."*

—RAY HILBORN,  
UNIVERSITY OF  
WASHINGTON, SEATTLE

## Rebuilding Global Fisheries

Boris Worm,<sup>1,2</sup> Ray Hilborn,<sup>2,3</sup> Julia K. Baum,<sup>3</sup> Trevor A. Branch,<sup>2</sup> Jeremy S. Collie,<sup>4</sup> Christopher Costello,<sup>5</sup> Michael J. Fogarty,<sup>6</sup> Elizabeth A. Fulton,<sup>7</sup> Jeffrey A. Hutchings,<sup>1</sup> Simon Jennings,<sup>8,9</sup> Olaf P. Jensen,<sup>2</sup> Heike K. Lotze,<sup>1</sup> Pamela M. Mace,<sup>10</sup> Tim R. McClanahan,<sup>11</sup> Cóilín Minto,<sup>1</sup> Stephen R. Palumbi,<sup>12</sup> Ana M. Parma,<sup>13</sup> Daniel Ricard,<sup>1</sup> Andrew A. Rosenberg,<sup>14</sup> Reg Watson,<sup>15</sup> Dirk Zeller<sup>15</sup>

After a long history of overexploitation, increasing efforts to restore marine ecosystems and rebuild fisheries are under way. Here, we analyze current trends from a fisheries and conservation perspective. In 5 of 10 well-studied ecosystems, the average exploitation rate has recently declined and is now at or below the rate predicted to achieve maximum sustainable yield for seven systems. Yet 63% of assessed fish stocks worldwide still require rebuilding, and even lower exploitation rates are needed to reverse the collapse of vulnerable species. Combined fisheries and conservation objectives can be achieved by merging diverse management actions, including catch restrictions, gear modification, and closed areas, depending on local context. Impacts of international fleets and the lack of alternatives to fishing complicate prospects for rebuilding fisheries in many poorer regions, highlighting the need for a global perspective on rebuilding marine resources.

Overfishing has long been recognized as a leading environmental and socioeconomic problem in the marine realm and has reduced biodiversity and modified ecosystem functioning (1–3). Yet, current trends as well as future prospects for global fisheries remain controversial (3–5). Similarly, the solutions that hold promise for restoring marine fisheries and the ecosystems in which they are embedded are hotly debated (4,6). Such controversies date back more than a hundred years to the famous remarks of Thomas Huxley on the inexhaustible nature of sea fisheries (7) and various replies documenting their ongoing exhaustion. Although management authorities have since set goals for sustainable use, progress toward curbing overfishing has been hindered by an unwillingness or inability to bear the short-term social and economic costs of rebuilding fishing (8). However, recent commitments

to adopting an ecosystem approach to fisheries may further influence progress because they have led to a reevaluation of management targets for fisheries and the role of managers in meeting broader conservation objectives for the marine environment (9).

In light of this debate, we strive here to join previously diverging perspectives and to provide an integrated assessment of the status, trends, and solutions in marine fisheries. We explore the prospects for rebuilding depleted marine fish populations (stocks) and for restoring the ecosystems of which they are part. In an attempt to unify our understanding of the global fisheries situation, we compiled and analyzed all available data types, namely global catch data (Fig. 1A), scientific stock assessments, and research trawl surveys (Fig. 1B), as well as data on small-scale fisheries (10). We further used published ecosystem models (Fig. 1B) to evaluate the effects of exploitation on marine communities. Available data sources are organized hierarchically like a Russian doll: Stock assessments provide the finest resolution but represent only a subset of species included in research surveys, which in turn represent only a small subset of species caught globally. These sources need to be interpreted further in light of historical fisheries before data collection and illegal or unreported fisheries operating today (11). We focus on two leading questions: (i) how do changes in exploitation rates impact fish populations, communities, and yields, and (ii) which solutions have proven successful in rebuilding exploited marine ecosystems?

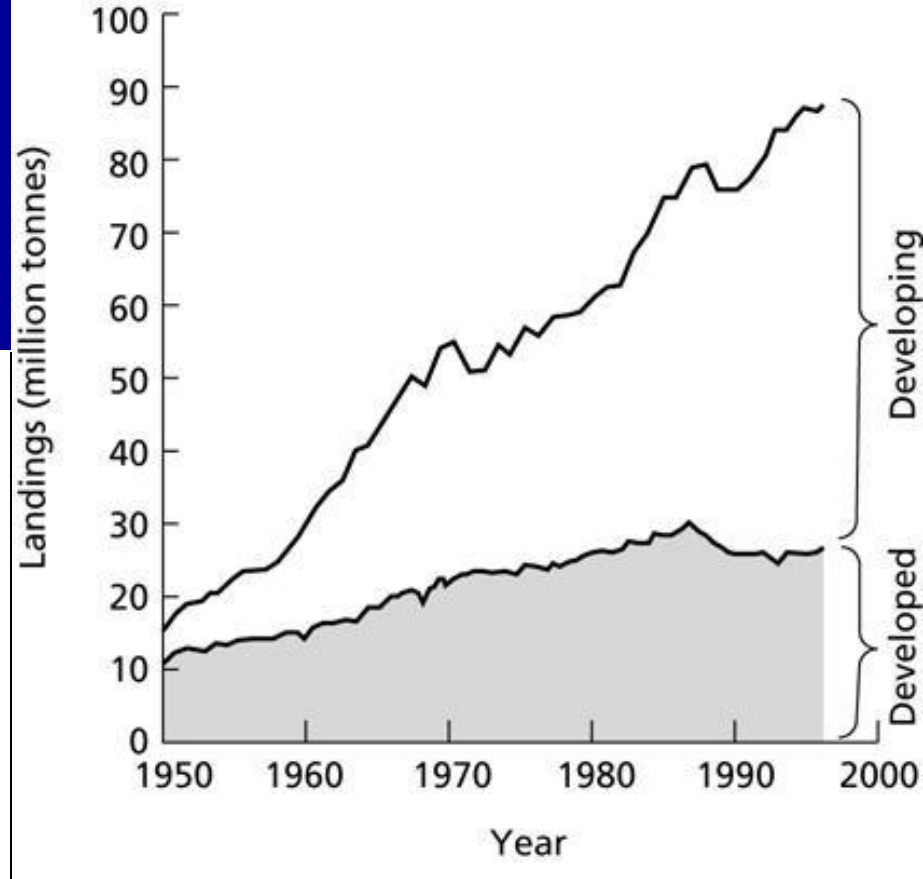
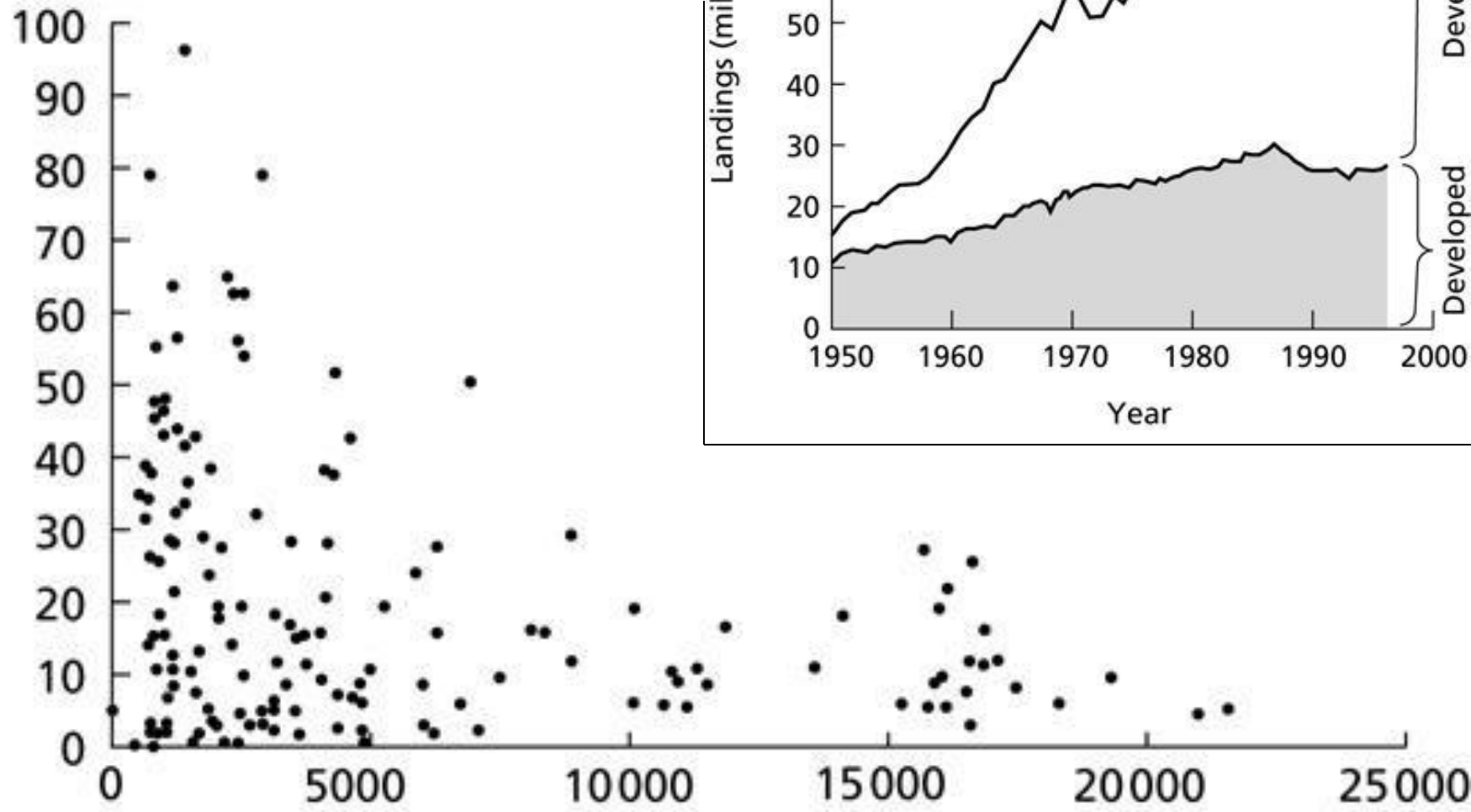
**Models.** A range of models is available to analyze the effects of changes in exploitation rate on fish populations, communities, and ecosystems. Exploitation rate ( $u_t$ ) is defined as the proportion of biomass that is removed per year, i.e.,  $u_t = C_t/B_t$ , where  $C$  is the catch (or yield) and  $B$  is the available biomass in year  $t$ . Single-species

models are often used to determine the exploitation rate  $u_{MSY}$  that provides the maximum sustainable yield (MSY) for a particular stock. Fishing for MSY results in a stock biomass,  $B_{MSY}$ , that is substantially (typically 50 to 75%) lower than the unfished biomass ( $B_0$ ). It has been a traditional fisheries objective to achieve single-species MSY, and most management regimes have been built around this framework. Recently this focus has expanded toward assessing the effects of exploitation on communities and ecosystems (9).

Multispecies models can be used to predict the effects of exploitation on species composition, size structure, biomass, and other ecosystem properties. They range from simpler community models to more-complex ecosystem models (12). Figure 2 displays equilibrium solutions from a size-based community model, which assumes that fishing pressure is spread across species according to their size and that a subset of species remains unfished (13). Results of more-complex ecosystem models across 31 ecosystems and a range of different fishing scenarios were remarkably similar (Fig. S1 and table S1). With increasing exploitation rate, total fish catch is predicted to increase toward the multispecies maximum sustainable yield (MMSY) and decrease thereafter. In this example, the corresponding exploitation rate that gives maximum yield  $u_{MMSY}$  is  $\sim 0.45$ , and total community biomass  $B_{MMSY}$  equilibrates at  $\sim 35\%$  of unfished biomass (Fig. 2). Overfishing occurs when  $u$  exceeds  $u_{MMSY}$ , whereas rebuilding requires reducing exploitation below  $u_{MMSY}$ . An increasing exploitation rate causes a monotonic decline in total biomass and average body size, and an increasing proportion of species is predicted to collapse (Fig. 2). We used 10% of unfished biomass as a definition for collapse. At such low abundance, recruitment may be severely limited, and species may cease to play a substantial ecological role. This model suggests that a wide range of exploitation rates ( $0.25 < u < 0.6$ ) yield  $>90\%$  of maximum catch but with very different ecosystem consequences: whereas at  $u = 0.6$  almost half of the species are predicted to collapse, reducing exploitation rates to  $u = 0.25$  is predicted to rebuild total biomass, increase average body size, and strongly reduce species collapses with little loss in long-term yield (Fig. 2). In addition to reconciling fishery and conservation objectives, setting exploitation rates below  $u_{MMSY}$  reduces the cost of fishing and increases profit margins over the long term (14). This simple model does not incorporate fishing selectivity; however, in practice the proportion of collapsed species could be reduced further by increasing selectivity through improved gear technology (15), by closing areas frequented by vulnerable species, or through offering incentives to improve targeting practices (16). Such strategies allow for protection of vulnerable or collapsed species, while allowing for more intense exploitation of others.

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Fish as proportion of animal protein in diet (%)



Gross Domestic Product per person (\$ US)

# Common Terms

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- Fishery
- Stock
- Stock assessment
- Fishery science
- Fishery management

# What is a fishery?

The human and biological components of a fish harvest system

## Who are the participants?

Fish

Fishermen

Other fish

Processors

Biologists

Retailers

Resource managers

Public

# What is Fishery Science?

**The mathematical and statistical approach to the study of fisheries**

- ultimately research utilized for an assessment of the stock (management unit)

# Fishery Management?

**The regulation of fishery stocks to achieve some pre-determined objective**

# Types of Fisheries

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- Artisanal
- Recreational
- Commercial
- Industrial
- Inshore
- Offshore
- Distant water



**b** Jennings, Kaiser, Reynolds  
Marine Fisheries Ecology



**b** Jennings, Kaiser, Reynolds  
Marine Fisheries Ecology

# Common Terms

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- Bycatch = unintended catch
- Biomass = total mass (kg) of a stock  
(determined by  $N \times \text{avg. weight}$ )
- Spawning stock biomass (SSB) = biomass of mature fish
- Spawning stock biomass per recruit = the contribution to the spawning stock biomass expected for an individual fish

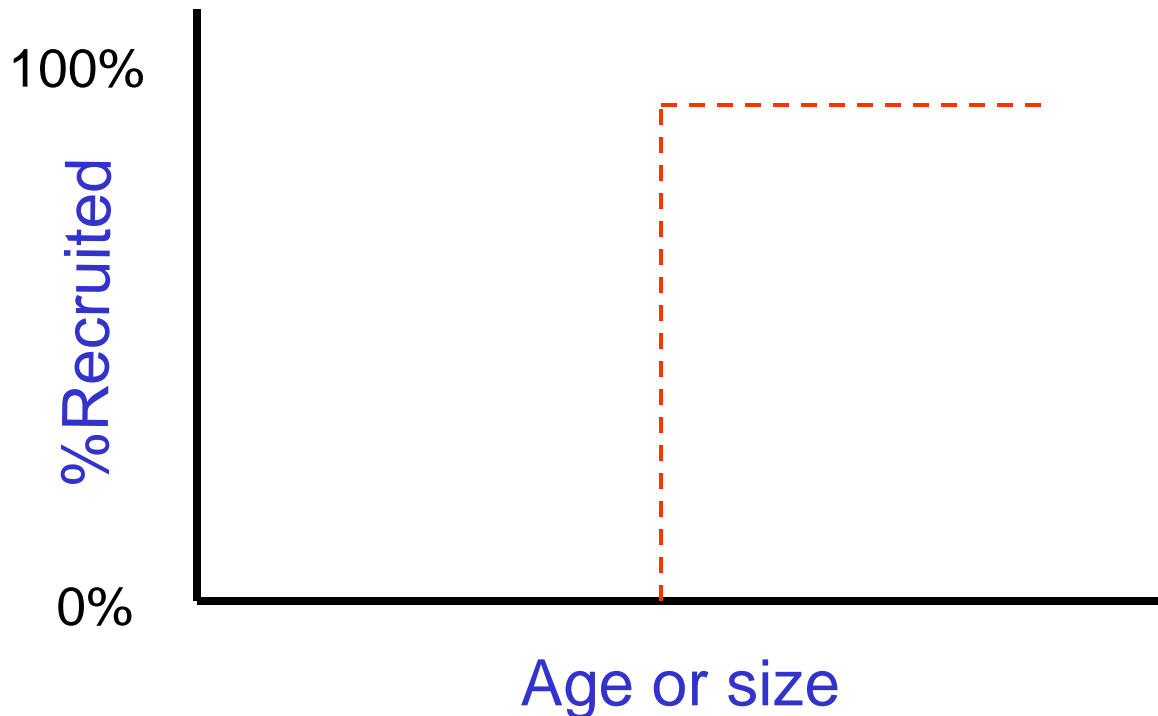
# Common Terms

- **Recruitment**

- addition of new members to a group
- can be very specific (recruitment to a given life stage or size)
- e.g., recruitment from egg to larval stage or recruitment to the fishery based on minimum size

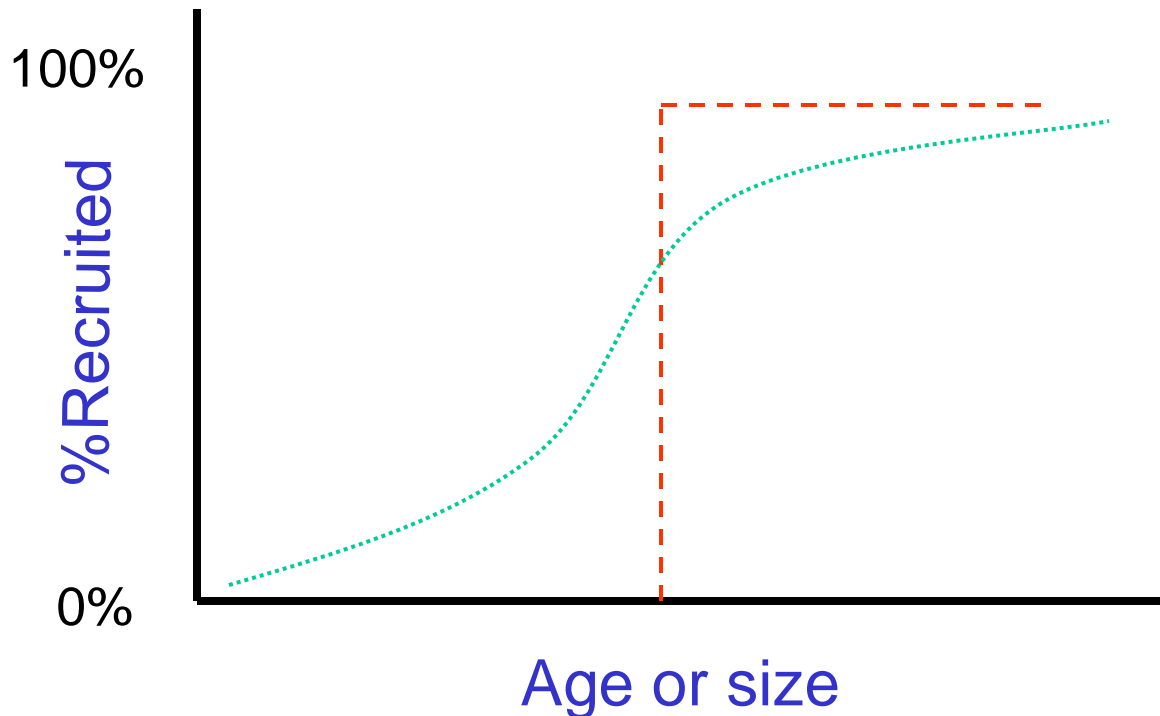
# Common Terms

- **Knife-edge** recruitment
  - addition of new members over a very short period of time or ages



# Common Terms

- Recruitment **ogive**
  - addition of new members to a group over an extended period of time or age groups.



# Common Terms

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- Selectivity = capture of fish of certain species or sizes
- Growth overfishing = increased harvesting causes reduced yields
- Recruitment overfishing = increased harvesting prevents population from replenishing itself

# Common Terms

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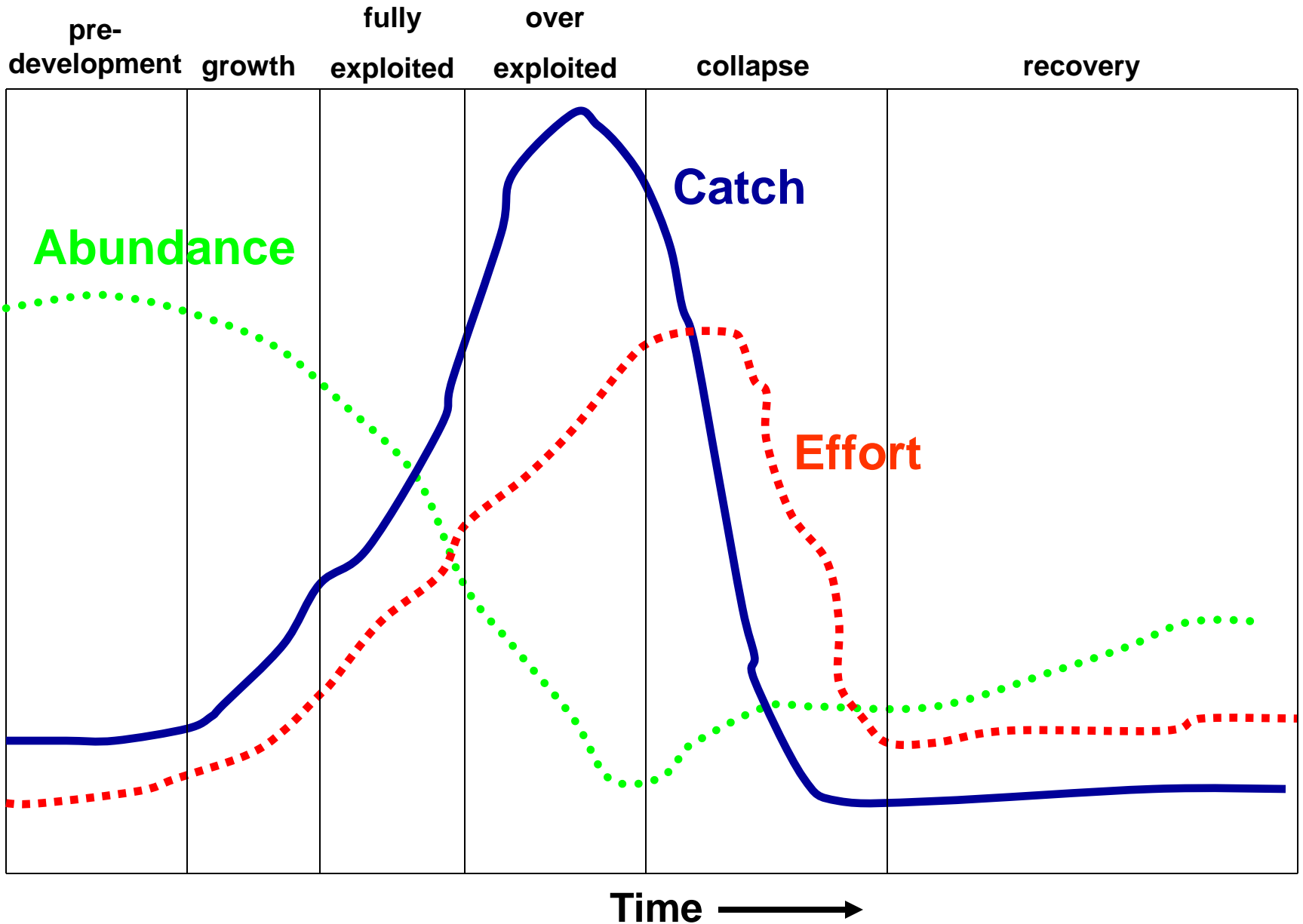
- Maximum sustainable yield (**MSY**)
  - maximum average yield obtainable from a single population on a continual basis without affecting the biology of the stock

# Common Terms

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- Pelagic fish = in the water column
- Demersal fish = associated with the bottom
- Benthic fish = on the bottom (e.g., flatfish)

# Phases of Fishery Development



# Limitations of the current approach to fisheries management

- Inability to deal with inherent **variability**
- Failure to define **specific long term** management goals
- Lack of **accountability** in decision making
- Misuse of **biological** advice
- Lack of effective involvement by **stake holders** in decision making