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**Te Tautiaki i nga tini a Tangaroa**

**A medium-term research plan for red rock lobsters  
(*Jasus edwardsii*)**

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## EXECUTIVE SUMMARY

Breen, P.A.; Starr, P.J.; Kim, S.W. (2005). A medium-term research plan for red rock lobsters (*Jasus edwardsii*).

*New Zealand Fisheries Assessment Report 2005/54. 52 p.*

This study addresses Objective 7 of the MFish contract CRA2003-01 awarded to the NZ Rock Lobster Industry Council. The objective was *To develop a medium-term research plan for rock lobster.*

This report reviews the historical sequence of research and management of the New Zealand rock lobster fisheries and briefly reviews recent management and research strategies in five overseas lobster jurisdictions. As part of the review, a bibliography of research and management of *Jasus edwardsii* in New Zealand was updated and revised. Recent and likely future changes in the fishery, management and the assessment are identified. Possible data sources and research projects are identified from the review and listed with comments on their importance, cost and other factors affecting their immediate and short-term utility.

## 1. INTRODUCTION

This study was conducted under MFish contract CRA2003-01: "Stock assessment of rock lobster", awarded to the New Zealand Rock Lobster Industry Council (NZRLIC). The study addresses Objective 7: *To develop a medium-term research plan for rock lobster.*

Medium-term research plans are used to direct research planning in a number of New Zealand fisheries. A medium-term plan was developed by the National Rock Lobster Management Group (NRLMG) in the mid 1990s, but is now obsolete: it has not been updated or replaced. Rock lobster research planning has consequently become increasingly *ad hoc* since then.

In an ideal world, a research plan would be linked to the fishery management plan. The extant management plan developed by the NRLMG is limited in its capacity to suggest what research should be considered and which should be given a high priority, so this document might be considered premature. We think it relevant despite that.

In research planning there is a tendency for existing projects to be continued and for new projects to attract greatly restrained support. The tendency is natural because funding is limited; extant projects consume the money available by definition; so new projects are viewed with a critical eye.

This document takes a fresh look at what kind of research is needed and compares current research with research conducted to solve analogous management problems in several overseas jurisdictions. The document then lists about 30 broad data or research projects that might be considered and summarises their current status, cost, potential utility, etc. A provisional list in priority order is then provided that we hope will be of value to the annual research planning process conducted by the National Rock Lobster Management Group.

This document contains the views and language of the authors on this topic. The views and language of the National Rock Lobster Management Group, who will develop and own a 'living' document that uses this one as a starting point, may differ.

### 1.1 New Zealand research planning context

A plan for the rock lobster fishery was developed by the NRLMG and is contained each year in its annual report to the Minister of Fisheries.

Research of various kinds enables the rock lobster fishery to comply with the Fisheries Act 1996, the requirements of which are discussed in some detail below. Some of the information used, such as catch and effort data, is provided by the operation of the Quota Management System (QMS). Much of the remainder is available through programmes contracted by the Minister of Fisheries (MFish) using money obtained from the commercial fishing industry in its cost recovery activities and Crown funding that recognises the shared nature of these fisheries. Rock lobster research information is also available from programmes directly funded by industry. Other available information is historical, much of that obtained by MFish and its predecessor, the Ministry of Agriculture and Fisheries (MAF). There is also information available from academic or "public-good" research such as FRST-funded studies.

The Ministry of Fisheries has a planning process to establish future directions and priorities for fisheries research in conjunction with fisheries stakeholders. The Ministry convenes an annual Research Co-ordination Committee (RCC), whose membership comprises Approved Parties and Ministry staff, for consultation on the nature and extent of required fisheries research services. The RCC serves as a forum for MFish and fisheries stakeholders to discuss, evaluate and make recommendations on proposed research projects.

Proposals come from Research Planning Groups: for rock lobster research, the NRLMG is used as the planning forum, to which interested parties are invited to attend. Projects are proposed by MFish, stakeholders or by potential research providers, then discussed and assigned priorities at the research planning meeting. Proposals from all such meetings in the MFish programme (for other fisheries and for environmental projects, etc.) are sent out to stakeholders for comments, the RCC meeting is held in October, the final selection of projects is made by MFish and tenders are let for successful proposals.

Some aspects of research affecting rock lobster fisheries are handled by groups other than the NRLMG. For instance, recreational catch estimates are the province of a Recreational Catch Working Group and research to support managing the environmental effects of fishing is also considered by the Aquatic Environment Working Group.

## 1.2 MFish research requirements

The purpose of the Fisheries Act 1996 ("the Act") is *"to provide for the utilisation of fisheries resources while ensuring sustainability."* "Ensuring sustainability" is defined in two parts as "maintaining the potential of fisheries resources to meet the reasonably foreseeable needs of future generations" and "avoiding, remedying, or mitigating any adverse effects of fishing on the aquatic environment". The Act defines a set of "environmental principles" to be followed:

- "associated or dependent species should be maintained above a level that ensures their long-term viability"
- "biological diversity of the aquatic environment should be maintained"
- "habitat of particular significance for fisheries management should be protected."

Thus management needs with respect to data and research required can be considered under the topics of sustainability, associated species, diversity and habitat.

The draft Statement of Intent for Fisheries Research Services for 2004-05:

<http://www.mfish.govt.nz/information/corp-docs/soi-05-08/index.html> indicates that the main current research requirements involve scientific evaluation of:

- sustainable yield from fisheries resources;
- the effects of fishing on the aquatic environment, including on the viability of associated or dependent species and on biological diversity;
- alternative strategies for achieving the desired level of yield while avoiding, remedying, or mitigating adverse effects of fishing on the aquatic environment;
- analysis of relevant cultural, economic and social factors that may need to be included in the management decision process and
- the specific measures needed to implement the preferred strategy.

With respect to sustainability, the Act specifies that the Minister will set a TAC to ensure that the biomass of each stock is managed so that the stock is "at or above the level that will produce the maximum sustainable yield", which is interpreted as  $B_{MSY}$ .

Neither the biomass target,  $B_{MSY}$ , nor the yield target,  $MSY$ , is defined in legislation. Two major MFish workshops have been convened, in 2001 and 2004, to clarify the application of these concepts to practical fishery management, so far without definitive result. The problems include:

- $MSY$  can be defined only after a harvest strategy has been defined, and  $MSY$  can be seen as an emergent property of the harvest strategy;
- $B_{MSY}$  is not a single value: populations fluctuate naturally even in the absence of fishing. Under any harvest strategy, biomass goes up and down, and how such fluctuating biomass relates to  $B_{MSY}$  and the Minister's obligations is not very clear;

- $B_{MSY}$  is also sensitive to the allocation of catch between user groups and to the methods used for harvest;
- For stocks with multiple user groups such as rock lobsters, the Minister can control the commercial catch level directly by setting a TACC; recreational catches and customary catches can be limited much less directly and illegal catches still less directly: there is thus only limited control over the total catch.

In the absence of a harvest strategy that would enable some definition of MSY and a characterisation of  $B_{MSY}$ , rock lobster management has used a proxy for  $B_{MSY}$  in recent years. This is called *Bref* and is based either on a selected target level of abundance in CRA 3 and CRA 8 or on the mean abundance over a period selected from the assessment's reconstruction of biomass in CRA 1, CRA 2, CRA 4 and CRA 5. At the MFish  $B_{MSY}$  Workshop held in November 2004, this approach was deemed acceptable for rock lobsters.

A previous report (Breen 2005) discussed in detail the research implications of managing the environmental effects of rock lobster fishing.

### 1.3 Scope of this plan

This project addresses only the red rock lobster, *Jasus edwardsii*. The packhorse rock lobster supports only a small, localised fishery and only very limited information is available.

The focus of this document is limited to research that enables the rock lobster fishery to operate in compliance with the Fisheries Act 1996 or that maximises the overall value of the resource. The document is not concerned with identifying fruitful or interesting topics for lobster research outside that context.

## 2. REVIEW OF CHANGES IN THE FISHERY, MANAGEMENT, ASSESSMENT AND RESEARCH

### 2.1 Bibliography

As part of this study, an annotated bibliography on *Jasus edwardsii* studies in New Zealand was updated and extended. The original, annotated bibliography compiled by McKoy (1979) and extended by Breen & McKoy (1988). The revised version (Breen & Kim unpublished 2005, available on request) contains no new annotations and condenses some previous annotations. The contracts were extended through literature searches involving the ASFA database, the beta version of Google Scholar, the NIWA library catalogue and canvassing of NIWA researchers in early 2005. It has not been further revised since early 2005.

### 2.2 The recent fishery

After introduction of the QMS, numbers of both quota owners and vessels fishing declined strongly in most areas (e.g., Table 1). Declining numbers of quota owners reflect aggregation: when quota is sold it tends to be bought by existing quota owners.

**Table 1: Number of vessels fishing in each area by year. Vessels may fish in more than one area, so the total number of vessels exceeds the actual total.**

Fishing year	CRA1	CRA2	CRA3	CRA4	CRA5	CRA6	CRA7	CRA8	CRA9	Total
1979	34	80	70	86	88	39	90	271	23	781
1980	34	89	85	86	86	42	86	253	23	784
1981	33	88	77	88	85	45	79	221	20	736
1982	33	82	85	89	93	54	42	214	19	711
1983	31	75	84	89	93	50	40	208	22	692
1984	30	73	86	90	95	53	59	212	21	719
1985	34	78	83	88	92	57	66	208	20	726
1986	35	70	76	88	91	48	58	187	20	673
1987	30	59	72	85	84	47	51	173	19	620
1988	26	55	58	87	71	42	38	135	10	522
1989	27	17	77	131	67	55	17	178	18	587
1990	27	57	58	85	63	40	37	134	12	513
1991	33	51	65	88	68	46	46	143	13	553
1992	31	47	54	94	59	50	35	144	12	526
1993	27	46	48	100	59	54	37	143	12	526
1994	22	47	41	89	51	59	32	122	16	479
1995	23	45	34	80	49	51	27	112	14	435
1996	26	40	32	74	47	50	22	111	18	420
1997	21	43	30	72	46	50	7	107	19	395
1998	19	36	30	65	41	42	18	104	16	371
1999	20	35	32	70	40	34	17	91	17	356
2000	18	40	33	61	36	33	25	87	9	342
2001	18	36	33	62	35	32	22	74	11	323
2002	17	36	38	64	35	32	20	69	10	321
2003	15	34	39	64	35	34	16	61	9	307

In the 1990s, markets changed from those for whole frozen or frozen lobster tails to those for live lobsters. The importance of the frozen tail market was reflected in the strong lobbying for a minimum legal size (MLS) based on tail width and not carapace length in the late 1980s. The switch to much more valuable live markets had a marked effect on behaviour of the fishery: handling became much more careful and sorting was done in real time instead of in batches long after the pots had been emptied; probably this change caused large reductions in associated handling mortality.

In the mid 1990s, catches shifted from summer to winter in many areas, again in response to Asian market opportunities. A typical example is shown in CRA 4 (Table 2). This change began in CRA 3, where a strategy implemented in 1993 explicitly allowed small males to be targeted in winter. As abundance increased in the mid 1990s in CRA 1 through CRA 5, the shift was accelerated because most of the TACC could be caught in the early part of the season, when value of the catch was highest. Associated with the seasonal shift was a contraction of fishing areas: fishers in a quota system tend to travel no further than they need to catch the quota. However, as CPUE decreased this shift has been reversed to varying degrees in various areas.

Responses to market forces also involve high grading, increased use of holding pots and directed fishing. High-grading, which is legal, occurs when lobsters are sufficiently abundant that a fisher can return legal lobsters to the sea and keep only the highest-valued sizes. Holding pots and directed fishing involve making landings only when processors want the catch.

Closure of areas to fishing by marine protected areas (MPAs) had begun by the early 1990s and accelerated in the late 1990s. The New Zealand Biodiversity Strategy has a target of 10% of marine areas to be protected. Compensation for this loss of fishing area has not been made.

**Table 2: The percentage of landings for each month for CRA 4, April 1979 through March 2003.**

Year	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
1979	0	0	9	10	5	7	14	23	13	11	5	2
1980	1	3	9	8	7	9	14	13	13	13	7	2
1981	1	3	7	10	6	10	12	10	14	15	9	4
1982	0	5	7	8	8	7	12	14	15	13	8	2
1983	0	3	13	8	9	6	12	16	11	12	6	3
1984	0	6	14	7	4	8	15	16	13	10	5	1
1985	0	1	11	8	5	5	13	15	18	15	7	2
1986	0	3	11	5	3	7	18	17	17	14	4	1
1987	0	4	10	4	6	5	23	18	14	9	4	2
1988	1	5	9	4	3	9	17	22	14	9	4	3
1989	1	3	8	7	2	9	12	20	15	15	6	3
1990	0	3	8	6	3	11	19	18	14	9	7	2
1991	2	4	6	12	5	5	17	18	15	12	4	2
1992	1	3	17	9	4	4	12	17	16	11	5	3
1993	1	14	17	10	4	2	15	15	14	5	2	1
1994	3	17	13	10	7	4	13	17	8	4	1	1
1995	4	25	12	12	6	12	13	7	3	2	2	2
1996	9	30	19	11	11	11	4	2	1	1	0	1
1997	7	31	19	18	10	8	3	0	1	2	0	0
1998	4	22	13	19	18	14	5	1	0	1	2	0
1999	2	20	20	20	11	19	2	1	3	0	0	0
2000	6	24	25	17	6	11	6	3	1	0	1	1
2001	6	1	25	12	9	17	5	5	2	2	1	1
2002	6	1	23	14	9	14	3	6	3	6	4	2
2003	5	9	18	15	6	11	12	7	3	7	2	5

Increased recreational catch cannot be documented but is thought to result from increasing interest in scuba diving, increases in the recreational charter fleet and increasing recreational population.

Tail fan necrosis has always been seen in the fishery at low levels, but recently has become a problem in parts of the CRA 3 fishery (especially area 910). The proximal cause is bacterial infection, but there may also be a relation with handling (Musgrove et al. 2005). This disease has serious quality implications if it becomes more widespread.

## 2.3 Recent changes in management

Ministerial management actions from 1993 include TAC and TACC changes (the major management tool under the ITQ system), changes to input controls on the commercial fishery, changes to regulation of non-commercial fisheries and what can be called technical management changes.

In the late 1980s the MLS was changed to the tail width measure, replacing the much-abused and difficult to enforce tail length measure. This was controversial at the time because of morphometric inequities among areas, but has been successful after an initial period of poor acceptance in some areas.

When rock lobster fisheries were included in the QMS in April 1990, TACCs for all areas were set at levels significantly lower than the preceding catch histories from 1982 through 1988. Since then, TACCs have remained unchanged in CRA 1 and CRA 9, have been increased through favourable stock assessments in CRA 2 through CRA 5 (although early further reductions occurred in some areas); they have been decreased further in CRA 6; and they have been modified both up and down by an operational management procedure<sup>1</sup> in CRA 7 and CRA 8. These TACC changes were:

- 1993: 50% decrease for CRA 3
- 1996: 25% increase for CRA 3
- 1997: 10% increase for CRA 2
- 1997: 25% decrease for CRA 6
- 1998: 60% increase for CRA 3
- 1998: 10% decrease for CRA 6
- 1999: 15-16% increase for CRA 4 and 5
- 1999: 20% decrease for CRA 7 & 8 (mandated by the management procedure)
- 2001: 20% decrease for CRA 7 & 8 (mandated by the management procedure)
- 2004: 6% increase for CRA 7 & 8 (mandated by the management procedure)
- 2005: 42% decrease in CRA 3

Where TACC changes were made after 1996, TACs were also established in those areas, allocating catch to other sectors. Allocation within TACs has been somewhat arbitrary and has sometimes differed from the information provided by MFish to the stock assessment team. No TACs have yet been set for CRA 1 and CRA 9.

In 1992, Minister of Fisheries Doug Kidd established the NRLMG as his primary source of management advice. This began a successful and unparalleled stakeholder participation in fishery management for lobsters. Although the NRLMG does not function without problems, it still writes the management advice paper for lobsters – there is no counterpart to this activity in other New Zealand fisheries.

Decision rules were established for the three substocks (NSN, NSC and NSS) in the mid 1990s, although these rules did not mandate any specific changes to catch limits. A more detailed management procedure was developed and adopted for the NSS substock in 1997 and was subsequently revised after extensive evaluation in 2002.

Major changes to input controls involve mainly CRA 3. A suite of measures implemented in 1993 along with a massive TACC cut included seasonal closures, prohibition of females in winter and a new MLS for males in winter. The seasonal closure for September-January was then removed in 2002. In 1994, in response to concerns about decreased stock and the different MLS in place for CRA 7, a new seasonal closure and a new area closure were implemented in that QMA.

An interesting change to commercial fisheries was implemented in 1997 to allow collection of puerulus and small juveniles for aquaculture. This was allowed, with Ministerial approval and with a suite of restrictions and reporting requirements, by using quota at an agreed exchange rate that specifies the number allowed per tonne of quota. This approach prevented the development of two competing commercial fisheries. However, commercial interest in growing puerulus was weak and the trade-off scheme has now lapsed.

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<sup>1</sup> Operational management procedures (OMPs) comprise a decision rule that specifies what data will be used as the basis for TAC decisions, how it will be used and how indices will be translated to TACC changes. OMPs are decision rules, but differ from simple decision rules by being extensively tested in computer simulations involving an operating model.

Mandatory catch and effort reporting is required under the QMS on several forms, the most important of which, from the research perspective, is the Catch Effort Landing Return (CELR). This form has been upgraded for some fisheries to resolve some reporting problems, but remains unchanged for the rock lobster fishery and is inadequate to address many pressing assessment and management issues. These include the failure to capture fine-scale catch locations (marine reserve applications, for instance, cannot be matched with detailed catch and effort data) and an inability to link landed catch with associated effort when catch is held for long periods in holding pots.

Changes to regulation of non-commercial fisheries have addressed permitting systems for the customary catch and established pot limits for the recreational fishery: these were put in place in CRA 2, 3 and 4 in 1996 and for remaining areas in 2004.

There has been a shift from on-water and on-dock compliance activity towards computer auditing as the QMS has matured (some recent evidence indicates that on-water enforcement activity may be increasing again).

The NRLMG has been successful in changing the regulation of recreational fisheries by introducing limits to the number of recreational pots. Marketing of fish from areas with non-standard or "concession" MLS has also been facilitated through the action of the NRLMG.

## **2.4 Recent stock assessment and research**

### **2.4.1 Historical perspective**

Although the modern fishery began in earnest in 1945, the CRA 8 fishery peaked in 1956, the Chatham Islands "boom" occurred in the 1960s and much biological work was conducted in the 1960s and onward, no stock assessment occurred before the work of Saila et al. (1979). This comprised a simple surplus-production analysis and some yield-per-recruit (YPR) analyses. Stock assessments remained both sporadic and simple until the early 1990s.

Until 1995, assessments were conducted directly by MAF. A Rock Lobster Fishery Assessment Working Group with a MAF or MFish Chair was established in 1990 and has continued through to the present to guide and provide quality control to assessments. For 1990 onwards, industry representatives participated in the Working Group process and scrutinised assessments at the very least, collaborated on some aspects (e.g., Breen & Stocker 1991), or conducted independent assessment work (e.g., Maunder & Starr 1995).

For 1995–96, assessments were conducted directly by NIWA on non-contestable contracts from MFish. Research has been contestable since 1997, when the NZRLIC Ltd. won and has retained the MFish contracts to do the assessment and other scientific work. Notably, in 2001, the contract was awarded for three years, which is unique among the NZ assessment contracts, and, in 2004, a renewed three-year contract was awarded to NZRLIC Ltd. NZRLIC Ltd. has no research capacity and in 2001 had no experience in research contract management, but at this time has an experienced contracts manager and has subcontracted the research objectives to experienced providers (Haist Consultancy, NIWA, Starrfish and Trophia). The contract has been expanded to include most facets of required research, and the current contract (CRA2003-01) is the second consecutive contract to span three years. The industry provision of research and the long contract periods are unique within New Zealand.

Contestability of research has had mixed effects on management-related research: most notably it has introduced a substantial lag between conception and funding of new research. A round of consultation with stakeholders is associated with contestable user-pays research.

Stock assessments have evolved dramatically from their simple beginnings (Saila et al. 1979) in yield-per-recruit (YPR) analyses and surplus-production analysis. This evolution has involved:

- institution of annual assessment work,
- evolution of contestable assessment contracts, now held by industry,
- evolution away from simple approaches (YPR, EPR and surplus-production) towards Bayesian state-space models,
- evolution towards smaller assessment stock units, thus with periodic rather than annual assessments for any one area: early assessments were applied to all of mainland New Zealand; in the mid 1990s they were applied to aggregations of two or three CRA areas; recent assessments have been applied to single CRA areas,
- progressive integration of data into the stock assessment models (see below),
- adoption of reference points based on demonstrated performance rather than theoretical ideas,
- development of management procedures to replace the annual assessment decision concept and
- a coherent programme of ancillary assessment-related research.

Ancillary research includes monitoring of the commercial fishery, tagging aimed at improving growth rate data, evaluation of data collection targets for tagging and monitoring, evaluation of management procedures, and various desktop studies. A standard approach and database have been developed for storing, preparing and analysing catch and effort data. Simple "movies" have been explored for examining trends in catch and effort data. Interactive tag-tracking software has been developed. The NZ RLIC has facilitated development of electronic data capture at sea.

#### **2.4.2 Recent perspectives**

Integrated modelling means, for instance, that the assessment model estimates growth parameters from the raw data. In the alternative segregated approach, growth parameters were estimated outside the assessment model and fed to the assessment model as if they were data. The current practice is to estimate as much as possible within the assessment model, and only the standardisation model that generates the abundance indices remains a sequential procedure.

Choice of which stock or stocks to assess is made by the NRLMG. Table 3 shows the recent history.

References are as follows. For 2004: Haist et al. (2005), 2003: Kim et al. (2004), 2002: Starr et al. (2003), 2001: Breen et al. (2002), 2000: Bentley et al. (2001), 1999: Breen et al. (2001) and Starr & Bentley (2002), 1998: Breen & Kendrick (1999) and Starr et al. (1999), 1996: Breen & Kendrick (1998) and Breen & Kendrick (1996), 1995: Breen & Kendrick (1997), 1994: Breen & Kendrick (1995), 1993: Breen (1994), 1992: Breen & Anderson (1993), 1991: Breen (1991a, 1991b), 1990: Breen & Booth (1990) and Breen & Stocker (1991), 1989: Breen (1989), 1988: Breen (1988).

**Table 3: Recent history of assessments. "X" indicates an assessment for the stock indicated. "NSN" etc. indicates that the CRA stock was assessed as part of the sub-stock indicated. "NSI" indicates an assessment for the North and South Islands combined stock.**

Year	NSI	CRA 1	CRA 2	CRA 3	CRA 4	CRA 5	CRA 6	CRA 7	CRA 8
1988	X								
1989	X								
1990	X								
1991	X								
1992	X								
1993									
1994		NSN	NSN	NSC	NSC	NSC	X	NSS	NSS
1995		NSN	NSN					NSS	NSS
1996		NSN	NSN	X			X	NSS	NSS
1997				X				NSS	NSS
1998		NSN	NSN	X	X	X		NSS	NSS
1999		NSN	NSN		CRA 45	CRA 45		NSS	NSS
2000				X				NSS	NSS
2001				X					
2002		X	X						
2003					X	X			
2004				X					

### 2.4.3 Data used by stock assessments

Recent assessments use several sources of data; early assessments used various subsets of these data.

#### 2.4.3.1 Catch

There are four types of catch: commercial, illegal, recreational and customary. Commercial catches are well known from 1979 through compulsory records collected by the Fisheries Statistics Unit and later as part of the QMS. The data were comprehensively summarised by Starr & Bentley (2005) by QMA, by statistical area and by month.

No other type of catch is well known. For illegal catches, MFish has provided estimates from time to time, and in 2004 made an effort to document the basis for such estimates. Despite this effort, the Working Group attaches considerable uncertainty to illegal catch estimates (Sullivan 2004).

MFish is attempting to obtain estimates of customary catches as part of the permitting system. In 2004, for the first time, information was collated on permits issued in some areas. Although these were far more than had been available before, the MFish caveat was *"These collated returns are indicative only of the customary harvest enacted under the guise of customary authorisations issued by Tangata Tiaki, and some amateur reporting that is recorded as customary take. They do not represent the full extent of customary fishing as a vast majority of customary fishing is enacted under the guise of recreational fishing management where there is no reporting requirement. Any attempt to gauge the extent of customary fishing in any year cannot be adequately gauged from these returns. For further information please contact Matiu Payne at MFish Dunedin."* (MFish, unpublished).

Surveys of recreational catch have not been definitive for rock lobsters. Surveys were conducted in the mid-1990s, involving a combination of random telephone contacts and diary information from voluntary participants. The estimates for lobsters were suspiciously low for some areas. As a result of methodological bias, the estimates are thought to be inaccurate throughout the species and areas. A nation-wide survey with revised procedures was conducted in 2000, but MFish and various Working Groups have not accepted the results because of concerns about the methodology employed in all three nationwide surveys. Further surveys, none specific to rock lobsters, are in progress at the time of writing.

Major data deficiencies thus exist with respect to illegal, customary and recreational catches, their timing, areas of capture and the size and sex composition of these catches. For the illegal catches, for instance, it is not known whether the catch comprises the full range of lobsters that enter pots, or instead comprises largely under-sized and berried animals.

#### **2.4.3.2 Commercial catch per unit of effort**

CPUE has been captured in several historical data sources (Bentley et al. 2005), although not all are considered reliable enough to use in assessments.

- 1945–62, Marine Department: landings and number of vessels by month by port (not used for CPUE),
- 1963–73, Annala & King (1983): catch and effort by statistical area, method and month,
- 1974–79, Annala & Esterman (1986): total annual catch and days fished for each quota management area (not used for CPUE),
- 1979–89, Rock Lobster Fishing Returns (FSU): catch and effort by vessel, day and statistical area
- 1989–Present, Catch and Effort Landing Returns (CELR): catch and effort by vessel, day and statistical area

A transitional period between the FSU and CELR systems in 1987–89 has poor data quality: for about 18 months, FSU reporting was not required but the CELR system was not operating properly.

Bentley et al. (2005) described these data in detail. A purpose-built database, CRACE, contains the raw data and standard error-checking routines that can groom the data with different levels of intervention. Bentley et al. (2005) described the errors commonly encountered, which include:

- duplicate records,
- statistical areas out of range,
- statistical area for a vessel far removed from its base,
- zero or unlikely numbers of pots recorded,
- more than 31 days fished in a month,
- incorrectly calculated catch and
- improbably high catches.

Catches can be based on the catch estimated at the time of landing, or on the actual catch weight recorded on another part of the form. Catch estimates are grossly in error for CRA5 for at least part of the period, because MFish advised fishers to record all lobsters caught, including sublegals and those returned to the sea for other reasons. Reports of MFish issuing similar instructions to fishers as recently as early 2005 were received, although the problem is believed to be resolved at the time of writing. Under current fishing practice, combined with the existing reporting regulations, the landed catch on the form may not relate accurately to the recorded effort because fishers may “land” to holding pots and then land the same catch later for sale, consequently recording these landings on a new form. Currently there is no way to connect the catch confidently with the effort used to catch it, which is a very serious problem for estimating CPUE. Bentley et al. (2005) describe alternative

methods for aggregating data from the CELR system into fisher/month/area cells. This data retrieval problem thus results in a loss of temporal and, possibly, spatial detail.

The CELR system does not capture information at the same level of detail as catch sampling. The spatial scale is large: statistical areas. Bentley et al. (2003) explored ways of capturing, and alternative scales for, smaller-scale spatial information by the compulsory catch/effort system. Depth, pot type, soak time and bait are not recorded.

Problems with the current CELR system include:

- lack of detailed information about fishing,
- disconnection of catch and effort when landing from holding pots,
- inadequate error management and
- inability to capture data from high-graded lobsters.

The CELRs require fishers to record the most abundant five species caught for each trip. Bentley et al. (2005) present an analysis by QMA of the most common species landed by potting. In all, 129 species are reported, but lobsters (both species) are 91–98% of the catch.

Given the importance of CPUE to assessment and management, the CELRs are a fruitful area for improvement.

#### 2.4.3.3 Observer catch sampling

Data from sparse and irregular observer catch sampling (as well as limited market sampling) occurring before 1989 are available in the MFish historical database. More regular observer catch sampling began in 1989. This continues through the present in areas without voluntary logbook programmes (see below).

These data comprise information about the fishing process: date, location, depth, soak time, pot type and bait, the number of lobsters caught for every pot lifted and measurements of the lobsters caught for as many pots as possible: tail width, sex, maturity code for females and an injury code. *Octopus* caught are recorded, but little information is collected about other species caught or observed. Procedures are standardised in a manual.

Table 4: Catch sampling output by CRA QMA, summed from 1986 to the end of 2004.

QMA	Days	Pots	Measured
CRA1	123	9 587	33 067
CRA2	82	8 766	16 542
CRA3	457	48 597	346 313
CRA4	461	53 080	296 130
CRA5	139	16 081	71 419
CRA6	178	12 186	15 616
CRA7	238	24 225	59 193
CRA8	611	63 224	276 011
CRA9	1	151	201
Total	2 290	235 897	1 114 492

Table 4 summarises the total output of catch sampling for each area, from 1986 through the end of 2004. This table includes some early observing that was conducted for morphometric analysis for the tail width measure. Over one million fish have been measured from nearly a quarter of a million pots.

The temporal pattern of sampling (in the basic unit of sampling, days) shows (Table 5) that observer catch sampling continues to be active in CRA 1 through CRA 4 and in CRA 7. All fish caught during a day's fishing are counted and about 75% are measured under the sampling protocol.

**Table 5: Numbers of days' observer catch sampling in each area by fishing year.**

Year	CRA1	CRA2	CRA3	CRA4	CRA5	CRA6	CRA7	CRA8	CRA9	Total
1986		3	2	2						7
1987		3		15			6	8		32
1988				15			14	6		35
1989			10	25	10	13	9	45		112
1990		3	17	39	11		9	65		144
1991		2	21	22	10		6	63		124
1992			23	20	12		9	59		123
1993			56	20	12	13	7	53		161
1994			51	12	12	12	12	57		156
1995			37	16	12	53	15	64		197
1996			32	7	9	51	28	79		206
1997	17		29	34	10	36	19	44		189
1998	9		32	27	8		14	10		100
1999	24	12	21	39	21		18	9		144
2000	15	13	20	39	12		15	21		135
2001	12	11	29	32			12	14	1	111
2002	15	14	29	35			15	14		122
2003	16	12	28	35			15			106
2004	15	9	20	27			15			86
Total	123	82	457	461	139	178	238	611	1	2 290

Bentley et al. (2002a) examined the question of optimum catch sampling and made recommendations about how much data were required. Their suggested minimum for observer catch sampling was 0.3 days per vessel per statistical area per 6-month season for the observer catch sampling programme, and they suggested a target level of 0.5 days. Table 6 shows the number of vessels and the seasonal days per vessel per statistical area achieved in the four most recent sampling seasons. Sampling in 2005-06 was increased in CRA 4 to move closer to achieve compliance with minimum recommended levels.

The pattern of observer catch sampling is evaluated each year for each area in April or May when good data have become available from the previous year's fishing. For each QMA we calculate the proportion of the previous year's catch that was caught in each statistical area/month cell, then assign catch sampling for the next year to area/month cells in proportion to these catches. Strict adherence to the schedule is impossible for logistic reasons and the schedule cannot be other than a year out of date. But this approach keeps the sampling in line with fishing patterns as far as possible.

**Table 6: Number of vessels by period and statistical area (or QMA) in the five CRA areas listed for periods 117 (2003 AW) to 120 (2004 SS). Also shown is the level of coverage for each period and statistical area (or QMA). Cells which fail to achieve the specified minimum level of coverage (0.3 trips/vessel-period; Bentley et al. [2002a]) are shaded in grey.**

	Number vessels in a period & area				Coverage level (trips/vessel-period)			
	2003 AW (117)	2003 SS (118)	2004 AW (119)	2004 SS (120)	2003 AW (117)	2003 SS (118)	2004 AW (119)	2004 SS (120)
901	1	1	3	3			1.0	1.0
902	4	5	3	5	1.0	1.2	1.0	0.6
903	2	3	2	4				
904	4	4	3	2	0.3			
939	6	5	5	5	0.5	0.2	0.4	
CRA 1	16	15	15	15	0.5	0.5	0.5	0.5
905	8	9	7	7				
906	14	13	15	14		0.3		0.3
907	7	7	9	8		0.3		
908	9	10	10	11		0.3		
CRA 2	36	37	37	37				
909	4	3	4	3	0.5	0.3	0.8	0.7
910	21	12	19	7	0.3	0.3	0.3	0.6
911	16	16	15	16	0.4	0.6	0.3	0.6
CRA 3	40	31	36	26	0.4	0.5	0.4	0.6
912	14	15	15	14	0.4		0.3	0.2
913	17	15	15	14	0.4	0.3	0.3	0.4
914	26	22	25	23	0.3			0.4
915	14	11	13	11				
934	0	0	2	2				
CRA 4	68	61	64	60	0.4		0.3	0.3
920	18	15	13	6	0.5		0.5	
921	3	3	5	3	1.0	0.3	1.4	
CRA 7	20	16	15	9	0.6		0.9	

#### 2.4.3.4 Voluntary logbooks

Since 1993 a programme of voluntary logbooks has been operating in some areas. Fishers mark a small number of pots (usually four). Whenever these pots are lifted, fishers record most of the information listed above for observer catch sampling (overall means 3.5 pots/day, 4.5 fish/pot). Fishers are not required to measure more than 25 lobsters from any one pot, although they record a count of the excess in a separate box. This occurs in less than 5% of the sampled potlifts. The voluntary logbook forms also request information on *Octopus* and "other", which can be named.

Numbers of days sampled, 1993 through 2004, are shown by area in Table 7, pots observed in Table 8, and fish measured in Table 9. This programme has measured almost 700 000 lobsters from 150 000 pots.

This programme is less intensive than observer catch sampling, because only a small number of pots are sampled each fishing day, whereas in the observer programme every pot lifted is counted and about 75% of lobsters caught are measured, but it is much more extensive because many more days are sampled than in the observer programme.

An industry-funded technician in each area with a logbook programme is essential to ensure adequate training and quality control and to maintain fisher participation at agreed levels.

**Table 7: Number of days' sampling in the voluntary logbook programme, by area and fishing year.**

Fishing Year	1	2	3	4	5	6	7	8	9	Total
1993	34	1875	208				27	1617		3761
1994	65	1658	362		986		778	1925		5774
1995	43	1072	211		523			2963		4812
1996		931	164		621			2181	42	3939
1997		779	41	60	465			2058	38	3441
1998		796	51	50	289			1700	85	2971
1999		973	29	33	551			816	42	2444
2000		983	39	7	982			1321	127	3459
2001	1	779	24		1131	62	187	818	141	3143
2002		1328		51	1262	161	71	962		3835
2003		1012		95	1007	277	43	777		3211
2004		1195		73	958	197		767		3190
Total	143	13381	1129	369	8775	697	1106	17905	475	43980

**Table 8: Summary of numbers of pots observed in the voluntary logbook programme, by area and fishing year.**

Fishing year	1	2	3	4	5	6	7	8	9	Total
1993	129	7071	790				73	5264		13327
1994	247	6245	1303		3626		2554	5987		19962
1995	170	3934	798		1884			9125		15911
1996		3492	621		2339			6847	153	13452
1997		2953	152	213	1725			6578	147	11768
1998		3051	192	174	1059			5487	329	10292
1999		3684	116	119	2110			2670	153	8852
2000		3787	153	23	3817			4176	488	12444
2001	4	2910	86		4299	142	478	2782	512	11213
2002		5014		200	4897	445	208	3105		13869
2003		3810		374	3842	732	116	2425		11299
2004		4562		278	3480	550		2450		11320
Total	550	50513	4211	1381	33078	1869	3429	56896	1782	153709

**Table 9: Summary of numbers of lobsters measured in the voluntary logbook programme, by area and fishing year.**

Fishing year	1	2	3	4	5	6	7	8	9	Total
1993	179	18172	6208				629	37653		62841
1994	477	18134	8559		17007		6119	33179		83475
1995	486	11658	6830		9547			44923		73444
1996		12522	6723		14087			28450	209	61991
1997		9225	1471	1844	11029			21421	266	45256
1998		9172	895	1397	8372			21780	606	42222
1999		10324	517	297	12725			11472	220	35555
2000		9186	769	331	26030			21041	1211	58568
2001	7	5895	348		30214	122	1816	12364	1208	51974
2002		8272		592	36095	599	1067	17745		64370
2003		7454		1501	31461	1171	1106	17090		59783
2004		8323		1024	28174	862		15766		54149
Total	1149	128337	32320	6986	224741	2754	10737	282884	3720	693628

Starr & Vignaux (1997) compared the results from the logbook and observer programmes in areas of CRA 8, where both were active, and concluded that data from voluntary logbooks were comparable with, and perhaps more representative of the fishery than, data from the observer programme.

Bentley et al. (2002a) examined the question of optimum catch sampling and made recommendations about how much data were required. Their suggested target for voluntary catch sampling was 30% coverage. Table 10 shows the number of fishers and participants by area for 2003. The programme had adequate coverage in CRA 2 and CRA 5, nearly adequate in CRA 8, less than adequate in CRA 6 and none in the other areas. Participation rate is falling in CRA 2 and CRA 8 but currently both have adequate coverage.

**Table 10: Number of vessels and participants in the voluntary rock lobster logbook programme by CRA QMA for 2003**

QMA	Vessels		Participation rate	Change in participation rate from previous year
	Numbers	Participants		
1	15	0	0.00	0.00
2	34	13	0.38	-0.11
3	39	0	0.00	0.00
4	64	1	0.02	0.00
5	35	20	0.57	-0.13
6	34	8	0.24	0.05
7	16	0	0.00	0.00
8	61	17	0.28	0.06
9	9	0	0.00	0.00

#### 2.4.3.5 Combined catch sampling data

As documented above, most areas have adequate catch sampling through either the observer (see Table 6) or voluntary programmes. Table 11 below summarises which programme is adequate for which areas. CRA 6 has logbooks but with below-adequate coverage and has no effective observer programme; CRA 9 has had no programme after 2001.

**Table 11: Programme type by CRA QMA, with a symbol indicating which programme is adequate for the indicated QMA.**

	Observer	Voluntary
CRA 1	☐	
CRA 2		☐
CRA 3	☐	
CRA 4	☐	
CRA 5		☐
CRA 6		
CRA 7	☐	
CRA 8		☐
CRA 9		

Assessments use these two types of data in the same way, although it keeps each data source separate in the model. Proportion-at-size for statistical area/month cells are combined into proportion-at-size by season (e.g., autumn-winter 1999) for each QMA, weighted by the commercial catch in each statistical area/month cell. The assessment model also estimates maturity parameters from the relative numbers of mature and immature females by size from the same data.

A second analysis produces a pre-recruit index based on the numbers per pot of lobsters smaller than the MLS. The raw data are standardised with a general linear model as for CPUE, except that depth information is used. This procedure has been documented by Bentley & Starr (unpublished results).

Other moments of abundance could be extracted from these data, but the assessment does not use these because of data overlap with the CPUE. Data on injuries codes (for sublegal lobsters these may be an index of exploitation rate) are not used in the assessment, but have supported *ad hoc* descriptive analyses.

#### 2.4.3.6 Tag-recapture data

Lobsters have been marked with numbered tags (or, in one study, numbers were coded by holes punched in the tail fan) in many studies, available in historical and current MFish databases. These studies had different objectives.

Tagging data from recent studies are summarised in Table 12. There are low numbers of returns in CRA 1, CRA 3, CRA 6 and CRA 9, and no recent study has been done in CRA 7 (it is possible that additional data are available from CRA 7 but have not been provided to the MFish database). More than 1000 returns are available from each of CRA 2, CRA 4, CRA 5 and CRA 8. Numbers of returns from historical studies (before 1990) were unavailable at the time of writing.

The stock assessment model uses these data, along with patterns in size composition, to estimate growth. The model assumes a fixed moulting pattern, based on biological studies, and uses a growth transition matrix to estimate expected increment-at-size and its variability.

How many tag-recapture data are required for each area? Bentley et al. (2002b) explored this question. These authors found relatively little variation in growth rates among areas within each stock, relatively little variation in growth rates among years within each stock and no evidence of autocorrelation in year effects. They suggested tagging could be done in periodic pulses: i.e., that tagging in consecutive years was not required except for any convenience to recovery programmes.

Precision of growth estimates is increased when more tag-recapture data are available. Bentley et al. (2002b) were unable to make any more specific recommendation. Recent assessments have pointed out inadequacies in the data. In 2004, CRA 3 data did not have many initial lengths above 65 mm TW and were augmented with some CRA 5 data (Haist et al. 2005). In 2003 (Kim et al. 2004), CRA 4 data were similarly augmented with CRA 5 data; in 2002 (Starr et al. 2003), CRA 1 was assessed using the combination of CRA 1 and CRA 2 data; in 2001, the very small numbers of males above the MLS in CRA 8 was cited as a major problem (Bentley et al. 2001). In some areas (e.g. CRA 2 and CRA 8), the tagging programme design specified that larger size categories, particularly for males, be targeted to ensure adequate representation in the recovery data.

Although much tagging has been done, the hunger of the assessment model for good growth information, intensified by the high variability of apparent growth in these data, is far from satisfied. The return rates from recent experiments have varied from 2–3% (CRA 1 and CRA 6) to 23% (CRA 8) and stands at 9% overall. In areas where tagging was done in 2003–05 these are of course under-estimates of the eventual return rate. The utility of tag-recapture studies to aid the assessment is far from exhausted.

**Table 12: Summary of recent tagging experiments. The recovery rate excludes tags released in 2004–05**

Area	Year	Released	Recovered	Rate
CRA1	2000	4796	1	
	2002	2347	148	
	2003	2482	89	
	Total	9625	238	2%
CRA2	1996	7858		
	1997	2768	1059	
	1998	16	797	
	2002	2426	96	
	2003	4812	89	
	Total	17880	2041	11%
CRA3	1995	1927	47	
	1996	3774	251	
	1997	582	152	
	2001	4729	80	
	2004	3421		
Total		14433	530	5%
CRA4	1998	9272	32	
	1999	6583	703	
	2000	3008	505	
	2001	62	127	
	Total	18925	1367	7%
CRA5	1996	5705	60	
	1997	4872	726	
	1999	3753	206	
	2000	4780	431	
	2001	5852	501	
	2004	5724		
	Total	30686	1924	8%
CRA6	1995	64		
	1996	3615	86	
	1997	878	65	
	Total	4557	151	3%
CRA8	1995	891	200	
	1996	103	277	
	1997	6431	1141	
	1998	6180	1835	
	1999	2202	1242	
	2003	4813	52	
	Total	20620	4747	23%
CRA9	1999	962	3	
	2000	219	15	
	2001	2026	2	
	2002	674	16	
	2003	350		
	Total	4231	36	1%
Total		120957	11034	9.1%

Movement patterns have not so far been used in assessments. Analyses of movement patterns from tag-recapture data were reported by Annala (1981), Annala & Bycroft (1993), Booth (1997), Kendrick & Bentley (2003), McKoy (1983) and Street (1969).

## 2.5 Other scientific information

There is a wealth of information from New Zealand studies of *Jasus edwardsii*, much of it listed in the revised bibliography (Breen & Kim unpublished) that forms part of this study. Many of these studies are academic research conducted without any special interest in the lobster fishery, but their utility to lobster management is often independent of the motivation for the study. For instance, the basic work of MacDiarmid (1989, 1991) on reproduction and moulting is a major source of understanding of lobster biology and forms the basis of the moulting sub-model in the stock assessment model.

A review of the recent literature would be a task beyond the scope of this project. Although most pieces of lobster research have some real or potential utility to fishery assessment and management, the sections below list only the bodies of data and work that are of immediate and directed relevance to the fishery. Exclusion of specific projects should not be viewed as any reflection of their scientific quality.

Common themes in the recent New Zealand literature, apart from those discussed briefly below, are (citations are examples only):

- larval lobster and ecology, including feeding (Jeffs et al. 2004a, 2005, Johnston et al. 2004, Bradford et al. 2005);
- marine reserves and their effects on lobsters, or vice versa (Babcock et al. 1999, Kelly et al. 2002, Davidson et al. 2002, Shears & Babcock 2002, Kelly & MacDiarmid 2003);
- mating ecology of lobsters and related effects caused by fishing (MacDiarmid & Butler 1999);
- aquaculture and enhancement (Hooker et al. 1997, Jeffs & James 2001, Sheppard et al. 2002, Stewart et al. 2002, Oliver et al. 2005);

### 2.5.1.1 Stock structure

The division of the New Zealand populations into nine "stocks" or CRA areas is unlikely to reflect the real stock structure. When smaller units are examined, for instance statistical areas within CRA areas, they often show contradictory trends. Recent assessments have treated individual CRA area as unit stocks.

At the same time, however, there are obvious relations among adjacent areas: for instance, CPUE trends show a roughly similar pattern of dramatic increase, 1993–99, from CRA 1 through CRA 5. This suggests that assessments might usefully estimate some parameters commonly across several CRA areas and estimate others specific to the CRA areas.

Information on stock structure explored so far includes tagging and movements, morphology, genetics and evaluation of parameters (Booth & Breen 1992, Bentley & Starr 2001) and modelling of currents (Chiswell & Booth 1999, Chiswell et al. 2003).

For DNA work see Brasher et al. (1992) and Ovenden et al. (1992).

What are appropriate stocks for management is still an open question. The question is to some extent pre-empted by the QMS: the unit of management is the QMA and QMAs are unlikely to be either subdivided or merged (a merger of CRA 7 and CRA 8 has been explored but has not yet happened); thus stock assessments at the QMA level are of most direct use to managers.

### 2.5.1.2 Puerulus settlement

Since 1979 a programme has measured puerulus settlement rates on artificial collectors set in shallow water at many locations (Booth et al. 2003). Bentley et al. (2004a) explored the standardised indices

with statistical tests to see whether settlement could be used as a predictor of later abundance, and could not find a significant relation.

The programme continues. Recent studies have examined oceanic processes in relation to settlement (Booth et al. 2000; Booth & Ovenden 2000; Chiswell & Booth 1999; Chiswell et al. 2003) to elucidate settlement mechanisms and suggest larval sources.

The relevance of larval settlement data to management depends on the relation between settlement and subsequent recruitment to the fishery. In Western Australia, an index of recruitment can be derived from an average of settlement indices estimated 3 and 4 years previously (Caputi et al. 1995). In South Australia the relation, based on a far shorter series, seems promising.

Difficulty in finding a relation in New Zealand (Bentley et al. 2004a) may be caused by several factors:

- a long period between settlement and recruitment to the pots, resulting in high attenuation of the settlement signal;
- natural variability and uncertainty in the settlement indices, plus the sampling variability caused by collectors being located in a small sample of possible locations;
- variation in survival among cohorts, weakening the settlement signal before it reaches recruitment to the fishery;
- variation in juvenile growth rates, so that a single cohort of settled lobsters reaches size at recruitment to the fishery over several years;
- natural variation in juvenile lobster growth rates from year to year, altering the time between settlement and recruitment between one cohort and the next (mean size at age for juvenile lobsters at Stewart Island shows such variation); and
- attenuation of the signal through density-dependent growth.

The larval settlement data are potentially valuable for management. The statistical quality of data and the actual relevance to management have yet to be demonstrated in New Zealand.

Related issues are interception of larvae by marine farms and the puerulus-quota trade-off (Section 2.3). Mussel farms catch puerulus larvae and many juveniles are killed when the mussels are harvested. It is unknown whether the puerulus are intercepted on their way to a natural settlement or whether they are surplus; whether mussel farms enhance early survival or cause a net loss.

Until recently, puerulus harvesting was managed under a "quota-trade-off" scheme in which a unit of quota could be traded for the right to harvest a number of puerulus or small juveniles, using a rate set under simple assumptions about mortality rates. This scheme is no longer in operation. If interest in harvesting puerulus becomes widespread, there may be a need to re-evaluate the trade-off rate.

### **2.5.1.3 Juvenile abundance and other studies**

There have been many studies of juveniles, many as part of behavioural or aquacultural studies. Several focused surveys of juvenile abundance include those of McKoy & Esterman (1981), Annala & Bycroft (1985), Breen & Booth (1989) and Booth et al. (2001), and there are considerable unpublished data. Street & Booth (1985), Breen & Booth (1989) and Booth et al. (2001) explored the relation between puerulus and later juvenile abundance.

Commercial pots do not catch juveniles efficiently. Full exploration of juvenile trapping is unreported; it may be that purpose-made traps could catch juveniles. Until then, juveniles are best studied by divers, which is expensive.

Oliver et al. (2005) described studies of predation risk to juvenile lobsters. Radford (2003) described feeding and digestion in juveniles.

If larval settlement proved to be important to management, then juvenile studies (especially of growth) would be required to elucidate the relationship. At present there is little other management use for studies of juveniles.

#### **2.5.1.4 Mating ecology**

In some areas, such as CRA 3, the fishery takes many more male than female lobsters. Although male lobsters are polygynous, they are limited in the amount of sperm they can produce (MacDiarmid & Butler 1999) and smaller males produce less sperm than larger males. There is also a requirement for successful mating that the male be at least as large as the female (MacDiarmid & Kittaka 2000). These facts lead to a concern that, even when spawning female biomass is high, egg production may be limited by male capacity and especially by shortages of large males.

Unmated mature female *Jasus edwardsii* develop short-term problems and show longer-term decreased fecundity (MacDiarmid & Kittaka 2000). Few such females are observed by observer catch samplers even where the fishery is mostly for males, but the short-term problems experienced by such females may limit their catchability. However, because there seems to be little evidence of any problem, and because good recruitment has appeared from small breeding populations, this problem is not thought to be of consequence in New Zealand.

#### **2.5.1.5 Morphometry**

To convert older standards of measurement to newer, such as carapace length (CL) found in older tagging to tail width used now, relations were provided by Breen et al. (1988). Sorenson (1970) provided conversions between tail length and CL.

Limited and unpublished length-weight data are available from parts of the observer catch sampling. These data may not be adequate for accurate characterisation of the relation between tail width and average weight for specific areas. The deficiency is probably not consequential to the current stock assessment because only the shape of the relation is important, and this is probably approximated sufficiently well with the existing data. The length-weight relation was more important when yield-per-recruit modelling was an important part of the assessment advice.

#### **2.5.1.6 Fecundity**

The definitive study is that by Annala (1991). It was important to characterise fecundity-at-size accurately when egg-per-recruit studies were a mainstay of assessment approaches (e.g., Annala & Breen 1989). The focus of current assessment has shifted away from stock-recruit considerations. If population egg production were to become an indicator again, as it is in fisheries for rock lobsters elsewhere, the extant information on fecundity is probably adequate (although based on carapace length rather than tail width).

A new issue is the relation between female size and egg size. Larger females tend to have larger eggs that may impart a higher probability of survival to the early larvae (MacDiarmid et al., unpublished data). If population egg production were to become an indicator again, these data should be worked up and documented for incorporation into the modelling procedure.

#### 2.5.1.7 Fishing power

In some other jurisdictions, notably Western Australia and South Australia, scientists try to measure the change in mean fishing power caused by technological improvements in fishing. A potlift might become more efficient over time as a result of:

- improved trap design,
- improved depth sounders,
- pinpoint navigation with GPS,
- increased mobility,
- improved bait,
- fisher learning and
- computerised analysis of pot catches in space and time.

Brown et al. (1995) examined the effect of specific technological change on the increased efficiency of pots in the Western Australian fishery for *Panulirus cygnus*. A questionnaire survey of South Australian fishers gave their estimate of annual 2.7% increases in efficiency in the 1980s (McGarvey & Prescott 1998), who suggested a 2–6% annual increase in effective effort in the 1990s, caused by colour depth sounders, sonar, larger vessels, larger engines, planing hulls and GPS. Bait is also mentioned by Brown et al. (1995). Prescott & Xiao (2001) used a series of analyses to estimate the increased efficiency in South Australia.

The concern is present in other fisheries, e.g. Robins et al. (1998) found that vessels with GPS were 4% more efficient in the same circumstances as vessels without in an Australian prawn fishery.

In New Zealand, there has been no work on fishing power and the stock assessment ignores the issue except indirectly. The assessment can estimate the shape of the relation between CPUE and biomass, potentially capturing some changes in fishing power. However, this approach is probably effective only in situations where the biomass has declined monotonically, and it has not been incorporated into rock lobster stock assessment. Economic forces are no doubt implicated.

#### 2.5.1.8 Catchability

In New Zealand, the catchability scalar is estimated by the assessment model, and no other work has been done on this parameter. In theory it might be possible to constrain the parameter through independent studies of the relation between catchability and lobster abundance in areas where lobsters are accessible to diving and abundant enough to permit of such a study. In practice this scalar is likely not to be constant: studies in Tasmania (Ziegler et al. 2003, 2004) show that it varies with season, temperature, density, sex and size structure and reproductive interests of the lobsters; in other words, catchability is a very complex process.

#### 2.5.1.9 Handling mortality

Many lobsters are returned to the sea alive, especially in areas (CRA 3 currently) where exploitation rate is high and sublegals are abundant. Where exploitation rates are lower, such as in CRA 8, returned lobsters may include undersized, berried females and legal lobsters returned so that more valuable sizes can be retained instead.

There is undoubtedly some mortality on such lobsters. In the past, lobsters were often taken out of pots and sorted some time later, after exposure suffering mechanical damage or to sunlight, wind or rain. Lobsters retained were about to die in any case, but lobsters returned to the sea were weakened by such exposure. New escape gap regulations and the live market have reduced such wasteful

practices because fewer sublegals are caught, lobsters are sorted immediately and handling mortality is no doubt reduced as a result.

The assessment model assumes a constant value (10%) for handling mortality and applies this to all periods and areas. If it is too low, the assessment could be biased. Handling mortality could be measured directly, at least in theory, in a combination of lab and field experiments.

### 3. TRENDS IN LOBSTER MANAGEMENT OVERSEAS

The literature and web (the latter contains most of the relevant information) were examined for five jurisdictions: the Canadian and United States fisheries for clawed lobsters, South Australia, Tasmania and Western Australia. The goal was to identify management harvest goals and strategies, reference points and biological indicators, assessment method and data collection.

#### 3.1 North America

The fishery is for the clawed lobster *Homarus americanus*. The fishery is managed with input controls that include, in some or all of the many jurisdictions, limited entry, universal (non-transferable) pot limits (limits can be as high as 425!), MLS and berried female restrictions, "V-notching, whereby a breeding lobster that is marked becomes legally invulnerable after egg hatching, escape gaps and biodegradable panels to prevent ghost fishing, prohibition of recreational fishing or recreational bag limits, and seasonal restrictions. Despite all these controls, effort is considered to be too high (FRCC 1995).

In both the United States and Canada, the management strategy involves simple reference points based on deterministic egg-per-recruit modelling (Fogarty & Gendron 2004). In the United States, the mortality that would produce 10% of the virgin egg production, called F10%, is a limit reference point. Actual fishing mortality rate, estimated from a DeLury analysis, is compared with the reference point, and mortality exceeding the reference point should trigger reductions in fishing mortality.

In Canada, the target reference point is twice the 1995 egg-per-recruit (FRCC 1995). Gendron (2005) described an increase in the MLS for part of the Quebec fishery to reach this target, which accompanied by increased mortality rates for large lobsters and concerns about the size and quality of eggs produced.

The reference points are deterministic estimates that do not incorporate the uncertainty of, for instance, the growth and mortality rates used to calculate them. Chen & Wilson (2002), using sets of Monte Carlo simulations, concluded that simple comparison of actual and reference mortality estimates did not provide a definitive evaluation of stock status for the Gulf of Maine. Chen et al. (2005) proposed a Bayesian length-based model for assessment of American lobsters in Maine.

In Canada, catch and effort are captured in fishing returns; "index fishers" (using voluntary logbooks) and at-sea sampling are used to obtain more detailed information and size structures; and some programmes examine juvenile settlement and habitat (FRCC 1995).

In Maine, the Department of Marine Resources (DMR) conducts catch sampling with observers, who record depth, soak time, location and lobster size, sex, cull status, v-notch if present, egg stage and moult status. DMR also conducts market sampling (port sampling), where samplers record from a trip the number and type of traps hauled, bait, soak time, area of fishing and average depth; and then catches are subsampled for lobster size, sex, weight, cull status and shell hardness.  
(<http://www.state.me.us/dmr/rm/lobster/lobstersamplingprograms.htm>).

### 3.2 South Australia (Northern Zone)

This is a fishery for *Jaſus edwardsii*. The most recent description of the management and assessment is from Ward et al. (2004; Table 13).

Table 13: Objectives and strategies used for the management of South Australian rock lobster (Ward et al. 2004)

Objective	Strategy
Maintain lobster population at a sustainable level across the fishery	<ul style="list-style-type: none"> <li>• adopt a precautionary approach</li> <li>• restrict nos. of licences to 75</li> <li>• control fish by manipulating days fished</li> </ul>
Harvest rock lobster at a size likely to provide for adequate levels of recruitment	<ul style="list-style-type: none"> <li>• set MLS to assist in protecting a proportion of the adult spawning stock</li> </ul>
Minimise the environmental impact of rock lobster fishing	<ul style="list-style-type: none"> <li>• promote environmentally sensitive fishing practices</li> <li>• identify areas of conservation significance that may be worthy of conservation (sic)</li> </ul>
Minimise potential conflict with other users of marine resources	<ul style="list-style-type: none"> <li>• be proactive in dealing with conservation issues that may impact on the fishery</li> <li>• take an ecosystem approach in considering management arrangements for the fishery</li> </ul>

Managers use five fishery performance indicators: exploitation rate, CPUE, egg production, pre-recruit abundance and mean size. The explicit goal of management is to maintain each within its 1992–96 range; thus, a set of performance-based management targets. When an indicator falls outside the range, a decision rule is triggered that requires

- notification of the Minister,
- an examination of the causes and implications of triggering,
- consultation with industry on alternative management actions, which may include changes to the season length, MLS or pot restrictions and
- a report to the Minister.

Annual assessments (for both fishery zones) are based on two models: the simple  $qR$  model of McGarvey & Matthews (2001) and a length-based Bayesian model of Ward et al. (2004). The latter is a sequential model - it assumes values for growth, natural mortality and selectivity.

Ongoing data collection involves fisher returns with catch and effort information, a limited voluntary catch sampling programme and a puerulus monitoring programme. The daily catch and effort returns contain information on area (broad statistical area), depth, number and weight of lobsters retained, numbers of undersized, berried and dead lobsters, numbers and weight of *Octopus* and giant crabs, and details of finfish retained.

A large programme of biological work in the 1990s (Prescott et al. 1996) collected very detailed information on length frequencies, growth and movements from large numbers of recovered tags, maturity, etc. These programmes are not ongoing.

### 3.3 Tasmania

Material for this section comes from Gardner et al. (2004) and the Australian government website: <http://www.deh.gov.au/coasts/fisheries/tas/rocklob/report/principle1.html>

The fishery is an ITQ fishery for *Jasus edwardsii*. The management strategy uses several performance indicators: commercial and recreational catch, vessels, CPUE, estimated recruited biomass, egg production, puerulus settlement, bycatch and impact on endangered or threatened species. These are compared with trigger levels that are based on previous performance. If indicators are triggered, then appropriate management changes, especially TACC changes, are considered.

The stock assessment model is the Bayesian length-based model developed by Punt & Kennedy (1997), which was used as the model for initial development of the New Zealand Bayesian assessment model. However, this model also incorporates a fleet dynamics model to predict the harvest rate in the different regions in each month for projections, a complication unnecessary for New Zealand.

Fishery monitoring is based on a catch logbook for 30 n.mile<sup>2</sup> blocks and includes depth. Fishery-independent data are obtained from research fishing at two locations before the season opens, during mid-season and towards the end. These lead to an estimated exploitation rate using the change-in-ratio technique. A tagging programme using a model developed by Frusher & Hoenig (2001) and conducted by research fishing is also used to estimate exploitation rate. A programme of fishery-dependent catch sampling is under consideration (Gardner et al. 2004).

Larval settlement is also monitored. Gardner et al. (2004) compared the larval settlement data with model recruitment estimates, but the time series is too short to make the comparison very robust for most areas.

Data on juveniles are poor, especially for growth rates, mortality and movement. MPAs are under formal consideration (an FRDC project) as an explicit management tool to allow females to grow larger and produce more eggs. Results suggest that (these are quoted from Gardner et al. 2004):

- *The introduction of large MPAs may not be beneficial if there is no reduction in catch at least equivalent to that displaced from the MPA.*
- *An MPA with no concomitant catch reduction could lead to further stock depletion in the open regions. This further depletion could in turn lead to a new equilibrium or fishery collapse, which would depend on the level of stock depletion when the MPA was introduced.*
- *If the fishery was close to or already collapsed an MPA was likely to be beneficial to stock recovery because of its contribution to recruitment.*

The authors conclude that MPAs are most valuable as research areas and must be treated cautiously as management tools. Their conclusions on depletion and increased exploitation rates are supported by Hobday et al. (2005).

Interactions with protected species are required to be reported: fishers are supplied with logbooks containing a protected species interaction section to improve reporting. Data collected through this new logbook will be reported in the next assessment report.

Tasmanian researchers monitor the occurrence of unmated mature females using abdomen colour as suggested by MacDiarmid & Butler (1999). The condition has been observed only rarely since 1992. Where infertility is seen, the prevalence is very low (maximum 0.5%). The risk of infertility caused by a lack of males appears to be low.

### 3.4 Western Australia

Information for this section comes mostly from the Australian government website <http://www.deh.gov.au/coasts/fisheries/wa/rocklob/report/summary.html> (WA Fisheries 2001).

The fishery is for *Panulirus cygnus*. There is no quota, but pot licences are a limited transferable property. Apart from the pot limitation, management is by input controls that include limited entry, MLS, a maximum legal size, protection of both berried and non-berried mature females, gear restrictions, prohibition of night fishing, escape gap requirements and seasonal and area closures. Recreational fishing is licensed, with bag and pot limits as well as other input controls.

The fishery management goal is to maintain breeding stock above a limit reference point of 22% of the unfished level of breeding stock. The breeding stock was estimated to be lower than this – 15% in the 1970s so the limit of 22% is considered to appropriately precautionary. It is thus a performance-based limit reference point. Annual comparison is made between this reference point and estimated actual breeding stock. If the actual stock is less than the reference point, options include

- reductions in the total number of pots,
- reduced season length or within-season closures,
- changed MLS or maximum size and
- area closures.

The fishery is monitored through monthly returns that show monthly catch, days fished and traps pulled per day. Market sampling in processing plants gives length frequency samples from each zone. An observer programme is designed to sample each zone, depth range and season, and records catch details for each pot, lobster size, sex and reproductive condition, *Octopus* numbers and interactions with seals, turtles, manta rays, dolphins, etc. A phone survey is used to estimate recreational catch.

Research fishing produces fishery-independent spawning stock estimates. Larval settlement is monitored monthly at standard sites.

The research most directly critical to management are a spawning stock index, derived from observer catch sampling, and the independent breeding stock index, derived from research fishing conducted at the beginning of the breeding season by chartered vessels fishing to specifications.

In addition, voluntary logbooks are provided by some fishers, who record daily catch, number of pots lifted, swell height and number of undersized and breeding lobsters returned.

The most recent assessment model, described by Hall et al. (2001), is age-structured and is fitted to observed landed catches, returned mature females and oversized lobsters, and observed egg production indices. The model is "sequential": natural mortality is assumed, growth rates are assumed based on external analysis of tag-recapture data, and the relation between puerulus settlement and recruitment is also estimated outside the model. A length-based model has also been described (Hall et al. 2000), and a modified DeLury approach has been used to estimate changes in exploitation rate and catchability over time, with external analyses of the relation between catch ability and environmental factors (swell and temperature) (Srisurichan et al. 2005).

A detailed environmental risk assessment (WA Fisheries 2001) was conducted to meet the requirements of "ecologically sustainable development (ESD) (Commonwealth of Australia 2001): this assessment, much more detailed than that for South Australia, was summarised by Breen (2005). Relevant points are:

- effects on bycatch species could be analysed sufficiently because of the data collected by fishers and observers;
- data on protected or endangered species are now collected and analysed to meet the relevant environmental principle;

- trophic effects of removing lobsters were dismissed after a relatively brief desktop analysis;
- bait effects were dismissed after calculating the annual bait density; and
- direct damage to the habitat (to corals and to limestone reefs) could be evaluated based on knowledge of habitats and their areas, estimates of potting intensity and diver surveys.

### **3.5 Summary and discussion**

The examples of overseas lobster management above show much diversity and also several themes in common. The five jurisdictions all have some kind of quantitative reference points. Only the USA has a target (F10%); the others have performance-based limit reference points. In Canada and WA, the limit is based on previous EPR or egg production respectively; in South Australia and Tasmania large suites of indicators are based on previous performance.

These five jurisdictions manage their fisheries on different suites of data. Some system of catch and effort data capture is common to all. Research fishing is an important data source for Tasmania and WA, but is not used elsewhere. Voluntary logbooks are important in South Australia and WA and are under development in Canada and Tasmania. Market sampling is important in the USA and WA, but not used elsewhere. Size frequency data are used in annual assessments in Tasmania and South Australia, but not elsewhere.

What is done in these five examples that is not done in New Zealand? Items include

1. the USA: V-notching practice,
2. protection of mature females and large animals,
3. calculation of egg production or EPR as a major assessment tool,
4. market sampling,
5. multiple assessment models,
6. more detailed fishing information on compulsory returns (depth, bait, etc.),
7. research fishing,
8. incorporation of larval settlement into the assessment model,
9. estimation of fishing power changes,
10. estimation of environmental effects on catchability and
11. collecting data on protected species interactions.

## **4. LIKELY FUTURE CHANGES IN NEW ZEALAND**

This section attempts to predict future directions. For convenience, although of course there is much overlap, changes are divided into fishery, management and assessment categories.

### **4.1 Changes in the fishery**

As the biodiversity strategy is implemented, access to more stock will be lost to extractive stakeholders through proliferation of marine reserves. Commercial fishers will experience further alienation of fishing areas through declaration of other special areas such as taiapure, mataitai and other potential exclusion zones allowed in legislation.

The population of fishers is likely to change as quota owners become less directly involved in actual fishing and as ToKM release quota to iwi. Pre-QMS expertise and experience will gradually be lost to the fishery. It is likely that voluntary data collection will face challenges as the fishing population changes, because the incentives for non-quota-owners to collect good data will be reduced.

Recreational fishing is likely to increase rather than decrease. Illegal fishing may increase in response to long-term increases in value, although decreases are possible under increased MFish Compliance attention.

As technology is developed, and perhaps as markets evolve, there will be increased interest in harvesting puerulus for on-growing under the quota trade-off scheme, perhaps leading to new sources of illegal fishing.

Fishing itself will become smarter, with developments in on-board data reception and analysis, and computerised capture and analysis of fishing data, leading to increased efficiency.

The fishing industry will face several sources of economic headwind:

- fuel prices and other operating costs will escalate, requiring changes to fishing strategies;
- fishing opportunity will deteriorate as historical fishing grounds are alienated;
- bureaucratic overheads may increase;
- competition from other lobster-producing nations may increase; and
- opportunities to diversify into other fishing activities will continue to become scarcer.

Industry will actively seek new markets and will explore opportunities for new product forms that might be currently denied by the regulatory framework. Communication and coordination between processors, exporters and the catching sector will increase as industry seeks to maximise its economic return despite the problems listed above.

## **4.2 Changes in management**

Through some mechanism, managers and stakeholders will codify their goals properly and reach agreement on management strategies. As a result, properly evaluated management procedures will become more common as the accepted mechanism for changing TACs and TACCs.

Where specific fisheries are in relatively good health, stakeholders and managers will explore the consequences of reducing input controls such as MLS differentials, berried female restrictions, closed seasons and method restrictions. There may be pressure to allow commercial hand gathering with compressed-air diving, although incumbent quota owners have reaffirmed potting as the sole commercial harvest method.

MFish will increase the effort aimed at quantifying non-commercial catches. There may be renewed attempts to manage recreational fishing with a rights-based system. MFish will attempt to reduce illegal catches. Catch labelling will be explored and considered critically.

MFish will progressively shift towards addressing concerns about the effects of fishing on the environment, in all its forms, and the economic and sociological implications of management (Breen 2005). Examples include the effects of pots on benthic invertebrates, the effects of decreased lobster abundance on sea urchins and kelp, the number of protected species injured or killed by buoy-lines, etc. There will be increased regulatory concern with "managing ecosystems", which is now embryonic in fisheries management in New Zealand.

Information required from fishers will expand. Reporting requirements will shift towards much more detailed area information and other details of fishing, including catches of associated species.

### **4.3 Changes in assessment requirements**

A change of emphasis will be away from strong dependence on stock assessment and towards development and evaluation of management procedures that specify how catch levels and other management options will change as a function of fishery observations.

There is some need for changes in the current assessment model. An essential change is to develop a standard way to deal with spatial closures. Others include

- inclusion of random effects to accommodate stochastic growth or mortality,
- revising the dynamics to prevent the low uncertainty caused by very high exploitation rate estimates,
- reducing the model's time step from six months to one or two months to include more biological detail and fine-scale dynamics,
- integration of CPUE standardisation into the model,
- incorporation of appropriate localised data, such as from community groups or marine reserves,
- expansion to facilitate simultaneous estimates in several QMAs, using a mixture of global and area-specific parameters and
- integration of additional data sources, perhaps including temperature or ocean climate.

The benefits of making such changes cannot be evaluated until the changes are actually made. However, these are all complex and time-consuming changes that can be made only at the expense of other work.

New directions in assessment outside the current model will include much more focus on associated species and the ecosystem and may include:

- evaluation of direct ageing techniques for lobsters (Sheehy et al. 1999, Sheehy & Bannister 2002) that, if successful would allow age-based assessment modelling,
- evaluating the effects of removing input controls such as the restriction on berried females,
- elucidating the relation between ocean climate and lobster catchability and dynamics,
- dissecting the relations among stocks,
- evaluating other information sources,
- using genetic approaches to understanding metapopulation dynamics,
- developing links with emergent economic analyses and
- making data more accessible to industry with tools like the tag tracker.

The assessment-related research must be responsive to proposed or actual changes to management changes. Evaluating the effects of changes will be important and time-consuming for the assessment researchers. Removing restrictions on berried females and diving, and removing seasonal and area closures, are distinct possibilities. In CRA 3, the possibilities include reverting to the 54 mm MLS in winter, or extending the 3-month 52 mm size to recreational fishing.

A challenge to assessment will be in accommodating small-scale interest. Iwi groups will be most interested in, and perhaps can supply data from, their restricted section of the coast; recreational fishers will want stocks to satisfy their interests in specific areas in specific seasons; commercial fishers will tend in future to be less mobile than at present because of high fuel costs and increased alienation of coastal sections.

## **5. MANAGEMENT NEEDS**

### **5.1 Sustainability**

Sustainability is currently maintained in the nine rock lobster fisheries by conducting periodic assessments, comparing estimated stock status against reference levels, and adjusting TACs and

TACCs as and when required to ensure that stocks remain or move towards their target levels. For CRA 7 and CRA 8 the process is broadly similar in the long term; in the short term, TACCs are adjusted by the management procedure without immediate reference to any stock assessment.

For discussion, consider the generalisation "at present, data and research are generally adequate to ensure sustainability." Major exceptions to this statement are CRA 6, where the biology (especially the source of biological production) is not understood, and CRA 9, which does not fit into the currently assumed substock pattern. For these two stocks, annual catch monitoring data from the fishery are absent or inadequate and there is no recent stock assessment. CRA 7 is adequately monitored, but the assessment cannot be called adequate for CRA 7.

Another exception to the generalisation is the question of stock structure. Researchers do not understand the sources of larvae for most stocks and only partly understand post-settlement processes that may cross stock boundaries. For instance, CRA 7 contributes some lobsters to CRA 8, but the scale of the interaction is unknown. Another example is provided by the abundance increase of the mid 1990s in CRA 2 through CRA 5: this began later in the more southern areas; a decline began soonest and was felt most strongly in the northern areas. Is this a result of lobster movements, or does it reflect a common environmental driver? Directed genetic work is a possibility that should be discussed.

Further caveats to the generalisation can be found when data availability is examined. The non-commercial catch data are inadequate. The CELR data are deficient, as discussed above: the spatial grain size is far too large to permit of detailed analyses; details of the fishing process are not captured (depth, bait, pot type, etc.); and in some circumstances catch and effort cannot be matched. The tag-recapture data used to estimate growth are adequate only for CRA 2, CRA 5 and possibly CRA 8 (new CRA 8 data have not been worked up).

Changes in fishing power have not been considered seriously in New Zealand, although much attention is directed at these in Australia. If technology has increased catchability, the current assessment approach is over-optimistic.

For the future, the development and adoption of management procedures will not displace the need for good assessments, because these rely on a credible operating model in the evaluation phase. But development of management procedures will require some substantial directed work, probably on a continuing basis because management procedures should not be left in place for more than five years without review.

The assessment model must be modified to allow marine reserves to be addressed, and probably should be modified to address both smaller-scale data, as they become available, and larger-scale metapopulation processes. Other changes to the model will be required to maintain it as the best contemporary option.

## **5.2 Associated or dependent species**

*Associated or dependent species are all marine mammals, seabirds, fish species, and benthic animals and plants for which no targeted fishing is permitted but which are affected by fishing targeted at other species. When taken as a non-target catch in legitimate fishing operations, catches of some Associated or Dependent Species may be sold.*

The concern reflected in the draft MFish Strategy on managing the environmental effects of fishing can be divided into bycatch and protected species. The concern is that substantial bycatch of a species might be unsustainable or threaten the species' viability. The concern for protected species is directed at iconic species such as dolphins, whales, seabirds and turtles.

### 5.2.1 Bycatch

The legal requirement to maintain associated species at a level that will ensure their viability requires data. Rock lobster potting is one of the most tightly targetted fisheries, and escape gaps allow fish and invertebrates to escape, but pots do catch other species incidentally.

The CELRs require fishers to record the most abundant five species caught for each trip. Documentation of the CRACE database (Bentley et al. 2005) presents an analysis of the most commonly species landed by QMA. In all, 129 species are reported, but are less than 10% of the catch by weight.

The most prevalent bycatch species reported by weight in lobster pots are, in order, *Octopus*, conger eel, blue cod, trumpeter, sea perch, red cod, butterfish and leatherjackets.

The voluntary logbook forms also request information on *Octopus* and "other", which can be named. Observer catch sampling records only *Octopus* bycatch.

For an initial risk assessment required for development of a fishery plan, and given the relatively low prevalence of bycatch in rock lobster pots, current data may be adequate to identify major bycatch species and estimate total catches by area. In the longer term, especially if MFish considered any bycatch species to be of concern (it is difficult to imagine how this could happen), having more extensive and detailed bycatch data would put the commercial fishery in a stronger position.

### 5.2.2 Protected species

Protected species are specifically protected under the Wildlife Act 1953 or the Marine Mammal Protection Act 1978 and may not be landed for commercial gain. They include seabirds, marine mammals and corals. They are designated as protected because it has been determined that they should not be available for commercial exploitation even when taken as an unintended non-target catch.

The draft MFish Strategy on managing the environmental effects of fishing, in discussing what should be research priorities in this area, focuses on threat classification and mitigation, suggesting a primary concern with endangered, threatened and vulnerable species. This may in turn reflect primary concern about the effects of fishing on what MFish calls "icon" species such as Hector's dolphins, Maui's dolphins, albatrosses and Hooker's sea lions.

There are no data on the interaction between the lobster fishery and protected species. Possibilities include entanglement of dolphins or whales (a well-publicised tragic incident in 2003 involved a humpback whale). Humpback whales may encounter lobster pots with some frequency. In the north, turtle entanglements are a possibility.

Better data will be required for a credible environmental risk assessment. These data – interaction with a protected species – could be collected by the industry and by observers during catch sampling.

### 5.2.3 Habitats – direct effects

There is no data on the effects of lobster fishing on habitats. "Habitats" are not formally defined in New Zealand. Common approaches in the New Zealand literature include modifying a physical description with depth, wave exposure and latitude (e.g. Schiel 2003) or defining habitats based on the dominant algal and invertebrate species (Schiel & Hickford 2001).

For a risk assessment, the lack of information is a problem. Damage caused by pots may vary from nil, if landed on sand or gravel, through minor, when landed on rocky reefs, to severe if landed on black coral or bryozoan gardens. In Western Australia, there was concern about damage to limestone reefs. Prevalence of substrates likely to be damaged mechanically in New Zealand is unknown but probably low, and the concern would be for fragile plants and animals rather than the substrate itself. Animals that could be destroyed by a pot are very diverse and range from sponges and corals (black corals and gorgonian corals) through nearly all the phyla. Some species might be locally important, such as black corals in Fiordland, brachipods in Paterson Inlet, pennatulids in the Narrows, bryozoans in parts of Tasman Bay, etc.

Western Australia was able to identify the habitats most likely to be affected by lobster fishing (seagrass meadows, coral reefs, limestone reefs) as a starting point for their risk assessment (WA Fisheries 2001). They calculated the proportions of reef area affected annually by potting and showed that it was low. There is no such obvious starting point in New Zealand. The coarse-scale "habitats" on which pots are placed are undefined and there are no data on what proportion of pots are placed on rocky reefs. The extent of such rocky reef habitats is also unknown. This major data deficiency could perhaps be addressed with a short-term industry study. This would be best undertaken when small-scale reporting of effort has been resolved.

#### **5.2.4 Habitats – Indirect effects**

Breen (2005) identified two areas of possible concern: bait and effects of fishing on community composition.

Bait seems like a minor issue, but in Maine, Saila et al. (2002) estimated that the quantity of bait imported to the ecosystem ( $8.5\text{g/m}^2/\text{yr}$ ) was a significant factor in lobster production. In Western Australia the trophic effect of bait was only  $0.5\text{g/m}^2/\text{yr}$  (WA Fisheries 2001) and considered negligible.

The effect of bait also depends on its source (local or imported) and on who eats it. In New Zealand, the effects of baits are likely to be small because intensity of potting is far lower, in most areas, than in North America. Some information on bait composition is available from the observer catch sampling database. For a risk assessment, information would be required on bait quantity and on composition in areas without observer programmes. This could be obtained with a short and simple project.

Effects of lobster fishing on community composition are poorly understood. A recent focus in New Zealand has been on sea urchins, which are a major grazer of macrophytes and a prey of lobsters. The hypothesis is that lobsters control sea urchins and that lobster fishing leads to dramatic sea urchin increases, dramatic kelp bed recession and further trophic effects on fish and shellfish populations: examples include Mann & Breen (1972) for Nova Scotia and Babcock et al. (1999) for New Zealand.

This idea and its relatives are controversial, because

- appropriate controlled experiments are difficult or impossible,
- the structure of food webs (who else eats sea urchins?) is difficult to dissect and
- marine systems are also affected by constantly changing environmental influences, which themselves may affect the plants, sea urchins and predators.

The controversy is also fuelled by such issues as:

- how representative the study areas are of larger scale process;
- how representative the study periods are in larger time scales;
- what the role is of physical disturbance, especially wave exposure, light and water temperature;

- how and why sea urchins change their behaviour from cryptic drift-feeders to aggregated attackers of whole plants;
- how sea urchin size structure is involved.

This area cannot be called a data deficiency: it is a major research topic. The issues are complex in the extreme and answers will be slow to obtain. No simple approach that can remedy this. The area is beyond the scope of a rock lobster research plan, but the industry should keep a watching brief on development of standards.

## 5.2.5 Habitats – maintaining diversity

The goal in the draft MFish Strategy is to *maintain biological diversity of the aquatic environment (including diversity within species between species, and of ecosystems)*. There is a New Zealand Biodiversity Strategy available at <http://www.biodiversity.govt.nz/picture/doing/nzbs/contents.html> but it is of limited help in suggesting what operational goals or standards would contain.

The MFish Strategy reflects an idea that area closures are the primary tool to protect specific habitats. This is in line with the Biodiversity Strategy's approach to protecting 10% of the marine environment. The MFish Strategy briefly discusses *habitats of particular significance to fisheries management*, but does not define these further. They might be areas important to juveniles, spawning habitat, etc. An area near North Cape is currently closed to fishing to protect egg release and prevent handling disturbance for packhorse lobsters (Booth 1979).

An exemplary approach is taken by the Fiordland Marine Conservation Society (Teirney 2003) for Fiordland. In a consultative process, they identified 23 "china shops" as *small discrete areas that are outstanding for the abundance and/or diversity of animal or mixed animal and plant communities or for the abundance of particular animal species*. The Society also describes defining representative areas and identifying whether and how they should be protected.

So, again, the relevant habitats are undefined, there are no published habitat maps or catalogues, there are no data on where lobster pots are fished and there are no standards. The data deficiency will be a problem, but resolution would be best undertaken when small-scale reporting of effort has been required.

## 6. RECOMMENDATIONS ON ONGOING AND FUTURE DATA REQUIREMENTS

In the sections above, the current work has been reviewed, historical work catalogued, changes to the fishery have been identified and management's research needs identified. In this section we list the various possible projects again and briefly summarise their importance, likely costs and other factors to consider in setting priorities. There will be some overlap among some projects.

### 6.1 Possible data and projects

#### 6.1.1 Ageing

This is discussed in Section 4.3.

**Current adequacy:** Currently impractical.

**Utility:** For estimating sustainability.

**Importance:** Very high if feasible, zero if not operationally practical.

**Cost:** High.

**Comment:** Uncertain prospects for operational success: a valid approach would be to watch international progress. Would require a captive population of known age.

### **6.1.2 Assessment model development**

This is discussed in Sections 4.3, 4.3 and 5.1.

**Current adequacy:** n.a.

**Utility:** For estimating sustainability and evaluating alternative management actions.

**Importance:** High: the model will become obsolete if not maintained.

**Cost:** Moderate to high depending on the specific work undertaken.

**Comment:** A 3-year plan would be useful to guide the required changes.

### **6.1.3 Bycatch data**

This is discussed in Section 5.2.1.

**Current adequacy:** Probably adequate for initial risk assessment, could be marginal depending on MFish standards.

**Utility:** For ensuring viability of associated species.

**Importance:** Low to moderate depending on MFish standards.

**Cost:** Low: high-quality data could be captured through existing catch monitoring programmes.

**Comment:** Not a high priority now but might become important later depending on MFish standards.

### **6.1.4 Catchability**

**Current adequacy:** No direct estimates (but estimated by the assessment model).

**Utility:** For estimating sustainability.

**Importance:** High if feasible.

**Cost:** High because potting and diving required.

**Comment:** Uncertain prospects for operational success: likely to be too complex a topic for a short study (complicated by season, local conditions, moon phase and animal size, sex and reproductive interests). Opportunities may exist in association with marine reserves. Has been studied in Australia but those studies are of limited utility for New Zealand.

### **6.1.5 Commercial catch per unit of effort**

This is discussed in Sections 2.4.3.2, 2.3 and 5.1.

**Current adequacy:** Adequate but not good.

**Utility:** For estimating sustainability.

**Importance:** Very high.

**Cost:** Data are captured as part of the QMS.

**Comment:** Catch and effort are disconnected when holding pots are used; data are error-prone and inadequate to address many pressing assessment and management issues; they fail to capture fine-scale catch locations and fishing details. **Must be improved.**

### **6.1.6 Commercial catch monitoring (including size structure)**

This is described in Sections 2.4.3.1, 2.4.3.3 and 2.4.3.4.

**Current adequacy:** Current coverage is adequate, except in CRA 6 and CRA 9, both of which areas would be difficult to assess in any case.

**Utility:** For estimating sustainability.

**Importance:** Very high.

**Cost:** Catches themselves are captured under the QMS; cost of catch monitoring by observers is high (c. \$150K); cost of voluntary catch sampling is moderate (technical assistance is required).

**Comment:** Programmes must continue; programmes for CRA 6 and 9 should be implemented to meet standards.

#### **6.1.7 Data visualisation**

This is discussed in Sections 2.4 and 4.3.

**Current adequacy:** Adequate only for tags.

**Utility:** For allowing industry and others simple and instructive access to fishery and research data.

**Importance:** Medium.

**Cost:** Low to moderate depending on the approach.

**Comment:** Many opportunities exist for data visualisation in addition to those (tags, catch and effort) explored so far. This approach can be useful in motivating those who provide data.

#### **6.1.8 Database development and maintenance**

This is discussed in Sections 2.4.3.1, 2.4.3.2 and 5.2.1.

**Current adequacy:** Adequate.

**Utility:** For estimating sustainability and providing routine summaries to industry and the NRLMG.

**Importance:** High.

**Cost:** Low.

**Comment:** CRACE is now an extremely valuable resource that saves much time and money and allows generation of reports based on high-quality data. Some continuing work is required to keep the database up-to-date and to accommodate new developments in reporting. TagTracker has been valuable in stimulating interest in accurate reporting of tag recaptures.

#### **6.1.9 Direct effects of fishing on habitats**

This is discussed in Section 5.2.3.

**Current adequacy:** Inadequate.

**Utility:** For managing the environmental effects of fishing.

**Importance:** Low to high depending on MFish standards.

**Cost:** Low.

**Comment:** Hampered by lack of habitat mapping and habitat definitions. Could wait until MFish standards appear.

#### **6.1.10 Evaluation of input controls**

This is discussed in Sections 4.2 and 4.3.

**Current adequacy:** Mostly inadequate.

**Utility:** For improving productivity, or maintaining productivity at lower cost to industry.

**Importance:** High.

**Cost:** Moderate.

**Comment:** Nothing is currently required. Stakeholders and managers should be aware that this option exists.

#### **6.1.11 Fecundity**

This is discussed in Section 2.5.1.6.

**Current adequacy:** Adequate.

**Utility:** For estimating sustainability (if EPR used, or if egg production calculated by model, neither of which obtain at present).

**Importance:** Moderate.

**Cost:** Low.

**Comment:** No work is currently required.

#### **6.1.12 Fishing power**

This is discussed in Section 2.5.1.7.

**Current adequacy:** Inadequate.

**Utility:** For estimating sustainability.

**Importance:** Moderate.

**Cost:** Moderate.

**Comment:** Limited prospects for success in survey- and model-based approaches. General problem is under-considered in New Zealand.

#### **6.1.13 Handling mortality**

**Current adequacy:** Inadequate knowledge.

**Utility:** For estimating sustainability.

**Importance:** High.

**Cost:** Moderate in a one-off study involving lab facilities.

**Comment:** Important but difficult.

#### **6.1.14 Indirect effects of fishing on habitats and the ecosystem**

This is discussed in Sections 5.2.4 and 5.2.5.

**Current adequacy:** Inadequate.

**Utility:** For managing the environmental effects of fishing.

**Importance:** Low to high depending on MFish standards.

**Cost:** Open.

**Comment:** Hampered by lack of habitat mapping and habitat definitions, and by uncertain scale of the problem; not clear what relevant research should be considered by the NRLMG. In any case, should wait until MFish standards appear.

#### **6.1.15 Juvenile abundance, growth and mortality**

These are discussed in Section 2.5.1.3.

**Current adequacy:** There are no continuing time series of abundance for any area. Growth has been estimated for several areas from model frequency shifts using methods now obsolete. Mortality is being studied experimentally as part of a FoRST project.

**Utility:** For estimating sustainability and evaluating alternative management actions.

**Importance:** For growth, would be high if utility of larval settlement indices were demonstrated; otherwise low.

**Cost:** High: with current technology all aspects require diving.

**Comment:** Low priority topics at present.

#### **6.1.16 Larval settlement**

This is discussed in Section 2.5.1.2.

**Current adequacy:** Adequacy depends on utility. Uncertainty around estimates in low-settlement areas is very high.

**Utility:** For estimating sustainability and evaluating alternative management actions.

**Importance:** Very high if utility is demonstrated, otherwise low.

**Cost:** High: the current project costs \$85K this year.

**Comment:** Utility has not been demonstrated.

#### **6.1.17 Larval sources**

This is described in Sections 2.5 and 2.5.1.2.

**Current adequacy:** Inadequate.

**Utility:** For elucidating stock structure.

**Importance:** High: managers need to know where production originates.

**Cost:** Moderate to high depending on the specific work undertaken.

**Comment:** Uncertain prospects for success.

#### **6.1.18 Management procedure development**

This is discussed in Sections 2.4 and 5.1.

**Current adequacy:** Adequate only for the NSS, with CRA 3 in progress.

**Utility:** For estimating sustainability and evaluating alternative management actions.

**Importance:** High: the model will become obsolete if not maintained.

**Cost:** Moderate to high depending on the specific work undertaken.

**Comment:** Highest priority area.

#### **6.1.19 Market sampling**

This is described in Section 3 in summaries of research overseas.

**Current adequacy:** Historical data only.

**Utility:** For estimating sustainability.

**Importance:** Low because of catch sampling at sea.

**Cost:** Much lower than observer catch sampling, more expensive than voluntary catch sampling.

**Comment:** No current need for further work unless current catch sampling collapses; industry could consider relative costs.

#### **6.1.20 Mating ecology**

This is mentioned in Section 2.5.

**Current adequacy:** Sparse field data.

**Utility:** For ensuring sustainability.

**Importance:** Low: potential problem is not evident in the field.

**Cost:** Low for field observations; moderate for lab studies.

**Comment:** No current need for further work.

#### **6.1.21 Morphometrics**

This is discussed in Sections 2.5.1.1 and 2.5.1.5.

**Current adequacy:** Adequate except for stock structure analysis.

**Utility:** For MLS and for converting data made with tail length or carapace length.

**Importance:** Moderate to high.

**Cost:** Further work could attach to the observer catch sampling.

**Comment:** No current need for further work unless intended for stock structure analysis.

#### **6.1.22 Non-commercial catches**

These are discussed in Section 2.4.3.1.

**Current adequacy:** Current data are inadequate for stock assessments.

**Utility:** For estimating sustainability.

**Importance:** High.

**Cost:** For recreational catches, very high: current surveys for priority species for this year are costing \$710K. For illegal catches: unknown; for customary catches: unknown but probably lower: some progress is being made in obtaining information about quantities specified on permits issued.

**Comment:** Stock assessment and management are both hampered, to different extents in different areas, by lack of credible information on catches and their size composition.

#### **6.1.23 Ocean climate studies**

This is discussed in Section 4.3.

**Current adequacy:** Relations are currently poorly understood at best.

**Utility:** For estimating sustainability and predicting the effects of alternative management actions.

**Importance:** High.

**Cost:** Moderate.

**Comment:** An area with mixed results in other fisheries; has led to good insights where successful.

#### **6.1.24 Optimising data collection**

This is discussed in Section 2.4.

**Current adequacy:** Good for catch monitoring, not fully adequate for tag-recapture, inadequate for other data

**Utility:** To ensure adequate data for the purposes required without collecting data needlessly.

**Importance:** High.

**Cost:** Moderate.

**Comment:** Potentially reduces data collection costs (at a cost).

#### **6.1.25 Periodic stock assessment**

This is discussed in Sections 2.4, 4.3 and 5.1.

**Current adequacy:** Good but not without problems.

**Utility:** For estimating sustainability and evaluating alternative management actions.

**Importance:** Very high.

**Cost:** Very high.

**Comment:** Need for periodic assessments will continue even if management procedures are widely adopted.

#### **6.1.26 Protected species**

This is discussed in Section 5.2.2.

**Current adequacy:** Essentially no data.

**Utility:** To manage the environmental effects of fishing.

**Importance:** Low to high depending on MFish standards.

**Cost:** Low.

**Comment:** An obvious first step would be to collect some data from the fishing process through existing catch monitoring programmes. Unclear what further work could be done.

#### **6.1.27 Research fishing**

This is discussed in Section 3 with respect to research elsewhere.

**Current adequacy:** No New Zealand data.

**Utility:** To estimate sustainability.

**Importance:** Unknown.

**Cost:** Very high.

**Comment:** High costs preclude use as a research tool in New Zealand; outputs are available through other programmes.

#### **6.1.28 Stock structure studies**

This is discussed in Sections 2.5.1.1 and 5.1.

**Current adequacy:** Not convincing, but the value of better information is unclear. Required data are generally not adequate.

**Utility:** To estimate sustainability effectively.

**Importance:** Open.

**Cost:** Moderate to high depending on the approach taken.

**Comment:** Low prospects for success without substantial expenditure (genetics, ROVs, etc.).

#### **6.1.29 Tag-recapture data**

These are discussed in Section 2.4.3.6.

**Current adequacy:** Adequate only for CRA 2, CRA5 and possibly CRA 8.

**Utility:** For estimating sustainability.

**Importance:** Very high.

**Cost:** Moderately high: requires boat charter.

**Comment:** Inadequacy of data is demonstrated in assessments and is mostly related to scarce information for larger lobsters. A rolling programme of tagging has improved the data, but return rates are low (5–10%). Recreational re-captures may be important but data are not well recorded. Important but difficult.

#### **6.1.30 Trap selectivity studies**

**Current adequacy:** No direct estimates (although indirect estimates are made by the assessment model).

**Utility:** For estimating sustainability.

**Importance:** Low to moderate depending on confidence in model estimates.

**Cost:** High: requires potting and diving.

**Comment:** There may be opportunities associated with marine protected areas. Logistically difficult.

## **7. PRIORITY LIST OF RESEARCH TO MEET MANAGEMENT NEEDS**

The list below is preliminary and subject to change after discussion within the NRLMG.

### **Essential:**

1. CPUE
2. Non-commercial catches
3. Commercial catch monitoring
4. Tag recapture data
5. Periodic stock assessment
6. Management procedure development
7. Assessment model development

### **Desirable:**

8. Optimising data collection
9. Database development and maintenance
10. Ocean climate data
11. Ocean climate studies
12. Larval sources
13. Bycatch data
14. Direct effects on fishing habitats
15. Stock structure studies
16. Morphometrics

### **Lower priority:**

17. Indirect effects of fishing on habitats/ecosystem
18. Protected species
19. Larval settlement
20. Juvenile abundance, growth and mortality
21. Evaluation of input controls
22. Data visualisation

### **Not required:**

23. Fishing power
24. Research fishing
25. Trap selectivity studies
26. Fecundity
27. Ageing
28. Mating ecology
29. Handling mortality
30. Catchability
31. Market sampling

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