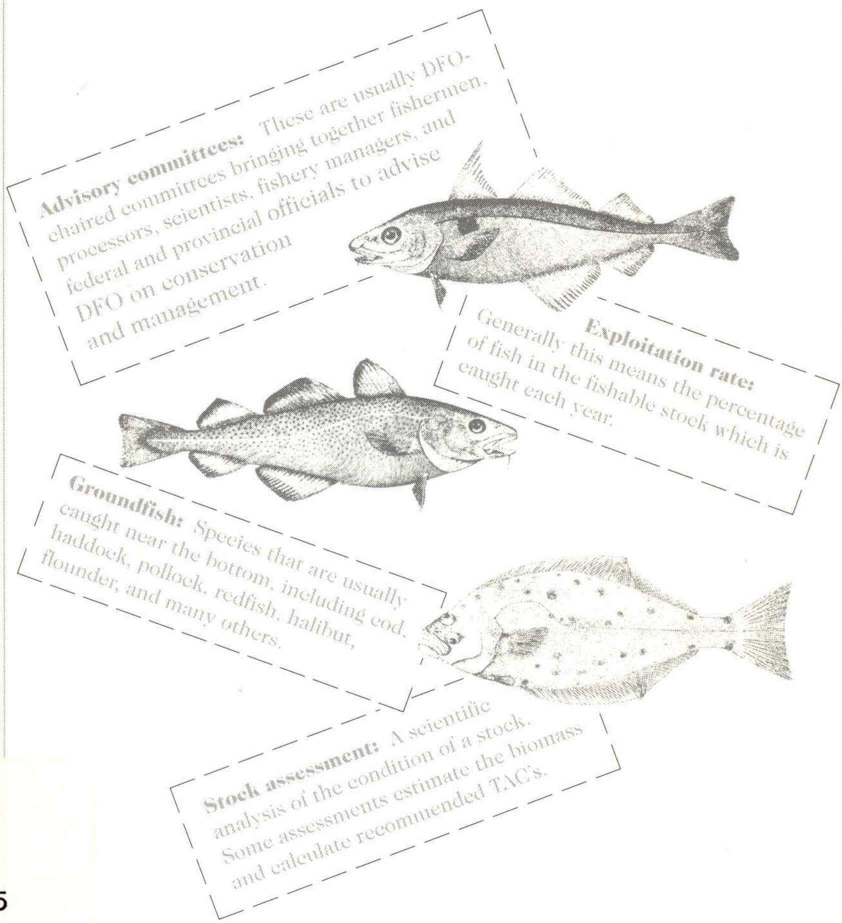
A GLOSSARY OF FISHERIES SCIENCE

Terms in Common Use in the Scotia-Fundy Region

Joseph Gough and Dr. Trevor Kenchington



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Introduction

As fisheries science grew in the twentieth century, it developed its own vocabulary of special terms. This booklet aims to explain some of the more common terms in use within Canada's Department of Fisheries and Oceans (DFO), particularly in the Scotia-Fundy Region.

Part One of the booklet gives brief definitions for quick reference.

Part Two gives longer explanations, and may serve as a teaching tool.

The booklet focusses mainly on marine commercial fisheries, particularly for groundfish, in Atlantic Canada. Scientists elsewhere in the world use some of the same terms with different meanings. This booklet is not to be taken as an official DFO statement on terminology or policy. Rather, the authors only seek to provide a general orientation, in their view, to the language of fisheries science.

Acknowledgements

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Suggestions for Further Reading

Groundfish Growth and the Health of the Stocks in the Scotia-Fundy Region,
Communications Branch, DFO, Revised edition September 1994.

Health and Growth of Shellfish in the Scotia-Fundy Region,
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The Science of Cod, The Fo'c'sle, Vol. 8, No. 2, February 1988, Communications Division, DFO, Newfoundland Region, ISSN 0838-2093.

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Parsons, L. S. 1993. ***Management of Marine Fisheries in Canada***. Can. Bull. Fish. Aquat. Sci. 225.

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NOTE

This small printing is intended to prompt comment. Please forward any suggestions for future editions to Joseph Gough, Director of Communications, Scotia-Fundy Region, Department of Fisheries and Oceans, Halifax, N.S., B3J 2S7.

PART ONE: BRIEF DEFINITIONS

Abundance: The number of fish in a stock or other group. (See: Biomass.)

Advisory committees: These are usually DFO-chaired committees bringing together fishermen, processors, scientists, fishery managers, and federal and provincial officials to advise DFO on conservation and management.

AGAC (Atlantic Groundfish Advisory Committee): Until 1992, this advisory committee formulated advice on the harvesting of Atlantic groundfish stocks. In 1992 the FRCC partly replaced AGAC.

Age class: All of the fish in a stock that are a particular age, such as all the 3-year-olds. (See: Year class.)

Age composition: Most stocks should have many age classes, that is, fish of different ages. The "age composition" is the proportion of fish of different ages in the stock or in the catches.

Allowance: An amount set aside from a TAC to allow for the expected catch of fishermen who are not subject to quota management.

Anadromous: "Anadromous" species such as salmon spawn in fresh water but spend part of their lives in the ocean. (See: Catadromous.)

Biology: Fisheries biology is the science that investigates how fish live and behave.

Biomass: The total weight of all the fish in a stock or other group, added together. (See: Abundance and Spawning stock biomass.)

CAFSAC: The Canadian Atlantic Fisheries Scientific Advisory Committee. Until 1992, it was the DFO "peer review" committee that reviewed stock assessments.

Catadromous: "Catadromous" species, eels being the main example, spawn in the ocean but live part of their lives in fresh water. (See: Anadromous.)

Catch: In scientific terms, catch means the number or weight of fish caught. Others sometimes use it to mean landings.

Catch-at-age: The numbers of fish in each age class in the catch taken from one stock, for example 100,000 fish at age 6.

Catch per unit of effort (CPUE); catch rate: The amount of fish caught by a fixed amount of fishing. For example, this could be pounds of fish per one-hour tow of an otter trawl or pounds of fish per hundred longline hooks hauled.

Cohort: See: Year class.

Cohort analysis: One type of Sequential Population Analysis, or SPA.

Discards: Discards are fish thrown back into the water after they are caught.

Division: For fisheries management purposes, the Northwest Atlantic is divided into a number of "divisions." (See NAFO map.)

Enterprise Allocation (EA): A catch quota from a particular stock, allocated to a company.

Equilibrium yield: The yield or catch that would in theory be taken every year by a certain amount of fishing effort, if the effort was kept steady year after year until the stock was in balance (or in "equilibrium") with the fishing effort.

Escapement: This term is generally used in the salmon and similar fisheries, and not in groundfish management. It means the number of fish escaping the fishery and reaching the spawning grounds.

Exploitation rate: Generally this means the percentage of fish in the fishable stock which is caught each year.

F: "F" stands for the fishing mortality rate in a particular stock. It is roughly the proportion of the fishable stock that is caught in a year.

F_{MAX}: The fishing mortality rate that would give the maximum yield-per-recruit from a particular stock. In theory, this would give the maximum catch year after year.

F_{MSY}: The fishing mortality rate that would, in theory, give the Maximum Sustainable Yield (MSY) from a particular stock year after year. F_{MAX} and F_{MSY} are similar ideas.

$2/3F_{MSY}$ (pronounced "two-thirds F.M.S.Y."): Two-thirds of the fishing mortality rate that would give the Maximum Sustainable Yield year after year.

$F_{0.1}$ (pronounced "F. Oh. Point. One."): For most groundfish, many pelagic, and some shellfish stocks, Canada bases the TAC's on a target fishing mortality target called "$F_{0.1}$." The aim of managing at $F_{0.1}$ is to assist both conservation and profitable fishing.

• For many groundfish stocks, fishing at $F_{0.1}$ means catching about two fish of every 10 each year.

Fishable stock: The part of a stock that is available to be fished. The fish must be big enough to be caught and must live in places where fishermen work to be part of the "fishable stock."

Fishing effort: The amount of fishing. It is usually recorded in units like "boat days" or "trap hauls."

Fishing mortality: The death of fish caused by fishing. (See: F.)

FRCC: Fisheries Resource Conservation Council. This partnership of government, industry, and the scientific community was created in 1993 to act as a "Board of Directors" for fishery conservation, in particular by advising the Minister of Fisheries and Oceans on the amount of fish that can safely be caught.

Groundfish: Species that are usually caught near the bottom, including cod, haddock, pollock, redfish, halibut, flounder, and many others.

Growth rate: How fast the individual fish put on weight.

Habitat: The environment in which the fish live.

High grading: Discarding of fish that could have been sold, to make room for more valuable fish.

ICCAT: International Commission for the Conservation of Atlantic Tunas. This organization oversees management of fisheries for tuna and similar species in the Atlantic.

ICES: International Council for the Exploration of the Sea. An international science forum, mainly for the European nations, founded in 1902.

ICNAF: The International Commission for the Northwest Atlantic Fisheries formerly co-ordinated management of many fisheries off Canada's east coast. ICNAF lasted from 1949 to 1979, when it was partly replaced by NAFO.

IQ, or Individual Quota: A quota assigned to an individual boat or licence. (See: Quota and Quota management.)

Landings: See: Catch.

Life history: A summary of the life cycle of a species, from spawning through the egg, larval, juvenile, and adult stages to eventual death.

M: See: Natural mortality.

Maximum Economic Yield, MEY: The sustainable yield for a particular stock that, in theory, should give the greatest difference between the value of the fish and the cost of catching them; that is, the best profits.

Maximum Sustainable Yield, MSY: The greatest sustainable yield for a particular stock. In theory, this catch will be sustainable year after year.

Model: To a scientist, a "model" is just an idea of how things work, usually written in mathematical terms.

Mortality: The death of fish. The proportion of the fish dying each year is called the "mortality rate." Scientists split the deaths of fish into those caused by fishing ("fishing mortality") and all the rest ("natural mortality").

MSY: See: Maximum Sustainable Yield.

NAFO: The Northwest Atlantic Fisheries Organization. It replaced ICNAF in 1979. NAFO sets quotas for some stocks that are outside Canada's 200-mile limit, straddle the line, or are of mainly foreign interest.

NASCO: North Atlantic Salmon Conservation Organization. This international organization was founded in 1982, to plan for the restoration and management of Atlantic salmon stocks.

Natural mortality: The death of fish caused by anything but fishing (see: Mortality). The "natural mortality rate" is roughly the proportion of the fish that die of natural causes each year. Its mathematical symbol is "M."

Numbers-at-age: The numbers of fish in each age class of a stock, in a particular year.

Optimum Sustainable Yield, or OSY: The best sustainable yield, for the combined purposes of the fishing industry, of conservation, and of the nation as a whole. It has no hard and fast definition. In Canada, the yield when fishing at $F_{0.1}$ is often used as a practical replacement for OSY.

Otolith: The earbone of a fish. The otoliths have rings on them like the rings on a tree-stump. They are used to find the age of the fish and its growth rate.

Overfishing: Generally, this means catching so much fish that it reduces the stock's biomass and future catches below desirable levels.

Partial recruitment: The degree to which a year class has joined the fishable stock. When a year class is young, only some of its fish are big enough to be caught, so it is partly but not fully recruited.

Pelagic: The "pelagic" species live in midwater or close to the surface. They include herring, capelin, swordfish, tuna, and many others. (See: Groundfish.)

Population dynamics: the part of fisheries biology which studies the numbers of fish and why they change.

Quota: An amount of catch that one group of fishermen is permitted to take from a stock during a year. (See: Allowance.)

Quota management: Managing a fishery by specifying how much fish may be taken, stock by stock.

Recruitment: When fish survive the egg, larval, and juvenile stages, and grow big enough to be caught in the fishery, they are "recruited" to the fishable stock. "Recruitment" can mean either the process of recruiting or the numbers of fish in a year class that are recruited.

Removals: All of the fish "removed" from a stock by fishing, including the catch and any fish killed but not caught.

School: A group of fish swimming together. Some fishermen call a school a "bunch," "run," or "pod" of fish.

Selection: The way fishing gear selects fish, catching some but letting others go. This can be size selection (usually letting small fish escape) or species selection, where only some species are caught.

Sequential Population Analysis, or SPA: A method used by scientists to determine the past history and present abundance of a stock.

Shellfish: Shellfish include both molluscs, such as clams, and crustaceans, such as lobsters.

Size limit: A minimum or maximum limit on the size of fish that may legally be caught.

SPA: See: Sequential Population Analysis.

Spawning stock biomass: The total weight of sexually mature fish in the stock. (See: Biomass.)

Species: A kind of fish, such as cod, haddock, or herring.

Stock: A population of fish of one species found in a particular area, which is used as a basic unit for fisheries management. All of the fish in a stock should share similar growth and migration patterns.

Stock assessment: A scientific analysis of the condition of a stock. Some assessments estimate the biomass and calculate recommended TAC's.

Surveys and samples: (See Longer Explanations.)

Sustainable yield; Surplus production: The catch that you could take from a stock year after year, without changing its biomass.

TAC (Total Allowable Catch)**:** The total tonnage of fish allowed to be caught from a particular stock in a particular year.

Trip limit: A maximum catch that each boat is allowed to bring back from any one trip.

Virgin stock: A stock in its natural condition before anyone has fished it.

VPA: Virtual Population Analysis: one type of Sequential Population Analysis or SPA.

Weight-at-age: The average individual weight of the fish in each age class of a particular stock.

Year class: All of the fish in a stock that were spawned in a particular year, such as all those spawned in 1990. Also called a "cohort." (See: Age class.)

Yield: Another word for catch.

Yield-per-recruit: "Yield-per-recruit" models calculate the different yields expected from a stock if it was fished with various amounts of fishing effort and with various fishing gears that had different size-selection characteristics. These models can be used to find the best size limits or to calculate F_{MAX} or $F_{0.1}$ for a stock. Because the yields change as stronger or weaker year classes recruit to the fishable stock, scientists prefer to calculate the yield expected from each recruit ("yield-per-recruit") instead of the yield from whole year classes.

PART TWO: LONGER EXPLANATIONS

Abundance: The number of fish in a stock or other group.

• Fisheries managers, like fishermen, are usually concerned with the amount of fish in terms of their weight (see: Biomass). When the number of fish in a stock, year class, or other group is of interest, it is called the "abundance" of that group.

Advisory committees: These committees bring together fishermen, processors, scientists, fishery managers, and other federal and provincial officials to advise DFO on conservation and management. There are more than 100 advisory committees in Atlantic Canada, covering all major fisheries. Most give advice on the fishery for a particular species or species group. Some advise on particular vessel or gear classes. (See: AGAC.)

There are also scientific advisory committees, such as the former CAFSAC, but these are usually restricted to DFO staff.

AGAC (Atlantic Groundfish Advisory Committee): Until 1992, this advisory committee formulated advice on the harvesting of Atlantic groundfish stocks. In 1992 the FRCC partly replaced AGAC.

Age class: All of the fish in a stock that are a particular age, such as all the 3-year-olds. Every fish is always counted in one age class and one year class. It stays in the same year class for its whole life but changes its age class every year. A fish spawned in 1989 would always be in the 1989 year class, but it would be in the age 3 age class in 1992 and the age 4 age class in 1993.

Age composition: Most stocks should have many age classes, that is, fish of many different ages. The "age composition" is the proportion of the fish of different ages in the stock or in the catches. A good mixture of age classes is one sign of a "healthy" stock. (See: Numbers-at-age and Catch-at-age.)

• Age composition is important to estimating abundance in stock assessments and for calculating Total Allowable Catches, or TAC's.

• How to find the age composition of the catch:

Fishermen often notice large numbers of a particular size fish, and count on them showing up again next year, when they will be a little bigger. Scientists make similar projections; but they base them on more reliable samples from many locations.

Port samplers (DFO employees also called "port technicians") sample catches at the wharf. They measure the lengths of the fish in the sample and collect the ear-bones, or otoliths, from some of them. Scientists count the rings in the otoliths to find the age of the fish. In 1987, for example, technicians measured the lengths of 262,000 cod caught in Divisions 2J3KL ("northern cod"), and scientists looked at the otoliths from 8,000 of them.

In such a case, once the scientists know the lengths and ages of the 8,000 fish, they can draw up an "age-length key" which compares the lengths and ages of the fish. Using this key, they can find the ages of the other 254,000 fish that were measured. They can then calculate the age composition of the port samples from the numbers in each age class. Since the samples are carefully chosen, the age composition of the catches can be reliably estimated from the age composition of the samples.

• What is a "healthy" age composition?

Age compositions vary widely, depending on the species, the stock, and the exploitation rate. There is no single "normal" age composition.

Generally, scientists expect to find relatively few fish at older ages, and a great many at younger ages. But in a healthy stock, there should be a significant number of fish in many age classes.

According to a recent stock assessment for the "northern cod" stock off Newfoundland, the age composition in 1991 was as follows:

- 19 per cent of the fish were age 3;
- 45 per cent of the fish were age 4;
- 23 per cent of the fish were age 5;
- 8 per cent of the fish were age 6;
- 3 per cent of the fish were age 7;
- 1 per cent of the fish were age 8;
- 1 per cent of the fish were age 9;
- about 1 per cent of the fish were age 10 or more.

On average, northern cod do not spawn until they are 7 years old, although some mature much earlier; so this was a very "unhealthy" age composition, with relatively few fish old enough to spawn (that is, the spawning stock biomass was low).

Allowance: An amount set aside from a TAC to allow for the expected catch of fishermen who are not subject to quota management.

Anadromous: "Anadromous" species such as salmon spawn in the fresh water but spend part of their lives in the ocean. (See: Catadromous.)

Biology: Fisheries biology is the science that investigates how fish live, die, and behave. One part of biology - a very important part for fisheries management - is figuring out the abundance of fish and how large a catch they can provide. (See: Life history and Population dynamics.)

Biomass: The total weight of all the fish in a stock or other group, added together.

• The "total biomass" is the total weight of all the fish in the stock, including the juveniles. Often, however, people use "biomass" to mean the biomass of the fishable stock, also called the "exploitable biomass" - that is, the weight of the fish that are big enough, and are living in the right places, to get caught.

• The spawning stock biomass is the weight of the mature fish only.

• Sometimes people talk loosely of the "strength" or "size" of a stock or a year class. They usually mean its biomass, though they can mean its abundance. Scientists speaking of the "status" of a stock may mean its current biomass, perhaps compared to the biomass it used to have.

CAFSAC: The Canadian Atlantic Fisheries Scientific Advisory Committee. CAFSAC began January 1, 1977, along with the 200-mile limit. It brought together DFO scientists to provide scientific advice on the management of major stocks, and reviewed scientific research relevant to stock assessment. CAFSAC scientists used "peer review": that is, they reviewed and challenged one another's stock assessments, to make sure that they were doing the best possible job with the available information.

CAFSAC was disbanded in 1992; recommendations on quotas are now made by the FRCC.

Catadromous: "Catadromous" species, eels being the main example, spawn in the ocean but live part of their lives in fresh water. (See: Anadromous.)

Catch: In scientific terms, catch means the number or weight of fish caught. Others sometimes use it to mean landings. Scientists add up the catch in several ways:

• The "removals" are all of the fish killed by fishing, and so removed from the stock. Removals include fish killed but never caught, and the fish discarded dead. They do not include fish that are released alive.

• The "landings" are the actual weight of the fish brought ashore after heading, gutting, or shucking. They do not include the discards.

• The "nominal catch" is the calculated live weight of the fish brought ashore. It is calculated from purchase slips and other information. The nominal catch also sometimes differs from the actual landings because of misreporting, the landing of some fish as fish meal, or other complications.

• From the nominal catch, scientists estimate the removals.

• All of these types of catch are usually recorded as weights, not as the number of fish. The weights are adjusted to the live (or "round") weight of the fish before they were caught. This compensates for any weight lost by heading, gutting, or filleting the fish before they are weighted. Most scientists keep the word "catch" to mean the numbers of fish caught, and call the weight caught the "yield."

Catch-at-age: The numbers of fish in each age class in the catch taken from one stock, for example 100,000 fish at age 6.

• Catch-at-age is different from the age composition of the catch. The age composition gives the proportion of the catch in the different age classes, for example 25 per cent of the catch at age 6. The catch-at-age gives the numbers (rather than proportions) in each age class.

• Purchase slips turned in to DFO reveal the total tonnage landed in any particular year, for example 1990. If the total catch from a stock was 10,000 tonnes, and 40 per cent of the catch by weight was six-year-olds, then the catch of six-year-olds came to 4,000 tonnes. How many fish in the 4,000 tonnes? Port samples show the average weight per fish. Arithmetic does the rest.

For example, if the average six-year-old in 1990 weighed 4.3 kilograms, then dividing the 4,000 tonnes (4,000,000 kilograms) of six-year-olds by 4.3 gives a total catch of about 930,000 fish from that age class in 1990.

Catch-per-unit-effort (CPUE); catch rate: The amount of fish caught by a fixed amount of fishing. For example, this could be pounds of fish per one-hour otter trawl tow, or pounds of fish per hundred longline hooks hauled.

• High catches do not always show that a stock is "healthy." Changes in technology, in fish prices, in regulations, or in many other things can make fishermen fish harder. With twice as much fishing effort in a year, we would expect double the catch if the biomass of the stock stayed steady, or the same catch if the biomass fell by half. So not much can be learned about the stock from the catch alone.

The catch rate is a better indication of the state of a stock.

• In theory, double the catch with the same effort shows that there was twice as much fish (twice the biomass) in the water.

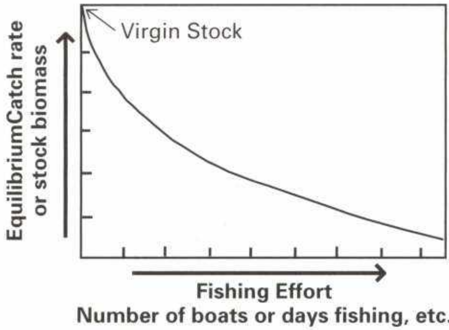
In real fisheries, this does not work very well. In fact, for many stocks scientists have stopped using CPUE in their stock assessments, because they cannot trust it as an indicator of biomass.

• When using catch rates, scientists have to take account of bigger, more powerful, or better-equipped boats being better at catching fish. They must also be wary of the few remaining fish in a depleted stock bunching up on the best grounds, where fishermen may find good catch rates. Finally, misreporting can make catch and fishing effort data questionable. Scientists must judge the reliability of the CPUE values, correcting problems when they can. If corrections are impossible, they have to use other measures of stock biomass.

• From a fisherman's point of view, higher catch rates mean more fish caught per dollar spent, and more profits.

• Catch rates will be highest when you start fishing a virgin stock. They are bound to drop as you thin out the fish.

The graph on page 14 gives a picture of the situation over time. The



farther to the right one looks, the more boats at work, and the lower the biomass and the catch rates.

More exactly, this graph shows, for many different levels of fishing effort, the "equilibrium" catch rate - that is, the catch rate when the fishing effort has been steady for enough years that the stock has had time to come into balance (or "equilibrium") with that effort.

In theory, if you increased the number of boats from 60 to 120, at first the catch rate would stay steady and the catch would about double. But the extra catch would come from the stock's biomass, which would fall. Eventually it would come into balance with the new level of fishing effort, to give an equilibrium yield. The biomass would be lower, and the catch rate would be lower too.

(In real fisheries, of course, both the fishing effort and the natural productivity of the stock are always changing, so there is never a true balance.)

The important point is that soon after the first boats start fishing a stock, the biomass and the catch rates will start to fall, as shown in the graph. Later, they will stabilize if the fishery can be held steady.

Cohort: See: Year class.

Cohort analysis: One type of Sequential Population Analysis, or SPA.

Discards: Fish thrown back into the water after they are caught. In many kinds of fishing, most of the discards are dead when they are thrown back, or else they die soon after.

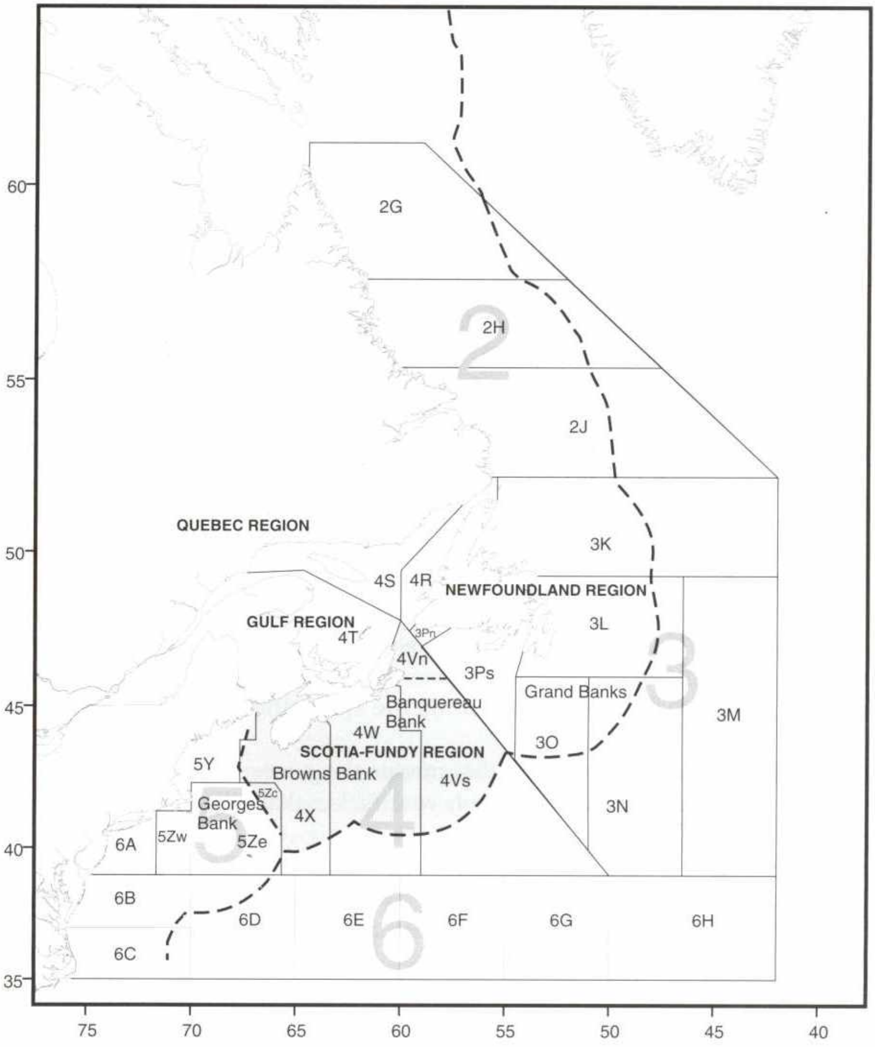
• Some discards are small fish released alive to give them a chance to grow. Others are undersized fish that cannot be landed legally, or are fish with low or no market value. The latter kind of discarding is illegal in many fisheries. Some people call discarding of lower-value fish, in order to land more high-value fish, "high-grading."

• Since the discards are not usually recorded, they cannot be included in scientists' estimates of the removals. This makes the stock assessments less accurate; so discarding risks the future of the fishery.

Division: For fisheries management purposes, ICNAF divided the Northwest Atlantic into seven "Subareas," and subdivided these into "Divisions." This scheme is still used by DFO and NAFO.

• Various sea areas are often referred to by their Division letters. For example, "Divisions 3LNO" means the Grand Banks and nearby waters. The number "3" means the area is part of Subarea 3, and the letters mean Divisions L, N, and O.

• Divisons 3P and 4V are each split into northern and southern subdivisions called 3Pn, 3Ps, 4Vn, and 4Vs. The Canadian part of Georges Bank has been split off from Division 5Z and is called 5Ze.



• For practical purposes, DFO divides most groundfish species into stocks following the boundaries of these divisions. So, the "northern cod" is also called "2J3KL cod," and the southwest Nova Scotia-Bay of Fundy haddock are grouped together as "4X haddock."

• Some other species are managed in diffferent units. Lobsters, for example, are managed by "Lobster Fishing Areas" (LFA's).

The map on page 15 shows the basic breakdown of the Northwest Atlantic based on the ICNAF or NAFO scheme. The current DFO Atlantic regions are shown for reference as well.

Enterprise Allocation (EA): A quota from a particular stock, allocated to one company. Generally the company is free to catch its EA whenever it chooses in the year, or to transfer it temporarily to another company. EA's, like other quotas, cannot be carried over to the next year.

• EA's are mostly used in the offshore fleets for companies operating more than one vessel. The same idea applied to a single vessel is generally called an Individual Quota (IQ).

Equilibrium yield: The yield or catch that in theory would be taken every year by a certain amount of fishing effort, if the effort was kept steady year after year until the stock was in balance (or in "equilibrium") with the fishing effort.

• Equilibrium yield is almost the same as sustainable yield.

• The idea of equilibrium yield is useful in helping us understand complicated fisheries, but no real stock is ever in balance with fishing effort. Even if the effort could really be held steady (which it never can), natural changes in the ocean mean that every stock is always expanding or shrinking. None is ever steady. For every stock and every amount of fishing effort there is an equilibrium yield, even though the actual yield in a particular year will be more or less than the equilibrium amount.

Escapement: This term is generally used in the salmon and similar fisheries, and not in groundfish management. It means the number of fish escaping the fishery and reaching the spawning grounds.

Exploitation rate: Generally, this means the percentage of fish in the fishable stock which is caught each year. (See also: Fishing mortality and F.)

• If fishermen every year caught 5 out of every 100 fish in the stock, that would be an exploitation rate of 5 per cent. For most groundfish stocks, fishery managers aim for something near a 20 per cent exploitation rate - two fish out of every ten.

F: "F" stands for the fishing mortality rate in a particular stock. It is roughly the proportion of the fishable stock that is caught in a year.

• Although F is roughly a proportion, it is not quite the same as the exploitation rate. Of the two, scientists usually prefer to use F because it makes their mathematics easier, even though it is a little harder to understand. At least it is easy to convert from F values to exploitation rates. If F is zero, fishermen are catching no fish from the stock. If F is 0.2, fishermen are catching 18 per cent of the fish (that is, the exploitation rate is 18 per cent), or about two fish out of every ten. This is around the best level for many groundfish fisheries. If F is 0.5, fishermen are catching about 39 per cent of the fish. If F is equal to 1, fishermen are catching about 63 per cent of the fish. F can go higher than 1, though that would be very undesirable in most fisheries.

• F is in fact mathematically derived from "logarithmic" relations between the number of fish alive in the stock and the number of fish caught. The mathematical details are not important here; it is enough to remember that F is almost, but not quite, the same idea as exploitation rate.

• Although the correct mathematics are complicated, it is true to say that the catch in numbers is equal to F multiplied by the average number of fish in the stock in a particular year.

• "F" can stand for what the fishing mortality rate is or it can stand for what fishery managers think the rate should be. There are some special kinds of "F" that scientists use in stock assessments. These "target fishing mortalities" include F_{MAX}, F_{MSY}, $2/3F_{MSY}$, and $F_{0.1}$. These allow fishery managers and scientists to decide major policy questions, such as whether to aim for the maximum catch (F_{MAX}) or some lesser target (e.g. $F_{0.1}$). Scientists can then calculate what TAC corresponds to the chosen policy.

F_{MAX}: The fishing mortality rate that would give the maximum yield-per-recruit from a particular stock. (In more strict scientific terms, the maximum for a particular set of partial recruitment values.) In theory, this would give the maximum catch year after year.

• When ICNAF controlled northwest Atlantic fisheries, it generally aimed for F_{MAX}.

F_{MSY}: The fishing mortality rate that would in theory give the Maximum Sustainable Yield (MSY) year after year. F_{MAX} and F_{MSY} are similar ideas.

• In reality, the productivity of the ocean changes from year to year, and a constant fishing mortality of F_{MSY} would give varying catches. It would also eventually lead to overfishing.

• F_{MAX} can only be calculated by yield-per-recruit models. F_{MSY} is calculated by a different kind of model, called a "general production model." (See: Stock assessment.) Scientists using the two techniques in stock assessments must use different data and different mathematics.

Often they will get very different values for F_{MAX} and F_{MSY}. They must then judge which is the more reliable and the more relevant.

2/3F_{MSY}: (pronounced "two-thirds F.M.S.Y."): Two-thirds of the fishing mortality rate that would in theory give the Maximum Sustainable Yield year after year. (See: F_{MSY}.)

• Trying to take the Maximum Sustainable Yield every year causes problems (see: Optimum Sustainable Yield). After Canada took over the 200-mile limit in 1977, the Department of Fisheries and Oceans used more conservative targets than F_{MAX} and F_{MSY}, in an attempt to avoid overfishing. One such target was 2/3F_{MSY}.

• By fishing at this level, fishermen put in only two-thirds of the fishing effort needed to get Maximum Sustainable Yield, but can still get 80 per cent or 90 per cent of the MSY catch. That means a higher catch rate - more fish for a given amount of work. Also it keeps the fish stock at a safer and steadier level.

$F_{0.1}$ (pronounced "F. Oh. Point. One."): For most groundfish, many pelagic, and some shellfish stocks, Canada bases the TAC's on a target fishing mortality called $F_{0.1}$. Broadly speaking, it is a similar idea to fishing at the Optimum Sustainable Yield level. The aim of managing at $F_{0.1}$ is to assist both conservation and profitable fishing.

• For many groundfish stocks, fishing at $F_{0.1}$ means catching about two fish of every 10 each year (or more precisely, 18 out of every 100, for an exploitation rate of 18 per cent).

• Under normal circumstances with most groundfish fisheries, TAC's based on $F_{0.1}$ are as close to the best as we can hope for.

• What is $F_{0.1}$ exactly? There is no easy explanation. Since $F_{0.1}$ can readily be translated into an exploitation rate (that is, percentage of fish caught from a stock in a year), it is often preferable to ask scientists just to give the percentage, and avoid mentioning $F_{0.1}$.

• Perhaps it is best to think of $F_{0.1}$ as a simple mathematical rule that calculates an F value close to the one that would give the best management. Instead of endless arguments over exactly how much fishing effort would give the best economic and social benefits to Canada or to particular fishermen, fishery managers can decide to use $F_{0.1}$. That way, they can get on with managing the fisheries knowing that the TAC's are set close to the best level. Using $F_{0.1}$ allows scientists to give a firm number to fishery managers. If they tried to calculate OSY, there would be no mathematical definition.

• Fishing at $F_{0.1}$ is similar to fishing at 2/3F_{MSY} in that you get a high level of catch but for less fishing effort than when fishing at F_{MAX}. When fishing harder than $F_{0.1}$, you catch only a few more fish for a lot more work.

However, like F_{MAX}, $F_{0.1}$ is calculated by yield-per-recruit models, so it cannot be directly compared with 2/3 F_{MSY}, which is calculated using "general production" models. (See: Stock assessment.)

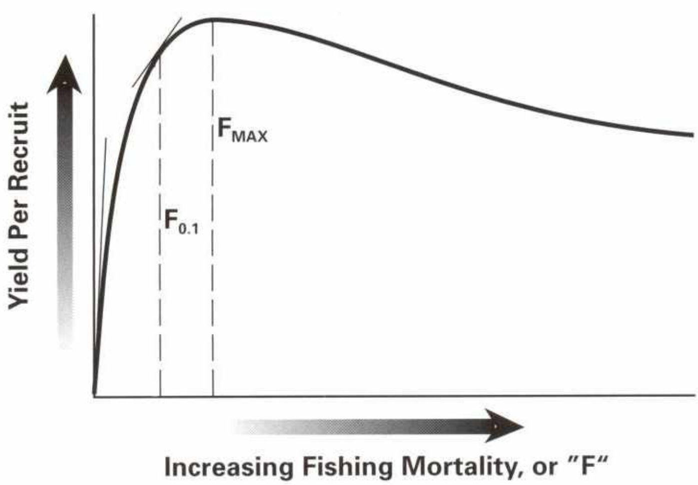
• Compared with fishing at F_{MAX}, fishing at $F_{0.1}$ provides more of a safety margin to help avoid overfishing. It lets more fish survive and grow larger before they are caught. This lets the stock's biomass increase, giving higher catch rates, so that it costs less to catch the same amount of fish. The extra growth also means that, on average, the fish in the catch are bigger, making them more valuable per pound. Under $F_{0.1}$ management, catches are generally more stable from year to year than if the fishing was at F_{MAX}. Also, the average fish has more chances to spawn, reducing the risk of recruitment failure.

• Aiming for $F_{0.1}$ seems better than any alternative. Where strictly followed, it gives good results. As Atlantic groundfish fisheries got weaker in recent years, it became apparent that fishing had been taking place at levels well above $F_{0.1}$. The fault was not with the idea of $F_{0.1}$, but with the follow-through.

• To understand $F_{0.1}$ more precisely, it is important to realize that it does not mean that F (the fishing mortality rate) is equal to 0.1 (or one-tenth). For many groundfish stocks, $F_{0.1}$ is closer to 0.2 or one-fifth. For small, fast growing fish it could be much higher still.

• The correct way to find $F_{0.1}$ is as follows. First, find the yield-per-recruit for the stock for every value of the fishing mortality rate (F) and for whatever set of partial recruitment values suit the fishery. Then plot the yield-per-recruit values on a graph (See figure below).

Then, measure how steep the curve is where F is zero. Find the point on the curve where its steepness is one-tenth as great as this.



As fishing increases from zero, the yield-per-recruit first rises through $F_{0.1}$, peaks at F_{MAX}, then falls. This graph is taken from a cod stock.

(That is where the "0.1", or one-tenth, in "$F_{0.1}$" comes from. If you drop straight down the graph, you can then read a fishing mortality rate, or F, value which is the $F_{0.1}$ value for the stock.

• Some persons give the following as a simplified explanation of $F_{0.1}$. Picture a virgin stock, and then picture the beginning and increase of fishing effort. The first boat while fishing alone for a time would produce an equilibrium yield from the stock - a steady catch year after year. As other boats joined in, each would bring an increase in the equilibrium yield; but as more boats joined in, the increase per boat would get smaller. Eventually, adding an extra boat to the fleet would bring a gain only one-tenth as great as the equilibrium yield if there were only one boat in the fleet. That would equal the $F_{0.1}$ level of fishing.

This explanation, however, is still hard to follow and is a bit unrealistic. No stock is ever truly in balance with an equilibrium yield. Natural changes in recruitment would alter the catches. The different boats in a fleet are more or less efficient than each other, so that they take different catches from the same biomass. And so on.

Fishable stock: The part of a stock that is available to be fished. The fish must be big enough to be caught and must live in places where fishermen work to be part of the "fishable stock." (See: Biomass.)

Fishing effort: The amount of fishing. It is usually recorded in units like "boat days" or "trap hauls."

• Since some boats can catch more in a day's fishing than others, scientists measuring fishing effort must take account of boat size, engine power, type of gear, electronic equipment on board, and so on.

• Measuring effort is part of finding the catch per unit effort, which in turn helps to show how much fish is in the water (that is, the biomass of the stock).

• If the scientists can successfully adjust their measures of effort to take account of the differences among the boats, fishing effort should be proportional to the fishing mortality rate (F). That is, twice the effort should give double the F.

• The fishing mortality rate is roughly the proportion of the stock that is caught, in a year. So increasing the fishing effort means that a higer percentage of the fish is caught. In the short term, that increases the catch; doubling the effort will roughly double the catch for a little while. However, the extra fishing mortality soon drives down the stock's biomass and with it the catch rate or catch-per-unit-effort so the long-term increase in catch will always be smaller than the increase in effort. Indeed, extreme increases in effort may decrease the long-term catch.

Fishing mortality: The death of fish caused by fishing. The "fishing mortality rate" is approximately the proportion of the fish in the fishable stock that are caught in a year. The mathematical symbol for the fishing mortality rate is F.

• The fishing mortality rate, in theory, varies with fishing effort. Fishing twice as hard should kill double the proportion of the fish. It will not double the catch unless the biomass stays steady.

• Fishing mortality includes the deaths of all fish killed by the fishery. Most end up in the catch, but some become discards, and a few are killed but never caught.

• The fishing mortality rate is the most important thing for fishery managers to control. In some fisheries, managers can control fishing mortality by limiting the fishermen's technical ability to take fish. This works quite well in the lobster fishery where trap limits control each boat's fishing effort. It does not work very well with groundfish because there are too many ways that a fisherman can improve his boat and gear without breaking any regulations.

It might be possible to control fishing effort, which is closely linked to fishing mortality. But again, fishermen can find many ways to increase their catch while staying within the rules limiting the number of days or hours that they fish. More catch means a higher fishing mortality in the short term.

So in most fisheries, the managers try to control fishing mortality by limiting the catch. In Canada, the managers choose a target fishing mortality (see: F) such as $F_{0.1}$. DFO's scientists then do a stock assessment. They find the abundance of the stock, calculate $F_{0.1}$, multiply these together and so (with a few extra complications) they find how many tonnes of catch from each stock will make the fishing mortality equal to the target. In theory, that tonnage becomes the TAC. Through quota management, the catch is held to this level and so the fishing mortality rate is controlled.

In reality, of course, many things can go wrong.

FRCC: Fisheries Resource Conservation Council. This government-industry body was created in 1993 to act as a "Board of Directors" for fishery conservation. It may recommend catch restrictions, set other conservation guidelines, review science operations, and generally advise the Minister of Fisheries and Oceans about conservation.

Groundfish: Species that are usually caught near the bottom, including cod, haddock, pollock, redfish, halibut, flounder, and many others.

Growth rate: How fast the fish put on weight. Unlike land animals, fish never stop growing. But they grow more slowly as they get older. Fishery managers try to direct the fisheries so the fish can grow to a desirable level that will produce good yields. But letting a year class age for too long a period before fishing it will actually reduce yields.

• A fish puts on weight fastest when it is still young. Between ages 2 and 3, a northern cod more than doubles its weight, from 165 g (grams) to 358 g on average, for a gain of 193 grams. From ages 3 to 4, although no longer doubling, it is adding even more weight: on average, 247 g. The greatest growth is from age 6 to 7, when the average fish puts on 469 g.

At this age, the fish is eating a lot and using the food to grow. Later, although it eats more, it is sexually mature and much of the food goes to make eggs or milt. The fish grows more slowly.

• If you were growing fish in an aquaculture farm, you might want to harvest them when their growth rate began to slow down. If you kept them any longer, you would get less growth for each dollar you spent on food.

• Scientists often measure growth rates as the growth in the length of the fish instead of in their weight. It is easy to convert the numbers from length to weight, however, and it is the weight that is more important to fishermen and fisheries management.

Habitat: The environment in which the fish live.

• A fish's habitat includes everything that surrounds it and affects its life: the temperature and depth of the water, the kind of seabed (mud, sand, rock, etc.), food supply, predators, and so on.

• "Habitat" usually means the fish's natural habitat. In freshwater and inshore areas, where human activities can have a big impact, some people would use the term "habitat" to include any pollutants or other artificial things that affect the fish. However, a fishery is not usually thought of as part of a fish's habitat.

High-grading: Discarding of fish that could have been sold to make room for more valuable fish. High-grading is illegal in many fisheries.

• High-grading can happen when a boat catches more than it can carry back from a trip. However, it is usually a way to evade quota management or trip limits. The regulations only allow a certain amount of catch to be landed; some fishermen discard less valuable fish so that they get as much money as they can for the catch they are permitted.

• High-grading wastes the fish resource. Since it is illegal, it is not reported; the official records of the catch do not include removals that were discarded. This puts errors into the data used in stock assessments, and so makes future management unreliable.

ICCAT: International Commission for the Conservation of Atlantic Tunas. ICCAT's first meeting took place in 1969. The organization oversees management of all tuna and swordfish fisheries in the North Atlantic.

ICES: International Council for the Exploration of the Sea. An international science forum, mainly for the European nations, founded in 1902.

ICNAF: The International Commission for the Northwest Atlantic Fisheries formerly co-ordinated management of many fisheries off Canada's east coast. ICNAF lasted from 1949 to 1979, when it was partly replaced by NAFO.

IQ, or Individual Quota: A quota assigned to an individual boat or licence. (See: Quota and Quota management.)

• When there is an overall quota for a stock, for which many fishermen compete, they may race one another to get the biggest share of the catch. This raises fishing costs, as fishermen tend to buy bigger, costlier boats using more fuel. It also increases the risk of overfishing and of cheating on the regulations.

• Individual Quotas, in theory, should give fishermen more of a feeling that they own the stock, and should encourage them to conserve it. Rather than racing for the fish with high-cost fishing, they should be able to cut fishing costs, and pace their fishing for best quality and prices. Government should be able to relax some regulations, and let the fishermen catch the fish in whatever way seems best to them.

• Individual quotas in Atlantic Canada began in the herring purse-seine fishery in 1976, and have since spread to many other fisheries. Here and elsewhere, IQ's have had mixed results, with different experiences in different fisheries. Broadly speaking, they seem to have given fishermen more security. But they have had less impact than hoped on fishing costs. Some people charge that they have worsened conservation problems, in that fishermen tend to high-grade.

• Some fisheries have Individual Transferable Quotas, which fishermen can buy and sell. Some fishermen can buy the individual quotas of others (usually within set limits); and this may make their operation more efficient and profitable. Those selling quotas may also benefit.

• ITQ's too are controversial. Some say they provide a painless method of fleet reduction or "rationalization," producing more profit and less government interference. Others say they benefit mainly those who already have money, weaken the "owner-operator" character of the fishery, and can hand over a common property to a small number of private individuals who pay few of the costs of maintaining the property.

• Some larger fishing companies have Enterprise Allocations, a type of individual company quota.

ITQ's: See: IQ's.

Landings: See: Catch.

Life history: A summary of the life cycle of a species, from spawning through the egg, larval, juvenile, and adult stages to eventual death.
M: See: Natural mortality.

Maximum Economic Yield, MEY: The sustainable yield for a particular stock that, in theory, should give the greatest difference between the value of the fish and the cost of catching them; that is, the best profits. MEY is often measured in dollars instead of in weight.

Maximum Sustainable Yield, MSY: The greatest sustainable yield for a particular stock. In theory, this catch will be sustainable year after year, if the biomass of the stock is at the right, intermediate level.

• From the 1950's to the 1970's, many fisheries were managed for MSY, in an attempt to take all of the fish that the ocean could continuously supply. Unfortunately, the scientific theory supporting MSY has some problems (see: Optimum Sustainable Yield), and the models used to calculate it are imperfect (see: Stock assessment). MSY has been abandoned for most Canadian fisheries, in favor of lower, more conservative yields.

Model: To a scientist, a "model" is just an idea of how things work, usually written in mathematical terms.

• Just as a model boat is a simplified version of the real thing, reduced to a convenient size, a scientist's model is a simplified idea of a real fishery, written in a convenient way that can be programmed on a computer.

• Scientific models confuse and frighten most people, including many scientists. So the models are often misunderstood and misused. No scientist's model pretends to be an exact copy of a real fishery, just as no model boat is a perfect copy of a real boat. The whole point of models is that they are simplified enough that we can handle them.

• The most important thing in a scientist's model is not that it mimics reality but that it gives answers that are useful and usefully accurate. To do that, it must use the data that are available. It must not need data that we cannot get. The major types of models used in stock assessment (SPA models and yield-per-recruit models) were designed to use the data that is available for many fisheries, and to produce the answers that fisheries managers need.

• For those answers to be accurate, the stock assessment must be under the control of a scientist who understands the models and all of their strengths and weaknesses. Scientists should never believe their own models when data show they are wrong; and fishery managers should never trust models they don't understand.

• No stock assessment or fisheries management is possible without models of some kind. The ones used in Atlantic Canadian assessments are the best yet developed for their purpose.

Mortality: The death of fish. The proportion of the fish dying each year is called the "mortality rate."

Scientists split the deaths of fish into those caused by fishing ("fishing mortality") and all the rest ("natural mortality"). Natural mortality includes death from sickness, starvation, and being eaten by other fish. It also includes death from less "natural" causes, such as pollution. Only death from fishing is excluded.

MSY: See: Maximum Sustainable Yield.

NAFO: The Northwest Atlantic Fisheries Organization (NAFO) replaced ICNAF in 1979. NAFO sets quotas for some stocks that are outside Canada's 200-mile limit, straddle the line, or are of mainly foreign interest.

• The Scientific Council of NAFO, made up of scientists from the member states (including Canada), develops scientific advice on various stocks for NAFO. When requested by Canada or another "coastal state," the Scientific Council also provides advice on stocks inside the 200-mile limit. These include stocks that Canada shares with Greenland and some, such as the Divisions 4VWX silver hake stock, that are mostly fished by foreigners even though they are found inside Canadian waters.

• NAFO recommends quotas and other management measures to member states, which almost always accept the recommendations. It is up to each state to make sure its fishermen follow the rules.

• Groundfish stocks managed by NAFO are:

Cod in Divisions 3M and 3NO.
Redfish in Divisions 3LN and 3M.
Plaice in Divisions 3LNO and 3M.
Witch in Divisions 3NO.
Yellowtail in Divisions 3LNO.

NASCO: North Atlantic Salmon Conservation Organization. This international organization was founded in 1982, to plan for the restoration and management of Atlantic salmon stocks.

Natural mortality: the death of fish caused by anything but fishing (see: Mortality). The "natural mortality rate" is the proportion of the fish that die of natural causes each year. Its mathematical symbol is "M".

• The natural mortality rate (M) has the same mathematical form as the fishing mortality rate (F). Like F, M is roughly, but not exactly, the proportion of fish that die.

• The natural mortality rate of very young fish is high. Often more than 99 per cent die in their first few months. But after recruitment this rate is lower, and is fairly steady for each stock. For many groundfish species the natural mortality rate is about 0.2 (two fish in every ten). For redfish, it is lower (perhaps 0.1), but for small pelagic fish it is higher.

• In groundfish, the natural mortality rate is thought to be fairly steady from year to year, aside from rare disasters. It is also fairly constant through all ages of the recruited fish alive in a particular year. That is, if a six-year-old fish has a one-in-five chance of dying of natural causes, a twenty-six-year-old in the same stock also has a one-in-five chance. (By contrast, human beings in old age have a higher chance of dying in a particular year.)

The numbers of fish in a year class of an unfished virgin stock drop in a fairly steady fashion as each year goes by. If M is equal to 0.2 (one-fifth), 45 per cent of new recruits would die of natural causes in less than four years from recruitment, but 1 per cent of them would survive for more than 23 years.

If there is a fishery, the fishing mortality rate must be added to the natural mortality rate, so the total death rate is higher and more variable.

• Because fish left in the water to grow may die of natural causes before they are caught, choosing the best minimum size limit or the bes mesh size for nets is a delicate balancing act. (See: Selection and Yield-per-recruit.)

Numbers-at-age: The numbers of fish in each age class of a stock, in a particular year.

• If the numbers-at-age were recalculated as proportions, they would be the age composition of the stock.

• Numbers-at-age are one result of Sequential Population Analysis, or SPA.

• The numbers of fish in each age class in the catch are called the "catch-at-age."

Optimum Sustainable Yield, or OSY: This is the best sustainable yield, for the combined purposes of the fishing industry, conservation, and the nation as a whole. It has no hard and fast definition. In Canada, the yield when fishing at $F_{0.1}$ is often used as a replacement for OSY.

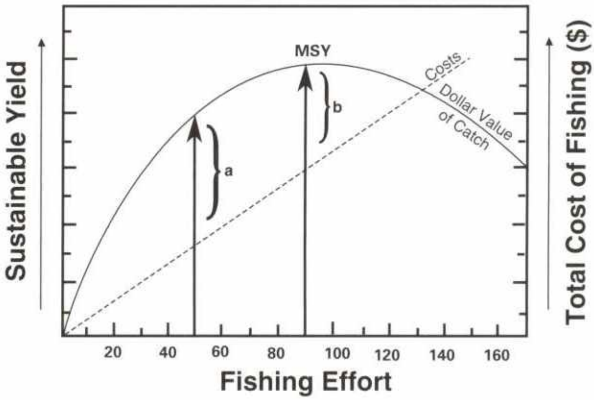
• OSY is the official policy objective in many fisheries in the U.S.A.

• In simple theory, the MSY should be the biggest, and so the best, catch that we could take every year from a stock. In reality this fails to work out, for several reasons. For one thing, there will always be ups and downs, good years when the stock creates more surplus production than simple theories suggest it should, and bad years when it creates less.

Also, scientists can never be exactly sure what the size of MSY is. If they underestimate it, or if there is a run of good years, the catch will be less than the real surplus production. In this case the biomass builds up a bit, which does no great harm.

If they overestimate MSY or if there is a run of bad years, the consequences are worse. The catch will be more than the surplus production, and the biomass will fall. Then the real sustainable yield will be less than MSY, and the fishery will have to be cut back until the stock recovers. It is safer to keep catches less than MSY and keep the biomass on the high side.

• This has another advantage. Because there are more and bigger fish in the water, fishing is easier and less expensive; that is, the catch per unit effort is higher.



The diagram above shows the amount of fishing, or fishing effort, increasing from left to right; and both the sustainable yield and the cost of fishing increasing from the bottom to the top. The costs of fishing tend to go up proportionately to the fishing effort.

At a certain level of fishing effort, the difference between the cost of fishing and the value of the catch is a maximum. In this diagram, the arrow "a" shows that point of best profitability.

The sustainable yield at this point is sometimes called the "Maximum Economic Yield" or MEY. If economics and conservation were the only issues in fisheries management, MEY and OSY would be equal.

• Holding the fishery to less than MSY has other benefits. The fish tend to be larger, for easier processing and better value. The scientific theory behind MSY pretends that each fish stock can be fished independently of the others. Yet we know that they are often linked ecologically, feeding on one another or competing for the same food. These ecological relationships are much too complicated to include in stock assessment calculations. But it is obvious that less intensive fishing puts less stress on the ocean ecosystem. Until we understand the ocean better, it would be wise to ease back on that stress.

On the other hand, fishing at less than MSY creates fewer jobs for fishermen and plant workers.

• The optimum yield is where you define it. If the country wanted MSY, in spite of the added costs and added dangers, then MSY would also be OSY. In practice, Canada has generally aimed for less intense fishing. In practice, for many stocks, this means aiming for the $F_{0.1}$ level.

Depending on the fishery, however, one could define the "optimum" as the level of fishing that would give maximum fish size, or that would create the longest season, or some other goal. In sardine fisheries, it can happen that it is more profitable to catch the fish when it is small than when it is large. In this case, one might define the "Optimum Sustainable Yield" in terms of the smaller fish, even though catching them small cuts off potential growth.

Otolith: The earbone of a fish. Otoliths have rings on them like the rings on a tree-stump, but harder to count. They are used to find the age of the fish and its growth rate. This is called "ageing" the fish.

• In some species, scales are used instead of otoliths for ageing.

Overfishing: Generally, this means catching so much fish that it reduces the stock's biomass and future catches below desirable levels.

• In an overfishing situation, fishermen would have better catch rates over the long term by cutting back their fishing.

• There are several kinds of overfishing.

• In "growth overfishing," the average fish gets caught when it is too small. The sustainable yield and the catch rate would be higher if the fish were left to grow bigger. Growth overfishing is the main type of overfishing of groundfish.

A stock can recover from growth overfishing in a single fish's lifetime. There would usually be good recovery in a few years after the overfishing stops.

• In "recruitment overfishing," too few fish are left to spawn (that is, the spawning stock biomass is pushed down too far). Hardly any little ones recruit to the fishable stock. This can cause a serious "stock collapse." When a fish stock collapses from recruitment overfishing, it can take 20 years or more to recover.

Recruitment overfishing can happen easily in some species such as herring or salmon. Most groundfish spawn so many eggs that even a small spawning stock biomass can support good recruitment. There is no proof that any major Atlantic Canadian groundfish stock has suffered recruitment overfishing. But some small local stocks probably have, and some major ones may now be near this kind of overfishing.

• Although "overfishing" is mainly a biological term, there is also "economic overfishing." When this happens, fishing is less profitable than it could be. (See: Optimum Sustainable Yield.)

• Finally, some people use "overfishing" to mean cheating on quotas or other regulations. This can be a source of confusion, since the original meanings of "overfishing" were biological and economic.

• Overfishing means catching more than one should. It does not necessarily mean catching more than the equilibrium yield.

It is also possible to "underfish." When that happens, it would be best to increase fishing effort, raise the catch above the equilibrium yield, decrease the stock's biomass, and (usually) increase its surplus production. Of course, these increases cannot continue for long. Eventually, the fishery must be limited to the Optimum Sustainable Yield.

• Despite attempts to control catches in Atlantic Canada, several major groundfish stocks have been "growth overfished." Some stocks are close to "recruitment overfishing," or stock collapse. Atlantic Canadian fishermen have lost millions upon millions of dollars through overfishing.

Partial recruitment: The degree to which a year class has joined the fishable stock.

• Fish do not suddenly recruit to the fishable stock, say on their third birthday. Instead, some fish get caught by chance when still quite small. Others stay away from the fishing grounds until they are quite large. As a year class gets older, first a few of its fish become somewhat vulnerable to fishing gear; then most of them are fairly vulnerable; and finally, all of them are fully vulnerable. At that point, the year class is "fully recruited." In scientific terms, its "partial recruitment" is equal to one.

Very young fish go totally uncaught, and have a partial recruitment of zero. When a year class is half as vulnerable to fishing as it will be when fully recruited, its "partial recruitment" is 0.5 (or fifty per cent).

• For northern cod (Divisions 2J3KL cod) in 1991, the partial recruitments were about as follows:

Age	Partial Recruitment
1	0
2	0
3	0.03
4	0.13
5	0.46
6	0.89
7 and over	1.00

• If the age composition of the stock were multiplied by the partial recruitments for each age, it would give the age composition of the catch.

Pelagic: The "pelagic" species usually live in midwater or close to the surface. (See: Groundfish.)

• Pelagic species include herring, mackerel, capelin, swordfish, tuna, and many others.

• Many pelagic species migrate over very long distances.

Population dynamics: The part of fisheries biology which studies the numbers of fish and why they change.

• A "stock assessment" is an application of population dynamics ideas to fisheries management questions.

Quota: An amount of catch that one group of fishermen is permitted to take from a stock during a year.

• In international fisheries, there may be one quota for all of the fishermen from a given country. This is a "national quota."

• National quotas may be broken down into separate quotas for the fishermen who use one type of boat or gear or who live in a given area.

• In some fisheries, there is a separate individual quota for each boat or an enterprise allocation for each company.

• Quotas are different from allowances because quotas are regulated limits. Allowances are the expected catches of some groups of fishermen where there is no regulation to stop those fishermen from catching more.

• All of the quotas, individual quotas, enterprise allocations, and allowances for a stock should add up to that stock's TAC or Total Allowable Catch.

• Some fishermen use the term "quota" to mean a trip limit. But to DFO, a quota and a trip limit are two different things.

Quota management: Managing the fishery by specifying exactly how much fish may be taken, stock by stock.

• Usually quota management controls not only how much fish is taken from the water, but who it goes to. Fishery managers divide up the Total Allowable Catch (TAC), into separate quotas for different fleets, and sometimes even into individual quotas by company ("Enterprise Allocations") or by vessel ("Individual Quotas").

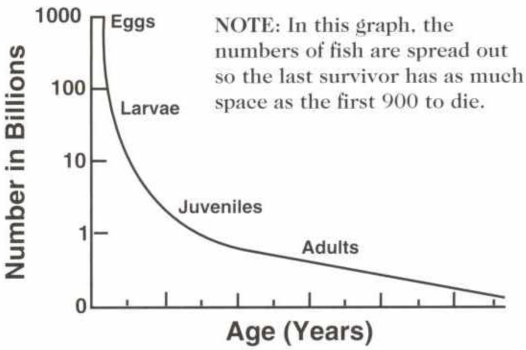
• In Canada, quotas rise and fall with the size of the stock, so as to keep the fishing mortality rate (the proportion of fish caught) steady.

• For some sectors of the fishery, quotas would be unfair or too hard to enforce. These include some types of inshore fishing. For these sectors, DFO sometimes sets up an "allowance," which is the catch that sector will probably take during the year. DFO subtracts the allowance from the TAC before allocating the rest to other sectors. Fishermen under an allowance are free to catch more than their allowance, if they can.

Recruitment: When fish survive the egg, larval, and juvenile stages, and grow big enough to be caught in the fishery, they are "recruited" to the fishable stock. For some stocks, they must also move from the nursery grounds to the fishing grounds.

• Typical fish spawn very large numbers of eggs. A big female cod spawns several million eggs every year. When the eggs hatch, the young fish appear as tiny "larvae" about 4 mm (less than 1/4 inch) long. The larvae drift in the upper layers of the ocean for several weeks, feeding and growing. When they are about 40 mm (about 1-1/2 inches) long, they settle to the bottom.

Of every million eggs hatched, only a thousand or so larvae survive to reach the bottom. The rest die from starvation, are eaten, or are swept away by water currents. Even when they reach the bottom, they still suffer a high rate of natural mortality. On average, only one or two young cod out of every million spawned reach age 1. After that, their chances of survival improve. About half of the age 1 cod will eventually recruit to the fishable stock.



This graph shows for a typical stock how fast the ocean conditions kill the great majority of larvae and juveniles.

• For groundfish, the number of adult spawners has little effect on recruitment, so long as there is a certain minimum spawning stock biomass. Usually there are far more eggs spawned than the ocean can support. How many survive depends on the ocean itself.

• Some other species such as herring or capelin spawn fewer eggs, for example only a few hundred thousand per female. A few adult capelin cannot "fill the ocean with eggs" the way a few cod can. Therefore, capelin would be more likely to suffer from recruitment overfishing, in which reducing the number of spawners leads to stock collapse. The sharks produce even fewer young, perhaps a half dozen each year per female. They are very vulnerable to recruitment overfishing.

• Although there are long-term averages, the survival of young fish and so the recruitment vary enormously from one year to another. A good year can produce ten or even a hundred times as many recruits as a bad year. The exact reasons are unclear. Recruitment remains one of the great puzzles of fishery science.

Scientists are trying to sort out the picture. They do know that the the survival of larvae depends on ocean currents, temperatures, food, and predation.

• Since they have no way to predict recruitment, scientists in their forecasts use a long-term "average" recruitment. More often than not, however, the real recruitment is nowhere near the average. Instead, the pattern over the years is generally a lot of small year classes, mixed with a few very large ones.

To add to the difficulty, the youngest year classes are the hardest to count. Scientists start getting a clear picture of year class abundance only when the fish are a few years old, and start getting caught in the commercial catch.

Removals: All of the fish "removed" from a stock by fishing, including the catch and any fish killed but not caught.

School: A group of fish swimming together. Some fishermen call a school a "bunch," "run," or "pod" of fish.

Selection: The way fishing gear selects fish, catching some but letting others go. Most gear selects by size, usually letting small ones escape ("size selection"). Some gear selects by species ("species selection"). For example, a cod jig will catch little except cod and a few pollock.

• Every commercial type of gear lets the very youngest, smallest fish escape. In net fisheries, the bigger the mesh, the more the smaller fish escape through the mesh. For some species, it helps to use square meshes. In hook fisheries, the size and type of hook and the size and type of bait influence selection. Fishery managers regulate mesh sizes and other features of the gear to make sure that most under-sized fish escape.

• Selection by the fishing gear is one major control on partial recruitment. The movement of small fish onto the fishing grounds is the other.

Sequential Population Analysis, or SPA: A method used by scientists to determine the past history and present abundance of a stock.

• SPA is the best method scientists have to calculate the abundance and biomass of a fish stock. It is used in stock assessments of an Atlantic Canadian marine fish stock, if enough high-quality data are available.

• SPA models are based on the numbers of fish in each year class. To determine those numbers, scientists use a combination of actual counts and other indicators, to make estimates.

Each year, scientists estimate the numbers of fish caught from each year class, and they calculate the numbers of fish dying from natural mortality. As a year class grows older, eventually all the fish will be dead, and all the numbers will be calculated. Scientists will then know how many fish were in that year class to start with.

In other words, the older the year class, the more the scientists know about its abundance. The younger the year class, the less they know. But they can still make estimates for younger year classes, using research vessel surveys and other data. They use various indicators to compare the abundance of younger year classes with previous ones.

• SPA's use the idea of a "virtual population." For many stocks, we know how many fish in each age class were caught each year (see: Age Composition). If we wait until the last fish in, say, the 1970 year class has been caught, we could add up all of the fish in that year class caught after, for example, 1 January 1975 (i.e. the catch at age 5 in 1975, at age 6 in 1976, etc.). We would know that the abundance of this year class at the beginning of 1975 was at least as big as the total of all these catches. (Actually, it would be bigger because some fish would have died without being caught; see: Natural mortality.)

If we repeated this for every other year class alive in 1975, we would get the numbers-at-age of the "virtual population" of the stock in that year. We could then repeat it for every other year and build a picture of the abundance of the "virtual population" in the last 20 years.

• The extra step in the SPA models used in stock assessments is that they add in estimates of the numbers of fish that have died because of natural mortality. So instead of the "virtual population," they calculate the past history of the numbers-at-age in the stock itself.

• In more detail, the process works like this:

From the various surveys and samples, scientists know the total catch each year. They also know the age composition of the catches. With these numbers, they can calculate how many fish of each age class were caught each year. That is the catch-at-age. They put these numbers together as a "Catch-at-Age Matrix," like the one for northern cod shown on page 34.

The 1970 year class was age 2 in 1972, age 3 in 1973, and so on. You can see that about one-quarter million of them were caught in 1972 as 2-year-olds; nearly 4 million in 1973 as 3-year-olds; more than 13 million in 1974 as 4-year-olds; more than 25 million in 1975 when they were 5-year-olds; then fewer each year. The last few were caught in the late 1980's, when they were nearly 20 years old.

Adding all the numbers together would give us the total catch from the 1970 year class: about 75 million fish. But some fish also died from natural mortality: about 20 per cent per year for cod. From the catch and the natural mortality rate, a computer can calculate how many fish

Catch Numbers at Age (in thousands) from the commercial cod fishery in NAFO Divisions 2J3KL for the years 1962-91. The bold numbers in the table represent fish from the 1970 year-class.

Age	Year														
	1962	**1963**	**1964**	**1965**	**1966**	**1967**	**1968**	**1969**	**1970**	**1971**	**1972**	**1973**	**1974**	**1975**	**1976**
2	301	1446	2872	85	819	790	288	59	6819	33	**236**	0	473	420	15
3	8666	5746	19338	5177	14057	15262	6142	4330	18104	12876	6737	**3963**	3231	3968	13767
4	26194	27577	27603	28709	65992	77873	94291	39626	60102	71557	79809	40785	**13201**	14101	33727
5	64337	6023	57757	46800	93687	100339	205805	100858	82357	95384	116562	94844	34927	**25370**	28049
6	58163	118112	60681	66946	62812	96759	150541	163228	101249	98111	76196	59503	74403	34426	**20898**
7	47314	58996	100147	64360	59312	54996	83808	107509	85696	57865	55984	35464	60539	39105	16811
8	27521	29349	50865	68176	30423	38691	39443	52661	29218	25055	29553	27351	35687	36485	16022
9	20142	15520	20892	33819	23844	17146	23171	19651	10857	11732	11750	14153	18854	13421	10931
10	18036	11612	12264	14913	8762	16084	10984	12370	3825	4470	6393	7566	10492	7514	4637
11	10444	8248	8698	6945	4528	5949	5591	6389	2000	2223	2987	3815	5818	2315	1462
12	9468	4204	6352	3729	2280	3367	5249	4479	1200	1287	1660	2153	2934	1179	631
13	7778	3942	4989	3948	1825	2108	1939	3004	507	1140	1388	1173	1078	808	292
14	5785	2933	4036	3730	1186	1529	1334	1557	224	720	725	450	652	372	251
15	4669	2928	2703	2722	967	685	818	622	214	355	748	278	249	165	100
16	3888	1737	1456	1859	806	424	610	567	244	474	606	309	338	82	50
17	3955	1263	1918	575	416	193	127	319	124	124	452	85	162	5	40
18	2161	1352	1154	971	279	107	89	100	32	128	136	27	113	8	64
19	232	328	501	183	486	72	83	46	10	148	195	38	45	22	30
20	403	182	312	226	178	211	26	99	34	78	36	8	20	1	20
2+	319457	355709	384538	353873	372859	432585	630339	517474	402816	383760	392153	291965	263216	179767	147797

Age	Year														
	1977	**1978**	**1979**	**1980**	**1981**	**1982**	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**
2	108	0	0	92	0	0	18	3	0	1	42	25	8	58	35
3	7128	1323	1152	2554	2185	1702	2585	782	650	831	2329	2779	1696	7693	3111
4	65510	17556	12361	12025	7172	31286	13616	14871	14824	15219	9217	14651	17639	40557	31654
5	40462	39206	37493	28814	13191	19003	42602	31760	36614	44168	32340	20184	21150	36410	53805
6	12107	20319	29202	30016	24800	14397	19028	38624	33922	45869	49061	47917	25212	22695	29553
7	**5397**	7711	10982	18017	22014	25435	12044	12503	28006	26025	28469	45725	38708	16390	9064
8	3396	**3078**	3460	4830	11848	16930	14701	7246	7050	14722	19505	18608	28499	17940	6164
9	2730	1530	**1300**	1217	3175	11936	8934	8910	3836	3104	5818	9026	8696	9156	4745
10	1381	1083	757	**520**	779	1923	6341	4227	5162	2000	1346	4337	3640	2865	1696
11	532	437	560	232	**309**	338	1018	2536	2905	1977	676	774	1695	1084	641
12	296	219	183	229	195	**156**	248	451	1681	1101	873	422	572	478	250
13	149	105	116	56	125	90	**90**	146	254	574	391	366	244	103	88
14	75	62	51	65	48	153	41	**48**	107	116	200	223	180	98	39
15	42	40	43	37	14	40	29	41	**39**	29	37	100	94	36	21
16	21	21	38	13	28	12	11	30	20	**18**	22	32	43	25	9
17	20	7	7	10	2	13	9	7	17	11	**3**	5	4	8	3
18	14	8	7	14	5	4	6	7	1	9	1	**10**	9	7	2
19	2	2	4	4	5	0	2	4	3	2	4	5	**0**	1	2
20	6	7	9	10	5	0	3	3	5	2	0	5	1	**0**	0
2+	139376	92714	97725	98755	85918	123418	121326	122199	135096	155778	150334	165194	148090	155604	140882

of the 1970 year class were alive in each year from 1970 to 1990. Doing this calculation for every year class and every year gives a big table of Numbers-at-Age, for fish that are or were alive in the water.

The top table on page 35 is a "Numbers-at-Age Matrix" for northern cod from 1978 to 1991. In 1978, the 1970 year class of northern cod was 8 years old. This table shows that in that year, there were still more than 7 million alive in the water; in 1979, under 4 million; and in 1983, around a quarter of a million, as 13-year olds. So few fish survive to age 14 that the table does not show them.

Scientists also know the weights-at-age from their surveys and samples, as shown in the "matrix" on the bottom of page 35.

They can multiply the numbers-at-age by the weights-at-age, to get

Population Numbers at Age (in thousands) from the commercial cod fishery in NAFO Divisions 2J3KL for the years 1978-91. The bold numbers in the table represent fish from the 1970 year-class.

Age	Year													
	1978	**1979**	**1980**	**1981**	**1982**	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**
3	300363	152275	160671	359797	320664	349967	432460	338626	157808	129970	160619	182303	95684	37065
4	272786	244719	123630	129236	292600	260997	284190	353361	276655	128450	104303	128990	147723	71378
5	209089	207453	189174	90339	99320	211251	201366	219219	275894	212735	96826	72139	89647	84248
6	63704	135712	135923	128811	62028	64121	134410	136127	146352	185918	144911	61011	39925	40452
7	19658	33771	84689	84125	83021	37757	35281	75097	80757	78319	107825	75286	27139	12153
8	**7741**	9117	17713	53035	48956	44958	20015	17572	36144	42570	38362	46906	26614	7389
9	4072	**3553**	4334	10131	32701	24763	23506	9830	8008	16271	17205	14571	12616	5557
10	3176	1950	**1733**	2447	5422	15973	12191	11183	4577	3748	8057	5919	4061	2044
11	1054	1621	911	**948**	1299	2699	7340	6156	4485	1938	1850	2672	1552	733
12	635	467	820	536	**497**	757	1289	3715	2412	1883	975	815	654	290
13	267	321	217	464	263	**265**	396	647	1520	978	752	416	149	103
3+	882545	790959	719815	859869	946771	1013508	1152444	1171533	994612	802780	681685	591028	445944	261412

Average Weight at Age (kilograms) from the commercial cod fishery in NAFO Divisions 2J3KL for the years 1962-91.

Age	Year														
	1962	**1963**	**1964**	**1965**	**1966**	**1967**	**1968**	**1969**	**1970**	**1971**	**1972**	**1973**	**1974**	**1975**	**1976**
2	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.00	0.11	0.26	0.25
3	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.44	0.32	0.35	0.45	0.45
4	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.53	0.47	0.68	0.63	0.61
5	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.64	0.71	0.91	0.96	0.93
6	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.08	0.96	1.11	1.18	1.32
7	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.52	1.30	1.27	1.39	1.75
8	2.12	2.12	2.12	2.12	2.12	2.12	2.12	2.12	2.12	2.12	2.13	1.80	1.56	1.74	2.07
9	2.64	2.64	2.64	2.64	2.64	2.64	2.64	2.64	2.64	2.64	2.86	2.20	2.05	2.21	2.24
10	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.29	2.82	2.75	2.61	2.99
11	3.76	3.76	3.76	3.76	3.76	3.76	3.76	3.76	3.76	3.76	3.95	3.19	3.13	3.34	3.67
12	4.15	4.15	4.15	4.15	4.15	4.15	4.15	4.15	4.15	4.15	4.12	3.79	3.41	3.66	4.56
13	6.06	6.06	6.06	6.06	6.06	6.06	6.06	6.06	6.06	6.06	5.00	4.53	4.92	4.78	6.18
14	5.54	5.54	5.54	5.54	5.54	5.54	5.54	5.54	5.54	5.54	9.32	6.93	4.40	5.20	8.19
15	6.11	6.11	6.11	6.11	6.11	6.11	6.11	6.11	6.11	6.11	9.40	7.22	6.33	5.20	9.77
16	5.83	5.83	5.83	5.83	5.83	5.83	5.83	5.83	5.83	5.83	6.89	7.05	5.50	5.46	11.23
17	6.44	6.44	6.44	6.44	6.44	6.44	6.44	6.44	6.44	6.44	14.67	9.45	7.57	8.51	12.44
18	6.07	6.07	6.07	6.07	6.07	6.07	6.07	6.07	6.07	6.07	12.04	11.16	11.07	9.24	11.16
19	6.61	6.61	6.61	6.61	6.61	6.61	6.61	6.61	6.61	6.61	7.62	7.62	7.62	7.62	7.62
20	7.19	7.19	7.19	7.19	7.19	7.19	7.19	7.19	7.19	7.19	17.46	17.46	17.46	17.46	17.46

Age	Year														
	1977	**1978**	**1979**	**1980**	**1981**	**1982**	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**
2	0.09	0.00	0.00	0.41	0.00	0.00	0.31	0.34	0.00	0.21	0.32	0.29	0.26	0.29	0.17
3	0.45	0.40	0.46	0.53	0.55	0.53	0.62	0.59	0.48	0.51	0.43	0.49	0.48	0.42	0.36
4	0.60	0.72	0.74	0.77	0.78	0.84	0.87	0.88	0.73	0.72	0.66	0.73	0.74	0.69	0.61
5	0.97	1.04	1.13	1.16	1.17	1.20	1.32	1.20	1.10	1.04	1.03	1.08	1.03	1.06	0.97
6	1.66	1.58	1.67	1.71	1.64	1.77	1.75	1.79	1.43	1.54	1.32	1.38	1.44	1.50	1.41
7	2.33	2.46	2.46	2.38	2.23	2.10	2.28	2.28	2.06	1.85	1.87	1.67	1.83	1.94	1.88
8	2.82	3.26	3.57	3.56	2.86	2.66	2.61	2.71	2.66	2.35	1.93	2.21	2.07	2.22	2.27
9	3.46	4.05	4.41	5.01	3.81	3.09	3.18	2.96	3.23	2.94	2.80	2.51	2.64	2.44	2.63
10	3.88	4.46	5.25	5.49	5.32	4.18	3.50	3.65	3.32	3.47	3.51	3.04	3.02	3.06	3.14
11	4.78	5.02	5.80	6.72	6.29	6.16	4.79	4.28	4.06	3.80	4.80	4.37	3.96	3.58	3.80
12	6.13	6.72	7.03	7.87	7.06	7.19	7.76	6.19	4.55	4.54	4.64	5.49	5.41	4.68	4.96
13	7.31	8.10	8.96	8.38	7.32	8.00	9.07	8.39	7.03	5.34	5.74	6.55	7.50	6.23	5.49
14	8.40	7.42	8.54	10.03	10.01	8.36	9.14	10.26	9.67	7.12	6.13	8.60	9.24	8.51	7.61
15	8.81	8.20	9.46	11.31	8.99	7.86	10.62	11.44	11.37	11.77	8.53	9.76	10.05	9.78	11.58
16	11.75	11.26	10.70	13.87	11.54	7.91	10.57	11.61	11.27	11.24	13.51	9.73	9.34	12.58	11.01
17	10.63	11.61	13.12	10.68	10.48	9.58	13.13	17.47	12.68	14.15	9.10	12.58	15.74	15.45	12.82
18	12.27	8.92	13.49	16.09	11.15	12.95	15.97	12.94	12.42	16.14	21.77	16.01	18.66	13.58	13.00
19	7.62	10.57	15.51	12.04	9.82	0.00	9.73	15.21	14.38	12.30	17.66	16.60	0.00	17.26	13.10
20	17.46	16.00	14.77	11.37	12.59	0.00	15.88	12.81	19.49	15.72	0.00	11.03	17.64	0.00	0.00

the biomasses of each year class in every year.

• All this works best for the older year classes. If most of the fish have been caught or have died naturally, scientists can more readily calculate how many were there to start with, and how many survived in each year since.

But what about a younger year class? We may know that fishermen caught 5 million fish from the year class last year, but how do we know how many fish are left in that year class? Are there 100 million, or only 5 million left?

To arrive at an estimate, scientists compare the catch-per-unit effort now to CPUE in earlier years. They also compare the counts of fish they made during their surveys last year and in earlier years. They make these comparisons for each age class and each year in turn. They make a first estimate of how many fish are left in each year class.

They then "tune" their analysis - that is, readjust their estimates - until the changes over the years in the numbers-at-age calculated by the SPA model line up with the changes in the catch-per-unit-effort and the survey counts. Getting the best agreement involves some complicated mathematics. The end result is a list of estimated numbers-at-age in the stock last year which fit with the measured changes in the stock. (Last year is the latest year for which information is available.)

The scientists then "project" the numbers forward to next year, allowing for catches and natural mortality.

This still gives an incomplete picture, because the scientists have no way to measure recruitment this year and next. They have to estimate the numbers for the youngest year classes. With those, they have found the numbers-at-age for next year. They can then multiply these numbers by the partial recruitment, and multiply again by the proportion that should be caught (usually $F_{0.1}$). This gives the numbers of fish of each age that should be caught.

Multiplying these numbers by the weights-at-age and adding up the totals gives the TAC for next year.

There are many twists and complications, but this is the general outline of SPA as used for most Canadian groundfish stocks.

Shellfish: The shellfish include molluscs and crustaceans.

• The molluscs include species such as clams, scallops, mussels, and periwinkles, with a soft body inside a hard shell. Squid are also molluscs, although they do not have shells.

• The "crustaceans" include species such as lobsters, crabs, and shrimps, with segmented body parts such as legs and claws. They have their skeletons on the outside.

Size limit: A minimum or maximum limit on the size of fish that may legally be caught.

• The most basic ways of protecting groundfish and most other species are to:

(1) control the size of the smallest fish caught (called the "size-at-first-capture,") so as to give the fish a chance to grow to the optimum size and value.

(2) control the total catch taken from the stock.

Most fishery restrictions - on time, place, and method of fishing - are only variations of these two basic methods.

These two methods must be used together to prevent growth overfishing and to take the Optimum Sustainable Yield.

• In species such as herring and salmon where recruitment overfishing is a danger, and for badly depleted groundfish stocks which could suffer the same problem, minimum size limits can help protect the fish until they can spawn. When recruitment is threatened, fishery managers may also use maximum size limits, to protect the reserve of very large and successful spawners. That is why some sport fishermen must release big "multi-year" Atlantic salmon, and can keep only the grilse.

• Sometimes size limits are set for market reasons, to stop fishermen from catching fish of little value.

• In 1993, there were no size limits for groundfish. Instead, fisheries managers aimed to protect small fish by closing areas where too many undersized fish occurred. This management method should cause less wastage by limiting discarding.

SPA: See: Sequential Population Analysis.

Spawning stock biomass: The total weight of sexually mature fish in the stock. (See: Biomass.)

• It is dangerous to let the adult spawning stock decline below a certain level. Depleting the stock below that level could lead to recruitment overfishing and stock collapse.

Some scientists have suggested that for safety's sake, a cod stock needs always to have at least 20 per cent of the original spawning stock biomass it had when it was an unfished "virgin stock." Other experts disagree, and researchers are pursuing the question.

Species: A kind of fish, such as cod, haddock, or herring. (See: Groundfish, Pelagic, Shellfish, Anadromous, Catadromous.)

Stock: A population of fish of one species found in a particular area, which is used as a basic unit for fisheries management. All of the fish in a stock should share similar growth and migration patterns.

• Scientists search for ideal stocks: well-mixed populations that are separate from all others, that inter-breed within the stock but not with outsiders, and that share common migration routes, growth rates, and so on. Such ideal stocks do exist but many fish live in less tidy groups. The "stocks" of practical fisheries management do not always fit the definition of what a stock should be.

• Defining a stock is partly a judgment matter. There is no hard and fast rule. For example, a herring "stock" might include a large migratory population and several small, resident populations. Management would be better if every population was called a different stock; but this would make it very difficult to collect separate data and set up separate quotas.

For one thing, fish from the different populations are often caught together. There are up to three different species of redfish in the northwest Atlantic, but even experts have trouble telling them apart. They are combined in each of the "stocks" used in redfish management. Similarly, the red and white hake or the various small flounders are not usually separated by fishermen (though scientists can tell them apart easily), and they are lumped into "hake" and "flounder" stocks for management.

• Groundfish populations usually stay inside natural boundaries set by water depth, temperature, and other ocean conditions. The NAFO Divisions were drawn to follow these boundaries. Accordingly, most groundfish stocks can be described by the Divisions they live in.

Some stocks overlap or move between two or three Divisions. For example, the northern cod or "2J3KL cod" live in Divisions 2J, 3K, and 3L. Sometimes two stocks of the same species share a Division. For example, the Division 4Vn resident cod stay in Sydney Bight all year. The Divisions 4TVn cod move into Division 4Vn in the winter, but spend most of the year in the southern Gulf of St. Lawrence (Division 4T).

• The fishable stock means all those fish in a stock which are big enough and live in the right places to get caught. They are the fish that have recruited to the fishery.

• The "spawning stock" means all those fish in a stock which are sexually mature, and so are able to breed. This group is also called the "adult stock."

Many fish in a stock's "spawning stock" will also be part of its fishable stock and vice versa.

• Some people misuse the term "stock" to mean the biomass of the stock; and accordingly, they use "fishable stock" to mean exploitable biomass, or "spawning stock" to mean "spawning stock biomass."

Stock assessment: a scientific analysis of a stock. Some assessments estimate the biomass and calculate recommended TAC's.

• Typically, scientists measure and calculate various indicators of the abundance of each year class, such as catch statistics and research survey biomass estimates. They also compare these results with their data on year classes of the past. These calculations and comparisons enable them to estimate the biomass of each year class and of the total stock. Working from this, they provide advice on the state of the stock and on future TAC's.

• Scientists use several models for stock assessment. These include General Production models, Yield-per-Recruit models, and Stock-Recruit models. The most advanced models are called Sequential Population Analyses, or SPA's.

• Sequential Population Analysis uses many kinds of data, particularly catches-at-age. It provides estimates of the abundance of the stock.

• General production models need only information on catch and fishing effort. These models ignore age composition; to them, a thousand pounds of small fish is no different from a thousand pounds of big fish. Using a general production model, scientists can calculate the Maximum Sustainable Yield and F_{MSY}. Unfortunately, most general production models are inaccurate, and they are little used today in Canada.

• Yield-per-recruit models need information on growth and mortality rates. They are used to calculate F_{MAX} and $F_{0.1}$. But because they only look at the yield per recruit, they have to be combined with SPA's to get TAC values.

• Stock-recruit models: for groundfish, the spawning stock biomass has little effect on recruitment, unless the stock's biomass is very low. In some other species - salmon is a prime example - spawning stock biomass affects the level of recruitment, and the level of recruitment is the major influence on future allowable catches. For these species, stock-recruit models use information on biomass and recruitment in earlier years, to calculate future recruitments and TAC's.

Surveys and samples: Scientists get information on the abundance and biomass of fish from various surveys and samples. These feed into different data bases, which provide the main information for stock assessment.

• Surveys and samples for groundfish include:

(1) commercial catch records from purchase slips. In some fisheries, there is also data from dockside weighouts.

(2) catch sampling by port samplers on the wharves (see: Age composition).

(3) logbooks from vessels over 25.5 gross tons.

(4) fisheries observers on all foreign and some Canadian vessels;

(5) research vessel surveys, towing nets in a pre-determined pattern year after year, or using acoustic sounders.

• Most information used in stock assessment comes from the commercial fisheries, through purchase slips, port samples, logbooks, and observers. This is used to add up the total catch from each stock, and the fishing effort. From these, scientists can calculate the catch per unit effort. Over the years, this gives them some idea whether the biomass is rising or falling.

There are weaknesses in these data. If some of the catch has been discarded at sea, the catch information is less reliable. Fishermen get more efficient year by year and from time to time they buy new and better boats and gear. As they improve their fishing techniques, one day's fishing (or one unit of fishing effort) can catch a higher proportion of the fish in the stock. As some fish get scarce, they keep bunching up on the best grounds, so that they are still easy to catch even though less plentiful.

In other words, a fisherman's catch per day (or catch-per-unit-effort) may hold steady or rise, even though the biomass is falling. This means that catch-per-unit-effort alone can give the wrong idea about the level of biomass. CPUE has to be interpreted in the light of other information.

• To provide data independent of the fishing fleet, scientists carry out their own surveys, with fishing gear or with special acoustic (echo-sounding) equipment. These surveys are carefully designed to give a count of the fish which can be compared from year to year. These surveys sample and estimate the whole of each stock, not just the fish on the commercial fishing grounds, so that the results are not thrown off when fish bunch up or spread out.

These research surveys often use fine-mesh gear. This lets them catch very small fish. From the results, scientists can get a first idea of how good the recruitment will be in the next couple of years. This helps them estimate future TAC's.

But they can make only rough estimates of how good recruitment will be. The picture of year class abundance only becomes clearer when fish start showing up in the commercial catches.

Sustainable yield or Surplus production: The catch that you could take from a stock year after year, without changing its biomass.

• In a virgin stock, the fish grow, spawn, and die without being caught. New fish are spawned and add weight to the stock, but old ones die and subtract weight. In simple theory, the gains through growth and recruitment exactly balance the losses through natural mortality. The biomass stays steady, except for changes as good and bad years come and go.

• If one boat starts fishing a virgin stock, it will take a good catch. Say it took 250 tonnes in the first year. Since the stock's natural mortality is balancing its growth and recruitment, the 250 tonnes can only come from "fishing down" the biomass. In that first year, the stock's biomass would fall by one tonne for every tonne the boat caught.

• After a few years with a few boats fishing, the biomass would be a bit lower than it was in the virgin stock. The fish would be fewer and more spread out. They would find more food, with less competition from other fish. Therefore they might grow and reproduce better, and be more healthy, with fewer dying from natural causes.

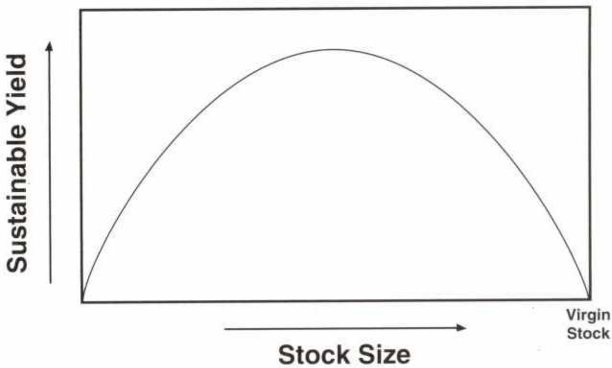
More importantly, the age composition would have changed towards younger fish, because the increased death rate (with fishing mortality added to natural mortality) means a shorter average life for the fish. Younger fish grow faster (see: Growth rate), increasing the stock's productivity.

• All these things mean that the stock can now produce more fish than it needs to maintain its new, lower biomass. This extra production is sometimes called the "surplus production." It is also the sustainable yield.

In this way, a fishery "creates" the surplus production which it then exploits.

• In effect, every stock tries to have as big a biomass as the ocean will support. When a fishery pushes the stock down, the stock produces a surplus which could go towards rebuilding to its natural biomass. Instead, the fishery can crop this surplus as a sustainable yield.

• The following graph shows how the sustainable yield varies.



Unlike most graphs, it is best looked at from right to left. The point on the far right represents a virgin stock, at its maximum size, with no fishing. There is no surplus production.

Fishing reduces the size of the stock. Each different level of fishing, if held steady, corresponds to a different stock biomass and sustainable yield. The fishery can go on taking that much fish year after year, without the biomass dropping any further. But some sustainable yields are higher than others.

• As fishing effort increases, the surplus production keeps increasing, and reaches its maximum at the point of Maximum Sustainable Yield, or

MSY.

• Higher levels of fishing effort will thin out the fish so much that the sustainable yield starts dropping. Each fish in the stock then grows fast, but there are so few of them that the total production is low.

• These ideas about sustainable yield and surplus production are valuable in helping us understand what happens to a stock as it is fished, but like all models, are highly simplified (See MSY, OSY, and Stock assessment).

TAC: Total Allowable Catch. This is the total tonnage of fish allowed to be caught from a particular stock in a particular year.

• TAC's are based on DFO's management policies and targets (often $F_{0.1}$) and scientific stock assessments. Most TAC's get divided into quotas for different gear types, vessel classes, or countries. (See: Quota management.)

• In Canada, TAC's are set by the Minister of Fisheries and Oceans, on advice from DFO's fisheries managers, from advisory committees, and for groundfish, from the FRCC.

DFO's scientists advise on the "status" (see: Biomass) of the stocks or the tonnage that matches the target fishing mortality (such as $F_{0.1}$). They do not recommend or set the TAC's.

• "TAC" should always be pronounced as three letters ("T-A-C"), never as "tack."

Trip limit: A maximum catch that each boat is allowed to bring back from any one trip.

• Trip limits are usually agreed between DFO and fishermen at meetings of advisory committees. They are sometimes used to spread out the fishing through a longer season, or to give more people a chance at the fish.

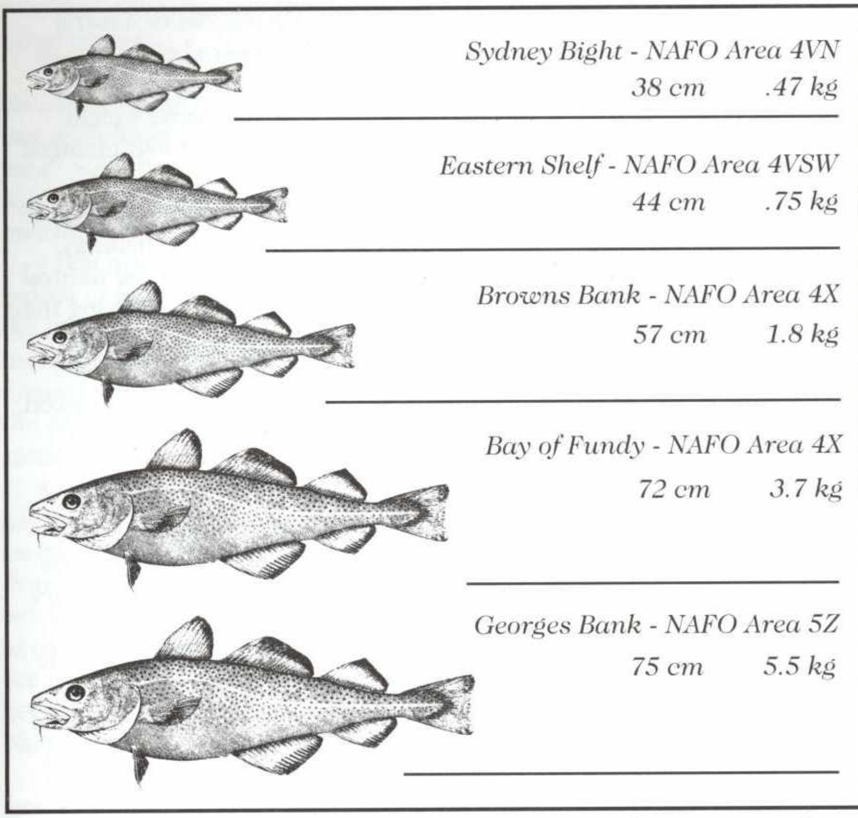
Virgin stock: A stock in its natural condition before anyone has fished it.

VPA: Virtual Population Analysis. One type of Sequential Population Analysis or SPA.

Weight-at-age: The average individual weight of the fish in each age class of a particular stock.

• Numbers-at-age are the numbers of fish in a stock. The catch-at-age is the numbers caught from each age class. But weight-at-age is the average weight of a single fish of each age, not the total weight (biomass) of all the fish in an age class.

• These weights vary for different stocks. For example, a four-year-old cod on Georges Bank will weigh more than a four-year-old cod off



Four-year-old Atlantic cod from different stocks in the Scotia-Fundy Region.

northeast Newfoundland. The diagram above shows the different sizes of four-year-old cod from different stocks in the Scotia-Fundy Region.

• Weights-at-age can also vary over time. For example, the average seven-year-old codfish in the Gulf of St. Lawrence in the late 1980's weighed only half as much as the average seven-year-old in the early 1980's. The reasons why are still unknown.

Year class: All of the fish in a stock that were spawned in a particular year, such as all those spawned in 1990. (See: Age class.) For example, the 1988 year class of Division 3Ps (St. Pierre Bank and southern Newfoundland) cod means all the cod spawned that year in that stock.

Sometimes scientists call a year class a "cohort."

• Year class growth and yield: In an aquaculture farm, with a cage full of fish of the same age, and relatively little natural mortality, you could keep a year class as long as you were getting good growth per dollar spent on food; and as growth slacked off, you could sell it.

The ocean differs in that more of the year class will die of natural causes (see: Natural mortality). The biomass of a year class increases as the individual fish grow and decreases as they die. Even while the year class is gaining weight through growth, it is losing some weight through deaths. The balance of weight gain versus weight loss changes at different ages.

• With young fish, the growth rate is higher than the natural mortality rate, so the biomass of the year class rises (if there is no fishing). Later in life, the growth rate slows down until it is less than the natural mortality rate. The year class then loses more weight by fish dying than it gains by the survivors growing. Its biomass drops away until it reaches zero when the last old fish dies.

In between, the year class reaches a peak biomass. In northern cod, if there were no fishery, this would happen when the year class was about seven years old.

• If we could, we would get the highest yield from a year class by waiting until it reached its peak biomass and then catching all of the fish. This is not practical in the ocean. It would take too many boats fishing hard to catch the whole year class quickly. Instead, the fishery is spread over a few years, catching some fish too soon (before they grow enough) and leaving others too long (which means many will die before anyone catches them).

To get the best yield, we must balance how soon we start fishing a year class with the amount of fishing effort to be used. Scientists can use yield-per-recruit calculations to find the best balance.

Yield: Another word for catch.

• Some models that fisheries scientists use in stock assessments are also used in managing wildlife hunting and forestry. Therefore it is convenient to use the wider term, "yield," rather than the fisheries term, "catch." (See: Sustainable yield.)

Yield-per-recruit: "Yield-per-recruit" models calculate the different yields expected from a stock if it was fished with various amounts of fishing effort and with various fishing gears that had different size-selection characteristics. These models can be used to find the best size limits or to calculate F_{MAX} or $F_{0.1}$ for a stock. Because the yields change as stronger or weaker year classes recruit to the fishable stock, scientists prefer to calculate the yield expected from each recruit ("yield-per-recruit") instead of the yield from whole year classes.

• The catch that can be taken from a stock year after year without driving down the biomass is sometimes called the "equilibrium yield." It is controlled by the growth rate of the fish, their natural mortality rate and the recruitment to the stock, as well as by the biomass itself.

• It is hard to calculate the equilibrium yields, because it is hard to measure recruitment - that is, the number of new fish entering the fishable stock.

Scientists can measure growth rates accurately (See: Age composition and Otolith), and they have a fair idea of natural mortality rates. But recruitment can change by ten or a hundred times from year to year. Scientists have no clear idea what causes these changes, and no way to predict or control them. For most stocks, scientists cannot even measure recruitment until several years after it has happened.

• Scientists in the 1930's and 1950's found a way to get around the puzzle of recruitment. If they could manage the fishery so as to make the best use of every million recruits, it would not matter how many million there were. The mathematical equations used to find the best management are called "yield-per-recruit" models, because they show the equilibrium yield we would get for every recruit entering the fishable stock.

• Getting the best yield-per-recruit requires letting the fish grow to a good size, but not letting them live so long that too many die of natural causes before they can be caught. (See: Growth, Natural mortality, and Year Class.) Catching a year class too fast would also be bad, because it would need a lot of expensive fishing effort, which would waste the value of the fish. The whole thing is a balancing act, juggling fishing effort and the age of the fish at recruitment (strictly: the partial recruitments) to get a high equilibrium yield without pushing the costs of fishing too high.

There are several yield-per-recruit models. Most often, scientists feed information on growth and natural mortality rates into a computer and it calculates the equilibrium yield-per-recruit for many different values of age at recruitment and of the fishing mortality rate. Managers can then choose the best age and fishing mortality (perhaps as $F_{0.1}$). From studies of gear selection, they can convert the age at recruitment into a minimum mesh size or some other control on the gear, perhaps with a size limit on the fish.

Also, they can calculate the fishing effort that matches the best fishing mortality rate. Or, if they know the biomass and age composition of the stock (see: Stock assessment), they can calculate the catch that matches this fishing mortality.

• In Atlantic Canada, DFO and the fishing industry have usually chosen to set the minimum mesh size to suit commercial needs. Scientists have related this mesh size to partial recruitments, and have calculated the corresponding equilibrium yields-per-recruit for different fishing mortalities. From these, they have found $F_{0.1}$.

Once the value of $F_{0.1}$ is known, it can be applied to the biomass of the stock. Stock assessment shows the biomass and age composition. Using these figures and $F_{0.1}$ gives the corresponding catch value which is often used as the TAC.

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