fish5109pa Principles of utilization: The precautionary approach

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`http://mareframe-fp7.org`
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1 Principles of utilization

1.1 Rio Declaration On Environment and Development

The Rio Declaration on Environment and Development was created in 1992 to "...protect the integrity of the global environment...". To accomplish this the document stated that actions impacting the environment should apply the precautionary principle.
Document Link: http://www.unep.org/documents.multilingual/default.asp?documentid=78&articleid=1163

1.1.1 Details

Background The Rio Declaration on Environment and Development was developed in Rio de Janeiro in June of 1992 as an expansion of the 1972 Declaration of the United Nations Conference on the Human Environment.

Goal ...protect the integrity of the global environment...

Important Principles

- Principle 4 ...achieve sustainable development...
  - In order to achieve sustainable development, environmental protection shall constitute an integral part of the development process and cannot be considered in isolation from it.
- Principle 8 ...eliminate unsustainable patterns of production...
  - To achieve sustainable development and a higher quality of life for all people, States should reduce and eliminate unsustainable patterns of production and consumption and promote appropriate demographic policies.
- Principle 15 ...the precautionary approach shall be widely applied..
  - In order to protect the environment, the precautionary approach should be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.

Impact on Fisheries The biggest impact was the application of the precautionary principle. However, the verbiage used, **should** rather than shall, limited its regulatory abilities.

1.2 Code of Conduct for Responsible Fisheries

The FAO's Code of Conduct for Responsible Fisheries was adopted in 1995 with the goal of establishing principles and standards applicable to conservation, management, and development of all fisheries. To accomplish this the doctrine addressed such issues as:

- Fisheries management
- Fishing operations
- Integration of fisheries into coastal area management
- Post-harvest practices and trade
- Fisheries research

Document link: http://www.fao.org/docrep/005/v9878e/v9878e00.htm

1.2.1 Details

Background The FAO's Code of Conduct for Responsible Fisheries was created to build upon currently established doctrines, including the Rio Declaration on Environment and Development, by establishing principles and standards applicable to conservation, management, and development of all fisheries. The document was created under the premise that aquatic resources, although renewable, are not infinite and need to be properly managed, if their contribution to the nutritional, economic, and social well-being of the growing world's population is to be sustained. The document was adopted in October 1995.

Objective Establish principles and criteria for the elaboration and implementation of national policies for responsible conservation of fisheries resources and fisheries management and development.

Article 6-General Principles

- 6.1 ...obligation...to ensure effective conservation and management of ... aquatic resources.
  - States and users of living aquatic resources should conserve aquatic ecosystems. The right to fish carries with it the obligation to do so in a responsible manner so as to ensure effective conservation and management of the living aquatic resources.
- 6.3 States should...ensure that fishing effort is commensurate with...sustainable utilization.
  - States should prevent over fishing and excess fishing capacity and should implement management measures to ensure that fishing effort is commensurate with the productive capacity of the fisheries resources and their sustainable utilization. States should take measures to rehabilitate populations as far as possible and when appropriate.
- 6.5...apply a precautionary approach widely..absence of...scientific information..not...a reason for postponing...measures...

  - States and subregional and regional fisheries management organizations should apply a precautionary approach widely to conservation, management and exploitation of living aquatic resources in order to protect them and preserve the aquatic environment, taking into account the best scientific evidence available. The absence of adequate scientific information should not be used as reason for postponing or failing to take measures to conserve target species, associated or dependent species and non-target species and their environment.

- 6.9 ...need for conservation...taken into account..coastal zone...

  - States should ensure that their fisheries interests, including the need for conservation of the resources, are taken into account in the multiple uses of the coastal zone and are integrated into coastal area management, planning and development.

Article 7-Fisheries Management

- 7.1.1 Conservation and management measures...should be...designed to ensure the long-term sustainability of fishery resources...short-term considerations should not compromise these objectives.

  - States and all those engaged in fisheries management should, through an appropriate policy, legal and institutional framework, adopt measures for the long-term conservation and sustainable use of fisheries resources. Conservation and management measures, whether at local, national, subregional, or regional levels, should be based on the best scientific evidence available and be designed to ensure the long-term sustainability of fishery resources at levels which promote the objective of their optimum utilization and maintain their availability for present and future generations; short-term considerations should not compromise these objectives.

- 7.2.1 ...long-term sustainable use of fisheries resources is the overriding objective of conservation and management...

  - Recognizing that long-term sustainable use of fisheries resources is the overriding objective of conservation and management. States and subregional or regional fisheries management organizations and arrangements should, inter alia, adopt appropriate measures, based on the best scientific evidence available, which are designed to maintain or restore stocks at levels capable of producing maximum sustainable yield, as qualified by relevant environmental and economic factors, including the special requirements of developing countries.

- 7.3.3 Long-term management objectives should be translated into management actions...

  - Long-term management objectives should be translated into management actions, formulated as a fishery management plan or other management framework.

- 7.5.1 ...apply the precautionary approach widely..to protect..and preserve the aquatic environment

  - States should apply the precautionary approach widely to conservation, management and exploitation of living aquatic resources in order to protect them and

preserve the aquatic environment. The absence of adequate scientific information should not be used as a reason for postponing or failing to take conservation and management measures.

- 7.5.2 In implementing the precautionary approach, States should take into account...uncertainties..size and productivity of the stocks,...,stock condition..., ...fishing mortality and the impact of fishing activities,including discards,...
  - In implementing the precautionary approach, States should take into account, inter alia, uncertainties relating to the size and productivity of the stocks, reference points, stock condition in relation to such reference points, levels and distribution of fishing mortality and the impact of fishing activities, including discards, on non-target and associated or dependent species as well as environmental and socio-economic conditions.
- 7.5.3 States...should..determine...stock specific target reference points...stock specific limit reference points...
  - States and subregional or regional fisheries management organizations and arrangements should, on the basis of the best scientific evidence available, inter alia, determine:
    - a. stock specific target reference points, and, at the same time, the action to be taken if they are exceeded; and
    - b. stock specific limit reference points and, at the same time, the action to be taken if they are exceeded; when a limit reference point is approached, measures should be taken to ensure that it will not be exceeded.
- 7.5.4 ...new or exploratory fisheries...should adopt...cautious conservation and management...allow for the gradual development of the fisheries.
  - In the case of new or exploratory fisheries, States should adopt as soon as possible cautious conservation and management measures, including, inter alia, catch limits and effort limits. Such measures should remain in force until there are sufficient data to allow assessment of the impact of the fisheries on the long-term sustainability of the stocks, whereupon conservation and management measures based on that assessment should be implemented. The latter measures should, if appropriate, allow for the gradual development of the fisheries.

Impact on Fisheries The code of conduct laid out specific goals and regulations on a global scale. However, the code is voluntary and as such the principles are written as **should** rather than shall.

1.3 Straddling and Highly Migratory Fish Stocks

The U.N.'s document on straddling fish stocks and highly migratory fish stocks was adapted in August of 1995 with the goal of setting guidelines for high seas fisheries, or those fisheries beyond national jurisdiction.
Document link: http://www.un.org/Depts/los/convention_agreements/convention_overview_fish_stocks.htm

1.3.1 Details

Background The United Nation's provisions on straddling fish stocks and highly migratory fish stocks were written to address inadequate regulation and its associated problems:

- un-regulated fishing
- over-capitalization
- excess fleet size
- vessel reflagging to escape controls
- insufficiently selective gear
- lack of cooperation among states

Goal The goal of the document was to ensure the long-term conservation and sustainable use of straddling fish stocks and highly migratory fish stocks.

Article 5 - General Principles

- 5(a) ...ensure long-term sustainability...and promote...optimum utilization
  - adopt measures to ensure long-term sustainability of straddling fish stocks and highly migratory fish stocks and promote the objective of their optimum utilization
- 5(b) ...maintain or restore stocks at levels capable of producing maximum sustainable yield...
  - ensure that such measures are based on the best scientific evidence available and are designed to maintain or restore stocks at levels capable of producing maximum sustainable yield, as qualified by relevant environmental and economic factors, including the special requirement of developing States, and taking into account fishing patterns, the interdependence of stocks and any generally recommended international minimum standards, whether subregional, regional or global
- 5(c) apply the precautionary approach...
  - apply the precautionary approach in accordance with article 6
- 5(h) ...ensure..fishing effort do not exceed...sustainable use...
  - take measures to prevent or eliminate overfishing and excess fishing capacity and to ensure that levels of fishing effort do not exceed those commensurate with the sustainable use of fishery resources

Article 6 - Application of the Precautionary Approach

- 6.2 States shall be more cautious when information is uncertain...
  - States shall be more cautious when information is uncertain, unreliable or inadequate. The absence of adequate scientific information shall not be used as a reason for postponing or failing to take conservation and management measures.
- 6.3 In implementing the precautionary approach states shall:...determine stock specific reference points and the action to and take into account...uncertainties...
  - 6.3(b) In implementing the precautionary approach, States shall: apply the guidelines set out in Annex II and determine, on the basis of the best scientific information available, stock-specific reference points and the action to be taken if they are exceeded
  - 6.3(c) In implementing the precautionary approach, States shall: take into account, inter alia, uncertainties relating to the size and productivity of the stocks, reference points, stock condition in relation to such reference points, levels and distribution of fishing mortality and the impact of fishing activities on non-target and associated dependent species, as well as existing and predicted oceanic, environmental and socio-economic conditions
- 6.4 ...ensure that, when reference points are approached, they will not be exceeded...
  - States shall take measures to ensure that, when reference points are approached, they will not be exceeded. In the event that they are exceeded, States shall, without delay, take the action determined under paragraph 3(b) to restore the stock

Annex II - Guidelines for the Application of Precautionary Reference Points in Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks

- 1.A precautionary reference point is an estimated value...which corresponds to the state of the resource and ...used as a guide for fisheries management
  - A precautionary reference point is an estimated value derived through an agreed scientific procedure, which corresponds to the state of the resource and of the fishery, and which can be used as a guide for fisheries management.
- 2.Two types of precautionary reference points...:conservation or limit, reference points and management, or target, reference points.
  - Two types of precautionary reference points should be used: conservation or limit, reference points and management, or target, reference points. Limit reference points set boundaries which are intended to constrain harvesting within safe biological limits within which the stocks can produce maximum sustainable yield. Target reference points are intended to meet management objectives.
- 5. ...If a stock falls below a limit reference point or is at risk of falling below...conservation and management action should be initiated to facilitate stock recovery.

  - Fishery management strategies shall ensure that the risk of exceeding limit reference points is very low. If a stock falls below a limit reference point or is at risk of falling below such a reference point, conservation and management action should be initiated to facilitate stock recovery. Fishery management strategies shall ensure that target reference points are not exceeded on average.

- 6. When information for determining reference points for a fishery is poor or absent, provisional reference points shall be set...

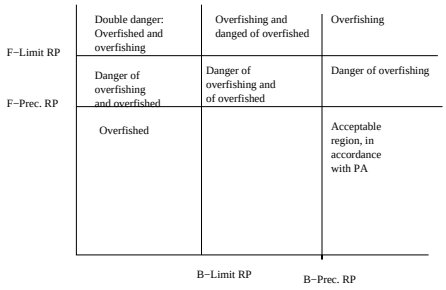
  - When information for determining reference points for a fishery is poor or absent, provisional reference points shall be set. Provisional reference points may be established by analog to similar and better know stocks. In such situations, the fishery shall be subject to enhanced monitoring so as to enable revision of provisional reference points as improved information becomes available.

Impact on Fisheries This document, unlike the previous two, contained provisions to the Law of the Sea and therefore carried much more weight. As such, the language used was much stronger, **shall** rather than should.

2 Reference points

2.1 Background to Reference Points

Reference points are designed to give indications of appropriate fishing mortality or biomass levels, whether target values or values to be avoided.



Role of limit reference points (Limit RP) and precautionary reference points (Prec. RP) in relation to over fishing.

2.1.1 Details

Note 2.1. Reference points are scientifically based stock specific guidelines to ensure the sustainability of a fishery and provide points at which conservation and management must be initiated to avoid over-fishing.

There are three main types of reference points.

- Target reference points provide management goals.
- Limit reference points provide benchmarks for when management needs to be initiated to avoid over-fishing.
- Precautionary reference points are reference points associated with the precautionary approach.

Reference points are based off of fishing mortality (F), stock biomass (B), and yield (Y)

Additional information can be found at:

https://documents-dds-ny.un.org/doc/UNDOC/GEN/N95/274/67/PDF/N9527467.pdf?OpenElement

- see Annex II

http://www.fao.org/docrep/003/v8400e/V8400E00.HTM

2.2 Types of Reference Points

3 major types of reference points:

- Limit reference points
- Precautionary reference points
- Target reference points

2.2.1 Details

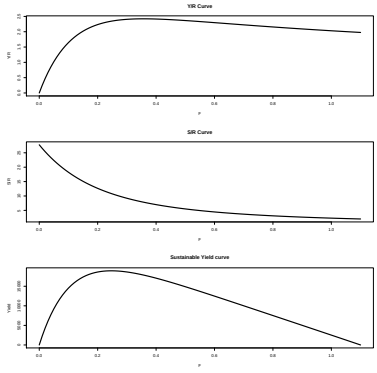
Reference points are presented in terms of fishing mortality (F) or stock biomass (B) and are divided into 3 major categories:

Type of Reference Point	Definition	Examples
Limit	a state of a fishery which is considered to be undesirable and which should be avoided	F_{lim}, F_{crash}, F_{loss} B_{lim}, B_{loss}
Precautionary	an estimated value derived though an agreed upon scientific method which corresponds to the state of the fishery and can be used as a management guide	F_{PA} B_{PA}
Target	level of fishing mortality or biomass, which permits long-term sustainable exploitation of the stock, with the best possible catch	F_{MSY}, $F_{0.1}$ $B_{0.1}$

2.3 Statistical Background to Reference Points

Reference points are calculated based off of:

- size of fish caught
- natural mortality rate (M)
- total mortality rate (Z)
- recruitment (R)
- economic considerations



Yield per recruit curve (Y/R Curve), stock per recruit curve (S/R Curve), and sustainability yield curve from simulated data.

2.3.1 Details

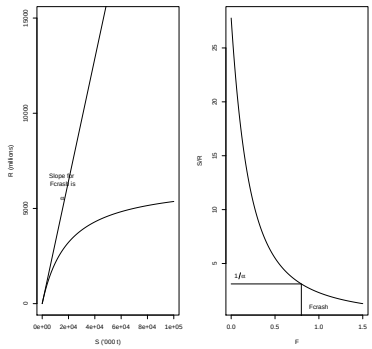
Different fisheries have different goals and in turn different reference points. As are result, different pieces of information are included in the calculation of reference points depending on the type of reference point being utilized. The following presents the basic pieces of information used to calculate the major reference points.

- Limit Reference Points
  - F_{crash}: Size of fish caught, natural mortality rate (M), total mortality rate (Z), and recruitment (R)
    - calculated from sustainable yield curve
- Precautionary Reference Points
  - F_{PA}: Size of fish caught, natural mortality rate (M), total mortality rate (Z), and recruitment (R)
    - calculated using F_{crash}
- Target Reference Points
  - $F_{0.1}$: Size of fish caught, natural mortality rate (M), and total mortality rate (Z)
    - calculated from a Y/R curve
    - is $1/10$ the slope of the Y/R curve at the origin
  - F_{MSY}: Size of fish caught, natural mortality rate (M), total mortality rate (Z), recruitment (R), economic considerations
    - calculated from sustainable yield curve

2.4 Limit reference points

The most common limit reference point is F_{crash}:

F_{crash}=fishing mortality corresponding to stock collapse



Simulated stock-recruitment curve with the replacement live for F_{crash}.

2.4.1 Details

To calculate F_{crash}:
1. Determine the slope, α, for the S-R curve by setting S to zero in

$$R = \frac{\alpha S}{1 + S/K}$$

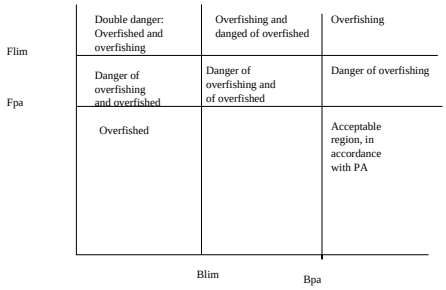
2. Plot F by S/R with $1/\alpha$
3. F_{crash} is where the slope of $1/\alpha$ intercepts the S/R curve

Interpreation of F_{crash}:
As a limit reference point, F_{crash} is to be avoided. Thus, F is to be set so that $F < F_{crash}$. Similarly, both precautionary reference points and target reference points are to be set much lower than F_{crash}.

2.5 Precautionary reference points

Precautionary reference points are set to ensure that annual fishing mortality should, on average, not exceed F_{PA}.

$$F_{PA} = F_{lim} \times e^{(-1.645 \times \sigma)}$$



The relationship between F_{PA} and F_{lim}. If the fishing mortality associated with F_{PA} is exceeded the fish stock is in danger of being overfished.

2.5.1 Details

To calculate F_{PA}:
F_{PA} is calcuated using the following precautionary approach equation.

Definition 2.1. Precautionary approach equation:

$$F_{PA} = F_{lim} \times e^{(-1.645 \times \sigma)}$$

F_{lim}=F_{crash}
σ=estimate of uncertainty associated with the level of fishing mortality (F)

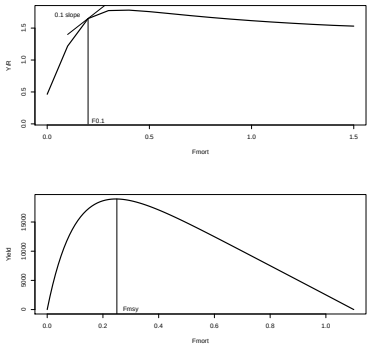
Interpretation of F_{PA}:
Precautionary reference points are set to ensure that annual fishing mortality should, on average, not exceed F_{PA}. The target F for F_{PA} should always be much lower than F_{crash}. Typically, F_{PA} is between $0.47F_{lim}$ and $0.61F_{lim}$.

According to Annex II of the U.N Conference on Straddling Fish Stocks and Highly Migratory Fish Stock all fisheries should adhere to the precautionary approach. Adherence would result in each years annual fishing mortality, F_y, being less than or equal to F_{PA}.

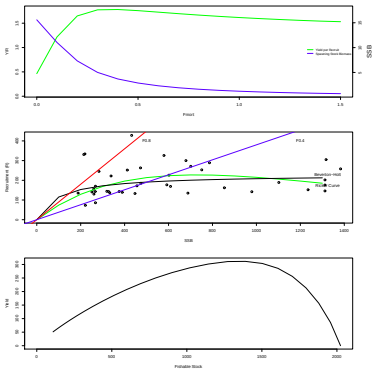
2.6 Target Reference Points

The most common target reference points are $F_{0.1}$ and F_{MSY}:

$F_{0.1}$= 10% of the slope of the Y/R curve at its origin
F_{MSY}= the F at which, if sustained, would result in maximum sustained yield



2.6.1 Details



Calculating $F_{0.1}$:
Graphically, $F_{0.1}$ can be calculated by:
1.) Plot the yield per recruit curve
2.) Determine the slope of the yield per recruit curve at its origin
3.) Calculate $1/10$ the slope at the origin
4.) Draw a slope parallel to the $1/10$ slope along the Y/R curve
5.) Determine the associated F by figuring out where the parallel $1/10$ slope meets the Y/R curve

Interpretation of $F_{0.1}$
$F_{0.1}$ was originally adopted by fisheries managers as a conservative target reference point. It has, however, become one of the most popular target reference points as it, unlike F_{msy}, appears to have an economic basis while incorporating sustainability. Specifically, increasing fishing mortality or effort beyond $F_{0.1}$ does not appear to be economically worthwhile.

Calculating F_{MSY}
To calculate F_{MSY} one can combine the yield per recruit computations and the stock per recruit computations as follows:
1.) Fix F
2.) Compute yield per recruit (Y/R)
3.) Compute spawning stock biomass per recruit (S/R)
4.) Compute S with S/R, α, and K using:

$$S = K \times [\alpha \times (S/R) - 1]$$

5.) Compute R using:

$$R = \frac{\alpha \times S}{(1+S/K)}$$

6.) Compute Y using:

$$Y = (Y/R)[\frac{\alpha S}{(1+S/K)}]$$

7.) Repeat steps 1-6 for a range of fishing mortalities and plot the yields against fishing mortality
8.) Determine the maximum of the curve, MSY, and the corresponding F, F_{MSY}

Interpretation of F_{MSY}
By definition F_{MSY} is supposed to represent a level of fishing mortality which can be sustained over long periods of time. However, high initial catch rates can artificially inflate the sustainability yield curve maximum and in turn F_{MSY}. As a result, in many cases F_{MSY} cannot actually be sustained over long periods of time and therefore functions more as a limit reference point rather than a target reference point.

2.6.2 Examples

Example 2.1. Calculating F_{MSY} in R using simulated data:
http://tutor-web.net/fish/fish5109pa/lecture20/fmsy.r

2.7 Reference Points in Advice

Management should choose F_{target}!
But, what if they do not?
What if management does not choose F_{PA}?
Advice needs to be in accordance with the PA!

2.7.1 Details

The Rio Declaration, Code of Conduct, and the agreement on straddling stocks all dictate the use of reference points. Advisory bodies around the world have designed schemes to implement the Precautionary Approach in their advice. This is done by carefully selecting reference points and specifying how these can be used in order to maintain sustainable fisheries.

However, it is up to managers to select a target fishing mortality (F_{target}) or a similar measure. If, however, management bodies do not do so, nor choose any precautionary values, then those providing advice have a dilemma in that the advice needs to be in accordance with the PA. So, the advisory bodies must set the F_{PA}. Because F_{PA} is the only reference point provided it in turn because a target reference point.

Ideally, managers should set an $F_{target} < F_{PA}$ to ensure the sustainability of the stock.

3 Harvest control rules

3.1 Harvest Control Rules - Background

Harvest control rules (HCR) detail catch limits for a particular fishery based off of indicators for stock status such as fishing mortality, stock biomass, or other indicators of stock size and harvest level.

3.1.1 Details

Harvest control rules (HCR) are set by managing bodies to explain how fishing harvests will be limited. The limits set are based off of indicators of stock status such as fishing mortality, stock biomass, or other indicators of stock size and harvest level. The limitations may:

- control the exploitation rate
- require a minimum proportion of the stock to escape capture
- limit max catch over a period of time
- implement a mixture of the above controls

HCRs are used to ensure the long-term sustainability of a stock. As a result, HCRs incorporate reference points. The incorporated reference points function as "trigger points"for indicating the type of management action that needs to be implemented according to the HCR.

HCRs are used to guide medium to long-term management decisions.

3.2 Types of Harvest Control Laws

There are two major types of Harvest Control Rules:

- Input controls: put restrictions on the intensity of gear used to catch fish
- Output controls: place direct limitations on the amount of fish being taken out of the fishery

3.2.1 Details

Harvest control rules can be broken down into two major categories: input controls and output controls.

Note 3.1. Input controls regulate fishing intensity by placing restrictions on the intensity of gear used to catch fish.

Note 3.2. Output controls regulate the number of fishing being taken from a particular fishery by placing direct limitations on the amount of fish being taken out of the fishery.

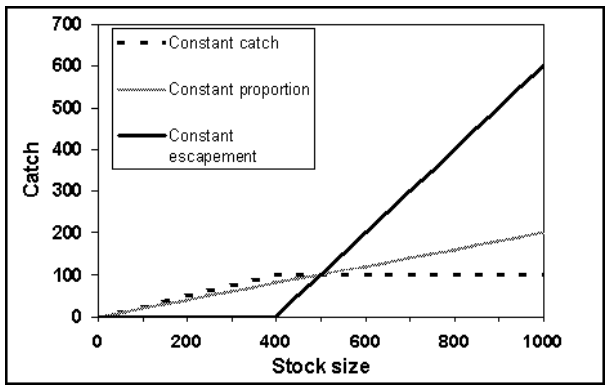
Examples of controls include:

- Input controls:
  - Fishing capacity controls: regulate the number and size of fishing vessels
  - Vessel usage controls: regulate the amount of time vessels are allowed to fish

  - Fishing effort controls: the product of fishing capacity controls and vessel usage controls

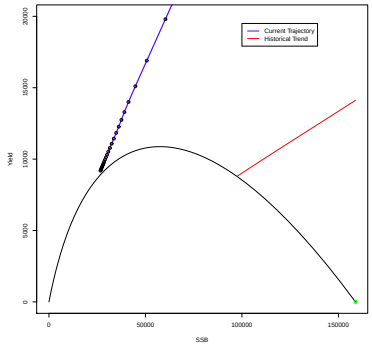
- Output controls:
  - Total allowable catch: limit either tonnage or number of fish that may be caught
  - Bag limits: limit the number of fish allowed to be caught per day

3.3 Implementing Harvest Control Rules



Typical projections of the three types of harvesting strategies based off of simulated data. Adopted from A Fishery Manager's Guidebook-Management Measures and Their Application, 2002.

3.3.1 Details



Mynd 1: Medium-term predictions for a constant harvest rate, $F_{0.1}$, from simulated data.

Input and output controls are implemented via one of three harvesting strategies:

- Constant harvest rate: constant fishing pressure across years
- Fixed quota: a fixed yield is harvested each year
- Constant escapement strategies: allowing fishing to occur only after a set biomass has been surpassed

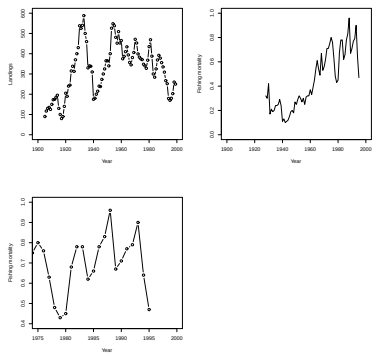
After the HCRs and harvesting strategies have been selected projections of their impact on the fishery needs to be determined. These projections are completed by the advisory body by conducting a management strategy evaluation (MSE).

Note 3.3. MSEs are risk analyses used to project the fishing stock biomass resulting from proposed controls.

Medium-term predictions regarding catch and stock development can be computed fairly easily when assuming constant harvest rate, such as $F_{0.1}$. However, the effects of a fixed quota are slightly more difficult to compute, since it requires the estimation of a fishing mortality rate corresponding to the catch quota.

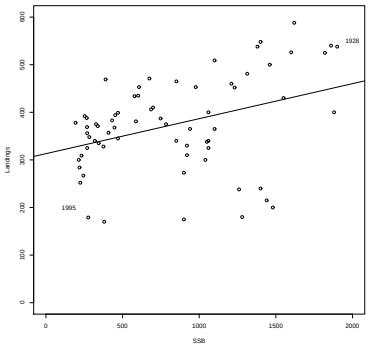
4 Case studies

4.1 History of Cod in Icelandic waters



Fishing mortality of cod in Icelandic waters from 1928 to 1995.

4.1.1 Details



Mynd 2: Fishing harvest data from 1928 to 1995.

Between 1928 and 1995 fishing effort increased. Exceptions to this were the second world war, the extension of the fishery jurisdiction to 200 miles, and the first adoption of a formal harvest control rule in 1994-1995. Although the adoption of a quota system in 1984 may have done a little to reduce fishing mortality it did not appear to significantly reduce fishing effort.

The continued decline of the cod fishery made the need for a formal, long-standing HCR obvious.

4.2 Assessment at ICES

In 1992 ICES was asked to provide advice on the cod stock in Icelandic waters. Considerable work was undertaken to prepare data, conduct analyses etc.

ICES recommended a 40% reduction in fishing mortality.

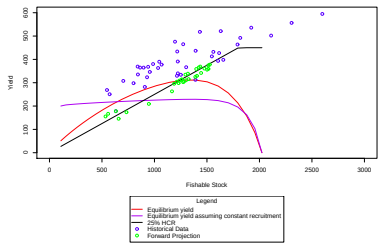
The advice was adopted.

Analyses included estimation of reductions which guaranteed with over 90% probability that fishing effort would not need to be cut further (i.e. that the stock would come back up).

4.2.1 Details

The first step in initiating the HCR was an assessment by ICES. The assessment was completed in 1992 and involved data collection and analyses. Based on their review, ICES recommended a 40% reduction in fishing mortality. With their recommendation, they guaranteed, with 90% probability, that fishing effort would not need to be cut further (i.e. that the stock would rebound). Iceland adopted the advice.

4.3 Harvest Control Rule Development



4.3.1 Details

In 1993 a working group was established to investigate the possibility of adopting a formal harvest strategy for cod in Icelandic waters. The working group included biologists, economists, and representatives from the fishing industry.

The group evaluated the biological and economic consequences of different strategies, took into account prejudices, and all known biological details.

The harvest control rules of the most interest to Iceland were based off of biomass, rather than other biological measures. The main reason for this is the simplicity involved and the ease with which these can be explained.

To evaluate the long-term impacts of the proposed HCRs on the species of interest, the projections were plotted along an equilibrium yield curve.

4.3.2 Examples

Example 4.1. The harvest control rule adopted for cod in Icelandic waters was in principle to catch 25% of the biomass each year.

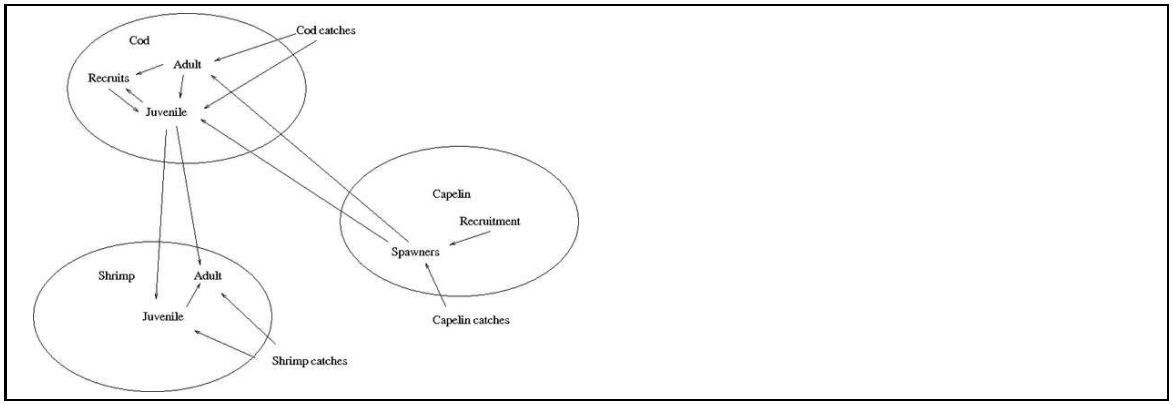
Specifically, this was to be computed as 25% of the biomass of 4 year old cod or older, but taken as an average of estimates in adjacent years. Initially it was suggested that this should be an average of the current year or the previous, but later on during the implementation phase, this was changed to 25% of the average of the current year and the projection one year into the future.

As it turned out, this simple change had drastic consequences. The reason for this is related to VPA convergence, since the projection is much more uncertain than the current year's estimate. During the first 10 years of using the HCR, the estimation error (measured as a retrospective pattern) was up to 60% for this projected average.

A politically important issue at the time was that catches should not be reduced below some minimal level. This corresponds to a minimum in the HCR, indicated with the lower horizontal line.

From a theoretical viewpoint it may be important not to allow catches to exceed a certain level and this is implied with the upper horizontal line.

4.4 Multispecies Concerns



4.4.1 Details

Once the impact of the proposed HCR had been evaluated from a single species perspective, the HCR had to be evaluated from a multispecies perspective.

Using an MSE, the multispecies impact of the proposed HCR was evaluated in relation to food supply as the stock recovers, predation effects, etc.

A multispecies model was developed and the proposed HCR was adopted in 1994/1995.