Fisheries and Oceans | Pêches et Océans

The Science of COD

Considerations in the scientific study and assessment of cod stocks in the Newfoundland Region.

Fo'c'sle

Vol. 8, No. 2, February 1988

A Special Science Edition

Newfoundland Region | Region Terre-Neuve

Canada

Fo'c'sle

THE SCIENCE OF COD

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Acknowledgements

Lawrence Jackson, a freelance writer living in Happy Valley, Labrador was contracted to prepare articles for this special edition of FO'C'SLE. Larry Coady, Science Branch, was coordinator and chief editor for the project, and wrote the closing article entitled "Where To From Here?". Publication design was by Sam Crowley, Peregrine Corp. Editorial and other assistance provided by E. Dunne, A. Pinhorn, R. Wells, H. Lear, G. Tucker, G. King, J. Pippy, J. Beckett and T. Nicholls is gratefully acknowledged.

Bernard Brown, Communications Division, brought the edition to press.

From the Director General

Mr. Eric Dunne is Director General, Department of Fisheries and Oceans, Newfoundland Region. He introduces this special edition of "FO'C'SLE."

VIRTUALLY 80% OF FISHERIES RESEARCH undertaken by Fisheries and Oceans scientists in the Newfoundland Region is geared toward stock assessment and the provision of advice on the management of our fishery.

Fisheries science is vital to the well-being of the industry. The scientists and technicians involved have dedicated many years to the pursuit of information on fish and their environment and are world experts in their field. They have made a substantial contribution to the rebuilding of overfished stocks as evidenced by the five-fold increase in northern cod since 1976. No other fishing nation in the North Atlantic can lay claim to such a phenomenal restoration of cod resources.

The report of the Task Group on the Newfoundland Inshore Fishery (TGNIF) has now been released. The Task Group was not able to define a single specific cause for the decline in inshore catches. Dr. Alverson and his colleagues concluded that the decline since 1982 in the inshore catches in Labrador and eastern Newfoundland was due to a combination of factors:

1. *Changes in availability, coupled with slower growth of the stock.*
2. *Uneven distribution of fishing effort offshore.*
3. *Possible depletion of local stocks or sub-stocks by inshore fishermen.*
4. *Redeployment of inshore effort.*
5. *Effects of fishing on recruitment.*
6. *Slower growth of fish.*

As part of the work of TGNIF, the size of the stock in 1986 was estimated. Dr. Alverson noted in a CBC interview on November 30 that "it's rather amazing that we (TGNIF and DFO scientists) are as close to each other as we are". The Task Group estimated rather fewer older cod (aged 7 years and older) and rather more cod aged 4-6 years. The difference in numbers overall was about 4 to 5%. The Task Group estimate of the overall weight or biomass of the stock in 1986 was about 11% lower than the Canadian Atlantic Fisheries Scientific Advisory Committee (CAFSAC) estimate.

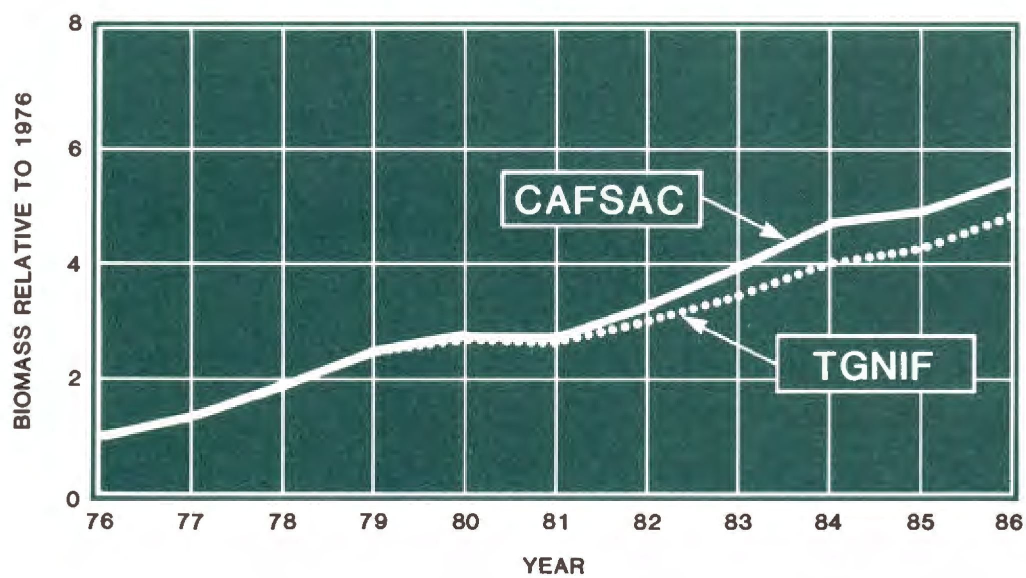
It is reassuring that the conclusions of the Task Group and CAFSAC about northern cod are quite similar with respect to the present stock size and the causes for the decline in the inshore fishery since 1982. The credibility of DFO scientific advice was not questioned. The northern cod stock continues to increase, but perhaps not *as fast as projected several years ago. The Task Group therefore recommended a cautious approach to managing the stock to protect the inshore fishery. The Minister has accepted this recommendation and set the 1988 TAC 27,000 tons below the calculated $F_{0.1}$ level.*

There is little doubt that fisheries science, of itself, is a complex business. The terminology alone (recruitment, biomass, mortality, $F_{0.1}$ year-class, etc.) can be confusing. I invite fishermen and the public to examine the accompanying articles, photos and illustrations and familiarize themselves with the work of cod researchers in the Newfoundland Region.

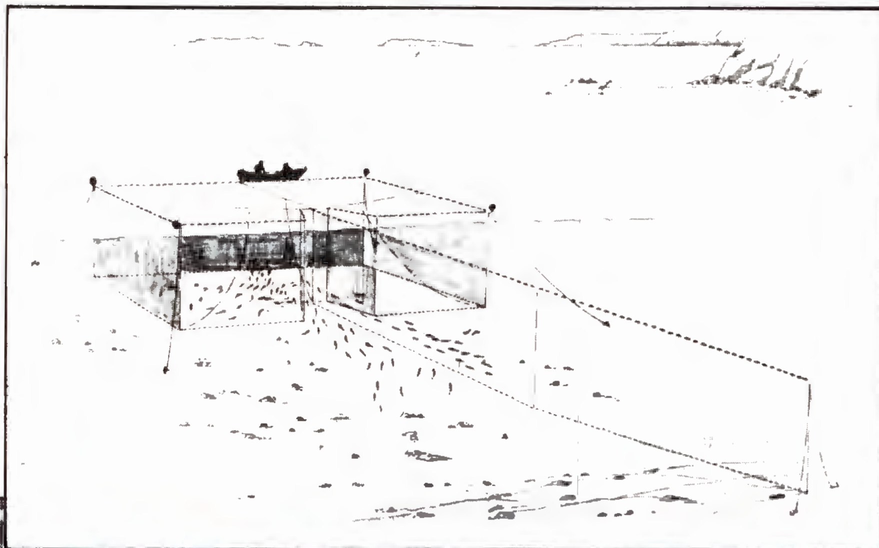
The scientific process is one of trial and error. A lot has been learned about cod but many questions remain. We are adding new staff to address questions of stock migrations, assessment methodology, species interactions, environmental influences and other areas of importance. These resources will permit new research in areas of long-standing concern to the fishing industry.

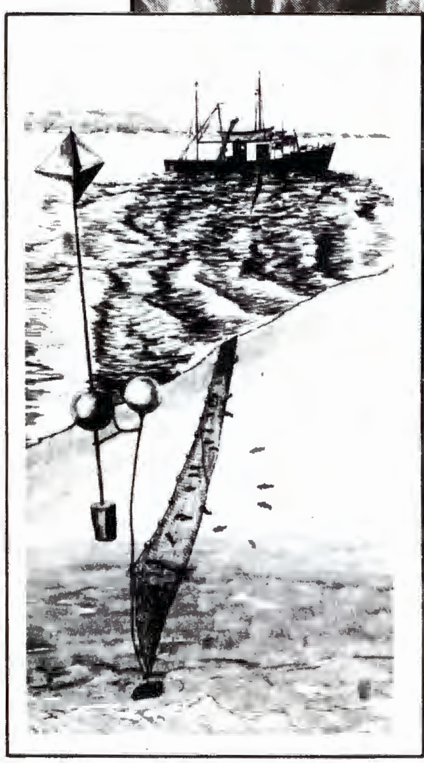
We welcome feedback on this and subsequent editions of "FO'C'SLE." There is, of necessity, a strong partnership between DFO and the industry it serves. Dialogue is important and we encourage questions and comments.

E.B. Dunne
Director General



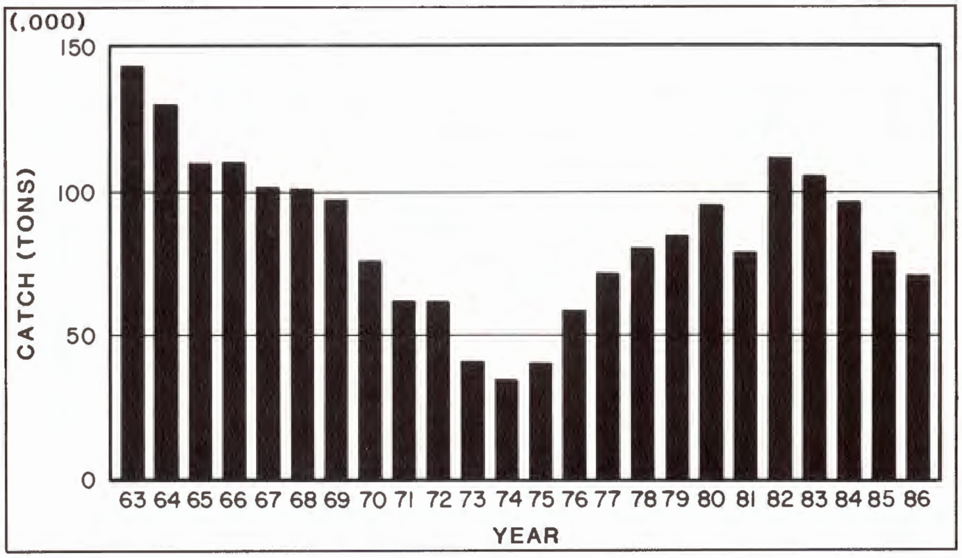
The conclusions of the Task Group on the Newfoundland Inshore Fishery (TGNIF) and Canadian scientists (CAFSAC) about the growth and present size of the northern cod stock are remarkably similar, ie. a five-fold increase since 1976.



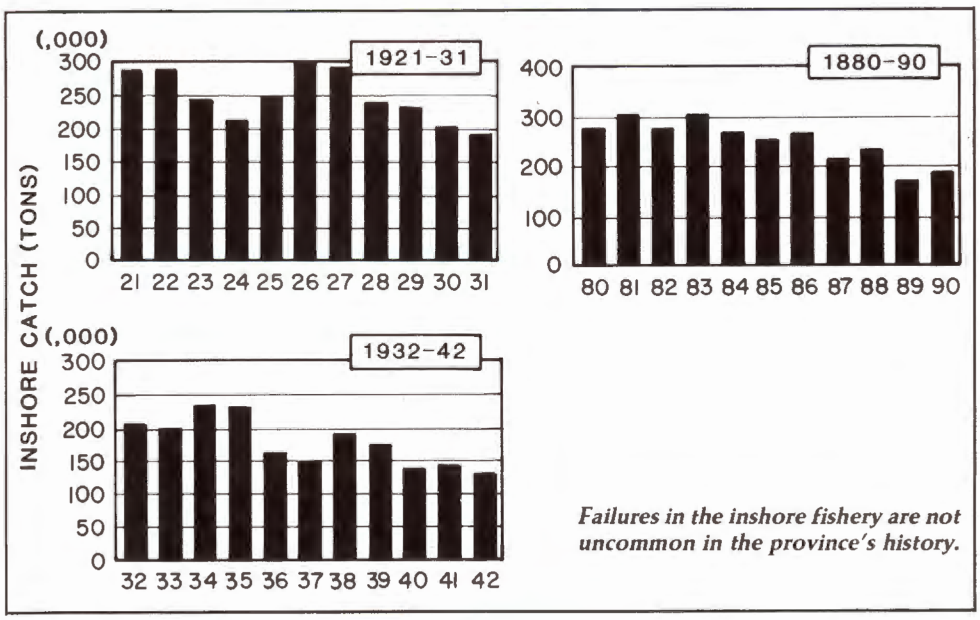


If Only The Fish Would Come Inshore

Declines in Inshore Catch 1964-75/1983-86



Previous Declines in the Inshore Fisheries



Failures in the inshore fishery are not uncommon in the province's history.

The low catch from the inshore cod fishery in wide areas of the northeast coast of Newfoundland in recent years, which some have called "a disaster," is many things to different people.

To the inshore fishermen who pinned their hopes on forecasts of large inshore catches by the mid-80s, it is a bitter disappointment.

To fisheries scientists, who calculate the adult stock has grown at least 500 per cent since 1976, the inshore failure is a puzzle that defies quick answers. They are often pressed to supply them anyway.

Many fishermen and groups which represent them already have a quick answer: the offshore trawlers are taking too much fish. Federal fisheries biologists belive the problem is much more complex, and they conclude the stock is still growing. If trawlers were depleting the resource, their catch rates would be expected to decline, yet instead they keep increasing. While the adult stock is still only half the size it was in 1962, it should easily support both the current offshore quotas and a much larger inshore catch, if the fish would only come inshore.

When asked why they don't, scientists suggested, for several years, that unusually cold water temperatures could be a contributing factor. Then in 1986, water temperatures returned to near-normal but inshore cod landings did not.

Biologists know that water temperature has a major influence on the migration of cod, but they are now certain it is only one of a number of factors, some of which are still poorly understood. Learning more about this is a high priority in fisheries research.

Following is a summary of what scientists now believe about factors affecting the low inshore landings of northern cod in recent years. First, a review of the landings themselves:

By 1976, after more than a decade of extremely heavy fishing by foreign trawlers, the stock had reached its lowest point. There were only about 124 million fish aged six and older, compared to an estimated 900 million in 1962.

Inshore catches, which had averaged 144,000 tons in the four years before heavy foreign fishing began, declined to a low of 35,000 tons in 1974. When Canada extended her fisheries jurisdiction out to 200 miles in 1977, largely to save the shattered inshore fishery, trawler quotas were cut back sharply and the stock began to recover.

Inshore landings rose steadily from 1974 to 1980, more than doubling in that period. They fell off sharply in 1981, rose again in 1982 and 1983, and have fallen steadily ever since, from 106,000 tons in 1983 to 72,000 tons in 1986. In fact, the inshore catch of northern cod in 1986 was the worst since 1976, when the stock was at its bottom.

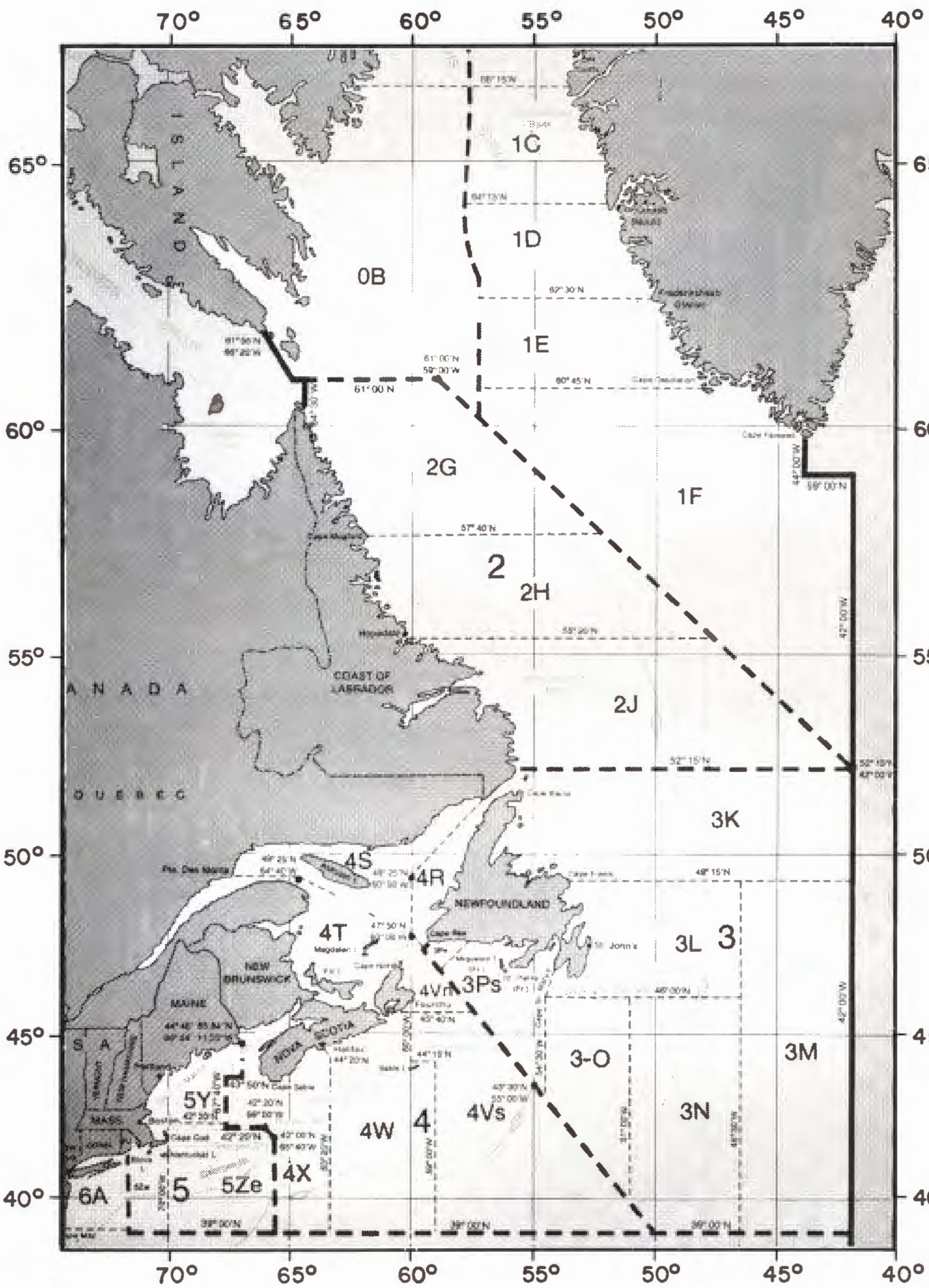
So the problem is urgent. What are some of its causes? The range of possible answers includes the following:
1) Not enough fish may be coming inshore.
2) Those which do may avoid the areas and water depths where inshore gear is set.
3) Inshore fishing effort is lower.

Let's look at these possibilities in order;

1) The Failure of Fish to Come Inshore.

The most obvious reason for low inshore catches would be a shortage of fish. Yet, every calculation of the abundance of northern cod shows that the stock is still growing.

Another possibility is that something is interfering with patterns of cod migration, so that fewer fish migrate to shore. Two things which could cause this are a cold



Canada's 200-mile offshore economic zone, and fishing zones established by the North Atlantic Fisheries Organization.

water barrier and an unusual abundance of young capelin.

It is not clear yet whether cod actually follow spawning capelin to the shore, or whether they just tend to show up at the same time. If they actively follow capelin, then an exceptional abundance of immature capelin, which do not come inshore, could tend to keep more cod out on the banks.

Capelin surveys on the Grand Bank show that immature capelin were more than 10 times as abundant in 1985 and 1986 as they had been in the three previous years. Such a huge food supply could simply make it unnecessary for cod to come inshore.

On the other hand, water conditions could make it very difficult. Cod avoid water much colder than 0 degrees Celsius, yet we have huge areas of such water off our coast every year. The cold water layer varies in area, thickness and depth from year to year, but in bad years it could be a serious barrier to cod migrating from the offshore banks.

Surveys in June of 1984 and 1985 found dense concentrations of cod off eastern Newfoundland below the cold core of the Labrador current. These fish were near the coast but far too deep for inshore gear. Some were tagged, and tag returns later showed that relatively few of these fish made it into shallower water.

Other studies also suggest that inshore catches in Labrador and along the northeast Newfoundland coast are closely related to water temperature. Years when surface water is cooler and the water at a depth of 100 to 150 meters is warmer than usual were the years of best inshore catches.

2) The Avoidance of Traditional Cod-trap and Gillnet Berths

The cod's dislike of cold water may also affect the behaviour of those which do come to shore. Early studies of the movements of cod in inshore waters suggest that cod tend to remain in water at a temperature of 1-5 degrees Celsius, avoiding water which is much warmer or colder than this. If winds and currents move a mass of cold or warm water into areas traditionally fished with inshore gear, the cod might stay away.

Early in the season, the temperature in shallow inshore water is normally about right for cod. However, heavy seas can mix this surface water with much colder water just below it, or strong offshore winds can push the surface layer out to sea, allowing colder water to well up from below. This can cut cod traps off from the fish. On the other hand, strong onshore winds can push the warmer surface water toward shore, making it deeper and opening up a larger inshore area with water suitable for cod.

Later in the season, the surface may become too warm for cod. They may avoid the depths in which cod traps are set, but still be accessible to deeper line trawls and gill nets. Strong onshore winds can once again deepen the surface layer near shore, forcing the cod to retreat to deeper, cooler water beyond the reach of inshore gear.

These are very simplified descriptions of complex processes. Local wind, current and bottom conditions can strongly influence what happens in a particular place.

3) Reduced Inshore Fishing Effort

Individual inshore fishermen know how hard they work, how much gear they use and what they get for their effort. But no one can accurately say how much inshore gear is in the water at any one time, or how much was fished this year compared to last.

Unlike the trawler fishery, where the number of vessels is limited and captains keep a detailed log of where and when and for how long they fish, the inshore fishery is a sprawling, complex industry, very difficult to measure. Fishermen move between shore jobs and their boats, between cod and other species, between different fishing areas, and between different types of fishing gear, trying to make the best of shifting opportunities. They might haul their gear eight times one week and three the next, depending on wind. They might start fishing in May one year and July the next, depending on ice.

All this makes it virtually impossible to evaluate the total inshore catch in terms of how much effort it took to land it. Yet, without some measure of effort, no one can determine how serious the recent inshore failure has been. Landings are only part of the picture -- the clear part.

4) Other Factors

There are at least three other possible causes of low inshore catches. One is that unusually cold water might delay cod spawning on the wintering grounds. If cod normally follow schools of capelin to shore -- which is still not known -- and if capelin move toward shore before cod have finished spawning, the cod may be late moving inshore and more of them might just stay on the banks all summer.

Research cruises in 1984 and 1985 found that more than half the female cod off Fogo Island and Cape Bonavista had still not spawned by mid-June. However, similar research must be conducted for several years to establish whether this was unusual or whether there are actually local populations of cod which spawn on the coastal shelves and in the deeper bays. If so, it could mean that late spawning signals a late start and probably lower catches for the inshore fishery.

Another factor, all too familiar to fishermen, is "slub." This is known to be formed from the discarded mucus "houses" of a jelly-like creature which lives in the Labrador Current. Sometimes, for reasons which are still unknown, they multiply tremendously. When local wind and current patterns bring the Labrador Current right to shore, this can have two effects. The cold water can prevent many fish from reaching the shore, and the slub can make it harder to catch those which do. Slub makes the nets more visible and much heavier to haul, and the time spent cleaning them can cut into a fisherman's earnings.

A third cause of low inshore catches in some areas could be the concentration of the offshore trawlers on a few favourite fishing grounds. While northern cod is managed as one stock complex, scientists know that many of these fish tend to move between the same spawning grounds and the same inshore areas year after year. So, if the trawlers concentrate their fishing in one zone, they could be hurting the inshore fishery in the area where fish from that zone tend to migrate in summer. With this in mind, scientists recommended that the offshore effort be spread out more evenly in the three NAFO zones occupied by northern cod. This recommendation was adopted in 1987.

Another possible cause for which there is only circumstantial evidence stems from the idea that the local bays supported resident stocks of inshore cod which remain inshore during the winter under the cold Labrador Current water. These local stocks may have been overfished by the inshore gears, principally gill nets, to such an extent that the inshore fishery is now relying totally on the migration of cod from offshore, a migration which is highly variable among years and among areas.

What Else Can Be Done?

In an effort to better understand the slump in inshore catches, DFO has stepped up its research into all the questions discussed above. No fish resource in Atlantic Canada has received more scientific attention in recent years, and the effort is ongoing. Some of the priorities in this research include:

- ☐ Refining methods of collecting data on catches and fishing effort by different types of gear used in the inshore fishery.
- ☐ Much closer monitoring of the temperature of the cold layer in the Labrador Current.
- ☐ Better estimates of the abundance of capelin each spring.
- ☐ More study of the behaviour of cod and capelin, in terms of migration and feeding and in terms of their movements under various temperature conditions in shallow inshore water.
- ☐ Ongoing efforts to refine the methods used to calculate and forecast the abundance of fish.

Many of these issues are discussed in more detail in the articles that follow.

(Northern Pen Photo)

St. Anthony fisherman Eldridge Cull lifts a portion of net covered with slub.

The Role of Science in the Fishery

When Canada extended fisheries jurisdiction to the 200-mile limit in 1977, she staked her claim to a vast ocean territory and took on the duty to manage resources within those limits. Many nations which had long fished in those waters did not resist this move. They knew that serious overfishing had depleted the stocks and that only good management could bring them back.

Now more than ever, fisheries management is a matter of high stakes. In the huge northern cod stock, for example, an error of 10% in the estimate of stock abundance can make a difference of 25,000 tons in the allowable catch. This much fish is worth $12 million at the wharf, and several times more than that in its total contribution to the region's economy.

Good fisheries management must be based on clear understanding of what is out there and how we affect it. This is the role of fisheries science.

Because the abundance of fish in different stocks can change greatly from year to year, catch limits must be based on reliable and up-to-date advice. And because most stocks are sensitive to overfishing, those in charge of managing the fishery must walk a fine line between getting the maximum benefit from the resource and taking too much.

This leads to a partnership between fisheries managers, the people who must make catch and quota decisions, and the scientists who supply the biological advice on which those decisions are based.

Scientists sometimes distinguish between "pure" and "applied" science. The first seeks knowledge for its own sake. The second draws on this basic knowledge to develop new inventions or processes. The first scientists to study radio waves, for example, merely wanted to understand them. Later, others began to see uses for this knowledge, developing radio, television, radar, microwave, Loran and scores of other applications that would astonish our ancestors.

In much the same way, fisheries science supplies two kinds of service:

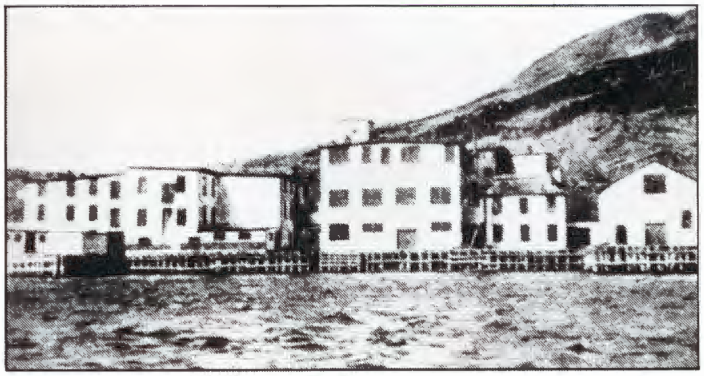
1. A basic understanding of different fish species and their environment.
2. Complex applications of this knowledge, allowing scientists to estimate stock abundance and predict the effect of different management choices.

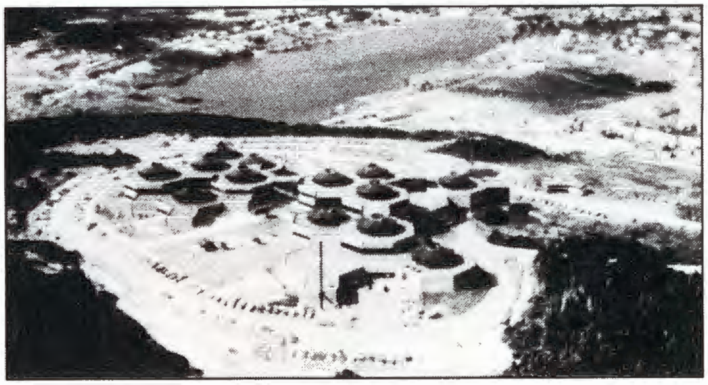
Federal government fisheries research directors in Nfld., 1944 to present (L-R): A.M. Fleming, 1975-78; M.C. Mercer, 1981-present; W. Templeman, 1944-72; E.J. Sandeman, 1978-81; A.W. May 1972-75.

A good scientist can think of several dozen challenging questions in an afternoon, any one of which could take years of study. So there are always many more questions than firm answers. Yet because of staff limitations and the urgency of completing stock assessments each year, assessment (rather than basic research) occupies more of the scientists' time.

Still, research is the foundation on which good management is built. Science must supply detailed knowledge of:

- where different species of fish live;
- what they eat, and what eats them;
- when, where and how they spawn;
- how fast they grow;





Three generations of fisheries research facilities in Newfoundland: the Newfoundland Fishery Research Laboratory, Bay Bulls, 1931-37 (top, center building); Water St. East, St. John's, 1940 to late 1970's (became a federal government facility after Confederation); Northwest Atlantic Fisheries Centre in the White Hills overlooking the east end of St. John's, headquarters for the Department of Fisheries and Oceans, Nfld. Region, opened 1978-79.

☐ at what age they normally die;
☐ where and when they migrate;
☐ what kinds of changes in the ocean environment affect them, and in what ways.

This kind of knowledge builds up as new studies are completed. In time, it provides an understanding of the basic nature, habits and life cycles of different species, and the relations between them. Such basic knowledge is crucial to the management of fish resources.

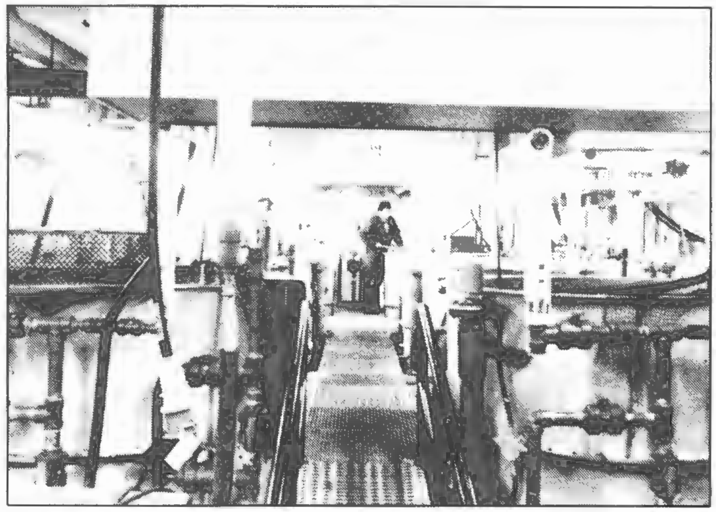
Scientific Advice and Forecasts

Fisheries management needs more than these basics, however. The managers must know the abundance not only of the different species, but also of the different stocks of the same species, in order to set allowable catches. They need to know how the stocks will change in response to fishing. This stock assessment is a lengthy, complex process, yet it must be done every year on every important stock. In the Atlantic area, biologists supply stock assessments on the following:

Category	Number of species	Number of stocks
Groundfish (cod, flatfish, redfish, etc.)	14	40
Pelagic Fish (herring and capelin)	4	20
Anadromous fish★ (salmon and charr)	4	30
Invertebrates★ (scallop, shrimp, crab, lobster)	5	56
Marine mammals (seals, whales and walrus)	12	26

★Many stocks exist that are not assessed.

In addition to these annual assessments, managers and people in the indusry need longer term forecasts of changes in stock abundance. Especially in the offshore fishery, where new vessels cost millions of dollars, companies want to be sure the fish will be available before they commit funding for trawler construction.



Research aquaria at the Northwest Atlantic Fisheries Centre.

Finally, fisheries managers need scientific advice on the biological impact of various management choices. Decisions on quotas, seasons, gear sizes and licensing are often complex and difficult. Managers must balance economic and social benefits against long-term effects on the resource. The pressure is high, because the livelihood of individuals and the prosperity of whole regions are at stake. Managers need the best available scientific advice to make good choices.

To supply such advice, science must draw conclusions from evidence, and the evidence must be measuable. Impressions and hunches, the kinds of judgements we all make daily from our own experience, are not enough when the stakes are high. A scientist needs data, often hundreds of pages of numbers systematically collected, and weeks of careful analysis of the numbers before it can be agreed that the evidence supports the conclusions.

Researchers deploying 'bongo nets' to capture plankton samples.

Fish Facts From the Cod Nursery

From February to June, adult cod concentrate in dense schools offshore, to spawn. A mature female cod produces millions of eggs. They are tiny as beads, and they float near the surface. They are food for many other species, and only about one in a million will live to maturity. Yet as long as an average of two offspring from each female grow up to reproduce, the population will remain stable.

The larvae that emerge when cod eggs hatch have a small yolk sac from which they draw their food during the first few weeks of life. When this is gone, they must fend for themselves.

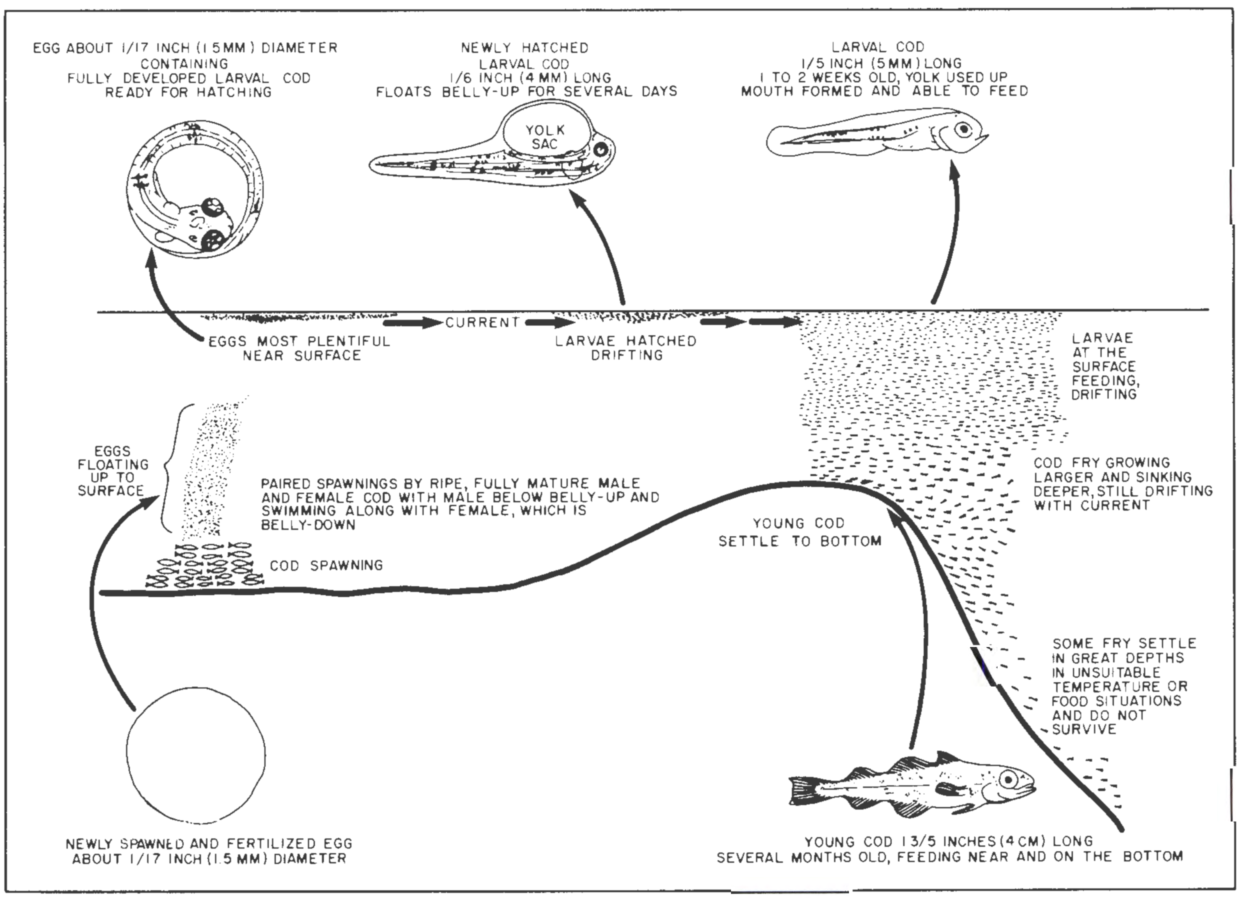
They live mostly on plankton, a name which covers many species of very tiny plants and animals living near the surface of the sea. Plankton multiply tremendously when conditions are just right. They are food for everything from the tiny cod fry, barely half an inch long, to the mightiest of whales. If the cod hatch at just the right time, and if winds and currents do not push them into a barren area, they will have plenty to eat.

When the fry have grown to 4 cm (about an inch and three-quarters) they settle to the ocean floor, to live the bottom-feeding life of cod. Young cod from the northern cod stock drift into the deeper bays of eastern Newfoundland, which serve as nursery areas. The young "tomcods" later migrate offshore to join the adult population.

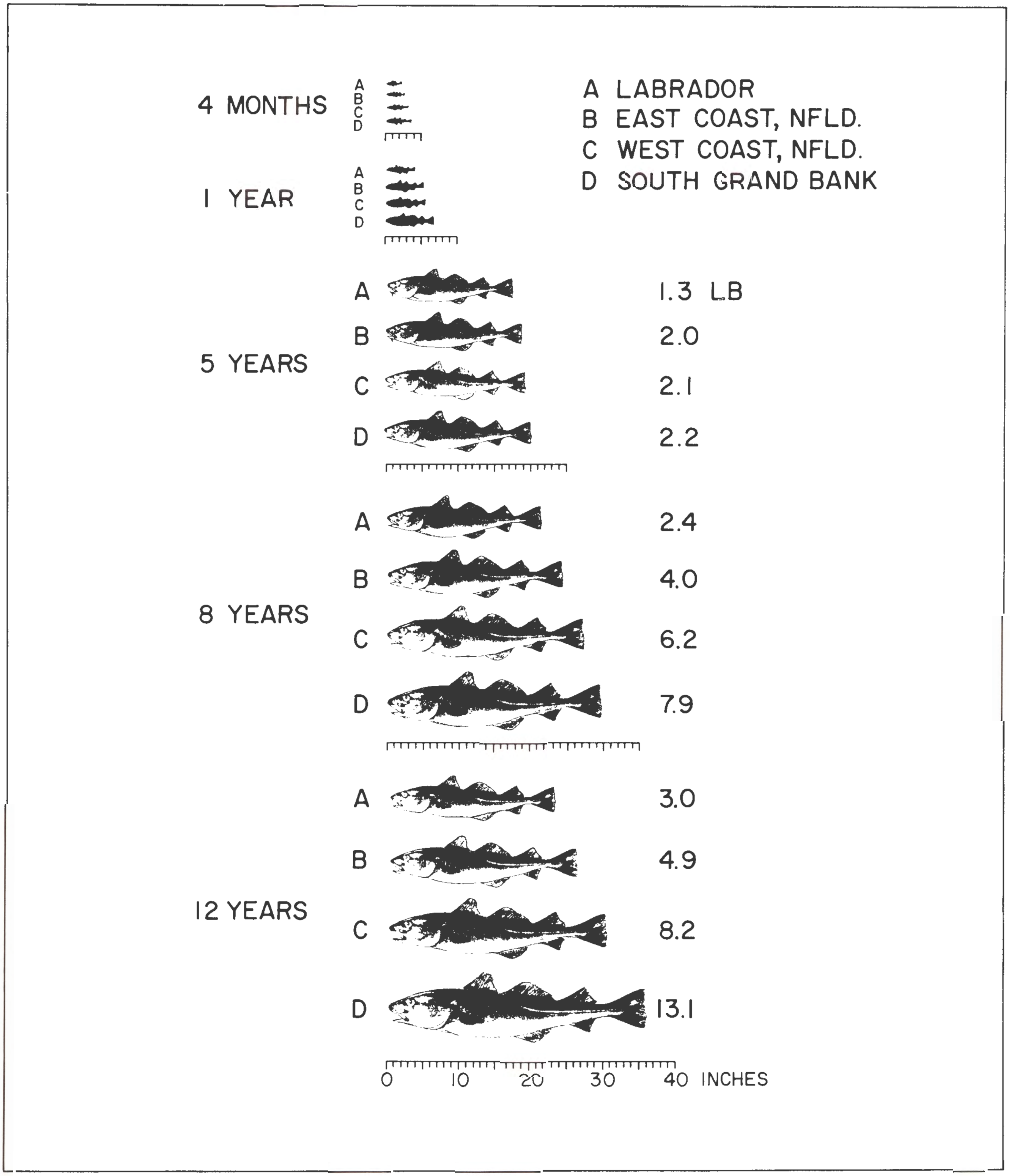
Adult cod eat nearly anything that moves and some things that don't, like stones, which they sometimes swallow to get the sea anenomes growing on them. More typically, they feed on capelin, herring, sand launce, flounder, young turbot, crabs, shrimp, brittlestars, combjellies and many other fish and shellfish.

By age four, cod have grown enough to be taken in the fishery. They are sexually mature by about age six. Cod from southern waters grow much faster than northern cod. By age 15, those from the southern Grand Bank are almost 85% longer than cod from southern Labrador. Cod from George's Bank, off Nova Scotia, are fully twice as big.

Most cod taken in the present fishery are between four and eight years old, and few are older than 15.



Cod spawning, larval development, and settling of young near bottom. (From Templeman 1966, Marine Resources of Newfoundland)



Lengths and weights of cod (gutted, head on) of the same ages from various Newfoundland and Labrador areas. (From Templeman 1966, Marine Resources of Newfoundland).

Cod Movements

After 400 years of fishing cod, there is still much we do not know about them. The things we don't know illustrate the difficulty of learning about creatures which live out their lives in a world beyond our view.

For example, we don't exactly know how and why cod come inshore. Yet this is crucial to the success of the inshore fishery, which must wait for fish to come to the traps, nets and line trawls. When they don't, we need to know why.

We have known for years that cod winter on the offshore banks and come inshore in late June and early July, and that they feed on capelin in inshore waters. We know that not all the stock comes inshore, but we don't know why some do and others don't. We don't know if those which do are chasing capelin or whether, just by following their own migration instinct, they simply tend to show up at the same time. We know also that some cod remain in deep water bays during the winter and may spawn there during spring and summer.

If cod are actually drawn to the coast by capelin, then an abundance of capelin inshore should mean a good trap fishery. On the other hand, an abundance of immature capelin, which do not come to shore, might tend to keep cod out on the banks.

Similarly, we have learned that cod generally try to avoid water colder than 0 degrees Celsius. Yet from surveys of water temperature at various depths, we know that cod migrating from the offshore banks must pass through a layer of cold water to reach the warmer, shallow waters near shore. We still don't know if they just swim up through this cold layer, getting through it quickly, or whether they follow the bottom as it rises toward the coast.

There is little direct evidence but some reason to think that they come up through it. For one thing, that would be more efficient. If the cod moved to shore along the bottom, they would expose themselves to cold water for a much greater distance.

Another clue is in the spring longline fishery off Cape Bonavista. There, fish are caught in May, before cod reach the shore, so this fishery offers one of the few insights into what cod are doing between the spawning season on the banks and their summer on the coast. In areas off St. John's, such as Cape Broyle, the earliest large catches were in May from baited longlines suspended at 10-20 fathoms over deep water. If the cod were following the bottom, they would not encounter this gear.

But evidence like this is scarce. Because most of what we know about cod comes out of the fishery itself, they present us with few clues about how they behave between the banks and the shore, the areas where most of the fishing takes place.

However, two techniques, one old and one very new, are gradually lifting the curtain on some of the questions about cod migration and the interaction between cod and capelin. One is tagging; the other is a new technique called hydroacoustics.

Tagging

Until recently, tagging was almost the only way to study the movements of fish. Biologists tag fish and release them alive, and keep careful records of where and when they were tagged. Then when fishermen catch some of them and return the tags, together with details of when, where, how the fish were captured, and the depth at which they were caught, scientists can build up a picture of the habits of fish from that stock.

Tagging is a slow and indirect means of gathering data, but useful knowledge emerges over time. Tagging studies help to distinguish one fish stock from another and show how much neighbouring stocks mingle with each other. Tagging can show both where the fish from a given stock go when they migrate inshore, and which stocks contribute to the fishery in a given area.

The accompanying diagram shows, for example, that most of the cod which spawn on the northeast Hamilton Bank will migrate to the Labrador coast or to White Bay. Fish from the northern Funk Island Bank, on the other hand, tend to spread out more evenly over a wider area when they go inshore. Fish from the northern Grand Bank migrate southwards over the shallow central part of the Grand Bank as well as inshore to the Avalon Peninsula.

Because tagging studies depend on the return of tags recovered in the commercial fishery, the standard tagging methods shed very little light on the question of how fish come inshore. But a new technique called acoustic tagging can help to fill in this gap.

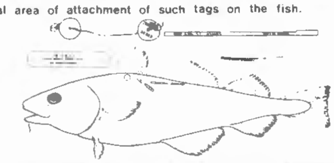
Acoustic tags can be tracked with equipment in a boat. This enables scientists to follow the movements of individual fish, sometimes for days. These observations, combined with information about water

REWARD

COD TAGS

$5·00

Some of the various types of tags used in our study of COD MIGRATIONS are shown below. A figure is also shown indicating the general area of attachment of such tags on the fish.

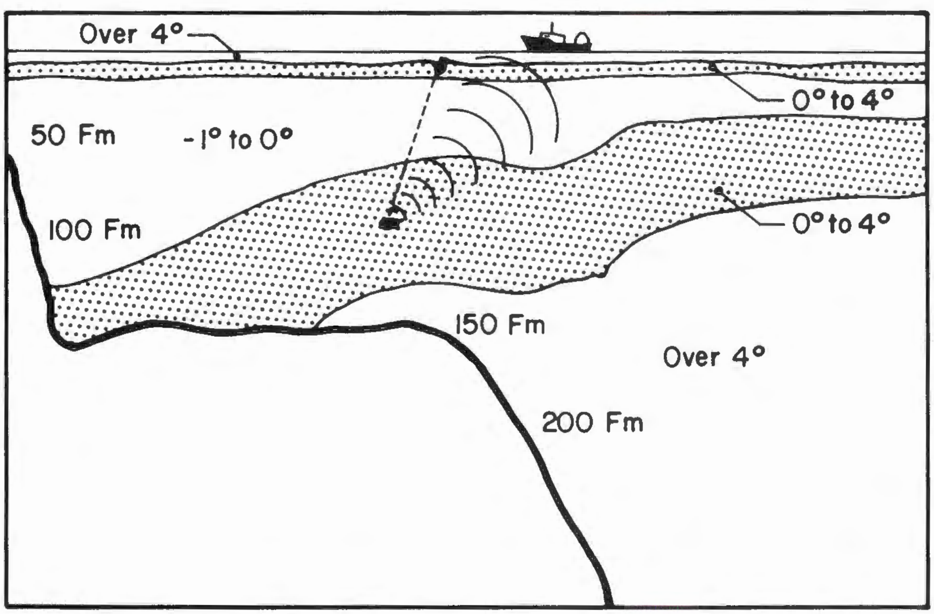


A $5·00 REWARD WILL BE PAID FOR THE RETURN OF EACH TAG. STATE DATE, PLACE, DEPTH AND HOW CAUGHT. ALSO, IF POSSIBLE, STATE LENGTH, WEIGHT AND SEX.

Return to:
Fisheries and Oceans
P. O. Box 5667
St. John's, Nfld., Canada A1C 5X1

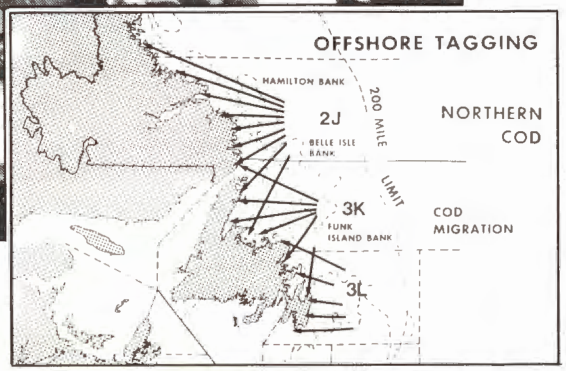
Tags or, more correctly, the information derived from their retrieval, is valuable to scientists in determining different fish stocks and migration patterns.

Temperature Effect



Cod are most likely to be found in waters about 0°C to 4°C in temperature.

Photo (left), tagging cod aboard research vessel. vessel.



temperatures and the presence of capelin in the area, will give new insight into the behaviour of fish in inshore waters.

Knowing more about how fish behave should make it easier to catch them, by finding better berths, improving cod trap design or simply by knowing more about where they should be.

Hydroacoustics

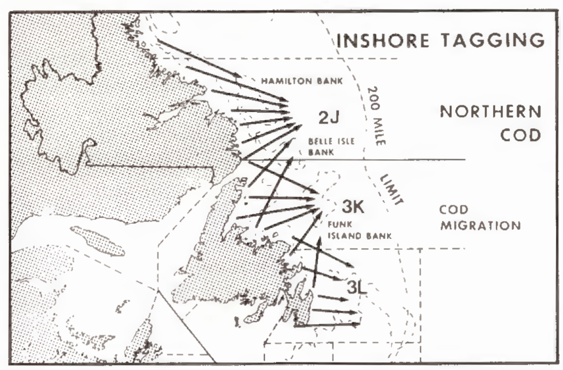
Fishermen with depth sounders have long known they can recognize schools of fish in the pattern of echoes which their sounders display. Hydroacoustics is a refinement of this technique. It offers a new way to locate schools of fish, follow their movements and estimate their abundance.

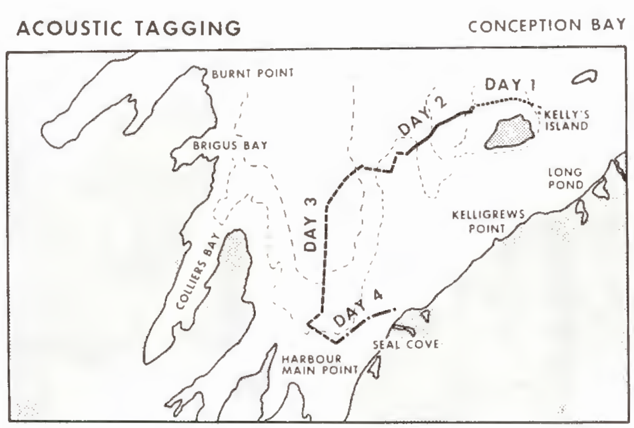
Two of the major improvements in this technique involve towing the transducer on a long cable and sending out a double beam or pulse of sound. The long cable puts the equipment deep in the water, away from interference by waves and the ship's own noise and motion. This results in a much clearer signal. The double beam offers a clearer picture as well. The signal returned from earlier systems was so affected by things like water depth and the size and swimming angle of the fish, it was hard to interpret the results.

The new system is so much more clear, it is becoming possible to distinguish individual fish. This would mean a great leap forward in the annual challenge of estimating the abundance of fish stocks. In the meantime, signals are clear enough that hydroacoustics offers a way to estimate the size and density of schools of fish. This makes it possible to double check the abundance estimates made by other techniques. Since these estimates are so important in setting annual catch limits, anything which helps to refine them is a welcome step.

The technique is still very new and being adapted to cod. It was first used in the Newfoundland region to track the movements and estimate the size of schools of capelin, redfish and herring.

Movement of cod, tagged inshore and offshore, between inshore summer feeding areas and offshore spawning areas. Note three distinct sub-groups of the northern cod stock.





Four-day journey of a cod wearing an acoustic tag tracked by DFO scientists.

What is a Fish Stock?

Fisheries managers deal with fish stocks, but just what is a stock?

In human terms, a fish stock is something like a community or tribe. A few of its members mingle with members of other groups, or even join them for good, but most stay with their own. A fish population is considered a separate stock when it can be fished without affecting other populations of the same species.

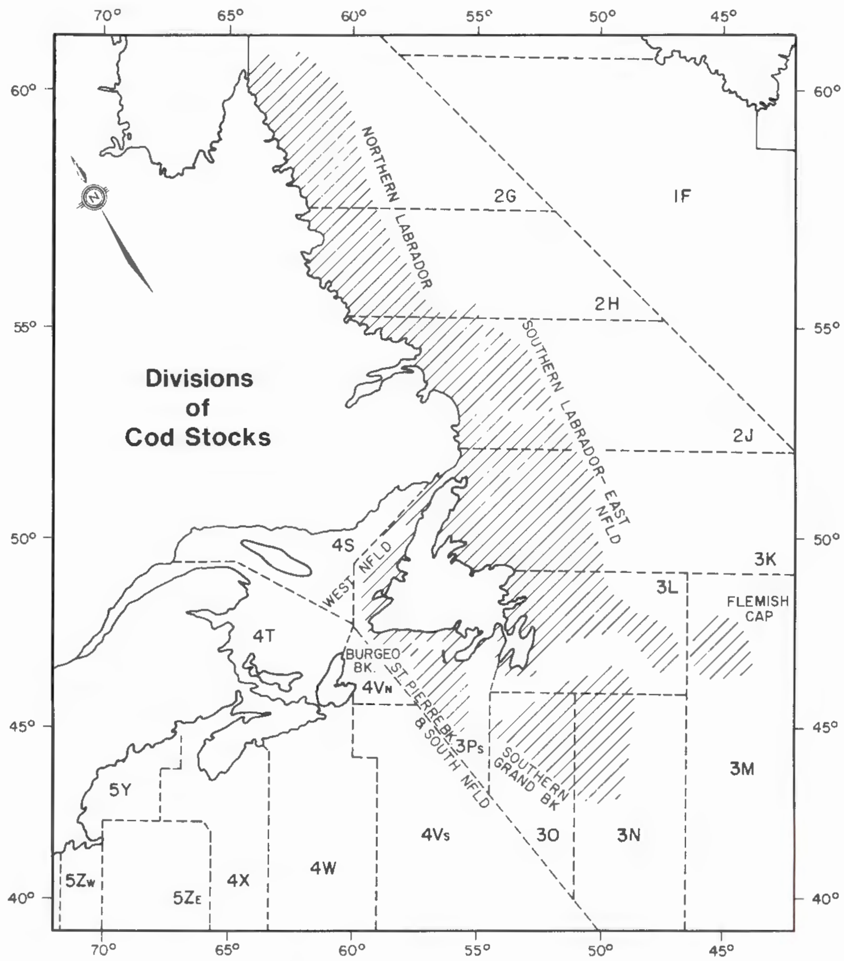
Managing fish on the basis of stocks offers protection against overfishing. For example, if all the cod in Atlantic Canada were managed as a single stock, with one overall quota, trawlers would concentrate their effort on the most accessible fish. This would likely overfish that area and underfish others. Identifying separate stocks allows fisheries managers to match the fishing effort to the size and distribution of the resource.

The annual groundfish plan, which sets out quotas for different fish stocks, identifies more than a dozen different stocks of cod in Atlantic Canada, of which six are accessible to fishermen of Newfoundland and Labrador. The largest of these, often called the "northern cod stock", is in fact a complex of four overlapping groups which spawn on the Hamilton Bank, the Belle Isle Bank, the Funk Island Bank and the northern Grand Bank.

By contrast, all the mackerel which appear in our waters in summer and fall are considered to come from a single stock. The same is true of Greenland halibut, or turbot, which occupy an area from Greenland to the southern Grand Bank.

Fish of the same stock often share common habits, like where and when they migrate to different feeding or spawning areas. One stock may tend to live longer or spawn at a different age than another. And just as one community can prosper while another runs into hard times, different stocks of the same fish species may grow at different rates. Cod in cold northern waters grow much more slowly than those farther south, and often grow several more bones in their spines as they develop. Counting these vertebrae is one of the ways of recognizing fish from the northern zone.

Fisheries managers, who make judgements about fish quotas, seasons and gear restrictions, have to know a lot about the different fish stocks to make good decisions. They rely heavily on the advice of scientists. To offer useful advice, the scientists put a lot of effort into distinguishing between different fish stocks, learning about their habits, studying their numbers and estimating how many may be caught without depleting the resource.



Cod stocks off Newfoundland and Labrador.

Fish of the same species from different stocks often show differences in certain physical characteristics, for example, in the number of vertebrae. Here a scientist examines spinal x-rays of cod to determine the stock of origin.

Here's to the Class of '87

One of the basic concepts of fisheries management is the "year-class". These are the fish of any species that hatch in a given year.

Because the success of the fishery will depend on how many of these young fish reach maturity and how much they grow, fisheries scientists work hard at figuring out how each class is doing. They want to know how many of them survive the many hazards of their early life, and how much weight they add to the total stock.

In short-lived fish species like capelin, where almost the entire catch is the same age, the strength of the year-class means everything. A successful year-class assures a chance of good catches and, equally important, a large spawning population for the future.

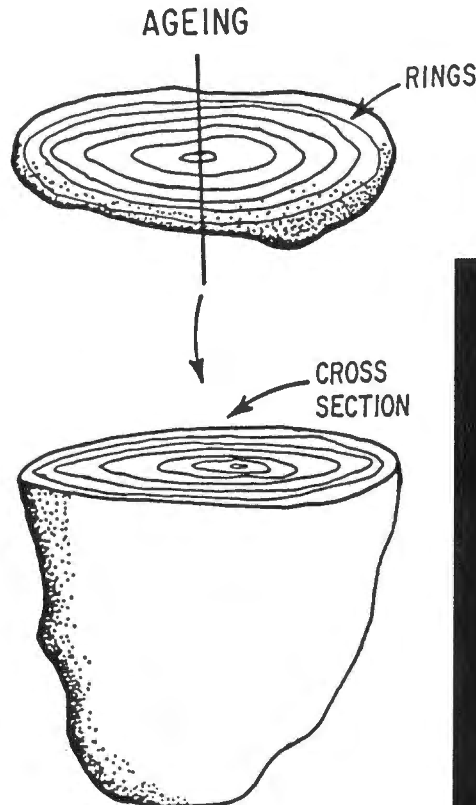
In more long-lived species like cod, where the catch includes fish of many different ages, the strength of a single year-class is less critical. Still, two or three small year classes in a row can make a big difference both to the fishery and to the ability of the stock to recover from heavy fishing.

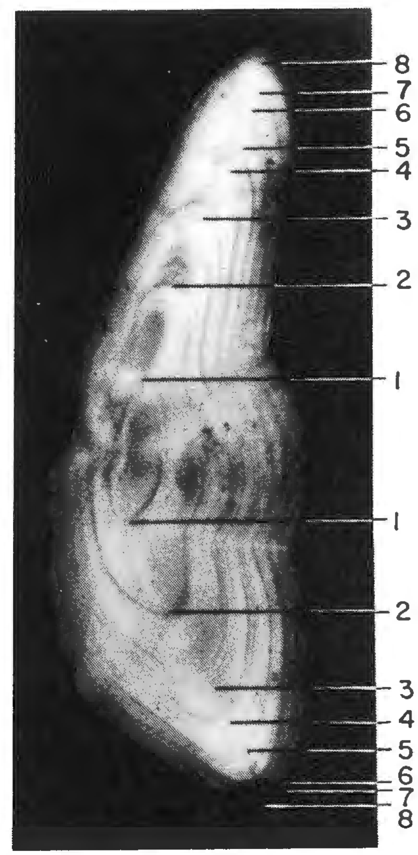
Even though the spawning population may lay roughly the same number of eggs each year, there can be great differences in the numbers which survive to the age of four, when they are first caught by otter trawls and cod traps. Some of the reasons for a poor year-class may include the following:

- ☐ Cod eggs may hatch too early, missing the annual plankton crop. Without an abundance of plankton available when cod larvae have used up their yolk sacs, the cod fry will starve.
- ☐ Even if the timing of the hatch is just right, winds and ocean currents may move the cod eggs or larvae into an area where there is little food.
- ☐ Cold temperatures may delay hatching and slow down the growth of cod larvae so that they remain longer at the surface. There, they are vulnerable to sea birds and larger fish.
- ☐ By the time cod fry settle to the bottom, currents may take them out beyond the edge of the continental shelf, where few would survive.

Even if a large number of a given year-class live to be a year old, they will continue to die from natural causes at the rate of about 20% a year. However, the survivors grow fast enough to more than make up in weight for the loss, so that the total weight of a year-class can keep increasing for about ten years, despite the constant loss in numbers. This makes it important to distinguish between abundance, which means numbers, and biomass, which means weight.

The Earbone Factor





As with a tree, the growth rings on a fish's earbone or otolith tell how old the fish is.

Biomass

To manage the harvest of a given fish stock, fisheries scientists must determine how much fish is out there. The number alone won't do, even if they knew it exactly, because what matters more to the commercial fishery is the total weight of fish in a stock - the BIOMASS. Managers can't manage numbers of fish and fishermen don't sell their fish in numbers - in both cases weight is used. Therefore, although fisheries scientists began by estimating the numbers of fish in the stock at each age and hence the total numbers, and although scientists mainly use numbers to evaluate the status of the stock, these numbers are converted to weight when advice is provided on how well the stock is doing and what can be safely taken.

Recruitment ... Your Fishery Needs You!

Young fish lead a dangerous life. The "natural mortality", or rate of death from natural causes, is so high that few ever live to maturity. Fish make up for this by laying hundreds of thousands, or in some species millions of eggs. Still, it takes only a small change in the environment or food supply to make a big difference to the number of survivors in a new year-class.

This creates one of the major difficulties in forecasting the growth of a fish stock. Even if biologists are able to estimate the size of a stock and the number and weight of fish at different ages, they cannot predict how many of the youngest fish will survive.

One of the best indications is the number of young fish caught by research vessels, which use a fine mesh net in their otter trawls. This catches young fish too small to be taken in the commercial fishery. Annual surveys by these research ships offer the first definite evidence of the abundance of young fish.

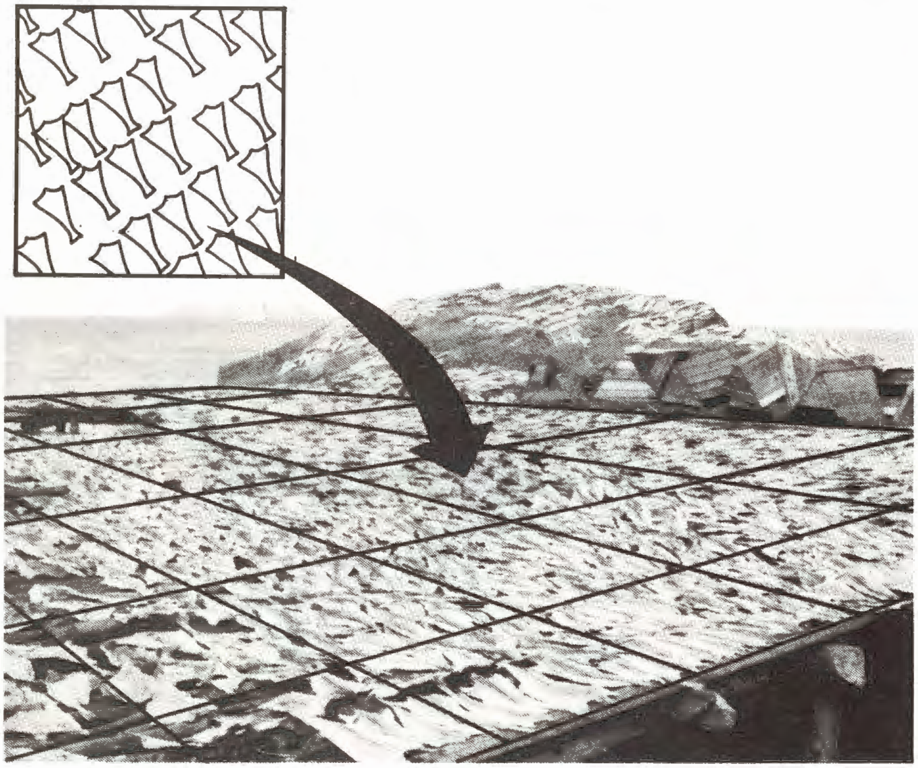
To fisheries biologists, the survival of a year-class to the age when it first enters the fishery is called "recruitment". Because in the end everything depends on the number of these young fish, recruitment gets a very high priority in research.

Several very good or very poor year-classes in a row can have a big effect on the size of a stock and therefore on the size of catches that can be sustained. For example, in 1979 estimates of the size and growth rate of the northern cod stock suggested that within six years the stock would be able to sustain a catch of 402 thousand metric tons if recruitment remained at recent levels. However, surveys in the next two years found that the 1976 and 1977 year-classes — the fish which would reach a catchable size by the early 1980s — were exceptionally poor. Since most fish taken in the commercial fishery are between five and seven years old, these two small year-classes would clearly mean less fish available in the mid-80s than scientists had hoped.

As new surveys continued to confirm that the year-classes in the mid- to late-1970s were poorer than in the 1960s, forecasts of the 1985 catch were lowered each year. In the end, the TAC for 1985 was set at 266 thousand metric tons, or only two-thirds of what had been forecast six years before.

In the same way, several strong year-classes in a row can mean a sharp jump in recruitment and biomass, so that catch limits may be raised. Once again, this has happened with northern cod. Research surveys have confirmed that the year-classes from 1980 to 1982 have been bigger than any since the 1968 year-class. By next year, when these young fish contribute most heavily to the catch, they could increase the biomass or total weight of the stock.

The survival of a year-class of fish (fish born in a particular year) until they are large enough to be caught in a regulated fishery is called "recruitment".



One way of estimating the number of fish in a large area is to make a close estimate of the number in a measured unit or sub-area and multiply by the number of sub-areas in the overall area.

Counting Fish

To understand how research surveys can produce an estimate of the numbers of cod in a stock, imagine trying to work out the number of some other fish which is hidden from view. One example would be the number of trout in a pond.

If you couldn't seine the entire pond to count each trout, you would divide the pond into a number of equal areas, and then very carefully seine the trout in several sections. If you took care to be sure that these sections were typical — for example, if they were scattered in various areas of the pond — you could expect that the results would fairly represent the larger picture. So, if you found 312 trout by closely searching 10 per cent of your pond, you could estimate there were roughly 3,120 trout in the pond as a whole.

Stock estimates based on surveys by research vessels work in much the same way. The vessels trawl at a variety of locations which are chosen to represent the offshore bank as a whole (ie. different areas, different depths). Then the total number of fish can be estimated from the number taken.

Prior to the early 1970s, research vessel stations were organized into a series of lines or transects with fishing stations determined by fixed depth intervals. More detailed stratification schemes where fishing stations are chosen randomly (ie. random stratified) were then developed. (maps, p. 14)

Research vessel surveys provide the following information:

- biomass (total weight of stock)
- abundance (numbers at different ages)
- recruitment (new fish available to fishery)

This information is combined with catch, effort and removal data obtained from port sampling to develop recommended Total Allowable Catches (TACs).

Estimating What's Out There

In managing a fish stock, the big problem is stock assessment, estimating how much fish is there. But how can anyone know?

Fish are not like sheep in a field, which can be counted with total accuracy, or even like caribou, which can be estimated from aerial surveys and photographs. Living beyond the reach of such methods, fish in the ocean cannot be counted at all; biologists can only estimate their numbers indirectly, from information collected from the fish which get caught, or through the use of advanced sonar techniques.

Yet to set catch limits, fisheries managers must have some idea of stock size. Complex calculations from heaps of data are the only way to get it. The estimates are not perfect but they are based on the best scientific methods available and are similar the world over.

Total allowable catches (TACs) can be based on average catches from earlier years. This is a fairly primitive method and was used in the past on minor stocks to "put a lid" on fishing. It is rarely used now.

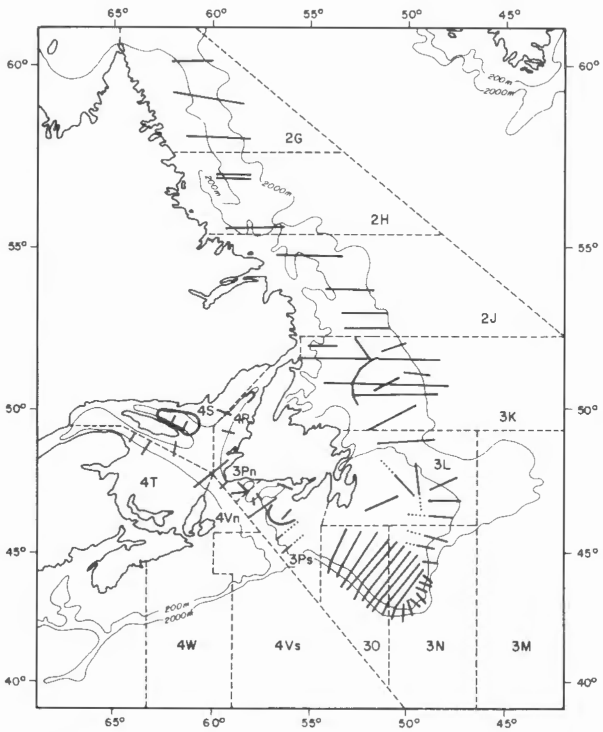
In a fishery where both catches and levels of fishing effort have been recorded for some time, the catch and effort data can be used to generate a "yield curve" which illustrates how much fish can be taken on a sustained basis with various levels of effort. This method may be used to set TACs for a few species such as redfish, where telling the age of a fish is very time-consuming and difficult, or where less biological data is available.

Neither of these first two methods is derived from any firm idea of how much fish is really there.

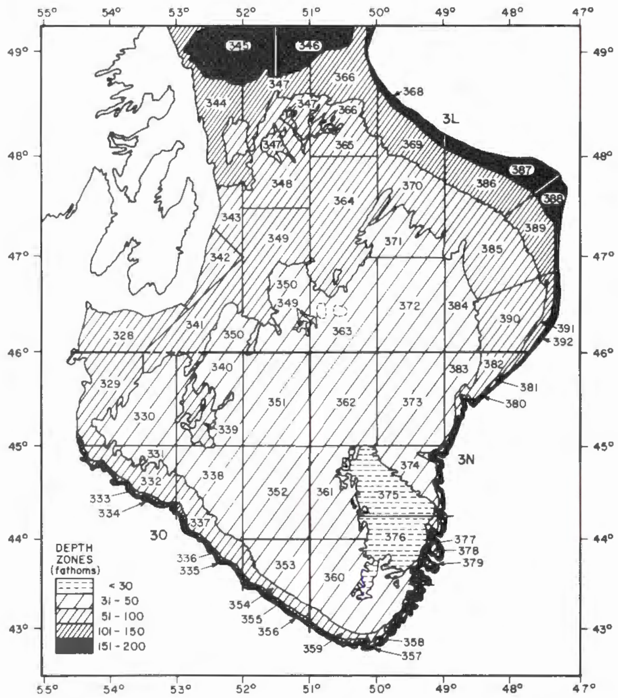
But, where both catch and effort data and a full range of biological data such as lengths and ages are available, biologists can work out not only the total weight, or biomass of a stock, but the number and weight of fish of different ages. In fact, it is from calculations of the size of each age-class that they estimate the total size of the stock.

For most of the species important to the Newfoundland fishery, stock assessments are done every year. Each annual estimate helps to check the validity of earlier calculations. Because the accuracy improves with each new set of data, numbers are revised each year in the light of new information.

It's all a matter of making useful calculations from mountains of information gathered by research surveys and sampling of commercial fish catches. These two sources can produce enough data for two independent estimates of the abundance of the stock. From this, scientists



These lines drawn across fishing areas off Newfoundland and Labrador are 'transect lines' along which research vessels conducted their various surveys before the introduction of random stratified surveys.



Map of the Grand Banks showing varying depth areas down to 200 fathoms. Fisheries scientists use the numbered blocks to randomly select areas in which to conduct surveys; hence "random stratified surveys".

can make their best calculation of the number of fish at each age at the beginning of the year.

Commercial Sampling

The commercial fishery is a major source of biological information. Technicians regularly sample the landings at fish plants, and the Canadian observers on foreign and domestic trawlers in our waters collect similar information on the offshore catch.

These data include details on the length and age of fish taken. In species like cod, the age is revealed by growth rings in the "otolith" or ear bone. (photo, p. 11) Last year, researchers collected about 38,000 otoliths and took length measurements of 314,000 fish in their sampling of the commercial groundfish catch, while observers collected about 425,000 lengths and 4,000 otoliths from the foreign catch.

Calculating a stock size from these data involves computers and complex statistical analyses. The basic steps are these:

- From the samples, biologists work out the average weight of the fish taken during the year. Dividing the total catch of a species by this average weight gives the number of fish caught.
- The sampling produces a clear picture of what proportion of the catch is made up by the different sizes: how many are from 12-14 inches, how many from 14-16 inches and so forth.
- The study of otoliths taken from thousands of the same fish gives the age for each size.
- Using these age-and-length data, and the estimate of the total number of fish taken, biologists break down the catch into the number of fish at each age.

All these steps involve information taken from the fish actually caught. The next step involves moving from these data to what it can tell us about fish still in the sea.

- Biologists now estimate the proportion of fish caught at each age. For example, has the fishery taken 10%, 20%, or 30% of the eight-year-old cod on the southern Grand Bank? They do this by applying standard statistical techniques designed to study fish populations.
- Once they have made this estimate of each age-class, they calculate how many there must have been at the start of the year to produce that catch. For example, if fishermen took 40,000 eight-year-old cod, and this represents 23% of that age-class, then there would have been about 175,000 eight-year-old fish in the stock when the season started.
- Performing similar calculations for each age-class produces a "population numbers table", showing the total number of catchable fish and the number at each age.

Yet, an assessment based on a study of fish caught by fishermen is only a partial picture, because it gives no indication of the number of younger fish too small to be taken in commercial gear. It can provide an estimate of the number of fish of spawning age, which is extremely important, but, that is still a far cry from knowing how many of their offspring will actually survive to a catchable size.

Without some clues to the abundance of the younger year-classes, scientists have no way to forecast future landings and no way to be certain that current catch limits will leave enough spawning stock to maintain a stable population.

Research Surveys

To get around this and to help complete the stock picture, research vessels conduct systematic surveys of the offshore banks. These surveys have two benefits:

- By using a smaller mesh than the commercial fishery is allowed, they can take samples of the entire fish population, not just those above a certain age.
- By systematically trawling at all depths at various locations, they provide the data for a second calculation of the size of the stock, to compare with estimates made from the commercial sampling process.

Logbooks

In addition, the logbooks of the voyages of commercial vessels allow scientists to monitor catch rates, or catch per unit effort. Catch rates by themselves are not a measure of stock size, but a clear trend in fishing success over a long period can help to confirm estimates gained by other means, or suggest problems that need more research.

Summary

Recommended TACs are developed from biological and statistical analyses dependent on the following inputs:

- ☐ biomass, abundance and recruitment estimates (obtained from research vessel surveys)
- ☐ catch, effort and removal data (collected from commercial sampling)

Resource assessments developed in this manner provide the scientific basis for management of the fisheries resource for its sustained economic utilization.

In doing stock assessment, researchers have to estimate the total weight of the fish in a stock, as well as the number of fish. Here a selection of fish taken in a research survey are being weighed.

Ocean Climate

People tend to think of the ocean as a huge, uniform mass. If we lived right in it, rather than around the edges of it, we would see it more clearly.

Instead, humans live at the bottom of an ocean of air. We are conscious of the huge range of changes which affect it, because most of them also affect us. We have hundreds of words for the differences in our weather, and there is probably no other subject which gets more of people's attention.

The ocean is just as complex and changeable, and it goes through many of the same kinds of changes. Water is more than 700 times heavier than air, so it takes a lot more energy to move it, yet much of the water in the ocean is moving all the time. Moving masses of water affect the ocean environment just as moving air masses — winds, warm fronts and cold fronts — affect our weather. Similarly, water is much slower than air to warm up and cool down, but its temperature does keep changing. These changes affect marine life in some of the same ways that weather affects life on land.

The atmosphere and the ocean are not only similar; each can profoundly affect the other. For example, some of the most basic features of our climate are determined by the Labrador Current, washing much of our coast with very cold water, and by the onshore winds which often blow across it. In the same way, changes of weather and climate can produce large-scale changes in the temperature and circulation of ocean water.

Some of the most important fish species in Newfoundland and Labrador are at the edge of their range in our waters. Atlantic cod, haddock and yellowtail can't go much farther north, and capelin don't go much farther south. So, when the conditions of the water keep changing, this can make a big difference to the numbers and movements of fish.

Scientists have long known this, but fisheries scientists have just recently begun to study the role of the "ocean climate" in the abundance and life cycle of different fish species.

One of the most fundamental features of our ocean environment is a layer of very cold water within the Labrador Current. This cold layer is water which has drained from the basin of the Arctic Ocean. Drifting slowly along the Labrador coast, it gets sandwiched between a deep layer of warmer water from the West Greenland Current and a surface layer warmed by sunlight and river run-off. At -1.5 degrees Celsius, this cold layer can kill fish. It develops in February on the inner half of the Continental Shelf, and gets larger and colder through the spring and early summer, as frigid Arctic waters reach the Grand Bank. The volume of this mass of cold water keeps increasing till about mid-summer, then begins to decline as it warms up. The layer of below-zero water is normally gone by November.

This is an annual and fairly regular cycle, but the maximum size of the cold-water layer appears to follow roughly a ten-year cycle as well. Scientists studying these fluctuations believe they are related to the severity of winter in the high Arctic, and to the position of the Icelandic low, a winter low pressure system in the North Atlantic. Normally this low shifts westward in early spring, generating southerly winds for much of the province. But, when it hovers around Iceland instead of moving west, it generates wind patterns which pour frigid Arctic air down upon us. And when those winds are strong enough to push more icy polar water into the Labrador Current, fish also find their environment getting chilly.

These changes in weather patterns and ocean currents will get a lot more attention in future, because the cold layer is now believed to interfere with cod migration. The way it shifts from one year to another may account for some of the wide fluctuations in the abundance of cod inshore. Bays and headlands that normally abound with fish can be cut off from migrating cod by a deep layer of cold water.

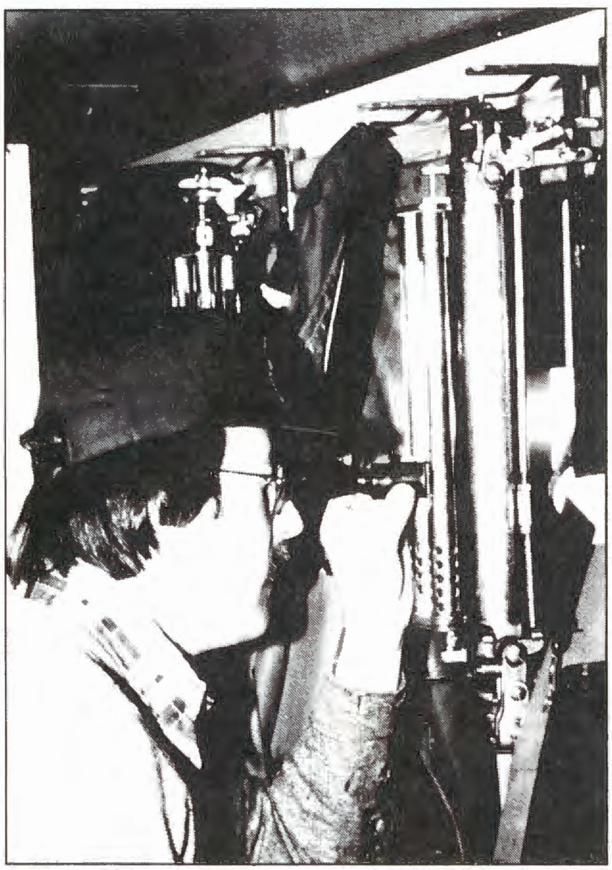
Water temperature appears to affect the numbers of young cod as well. In many cases, warmer water means more abundant cod larvae, but scientists aren't sure why. It could be that adult fish use less of their stored fat just to stay alive, and so are able to produce eggs in better condition. Or the fertilization of eggs during spawning may be more successful in warmer water, or more of the fertilized eggs could live to hatch.

On the Flemish Cap, an international research project has studied water currents and the movement of redfish larvae for nearly ten years to see if currents affect recruitment, or the survival of the young. It was thought that in years when the Gulf Stream was especially strong, it would wash a lot of the larvae off the Flemish Cap. If this was true, measuring currents could be a shortcut to predicting recruitment, which is one of the keys to managing a fish stock.

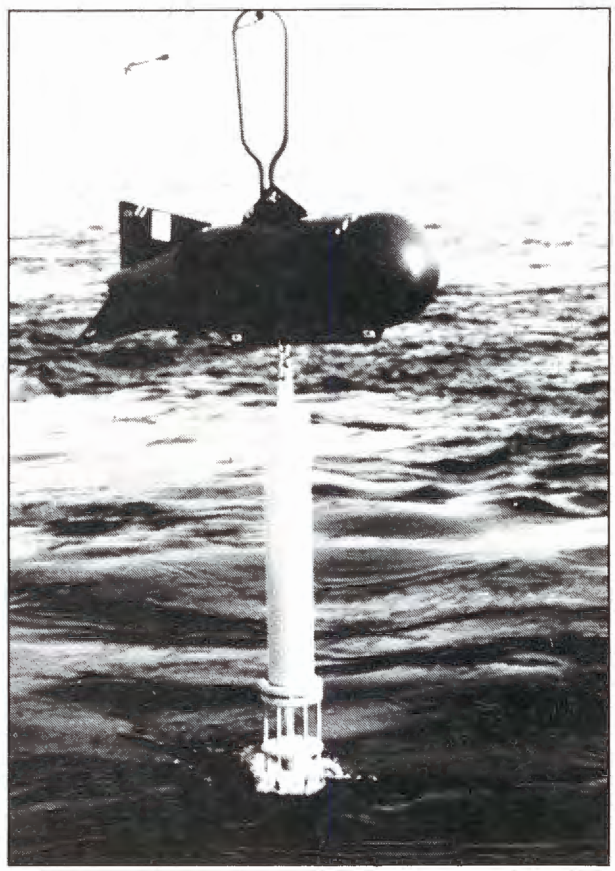
However, the larvae don't seem as helpless as was thought. They appear to have some ability to hold their position despite the current, so that watching currents alone may not tell us much about recruitment.

From 1973 to 1986 scientists have recorded the position of Gulf Stream warm core rings (features with circular flow patterns a bit like whirlpools), the shelf-slope front, and the Gulf Stream from the mid-Atlantic Bight to the Grand Banks, using satellite imagery. They were interested in determining if the entrainment of shelf water by warm core rings reduces recruitment of groundfish. Using data on 17 groundfish stocks, there was evidence that warm core rings reduced recruitment in 16 of those stocks. They concluded that Gulf Stream warm core ring activity is assisted with a significant reduction in recruitment of groundfish stocks in the Northwest Atlantic.

Research like this depends on the systematic collection of data over a long period. Measurements of water temperature, currents and salinity or salt content can be taken during cruises by DFO's research trawlers, but ideally should be taken regularly at the same location for as long as possible. Since Confederation, research vessels entering or leaving St. John's harbour have stopped to make these measurements at Station 27, a position near Cape Spear. With 20 to 40 observations each year since 1949, Station 27 data present an unusually thorough picture of changes in the ocean climate.

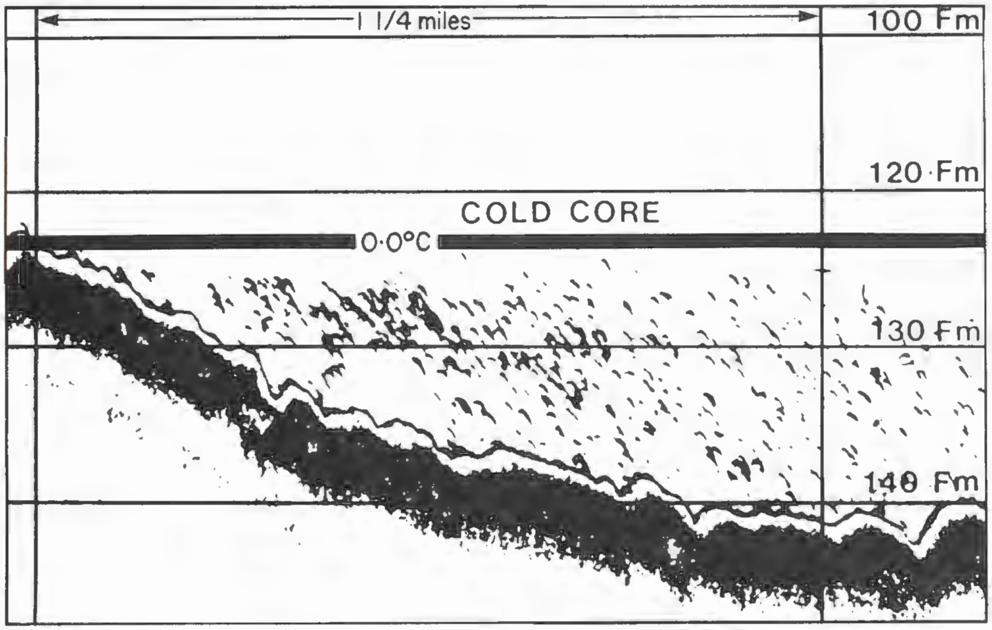


A science technician reads water temperatures in a series of reversible thermometers that have been immersed at various depths.

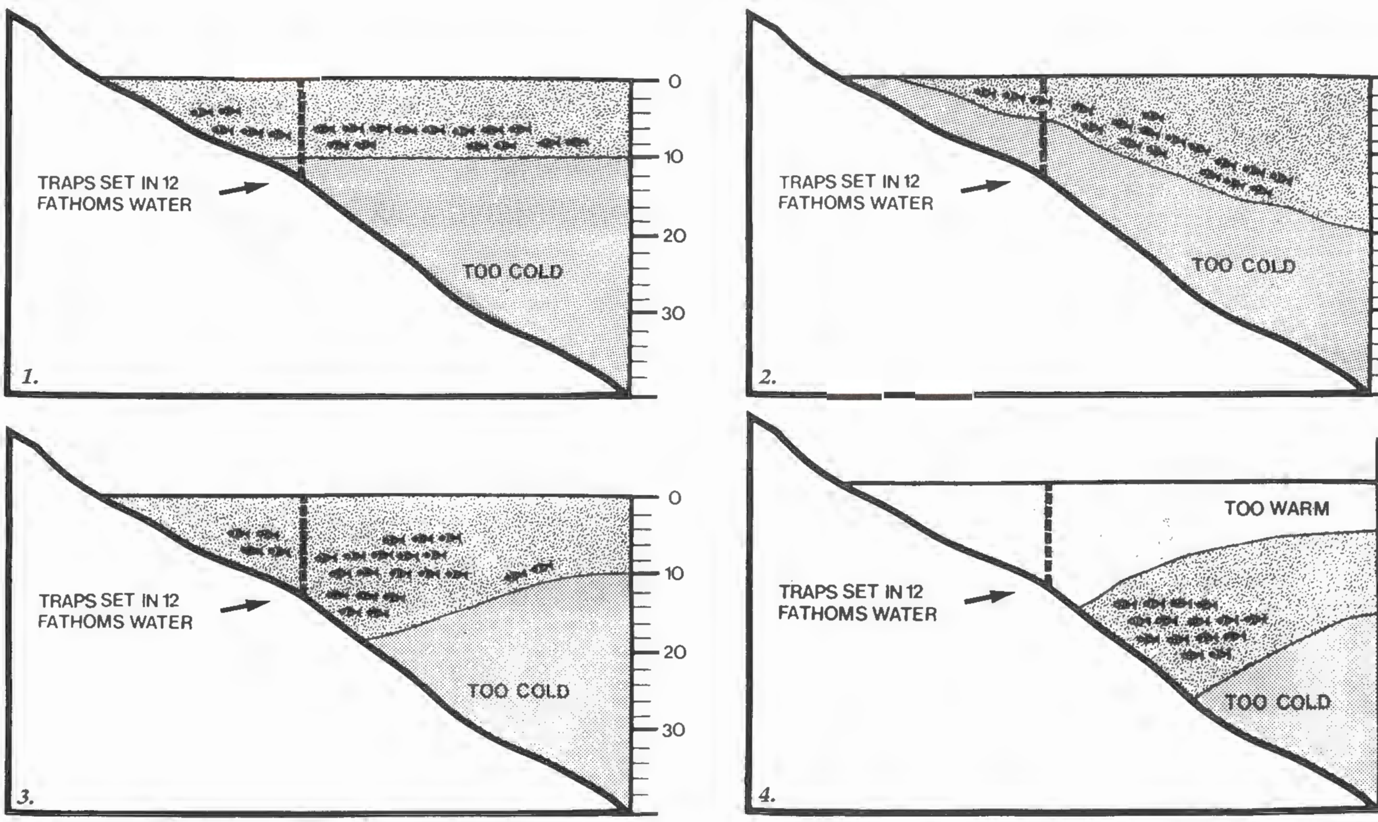


A current meter used to measure the speed of ocean currents at various depths.

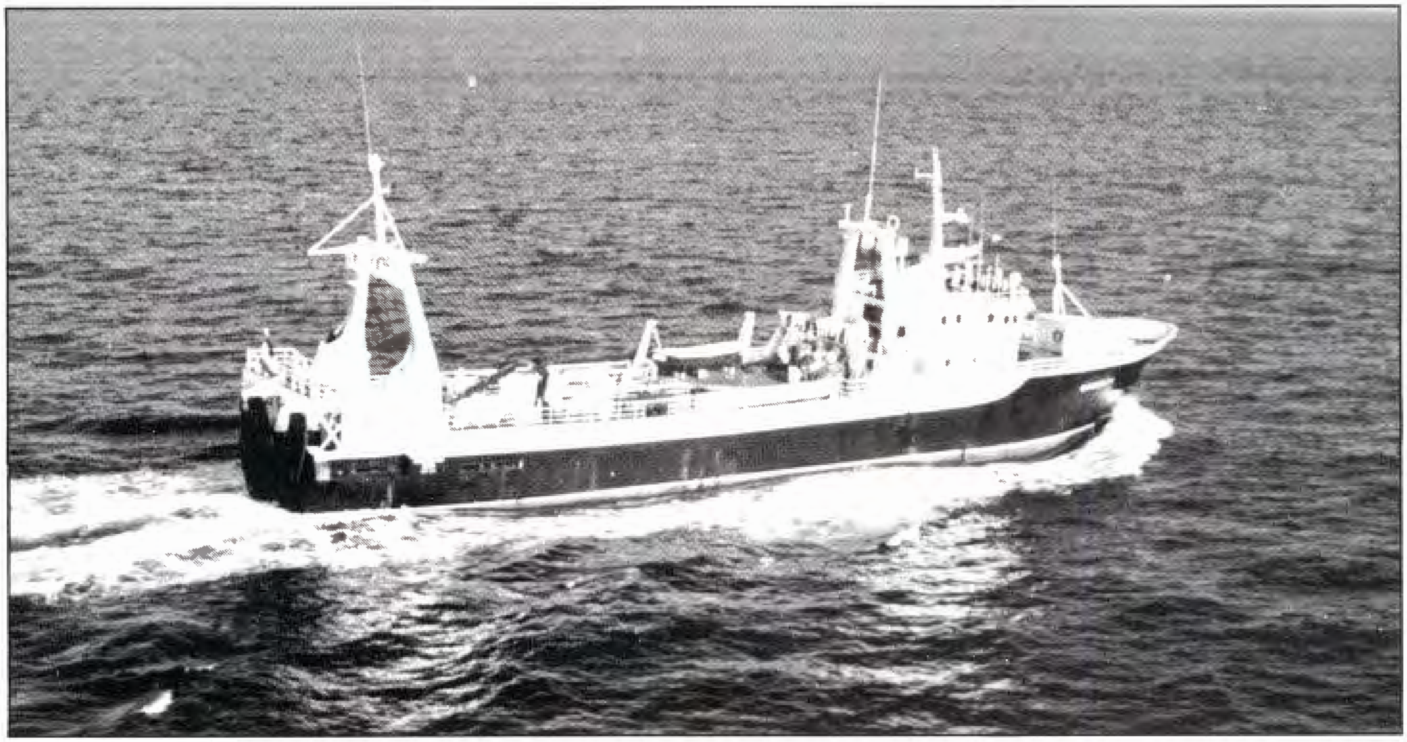
Sounder Surveys



A sounder has detected a large school of fish lying in warmer depths beneath the cold core of the Labrador current.



The trap fishery and other inshore fisheries can be drastically affected by local water temperature conditions, which in turn are determined by prevailing wind and air temperature conditions. Illustration (1.) above shows a typical June situation in an area having a late, cold spring with light variable winds prevailing. Surface water has warmed up enough to a depth of about 10 fathoms to allow cod to come close inshore at shallow trap berth depths. In (2.), prevailing offshore winds have driven the suitable water layer off the shore, and cold water coming to the surface is severely restricting the area in which trap fishing might be successful. In (3.), prevailing onshore winds early in the season has had an opposite effect, pushing the suitable 0°C to 4°C water layer onto shore, deepening it and expanding the potential for good trap fishing. Finally, in (4.) we see a late-season situation where prolonged warm weather and onshore winds have combined to produce close to shore in trap berth depths a layer of water too warm for cod; the fish stay below it out of reach of the traps.



It's a Matter of Effort

Fishermen know all about effort. Fishing is a hard business, and for men hauling a cod trap or beating the slub off a salmon net, perhaps the hardest part is knowing the net might be empty no matter how much effort they put in.

Fisheries scientists know about effort, too, but they don't know nearly enough about the effort of inshore fishermen.

For a scientist, effort is not hauling and grunting. Effort is something to measure, as a step toward measuring success in the fishery. Since one of the main goals of fisheries management is the success of fishermen, anything that helps to measure success is useful.

Obviously the catch itself is one measure, but landings alone don't tell the whole story. Landings per fishermen or landings per vessel come closer, but not close enough. If fishermen must use twice as much gear or burn twice as much fuel to land the same catch, the fishery may be in trouble and landings alone won't show it.

The real measure of success is how much a man gets back for what he puts in, or how much fish a given level of effort will produce.

In the offshore fishery, getting a handle on effort is fairly easy (although the details are always discussed at great length at scientific meetings). Trawlers' log books show how often the trawl was set, and where, and for how long, and the landings show the result. For the sake of the scientists' calculations, one set of the trawl can represent a unit of effort, and how much fish it brings up in one tow is a fair measure of fishing success. The figure may have to be adjusted for things like how long the gear was in the water and how fast it was towed, but this is more straightforward than for the inshore.

With this information, scientists can fairly easily work out the catch rate, or "catch per unit effort", and use this as a measure of how well the fishery is being managed. Catch rates, combined with information from other sources, also help biologists estimate the size of a fish stock and thus to provide accurate advice on which the managers can make decisions about quotas for future years.

Inshore, it is much more complex. There are thousands of boats, not just a few dozen, and many thousands of fishermen. Moreover, most of them fish for several different species, and use several types of gear. The length of the inshore fishing season also varies by species, from one region to another, from year to year and from one man to the next.

All this makes it maddeningly difficult to come up with a way to measure total inshore fishing effort. Yet without some measure of effort, biologists are unable to fully understand what is happening in that part of the fishery.

For example, it is currently impossible to precisely interpret the recent slump in inshore cod landings on the northeast coast. Are just as many fishermen fishing just as long and hard with just as much gear as they used a few years ago, or have many of them turned to other options? Individual fishermen may fish as hard as ever, and certainly they know how well their efforts have paid off, but no-one can know whether the inshore cod-fishing effort as a whole has increased or declined in recent years, or by how much. Without knowing this, it is impossible to assess the severity of the decline in inshore catches.

Several things are clear. One is that catch rates in the offshore fishery have been improving every year. Catch per unit effort calculations confirm that the stock is still growing. Another is that heavy ice, is delaying the fishing season in some years, can reduce fishing effort. And if many cod fishermen turn to capelin in June and early July, as hundreds on the northeast coast did in 1985 and 1986, this can also mean a significant change in the effort directed at cod. In a 1985 study of factors influencing the availability of cod in Conception Bay, about 40% of the reduction in cod landings in that year could be attributed to diversion of effort from the cod fishery to the capelin fishery.

One other thing is clear, and that is the need to find more accurate ways to measure inshore fishing effort. It won't be easy, and whatever system is devised, it will need the co-operation of fishermen themselves.

Measuring fishing effort in the offshore sector, where numbers of vessels and gear types are relatively few and complete operational logs are kept, is comparatively easy; but a tremendous variety of vessels, gears and other factors make effort measurement in the inshore sector a nightmare of complexity.

Peer Review

How can we be sure the people who set fishing quotas know what they are doing? Sure, management decisions are based on scientific advice, but how do we know the advice is sound?

The answer lies in the nature of science itself.

Science is a curious trade, because scientists thrive by giving away the results of their work. A fisherman who did that would be bankrupt in a season.

Scientific knowledge is like a huge pool which belongs to everybody and which grows as new knowledge is added. But not just any new information is dumped in. Scientists are cautious, skeptical folk, and each new contribution to the pool of knowledge is closely examined by other experts in the same field.

It's a process of quality control, like fish inspection.

Scientists rise in their profession by the number and importance of the contributions they make to the pool of knowledge. So a scientist who discovers something no one else knew before - some new detail about the feeding habits of cod or the way unusual weather patterns may affect the survival of young capelin - doesn't just keep it to himself. He writes a report to share this new knowledge with all the other biologists and others who may be interested in the same things.

What is more important, he doesn't just announce the results; he carefully describes how he reached the conclusions he did - how he did his research, what the conditions were, what data he gathered and how he interpreted the results. He has to do this so thoroughly that any other fisheries biologist studying his report can judge whether his conclusions are sound.

In this process, sloppy work soon gets discarded. And the same strict standards apply whether the information is some new discovery or just raw data - the average number of bones in the spines of cod on the Funk Island Bank, or the daily water temperature at various depths from a station off St. John's. This raw data alone may seem less important, but could become an ingredient of important new discoveries in the future, so it must be reliable.

As the pool of knowledge grows, each scientist can draw on the discoveries and information supplied by others. Knowledge that may have cost some scientist a lifetime of work is available to a newcomer just entering the field. As one famous scientist said, "I'm not taller than those who came before me. But I'm standing on their shoulders."

The system is not perfect. Some of what we think we know today may be shown to be only partly true tomorrow. But the process is above all cautious. There are few reckless conclusions.

A big part of the system is "peer review." In the case of fisheries science in Atlantic Canada, much of the screening takes place in groups whose names read like a mug of alphabet soup. There is CAFSAC, NAFO and ICES, and a swarm of subcommittees with names like STACFIS, STACREC and STACPUB.

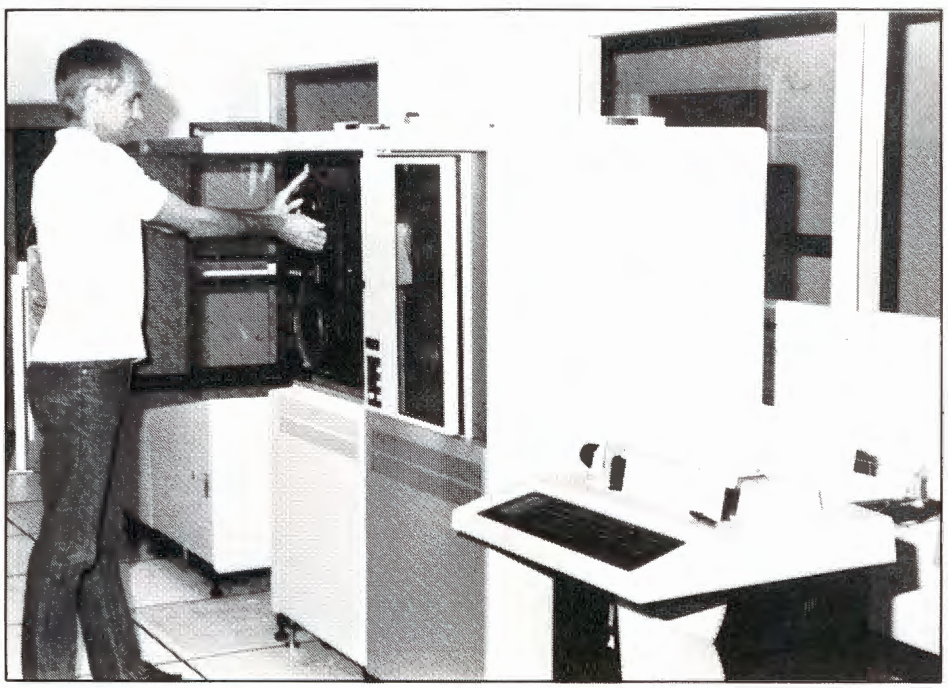
These groups evolved to meet the challenge of providing the scientific basis for management of fish resources in the North Atlantic, where thousands of boats from dozens of nations pursue the same fish.

Canada, whose fish resources are the envy of most fishing nations and whose fisheries scientists are among the best anywhere, plays a leading role in the work of these organizations. They, in turn, serve as a forum in which Canadian scientists sub-

Statistics

Every four years, Statistics Canada does a nation-wide census, counting Canadians and gathering data on everything from family incomes to the number of rooms in the average house. In stock assessment, fisheries scientists do a kind of fish census every year. Here are some of the kinds of statistics they need in order to provide sound advice on the management of a fish stock:

- ☐ The abundance of the population. This is the number in the population, as distinct from the total weight in the population.
- ☐ The biomass, or total weight of a fish stock.
- ☐ Natural mortality, which is the rate at which fish die of natural causes, from disease, old age, parasites or predation - being eaten by other species.
- ☐ Fishing mortality, which is the rate of death as a result of fishing. Of the total number of fish in a stock, what proportion is caught?
- ☐ The mortality at different ages, as a result of both fishing and natural mortality. Biologists want to know, for example, how many of the six-year-old cod in a stock will not live to reach age seven.
- ☐ Catch rates, or catch per unit effort. This is a way to measure fishing success.
- ☐ The growth rate of a fish stock, or how much weight the fish put on in the course of a year.
- ☐ Year-class strength, or how many fish there are at each different age.
- ☐ Recruitment, or how many young fish enter the commercial fishery for the first time in a given year.
- ☐ Surplus production. This is weight added to a stock by the growth in weight of individual fish, plus new recruitment, minus weight lost by natural mortality.



Scientists use computers to analyze the mountains of statistical data they collect in fisheries research.

mit their work to the scrutiny of leading world experts in the same fields.

In the case of a stock assessment, the peer review process is complex. Each of the steps involved is a safeguard against poor research or hasty conclusions.

In an assessment of the capelin stock within NAFO division 3L, for example, the work would pass through a two-tier review process. In the first, a standing committee of scientists who specialize in assessment science would review the work, challenging some points and insisting on clarification of others. When the assessment finally satisfied this committee, it would be referred to NAFO's Scientific Council, composed of scientists who again would check it closely and perhaps insist on improvements before they gave it their approval.

At this point, NAFO would pass the assessment on to the Government of Canada. The assessment would describe the current state of capelin stocks in that area and advise on a catch associated with whatever level the managers wished to fish. It would still be up to Canadian management authorities to decide on the TAC. They may have to consider a host of other factors before arriving at a figure, but they would make their decision knowing they were drawing on the best scientific advice available.

Getting Advice

When Canada extended fishing jursdiction out to 200 miles in 1977, we claimed responsibility for the marine resources within a vast new area. The whole process of fisheries management had to be overhauled to meet the scope of this challenge.

Canada was determined that the disasterous overfishing of earlier years would not be repeated. This meant that management decisions would have to be based on good science, and lots of it. Managers had to be able to foresee the results of the various choices they faced in setting things like catch limits and seasons.

Today, scientific advice on managing Atlantic Canada's fish stocks comes largely through one of two bodies, depending on whether or not the stock is wholly within Canadian waters. These are:

☐ CAFSAC, the Canadian Atlantic Fisheries Scientific Advisory Committee

☐ NAFO, the Northwest Atlantic Fisheries Organization.

CAFSAC, formed when Canada extended her fishing jurisdiction, provides advice on the management of species within the 200 mile zone. NAFO is responsible for management of stocks outside it. Fish, however, recognize no such boundaries, so the actual division of responsibility is as follows:

1. NAFO has responsibility for stocks entirely outside our 200 mile limit, like those of cod, redfish and American plaice which live out their entire lives on the Flemish Cap. NAFO alone sets the total allowable catch and the quotas on these fish.

2. NAFO also sets TACs and quotas on stocks which overlap the 200 mile limit, like cod, redfish and yellowtail on the southern Grand Bank.

3. NAFO provides scentific advice on the management of some stocks which overlap the territorial waters of Canada and another coastal state. Two examples are turbot and shrimp in Davis Strait, between Canada and Greenland.

4. NAFO provides advice on stocks within Canadian waters (at Canada's request) in cases where Canadians have little fishing experience and European fishing nations have much more. One example is turbot on the northeast coast. Canada alone, however, sets the TACs and quotas on such stocks.

The reason for seeking outside advice on these stocks is that offshore fishing itself provides much of the data on which stock assessments and management decisions are based. In the case of northern cod, Canadian trawlers did not really enter the picture until after 1977, when the foreign effort was severely cut back. Now, after a decade of Canadian offshore catches, Canada has the data to assess this stock herself and began doing so for the first time in 1987. Prior to this, Canadian scientists participated in the stock assessment, but did so through the working committees of NAFO. Now stock assessment, as well as management of northern cod, is entirely in Canadian hands.

With the exceptions noted above, scientific advice for all other Atlantic fish stocks within Canadian waters comes through CAFSAC.

NAFO and CAFSAC committees spend many weeks each year reviewing the scientific reports which form the basis for decisions by managers. The advice contained in the reports is publicly released and is received by senior DFO officials in the Atlantic Region, who hold extensive consultation with clients. The advice is then referred to the federal Minister of Fisheries and Oceans, who has the final authority for catch and quota decisions.

In addition to CAFSAC and NAFO, Canada is a member of ICES, the International Council for the Exploration of the Sea, based in Copenhagen. ICES provides its European members with advice on fish stocks in the Northeastern Atlantic. Canadian scientists participate in studies of the West Greenland salmon fishery, which takes some Canadian salmon, and in studies of harp and hooded seals. They also serve as members of most ICES working groups and contribute to the exchange of ideas among North Atlantic scientists.

Most is not Best

The more fish you take from a fish stock, the harder the rest are to catch.

This principle is behind what is probably the most important shift in fisheries management policy other than Canada extending fisheries jurisdiction to 200 miles in 1977. This was the abandonment of catch limits based on "maximum sustainable yield". Usually shortened to MSY, this approach was aimed at landing as much fish as a stock could continue to supply.

What's wrong with that? The problem is that as you approach the maximum, the total catch rates for all decline (in proportion to any increases in effort) and the cost of fishing increases rapidly.

The usual rule now is to set the total catch below the maximum sustainable yield. There are many benefits, but the biggest is greater efficiency — catching a little less fish with a lot less effort. With some fish stocks, present catch limits allow the fishery to land up to 90 per cent of the maximum sustainable catch with only about 65 per cent of the effort.

Other benefits of limiting catches below MSY are that fish will be bigger and the population will be more stable from one year to the next, providing a more reliable catch.

To see how this works, imagine a fish stock which has never been fished. Such a "virgin stock" is in balance with its environment. The weight of fish which die from various natural causes is more or less matched by the addition of new younger fish and the growth of the existing fish. Limitations of food supply, living space, etc., maintain this balance. Growth, the rate at which new weight is added to the stock, is zero, because the biomass is already in balance with the environment and will not get any bigger.

For the lucky fishermen who first begin to harvest this stock, catches are tremendous. As word gets around, scores of other fishermen flock to join them. For the first few years their catches remain very large, and a high proportion is old, big fish. As these disappear they are replaced by younger fish, which grow quickly now because they have less competition for food.

After a few years of heavy fishing, the size of the stock is down somewhat but its growth rate is now high. The stock is trying to rebuild, and the spawning population is still large enough to add young fish faster than the old ones are caught.

However, as the catch keeps rising, the average age and size of fish in the stock keep declining every year. So do fishermen's catch rates — the amount of fish they can land with a given level of fishing effort. In a few more years, as the catch removes more of the spawning population, the growth rate starts to level off until the annual growth barely keeps pace with landings.

This is the level of maximum sustainable yield. It amounts to harvesting as much as the growth rate will support. If nothing else mattered but the size of the catch, this would be the best way to manage this stock.

However, other things matter a great deal. We do not have perfect information, perfect enforcement, or perfect management systems. Long before landings reach the maximum level, the cost of fishing goes up and the average size and therefore the value of the fish goes down. When the goal of fisheries management is to make the best use of the resource, a level of landings well below the maximum offers more benefits.

For the fish stock itself, a lower total catch means more older fish. A larger stock spreads out more, which helps to cushion it from the impact of any severe problems of water temperature, food supply or overfishing in a given area. In the same way, having more large fish in a variety of ages, spawning over a wider area and perhaps also over a longer period of time, should increase the survival of larvae and fry. A year-class is more vulnerable if all the young are massed in a small area.

These benefits to the fish stock pay off for fishermen in terms of higher catch rates, more large fish and a more stable resource. Moreover, the abundance of larger fish pays off at several levels — in higher prices to fishermen, lower processing costs and more of the by-products like tongues, cheeks, livers and roe which are available from large fish.

In the Canadian fishery, the days of maximum sustainable yield are gone. Present management strategies are aimed at optimizing economic and other returns to the industry and ensuring better overall management.

What Is $F_{0\text{-}1}$?

This curious phrase "$F_{0\text{-}1}$" is at the heart of Canadian and NAFO fisheries management these days, but many scientists would sooner have a cold bath than try to explain it.

The basics are simple enough. Think of it as the level of fishing effort beyond which catch rates start declining sharply for everyone.

With cod it's about 16 per cent. That is, when a cod stock is fished at the $F_{0\text{-}1}$ level, fishermen are taking about 16 per cent of the fish each year. With American plaice the $F_{0\text{-}1}$ level is about 20 per cent.

In species like silver hake, which grow fast and die young, you can catch more than 20 per cent, knowing most will die anyway.

With longer-lived species like redfish (which commonly live to 40 years of age) you can afford to leave more of them in the water, knowing most of them will still be there next year and they'll be bigger.

To get right to the heart of the matter, $F_{0\text{-}1}$ is the level of fishing effort at which adding one more boat would result in increasing the total catch by only 10% as much as the very first boat to fish that stock.

Imagine, once again, a stock which has never been fished. The first boat on the scene will have a wonderful catch rate. As more boats join it, the total catch increases but the success of each boat declines, because of the reduction in the population of fish. At some point, the incremental catch of the latest boat to join the fleet will be only one-tenth that of the first one.

At this point, the stock is being fished at the level of $F_{0\text{-}1}$. The stock could stand a heavier catch, but the extra fish would hardly be worth the added cost and effort. It wouldn't make economic sense to add more vessels.

$F_{0\text{-}1}$ is a useful idea in fisheries management because it does two things the old "maximum sustainable yield" did not. It takes some account of the economics of fishing and it leaves a wide margin of biological safety. Stock assessment is a young science, still struggling to refine its techniques. The results of error would be much more serious if stocks were being fished near their estimated limit.

Biologists have found, on occasion, that they have over-estimated the abundance of one fish stock or another. The reasons are unclear. Since the stock was smaller than scientists thought when they set the TAC each year, fishermen may have been taking a larger share than anyone realized.

If the fishery had still been operating under the old system, with TACs based on the maximum sustainable yield, the result of such an error would have been very serious. But with TACs based on a fishing effort of $F_{0\text{-}1}$, there was room to manoeuver. Even catches of 30%-40% of the stock still left plenty to spawn, and the stock has kept rebuilding.

The Diet of Cod

Examining the contents of a cod stomach, as many fishermen do, can tell you what the cod ate over the last few days. Studying thousands of stomachs collected from fish of different ages, at different seasons, from different areas and different years, as some fisheries scientists do, can reveal much more.

One of the chief goals of this research is to learn whether, as many fishermen believe, cod are so dependent on capelin that the capelin fishery has an effect on cod stocks.

In summer, of course, cod feed heavily on capelin near shore. Whether they do the same in winter seems to differ from one area to another. In northern waters like the Hamilton Bank, cod feed very little in winter, whereas on the northern Grand Bank they feed intensively on capelin. The major prey overall on the southern Grand Bank is sand launce.

But cod are opportunists and will eat almost anything when it is available. Where capelin are scarce cod may turn to shrimp, crabs, or squid. American plaice turn to things like sand dollars and brittlestars, while turbot seem prepared to go hungry rather than eat these sea-bottom species.

The population of a shortlived species like capelin can swing between wide extremes. Depending on the survival of a year-class, there can be many times more capelin one year than another. So if cod were not prepared to eat many other species, they would have some lean times.

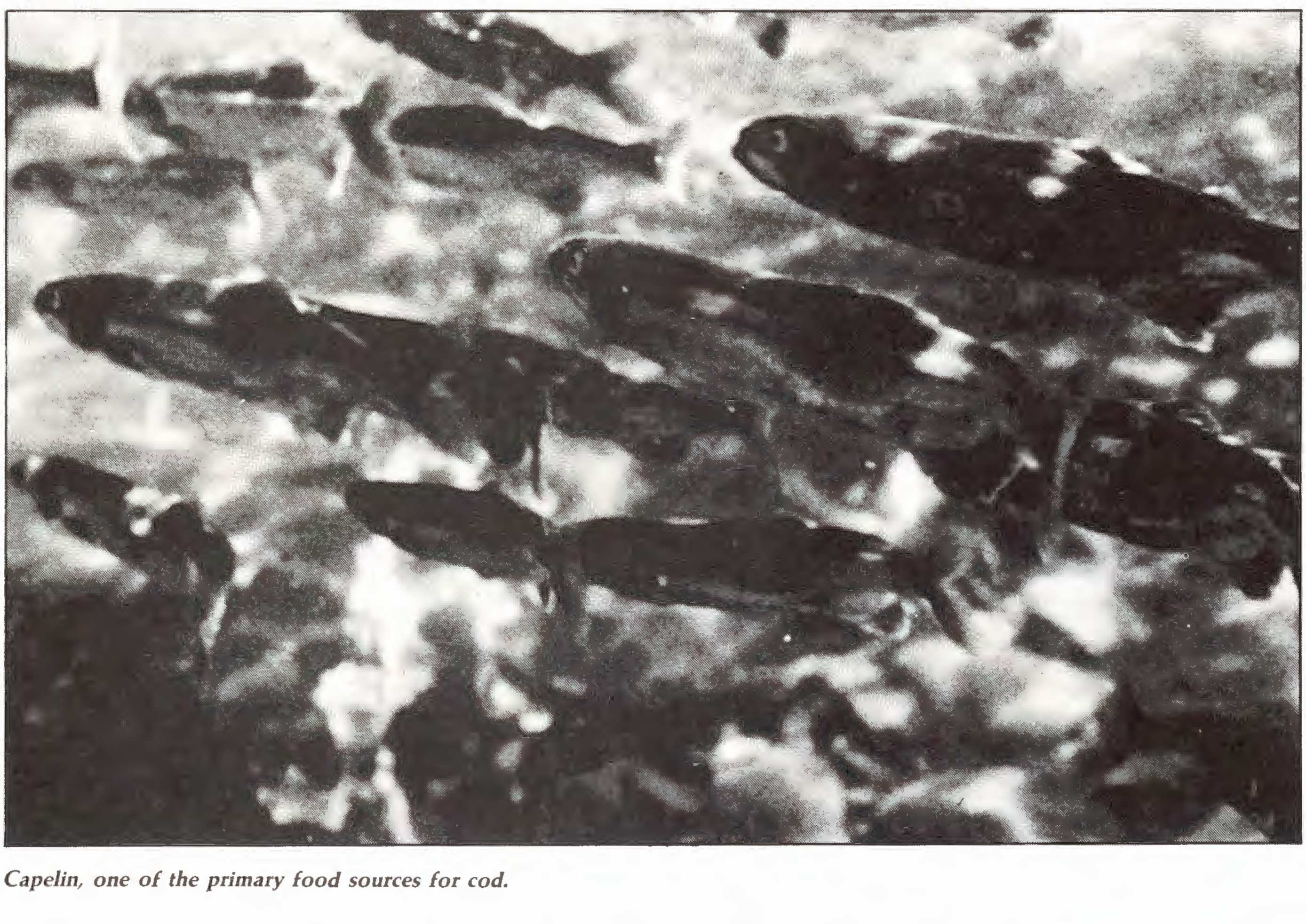
Scientists want to watch several complete cycles of capelin abundance and decline, and study the growth, migration and feeding habits of cod over the whole period. Then, maybe, they'll know whether to be more careful or more relaxed about the effects of the capelin fishery on cod stocks.

Cod and capelin are not the only two species where both the predator and the prey are important to the fishery. The same is true with shrimp, which are valuable both as catch and as food source for cod and turbot. Both species eat large volumes of shrimp, but whether they actually compete with the shrimp fishery is not yet clear. The same question comes up with snow crab. Cod feed on the young crab, but scientists are not sure if they eat enough to make a difference to the crab fishery.

Fish have always been managed as if one stock was more or less independent of others. Scientists have always know this is not true, but never had the knowledge to be certain how different stocks affect each other. Ten years ago they began trying to move toward a more integrated approach — considering cod stocks when setting capelin and crab quotas, for example. But getting the knowledge to do this effectively has been difficult, because the relations are so complex. The abundance of one species may depend not only on the habits and abundance of several others, but on the effects of fishing and of things like weather and ice conditions, and water temperature.

The relationship is much like a web. Touch it here and it jiggles everywhere. Yet it jiggles more in some places than in others, and the reasons aren't clear yet. Some parts of the web may even be invisible, given current knowledge.

One difficulty is that the questions are so much greater than the resources of any fisheries research group. Unravelling the complexity of relations between different fish species takes years of effort. Yet most of the effort of scientists in the department is focused on stock assessment, which is critical to the industry and must be done on dozens of stocks every year.

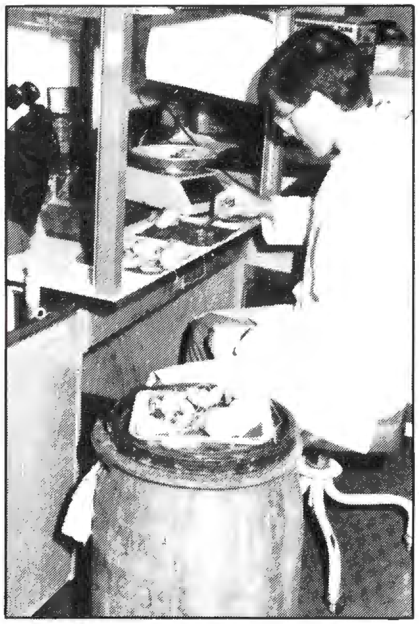


Capelin, one of the primary food sources for cod.

Cod as a Sampler

One of the benefits of the cod's wide-ranging appetite is that scientists can use cod as a sampling tool. Examining cod stomachs can tell a lot about other species. For example, stomachs from cod off Labrador contained shrimp smaller than those caught during shrimp surveys. Scientists decided to re-evaluate the results of earlier shrimp surveys. They concluded that shrimp must be growing more slowly than they had thought.

Similarly, cod stomachs recovered from two or three surveys each year on the Grand Bank provide data on the abundance of capelin and where they are at different seasons. The one trip a year devoted to capelin research cannot supply this information.



Examining cod stomachs for food contents.

The Old Way: MSY

The objective of MSY (Maximum Sustainable Yield) management was to obtain the maximum sustainable (average) physical yield from the resource, i.e. to get every available ounce of sustainable production from the fish stocks.

Problems:

- ☐ low catch rates
- ☐ relatively small fish
- ☐ high production costs
- ☐ relatively low stock sizes
- ☐ great variability in supply
- ☐ stock decline (TACS exceeded)

The New Way: OSY

OSY (Optimum Sustainable Yield) was established as an alternative resource management concept to MSY. In addition to biological aspects, economic and social factors are taken into consideration.

Protecting the Spawning Stock

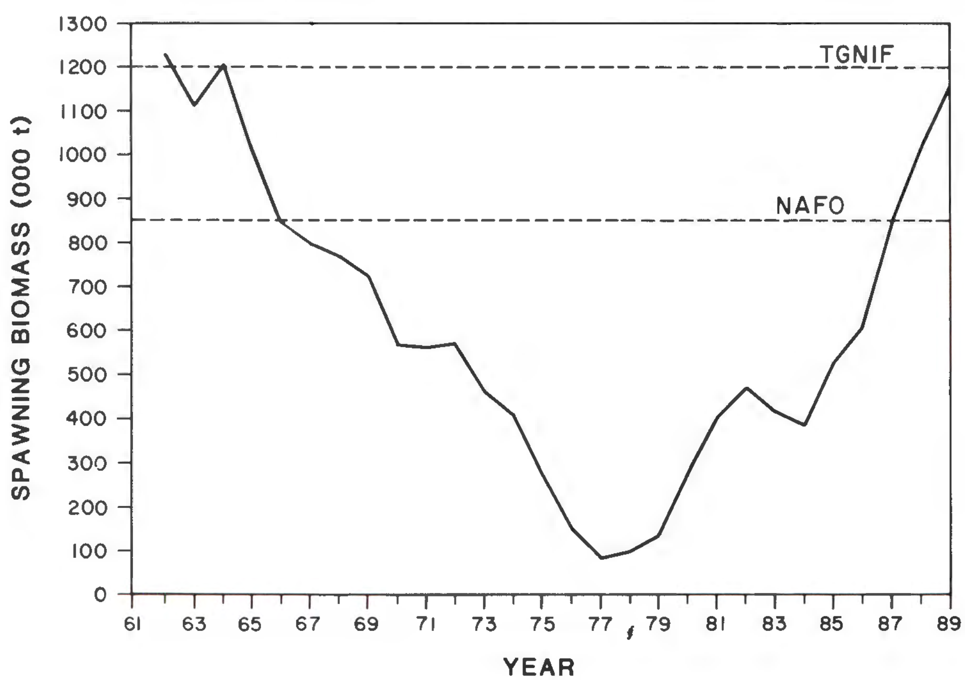
The Alverson Task Group on the Newfoundland Inshore Fishery concluded that, to ensure good recruitment, the northern cod spawning stock should be at least 1.2 million tonnes.

This advice is similar to that provided by NAFO in 1977 and within the range of more recent NAFO advice of 0.85 - 1.35 million tonnes.

The Department of Fisheries and Oceans believes that this is good advice.

The level of spawning stock (cod aged seven years and older) at the begining of 1988 is estimated at about 1.02 million tonnes. With a catch of 266,000 tonnes in 1988, the spawning stock should reach 1.16 million tons by the beginning of 1989.

So we are close to the target now and getting closer.



The level of northern cod spawning stock (cod aged 7 years and older) has increased dramatically since the introduction of the 200-mi. limit.

The Appetite of Seals

Many fishermen worry that the end of the harp seal hunt poses a danger to the commercial fishery. They believe the seal population could multiply enormously, and that seals will take thousands of tons of fish that would otherwise be available to fishermen.

Scientists have found this a difficult question to evaluate. If the only species involved were humans, harp seals and cod fish, there is little doubt that seals and humans would be in direct competition. Every cod a seal took would be one less fish available for people, so that a large increase in the seal population would cut sharply into commercial catches.

But the ocean is vastly more complex than that. Many hundreds of species are linked together in ways we can hardly understand. So little is known about the whole system, no one can predict confidently the effects of an increase or a decline in any one species.

All that can be said for certain is that harp seals do eat capelin, Arctic cod, shrimp and crab, (among a great many other things) and that a rising seal population will therefore likely have some effect on these prey species.

However, there is no risk of the seal population endlessly rising. In nature, every species finds a role for itself in the system, and tends to maintain its population at a level which conditions permit. Species almost never multiply out of control, except when a creature is introduced to some new environment where there is little competition for food and few diseases or predators.

This could not happen to harp seals in the Northwest Atlantic, where numerous other species (e.g. cod) compete for the same food. So while harp seals are increasing, scientists are certain they will reach some natural limit. How much difference they make to commercial fish species by that time will depend on several things, including what seals eat, how much they eat, where and when they eat it, and how much these effects of seal predation further influence the commercial catches.

Scientists know the diet changes over the seal's lifetime. Young seals take mostly shrimp and other shellfish, but turn more to larger fish species like Arctic cod and capelin as they get older. Mature harp seals seem to be opportunists, as cod are, so that the diet varies from place to place and season to season, depending at least partly on what is most available.

As for how much they eat, estimates vary from 4 to 6% of their body weight each day. If the average was 5%, a harp seal herd of 2,000,000 animals could eat 2,900,000 tons of food a year.

If this was all cod, shrimp and crabs, and if the herd spent its entire life in Newfoundland waters, such a diet would clearly be something to worry about. But in fact seals spend only part of their lives in our waters and eat many other things we don't use as well as some that we do.

Adult harp seal and pup.

The seal herds migrate from Arctic waters and reach northern Labrador by mid-October and work their way south over the winter. They eat heavily in January and February, to store fat for the long period of whelping and moulting, when they hardly eat at all. They whelp in March and head north again in May.

They are in Newfoundland and Labrador waters about seven months. For roughly the first two of those they are migrating down the Labrador coast, where studies suggest they eat chiefly capelin and Arctic cod. Capelin, of course, are an important species, but they are eaten by many other fish and they vary tremendously in abundance anyway.

DFO scientist tags harp seal pup.

If seals do prey heavily on any other commercial species, the period would probably be in January and February, when they must put on a heavy layer of fat, particularly the females, to carry them through the whelping and moulting period. Studies so far suggest the seals which winter off the northeast coast eat an extremely varied diet, with more shrimp and related shellfish than cod, herring or capelin. The seal herd which winters in the Gulf of St. Lawrence seem to depend more on fish, particularly herring.

In summary, then, harp seals will continue to increase, but not forever. As they increase they will probably eat more cod, shrimp, crabs, capelin, Arctic cod and herring; however, they only take about 40% of their total food consumption in waters off Newfoundland and southern Labrador. Codfish is not a significant food species for harp seals. But whether they will eat enough to make a noticeable difference to the fishery remains unclear. Further research studies will provide additional information.

Who's Who

Fishermen often see fisheries officials as all one group but they are not, any more than all fish are cod. There are a variety of individuals with different responsibilities within the Department of Fisheries and Oceans, and a fisherman will do better in his dealings with government if he can tell one from another.

The three major groups are the Enforcers, the Managers and the Scientists.

Enforcers are the inspectors, the wardens and the men in patrol boats who see that fishing regulations are obeyed. Most fishermen already know the enforcers.

Managers try to regulate the fishery to the benefit of all those involved, without harming the resource, so they are the ones to make decisions about quotas, licences, mesh sizes and so forth. Scientists advise them about the conditions of various fish stocks and the likely results of different actions the managers might take.

Scientists are methodical. They value only what they can measure. Guesses, hunches, impressions, rumours, pet theories, likes and dislikes — all these things the rest of us find so absorbing must be avoided by a scientist. He puts them aside and looks for facts.

To be any good as a scientist or advisor, the DFO biologist must be neutral, objective, and professional. He must hold himself apart from the intense debate that often goes along with quota allocations. He must be able to say, "Here is what we know about this stock", without being drawn into the social and economic issues of how it may be shared.

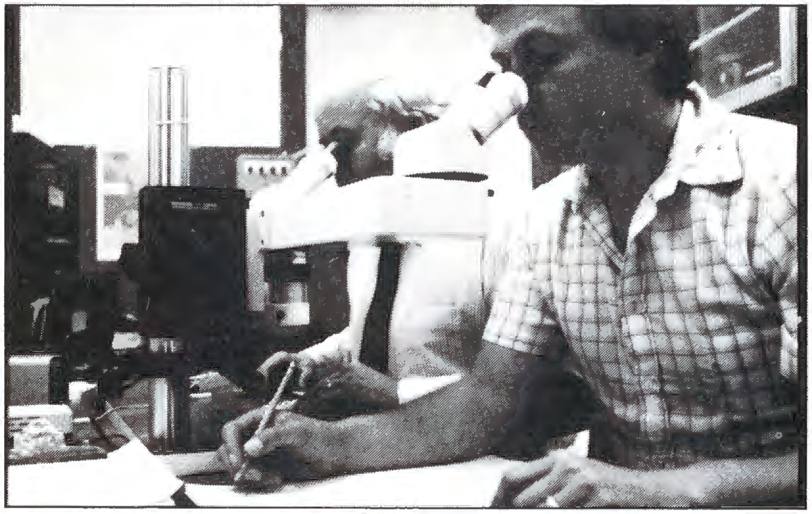
Fisheries managers, on the other hand, are up to their ears in the very issues scientists must avoid. They must take into account social and economic benefits of the fishery, which involves them heavily in debates about how much fish can be caught and who can catch it.

In the fishery, nearly everyone wants more than he is getting. Yet, even the largest fish stock has a limit, so no one denies that catches must be controlled. Inevitably there are groups who feel they are getting less than their due, while others are getting more. The stakes are high, because decisions can affect the livelihood of entire regions. This adds to the pressure on the managers.

Sometimes authorities just don't know enough about the issue they must settle, yet the situation demands a decision. Managers (fisheries-oriented) press the scientists for their best advice about the results of some policy choice. The scientists (fish-oriented), trained to avoid guesswork, stand by and do what they can.

Enforcers — Like this Inspection Services officer checking a plant production line, they ensure that all participants in the fishing industry adhere to the regulations that apply to the industry's various sectors.

Managers — DFO fisheries management personnel meet with fishermen and processors in a Species Advisory Committee meeting. (Scientific staff also attend many of these sessions.)



Scientists — methodical seekers after measurable information.

Dividing the Pie

By now surely everyone in the fishery knows that TAC means "total allowable catch". Yet many people still mix that up with quotas.

There is no need for confusion. Think of it this way: the TAC is a pie and quotas are slices.

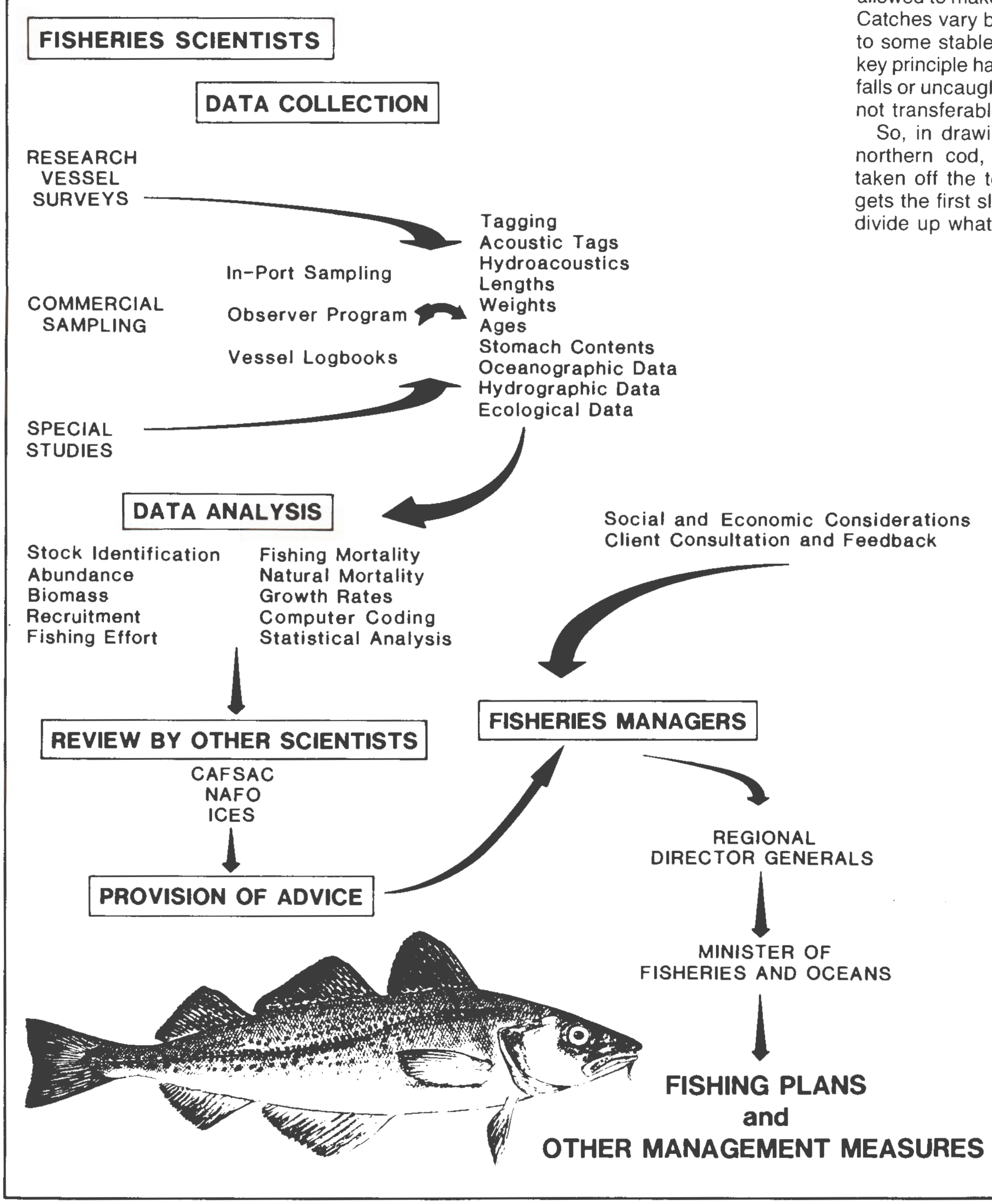
Before fisheries managers can produce a fishing plan, a TAC has to be determined for each groundfish stock. Scientists recommend a level of TAC based on the best available information and managers apply various social and economic considerations before finalizing figures. Fishing plans are recommended to the Minister only after extensive consultation with all fishery representatives. When the TAC is established (the pie) each fleet sector is given a portion of the pie, i.e. a quota.

In the case of northern cod, the inshore fishery is not given a quota but an "allowance". The different is that a quota is a fixed limit, while an allowance is an estimate of how much fish the inshore sector will land on average.

When trawlers reach their quota on northern cod they are obliged to stop fishing but inshore fishermen are allowed to catch all the cod they can, even if they exceed the inshore allowance.

There are several reasons for this. One is the longstanding dependence of the inshore fishery on cod. Another is that because inshore catches vary from one year to the next, inshore fishermen should be allowed to make the best of the good years. Catches vary but in the long run even out to some stable level of catch per year. A key principle has been that allocation shortfalls or uncaught parts of the allocation are not transferable.

So, in drawing up the fishing plan for northern cod, the inshore allowance is taken off the top (i.e. the inshore sector gets the first slice of the pie). The quotas divide up what is left.



Inputs and flow of scientific data and other information used in producing fishing plans.

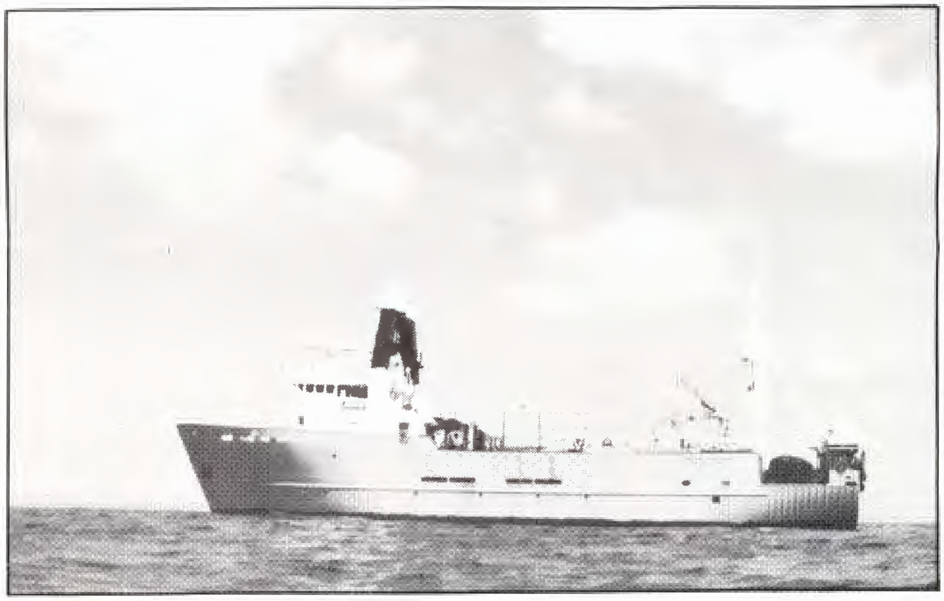
Where To From Here?

In 1930, Dr. Harold Thompson of the Scottish Fisheries Board visited Newfoundland under the auspices of the Empire Marketing Board to report on fishery research requirements in Britain's oldest colony. On his recommendation, an agreement was reached providing for a five-year period of fishery research in Newfoundland waters. In 1931, a Biological Laboratory was opened at Bay Bulls, 30 km south of St. John's. From this start, an active fisheries research program has continued to the present day.

The original research program developed by Thompson in 1931 concentrated on the provision of advice to fishermen on the movements of the major commercial species. Researchers were instrumental in the location of many new fishing grounds and the introduction of new fishing methods (eg. trawling, longlining, seining) to the fishing industry.

Following the exploratory phase, research shifted to aspects of fish in relation to their environment and an understanding of stock relationships. By the early 1960s research attention had turned to the development of scientific assessment techniques, predictions of yield and the provision of advice to national and international fisheries managers on minimum mesh size and other regulatory measures. General emphasis was given to stock discrimination techniques, migration patterns and the influence of the environment and fishing activities on fish populations.

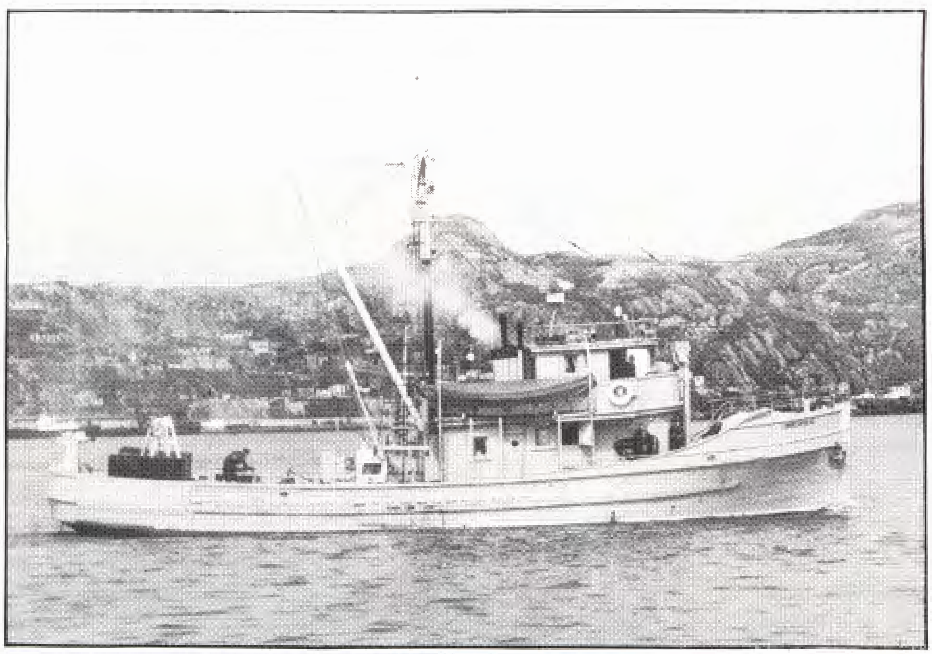
The heavy international exploitation of groundfish resources by the late 1960s led to the introduction of TACs (total allowable catches) in 1974, and increased research emphasis was given to more precise estimates of resource prospects on a stock and area basis. Then, in 1977, Canada extended fisheries jurisdiction to 200 miles. The extension of jurisdiction brought new research resources, and offshore research and stock assessment efforts increased to a significant degree.



The 50 m (165 ft.) research vessel WILFRED TEMPLEMAN was assigned to the Newfoundland Region in 1982.

The formation of CAFSAC in 1977 and NAFO in 1979 placed added scientific responsibilities on Newfoundland researchers, and by 1980 fully 80% of DFO's Newfoundland Region Science Branch resources were devoted to resource assessment and related research.

Through all of this period, fisheries scientists have learned a great deal about cod and their habits ... when they spawn and where, how many eggs they produce, how fast they grow, at what age they mature, what they eat, their migrations routes and temperature preferences, their survival rates, the effects on them of fishing, and so on. They have also formed a good idea of which management units (stocks) are most appropriate.



The INVESTIGATOR II, the first fisheries research vessel to operate in Newfoundland, served from 1946 to 1970.

While we understand the basic biology and life history of cod and some of the factors affecting survival and recruitment to the fishery, further research is needed in a number of areas. Researchers are examining the facts and concepts available to them and attempting to clarify the interactions of cod with other organisms and the environment they share. This 'ecological' approach to fisheries management is complicated and only now advancing to the point where researchers are starting to understand the best approaches with any degree of confidence.

There are many related questions which need to be addressed:

- ☐ What fraction of the total offshore cod visits the inshore?
- ☐ Is migration to the inshore a feature of every cod's lifestyle? If not, are there distinct populations?
- ☐ Are there resident populations inshore? Have these been overfished and if so, can they be re-built?
- ☐ To what extent do the offshore and in-

shore populations of cod intermingle during the period when both are in the bay?

- ☐ To what extent do currents, tides and temperatures affect migration to the inshore?

In September, 1986, the Minister of Fisheries and Oceans announced a significant strengthening of the department's scientific effort in the Newfoundland Region. As part of a department-wide integration of science activities, an additional 38 researchers were added to the Region's Science Branch. These new resources, representing a 22% increase in staff, will permit new research initiatives in areas of long-standing concern to fisheries managers and the fishing industry. Progress has already been made on some of the more obvious species interactions (such as cod-capelin), and aspects of ocean climate are also being clarified.

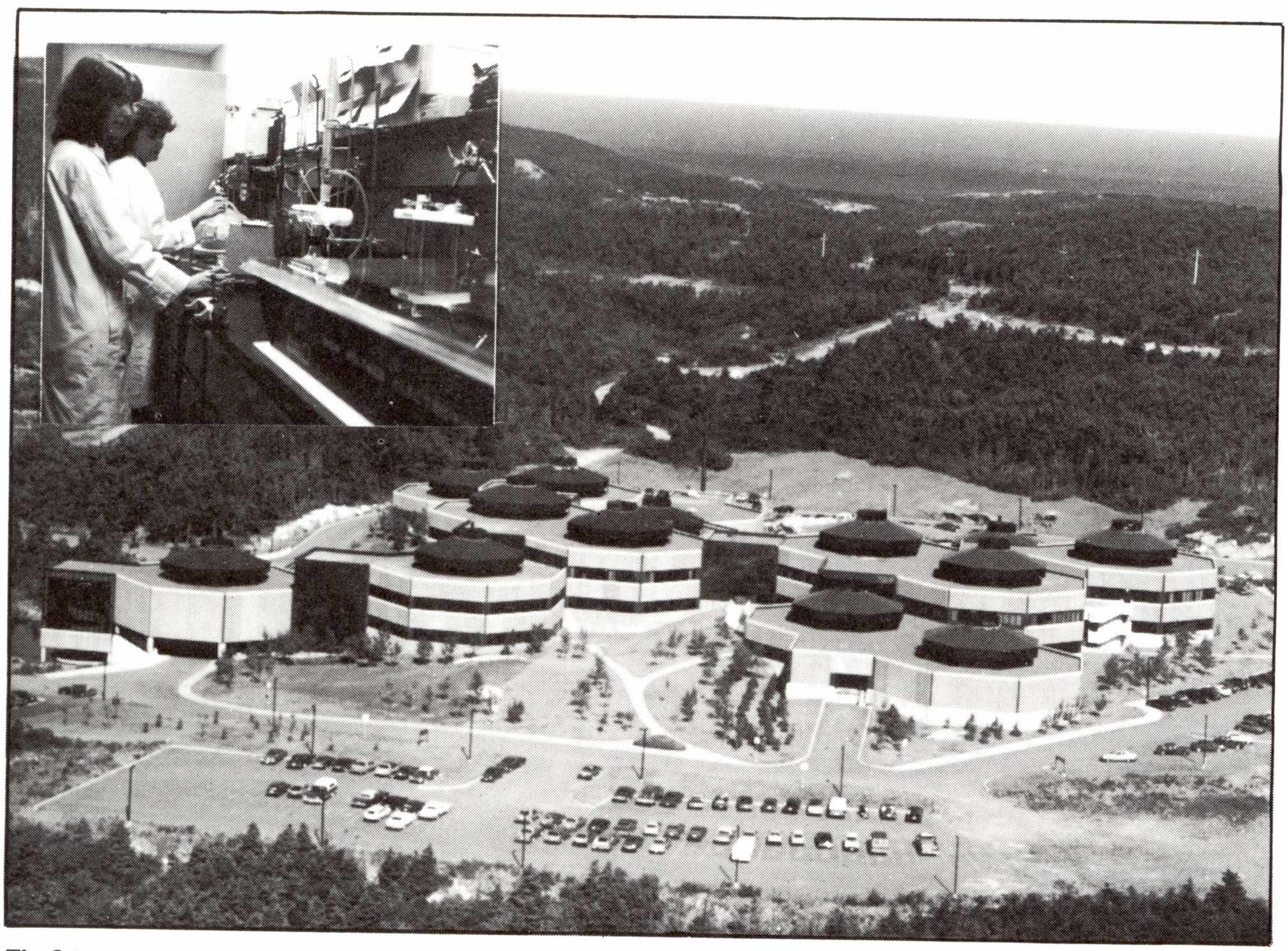
The addition of scientific staff in the Newfoundland Region enables new research capabilities in a number of areas:

- ☐ research on cod has increased and the Newfoundland Region will be the lead region for cod research in Atlantic Canada
- ☐ an oceanographic research component has been added to examine ocean climate and the environmental influences on fish distribution and abundance
- ☐ a national Centre for Resource Assessment and Survey Methodology is being established in St. John's to improve the precision of estimates of total allowable catch, catch rates, stock forecasts and other outputs from stock assessment in support of the fishing industry
- ☐ increased attention is being given to fisheries ecology research, ie. the interactions of fish with their environment and processes affecting survival and recruitment
- ☐ research on crab will be increased, as will parasite studies
- ☐ a team of hydrographers has been transferred to the Newfoundland Region to provide detailed information required in the production of nautical charts, tide and current tables and sailing directions (the hydrographic vessel MAXWELL is also assigned in support of coastal mapping).

The creation of these new capabilities responds directly to expressed requirements of the fishing industry and other private sector interests.

The Department is also taking steps to increase the participation of fishermen in the assessment process. The Advisory Committee structure is being expanded to permit a better exchange of opinion and information between fishermen and scientists, and other strategies are being explored.

The Department of Fisheries and Oceans prides itself on a world-class scientific capability. The unprecedented rebuilding of the northern cod resource since 1977 is ample testimony to sound management practices based on good scientific advice. Having nurtured the resource to a good stage of health overall, the department is now setting out to enhance that all-important achievement by addressing more intensively and more comprehensively other problems in the fishery.



The Science component of the Northwest Atlantic Fisheries Centre has been assigned the lead role in cod research for Atlantic Canada.

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The "Fo'c'sle" is a quarterly publication of the Department of Fisheries and Oceans, Newfoundland Region. It is designed to inform fishermen and others of the Department's policies and programs, and to improve communications generally between Government and the industry. Readers are invited to respond to any of the articles contained herein, and to submit suggestions for future articles. The "Fo'c'sle" is distributed to full time fishermen, other industry representatives and Department of Fisheries and Oceans personnel throughout Newfoundland and Labrador. Please address all correspondence to:

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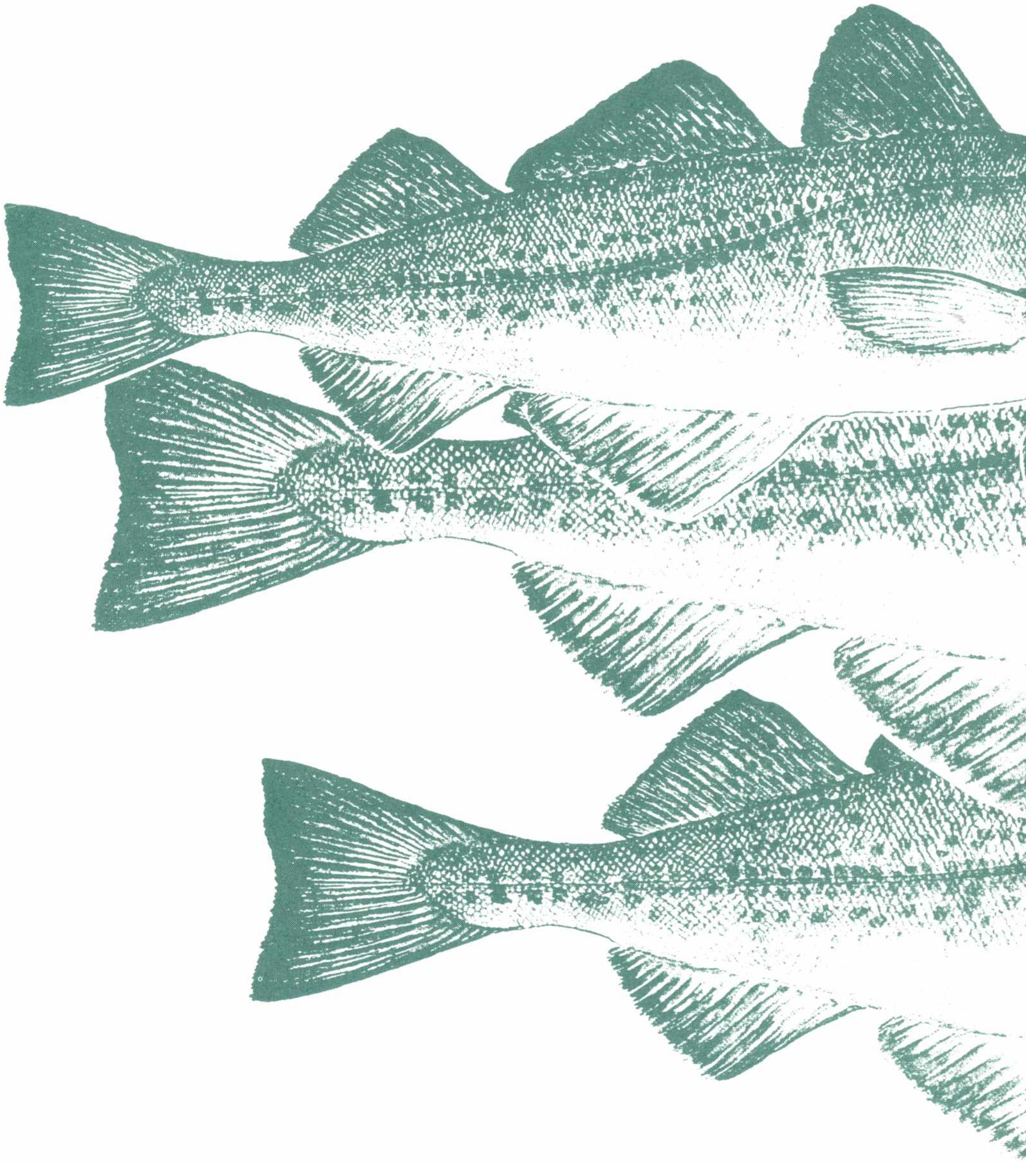

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