Bord Iascaigh Mhara
Irish Sea Fisheries Board

The Biology and Management of Clawed Lobster (*Homarus gammarus* L.) in Europe

Oliver Tully (Editor)

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Fisheries Resource Series

Foreword

Since its inception, Bord Iascaigh Mhara (BIM) has regularly reported on the work it undertakes as the agency responsible for the sustainable development of the Irish seafood industry at sea and ashore. The *Resource Records Series,* which ran for many years, is a notable example of this and admirably fulfilled the Board's remit to print and circulate bulletins, periodicals, pamphlets, and other literature, as the Board deemed advisable, in the interests of the sea-fishing industry. Building on this tradition, whilst also recognising the challenges and opportunities that face the sea-fishing industry today, the *Fisheries Resource Series,* produced by the Fisheries Development Division of BIM, is intended as a professional, broadly based, peer reviewed publication.

The content of the *Fisheries Resource Series* reflects a synergy of resources and expertise between BIM and the Irish fishing industry, national academic institutions, international partners, other state and semi-state agencies and provides a vehicle for the dissemination of the results of the Board's innovative, technical and applied research and development activities.

Technical and scientific contributions to the *Fisheries Resource Series* are invited, from internal and external sources, which primarily promote the sustainable development of the Irish sea fisheries sector and, in addition, support its diversification in the coastal regions so as to enhance the contribution of the sector to employment, income and welfare both regionally and nationally.

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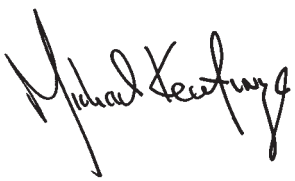

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Taighde Mara Teo

Preface

During the 1990s the lobster fishing industry in Ireland organised into co-operatives (co-ops) and developed various conservation measures, management plans and fishing control initiatives. These actions were taken unilaterally by individual co-ops, and neither government nor industry groups made any attempt to develop a regional or national management policy. Nevertheless, the establishment of the co-ops and the conservation measures they adopted, represented real progress in the drive to achieve sustainable exploitation in lobster fisheries.

A meeting was held in Galway during November 2000 as a forum for Irish industry groups to express their opinion on the management of lobster fisheries (both the structures and the fishing controls). This discussion was facilitated by the presentation of results of recent stock assessments, v-notching programmes, local management plans and voluntary fishing controls in Ireland and of management systems and policies in other countries that gave a Europe-wide perspective on this species. Contributions on American lobster were also included. This volume contains a series of short papers summarising some of the presentations to the meeting.

This meeting was a first step in a process that subsequently saw the industry proactively seeking the establishment of limited entry to lobster fisheries in Ireland. This process culminated in May 2001 with a formal submission to the Irish Minister for the Marine by the co-ops for the introduction of a lobster permit that would limit entry to lobster fisheries. No action was taken at that time because many potential applicants for such permits did not have registered sea fishing vessels. This situation was eventually solved in 2003 through the Limited Scheme for Traditional Inshore Potting Vessels, which enabled unregistered vessels to apply for a general potting licence. At the time of writing, a new framework for the management of crustacean and molluscan fisheries in Ireland is being finalised, which outlines the institutional arrangements under which these fisheries will be managed.

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1 Integration of Biology and Management in Lobster Fisheries

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1.1 Introduction

The biological characteristics of exploited shellfish populations determine how they should be regulated and managed (Jamieson and Campbell 1998). The biological characteristics can inform fishery managers about the expected response of a species to particular regulatory measures. This integration of biology and management is particularly important in cases where there is insufficient data to allow quantitative stock assessments to be undertaken. The lobster fishery in Ireland is one such case. Stock assessments are not routinely carried out, and there is, for instance, insufficient quantitative information available to identify the population structure or the stock recruitment relationship.

In this paper two points are emphasised

- Biological characteristics of lobster inform management of the effects of various conservation measures and their relationship with catch rates
- Management scale needs to map onto the stock structure if regulations are to be effective.

The implications for management of some biological characteristics of lobsters are presented in Table 1.0. Variable growth rate smoothes the effect of variable recruitment on catch rate, because a single cohort may recruit to the fishery over a period of years. There is a significant delay, of probably at least five years, between the introduction of measures to protect spawning and any effect on catch rates. The expected return will be affected by local environmental conditions and, therefore, will not be the same in all areas. Even if spawning potential is increased, there will not necessarily be a beneficial effect in all years if environmental conditions for larval survival or settlement are unfavourable. Discarding undersized lobsters will generally result in higher yield per recruit, because natural mortality and discard mortality are low. Conservation of large female lobsters is an effective way to increase egg production because of higher individual fecundity, higher frequency of spawning, low natural mortality and long life span. If fishing activity is very high, however, sufficient numbers of lobsters will not 'escape' into these larger size classes. Dispersal of larvae and of adults in particular is probably restricted to a regional scale of <100 km, thereby suggesting the appropriate geographic scale along which this species should be managed and regulated.

1.2 Geographic variability in Irish lobster stocks

Size structure, catch rates, size at maturity and possibly spawning frequency of Irish lobster stocks vary geographically.

1.2.1 Size composition

The size composition of the landings partly reflects recent levels of fishing effort but may also be due to differences in environment. Data from Wexford during the 1990s showed, however, that v-notched lobsters, which are protected from fishing, increased in size and developed a very different size structure to that of the fishable stock. The impact of fishing on the average size is very significant, therefore (Tully 2001). The size structure of the landings shown in Fig. 1.0 indicates the following:

- A higher proportion of large (>120 mm) lobsters occurs in Donegal, although these large lobsters are usually from offshore grounds,
- Lobsters in the western region are smaller than those from other areas,
- The shape of the size distributions suggests a moderate to high level of fishing mortality in the stocks.

1.2.2 Size at maturity

The size at which 50% of female lobsters are mature and capable of spawning varies from 92-96 mm carapace length (CL) depending on the coastal region (Table 1.1). This means that at the current minimum landing size of 87 mm CL, approximately 15% of lobsters are protected from fishing, prior to their first spawning.

Table 1.0 Biological characteristics of lobster and their implications for fishery management and performance.

Characteristic	Implication
Growth rate is variable	■ All individuals born in a given year will not recruit to the fishery at the same time but may reach the minimum size over a period of five years. ■ Recovery of catch rates will take at least five years and possibly between 5 and 10 years after the introduction of new regulations. ■ Catch rates are stabilised as a number of both strong and weak cohorts may be in the fished stock at any given time. ■ Due to the 5-10 year delay between egg production and recruitment to the fishery, overfishing of spawning stock may go unnoticed for 5-10 years.
The environment affects recruitment	■ Larval survival and settlement to the seabed will vary annually. ■ Similar conservation measures may not have the same benefit in all areas. ■ The relationship between spawning stock and recruitment may also be different in each region.
Stock performance is density dependent	■ There is an optimal level of spawning stock. ■ Density dependence is unlikely to be important in Irish stocks, at the moment because of low egg production.
Natural mortality is low	■ Yields will usually benefit from allowing lobsters to grow to a larger size, because there is a low probability of lobsters dying from natural causes from one season to the next.
Lobsters have a long life span	■ Large lobsters that produce more eggs and spawn more frequently should be conserved.
There is a larval dispersal phase	■ Although adult lobsters do not travel great distances, the larvae have the potential to travel 10s, if not 100s, of km. The stocks are probably not isolated locally, but there may be regional stocks within the country. ■ Management structures should be regional rather than local in scale.

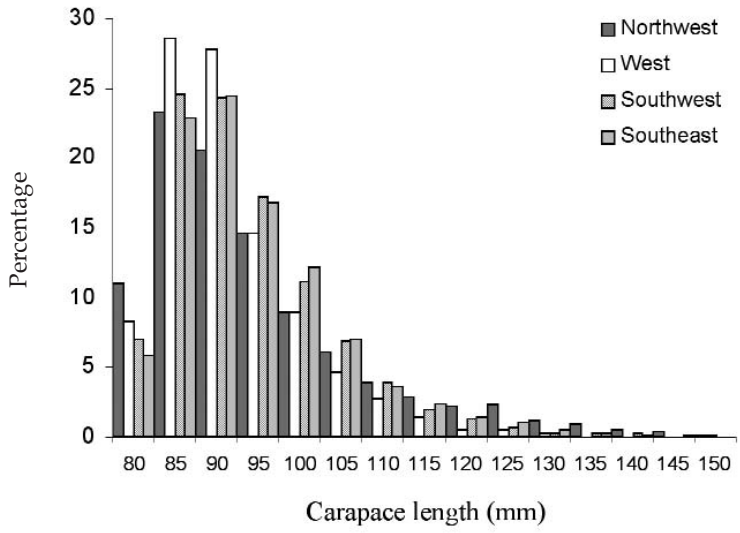

Figure 1.0 Size distribution of lobsters in the landings in four coastal regions of Ireland in 1998.

Table 1.1 Size at maturity of lobsters in four coastal regions in Ireland

Region	CL at 50% maturity
North West	96.0
West	92.5
South West	94.0
South East	95.0
Average	96.0

1.2.3 Catch rates

Catch rates estimated from the BIM voluntary logbook scheme in 2002 were higher on the south west and west coasts compared to the south east (Fig. 1.1). These catch rates also vary seasonally due to in-season stock depletion, moulting and reproductive behaviour and sea water temperature.

1.3 Biological variability and management of lobster stocks

Geographic differences in catch rate, size structure, size at maturity and possibly growth rate and egg production exist in Irish lobster stocks. These differences need to be incorporated into the set of regulations that might be used to manage lobster fisheries. Industry expectations and objectives in relation to target catch rates also need to consider these biological differences. For example, in areas where catch rates are low, size range is restricted and size at maturity is high, more rigorous conservation measures would be required if the management target is to achieve catch rates comparable to other areas.

Another advantage of regionalising, at some scale, the regulations used in the fishery, is that management learns from the experience. For example, if catch rates are known before introduction of new measures, and the new measures are introduced at different levels in each region, then management can both model the expected outcome and collect empirical data on the actual outcome. The new information about how a stock responds to regulation can then be incorporated into the management framework and into a revised set of regulations. This form of experimental adaptive management is highly suited to stocks, which are structured geographically, and where the relative effects of fishing and environment on catch rates are unknown. In effect, the existing v-notch program in Ireland is an exercise in experimental adaptive management. V-notched lobsters are released, by each co-op, locally and since 2002, have also been tagged with an individually-numbered tag. Different numbers are released and, as a result, the proportion of the stock that is v-notched and the impact on population egg production varies between co-op areas. The expectation is that an increase in local recruitment will result. Information on the relationships between local increases in egg production and local increases in catch rates, the growth rates and reproductive patterns of lobsters in each region and the migration of lobsters between regions can be obtained. The v-notch program and the associated data collection can, therefore, answer important questions relating to the stock–recruitment relationships in lobster fisheries and the geographic scales over which these relationships are coupled.

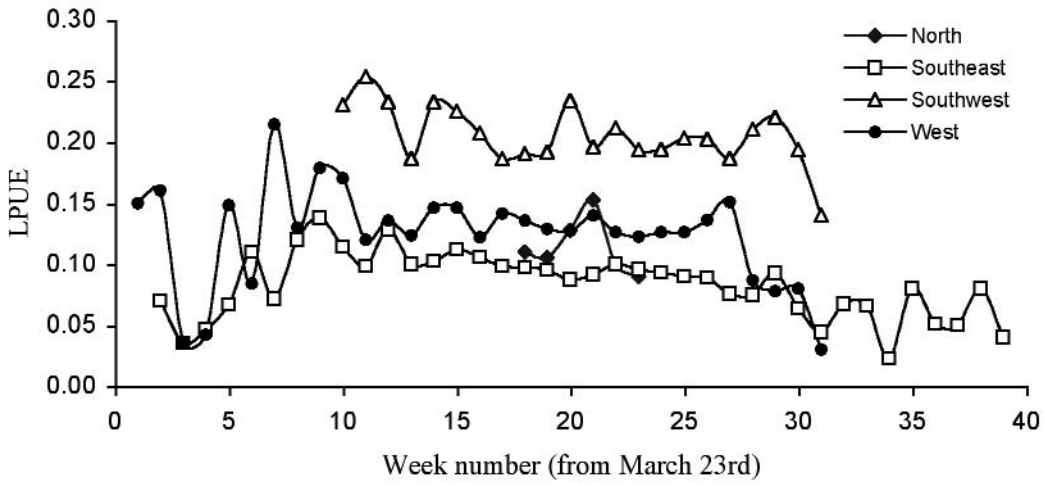

Figure 1.1 Number of lobster landed per pot hauled (LPUE) by coastal region in Ireland between March and December 2002.

1.4 The Irish lobster co-operatives and management scales

Lobster co-operatives in Ireland are local structures that administer conservation schemes such as v-notching and in some cases develop management plans, along relatively small areas of coastline (20-80 km in length) (Fig. 1.2). The dispersal of larvae and, less importantly, the movement of adult lobster suggests that management needs to be developed regionally rather than locally (Table 1.0). Each co-op is unlikely to be fishing its own individual stock, and it is necessary for neighbouring co-ops to consider how their respective conservation programmes may impact on each other.

The correct scale of management is uncertain, but as far as possible it should map onto the actual stock structure. It is difficult and possibly inappropriate to draw rigid sea boundaries that purport to reflect stock structure in lobsters. Lobsters have more or less a continuous distribution along the Irish coast and dispersal from one area to neighbouring areas occurs. Nevertheless, local recruitment is more likely to originate from local spawning stock than from spawning at some very distant location, i.e. it is certain that recruitment to lobster stocks in Wexford does not originate from spawning in Donegal, but it is less certain if recruitment in Wexford could originate from spawning off the Cork coast or in the south Irish Sea. Larval biology and dispersal suggest that connectivity between coastal areas may exist on scales of at least 100 km and that the connectivity between coastal areas may be inversely related to the distance between them. Communication between managers or local co-ops is therefore necessary over coastal distances larger than that of individual co-ops. Local management plans or conservation initiatives should consider the impact on neighbouring areas or even the possibility that benefits will accrue 'downstream' rather than to the local area itself. The local conservation strategy must bear in mind, therefore, the scale over which spawning and recruitment are coupled. If the information suggests unfavourable outcomes then different strategies are required. In Wexford during the 1990s for example, two strategies were adopted to increase local catch rates; v-notching and release of hatchery produced juveniles (Hickey ibid). Both could potentially increase local catch rates, but the release of juveniles to the seabed by-passed the uncertainty inherent in increasing egg production, hoping that this would result in higher recruitment to the local fishery. It was not possible, however, to determine the relative contributions of v-notching and juvenile release, on the observed increase in catch rates, as both conservation programs were concurrent.

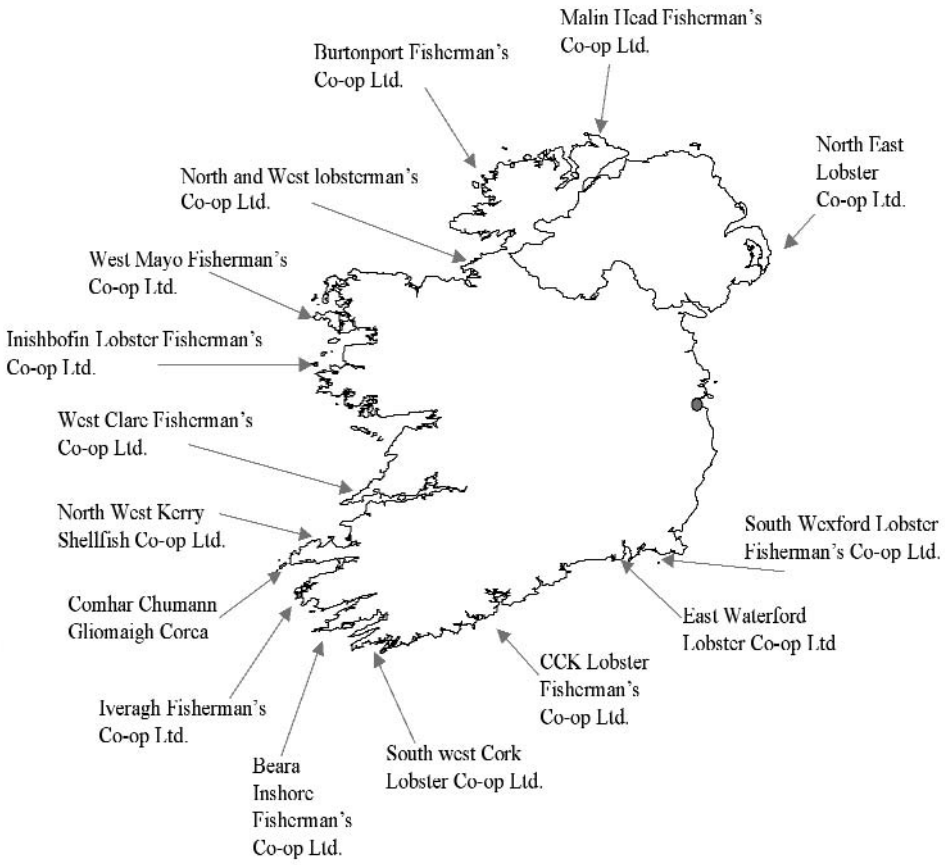

Figure 1.2 Lobster co-operatives in Ireland. Other groups may also be active locally and are not included in the map.

1.5 References

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2 Restoring Egg Production in Irish Lobster Stocks

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2.1 Introduction

Recent work on lobster fisheries biology in Ireland, identified the effects of different conservation measures on egg production. The work, which is summarised in this paper, provides information on the following issues:

- It calculates how many eggs the average lobster produces in today's lobster fisheries before capture, and it compares this to the number that would be produced if there were no fishing
- It recommends a target egg production that managers of Irish lobster fisheries should aim to achieve
- It provides advice on how to get to specified targets

2.2 An explanation of the impact of fishing on lobster spawning stock

In an unfished stock lobsters generally moult and spawn in alternate years; although in some areas they may spawn and moult in the same year, depending on temperature. Natural mortality is low, with lobsters living for more than 30 years and producing more eggs as they get larger. The probability of annual spawning increases as size increases, whereas the probability of annual moulting decreases. Lobsters from such unfished populations may, on average, produce between 90,000-100,000 eggs during their lifetime.

Fishing reduces egg production of the stock. The effect of this depends on the total fishing effort on different size classes of lobster (Fig. 2.0). The size of the fishing box in Fig 2.0 can be changed in two directions. The width of the box can be reduced by an increase in minimum landing size (MLS), or by the use of other size limits. The height of the box can be reduced by removal of some fishing effort. A combination of both will change the overall size of the box, and the effect of change in one direction can be negated by a change in the other, e.g. an increase in egg production due to an increase in MLS can be negated by an increase in fishing effort.

2.3 Regulation through size limits or effort/catch control?

Given that the impact of fishing can be changed by MLS and/or catch/effort controls, can a sustainable and viable fishery be developed using size restrictions only? In such a case, continued increase in fishing effort and catch would mean that the MLS or other size restrictions would need to become progressively more rigorous in order to maintain spawning stock at any given target level. In effect, this would mean attempting to catch progressively larger lobsters only, with more pots. This would lead to more costly fishing, increased discarding and an inefficient industry. Management needs to be aware, therefore, of the interaction between fishing effort/catch restriction and technical measures such as MLS.

A summary of the different methods of controlling the size and impact of the fishing box (Fig. 2.0) is given in Fig. 2.1.

2.4 The egg per recruit assessment

The effect of fishing on the egg production of each lobster recruiting to the fishery is substantial. The current level of fishing in the Irish fishery reduces egg production per recruit to approximately 7% of its potential (Fig. 2.2). This low level of egg production probably limits recruitment, and stocks have almost certainly declined because of this. In the American lobster fishery this same index of egg production is used in management. In that fishery, egg per recruit below 10% of that of an unfished stock, is regarded as a danger zone to be avoided in order to reduce the risk of stock collapse. An egg per recruit of 20% of the unfished stock could be a management objective in Irish lobster fisheries. This level of egg production is the target used in many other fish stocks.

An egg per recruit of 20% of an unfished stock can be achieved by reducing fishing effort (Fig. 2.2), by size limits or by a combination of both (Fig. 2.3). This is equivalent to reducing the size of the fishing box (Fig. 2.0) in one or both directions.

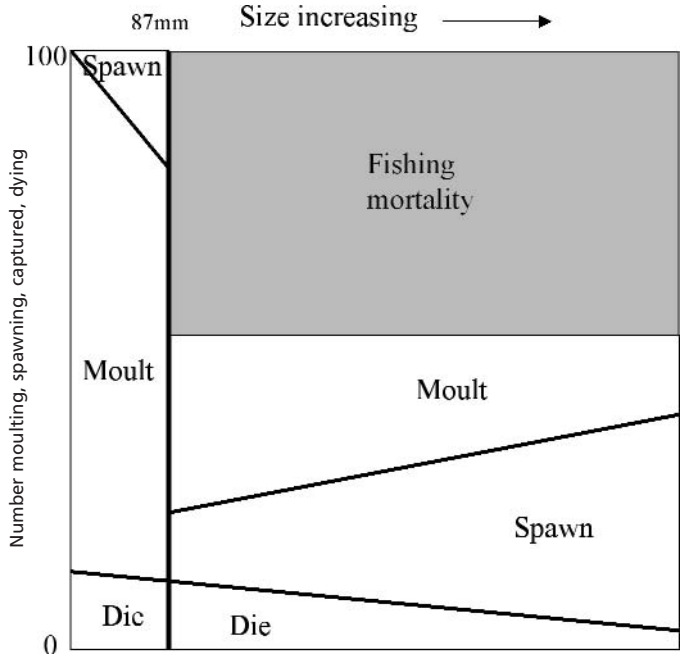

Figure 2.0 Below the minimum landing size (MLS) of 87 mm carapace length up to 15% of lobster may spawn. Natural mortality may be 10% per annum and moulting is the main biological process occurring in the stock. Above the MLS the incidence of spawning increases with size and the frequency of moulting decreases as does natural mortality. The actual number of lobsters in the stock however is very significantly reduced by fishing. The impact of fishing (the grey box) can be controlled by increasing the MLS (reducing the width of the grey box) or by limiting fishing effort (controlling the height of the grey box). It is obvious however that the use of MLS alone cannot control fishing mortality as the effect of this can be negated by an increase in fishing effort.

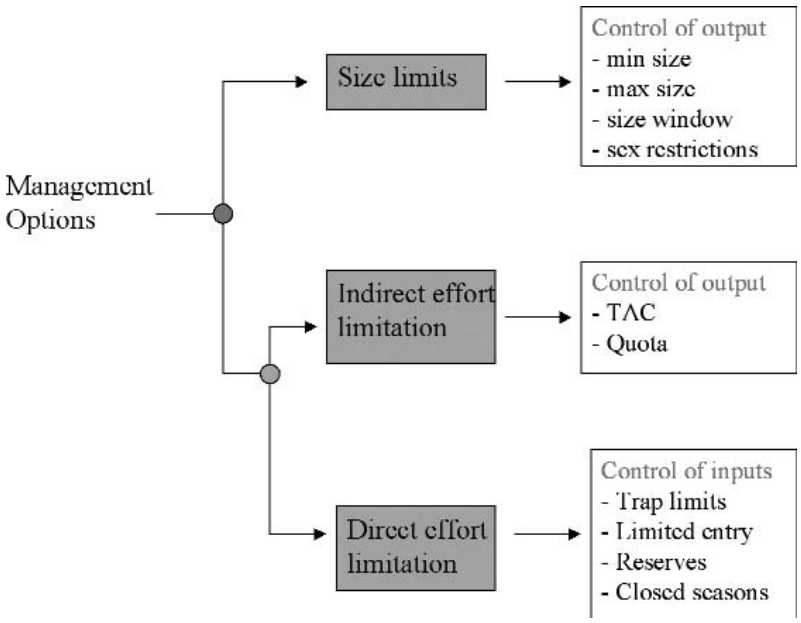

Figure 2.1 Methods to control fishing and protect spawning stocks (adapted from Perry 1999)

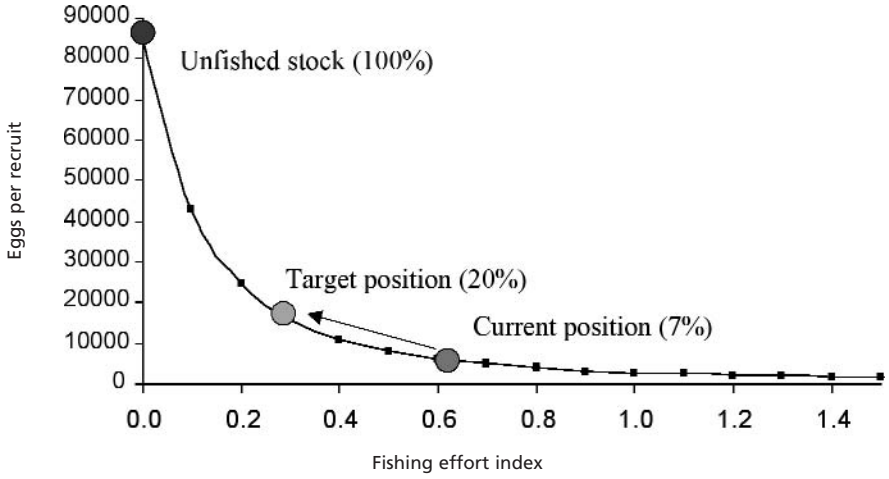

Figure 2.2 Effects of fishing on egg production in lobsters. The fishing effort index is technically the instantaneous rate of fishing mortality. The current position at 0.6 is determined from an analysis of the size distribution of the landings. A target position of 20% is suggested as a reasonable management target that would protect recruitment. In this diagram the target is achieved by reduction in fishing effort. This can also be achieved by using size limits or other conservation measures.

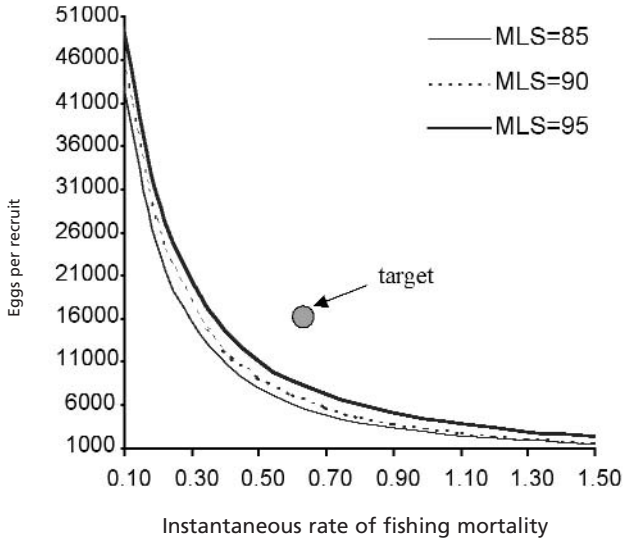

Figure 2.3 Effect of changes in the MLS on egg production per recruit relative to the preferred target position of 20% of virgin egg production.

2.5 Effects of changes in the MLS

Large changes in MLS would result in some benefits to egg production per recruit, although the target of 20% could not, realistically, be achieved using this measure alone, given the current levels of fishing effort. Increasing the minimum landing size to 90 mm would increase egg per recruit from 7% to 8.2%.

2.6 Effects of a maximum landing size

If the current MLS of 87 mm was retained and a maximum landings size of 120 mm introduced, then egg production per recruit would increase from 7% to 11.8%. (Fig. 2.4). Combined with a modest reduction in fishing effort, the target of 20% of virgin stock egg production could be achieved.

2.7 A strategy for the recovery of the spawning stocks

Improvements to the existing technical conservation measures could be used to effect immediate improvements in egg production; if they were accompanied by at least a stabilisation in fishing effort (Table 2.0). Technical measures to increase egg production should involve the use of a maximum landing size. Although a maximum landing size would not be very effective in areas where fishing mortality is high, when coupled with a v-notching program it would have the benefit of permanently protecting v-notched lobsters from fishing, if they reached the maximum size before the v-notch was repaired. Prior to introduction of additional landing size limits, however, management must consider how fishing effort can at least be stabilised so that the benefits of additional landing size limits can be realised and the viability of the industry can be protected.

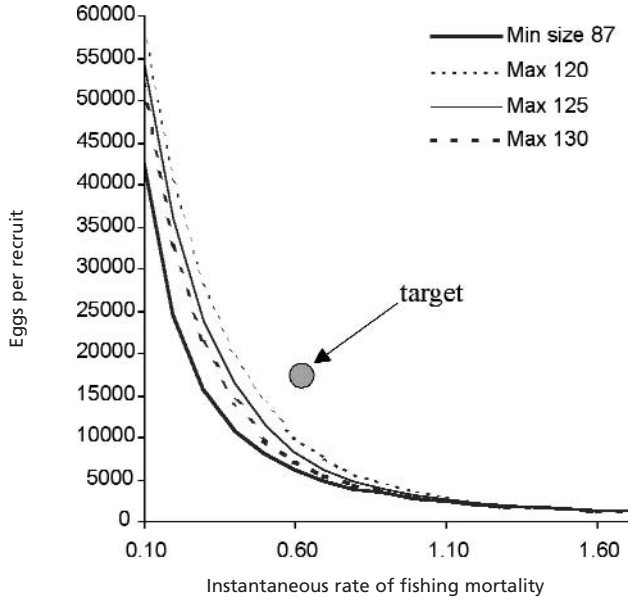

Figure 2.4 Effects of different maximum landing sizes of 120, 125 and 130 mm CL on egg production per recruit relative to the preferred target position of 20% of virgin egg production.

Table 2.0 Percentage benefits of a combination of effort reduction and changes in the MLS relative to an MLS of 85 mm CL and an exploitation rate of 0.45 (shaded). Any reduction in effort in particular results in significant increases in egg production.

Exploitation Rate	Minimum landing size (mm)			
	80	**85**	**90**	**95**
33	51	80	108	146
39	7	31	54	87
45	-21	0	18	47
50	-39	-21	-6	19
55	-52	-36	-24	-2
59	-61	-47	-37	-17
63	-67	-56	-47	-29
67	-73	-62	-54	-39

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3 Management of Crustacean Fisheries in France

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3.1 Introduction

In France lobster and crab fisheries are mixed and there is a significant by-catch of crab or lobster in gear targeting one or other of these species. In such a pluri-specific fishery, management decisions targeted at a single species do not necessarily guarantee its protection.

Currently, 1,000 boats fish for crabs and lobsters along the Atlantic and the English Channel coasts of France. Some of them are exclusively potters and may, in the case of the offshore vivier boats, fish throughout the year. Boats between 6-16 m in length fish seasonally and undertake one or several complementary activities such as dredging, netting or lining.

The annual landings of this fleet (Table 3.0) are valued at approximately €50 million.

Table 3.0 Annual landings of the French potting fleet

Species	Landing (tonnes)
Edible crab	>6,000
Spider crab	5,000
Velvet crab	<300
Lobster	400
Spiny lobster	150

This fishery is managed through a series of technical measures and input controls. Some of these have been enacted recently, some have been in place for more than 30 years and have evolved through time, and others, implemented in the past, have been abandoned. In other words, management is a continuously evolving process.

3.2 Technical measures

Technical measures are the easiest to put in place and often are the first step on the road to more complete management control.

The various MLS in use in France are as follows:

- **Edible crab:** 14 cm carapace width (CW) according to EU regulation. MLS was 7 cm carapace length (CL) in 1964, 8 cm CL in 1978, 9 cm CL in 1984 and 14 cm CW in 1995.
- **Spider crab:** 12 cm carapace length according to EU regulation. This has been in place since 1981.
- **Velvet crab:** 5 cm CW (national regulation).
- **Lobster:** Currently 87 mm CL according to EU regulation. MLS was 20 cm total length (TL) before 1960, 23 cm TL in 1964, 24 cm TL in 1990, 85 mm CL in 1996 and 87 mm in 2001.
- **Spiny lobster:** According to EC regulations MLS is currently 95 mm CL

In addition to the MLS additional technical measures apply to the landings:

- **Soft crabs:** Landing of recently moulted edible crab and spider crab has been forbidden since 1985. Unfortunately, quantifying the soft condition of those species is not easy and it is difficult to enforce these measures.
- **Claws:** Landing of crab claws separated from the body has been forbidden since 1990.

3.3 Input controls

Four input control measures are used: a closed season, a licencing scheme, pot limits per boat and a prohibition on trawling and restricted use of some types of pots.

- **Gear restrictions:** Pots and nets are the only gear allowed for crab and lobster fishing. Trawling is prohibited, but crab by-catches of up to 10% of the total catch are allowed. The parlour pot, which was introduced in the 1990s, is now banned except in one fishery around Jersey. In this fishery, parlour pots must not exceed 50% of the total number of pots per boat.
- **Closed season:** This measure is aimed at protecting recently moulted individuals and, currently, only applies to spider crab. It has been in place annually since 1985, but the date and duration varies from one year to the next and from one region to another. Generally the closed season is September and October in the western Channel, just after the molting period.
- **Licensing scheme:** A licensing scheme was established in 1993 to protect the fishery from open access and the series of problems it causes. It is compulsory to have a licence "grands crustacés" in order to fish for crab and lobster, both inside and outside of national waters (12 nm limit). Only potters and netters may have this licence, trawlers may not. In addition a "European Special Fishing Permit" (EU regulation 1627/94) is required in order to fish for crab, both inside and outside of the 12 nm national limit, in boats larger than 10m in length.

  Licences are administered on a regional basis by industry, which recommends the number to be issued and the cost. They are issued to the skipper/boat, must be renewed annually and currently cost between €50-€100. A fixed part of the fee goes to each of the three representative structures in industry; local, regional and national. The licence holders must return completed logbooks. Although in the first year of its introduction, every applicant got a licence, rules were subsequently put in place to deal with new demands.
- **Number of pots:** In addition to the licencing scheme, a limit on pot numbers was established in 1997. The number of pots allowed per boat is related to the number of crew. In most fisheries it is 200 pots per crew member, with a maximum of 1000 pots per boat. Manufactured plastic tags, attached to every pot, identify the licencee and the individual pot number.

3.4 History of licensing

Licensing of crab and lobster fishing is not recent in France. Although it was first implemented in 1971 the objective of licensing has changed over time. During the 60's, 70's and 80's a policy aimed at increasing lobster spawning biomass was pursued, and from 1970 to 1984 the licence was mainly a way to collect taxes dedicated to lobster restocking actions such as: the ban on the landing of berried females, the creation of sanctuaries and the release of hatchery-produced post larvae and juveniles. This policy did not prevent a decrease in catch rates of crab and lobster, probably because of a continued increase in fishing effort. Due to the lack of any evident impact of restocking, a growing number of fishermen requested that the licence fee be used for fisheries management, including a limit on fishing effort. In 1993, industry made the decision to "*establish a limit for the number of licences to adjust the size and characteristics of the fleet to the resource*", which led to the current type of licence.

3.5 The future

Although limited entry and licensing has been introduced in France for crab and lobster fisheries, the scheme needs to be improved. Future issues that the French industry and administration must consider include:

- developments in fisheries management in other countries
- means to develop and strengthen the current regulations, including both technical measures and input controls. It is very clear that several years are necessary for full national-scale implementation of new management measures. For instance, one region is still reluctant to use licensing; the rule about the pot number per boat and the link between the pot number and the crew number is questioned; is the maximum of 1000 pots per boat a good idea? Many other questions have arisen and remain to be answered.

4 Changes in Management of Fisheries in Jersey: A 14-year Process

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4.1 Introduction

The Channel Island of Jersey is located west of the Cherbourg Peninsula, in the Bay of Granville on the South side of the English Channel. The waters around the island are relatively shallow and generally no more than 40 m datum deep. They are interspersed with many rocky reefs, some equal to the area of Jersey itself, and the entire zone is exposed to the west. Due to the shape and orientation of the English Channel, the area around Jersey is subject to a very vigorous tidal regime. The tidal range is approximately 14m during equinoctial spring tides. This gives rise to very strong currents around the reefs and the island itself, and current speeds of 3-5 knots are common making the area very difficult to work with static gear. Of particular note is the proximity of Jersey to the western coast of the Cherbourg Peninsula. At low water this distance is only some 13 miles, and Jersey is essentially within the coastal zone of France. This of course means that there is a lot of joint exploitation of the marine resources by both the Jersey and the French coastal fishing fleets.

The vessels that work from Jersey are 8-13m in length, fishing strings of 30-50 lobster pots. There are some 50-60 vessels working out of Jersey, and a total of about 17,000 parlour pots and 10,000 traditional inkwell pots are used. This does not include the leisure effort and the French fishing effort in the Jersey zone both of which, at the moment, are unquantified. These pots are set daily within about 12 miles of the island coast. The fleet is licenced, and a fishing vessel may not go to sea to catch and land fish for profit without a licence. There is no limit on the number of pots that are set, although this is the subject of some discussion between the Jersey and the French authorities. It is mandatory that all parlour pots, set by Jersey vessels, have an escape gap, set in the parlour, to allow both undersized lobsters and crabs to escape. The catch of lobster has remained very constant over the past number of years and at the moment is between 150-160 tonnes per year. By comparison the catches of spider crab and brown crab vary and are currently about 300 and 600 tonnes per year respectively. The lobster, with the high price that it generates, is,therefore, by far and above the most valuable crustacean species landed in Jersey. Wet fish landings are less important, and in 1999 Jersey vessels landed a total of 350 tonnes of wet fish species.

Due to the proximity of Jersey to the French coast and the joint exploitation of the stocks by the Jersey and French fleets, there has been a certain amount of interaction between the two groups of fishermen which, with no proper regulatory mechanisms in place, has sometimes boiled over into rather difficult incidents. Newspaper headlines such as "*Fish Wars - French in New Incident*" or "*French Invaders Set Sail for the Ecrehou*", or "*One Shoots and then One Discusses*" have been seen over the past 10 years or so. This situation has occurred because of the lack of clarity on access and management systems for the area. The only treaty that regulated fishing between these two countries was agreed in 1839 and was put in place to cover a now extinct oyster fishery. Some 14 years ago the island decided to push hard, through the British Government, for proper negotiation to resolve this situation. It was recognised by the Island and the British Government that certain objectives needed to be addressed. These included:

1. Identification of the management zone;
2. Identification of the responsibilities within that zone;
3. Creation of a management system that would (a) involve all stake holders (b) manage for the sustainability of the fishery (c) encourage a problem-solving dialogue and (d) address marine environmental issues;
4. Harmonisation of regulations;
5. Dealing with control and enforcement issues.

Having identified certain objectives, the Island set about firstly convincing local political bodies that the system was worth re-negotiating and then convincing both the Home Office and the Foreign Office to begin opening a negotiating dialogue with France. Thus the chain of negotiation was long and tortuous, beginning with the Jersey Fishermen and Department of Agriculture and Fisheries through various local committees, then onto the Home Office and finally the Foreign Office. The

intention was to first extend the territorial waters to 12 nautical miles, then negotiate a median one, then re-draft the ancient 1839 Granville Bay Agreement and finally set in place management and feed-back systems that would serve to manage the fishery.

4.2 The Granville Bay Treaty 2000

A new Granville Bay Treaty was signed on July 4, 2000. It clarified the extent of the Granville Bay zone and access for the different fishing communities in it. Although these access arrangements are quite complicated and detailed, nevertheless, the details were necessary to gain the agreement of all of the different groups of fisherman from both France and Jersey that were involved. The agreement extends Jersey's three-mile exclusive zone to six miles in certain areas, preserves the ancient A to K line between St Malo and north of Carteret, which was intended to be broadly equivalent to the three mile limit drawn from low water save that it made allowance for the Iles des Chausey and confirms certain access by Jersey boats in the three- to six-mile zone north of St Malo and east of the Les Roches Douvres. Access in other areas is only allowed up to six miles. More importantly, the treaty puts in place a management system. There is a joint advisory committee composed of four Jersey fishermen, four Breton fishermen, and four Basse-Normandie fishermen, together with biologists and administrators. They advise a senior management committee and the respective governments on management measures they feel need to be implemented. This advice will be vetted to ensure that it does not conflict with EU or other National Legislation and then implemented in the respective legislation of the Jersey and French Governments. The Granville Bay Treaty also covers control and enforcement, and it identifies the levels of fines and penalties for breaches of regulations.

Due to the length of time that these negotiations have taken, the management authorities of Jersey and France decided to meet informally before the negotiations culminated in the signing of the treaty. These meetings resulted in the agreement of certain conservation issues. A ban on parlour pots in a 70 square mile area of Les Minquiers Reef, a spider crab closed season and a trawler-potting zone agreement, to help prevent damage to static gear by trawlers at certain times of the year south west of Jersey, are some issues that were resolved. The French implemented a pot-tagging scheme with the objective of limiting the amount of fishing effort by pots in the area. This is likely to be the next major item to be discussed at the joint advisory committee meeting. Jersey fishermen are now attuned to the concept of pot limits and are willing to bring in some form of system to address the escalating fishing effort that is occurring in local crustacean fisheries. Since the Jersey and French fisherman have got together to talk on these joint issues, relations between the two authorities have improved. The media has spoken of a honeymoon between Jersey and the Granville Bay area and of a communal cadre that has sprung up between the fishermen's organisations.

To conclude, the fisheries management system around Jersey and the adjacent coast of France was totally ineffectual and rested solely on a regime agreed in 1839. After a long uphill struggle, through complicated bureaucracy, a treaty was signed that enabled the participation of local fishermen in the fishery management process for waters between Jersey and France. Zoning agreements for different types of gear and pot limits are being negotiated for the area and licences are already in place for all Jersey and French fishermen. A third communal Granville Bay licence will be brought in to cater for the Granville Bay area. The fishermen have also recognised that effort limitation is necessary to maintain both the stocks and the viability of the industry into the future.

5 National and Regional Management of Lobster Fisheries in the United Kingdom

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5.1 Introduction

The fishery for lobster in the United Kingdom (UK) is primarily a small vessel, pot fishery located, mainly, in coastal waters within five miles. The past 25 years, however, has seen an expansion of the fleet to include a significant number of larger or faster vessels that exploit offshore grounds. Officially recorded landings of lobster in the UK have remained relatively stable at around 1000 tonnes for the last 25 years, although there has been an increase in landings in recent years. Currently the UK lobster fishery is worth around £15 million at first sale. Fisheries intelligence suggests, however, that the true level of landings may be very much higher than the recorded level. Whilst catch per unit effort (CPUE), which is a more reliable index of abundance than landings *per se*, has remained stable or even increased in some areas, there are some inshore areas where CPUE has declined in recent years, and there have been calls from the industry for tighter regulations.

5.2 Current management of the UK lobster fishery

Lobster fisheries in the UK are currently managed under a hierarchy of management measures. At the highest level they are subject to EU regulations, at the next level there are a number of national regulations that apply throughout the UK, and finally there are regional management measures, enacted and enforced through bylaws of the local Sea Fisheries Committees (SFCs).

The only current, EU-wide legislation is the minimum landing size (MLS) of 87 mm carapace length (CL). The landing of V-notched lobsters is prohibited under national legislation. In some districts there are also Regulating Orders that permit the control of fishing effort and other management measures, such as providing some degree of ownership for the ongrowing and future re-capture of hatchery-reared lobsters released into the wild. Although legislation in the UK previously prohibited the landing of egg-bearing (berried) female lobsters, this legislation was rescinded in 1966, primarily due to problems of enforcement. Restrictive licencing for crustacean fisheries was introduced in 2004.

In addition to these national regulations, a number of regional measures have been introduced by the 12 local SFCs that cover the coast of England and Wales (Table 5.0). No such bodies exist in Scotland where local or regional management measures have to be enacted under the Regulating Order legislation. Regional measures range from additional technical measures such as a higher MLS than applies nationally or a ban on the landing of berried females, to schemes that may require permit holders to make detailed returns of their landings.

Due to the geographical extent of SFCs their bylaws should really be considered as regional rather than local management measures. They can have significant benefits over national legislation. Firstly, they can be tailored to meet local biological differences by, for example, adopting regional minimum landing sizes or specifying the use of only certain types of gear. In contrast, national measures must, by their very nature, represent a lower common denominator that does not fully account for regional differences. A further benefit of SFC bylaws is that they can be locally enforced. SFC bylaws do have some limitations, however; they extend only out to six miles from the coast and enforcement can thus often be hindered by the requirement to prove that offences under the bylaw were committed within, and not outside, the six-mile limit. There may also be enforcement difficulties at the boundaries between two areas. SFC bylaws must be approved by the UK Ministry; The Department for Environment, Food and Rural Affairs (DEFRA). This ensures that the bylaw is based upon sound science and has conservation merit. It is customary that DEFRA ensures that bylaws do not discriminate against particular sectors of the industry. Proposed bylaws may not be ratified until they meet these criteria.

Table 5.0 Sea Fisheries Committee bylaws

Management measure	Sea Fisheries Region
MLS of 90 mm	Cornwall, Devon, Isles of Scilly, South Wales
Maximum size	South Wales
Soft lobsters	Eastern, Northumberland
Berried females	Cumbria, Devon, Eastern, Kent and Essex
V-notching	Devon, North Eastern, Northumberland,South Wales, North Western and North Wales
Escape gaps	Cumbria
Permit schemes	Cornwall, Cumbria, Eastern, North Eastern, Sussex, Northumberland, North Western and North Wales, South Wales

5.3 Future management of the UK lobster fishery

Given the current UK management position what future measures could be introduced to improve management of the fishery, what do scientific assessments show about the status of the stocks, and which management measures are enforceable and are likely to be acceptable to the industry? Possible measures include a higher MLS than the national measure, maximum landing sizes, prohibitions on landing berried and V-notched females and the release of hatchery-reared juveniles to increase recruitment. Many of these have already been introduced regionally by SFCs.

5.4 Scientific assessment of management measures

Previous scientific assessments of lobster fisheries centred on yield-per-recruit as opposed to egg-per-recruit analysis, i.e. they were concerned more about growth overfishing than recruitment overfishing. These assessments show that:

1. An increase in minimum landing size (MLS) or a reduction in fishing effort are generally the only management measures likely to increase yield-per-recruit;
2. Other measures such as maximum sizes and bans on landing egg-bearing or V-notched lobsters tend not to significantly increase yield-per-recruit.

Historically, there has been no mechanism for limiting fishing effort. Fishery managers have concentrated, therefore, on increasing the MLS as the most effective way of increasing yield-per-recruit, whilst simultaneously increasing egg per recruit. Fishery scientists and managers have recently considered, however, that to ensure sustainability of the fishery it is essential to safeguard against recruitment overfishing and as a result egg-per-recruit analysis is now becoming the most appropriate approach. UK scientists recently reviewed a variety of management options and reached the following conclusions on the likely impact of measures on egg production in lobster fisheries:

1. Reducing fishing effort is a very good way to increase egg production;
2. Prohibiting the landing of egg-bearing females will substantially increase egg production;
3. V-notching female lobsters will only have an impact on egg production if a significant proportion of females are notched regularly;
4. Increasing the minimum landing size to 90 mm CL will substantially increase egg production;
5. Introducing a maximum size has relatively little effect on egg production at the current levels of fishing effort in most areas;
6. All technical conservation measures (2 to 5 above) will only increase egg production if the level of fishing effort is maintained at or near its current level;
7. Enhancement of natural stocks through the release of hatchery-reared juveniles could be beneficial in areas where recruitment has failed.

5.5 Industry uptake and enforcement of management measures

From the scientific viewpoint the fishery is likely to benefit from a range of conservation measures. Success also depends on what can be enforced effectively and has the backing of the industry. Recent dialogue with the industry and enforcement officers suggests the following:

1. Limitation of fishing effort is highly sought after by the industry, but it may be difficult to introduce a fair system of allocation and will be difficult to enforce;
2. Proposals to ban the landing of egg-bearing (berried) females receive mixed reaction from the industry, but they should be relatively easy to enforce;

3. V-notching programmes are popular amongst the industry when statutory bodies pay for the programme, but individual fishermen are generally reluctant to V-notch and release females that could otherwise be landed. The measure should be reasonably easy to enforce, although there are reported problems over V-notches that have partially grown in after a moult;
4. Minimum landing sizes that are appropriate to each region are acceptable and are very easy to enforce;
5. A maximum landing size is simple to enforce and is acceptable in the inshore fisheries, but is less acceptable in the offshore fisheries that would initially bear the brunt of the impact;

Limitation of fishing effort is undoubtedly the key management measure required to ensure that yield and egg-per-recruit are sufficient to sustain the fishery. Technical measures can increase egg production per recruit, but analysis shows that this benefit can be negated by an increase in fishing effort. Effort limitation has to occur, therefore, through a licencing or permit scheme. A national shellfish licencing scheme was introduced in 2004 although it does not restrict the effort of individual licence holders. All licensees under this scheme must submit landing records annually.

5.6 Conclusions

A range of management measures is available to ensure continued egg production and future recruitment to the stock to sustain the lobster fishery in the UK. Each fishery within Europe will need to introduce those measures, which are particularly well suited to the regional and local characteristics of the fishery. Limiting fishing effort is likely to be desirable in all localities and regions, but other measures need to be tailored to meet local requirements. In the UK, varying minimum landing sizes already reflect the nature of local fisheries. The importance of adjusting measures to local biological characteristics of the stock is illustrated by the following;

The introduction of a maximum landing size would clearly benefit stocks on the UK offshore grounds, where there is currently a low exploitation rate and which might be the source of larvae production for adjacent fisheries. There is little point, however, in introducing a maximum size in inshore fisheries where the exploitation rate is very high and very few, if any, large lobsters are caught. In this scenario, alternative management measures are more appropriate.

A second example concerns the release of hatchery-reared juvenile lobsters to enhance natural stocks. Whilst this is likely to benefit fisheries where there has been a recruitment collapse, such as in Norway, or where local factors have damaged previously good lobster ground, there is little to be gained from releasing hatchery-reared lobsters on grounds where there is already good recruitment, as on many inshore fishing grounds in the UK. In those circumstances, the better aim is to maximise the yield and egg production from the already high level of natural recruits.

6 Local Industry Lobster Management Plans in Ireland

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6.1 Introduction

The South Wexford Lobster Fishermen's Co-operative Society Ltd. (the co-op) developed and implemented a seven-year management plan for their local fishery in the early 1990s. They successfully implemented two main conservation/stock restoration measures; the v-notching of over 9000 female lobsters and the release of over 90,000 hatchery-produced juveniles. A stock-monitoring and research program was also established. Catch rates in the fishery improved substantially four years after initiating the management plan. During the early years of the plan, the co-op was successful in attracting research and development funding in collaboration with the university and state sectors. This assisted the co-op to employ hatchery workers and researchers to provide data on stocks and to evaluate the potential benefits of the plan. The plan represented a unilateral initiative by the co-op and was not supported by either national or local legislation to limit effort. Without this support, the co-op had no power to control the fishing activities of fishermen in the area. Fishing effort doubled between 1995 and 2003, and catch rates declined to pre-management plan levels by 2003. The initiative foundered mainly due to the lack of legislative support. Nevertheless, it remains an outstanding example of the ability of local industry to develop fishery management plans and to effect significant restoration of stocks.

6.2 Background to the formation of the lobster co-op

In 1994, 106 people were directly employed and a further 35 indirectly employed in lobster fishing in the south Wexford region. This area of coast is approximately 40 nm in length and lobster fishing extends to approximately six miles from the coast. Effort, in terms of number of pots per boat, and the number of boats was increasing, and the fishing season was being extended. Catch rates were declining, and there was, therefore, concern for the future viability of lobster fishing.

In 1992, lobster fishermen from south Wexford approached Bord Iascaigh Mhara; The Irish Sea Fisheries Board (BIM) stating their concerns. In 1993 the conservation measures used in the lucrative American lobster fishery were outlined at a seminar at Kilmore Quay. BIM, The Wexford Organisation for Rural Development (WORD) and The Irish Training and Employment Agency (FÁS) then assisted the co-op to produce a management plan for lobster stocks. In 1994, the co-op was formed and the management plan adopted. The management plan had two principal and related objectives:

1. Manage current stocks to prevent further decline;
2. Restore stocks in order to improve catch rates.

6.3 The lobster management plan

The targets of the plan were:

- That the co-op would have a representative structure;
- To V-notch and release 7,000 female lobsters;
- To produce and release 70,000 stage VI hatchery reared juveniles;
- To establish a fisheries monitoring programme;
- To raise funds through a 2% levy on landings and obtain matching funds from grant aid;
- To obtain legislation in order to protect investment.

In addition, the objectives of the co-op were to:

- Maintain the number of participants in the fishery;
- Achieve sustainable CPUE/income levels;
- Optimise market returns.

6.4 Achievements of the seven-year management plan

The achievements of the seven-year plan were as follows:

- V-notching; 9,600 lobsters were released up to the end of 2000, producing an estimated 45 million eggs per annum. These contributed up to 60% of total local population egg production

- Juvenile releases; A facility was adapted to be a lobster nursery and was later upgraded to a lobster hatchery and nursery facility. Ninety thousand, stage VI lobsters were released into the fishery
- Representative structure; The Co-op was established with 127 members, and the area was selected as a BIM pilot area for an Inshore Fisheries Development Committee (IFDC);
- Legislation to protect V-notched lobsters was introduced in 1994;
- Monitoring; Log books were distributed to all boats and a database of catch rates established in 1995. This was updated on an annual basis. Surveys, including onboard boat surveys and acoustic seabed classification surveys were undertaken with a view to identifying critical habitats for juveniles;
- Funding; The co-op was very successful at attracting grant aid either independently or in collaboration with researchers. Sources of funding included:
  - Once-off membership fee payment: total fishermen's membership fund of €20,000 was raised
  - The 2% levy on sales was increased to 4% in 1999. Total fishermen's levy contribution up to 2000 was €160,000
  - Matching grants were obtained from the following sources: BIM, The European Regional Development Fund (PESCA), The European Union Directorate of Fisheries (DG Fish), Local Community Groups (LEADER), WORD, FÁS, The Irish Development Agency (Forbairt), Trinity College Dublin (TCD) and the Marine Institute (MI).

6.5 Impacts on the fishery?

Landings per 100 traps, increased from 7.6 lobsters in 1995 to 9.4 lobsters in 1999. Catch rates of undersized lobster increased from 4.9 lobsters in 1995 to 11.2 lobsters in 1999, indicating that recruitment had increased (Table 6.0).

6.6 Some concerns

- Catch rates of V-notched lobsters declined after 1999, suggesting that the V-notch was being lost due to moulting and that the egg production from V-notched lobsters may have been significantly lower than estimated.
- The number of pots increased dramatically during the late 1990s (Table 6.0).
- There was a lack of protection for stakeholders originally involved in the management plan as new effort entered the fishery.
- There were difficulties in enforcing legislation and local agreements, reflecting the lack of authority of the co-op.

Table 6.0 Changes in catch rates of lobster in south Wexford before and during the seven-year management plan.

Year	Undersized/ 100 pots	V-notched/ 100 pots	Landed/ 100 pots	Total no. of pots
1960s			33.00	5,000
1995	4.96	0.18	7.57	
1996	5.70	0.58	7.23	
1997	4.79	0.75	7.06	11,000
1998	8.38	0.98	7.72	
1999	11.20	0.78	9.40	
2000		0.56		14,500
2002*	14.4	0.18	11.9	22,000

**2002 data is targeted catch only*

6.7 Future requirements

The experience of the South Wexford lobster co-op in implementing local management plans indicates a number of requirements if such plans are to be effective in the long term;

- The control of fishing effort;
- The continuation and development of the programme;
- The setting of target goals over a time scale;
- The strengthening of the monitoring programme;
- The development of a strong local structure capable of recommending adjustments to the programme;
- A commitment from stakeholders to comply with a new management plan.

The control of fishing effort was central to the conservation objectives of the co-operative. They and a number of other co-operatives had a common view on how this should be implemented. The South Wexford, Dingle, West Galway (Clifden area) and East Waterford lobster Co-ops for instance had, by 2000, agreed the following objectives:

1. Prevent the expansion of fishing effort by way of input controls;
2. Pursue the establishment of a licenced, limited entry system for all crustaceans, excluding shrimp;
3. The Department of Communications, Marine and Natural Resources (DoCMNR) should administer licences after consultation with local industry;
4. Petition that the track record of fishing for lobster be used as a criterion for obtaining a licence;
5. The licences be issued annually and be non-transferable privately;
6. That a completed logbook be submitted to the DoCMNR as a condition of licence renewal;
7. To lobby for national legislation to limit the number of pots per boat, that would also cater for regional differences in stocks;
8. To advocate that all fishing gear has approved identification;

In 2003, the south Wexford and Waterford co-ops agreed jointly to introduce a limit of 400 pots per boat inside 6 nm by a majority (90%) vote. Legislation to support this initiative was being sought at the time of writing.

7 Lobster Management in Maine, USA

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7.1 The early fishery

The commercial lobster fishery in the state of Maine, USA, began nearly 100 years prior to Maine's statehood in 1820. Lobsters were so plentiful that they could be harvested by hand or with nets in the intertidal zone during periods of low tide or in the sublittoral fringe. In time, however, both the abundance of lobsters and the average size began to decrease, forcing fishermen to use other means of capture. Around the middle of the 19th century, fishermen began using baited traps or pots to harvest lobsters. Shortly after the pot fishery began, in 1872, Maine enacted one of the first protective measures to ensure a healthy fishery that prohibited the catching, buying, or selling of berried females (Nicosia and Lavalli, 1999). This law was repealed two years later and a closed season from 1 August to 15 October was adopted to protect ovigerous females (Dow, 1949). Beginning in 1917, berried lobsters could only be sold to the state of Maine's commercial fisheries bureau, later named the Department of Sea and Shore Fisheries, which, today, is named the Maine Department of Marine Resources (DMR). Marine wardens would punch a hole in the uropod of these ovigerous lobsters and release them back in the general vicinity of where they were caught. These lobsters were considered the property of the state and possessing them for sale or other commercial endeavour was illegal. In 1948, the uropod punch was replaced by the V-notch (Miller, 1995).

Since 1874, a minimum size law has also regulated the Maine fishery. The minimum size is a straight line measure from the eye socket to the distal end of the carapace, referred to as the carapace length (CL). The earliest measure of 92.1 mm CL (3 5/8 inches) was the greatest minimum size (1874 – 1919). Since that time, the minimum size has fluctuated between a low of 77.8 mm CL (3 1/16 inches; 1933 – 1942) and a high of 82.6 mm CL (3 1/4 inches; 1989 – present). Since 1933, Maine has supported regulations governing the maximum size harvested. Initially, this measure was 101.6 mm CL (4 inches), which was increased to 127 mm CL (5 inches) from 1935 to 1958. For three years beginning in 1958, the maximum size was 131.8 mm CL (5 3/16 inches), but, since 1960, the maximum size has been 127 mm CL (Nicosia and Lavalli, 1999). Both minimum and maximum size laws are intended to increase the production of eggs per individual recruited to the fishery.

7.2 Commercial landings and current management schemes

Historically, the Maine lobster fishery has been a roller coaster of boom-and-bust periods. The lowest landings occurred during the 1920s and 1930s, when an average of 2,000 – 3,000 metric tons (t) were caught. A dramatic increase in the catch occurred during the Second World War, as landings doubled from a pre-war figure of 4,000 t in 1940 to a post-war level of 9,000 t in 1949. From 1949 to 1980, landings fluctuated marginally from a high of 11,000 t in 1957 to a low of 7,500 t in 1974. Beginning in 1988 and continuing throughout the decade of the 1990s, the boom period of lobster fishing in Maine occurred. In 1997 and 1998, nearly 22,000 t were landed with a dockside value of approximately $140 million. Fishermen and scientists have different explanations for the boom-and-bust cycles, however, both believe that a combination of fishing practices and environmental variables has resulted in the recent surge in landings (Acheson and Steneck, 1997). Biologists point to the importance of fishing effort and increases in seawater temperatures that have resulted in nearly a 1°C increase in mean annual seawater temperatures since the mid-1950s. Fishers believe that lobster populations have been strongly affected by environmental factors (what they term "natural cycles"), the way people fish and the regulations imposed on the fishery (i.e. by a reduction in the amount of illegal activity, by restrictions on size and taking of breeding females etc.). In addition, fishers generally believe that biotic factors, such as the recent decreases in predation on lobsters by groundfish, have also played a major role in recent landings increases. These central divisions between fishermen and scientists are the foundations of a co-managed fishery in Maine. As a result, biologists are committed to controlling effort, while fishers believe that management should be based on rules to conserve the breeding stocks directly (Acheson and Steneck, 1997).

One of the biggest worries managers of the Maine fishery face today revolves around recruitment overfishing, a term used to describe the relatively large proportion (>90%) of lobsters that enter the fishery prior to maturity. Scientists argue that the current minimum size of 82.6 mm CL is not large enough to produce sufficient eggs to maintain recruitment to the stock in the future. In addition, they would like to reduce pressure on the fishery through limited entry and lower trap limits. Fishermen argue that catch and effort have been positively related during the past decade. That is, the more traps fished, the better the catch. They also argue that the mathematical models scientists use to estimate maximum yields are unrealistic, or, at least, do not adequately model what is presently occurring in the fishery. In addition, fishermen are convinced that the management tools currently in place (trap limits, biodegradable escape vents, minimum and maximum landing sizes, V-notching and making possession of ovigerous females illegal) provide significant compensation for a fishery, in which >90% of the individuals are immature. Maine fishermen are prepared, however, to increase the minimum CL size to 84.1 mm over a two-year period when other New England states adopt the same minimum size.

7.3 Specific rules and regulations

Maine's lobster fishery management plan has been used as a model for other New England states and the federal government, which has jurisdiction from twelve miles offshore to the 200-mile limit. Several of the laws (such as minimum and maximum carapace length, V-notching, and licencing) have been in effect for more than a half a century. Other regulations such as escape vents, trap limits, licencing classes and trap tags have been in effect for two decades or less. Today, seven regional management committees decide the way in which local waters will be fished and regulated, and these rules are superimposed on statewide regulations. The management committees may not override a statewide rule or regulation, they may only make it more stringent.

The following section contains excerpts from Chapter 619 (LOBSTER AND CRAB FISHING) of the State of Maine regulations and statutes (12 M.R.S.A. Subchapters I (§6421) – V (§6477) [2003])

a) Minimum and maximum landing sizes

- Minimum carapace length (CL) = 82.6 mm, or 3.3 inches
- Maximum CL = 127 mm, or 5 inches

b) Licensing

All fishers who wish to harvest lobsters in Maine must be licensed. The license enables the licensee to "fish for, take, possess, ship or transport within the State (of Maine) lobsters (*Homarus americanus*) or crabs (*Cancer irroratus and/or Cancer borealis*) and sell lobsters or crabs the license holder has taken (caught)." The licence *does not* authorise the licence holder to remove lobster meat from the shell or to take, possess, transport or ship lobster parts or meat.

There are seven discrete classes of licences and an annual licence fee:

a) Class I -- $56 for applicants under 18 years of age; $93 for applicants 18 years of age and older. A Class I licence authorises the holder to fish for lobsters and crabs. Any individual assisting or helping a Class I licence holder in these activities must also be licensed.

b) Class II -- $228.50 for all applicants. A Class II license authorises the license holder to fish for lobsters and crabs and the licence holder may engage one unlicensed crew member to assist in the licensed activities under the direct supervision of the Class II licence holder.

c) Class III -- $341.25 for all applicants. A Class III licence authorises the licence holder to fish for lobsters and crabs and the licence holder may engage two unlicensed crew members to assist in the licensed activities under the direct supervision of the Class III licence holder.

d) Apprentice -- $56 for applicants under 18 years of age; $114 for applicants 18 years of age and older. An apprentice lobster and crab fishing licence authorises the apprentice so licensed to fish for lobsters and crabs on that apprentice's sponsor's vessel when the apprentice's sponsor is on board the vessel. A person who holds an apprentice lobster and crab fishing licence may not tend any traps unless the traps are fished by the sponsor of the apprentice so licensed. An applicant for an apprentice lobster and crab fishing licence may designate up to 3 sponsors. An "apprentice's sponsor" means a person who holds a Class I, Class II or Class III lobster and crab fishing licence.

e) Student -- $56 for all applicants. A student license authorises the license holder to fish for lobsters and crabs. The licensee may not submerge at any one time more than 150 lobster traps in the coastal waters of the State (of Maine). An applicant for a student licence shall designate a sponsor. A person

issued a student licence is enrolled in the apprentice program. A "student's sponsor" means a person who holds a Class I, Class II or Class III lobster and crab fishing licence.

f) Commercial (over 70 years of age) -- $56 for all applicants.

g) Noncommercial -- $56 for all applicants. A noncommercial lobster and crab fishing license authorises the license holder to fish for lobsters and crabs, however, he/she may not submerge, at any one time, more than 5 lobster traps in the coastal waters of the State (of Maine).

In 2000, the following number of licences were sold in each class: Class I – 2,008; Class II – 2,799; Class III – 459; Apprentice – 563; Student – 927; Commercial (over 70 years of age) – 351; Noncommercial – 1,406. There was a total of 7,107 licences sold, 75% of which were either Classes I, II, or III. Of the total number of commercial licences sold in 2000, 92% went to licence holders in Classes I, II, or III.

The state of Maine has imposed a limit on the number of fishermen, in that a Class I, Class II, Class III, apprentice, noncommercial or student lobster and crab fishing licence may only be issued to an individual and is a resident licence. Further, a Class I, Class II or Class III licence may be issued to a person only if the person possessed a Class I, Class II or Class III lobster and crab fishing licence in the previous calendar year. Individuals who retire from the fishery may not "pass along" their licence to anyone.

c) V-notching and egg-bearing female protection

The state of Maine and fishermen have been v-notching lobsters since the 1940s. It is unlawful to take, transport, sell or possess any lobster that is bearing eggs or any *female* lobster marked with a V-notch in the right flipper (endopod of the uropod) next to the middle flipper (telson) or any female lobster which is mutilated in a manner which could hide or obliterate that mark. The right flipper is determined when the underside of the lobster is down and its tail is toward the person making the determination. If an egg-bearing female is discovered in a lobster impoundment, the pound owner will notify the DMR who will take the lobster, V-notch her if not already notched, and liberate the lobster into the immediate vicinity outside the impoundment area. The pound owner will be reimbursed the price of the lobster at a rate that is agreed before the season begins by the DMR and the Maine Lobsterpound Owner's Association.

If anyone is caught illegally possessing an egg-bearing female or any lobster whose right flipper is V-notched or mutilated in a manner which could hide or obliterate such a mark it shall be *prima facie* evidence that the lobster is a V-notched female lobster. The penalty for possession of such lobsters is a fine of $50 for each violation and, in addition, a fine of $100 for each lobster involved that is bearing eggs and a fine of $50 for each female lobster involved that is marked with a V-notch.

It is also illegal to artificially remove the extruded eggs from a female lobster or to take, buy, sell, possess, transport or ship any female lobster, from which extruded eggs have been removed by any means other than natural hatching. The penalty for this, is a fine of $500 for each violation and, in addition, a fine of $150 for each lobster.

d) Traps, tags, and escape vents

The maximum size for traps in Maine is a volume no larger than 22,950 cubic inches. Beginning in 1996, lobster and crab fishing licence holders had to purchase tags (one per trap) for the purpose of identifying and tracking traps. Tags must be purchased through the DMR and cost $0.50 each. Trap tag fees must be deposited in the Lobster Management Fund.

An escape panel or "vent" is required in every lobster trap in the state of Maine. The vent sizes are as follows: a rectangular or oblong escape vent not less than 1 3/4 inches (44.5 mm) by 5 3/4 inches (146 mm) located next to the bottom edge, or on the top if the escape vent is placed over the head of an end parlour section. Circular escape vents can also be used, but there must be two of them and they must be not less than 2 1/4 inches (57.2 mm) in diameter, located next to the bottom edge or on the top if the escape vents are placed over the head of an end parlour section. An escape vent may also be created in a wooden trap by creating a gap caused by raising, modifying or separating horizontal laths so as to create a space that is at least 44.5 mm x 146 mm. In a wire or plastic trap, an escape vent may be a gap created by cutting vents (at least 44.5 mm x 146 mm) in the side or end. Whenever the minimum legal carapace size is adjusted, the commissioner of the DMR shall specify, by rule, the dimensions of vents in lobster traps, which shall be appropriate for the minimum legal lobster size in effect.

Beginning on 1 January 1990, all lobster traps were required to be equipped with a biodegradable ghost panel. A "ghost panel" is an escape panel that is designed to release lobsters from traps that are lost while fishing. The majority of escape panels double as ghost panels, which means they must be replaced every 1-2 years.

e) Closed periods

Maine law establishes two closed periods during the fishing season, during which times it is unlawful to raise, haul or transfer any lobster trap from the coastal waters. These are:

Summer During the period 1/2 hour after sunset until 1/2 hour before sunrise from June 1st to October 31st, both days inclusive;

Weekends During the period from 4 p.m., Eastern Daylight Saving Time, on Saturday, to 1/2 hour before sunrise the following Monday morning from June 1st to August 31st, both days inclusive, except that it is lawful to raise, haul or transfer traps during this period if a hurricane warning issued by the National Weather Service is in effect.

These closed periods were created to reduce the chances of illegal hauling by unlicenced fishers during the summer and on weekends.

f) Trap Limits and Management Zones

Beginning in 1996, Maine adopted a statewide limit on the number of lobster traps that could be fished by a licencee. This limit, initially, was 1,200 pots per licence but was reduced to 1000 per licence from 1 January 1998 to 29 February 2000 and after 1 March 2000 was further reduced to 800.

In 1996, the Maine DMR and Maine lobster fishermen agreed on a new policy to effect local control over managing lobster stocks. Legislation created seven distinct, non-overlapping management zones. A person must declare on an application for a Class I, Class II or Class III lobster and crab fishing licence the lobster management zone, in which that person proposes to fish a majority of that person's lobster traps. A licence must identify the zone, in which the person is authorised to fish a majority of that person's lobster traps.

Management zones are intended to produce local rules for fishing effort or other schemes that are stricter than current statewide law. For example, zones may extend limits on the number of traps fished by an individual lobster licence holder, or two or more lobster licence holders, who fish from the same boat fishing in a particular lobster management zone and may also extend the time periods allowed for complying with that number. Zones may impose a limit on the number of lobster traps allowed on a trawl fished, or place limits on the time of day when lobster fishing may occur. Each zone is governed by a policy council that abides by a local set of bylaws. Councils may conduct their business and decide all issues by consensus, except the decision to hold a referendum on lobster fishing effort limitations. This decision must be approved by a majority of the council members present and voting. Each voting council member has one vote. No vote is binding unless a quorum of two thirds of the council members is present and voting. After a council votes to hold a referendum, the referendum question must be mailed to all eligible licence holders who have designated that zone as their declared zone. The referendum ballots will include a postage-paid return address at the DMR. The council may submit a proposed effort limitation rule to the Commissioner if it is approved by two-thirds of those voting in the referendum. If a council recommends a rule to limit lobster fishing effort in its zone after approval in a referendum, the Commissioner of the DMR may adopt and publish the rules verbatim or may adopt and publish rules that accurately reflect the intent of the council's recommendation. The Commissioner may also reject the proposed rule if he/she finds it to be unreasonable.

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8 Effects of Fishing Strategies on Yield and Egg Production of American Lobsters in Nearshore Gulf of Maine

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8.1 Introduction

Different fishing strategies for American lobster, *Homarus americanus*, have evolved in part due to variations in resources, markets and the types of management measures supported by fishers. In the United States, with a few minor exceptions, there are no regulated seasons, and limits on traps have only recently been adopted. The evolved patterns of fishing show a temporal concentration of effort and a subsequent high proportion of landings over a very short portion of the year. This is, in part, a response to competition amongst fishers. A simulation model, using population dynamics parameters for lobsters, was developed to examine yield and egg production of lobsters under different life-history patterns and/or management and harvesting regimes. The model allows multiple time steps during a year in order to incorporate differences in life history and fishing tactics on a fine temporal scale. By using this model the differences in yield and egg production have been examined and relative effects of different fishing strategies evaluated.

8.2 Egg and yield per recruit model overview

Conventional egg production and yield per recruit models are not useful for lobster because age determination is difficult; growth in length is not continuous and the relationship between size and annual egg production is complicated. The model used in this study, incorporates size-specific, annual, moult probabilities, assumptions about intermoult duration, moult increments, maturity schedules, fecundities and length-weight relationships. Calculations incorporate interactions between reproduction and growth (e.g. female lobsters suspend moulting and growth when they are carrying eggs) and size specific management measures for female lobster (e.g. maximum and minimum size regulations).

In these models for lobsters, it is important to distinguish among "nominal" encounter, capture, retention and fishing mortality rates. The *nominal encounter rate* is a measure of the rate, at which individual lobsters encounter and enter traps. In baseline runs, nominal encounter rates were assumed equal for lobsters of all sizes. *Capture rates* measure the rate, at which individual lobsters enter traps without leaving. Capture rates are less than encounter rates because escape vents allow small lobster to leave traps. Capture rates depend, in part, on size because large lobsters are unable to leave traps through escape vents. *Retention rates* are based on management regulations and fishery behaviour. Legal requirements (minimum and maximum size, prohibition of landing berried lobsters and v-notch protections) as well as size specific and/or other quality considerations affect release of captured lobsters. Only those lobsters retained are removed from the model population. Encounter and retention parameters in the model can be changed to simulate management measures. In contrast to nominal encounter and capture rates, fishing mortality rates measure the rate, at which lobsters are landed and killed. *Fishing mortality rates* are usually less (and never greater) than capture rates because management measures (e.g. maximum and minimum size limits, restrictions on landing berried or v-notched females) require that some lobsters caught in traps be released.

Each model run was based on a cohort of male and female lobsters. Growth is modeled using 1 mm size groups and is determined by the interaction of size specific moult interval (the time between molts) and a range of molt increments. The model simulates growth and mortality and keeps track of the number of survivors, number of natural deaths, numbers landed, number mature, number V-notched, number moulting and egg production by size group, in each time step over the lifetime of the cohort. A monthly time step allows investigation of temporal differences in growth and implementation of management measures.

8.3 Simulations

The model was run using combinations of different management measures: minimum size (MIN) of 83mm CL, maximum size (MAX) of 127 mm CL, protection of berried females (EP) and v-notching (VN) and subsequent protection, for two molts, of notched females. The combinations of measures examined were:

1. Minimum size protection only;
2. Minimum size and berried females protection;
3. Minimum size, berried females and maximum size protection;
4. Minimum size, berried females and v-notching;
5. Minimum size, berried females, v-notching and maximum size protection.

In all cases, all protections apply to females. Only the minimum and maximum gauge sizes offer protection to males, however, so combinations 1, 2 and 4 are equivalent (minimum size protection only) and combinations 3 and 5 both offer the same minimum and maximum protection. Model runs were made over a range of encounter rates from 0 to 2.0, and yield and egg per recruit estimates were compared for the five sets of management measures.

8.4 Results

The results, in terms of egg production and yield per recruit for the five combinations of management measures are shown in Table 8.0, for two values of F(capture) or effective effort; the low F = 0.3, the high F = 1.0. The yield per recruit (YPR) values are for both sexes combined (values for males, females follow in parentheses). Egg production per recruit (EPR) is also shown. An additional metric is presented. This is listed as a relative catch per unit effort (RCPUE) ratio. This is simply the YPR under low F divided by the YPR at high F, times the inverse ratio of F capture rates (effective effort). In this case, the effort ratio is 1.0/0.3 = 3.333. This is an indication of the additional effort (at high F) required to produce the YPR difference.

Table 8.0 Effects of different management controls in terms of yield and egg production per recruit.

Run	Management controls	Low F YPR	High F YPR	RCPUE ratio	Low F EPR	High F EPR
R1	1) MIN only	325 (340, 310)	316 (329, 304)	3.4	4,198	296
R2	2) MIN + EP	324 (340, 308)	318 (329, 306)	3.4	7,682	834
R3	3) MIN + EP + MAX	312 (340, 285)	313 (329, 296)	3.3	11,487	2,306
R4	4) MIN + EP + VN	279 (307, 250)	312 (329, 296)	3.0	18,616	2,484
R5	5) MIN + EP + VN + MAX	284 (307, 260)	317 (329, 305)	3.0	15,100	1,032

MIN = Minimum landing size (83 mm CL), **EP** = Egger Protection

MAX = Maximum landing Size (127 mm CL), **VN** = V-notching and V-notch protection

RCPUE ratio = (Low F YPR/High F YPR)*(High F/Low F)

8.5 Discussion and Conclusions

YPR and EPR differences, among scenarios, are functions of the type and timing of protective measures implemented. In the majority of the US Gulf of Maine (GOM) (in terms of lobster abundance), large animals (>127 mm CL) of both sexes and v-notched females are non-harvestable.

The "bottom line" of these differences in management measures is that, for a given capture rate, there is a gain in egg production per recruit, a loss in total yield per recruit and a forfeiture of the additional effort necessary to acquire that yield. Under current US management in nearshore Gulf of Maine (GOM), the female yield per recruit is asymptotic. Since females are protected *via* V-notching and a maximum size, the usual peak at low exploitation is dampened by the unavailability of those animals. The males in most of the GOM are also protected by a maximum landing size and show a similar damping of maximum yield, but not to the same degree. Total yield, though dampened by the female contribution, still shows a peak at low exploitation.

What is very clear from this exercise, is that the benefits of these management regimes are higher at low exploitation or low fishing effort (Figs. 8.0, 8.1 and 8.2). This is simply the manifestation of allowing the lobsters to express those traits that give them protection from harvesting. In the US, this means that at low harvest rates, both male and females are allowed to reach the maximum size (127 mm CL) that ensures their return to the water. With regard to V-notching, a female must become mature to become egg-bearing and thereby have a potential to be V-notched and then protected. With the minimum size of 83 mm CL, only about 2-5% of the females are mature, and are 1-2 moults away from 50% maturity (around 95 mm CL). Additionally, with a year-round fishery, the mature females may be harvested before they extrude eggs, and thus the potential protection (both from being berried and also possibly notched) is not realised. When the harvesting rate is low, more animals will mature and then be potentially notched (Fig. 8.3) and survive to the maximum size.

It appears that the most effective way to provide sustainable lobster resources is to attempt to reduce the harvesting rates. The gains in yield and potential decrease in costs associated with harvesting should make this an attractive avenue to pursue. Additionally, the current restrictions introduce inefficiencies into the harvesting of lobsters. While some minimum size is practical, in terms of markets as well as in terms of protection of spawning stock, the other measures all require greater discarding of animals that are not legally harvested. It is this process that flattens out the yield per recruit curves and creates the likely increased effort to take what is available (legally) from the resource. As effort increases and the size composition of landings becomes more compressed, the only thing that maintains harvest levels is constant or increased recruitment. Additionally, the size composition of the resource itself will become compressed if the minimum size is insufficient to protect mature females. At present in the GOM, the minimum legal size of 83 mm CL is essentially the onset of maturity for female lobsters. With nearly 90% or more of the landings coming from sizes within one or two moults above this minimum size (i.e. 94 mm CL or less), this means most lobsters do not have the opportunity to spawn once. At the current level of removals, the incorporation of a maximum size, V-notching and berried female protection cannot compensate for the reduction in spawning potential. Currently in the GOM, there is essentially open access to the fishery. If all legal permits were to fish the current trap "limits", there could be a two- to three-fold increase in the amount of gear, assuming there is sufficient room to fish that much gear. As it is, reports of expansion into areas which, formerly, were lightly (if at all) exploited are more frequent. The current management tools that incorporate inefficiencies, without addressing control of effort, cannot be expected to protect the resource at present levels of recruitment, much less in the event that recruitment should drop off.

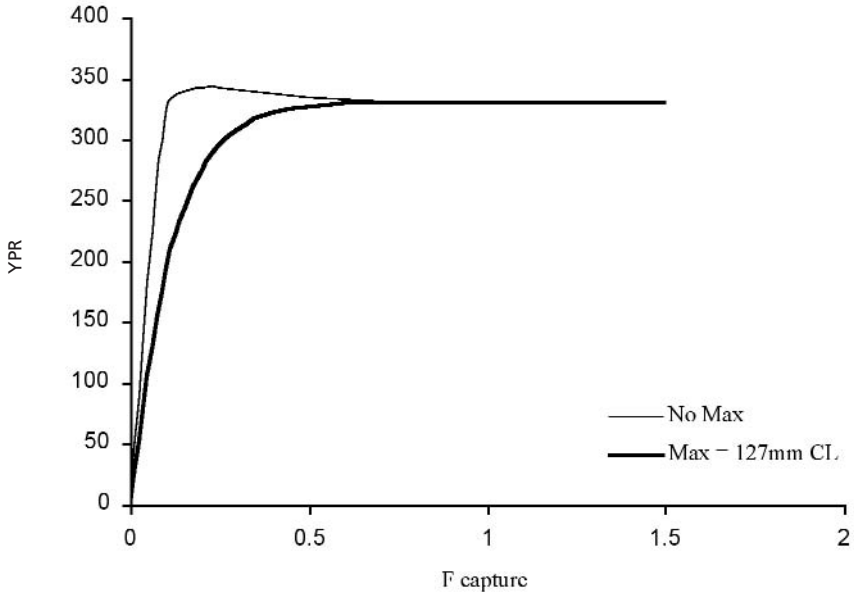

Figure 8.0 Yield per recruit for male lobsters in the Gulf of Maine (GOM).

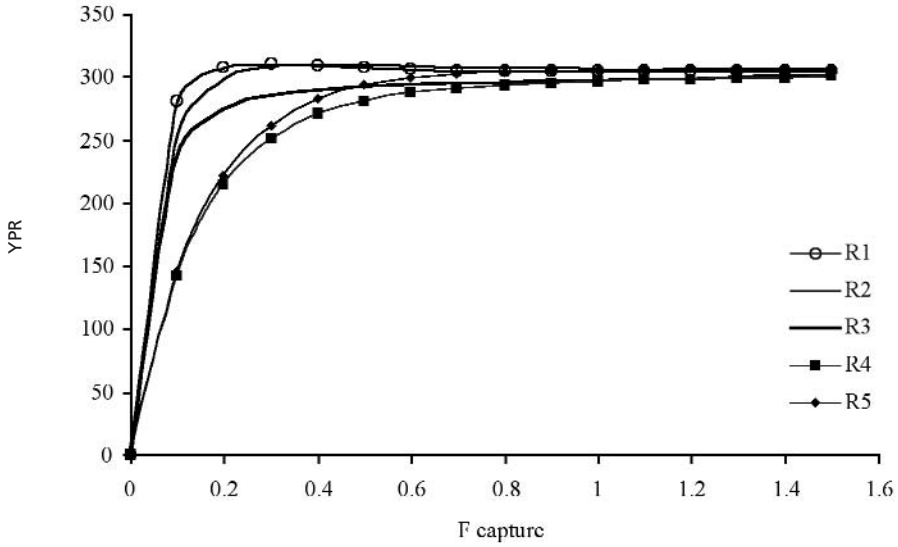

Figure 8.1 Yield per recruit for female lobsters in the Gulf of Maine. Refer to Table 8.0 for model run (R1-5) conditions.

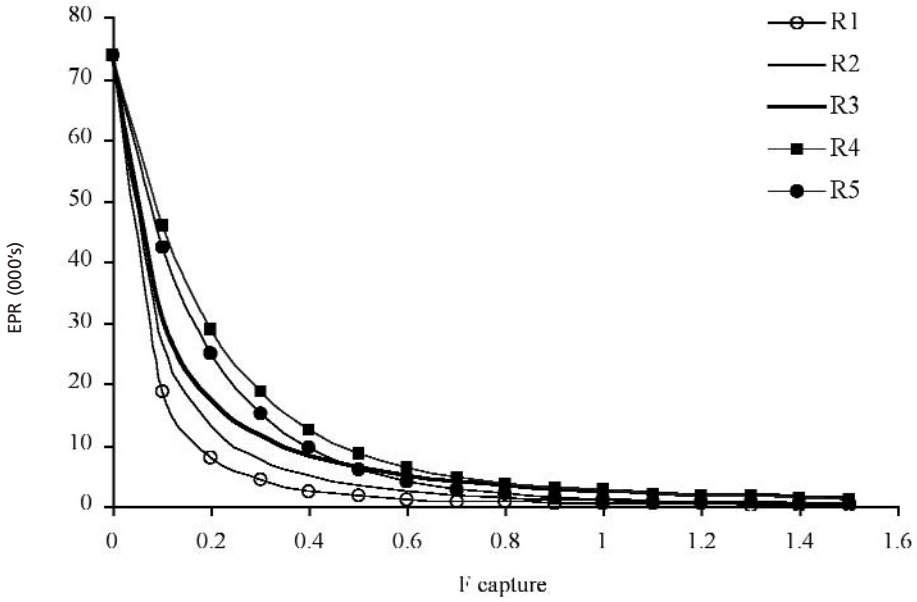

Figure 8.2 Egg per recruit for female lobsters in the Gulf of Maine. Refer to Table 8.0 for model run (R1-5) conditions.

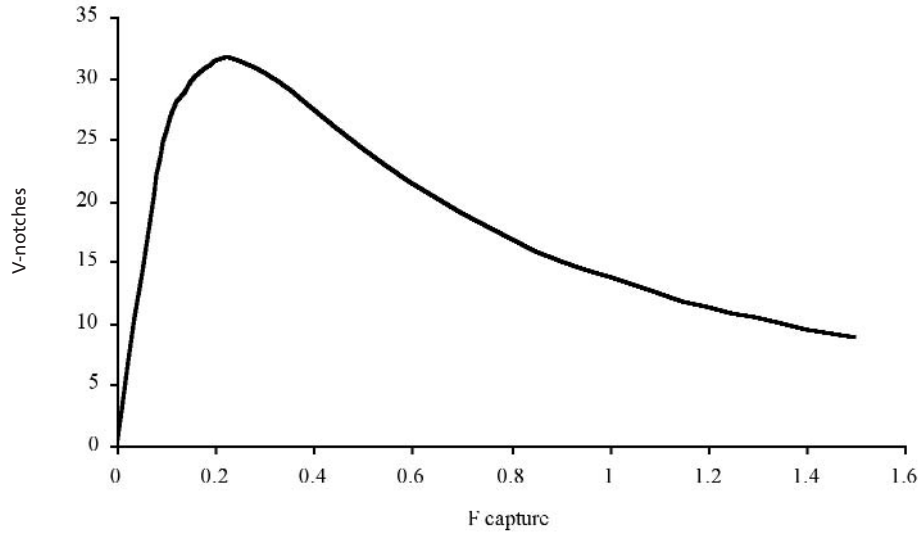

Figure 8.3 V-notching as a function of fishing effort in the Gulf of Maine. At low effort, more females mature, spawn and are available for v-notching.

9 Regulation of Lobster Fisheries in Ireland, Europe and USA: A Summary

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9.1 Development of research and management measures in Ireland (1992 – 2003)

Concern from lobster fishing groups about stock levels has led to the establishment of a range of management strategies and attempts at restocking or enhancing exploited fisheries in Europe and North America. In Ireland, it is generally perceived, both by fishers and state bodies, that the pressure on lobster stocks is increasing and is resulting in the depletion of stocks. During the 1990s, a number of innovations occurred in the Irish lobster fishery. Many of these initiatives were pursued by local and voluntary groups, which in turn generated considerable enthusiasm for conservation measures and their legislative development.

Some important events and work in the evolution of lobster management that have occurred in Ireland since 1992 are described in Table 9.0. Many of the activities described are interrelated and were undertaken over a period of several years, with multiple participants and organisations involved.

Table 9.0 Chronology of recent events in Irish lobster fisheries management

Year	Event
1992	■ Lobster stock enhancement programme commenced at The Shellfish Research Laboratory (SRL), Carna with support from Taighde Mara Teoranta (TMT); Irish-American Aquaculture conference with emphasis on lobsters (Galway);
1993	■ Brian Beal undertook lecture circuit of Ireland (Galway, Donegal, Wexford and Kerry) funded by Údarás na Gaeltachta and SRL; Voluntary conservation of "V -notched" lobsters commenced; Wexford lobster Co-op initiated;
1994	■ Wexford lobster nursery opened; International lobster conference in Galway organised by John Mercer (SRL); Irish Lobster Association (ILA) established; Irish fishermen visit and work in USA (Maine) at the invitation of The Maine Lobster Fishermen's Association (MLFA); ■ Legislation introduced to protect V-notched lobsters;
1995	■ Lecture circuit of Ireland by David Dow (Maine Lobster Association) on lobster conservation; ■ Lobster conservation posters campaign (ILA); ■ A review of potting and creeling by Irish Sea Fisheries Board (BIM); ■ A study of the impact of v-notching in Wexford began by Tully, Trinity Colege Dublin (TCD);
1996	■ Lobster ecology and recruitment study (LEAR) commenced funded by European Commission;
1997	■ ILA became a registered Co-operative Society;
1998	■ Study on the genetics of European lobsters (GEL) commenced, funded by the European Commission; A study on egg per recruit production in Irish stocks began (TCD and TMT)
1999	■ BIM review and recommendations on inshore fishery sector;
2000	■ Establishment of Local Inshore Fisheries Development Committees (IFDCs) in Wexford, Dingle and Galway;
2001	■ Expansion of the IFDCs to seven areas; ■ Submission by industry to Minister Fahey for licenced limited entry lobster fisheries;
2002	■ V-notching, voluntary logbook program, lobster tagging, supported by National Development Program (NDP) and BIM;
2003	■ V-notching, voluntary logbook program, lobster tagging, supported by NDP and BIM; ■ Scheme to regularise illegal inshore fishing activity launched; Framework for the management of crustacean and molluscan fisheries drafted by BIM.

9.2 Summary of lobster management in Europe and USA:

A variety of issues relating to the management of lobster fisheries in Europe and the USA (Table 9.1) were presented at the workshop. From these it appears that fisheries regulations should support predefined objectives and, in many instances, a combination of regulations is required to produce the desired results.

Although the European lobster fishery has existed for as long as the American fishery, the present day European regulations are few in number and simple. In general, the sole and common regulation in Europe, until relatively recently, has been a MLS, with some notable exceptions (Table 9.1). In contrast, the Maine (USA) management strategy includes protection of egg bearing females, licencing, limited entry of commercial fishers, minimum and maximum landing sizes, V -notching, closed periods, trap limits and requirements that traps have escape vents and biodegradable elements to prevent ghost fishing. In addition to these regulations, there are three organisations that benefit financially from lobster licence fees; these are the Lobster Fund, the Lobster Management Fund and the Maine Lobster Promotion Council. The overall format of Maine regulations is such that a portion of the broodstock is protected, and the competitive nature of the fishery is constrained by the regulations. Even in Maine there is a debate, however, on the issue of recruitment overfishing (Beal *ibid* and Idoine *ibid*).

Table 9.1 Lobster fishery regulations in North America and Europe.

Regulation	USA	Maine	Norway	UK	France	Jersey	Ireland
Berried female ban	Yes	Yes					
Minimum size	Yes	Yes	Yes	87-90 mm	87 mm	87 mm	87 mm
Maximum size	Yes	Yes					
V-notching	Yes	Yes		6 areas			Yes
Licensing	Yes	Yes		Yes	Yes		
Trap limits		Yes			Yes		
Gear regulation	Yes	Yes			Yes		
Seasonal closures		Yes	Yes				
Reserves					20 locations		
Other	*	*					

** escape vents, licence fees used for lobster conservation*

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