REGIONAL DEVELOPMENT AND OPTIMAL MANAGEMENT OF THE PRINCE EDWARD ISLAND LOBSTER FISHERY*

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Introduction

It has been estimated that in 1978 it cost $41 million to produce $28 million worth of fishery products in P.E.I. [20:29]. Six million dollars was spent on administration and $8 million on subsidies. If the opportunity cost of labour had been equal to zero, costs would have fallen from $41 million to $25 million. This low productivity and the usual cost-price squeeze have been partially offset by excellent harvests in the last three years. However, the long term outlook is not good, and the federal government is concerned with devising a long term solution.

"The continuing contradictory policies and actions ... encouraging efficiency and inefficiency which emerged during the 1950s and 1960s [has resulted in a] subsistence system ... and in palliatives which provide a comfortable dependence for inshore fishing communities in the short run" [23:2124]. An alternative is "unionism, corporate mergers, more efficient and coordinated government action, and the inevitable power concentration, centralization, and shakeout of 'fishless' fishermen" [23:2124]. This appears to be what the Kirby Task Force is suggesting, as it recommends unionization [18:631], a more sophisticated income stabilization

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program [18:67], restrictions on licensing of fishermen [18:78], and a catch quota system [18:79-82].

There is a third alternative of "decentralization and dispersion of economic and political powers... creation of incentives for work, productivity, sacrifice, and self help, through social security reform, particularly in rural areas where living costs are significantly less" [23:2125]. It is the contention of this paper that only this third alternative would indeed lead to the "optimal" management of the lobster fishery on P.E.I. The word optimal is used in the sense of a policy which will not only minimize seasonal, spatial and inter-temporal costs of harvesting and processing but will minimize transaction, administration and compliance costs.

Regional Development in Canada

There is a need to "integrate programs for fishery development with those designed for regional economic development in general" [4:4]. The failure of fifteen years of regional development of P.E.I. has demonstrated, in turn, that regional development cannot take place in isolation. One is forced to examine the fundamental economic problems facing Canada before discussing either regional development or fisheries management.

Canada has always been thought of as a resource rich country [22]. However, the fundamental problem is that there are few backward and forward linkages. Much of the machinery and equipment is bought from other countries and there is very little value added beyond the initial processing stages. Prices of most resources we sell face increasing pressure from third-world suppliers, and yet our costs are rising as Canadian resources become less accessible and of lower grade.

Turning from resources to the industrial sector, it appears that the fundamental problem in Canada has been our emphasis on large scale, capital intensive, assembly operations [3,26]. Foreign ownership is one of the major causes. Foreign companies keep the labour-intensive, high value added stages of the production process in the home country and "farm out" the assembly operations to host countries in order to get under tariff barriers. Research and development, design and fabrication are kept at home. The result is a loss of employment and value added for Canada. This is made worse by the practice of selling components to Canadian branch plants at inflated transfer prices in order to take taxable income where tax rates are lower. Another consequence of foreign ownership is that the early stages in the life cycle of a product are kept at home during the lucrative "stocking up" period. Only when the "replacement" market for the mature product is reached are branch plants allowed to start assembly operations.

With higher capital costs, higher borrowing costs, higher transport costs, higher priced components, and a mature product facing fierce competition for a limited market, it is no wonder that so many Canadian companies find it hard to compete internationally. There has been a confusion between concentration and productivity in Canada when it is competitiveness and not productivity that is the key.

Since Confederation the Canadian goals of national unity, a manufacturing sector which could compete with the U.S., and an emphasis on transportation and communication to overcome the natural North/South flow inevitably led to the concentration of industry in Ontario and Quebec. Prior to 1945 there was a belief that the backwash effects resulting from this nodal growth would eventually be replaced by the spread effects as economic opportunities in depressed regions became attractive. However, the findings of the Rowell-Sirois Commission and a recognition of the reality of concentrated industrialization led to an emphasis on equal social opportunity after 1945.

Rather than moving people to the jobs, there was an attempt to revamp the jobs so people could stay where they were. This attempt to upgrade productivity led to the creation of ARDA. As productivity improvement in rural areas usually means increasing the capital/labour ratio and as capital is not attracted to depressed regions, it requires a policy of "getting rid of the surplus farmers." ARDA then found itself involved in manpower retraining so that displaced farmers could find alternative employment opportunities in urban areas. With some sense of desperation FRED was created to improve rural opportunities through better education and more productive systems. Unfortunately, the value added from the latter was too small to pay an acceptable wage to the better educated farmers.

Although FRED was abandoned when it was realized that rural areas are too small and isolated to be developed effectively, there was just time for P.E.I. to negotiate a 15-year Comprehensive Development Plan in 1969. All attempts at development, however, were soon abandoned and the Development Plan became a special funding mechanism for putting money into a depressed area.

Regional Development in P.E.I.

According to the staples theory, expenditures on public infrastructure and transfer payments simply retard the outmigration so
essential for adjustment [29]. For P.E.I., forestry and shipbuilding were the staples until 1890, when steel hulls led to their collapse. Outmigration then led to a steady erosion of Island communities. As the Island shifted to the next layer of staples, skilled labour and capital left and the tax base shrank.

Unless one shuts down the whole region and evacuates all the inhabitants, migration is not a long term solution [14]. The problem is that people do not just leave from one community. If they did, that community could be shut down and the others left at the same viable level. Instead, all communities suffer out-migration until a minimum threshold number of people is reached, at which point the community collapses. After several communities have collapsed there is an attempt to "centralize" or "rationalize", usually by shutting schools down and/or closing down other services. Although migration should not be an "all or nothing" proposition, the reality of the situation is that it is extremely difficult to reorganize a declining region into communities with economically viable population sizes.

Ninety-four communities in P.E.I. depend to some extent on fishing. Of these, 37 are almost wholly dependent on lobster fishing. The "ecological niche" for these fishing communities started changing after 1945. Until then lobster fishing had never been considered a full-time occupation: there were other species of fish, a small amount of agriculture, and the usual logging in New Brunswick in the winter. Despite the poverty, the community was robust in the sense that no-one could afford to "overbuild", be in vessels or gear or processing equipment. By the late 1950s the "equalization" of economic opportunity resulted in the use of the powerful tool of money or in-kind (services) transfers to lobster fishermen.

Entrepreneurial skills were redirected away from survival in a fairly harsh environment to one of "qualifying" for various "harvests" of money and services. The payoff was so large during a period of increasing landings of lobster, first by weight (in the 1960s) and then by value (in the 1970s) and then in cash and service transfers, that communities flourished as they had not done for a long time. As a result, the ecological efficiency of communities in terms of the natural resource base steadily declined, which is quite normal when the resource base has changed. Because these communities are no longer robust in an ecological sense, any attempt to switch them back from cash and services to the old natural resource base is bound to meet with very stiff resistance (politically) or a complete collapse of the community.

With the realization that productivity enhancement was not working to improve the jobs so people would be induced to stay
An Alternative Approach to Regional Development

Moving people to the jobs has served to beggar the region because many businesses and communities are no longer viable when populations are reduced below certain minimums. Attempts to increase productivity have led to a dual economy, with highly productive farmers and fishermen who often have large capital investments. The majority, however, cannot afford to take the risk and either quit or cobble together a meagre existence. Attempts to alter the structure of the Island to promote high wage secondary manufacturing have failed. There is no comparative advantage and there is a distinct locational disadvantage to operating on P.E.I.

Perhaps these three policy approaches have failed because they have all tried to eradicate dualism or pretend it did not exist. Living in a depressed region has distinct advantages, however, not the least of which is cheap housing and a slower pace of life. Equalization payments, transfer payments, and subsidies have created an economic system which is exploited to the extent necessary for individuals to qualify for unemployment insurance, firms to qualify for subsidies, and governments to qualify for public infrastructure projects. Not only does this reduce the incentive (and productivity) of the two-thirds of the population that does not subscribe to this way of life, it has transformed the lobster fishery into a ten-week race for a high premium unemployment insurance qualification.

An alternative approach must be sought if one is to discuss fisheries management in a meaningful way. Although the Kirby Task Force did an excellent job of examining the state of the fishing industry and the need for fishery resource management, it failed to come to grips with the fundamental problem of human resource management. “A fairly substantial part of the labour force, particularly in the rural areas, consist of men who work occasionally at a number of different jobs and who show no apparent desire to acquire full-time occupations. . . . Many in the group have a great liking for their way of life. . . . If they succeed in building up unemployment insurance benefits they are content to coast along . . . without looking for or wanting work. . . . It is possible that the low-income casual worker is not really misallocated in that he and his family may be less of a charge on the rest of the community if he is left where he is” [14:121-122].

It appears there has been a fundamental misconception since 1945 that dualism is bad and represents a misallocation of resources. Small scale fishing, farming, and forestry is a way of life. The process of production involved in such occupations is radically different from that in manufacturing [13].

For Canada as a whole, an alternative approach would view the economy as consisting of three sectors: a large scale assembly plant sector, a small scale subcontracting sector, and a quasi-traditional/transitional sector [15;26]. Canada is characterized by large, multi-plant firms, whereas countries like Germany, Sweden, and Japan have large scale assembly plant firms surrounded by groups of small subcontractors. The advantage of the latter arrangement is that firms can shift many of the management problems plus some of the risk onto the subcontractors. The latter gain the advantage of realizing the fruits of their own labour and an ability to diversify across industries to minimize risk. Sixty-eight percent of the workforce in Japan is employed by small subcontractors [26:15].

Small firms are known to be more capital efficient and innovative. However, the expensive part of the research and development can be performed by the large scale assembly plant corporation. Availability of credit is of far greater concern than cost of credit for small firms. A contract from a large firm can act as the credit guarantee required by the bank. The large firm guarantees the sale of the output and also provides the inspection and testing needed for quality control.

It has been estimated that there are five layers of management in a typical Japanese firm versus twenty in the Canadian counterpart [24]. Are we wasting entrepreneurial talent in bureaucratic management of highly integrated operations? Dualism permits an efficient division of labour, specialization, and a profitable return to craftsmen.

Agglomeration economics and the high technology nature of this symbiotic relationship would preclude the location of a large scale assembly plant in P.E.I. However, with careful planning a subcontractor sector could be fostered on the Island to cater to some large firms in centres such as Halifax, Saint John, Montreal, or Toronto. Industries which have survived and are thriving on P.E.I. tend to be of this subcontracting nature.

For those who do not have the skills, the entrepreneurial ability, nor the right disposition to accept risk through capital investment, the alternative is the quasi-traditional sector. Farming, forestry, fishing, and tourism do not require a great deal of education and skill and the input combinations are very flexible. These industries can be exploited with varying capital/labour ratios, hence the word “transitional”. Instead of being subsidized, individuals should be encouraged to diversify across several sectors as was quite common prior to 1956.

In an extensive study done in 1981 and 1982 [10], it became very clear that diversification makes good economic sense from several standpoints. For example, a combination of intensive
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Corporations do not have the problem of open access to their workers’ production. They have also overcome the “creeping mediocrity” resulting from any democratic form of decision making by divorcing management from ownership. This allows them to make decisions without the constraint of constant accountability to shareholders. However, cooperatives have been successful in terms of motivation of workers because they actually own the fruits of their labour (albeit in a group), whereas corporations do not have worker ownership, which often leads to poor motivation, management diseconomies of scale, and problems with productivity.

An implicit assumption on the part of policy makers is that fishermen and other small resource producers are just too independent and uncooperative to be able to help themselves. Governments must step in with new initiatives, projects, and proposals to bypass these “social” problems by providing an organized market and systems of production for them. The whole port market structure, new licensing scheme, catch quotas, boat and gear financing, and so forth proposed by the Kirby Task Force demonstrates that the Task Force has fallen into the same trap.

From an economic point of view the optimal solution would appear to be to foster an institutional framework which provides strong incentives and support and, where necessary, to provide external advice and non-pecuniary assistance during the development period. Otherwise we are simply substituting heavily subsidized, inappropriate and complex forms of social assistance for the system of regulations and unemployment insurance used today.

Scott and Tugwell [30:44-49] have stated the point very succinctly:

because fishery inputs are to a certain extent, and at some cost, substitutable for one another, the limitation of the use of one or two inputs will eventually result in the expansion of the use of other inputs.... Not only enforcement, therefore, but flexibility in enforcement, in the spirit of preventing over commitment of effort, will be required.... To prevent the possible massive failure of regulations that can result from the myriad of minor and trivial violations, it is necessary that every participant have an almost religious belief in the need for an efficiency of each regulation.... The regulatory route... does not tend to create constructive fishermen incentives to preserve and enrich the resource stock, cut harvesting expenses and improve working conditions.

The fundamental problem in the fisheries is the failure of human resource management. A new approach toward fisheries management must examine alternative institutional arrangements to those which prevail today.
Management of the P.E.I. Lobster Fishery

Almost all P.E.I. fish processors have excess capacity for two major reasons. First, seasonality of the catch forces the processors to operate at full capacity for however long the fishing season lasts. The rest of the year the capital stock lies idle. There is, however, a second, equally serious cause of excess capacity; processors would prefer to handle and process lobsters only, but to extend the season to qualify for U.I. and to maintain as high a net income as possible during the qualifying period, fishermen will only sell lobsters to a processor if he agrees to buy their "junk" fish as well. Lobster processing equipment and plant may be operating at full capacity, but by never saying "no" to a fisherman's catch of "junk" fish, which can only happen if there is excess capacity, a processor can build up a form of loyalty which protects him against "outside" processors. This form of "monopsonistic" competition does not confer any excess profits but does at least ensure the continued operation of the plant [25]. On P.E.I. this manifests itself in the form of processors saying "yes" to catches of species other than lobster just to get the fishermen's lobster catch. This second major reason for excess capacity results from the need for open access to fishermen's "premium" lobster catches. The processing equipment for species other than lobsters is kept operating so as to allow access to the lobster catch, even though this may not be economically efficient.

As lobsters represent 70 percent of the value of landed species on P.E.I. and as the lobster season is limited to ten weeks per year, it becomes clear that fishermen are prepared to take a lower price on lobster in return for processors buying the "inferior" fish in order to extend the season to the period required for unemployment insurance qualification. Furthermore, as the majority of wives work in the canneries during the lobster packing season, the processors provide another member of the family with an unemployment insurance qualification as well. This symbiotic relationship with processors makes it very clear why there is such strong resistance to attempts to increase carapace size for lobsters. Most canneries would go bankrupt, because larger carapace lobsters would be too large to can and would be frozen instead. The number of "canner" lobsters would fall dramatically, reducing the need for wives to work in canneries. The loss in income plus U.I. qualification for a fisherman's wife far exceeds the benefits of increased lobster size. That is, returns per pound on lobsters would rise but not by enough to offset the reduced market for inferior fish species and wives' qualification for unemployment insurance.

In a study done for the Department of Fisheries and Oceans, Gardner [8] showed that no matter how slowly or gradually a larger carapace program were phased in, the social returns to fishermen were not great. Ignoring the above argument of loss of wives' income plus U.I. qualifications due to closure of the canneries, the weight increase due to larger carapace size is offset by greater mortality and the larger proportion of mature "berried" females which must be thrown back. That is, the social returns to a program of increasing carapace size are already low due to these biological factors, and fishermen have very shrewdly worked out that the private costs exceed the social benefits because of the loss of wives' incomes.

A new institution is required, and it cannot be of the cooperative type because of the strength of the symbiotic relationship between processors, fishermen, and fishermen's wives. The creation of a large corporation with monopoly rights may conquer some of the problems, but the monolithic power of large corporations (be they private or Crown) tends to discourage small producers. P.E.I. is characterized by the cottage industry nature of its small scale diversified resource production. This is very common in a number of underdeveloped economies around the world, and a great deal of money and effort have been spent in devising either cooperative or corporate structures to deal with resource production problems. The cooperative structure has proven too fragile, and yet the corporate structure ends by enriching a few at the expense of many.

It appears that the approaches that have stood the test of time are integrated rural development projects. They have been able to "transform existing institutions so as to enable society to capture the economic gains implicit in new technological alternatives . . . . The key to success . . . was the strategy of first obtaining intimate knowledge of the local people and their problems, and then seeking local solutions" [34:23-23]. After analysing a number of projects, including those developed in Columbia [34] and Trinidad [16], it appears that the best solution would be offered by a natural resource "guild" based on the hybrid institution developed in Mondragon, Spain [17, 31].

Even though a guild would be larger than any single producer, it is still small enough that consistent quality and volume are absolutely essential to its survival. Therefore, the guild must be a vertically integrated structure involved in centralized management and administration, bulk buying of inputs for producers, and group selling of the outputs. The guild must be externally financed to avoid the conflict between group ownership and internal financing. In this way, "de jure" ownership remains outside while "de facto" control rests in the hands of management. The short-
sighted goals of individual producer-owners would not constrain
the long term goals of management.1

For the P.E.I. lobster fishery there is a great need for cooperative
management of the lobsters, the vessels and gear, and the
processing plant. The first unit in such a guild should consist of a
group of technicians who could diagnose the biological problems
and prescribe guidelines in terms of federal government policies.
The second unit should include the fishermen, who would have
control over entry into the harvesting section through some sys­
tem of licensing which does not lead to overcapitalization.2 The
third unit should consist of the processors, who would be given
rights to limit access to the catch from the harvesting unit.

Once the lobster fishery is organized into a guild, management
of the fishery becomes a process programming problem. The
objective function could include such things as average income to
fishermen and plant workers, profit maximization for the unit as
a whole, the payment of a royalty or tax to the federal government
for the use of the fish stock, or the possibility of maximizing
employment in the fishery [18:60]. The correct mix of average
income and employment would be a matter of negotiation between
the guild and the federal government.

The government could bargain away any royalty in return for
higher numbers employed. On the other hand, fishermen and
plant workers would be anxious to protect their average income
against large scale forced entry on the part of government. Alter­
natively, the guild could maximize growth through a system of
sequential investments. This would entail the sacrifice of current
income for future income by: 1) investing in increased carapace
size for lobsters through abstinence; 2) investing in nearshore and
offshore fleets (training and construction); or 3) investing in the
potentially very rich aquaculture fishery.3

The problem with centralized, concentrated and bureaucratic
structures is that they tend to be autocratic and stifle the talent of
workers within the hierarchy. On the other hand, unregulated
small lobster enterprises appear to have worked reasonably well
in Maine [1:30:36], but have found it difficult to enhance their
incomes because of the common property problem. What is so
difficult is trying to achieve the optimal balance between highly
motivated individual activity and a cooperative support structure.
People want to do things for themselves, but with a devolution of
power comes an increasing responsibility. In a small survey of
P.E.I. fishermen [8:40-42], it was found that fishermen would like
to manage their own affairs but are fearful that assuming such
responsibility would lead to a few doing well at the expense of
many.

To avoid the control that inevitably creeps in through external
asset ownership, be it federal or private, it is proposed that the
guild lease the lobster asset from the federal government and that
it be financed through long term loans carrying a fixed interest
rate. The federal government could waive any "rental" for the
lease of its lobster asset in return for certain employment conces­
sions. This avoids any complications of proprietary rights under
the Constitution. Each fisherman entering the guild would lend a
basic amount of investment capital which would be credited to his
capital account and on which he would be paid a market rate of
return.

If management decided to reinvest profits, the funds would be
added to the balance held in the fisherman's name. The guild
would then have an incentive to add new members and to reinvest
profits, and fishermen would be motivated not to sell outside
the guild for fear it would damage their growing investment. On
retirement, a fisherman or plant worker would receive the total
value of his balance or a pension (depending on length of service).
No one could invest in the guild without joining, and no one
could join without a substantial investment. This approach separ­
ates management from ownership, which would ensure that the
tough decisions needed to guarantee consistent volume and qual­
ity could be made without recourse to voting. And yet, direct
producer ownership would provide strong incentives to maintain
high productivity. It would also provide a retirement plan, which
is a desperate need for small resource producers who do not have
access to "company" plans. Nor would there be any incentive to
leave the guild when there was a chance to earn an income and
possibly capital gains on assets in excess of what could be earned
in a bank.

Given the serious consequences of large budget deficits for the
Canadian dollar, the federal government will be under increasing
pressure to restrict current levels of unemployment insurance
and support services. The Kirby Task Force is proposing to
change the rules of the game; perhaps the time has come to
change the game itself. A guild system could go some way
towards offsetting any future reductions in unemployment insu­
rance by diversifying into other areas of resource production and
marketing [10].

1A more detailed discussion of the guild concept is available in Gardner [10].

2See, for example, the proposal put forward by the Maritime Fishermen's
Union [21].

3A heavy initial capital investment is required for aquaculture because cul­
tured stocks must be built up rather than being "fished down".

1
Guild Management of Recruitment and Harvesting

Given one of the objectives of maximizing income, maximizing employment or maximizing growth in the fishery, the guild would be involved in the management of recruitment or harvesting over the three dimensions of space, time, and season.

The spatial dimension for lobsters is pre-determined by nature, but the allocation of harvesting effort in terms of number of vessels, number of traps, and number of fishing ports plus the spatial location of processing plants can be determined by programming. Such factors as steaming time to and from port destination, optimal trap layout and hauling times, the requirements for local storage of fresh catches, the optimal pattern of pickup of the catches, the optimal location of processing plant by type of facility (fresh, frozen or canned), and the optimal pattern of distribution of the final product would all be included in the program.

The management program would attempt to optimize, subject to the constraints in the objective function, by moving the own rate of return for the lobster stock, gear, and vessel stocks, and stocks of processing equipment to the market rate of return. All the intertemporal biological factors as they relate to the three elements of reproduction, growth, and mortality must be considered. Changes in the lobster stock would lead to changes in the vessels and gear used in harvesting. The program would have to answer questions related to the optimal number of vessels, gear, and fishermen needed over time. Assuming, for example, that there was too much effort, the program would have to reduce the amount of harvesting effort according to natural attrition or generational turnover rates for fishermen and depreciation rates for vessels and gear. Changes in both the lobster stock and the harvesting capital stock would lead to similar changes in the processing plant. The optimal amount of plant would depend on catch levels and the catch delivery system.

There are several biological, harvesting, and processing elements which are distinctly seasonal. The more peaked the delivery pattern the more plant is required and the more expense involved in the idle period. On the other hand, there are such things as the seasonal pattern of prices and firmness of flesh which make it worthwhile to harvest early rather than waiting for the summer moult. If it is decided to develop the mussel aquaculture fishery, some blending of the seasonal harvesting patterns would also be desirable. And finally, it if appears that less harvesting effort would be optimal, fewer fishermen working with fewer vessels and less gear could harvest more slowly over the whole season. With a seasonally adjusted price subsidy instead of unemployment insurance, fishermen would be motivated to fish a much longer season. The smaller deliveries over a longer period of time would be ideal for keeping a minimum amount of processing plant operating longer at full capacity.

Social and political constraints could be built into the management program. For example, the optimal solution may specify only 25 fishing communities when it may be desirable to keep the original, highly dependent 37 communities involved. The program could be re-run and the approximate cost in terms of average annual income lost to fishermen calculated. The optimal solution may suggest, for example, that only two processing plants are required. However, if it is desirable to keep all 20 existing plants operating, the program could be re-run and the approximate cost in terms of lost income calculated. The cost of each of these additional social and political constraints could then be discussed among the members of the guild and a decision made by all fishermen based on the trade-offs they felt were most important.

Ignorance of these trade-off costs is the greatest barrier to any cohesive management plan in the lobster fishery today. One of the most important jobs in the guild would be production of this information. If the data were collected by fishermen or their spouses, programmed by them, and published by them, the amount of suspicion and mistrust which exists today should slowly dissipate. Fishermen themselves could then decide if they wanted to close a community down, or open a new processing plant, or undertake investment in increased carapace size, or reduce the number of member fishermen, or change the fishing season around.

These are, of course, very contentious issues, and it would be unrealistic to assume that because fishermen are united in a guild they would be united in all decisions. However, from Thomas and Logan's [31] discussion of the decision making process in the Mondragon producer cooperative, it is clear that even very difficult decisions can be reached as long as there is some tangible compensation for the losers. For the most part this would probably involve retraining, relocation allowances, and the prospect of a better economic future in terms of higher net income.

Increasing Carapace Size

One of the most important questions to be examined by the guild is the whole question of increased carapace size. A recent study [1] demonstrates how small and uncertain the returns might be for Maine fishermen. So little is known of the reproduction phase that it might as well be left out of the discussion. Increasing carapace size simply increases the weight of landings by allowing
more lobsters to go through another moult. The effect is offset by a decrease in numbers due to natural mortality (which continues during the longer growing time before harvesting) and a larger proportion of berried females (more mature lobsters), leading to a higher throwback rate. Using an incremental approach, the Maine study found a rate of return of only 10 to 12 percent.

It is most convenient to think of lobsters as moving through a pipeline. Newly hatched larvae rise to the surface and are carried by ocean currents. About one percent survive to the stage where they burrow into the mud in waters around 25 feet deep. In warmer waters around P.E.I. the females mature more quickly (before seven years) and are ready for breeding at a smaller size. It is around that critical size that they become vulnerable to traps. If temperatures drop, fewer females mature and breed before they are trapped and the pipeline of all lobsters slows down as colder water reduces the abundance of food and slows down the moulting process.

Once lobsters become vulnerable to the fishery it appears that 90 percent of them are removed from the pipeline. The 10 percent left in the pipeline are no longer vulnerable to harvesting because they are too large to get through the 10-13 cm. ring in the funnel of the traps. As these lobsters grow larger, like all bottom dwelling species, they are forced out to deeper, richer feeding grounds. Eventually some of them migrate out to offshore areas. This explains why migration within a single year class may be small (as substantiated by the one-year carapace tags) whereas over several year classes, lobster migration may be quite substantial. It is obvious that these survivors are past the vulnerable stage or "window" in the pipeline and may be one of the keys to reproduction in the fishery.

It appears that only a third of the sub-legal lobsters escape through the vent holes. The remaining sub-legal lobsters plus any berried females (roughly 8-10 percent of legal size lobsters) must be thrown back by fishermen. It has been estimated that on P.E.I. "a fisherman who lands 10,000 pounds of lobsters in a season handles approximately 23,000 short (sub-legal) lobsters" [30:37]. Each time a lobster is thrown back, its growth rate is affected and it becomes vulnerable to predation from other species such as cod, cannibalistic attacks by larger lobsters while caught in a trap, handling by fishermen who, for common property reasons, have little motivation to be careful, a dramatic change in water temperature, and exposure to fresh air.

Is it possible for the guild to increase returns to fishermen by rearranging current harvesting practices to offset these losses and by experimenting with improved escapement mechanisms in traps? Is it possible to increase carapace size by offsetting the temporary sacrifice entailed by abstention? A carapace size program involves an upward shift in the lower end of the recruitment "window" in the pipeline, that is, the actual legal size period of vulnerability to traps being decreased for the life of the program. There may, however, be an accumulated surplus of lobsters who have grown past the vulnerable stage and have not yet migrated out to deeper waters. During the period of increase in carapace size, funnel ring sizes could be increased to allow capture of "jumbo" lobsters. As soon as the increase in carapace size had been accomplished, funnel rings would be reduced to the original size. Another possible way to offset the period of lower catches is to increase vent holes to allow greater escapement but to allow fishermen to retain all trapped lobsters except berried females.

The Regulatory Environment

From the small survey [8:40-43] conducted among fishermen, it appears that most understand the need for regulation to prevent the common property problem. However, many fishermen appear to be frustrated by "over-regulation" in the industry. They believe the regulatory environment actually increases costs; that is, they recognize the need for regulation and they realize that this will impact on their revenues; it is the cost side to which they object. Do current regulations increase costs? If so, the guild will have to search for more effective regulations or there will be serious disputes.

The first regulation to question relates to the number of traps. Before 1968 some fishermen set as many as 1,600 traps, and the federal government decided to impose trap limits of 300 in two districts and a limit of 250 in a third district. However, as a study of the data for traps per vessel indicates [9], the average number of traps per boat for the whole of P.E.I. did not increase to more than 300 until after 1945. Although the figures for traps after 1960 are not completely reliable, they do show a steady decline after 1970, with the number finally going below 300 per boat in 1979. To haul, empty, and re-bait a large number of traps must increase bait, fuel, and trap costs. Furthermore, a fishermen is forced to use more sophisticated and expensive gear to handle that many traps. In this case, regulations may have saved some costs, and some fishermen express an interest in reducing the trap limit to 250 per boat in all districts.

Although the ability of the harvesting sector to decimate the stocks of legal size lobsters is questionable, there is a great deal of excess capacity in the harvesting sector. Poaching is already a serious problem in some parts of P.E.I. And the introduction of a
system of price subsidies to replace unemployment insurance could increase the pressure on existing lobster stocks. One of the major constraints on fishermen pushing for greater access (both seasonally and physically) is that there is no incentive to work beyond the best 20 weeks in order to qualify for unemployment insurance. The latter may be the most "effective" regulation of all to prevent "overfishing" any of the fish stocks, including lobster. The guild would have to be very cautious in its approach to releasing constraints on effort. "Rationalizing the fishery, conserving the stock and assisting the local community by stabilizing employment and income, will not necessarily enrich fishermen. The extent to which they gain arises from details of the regulations or property rights" [30:60].

There are other regulations and other factors that the guild could examine in an effort to reduce costs, maximize revenues, or minimize risks. These would include such things as the damage to lobster grounds resulting from moss raking and scallop dragging, seasonal blending of a mussel aquaculture fishery, bookkeeping and tax accounting services, marketing, motivation, and incentives for processing plant workers, the role of institutions, and the problem of capital stuffing [8; 30].

Data and Parameter Estimates

The most important tasks facing the guild would be the creation of a data base, the estimation of biological and economic parameters, and the development of a programming model to permit optimization of the objective function. As a first step, a data base was built up from the observations available on landings, boats, men, traps and average air temperatures [9]. As a second step, parameter estimates were made for the harvesting production functions.

The parameter estimation involved a reformulation of Bell's [2] classic study of the lobster in Maine. The basic functional equation which he used in parameter estimation was of the form:

\[ C(f) = a + b(f) + c(Temp) \] (1)

where

- \( C \) = catch: annual landings of lobster
- \( f \) = effort: annual number of traps fished
- \( Temp \) = annual seawater temperature
- \( a, b, c \) = parameters

The most serious econometric problem with this formulation is the presence of \( f \) on both sides of the equation. This technique is derived from the work of some biologists, and its rationale is explained by Bell [2:149-150]. It invariably leads to a good fit but yields disappointing results when the parameter estimates are used for future projections. This is not the formulation used by Tugwell [32:51, 95]. However, the problem with the latter is that there is no underlying theoretical analysis to support his general hypothesis that landings are a function of effort, the stock of lobsters, days of fishing and temperature. Note that in the working formulation [32:95] the stock has been dropped and effort appears in four forms: men, men squared, traps, and traps squared. Except for water temperature lagged one period, there is virtually no proxy variable for stock or escapement.

Part of the problem for economists is that there is no agreed-on biological model to be used in estimating population or recruitment of lobsters. The relationship between catch and effort is therefore crucial for determining biological reactions. And any estimation procedure is essentially determining both biological and production function parameters simultaneously.

If we recognize that water temperature can be used as a proxy for a number of environmental factors [6], it may be possible to use temperature as a guide to the ecological constraint on lobster population prior to fishing mortality. Temperature is believed to have an impact on the survival rate of larvae, the frequency of moult ing, and the maturity of females [28,33]. At any point in time there are roughly six year classes behind a newly recruited lobster. If water temperatures increase, lobsters moult more often and the vulnerable stage extends backwards into year class six. If water temperatures decline, some lobsters in the seventh year class do not go through the last moult prior to the vulnerable size. The vulnerable stage may be delayed until the eighth year.

It should be clear that it is not just current effort and water temperatures that are important but those in previous periods as well. Because of the importance of the sixth and seventh year classes in recruitment, escapement six or seven years ago can be a critical factor in current recruitment. If there are changes in moult ing patterns, the rate at which fishermen "throw back" undersized lobsters will tend to increase as temperature declines and to decrease as temperature increases. If water temperature is used as an approximation to the average abundance, the previous year's catch subtracted from the previous year's water temperature (appropriately scaled) should act as a proxy for escapement in the previous year. As the smallest lobster which is still able to get into the trap is probably from the fifth year class, the influence of escapement beyond the last two years would diminish rapidly. However, effort and temperature five, six, and seven years ago should have an important influence on reproduction and survival respectively.
It is well known that there are different sub-species or races of lobsters, and a study was made of the pattern of movements of the Labrador currents and the St. Lawrence River. It was decided that surface currents and tidal patterns tend to be quite different at the eastern and western ends of the Island and that they tend to meet in the middle. For this reason, the data were subdivided into western catches (Prince County), central catches (Queens County) and eastern catches (Kings County). An aggregated catch model was tried for the whole Island but was not as successful as the parameter estimation for disaggregated catch.

The results of the parameter estimation based on the above considerations gave a substantial improvement in fit compared to the older work based on traditional assumptions. Some of the results were quite unexpected. Despite the use of the most significant formulation for effort, the current effort variable is not significant. This demonstrates that there is far too much effort in the fishery; so much so that past events are of much greater significance. Temperature and temperature constrained escapement are most important in recent periods, whereas effort tends to be more important in terms of periods further away. This would suggest that past effort has an important impact in terms of reproduction, whereas environmental and escapement (throw back) factors have a more important impact on weight and numbers maturing.

The results also indicate that there are substantial differences among the three races of lobster. In recent years Prince County catches accounted for 45 percent, Queens County for 15 percent and Kings County for 40 percent of total lobster catches. It was found that the fit was less significant for Prince than for the other two counties, and the reason is probably related to the fact that poaching, the retention of sub-legal lobsters, and the use of illegally large numbers of traps is much more common in Prince County [30:47]. This would mean substantial measurement error in the data.

**Conclusion**

These results indicate that there is a very close, positive relationship between water temperature and lobster catches. Unfortunately, temperatures are predicted to decline “through the remainder of the century, with a strong possibility of some recovery in 1980-1983” [7:294]. The last part of this prediction has certainly proved correct, as lobster landings in the last three years have improved substantially with warmer water temperatures. Whether water temperatures will decline in the face of the “Greenhouse Effect” is hard to predict.

What is clear is the need for a new approach to management which will turn the present waste of time, effort, and money away from internal bickering towards improving the position of fishermen and the conservation of the lobster resource. The use of a guild structure could go a long way in redirecting the energy of technical experts, fishermen, and processors toward the cooperation needed to cut costs and increase revenues in the fishery. This will become increasingly urgent if lobster stocks are threatened by colder temperatures and if federal government programs are cut because of budget constraints.

**References**


