Innovation and Capacity in Fisheries: Value-Adding and the Emergence of the Live Reef Fish Trade as part of the Great Barrier Reef Reef Line Fishery

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James Cook University

STATEMENT OF SOURCES

DECLARATION

I declare that this thesis is my own work and has not been submitted in any form for another degree or diploma at any university or other institution of tertiary education. Information derived and published or unpublished work of others has been acknowledged ion the text and a list of references given.

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ABSTRACT

According to the Food and Agriculture Organisation approximately 70% of the world's fisheries are fully or overfished. One approach posited to address economic and biological sustainability goals is to value-add existing target species. The emergence of new 'high value-added' products in expanding markets, however, can have unique implications for the management of fisheries resources. Understanding the relationship between investment and effort, and investment and profits is regarded as essential to effective fisheries management, as most fishery problems are partially the result of over-investment in excess fishing capacity. Moreover, economic incentives for increasing capital investment in such industries are compounded by the presence of a) latent effort and b) under-utilisation of existing capacity. Lastly, participation in the value-adding process may require the take-up of new technology. Most research into technological change and innovation adoption in fisheries is confined to innovations that enhance productive capacity of the fishing vessel, not product form or quality.

The Great Barrier Reef reef-line fishery (RLF) is a multi-species fishery that has traditionally marketed its catch as either frozen fillets, frozen whole or whole chilled fish. Since 1994, some species of coral reef fish have been kept alive for export, with the expectation of increased returns per unit of effort. The development of this live reef fish fishery (LRFF) has coincided with reported increases in catch and effort and a recognition that considerable latent effort exists within the fishery that may mobilise.

This research is an attempt to draw together related but previously unconnected themes of value-adding, innovation and adoption, investment, capacity and latent effort into a coherent framework to explore; the link between value-adding opportunities and profit maximising behaviour; constraints to adoption of and investment in value-adding innovations; profitability, efficiency and capacity comparisons between users and non-users of value-adding innovations and capacity implications of value-adding innovations where latent effort exists. This thesis has three primary research objectives:

1) To examine the financial and economic motivations for participating in the LRFF as a component of the commercial RLF and for the re-allocation of fishing effort on a spatial and temporal scale;

2) To identify the economic and non-economic factors dictating the adoption of requisite technology for participating in the LRFF; and

3) To analyse fishing capacity outcomes for the live and frozen commercial RLF sectors and explore the implications arising from the emergent LRFF for the management of a commercial RLF with a heterogeneous fleet structure.

A survey of fishers endorsed to remove reef fish by line was conducted and a response rate of 60% was achieved. The operation and profitability profiles and investment behaviour of both live and non-live operations was compared across spatial scales.

The data showed high take up of live fishing technology by the existing 'active' fleet with more than 80% of all vessels in the sample converting to live operations between 1994 and 2000. Live catch as a proportion of total catch increased in all sections of the Great Barrier Reef Marine Park over the period of this study. The average cost of entry into the LRFF ranged from $24,440 for those converting existing vessels to $438, 875 for those with no history in the RLF for whom entry necessitated the purchase of a vessel and license suggesting considerable barriers to entry for some intending participants. In general, fishers responded positively to economic incentives as evidenced by their switching between marketing frozen/fresh and live fish, with a slight time lag. Moreover, fishers with a longer history in the LRFF responded with less alacrity to downward movement in prices, suggesting a better understanding of comparative costs and revenue structure of their fishing firm over time.

In terms of financial and operational characteristics, live operations differed significantly from frozen operations. Live operations were more highly capitalised than frozen operations and while incurring per unit higher costs, live operations generated higher gross and net revenues and were more economically efficient than frozen operations. Lastly live operations differed significantly from frozen operations at a micro-operational level (trip length, number of trips) but not in terms of aggregate annual days fished. The superior financial and economic returns offered from marketing product alive as opposed to frozen, provides the necessary incentive to take-up of live technology although barriers to entry faced by those wishing to enter the LRFF vary according to existing capital and their history of participation in the RLF.

Comparatively high returns to capital, relative to other smaller-scale Australian fisheries, suggest incentives do exist for the entry of first time fishing operations.

Determinants of adoption or non-adoption of live technology were separated into personal and attitudinal characteristics, and perceived attributes of the innovation. The adoption sequence was examined in two parts; firstly, what influenced the decision to proceed and subsequently what determined the investment decision, or the scale to which live technology was incorporated into the vessel. For non-adopters, their decision was examined using the same conventional investment determinants; expected income, expected costs and existing capital. Firm size (i.e. vessel length) and expected income are the principal determinants in the decision of operators to convert to live or remain as frozen operators during both the decision-making stage and, in the case of adopters, following the commitment to innovate. Moreover, expected income and existing capital were more important determinants of the adopter's decision to undertake investment than it was for non-adopters to reject it. Expected costs exerted a minimal influence for both adopters' and non-adopters'. For adopters it is speculated that anticipated higher incomes prevailed over the influence of costs while for non-adopters this low importance reflects recognition of the financial barriers to adoption posed by limited capital stocks. Over time, as uncertainty declines in respect of technological capability, observable benefits become more obvious and the gap between expected income and investment risk closes, adoption of live technology may be may become more endemic, thereby accelerating the mobilisation of latent effort. This will have implications for managing the fishery to counter against over-capacity in the fishing fleet.

Data Envelopment Analysis (DEA) was used to compare the efficiency and capacity of live and frozen operations within the RLF fleet. Two efficiency measures calculated using DEA; technical (TE) and revenue efficiency (RE); showed interesting contrasts. Frozen operations were overall more technically efficient than live operations; but these positions were reversed in terms of revenue efficiency. Only 28% of frozen operations had a TE score of less than 0.95 as compared to 63% of live operations. In contrast, 78% of frozen operations had an RE score of less than 0.5 as compared with only 13% of live operations. In terms of capacity measures, frozen operations exhibited a higher degree of capacity utilisation than live operations while a greater number of live operations could increase their variable inputs in order to operate closer to full capacity.

Both efficiency and capacity results highlight that frozen operations have lesser capital endowments and that live operations are poorly utilising their combined freezer and live capacity to increase overall catches. Based on the entire licensed fleet mobilising into the live fishery over time, and irrespective of catch constraints from additional effort, the estimated harvesting capacity of the fleet for coral trout is approximately 2,400 tons higher than current catch levels.

For fisheries where latent effort exists, emerging pecuniary incentives can result in that fishery exhibiting common property characteristics. Any potential rent gains from value-adding of existing target species may be eroded by an influx of effort, leading to overcapacity. In fisheries characterised heterogeneity in effort, capacity reduction programs will need to not only target removal of ‘effective’ (active) effort but also of latent or less active licences that may, in the space created by fewer active vessels’, increase their individual effort. Economic efficiency measures are deemed more appropriate to guide capacity reduction in heterogeneous fleets, such as the RLF.

LIST OF ACRONYMS AND ABBREVIATIONS

AE	Allocative Efficiency
ANOVA	Analysis of Variance
AQIS	Australian Quarantine Inspection Service
CRS	Constant Returns to Scale
CU	Capacity Utilisation
DEA	Data Envelopment Analysis
DPI & F	Department of Primary Industries and Fisheries
ELF	Effects of Line Fishing
GBR	Great Barrier Reef
GBRMP	Great Barrier Reef Marine Park
GBRMPA	Great Barrier Reef Marine Park Authority
GFI	Goodness of Fit Indices
HKCSD / CSD	Hong Kong Census and Statistics Department
HKAFCD / AFCD	Hong Kong Agricultural, Fisheries and Conservation Department
IMA	International Marinelife Alliance
ITQ	Individual Transferable Quota
LRFF	Live Reef Fish Fishery
LRFF	Live Reef Food Fish Trade
LTV	Live Transport Vessel
LWE	Live Weight Equivalent
CPUE	Catch Per Unit Effort
MPA	Marine protected areas
MEY	Maximum Economic Yield
DPI&F	Department of Primary Industries and Fisheries (Queensland)
QFMA	Queensland Fisheries Management Authority
QFS	Queensland Fisheries Service
RE	Revenue Efficiency
RLF	Reef Line Fishery
PCP	Price Conversion-for-Product
RTE	Red-throat Emperor
RMSR	Root Mean Square Residual
TACC	Total Allowable Commercial Catch
TE	Technical Efficiency
TNC	The Nature Conservancy
VRS	Variable Returns to Scale
WWF	World Wildlife Fund

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CHAPTER 1

INTRODUCTION

1.1 Introduction

According to the FAO, more than 70% of the worlds marine capture fisheries are fully exploited, overexploited or recovering from depletion (see FAO Fisheries 2002). Excess harvesting capacity has been widely cited as the major factor contributing to overfishing in the world's fisheries, across the range of large and small-scale, industrial and artisinal fisheries in developed and developing countries (FAO Fisheries 1997; Pikitch et al. 1997). It is generally understood that the unregulated nature of open-access resources is the catalyst for excessive fishing effort, as profit maximizing fishers compete for limited resources (Grafton et al. 1996). Since Gordon's (1954) seminal paper, there has arisen a large body of literature addressing the causes, effects and prescriptive solutions for redressing excessive effort levels and over-capitalisation in wild harvest fisheries. Most literature is based on data from the large single-species fisheries of the Northern hemisphere that employ homogenous fishing gears (Rettig and Ginter 1978; Scott 1979; Pearse 1980; Sissenwine and Kirkley 1982; Anderson 1985a; Scott 1988; Townsend 1990; OECD 1993; Schlager and Ostrom 1993; McCay 1995; Young 1995). Much less emphasis has been given to managing overcapacity in multi-specific, multi-gear coral reef fisheries, probably because of their comparatively small absolute yields and relatively low economic value (Russ 1991; Russ 1996).

1.2 Managing for Biological, Social and Economic Goals

Fisheries on a global scale from large, industrial fisheries to small-scale artisinal fisheries are suffering from failure in the three fundamental areas of biological, economic and social sustainability: resilience of the resource to harvest; economic efficiency; and provision of broad social benefit. The causes of these failures have been identified as high biological uncertainty and the conflict between biological constraints and social and economic priorities (Cochrane 2000). These conflicts are a product of contrasting fishery paradigms of conservation, rationalisation and community (Charles

1994). The conservation paradigm is based on the sovereignty of the fish stocks while the community paradigm focuses on distributional equity among user groups. The rationalisation paradigm is driven by the tenets of economic efficiency and typically involves: i) reducing the number of fishers (i.e. capacity) to some optimal level; and ii) instituting a system of property rights. Rationalisation in the form of fewer fishers has been regarded by some fishery scientists as serving conservation goals but on the whole economic goals are seen as inconsistent with biological or social sustainability (Roughgarden and Smith 1997; Copes 2000).

The biological and ecological crises in fisheries are seen to result from the primacy given by decision-makers to economic priorities over conservation and social priorities (Mace 1997, Cochrane 2000)[1], despite recognition that economic efficiency goals such as rent maximization are inherently difficult to achieve. The complexity of fisheries management in terms of market and biological uncertainty (Hilborn and Walters 1992; Dupont 1993) and the socio-political framework within which it must operate detract from the prospect of realising optimal economic or resource outcomes. Managing for biological sustainability by recognising the sovereignty of the biological basis on which fishery depends will also produce sub-optimal economic and social outcomes (Common and Perrings 1992)[2]. The case for the coral reef fisheries is even more pronounced where biological information is often not available (Russ 1991), institutional frameworks are inadequate and managing fisheries to meet social interests (food, employment etc.) can take precedence over longer-term sustainability goals. The efficacy of alternative management regimes will depend on specific fishery goals and the characteristics of the fishery and its participants.

Allocating property rights over the resource in the form of individual quotas (ITQs) is advocated as the regulatory tool most compatible with achieving economic efficiency goals (Grafton 1995). ITQ systems, however, can have considerable adverse impacts on conservation and fish harvest productivity (Copes 2000). Quota-based management is also considered inappropriate in multi-species fisheries in general, and the majority of coral reef fisheries in particular where opportunity costs are low and monitoring and

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[1] Cochrane (2000) and Mace (1997) both contend that the failure of modern fisheries management is politically, as opposed to scientifically motivated
[2] See Common (1995) and Maler and Munasinghe (1996).

enforcement is problematic (Grafton et al. 1996; Munro 1996)[3]. The incompatibility of private property rights to many fisheries, especially tropical inshore multi-species fisheries, means management of these fisheries is still largely accomplished through a ‘second-best’ policy of license limitation[4] (Kirkley et al. 2003; Squires et al. 2003). Under license limitation, property rights are incomplete and non-exclusivity and resource exploitation rivalries persist. Also, because it only indirectly tackles capacity through limiting capital stocks or numbers of vessels, excess capacity develops in the fishing fleet through over-investment in capital stocks[5]. Lastly heterogeneity among vessels, competition between user groups and geographically distant fishing grounds and landing sites leaves non-cooperation as the dominant fishing strategy for each participant. While license limitation can lead to second-best outcomes, it is seen as a more feasible policy alternative in tropical inshore fisheries (Squires et al. 2003).

1.3 Capacity and Excess Capacity

The notion of productive capacity is well chronicled in the fisheries economics literature[6]. Many of these studies have defined capacity in terms of achieving some bio-economically optimal fleet size based on catching power and levels of fish stocks. With an increasing number of fisheries showing signs of overexploitation due to excessive harvesting capacity, the emphasis has shifted to managing and reducing fishing capacity and fish catches (FAO 1998). Addressing the problems of excessive harvesting capacity, however, has been hampered by a lack of universal accord on definitions of and differentiation between various measures of capacity (Ward et al. 2004).

Capacity is traditionally an output-based measure that describes potential output in the short-run. Capacity is usually defined either technologically as the maximum physical output given full utilization of fixed and variable inputs or output relative to an economic optimum such that which minimises costs or maximises profit (Greboval and Munro 1999). Capacity can also be defined as the minimum inputs required to produce

[3] There are exceptions, mostly in the developed world, such as where a single fishery, defined by gear, or a fish species dominates catch volumes and there is adequate investment in management
[4] Management of tropical inshore multi-species fisheries, especially in developing countries, relies primarily on limiting access, often in response to limited institutional capacity (Kirkley et al. 2002a)
[5] Regulatory controls can be undermined by substitution of inputs or ‘capital stuffing’ that increases the capacity, size and power of fishing operations (Townsend 1985; Dupont 1991)
[6] See Kirkley and Squires (1999a) for a comprehensive review of the literature

a specific harvest level, or harvest efficiency (Terry et al. 2000). Managing for excessive harvesting capacity requires measuring output relative to these maximum or minimum criteria.

Many early studies measured capacity in terms of investment in capital stocks and in the resource simultaneously to identify optimal investment paths (Clark et al. 1979; Charles 1983a; Charles 1983b; Charles and Munro 1985)[7]. Other previous studies have measured capacity in terms of the number and size of fishing vessels (Smith and Hanna 1990; Hannesson 1993a; Matthiasson 1996) and fishing effort as a standardised measure of gross revenue (Smit 1996). The influence of technology on fishing productivity and hence capacity has also been addressed by several authors (Squires 1992; Valatin 1992). These 'primal' measures have considered capacity as an output maximisation problem, given capital and resource stocks. Considerably fewer studies have used economic measures to identify capacity in terms of cost minimisation (Segerson and Squires 1990; Greboval and Munro 1999) or profit or revenue maximisation (Segerson and Squires 1993; 1995)[8]. This is despite a preference among fisheries economists for economic-based measures of capacity (Ward 2000). A paucity of useable cost and revenue data for most fisheries however, has seen greater attention given to technological measure of physical capacity. In addition to overcoming data limitations on prices, these measures have advantages over economic approaches in that they accommodate multiple outputs and inputs, heterogeneous capital stocks and zero-valued outputs or inputs, typical of multi-product fisheries (Kirkley et al. 2001; Pascoe et al. 2001; Kirkley et al. 2002a; Squires et al. 2003; Tingley et al. 2003). With few exceptions (Kirkley et al. 2003; Squires et al. 2003), developing country fisheries are absent from the literature. Moreover, all studies I have been able to identify use data from capital-intensive trawl and net fisheries as opposed to the more labour-intensive inputs that typify tropical inshore and reef-based fisheries.

All measures of fishing capacity are complicated by the need to consider both capital and resource stocks in that capital inputs are applied to the resource to produce a flow of

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[7] Problems such as the non-malleability of capital and uncertainty in fish stocks have meant more conservative investment in capital to avoid over-capitalisation (Clark et al. 1985)

[8] See Kirkley and Squires (1999a)for a comprehensive overview of the literature on approaches to measuring capacity and fishing power.

outputs (Squires et al. 2003). The state and productivity of the resource stock imposes an upper limit on the maximum amount that can be harvested or capacity output as measured in either primal or economic terms. The problem of dependence on natural resource stocks is further compounded by mobile capital targeting multiple stocks, multi-species or multi-product fisheries, and the heterogeneity of the capital stock (Kirkley et al. 2002a). Moreover, fishing capacity must contend with resource stocks changing over time. Using definitions proposed by Kirkley and Squires (1999a) and the Food and Agriculture Organisation (1998), a technological fishing capacity is defined as:

> *…the maximum yield that can be produced over a set time period when capital stocks (i.e. variable and fixed inputs) are fully-utilised, given the biomass and age structure of the fish stocks and the present state of technology.*

Kirkley and Squires (1999a; 2001; 2003) introduce the concept of capacity utilization and excess capacity to describe the position of the firm or industry relative to potential capacity. Capacity utilization measures the difference between observed output and maximum potential output or the output that minimises harvest costs[9] while excess capacity recognizes that fishing firms can make better use of capital stocks to increase physical production or produce a given level of output more efficiently (i.e. with fewer inputs). It is important to recognise that excess "economic" capacity occurs as a result of changes to input and output prices and the inability of capital inputs to adjust instantaneously to these changes in order to produce at some economic optimum.

Excess capacity is thus a short-run[10] concept that recognises fishing vessels or fleets can produce equivalent or additional outputs with fewer inputs, and at lower cost. Excess capacity should ideally be measured relative to a biological or bio-economic reference point that meets sustainable resource use criteria (Squires et al. 2003). In contrast,

[9] Two economically efficient measures of capacity utilisation can be constructed. One measures the cost gap between the actual output and the output level that would minimise long-run costs. The other measures the gap between actual profits and the level of output that maximises profits (Segerson and Squires 1993).
[10] In the short run, the firm's productive capacity is considered static and any increases in output can only be achieved by varying the level of variable inputs.

overcapacity is a long-run[11] problem that exists where vessel/fleet capacity, if fully utilised, exceeds the productivity of the resource or some biological (TAC) or economic (MEY) target (National Marine Fisheries Service 2004; Ward et al. 2004).

1.4 Latent Effort and Technology

Problems of overcapacity in both the developed and developing world are exacerbated by the presence of latent capacity or 'latent effort'. Attempts to reduce capacity will be confounded where significant latent effort exists (Mace 1997; Holland 2000b). The concept of latent effort is usually referred to in the literature in terms of vessels not working to their capacity. This research is concerned not only with under-utilised, but also inactive, licenses which are common in multi-endorsed, multi-specific fisheries.

Latent effort is a particular form of capacity under-utilisation that has received considerably less attention yet has major implications for resource sustainability (Thunberg 2000; Holland 2000b). Latent capacity is usually associated with limited license fisheries and describes the potential for increases in effort allocation when a percentage of licensed participants are inactive or active at low levels of variable input utilization (Kirkley and Squires 1999b; Ward 2000). Latency typically indicates the potential for excess capacity to develop in response to improved economic conditions[12] or regulation changes in a fishery and is generally a pointer to fishers being active in more than one fishery (Smith and Hanna 1990; Maurstad 2000). Limited entry fisheries that can be shown to harbour latent effort are especially prone to developing excess capacity (Ward and Hegerl 2003).

Estimating excess capacity and capacity utilization will be problematic where latent effort exists, particularly when there are heterogeneous capital stocks. The 'latent' component of the fleet will generally comprise vessels whose participation is dictated by market conditions. Their transient nature will make obtaining measures of capacity utilisation difficult. Moreover, their multi-fishery activities, heterogeneous capital

[11] In open-access or common-pool resources, excess profits will attract additional fishing firms until rent has dissipated or economic profits are zero but because capital is non-malleable and has low opportunity cost, it cannot be readily divested of or employed outside of its current use.

[12] In fisheries where latent effort exists, the prospect of higher rents may see the mobilisation of previously dormant licenses (Matthiasson 1996).

structure and greater susceptibility to weather conditions will undermine the use of proxy capacity measures. Some knowledge of the effort characteristics of these 'latent' vessels will be required for effective capacity management (Maurstad 1998). Changes in market conditions or technology that lower input costs or increase output prices can encourage mobilisation of latent effort and place increased pressure on resource stocks.

The common-property nature of fish stocks encourages the competitive build-up of excessive harvesting capacity (Lindebo 1999). Technological improvements in the harvesting sector are a major contributor to this excessive harvesting capacity in global fisheries. Technological developments in fisheries have tended toward those that increase both the productive capacity and the efficiency of fishing vessels such as navigational technologies, electronic fish-finding devices, freezing technologies and gear improvements (Valdemarsen 2001). The trend toward overcapacity is widely recognised as arising from the need to enhance catching power to compensate for ever declining fish stocks. Continual investment[13] in fleet technology that increases fishing power or lowers fishing costs is the only way to sustain catches and profits in this environment (Pitcher 2001)[14]. New technology that increases effective fishing effort or lowers fishing costs may generate above-normal profits in the short-term. In open-access fisheries, however, these profits will only be temporary as they will attract new entrants, leading to even further increases in effort and pressure on fish stocks (McManus 1996).

Besides technical developments aimed at increasing fishing efficiency, new technology (innovations) that reduce the catch of non-target species are being developed and diffused (McElroy 1993; Robins et al. 1999), while social pressures continue to drive innovations that make sustainable use of unwanted but unavoidable catch (Valdemarsen 2001). Market changes such as growing consumer demand or changing consumer preferences can also drive changes in technology. For example there are growing trends towards innovations that enhance product quality (Le Floc'h and Wilson 1998; Charles

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[13] Because adopting a new technology may require an initial capital outlay, innovation can be considered an investment decision by the firm in that it involves expenditure now in anticipation of a future stream of benefits. The fisher's desire to innovate may be constrained by entry barriers such as access to financial capital

[14] Pitcher (2001) uses the term ''Ludwig's ratchet'' to describe the continuous cycle of investing in new technology to sustain catches from an increasingly depleted fish stock in order to meet the costs of existing capital investments.

and Paquotte 1999; Gouin and Fady 2000; Boude et al. 2000b). These product developments, however, will not necessarily alter total production, just the form in which fish are produced for food. New technologies can help mitigate problems of relative scarcity through increasing the efficiency of resource conversion or utilization [i.e. the amount of value extracted per unit of resource] (Barbier 1989) and many fishers, processors and governments are accordingly advocating product enhancement that adds value to the existing catch or utilises by-catch species (Fornshell 2002).

Adding value to existing or by-catch species usually implies revenues from implementing the new technology will increase relative to costs. Unless the fishery in question is well regulated, additional profits will attract new entrants and increase fishing pressure, usually to the point where excess profits have again been dissipated. With few exceptions, reef fisheries are unmanaged or under-managed (Russ 1991; Sale 2002). For artisinal and subsistence reef fisheries already subject to heavy stock depletions, any new technology that increases revenues or lowers relative costs will only further exacerbate their overfishing problems (Pauly 1997; Hamilton 2001). Responses to value-adding in artisinal and subsistence reef fisheries are compounded by two factors: barriers to entry are virtually nil with little capital outlay required to commence fishing (McManus 1997); and the opportunity cost for fishers' labour is close to zero (Munro 1996). With few alternative employment opportunities for coastal communities and continual recruitment of effort from non-traditional sources (e.g. displaced farmers) the 'latent' effort problem is limitless and immeasurable.

Even in the better regulated fisheries of the developed world, the positive aspects of value-adding innovations may be undermined where latent effort exists, both in terms of inactive access rights and less than full utilisation of active rights. The potential implications of latent effort for sustainability of affected stocks have been recognised by numerous fisheries management agencies in Australia, Northern America and Europe. I cannot find any empirical studies however, that examine the impacts of exogenous (i.e. market) or endogenous (i.e. technology) drivers upon the mobilization of latent effort as a fishing capacity problem or in terms of the potential impacts of such mobilisation on resource sustainability. Moreover, the link between latent effort and limited license fisheries that create 'regulated' open-access type outcomes (Homan and Wilen 1997) is not explicitly recognised in any of these empirical case studies.

1.5 Overcapacity and Coral Reef Fisheries

Overcapacity, or “excess fishing capacity” is seen as the most pressing problem facing the world’s capture fisheries (Mace 1997). Most studies draw on over-capitalization in industrialized, capital-intensive fisheries to examine overcapacity. Much less emphasis is given to overcapacity in coral reef fisheries. Tropical inshore subsistence fisheries do suffer from overcapacity, however, usually in the form of too many participants given the state of the resource. This situation has been recognised as leading to ‘Malthusian overfishing’, with all its associated problems (Pauly 1997).

Coral reef fisheries make up only 10% of commercial fish production worldwide but are of significant regional social and economic importance in many developed and developing countries (Medley et al. 1993). Successful management of coral reef fisheries is hampered by several factors. Fishing effort is usually unevenly distributed spatially with catches landed at number of sites across a wide geographic area. Most coral reef fisheries are multi-specific, targeting a large number of species using a variety of fishing gears including hook and line, spears, traps, nets and poisons (Munro 1996). In many situations, much of the catch from coral reef fisheries is retained, with very low levels of discards and non-commercial product being consumed by the fishers (McClanahan and Mangi 2004). The spatial complexity of fishing activity and the use of multiple gears makes catch and effort data needed for management difficult to procure. These characteristics of coral reef fisheries are aggravated in developing countries where the fisheries are dominated by subsistence and artisinal fishers with few alternative employment opportunities or protein sources (Russ 1991). Moreover, there is often limited human and institutional capital with which to collect basic catch and effort data while the social, economic and political complexities diminish management agencies’ monitoring and enforcement capabilities (Levin and Grimes 2002).

Overfishing as a product of overcapacity affects small-scale and industrial fisheries in developed and developing countries alike. Overcapacity not only leads to the dissipation of potential economic rent (Edwards and Murawski 1993) but also can lead to wasteful and destructive fishing practices (Pikitch et al. 1997). Management of overcapacity in coral reef fisheries will differ across developed and developing countries in response to different management goals (McManus 1997). Traditional fisheries management based on harvesting the largest sustainable catch – maximum sustainable yield – or generating the largest profit – maximum economic yield[15] – rely on controlling fishing effort and hence capacity. These approaches have been acknowledged as not translating well to most fisheries (Caddy 1999), and are even less applicable to coral reef fisheries given their multi-gear, multi-species nature and the limited understanding of by-catch, habitat and environmental impacts on fish populations (Sale 2002). Moreover, these approaches are data-intensive and cannot be applied easily in fisheries that are predominantly data-poor, which is largely the case in developing countries (Polunin et al. 1996), while the ability to restrict fishing effort is bounded by social, political and institutional constraints and regulatory capacity (Holland and Brazee 1996). In much of the developing world, controlling or reducing fishing capacity and fishing effort is especially complicated by the artisinal and subsistence nature of the fisheries (see McManus 1996). In recognition of the difficulties in applying conventional effort based management approaches to coral reef fisheries and the failure of effort measures to address overcapacity, the use of marine protected areas (MPAs) has been identified as an alternate strategy to address fisheries management and conservation goals (Roberts and Polunin 1991; Holland and Brazee 1996; Russ and Alcala 1996a; Agardy 1997; Bohnsack 1998; Murray et al. 1999). In the face of limited potential for increasing global fishery yields, however, reducing overcapacity remains the key to ameliorating impacts beyond MPA boundaries and re-building or increasing net benefits from fisheries (Pikitch et al. 1997)[16]. Capacity reduction programs, however, in whatever form, may achieve little reduction at considerable expense if significant latent effort exists (Holland et al. 1999, Holland 2000b).

[15] Note that when managing for maximum economic yield, effort and catch are often less than under a traditional maximum sustainable yield as the objective is maximising profits not catch volumes (Waugh 1984)

[16] Garcia and Newton (1997) estimate worldwide harvest costs greatly exceed harvest revenues and that about US$300 billion of investment in the harvesting sector does not earn an economic return.

1.6 The Queensland Demersal Reef Line Fishing Industry

1.6.1 The Great Barrier Reef and the Reef Line Fishery

The Great Barrier Reef (GBR) ranges from approximately 9º50S off the southern coast of Papua New Guinea to 24º50S off the cosat of southern central Queensland. Most of the GBR is included within the Great Barrier Reef Marine Park (GBRMP), which comprises over 350,000 km^2 of marine habitat along the Queensland coast from latitude 10º41S to 24º50S (Fig 4-4). The GBRMP was designated a multiple use marine park in 1975 under the Great Barrier Reef Marine Park Act (1975) and as a World Heritage Area (GBRWHA) in 1981 (Australian Heritage Commission Act 1975, World Heritage Properties Conservation Act 1983). As the worlds largest multiple use marine park, the GBR has been recognised for it's national and international ecological and cultural significance (Kenchington 1990). Fishing is the major extractive activity permitted within the GBRWHA and according to Mapstone et al. (1996c) line fishing poses the "…*greatest potential to affect the biological communities on coral reefs of the GBR*".

There are over 3000 individual reefs and shoals in the GBR, mostly lying well offshore, with coral reef habitat accounting for an estimated 5-7% of the area of the Marine Park (Mapstone et al. 1996c). Within the park, coral reef finfish are targeted by three main sectors: private recreational fishers, charter vessels who ferry recreational fishers to offshore sites, and commercial fishers (Gwynne 1990). Collectively this fishery is referred to as the reef-line fishery (RLF) and refers to targeting of fin-fish in coral reef or shoal habitats using hook and line gear. The majority of fishing effort in the RLF occurs within the waters of the GBRMP. This research focuses only on the commercial line fishing sector operating within the boundaries of GBR region, since catches of food fish are rarely kept alive by either recreational or charter fishers.

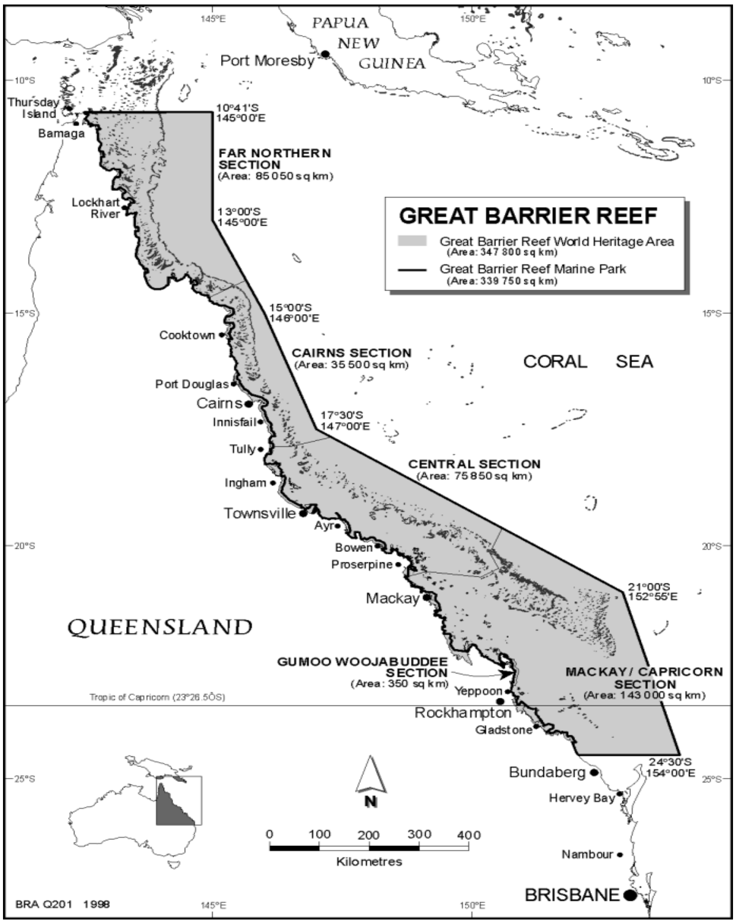

Figure 1-1: Map of the Great Barrier Reef showing boundaries of the Marine Park (shaded) The management sections of the Marine Park are designated by solid lines running from the parks outer boundary to the coastline**.**

The commercial RLF is a multispecies fishery with over 125 species of fin fish recorded as being captured by line between 1989 and 1994 including both demersal and pelagic species (Gwynne 1990; Mapstone et al. 1996b). The catch comprises mainly demersal species with *Plectropomus* spp. and *Lethrinus* spp. being the main target species groups. Coral trout, mainly common (*Plectropomus leopardus*), accounted for approximately 35-45% of the total annual demersal catch prior to 1996, while red throat emperor (*Lethrinus miniatus)* accounted for a further 16-22% of total annual catch (Mapstone et al. 1996a).

The commercial RLF is characterised by main, or primary, vessels (7-20m) moving between fishing locations, many supporting one or more tender vessels (dories). Dories are small (4-6m) aluminium or fibreglass boats, powered by an outboard motor, that roam within each location (usually a reef). Fishing is by a single hand-held line operated by each fisher and mainly takes place from dories at anchor, with typically only one fisher per dory. Fishing is divided into morning and afternoon sessions and within each session dories move between several anchorages, returning to the primary vessels at the end of each session to unload their catch. Some fishing may also take place from some primary vessels.

Fishing vessels and fishers must be properly endorsed to commercially harvest coral reef fin fish from the waters of the GBRMP using line fishing methods (Taylor-Moore 1998). Prior to 2004 approximately 1800 commercial vessels, including trawlers and other vessels primarily engaged in non-line fisheries, were endorsed to line fish in the Queensland jurisdiction for fisheries management (which includes the GBR, see section 4.4.2 below). Mapstone *et al.* (1996a) noted that less than 600 such boats reported catches of fin-fish by line in Queensland in each year between 1989 and 1994, of which only 361-416 reported catches of reef fish within the GBR region. These boats can be further distinguished by noting that only ~300 boats reported landing coral trout (*Plectropomus Spp.)*, the main demersal target species of the commercial RLF. Mapstone et al. (*ibid*) attributed the majority of the effort applied to and catch removed from the fishery to the top 15-20% of vessels. In the case of boats that landed coral trout, around 60 boats accounted for roughly 60% of total annual effort and between 75-85% of the total annual catch in any year from 1989 to 1994.

At the time data were collected for this thesis, licence holders entitled to fish within the boundaries of the GBRMP could have one of two line fishing endorsements: an L2 endorsement, which permitted the holder to operate two or more tender vessels in conjunction with the primary vessel; or an L3 endorsement, which permitted the holder to operate a maximum of one tender vessel in conjunction with the primary vessel. L2 endorsements numbered 228 (DPI & F, 1999, unpublished data), although not all were active in the commercial RLF, with L3 endorsements comprising the remainder of the 1800 licensed operators. Mapstone *et al.* (1996a; 1996b) reported that L2 endorsed boats accounted for approximately 60% of total effort and 63% of total catch of all species. I focus hereafter only on L2 endorsed vessels operating in the commercial RLF on the GBR up to 2001 as this sector of the fleet would be most capable of mobilising relatively quickly in the face of emerging economic incentives.

1.6.2 Management of the Reef Line Fishery

The Great Barrier Reef Marine Park Authority (GBRMPA) was formed under the Commonwealth's Great Barrier Reef Marine Park Act (1975) for the purpose of managing the GBRMP for conservation and multiple-use and has only an indirect role in managing the fishery. The GBRMPA's primary management strategy is zoning, which regulates the activities that may be undertaken in certain areas of the marine park. Prior to 2004, zoning excluded all line fishing from approximately 24% by area of reef habitats (Mapstone et al. 2001) but this 'closed' area was increased in 2004 to ~33% of reef habitat (Fernandes et al. 2005).

Under the terms of the Offshore Constitutional Settlement between the Commonwealth and state governments in 1981, the management of most fisheries in state waters was delegated to state agencies. Thus the RLF is the responsibility of the Queensland Department of Primary Industries and Fisheries (DPI & F)[17] on behalf of the Queensland Government (Gwynne 1990). Direct regulation of the fishery is administered by the DPI & F under the Queensland Fisheries Act (1994). Management measures for the commercial RLF up to 2004 included: a cap on the total number of commercial licences; minimum and maximum legal size limits for selected reef fish species; gear restrictions (size of primary vessel, number of dories per primary vessel, number of lines and hooks per fisher); and a strict vessel replacement policy for upgrading of primary vessels.

As the main target species of the commercial reef-line fishery, coral trout is the species of principal concern to the DPI & F in managing the reef line fishery (Mapstone et al. 1996a). The bulk of the reported catch and effort has been associated with regions between 17º S and 21.5º S (Mapstone et al. 1996a). The main ports signifying the start and end points of commercial fishing trips are Cooktown, Cairns, Innisfail, Mourilyan, Lucinda, Townsville, Bowen, Mackay and Gladstone.

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[17] Prior to July 1, 2000, the Queensland Fisheries Management Authority held responsibility for managing the Reef Line Fishery. From July 1, 2000, the Queensland Fisheries Management Authority and the Department of Primary Industries Fisheries Group were amalgamated to form the Queensland Fisheries Service. Finally in 2003, the Queensland Fisheries Service was subsumed under the Queensland Department of Primary Industries and Fisheries, becoming the Fisheries section within that organisation.

Effort in the commercial RLF remained relatively stable from the introduction of a logbook program in 1988 until the mid-1990s. From 1995 to 1997 however, the number of vessels reporting catch and the number of operation days increased by more than 40%, while reported catch increased by nearly 25%. The growth in these indicators coincides with the initial development of the live reef fish export trade from the GBR region. Following a period of stagnation, which may be linked to biological, and market conditions (see 4.4), catch and effort, again rose sharply in 2001 and 2002 (Table 1-1).

Table 1-1: Catch (all species) and effort data for the commercial sector of the reef-line fishery from the Great Barrier Reef Marine Park from 1988 to 2002. Catch and effort from suitably endorsed vessels in the trawl, net / crab or harvest logbooks are excluded

Year	Commercial Operators			Catch (t)
	Operators reporting catch	Effort Days (Operation) [a]	Effort Days (Total) [b]	
1988	374	11022	34013	1495
1989	362	14552	44166	1817
1990	389	15390	49692	2251
1991	368	15153	50073	2595
1992	362	15315	51684	2686
1993	388	17835	61336	2625
1994	383	18702	65634	2545
1995	408	19591	66435	2838
1996	519	24999	82237	3370
1997	567	28490	92524	3674
1998	518	27583	88889	4010
1999	499	25821	82613	3715
2000	540	27334	87197	3841
2001	566	35651	111676	4665
2002	563	37918	121937	4447

Sources: Queensland Fisheries Service

[a] Total annual days effort by primary vessels only

[b] The sum of annual effort days by primary vessel and all dories supported by that vessel

Subsequent to 2004, under a new management plan, regulations within the commercial RLF have changed (e.g., new minimum and maximum legal size for several species) and a commercial quota management regime was introduced. Of most interest potentially to this thesis is the quota management regime, comprising Total Allowable Commercial Catch limits (TACC) and Individual Transferable Quotas (ITQs) for coral trout, red throat emperor and aggregated 'other' demersal reef species. I do not examine these changed arrangements in detail in this thesis but I do consider the relevance to them of the results of this study, particularly in respect of the mobilisation of latent effort and capacity

1.7 Technology, Capacity and Latent Effort in the GBR Reef-Line Fishery

The process-oriented technology improvements which dominate in fisheries have impacted upon biological sustainability by making fishers more efficient at finding and killing fish (de Wilde 2002). Post-harvest utilization technologies are now receiving greater attention, partly in recognition of declining fish stocks, partly as a means to enhance profitability in over-fished and overcapitalized fisheries and partly in order to meet changing consumer preference. Consumer preferences and product differentiation in particular can provide both the motivation and the platform for improving end-use efficiency of resources.

Growth that doesn't rely on increased resource throughput recognises the need to adjust sectoral activity within the limits of the systems carrying capacity. Despite the potential for value-adding innovations to aid fishery managers in meeting social, economic and biological goals simultaneously (Charles 2001), such developments have received scant attention in the literature. A contemporary example can be found in the GBR commercial RLF, which has historically marketed only frozen or fresh product. Product innovation has added considerable value to the existing target species enabling their presentation to market as live product. Whilst the current levels of exploitation have not declined with advent of the new 'live' product, and indeed increased in the 5-6 years after the market innovation, opportunities may exist to manage the fishery so that it remains within its environmental carrying capacity, while maintaining or even enhancing socioeconomic and community sustainability. While not proposing value-adding as a panacea for overcapacity in modern fisheries, this thesis uses the commercial RLF to explore how increasing resource extraction from outputs can facilitate the achievement of biological sustainability, social and economic goals in the presence of adequate management. In fisheries that are not well managed though, such as many coral reef fisheries, value-adding may only exacerbate overfishing problems as higher profits attract increases in effort (Sadovy and Vincent 2002)[18].

There has been an enthusiastic response by fishers within the commercial RLF to the higher revenues from marketing species in live as opposed to frozen form, with diverse levels of investment undertaken to enable vessels to catch and store live fish in the expectation of higher returns. In most cases, adopters of the new technology have sacrificed existing freezer capacity for new live holding capacity, with the result that overall vessel capacity has been reduced. In terms of trip catches, Mapstone et al. (2001) have demonstrated that multi-purpose frozen and live operations retain less overall product than do operations that market exclusively frozen product. The prospect of improved profitability with lower resource throughput will have implications for measures of capacity and capacity utilization in the fishery.

While the trend in most fisheries is for harvest capacity to exceed the reproductive capacity of the fish stock, this relationship is inconclusive within the commercial RLF. In the short term, with effort unchanged, Mapstone et al. (2001) suggest the modified targeting behaviour of those fishers marketing live product may reduce fishing impacts of individual operations (see 4.4.2). In the longer term however, the relatively higher prices for live product may see the mobilization of the high proportion of currently inactive licenses in the commercial RLF. Any positive effects on the target stock would be dissipated by the redeployment of previously inactive vessels. Moreover, there may be incentive for individual operators to increase individual outputs by increasing the size of their vessel, thereby expanding overall industry capacity.

As previously noted, trying to control or reduce capacity through license limitation can be exacerbated in fisheries where latent effort exists. The existence of latent effort is usually evidence of a heterogeneous fleet structure, and one that is more sensitive to market conditions, such as valorisation of fishery products. Uncertainty over the longer term biological, economic and social impacts of value-adding technology on capacity and effort in the commercial RLF is worthy of further investigation.

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[18] In many countries of Southeast Asia, the high value afforded many reef species, such as serranids, presented in live form has led to heavy overfishing and depletion of stock to very low levels.

1.8 Thesis Outline

The concepts of value-adding, innovation and adoption, investment, capacity and latent effort are not absent from the fisheries literature; what is lacking is empirical research that recognises the links between them and that explores this relatedness within a context of rent appropriation. This research is an attempt to draw together these related but previously unconnected themes into a coherent framework to explore; the link between value-adding opportunities and profit maximising behaviour; constraints to adoption of and investment in value-adding innovations; profitability, efficiency and capacity comparisons between users and non-users of value-adding innovations and capacity implications of value-adding innovations where latent effort exists. Collectively these lead us to the main research question, that being;

> *Does value-adding that leads to improved rents present a solution to overfishing through moderating the social and economic impacts of fisheries management decisions and if so under what conditions may these benefits be diluted.*

This thesis has three primary objectives:

1) To examine the financial and economic motivations for participating in the live reef fish fishery (LRFF) as a component of the commercial RLF and for the re-allocation of fishing effort on a spatial and temporal scale;

2) To identify the economic and non-economic factors dictating the adoption of requisite technology for participating in the LRFF; and

3) To analyse fishing capacity outcomes for the live and frozen commercial RLF sectors and explore the implications arising from the emergent LRFF for the management of a commercial RLF with a heterogeneous fleet structure (latent effort).

Chapter 2 is a review of the literature pertaining to technology adoption in resource sectors and of the relationship between investing in new fishing technologies and fishing capacity. Chapter 3 outlines the sampling design and methodological issues associate with using survey instruments to gather multivariate research data. Chapter 4 describes the development of the live reef food fish fishery (LRFF) on the GBR in the context of the global trade in live reef fish, while chapter 5 investigates the fleet-wide and business unit response to the LRFF that warrant further research. The sixth chapter examines the economic, financial and operational profiles of the two sectors of the GBR reef line fishing fleet, including those marketing only frozen or fresh product and those marketing a mix of frozen, fresh and live product. A standardized index of effort is constructed for the purposes of comparison. Economic and financial profiles are used to indicate the incentive for new investment and augmenting fishing effort while operational profiles are compared to identify management implications for this dual-sector commercial RLF fishing fleet. Chapter 7 draws on existing literature to explore the principal economic and non-economic factors influencing adoption behaviour of active fishers in the commercial RLF. These results are used to conceptualise the link between innovation, investment and capacity and the potential for new harvesting capital to enter the fishery.

In Chapter 8, established analytical methods are used to develop a range of measures of fishing capacity and excess capacity for a sample of operations in the commercial RLF. Using secondary data sources on trends in fishing effort and catch, these measures are used to explore the potential for further excess capacity to develop in the commercial RLF through the mobilization of unused fishing endorsements. The final chapter is a synthesis of research results and draws on the themes of technology adoption, investment and fishing capacity that are carried throughout the thesis to discuss policy measures to control for or reduce excess capacity to give more sustainable fishery outcomes.

CHAPTER 2

TECHNOLOGICAL CHANGE, FISHERIES INVESTMENT AND EXCESS CAPACITY: A REVIEW OF THE LITERATURE APPLIED TO THE GREAT BARRIER REEF REEF-LINE FISHERY

2.1 Introduction

In this chapter I draw on two independent but related bodies of literature to discuss issues related to managing excess capacity in fishing fleets and the processes of innovation and adoption that often are associated with or drivers of changes in capacity. First, the causes and consequences of excess harvest capacity are discussed along with the research pursued to address this situation. Second, the process of technological change and innovation adoption and the role they play in contributing to excess capacity is explored. The link between investment, technology and excess fishing capacity is reviewed with particular reference to latent, or unused, effort concluding with a brief discussion on the management of fishing capacity. Lastly, I highlight the unique issues for managing fleet capacity within the Great Barrier Reef (GBR) commercial reef-line fishery (RLF), as an example of an inshore multi-species tropical reef fishery, in light of recent adoption of innovations in the fishery. I also provide a brief review of relevant data requirements for improvement of future management of the fishery,

2.2 Fleet Capacity and Investment in Management Context

Most fisheries problems are partially the result of over-investment in fishing capacity (Hilborn 1985a; Lane 1988; Roughgarden and Smith 1997). Managing this overcapitalisation and overfishing of fish stocks is recognised as essential to realising the economic benefits from a fishery (Kirkley and Squires 1988). Overfishing, excess capacity and substitution of unrestricted for restricted inputs[19] are regarded as symptoms of the real fisheries exploitation problems arising primarily from a lack of property rights, and accentuated by the non-malleability of capital that impedes its

[19] For example increasing vessel tonnage to counteract restrictions on days fished

exiting the fishery[20], effort displacement in other fisheries, and technological progress (Dupont 1990; Dupont 1991; Grafton et al. 1996; Matthiasson 1996; Munro 1999). The lack of well defined fishing rights has been identified as the leading cause of fisheries problems and the starting point from which other causes emerge (Scott 1988; Grafton et al. 1996).

This prevalence of excess capacity is most often attributed to a lack of clearly defined and enforceable property rights (Ward 2000). The argument proceeds that as long as positive returns from fishing are present, an incentive exists for additional users to enter the fishery and share in these returns (Gordon 1954). Under such open-access regimes, non-exclusive access to the resource leads to excessive depletion of the stock and dissipation of potential economic benefits (Munro and Scott 1985; Grafton et al. 1996).

One of the most widespread strategies for regulating access and reducing excess capacity is limited licensing, whereby the number of participants in a fishery is directly controlled through allocating a limited number of fishing licences to individual vessel owners. Restricting fishery access, however, does not guarantee the stabilisation of positive fishery rents (Grafton et al. *ibid*.)[21]. For example, a restricted access fishery that limits vessel numbers but not individual harvests may still experience open-access outcomes (Ciriacy-Wantrup 1971).

Restrictive licensing that contains or reduces vessel numbers may improve industry rents in the short-run (Townsend 1990). This positive outcome often results in 'capital stuffing' however, where in response to positive rent generation, individual operators increase the capacity of their vessels in order to capture a larger slice of the available pie (Townsend 1985; Stollery 1986). Protecting against 'capital stuffing' by restricting inputs is dogged by fishers substituting regulated with unregulated, and more costly, inputs thereby further eroding rents (Dupont 1990). As a consequence it has been

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[20] Capital is malleable if it can be removed quickly and easily from the fishery at no economic loss. In fisheries, capital (eg. boats) tends to be specialised and not easily transferred to alternative uses.

[21] Regulations such as Total Allowable Catch (TAC) or the allocation of harvesting rights in the form of individual quotas (ITQ), while recognised as a means of addressing common property externalities, are not introduced into this discussion in any detail. This is partly because these management tools are difficult to implement in multi-species fisheries (Squires et al. 1994; Dupont and Grafton 2001) and also because they were not part of the GBR RLF prior to 2004; the time during which the subject of this thesis was being developed. These regulatory tools are invoked in later chapters of this thesis, where relevant.

recognised that capture of rents in limited entry fisheries requires not only restricting vessel numbers, but also regulating the effort produced by each (Anderson 1976; Townsend 1990; Schlager and Ostrom 1992).

Technological innovation is a form of capital stuffing that has been shown to undermine effort limitation programs (Fitzpatrick 1995; Ward 2000). Gains from innovations tend to either reduce the costs of fishing effort or enhance fishing productivity. In both open-access and limited entry scenarios, technology induced efficiency gains that lower per unit catch costs and increase profits usually will result in increased capacity (Townsend 1985). Technology improvements that initially augment individual fishery rents by increasing vessel productivity will likely decrease fishery wide rents in the long-run (Whitmarsh 1978; Smith and Hanna 1990; Sampson 1992; Whitmarsh et al. 1995). Under open-access, increased capital use will emanate from both existing and new vessels attracted by the higher profits, leading to a dissipation of fishery rents. Rent dissipating levels of effort may also arise in limited entry fisheries that are fully exploited economically (Townsend 1990). For example, if the fishery is operating at or just below the level of effort that generates the maximum economic yield (MEY), then additions to fishing capacity may result in economic overfishing and rent dissipation. The literature into technology and innovation is extensive, but that which pertains directly to the fishing industry is not. The following section is intended to set out a framework for fisheries development in the context of technological innovation.

2.3 Technological Change and Innovation Adoption

The process of technological change comprises three distinct, yet related phases: invention, innovation (or technological change) and diffusion (Schumpeter 1934). The first of these, invention, describes the process by which an idea is created or discovered, whereas an innovation occurs when that idea is adopted (Rogers 1995)[22]. In an economic sense, innovation is consistent with the first *commercial* transaction involving the new process, product, system or device (Stoneman 1983; Rosseger 1996). Diffusion is the process by which an innovation spreads throughout the industry (Stoneman 1983; Rogers 1995). The process by which invention, innovation and diffusion occur has

[22] Freeman (Freeman 1982) observes that inventions do not always lead to technical innovation

spawned a considerable volume of literature. Although much of the literature is outside the scope of my research, a brief summary of the major themes will more clearly position this research.

Innovation theory regards technological change as being driven either *endogenously* (Freeman 1994; Rosenberg 1994; Rosseger 1996) or by *exogenous* (Rosseger 1996; Ruttan 1997) changes in the economic environment. Endogenous change is seen as being motivated by a firm's desire either to solve a production problem, improve productivity, or increase market share through product differentiation in order to capitalise on latent demand (Rosenberg 1976; Nelson and Winter 1982; Dosi 1988; Rosseger 1996:19). Innovation does not always emanate from firms seeking to reduce production costs or improve the efficiency of factor inputs[23]. The origins of technological change may be more accurately described as being subordinate to, or 'induced' by, *exogenous* changes in the economic environment (Rosseger 1996; Dosi 1997:1534; Ruttan 1997:1525) or regulatory environment[24]. Factors such as market demand and relative prices (of outputs) are seen as instrumental in influencing a firm's search for or adoption of innovative techniques (Griliches 1957; Schmookler 1966). In reality, technological change will be a product of opportunities provided by exogenous change to advance endogenously accumulated knowledge (Dosi 1988:1140-1142).

Not all innovations are of equal technological and economic significance, which has given rise to contrasting views over what constitutes innovation. According to Rosseger, (1996:18) innovations tend to be classified as either *major* (fundamental) or *minor* (incremental). Much of the theoretical and empirical research into technological change and innovative activity focuses on major innovations in the manufacturing, information technology and non-renewable resource sectors (Mansfield 1968; Walsh 1984; Thirtle and Ruttan 1987; Stokes 1994; Baldwin and Rafiquzzaman 1998)[25]. A number of authors, however, insist that an innovation should not be regarded in terms of its complexity or be restricted to the introduction of new types of process technology. As

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[23] Factor inputs efficiency implies improved returns on labour and capital inputs to the production process, *ceteris paribus.*

[24] Changes in regulations may require firms to meet more stringent environmental targets (e.g. exclude or reduce fisheries by-catch)

[25] A review of key texts and papers in the area of technological change and innovation shows a predominance in the traditional sectors of manufacturing and mining industry's (Salter 1966; Dosi 1982; Nelson and Winter 1982; Stoneman 1983; Rosenberg 1994; Rosseger 1996).

Rogers' (Rogers 1995:11) points out "if the idea seems new to an individual, it is an innovation". In a market economy, innovating simply means "doing things differently from one's competitors in order to gain an advantage over them" (Rosseger 1996:171). I adopt, for this thesis, Rogers' and Rossegers' proposition that innovation is not defined by technical or scientific complexity or scale and cost of implementation. 'New' knowledge upon which a decision can be made to either adopt or reject is sufficient for the new process to be considered an *innovation*.

Another frequent distinction in the literature is between *process innovations* and *product innovations*. In practice however, there are few new products for which a process change of some sort is not required (Morroni 1992; Rosseger 1996). The boundaries are further blurred in that a process innovation enabling one firm to improve its productivity or produce a new good may rely on the product innovation of another firm as input into that process. Finally, Stoneman (Stoneman 1983) contends that innovations are either cost reducing (process) or demand stimulating (product). My research typifies the difficulty in classifying innovations as either process or product; cost reducing or demand stimulating. For my purposes, it is sufficient to recognise that adoption of a process innovation is a feature of the firm's decision-making.

The literature on technological change tends to focus on those major innovations that either increase the volume of productive throughput from existing inputs or decrease per unit production costs (Rosenberg 1976; Stoneman 1983). An economic analysis of technological change, however, should examine the relationship between physical productivity (input and output quantities) and profitability (input costs and output revenues) (Morroni 1992:14). Research into innovations that impact positively on output prices is scarce, however, despite recognition that technological change can have consequences other than a reduction of input costs per unit of production. For example, a change in the quality of the output with little or no variation in its quantity may still result in increased output revenue. This point is further emphasised by Dosi (1988) who draws a slight distinction between technological change and innovation, describing the latter as being not only consistent with changes in production techniques but also related to changing market conditions that have only a small influence on overall production processes. Consequently any analysis of an innovation should embrace quantitative, qualitative and temporal dimensions of the production processes it alters.

Innovation is described as the beginning of diffusion of a process or idea throughout the firm or industry. Empirical investigations have found that the diffusion process of firms adopting the new technology through time is best described by the sigmoid or logistic diffusion curve (Griliches 1957; Mansfield 1961; Rogers 1995). This recognises that adoption of the new technology is initially slow, perhaps through lack of knowledge or risk averseness, followed by a period of rapid diffusion as the superiority of the new technology becomes evident and replaces the old technology. Rates of adoption are regarded as strongly correlated with the market structure and improved profits expected following adoption of the new technology. In a majority of industrial settings, where resource scarcity is not a decision variable, cost reducing or productivity enhancing innovations will be influenced more by profitability considerations than investment costs (Common 1995).

Innovation in fisheries, however, is very different, because relative profitability of any given fishing technology is directly related to fish stock abundance, catchability and the impacts of that technology on future abundance. Technology changes in the fisheries systems require further examination because, unlike many other resource-based industries, there are direct interactions between factor inputs and resources stocks and the potential exists for capacity induced impacts on physical resources (Sampson 1992).

2.3.1 Technological Change and Innovation Adoption in Fisheries

Research in the area of adoption of technological changes in fisheries has remained virtually untouched for more than a decade. Further, previous innovation adoption research in fisheries has been heavily process oriented. The research has a strong bias toward human-centred productive organisations and the mechanical processes that govern their productive capacity. The focus in the literature, as for more traditional manufacturing industries, has tended to be on technological changes designed to increase the productivity of factor inputs, principally capital employed by the fishing firm, through reducing input costs or increasing harvesting efficiency and capacity. These include those that: improve the fish finding ability of vessels (Acheson and Reidman 1982; Dewees and Hawkes 1988; Le Floc'h and Boude 1998); increase fishing power and catch capacity (Whitmarsh 1978; Smith and Hanna 1990; Sampson 1992;

Squires 1992; Whitmarsh et al. 1995); allow diversification or switching between fishing gear types (Levine and McCay 1987); reduce costs of factor inputs (Nissan et al. 1986); or improve safety (Dewees and Hawkes 1988). Adoption of an alternative technique need not always be the result of changes in input prices relative to output prices (Dosi 1997), but innovations that address handling and conditioning techniques on board vessels in order to improve product quality have received relatively little attention (Charles and Paquotte 1999; Boude et al. 2000a).

It has been contended that focus on *major* innovations and the processes that drive technological change are unsuited for fisheries (Sampson 1992). The fishing industry is viewed as 'historically imitative' and fishing firms as 'mainly users and rarely producers of innovations' (Le Floc'h and Wilson 1998). Innovation in fisheries is predominantly of a gradual nature because the opportunities for improvements in fishing are constrained by technical lock-in. It is the efficiency of the underlying technique (e.g., trawling) that is augmented as opposed to transforming the basic method. The propensity to import innovations from industries outside fishing supports the contention that fishery innovations tend to be minor, or incremental.

Technology as a potential source of excess fishing capacity impacts at both an individual and industry level. Innovations in the renewable resources sector have been recognised as giving rise to both positive and negative spillover effects[26] (Le Floc'h and Boude 1998; Whitmarsh 1998). In the exploitation of marine resources, these technological externalities may be positive at the level of the fishing unit but negative at an industry level. For example, improved fish-finding techniques that reduce search times and improve catchability of stocks may have propitious short-term effect in the form of improved profits for existing firms. In the longer term, however, stocks may be driven down both because the new technology increases individual and collective catching power and through increases in the effort applied at an individual and industry scale[27]. As Whitmarsh (1990: 16) states:

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[26] Four our purposes, spillover effects can be thought of as a production externality whereby the actions of one or more persons generate unintended effects upon others and for which no payment or compensation is made. They are generally symptomatic of a lack of enforceable property rights over the resource.

[27] Even fisheries regulated by limited entry may suffer the fate of a common property resource where there exists unused licences or effort. This circumstance may arise where fishing vessels are endorsed to

> "*The adoption of new technology by fishermen, that raises efficiency and profitability, results in intensified fishing by established operators and also acts as an incentive for newcomers to adopt the new technology and enter the fishery*".

This implies that adoption or diffusion of an innovation may have conflicting short and long term effects on fishery profits and rents. Levins and Cochrane (1996) and Whitmarsh (1998) describe this as the 'treadmill' effect, whereby improved technology that reduces costs or improves catching power leading to higher profits, is adopted by fishers in order to offset lower catch rates. While this strategy may be successful at the firm level, firms' collective actions may lead to even further decline in stocks, precipitating on-going searches for even more superior technology. Any short-term cost savings or profitability increases from the new technology will eventually be defused by progressive depletion of target stocks. In the absence of adequate management, over-fishing is the inevitable long-term result, to the detriment of all that exploit the stock of fish (Cunningham et al. 1985; Anderson 1986; Whitmarsh et al. 1995; Wilen and Homans 1997).

The premise of profit maximisation is often regarded as the singular underlying motivation for the firm's behaviour and is based upon neoclassical theory that all firms will choose to operate so as to maximise returns (McKelvey 1983). Profit maximisation is considered too restrictive, however, for widespread application as the primary motivator of fishing and fishing behaviour across all fisheries, particularly the less "industrial" inshore and small-scale fisheries (Charles 1988:277; Kurien 1998). Profit maximisation opportunities are contingent on the existence of competitive markets (Braff 1969; Cyert and March 1992), which in the case of all fisheries is often an unrealistic assumption (Gates 1984; Ward 2000). Several studies have suggested there are other non-pecuniary reasons dictating fishing behaviour (Anderson 1980; Heen 1989; Hillis et al. 1997). The existence of non-monetary benefits in a fishery, however, does not preclude the possibility of profit maximising behaviour (Bockstael and Opaluch 1984; Allen and McGlade 1986; Charles 1994; Robinson and Pascoe 1997), though such behaviour might operate within the constraints of non-pecuniary objectives.

participate in more than one fishery and are able to switch between them as relative profitability's change, perhaps as a consequence of an innovation (McKelvey 1983; Smith and McKelvey 1986).

Fishermen will only adopt new innovations where those innovations are more profitable than the technology they replace (Whitmarsh 1978; Sampson 1992; Le Floc'h and Wilson 1998). Studies of adoption in other resource-based industries have found that the likelihood of adoption of an innovation varies with the relative expected profitability (Feder et al. 1985; Rauniyar and Goode 1992; Feder and Umali 1993; Rauniyar 1998). Under open-access fisheries conditions, incentives to over-harvest resources compound the pressures of competition, obliging firms to adopt innovations as soon as commercial circumstances allow (Whitmarsh 1978). Economic performance, however, is only one of a range of criteria upon which fishers judge the suitability of an innovation. The rate of fisheries wide adoption will likely be influenced by several determinants, including the radicalness or otherwise of the innovation, the size of the fishing firm, the attitude of the fishing community, and the rate at which knowledge of the innovation disseminates (Dewees and Hawkes 1988).

The fishing industry is dependent on the exploitation of a renewable resource that is characterised by strong biological and economic uncertainties (Anderson 1986). Innovation is likewise an uncertain activity. Adoption of the new technology will normally be postponed until there is more certainty as to the superiority of the new technology over the old. Further, investment in new technology is often irreversible in nature; an important consideration in fisheries where non-malleability of capital is an issue (Clark et al. 1979; Charles and Munro 1985). The irreversible nature of technology adoption and the speed at which innovation benefits become more widely disseminated among the fleet contribute to the s-shaped diffusion profile described earlier (Whitmarsh 1990:8; Hanna and Smith 1993).

Another factor inhibiting the take-up of technology is risk. Despite the inherent riskiness of the fishing industry, fishers are clearly risk averse. They react positively to increases in expected returns and negatively to variability of returns (Bockstael and Opaluch 1983). Innovation risk can be considered on two levels: the innovation itself, and its interaction with exogenous variables. The extent to which an innovation can be tried on a small scale (divisibility) or limited basis (trialability) prior to adoption, will lower risk (see (Tornatzky and Klein 1982). As noted above, the uncertainty of biological and economic parameters (catch rate, price) can increase risk and delay the decision to adopt. Both of these uncertainties will change over time, altering the risk perceived by the potential adopter and the perception of the suitability of the innovation (Levine and McCay 1987; Feder and Umali 1993; Purvis et al. 1995).

Because adopting a new technology will require some sort of initial capital outlay, innovation can be considered essentially a classical investment decision by the firm in that it involves expenditure now in anticipation of a stream of benefits in the future (Whitmarsh 1990; Rosseger 1996). Investment in innovation is slightly more complex than the standard investment decision rule[28], however, because not only must the stream of benefits justify the additional outlay required to incorporate the innovation, but it must also be technically superior to existing technology (Nissan et al. 1986). Further, the fisher's desire to innovate may be constrained by access to capital (Huppert and Odemar 1986; Ward and Sutinen 1994; Le Gallic 2000). Both will result in a heterogeneous mix of fleet technologies.

2.3.2 Investment Decisions in Fisheries

Understanding fisher's behaviour has long been regarded as paramount to the efficacy of fisheries management (Wilen 1979). Hilborn (1985a) argues that the study of fishers and fleet dynamics should be a key focus of fisheries research. Investment decision-making is a central component of this fleet dynamics research. Investment studies have historically conformed to one of two types: those that analyse optimal or theoretical behaviour at a fleet-wide level and those that draw on empirical data to describe individual fisher behaviour.

Most of the early fisheries investment literature has concerned itself with long-run optimal outcomes at a fleet-wide scale addressing capital investment and investment in the resource simultaneously. This literature argues that by maintaining an optimal investment program over time, long-term equilibrium biomass levels will be attained and returns to the fishery maximised for an optimal fleet size (Clark et al. 1979; Charles

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28 An investment project is worth undertaking when:

$$NPV = \sum_{i=1}^{n} \frac{(B_i - C_i)}{(1+r)^i} > 0$$

where, NPV is Net Present Value, B the benefits and C the costs (all values in dollars) accrued by the project for the periods (i = 1 to n), and r is the discount rate. The greater the risk associated with an innovation, the higher will be the return required, relative to the old technology, for it to be adopted.

1983a; Charles 1983b; Charles and Munro 1985; Clark et al. 1985; Bjorndal and Conrad 1987b; Hannesson 1993b). Most economic optimisation studies have dealt with the problems of non-malleability of capital and uncertainty. Findings have suggested that where capital is less malleable, fisheries investment programs should be more conservative because fleet over-capitalisation is more likely to occur, particularly where the fishery displays common property characteristics. The impacts of uncertainty on optimal investment, usually incorporated in the form of stochastic variations in biomass, are much less clear, but generally support a more cautious approach to fisheries management.

Optimisation models are generally premised on the idea of the 'average' fisher who behaves myopically (e.g., profit-maximisation) in order to increase or maintain a share of fishery returns, and who ignores the effect of their fishing activities on the resource stock (Wilen 1979). Most research into the determinants of capital investment and disinvestment tends to be similarly based on the 'homogeneous' fishing entity and focused on entry to or exit from the fishery in response to aggregate industry profitability (Gatto et al. 1975; Wilen 1976; Botsford et al. 1983; Allen and McGlade 1986). Bjorndal and Conrad (1987b) and Kirkley and Squires (1988) concluded that entry and exit behaviour showed a lagged response to changes in fish stocks and profits in the current or previous period. Sampson (1992) likewise contended that fleet size (investment) was stock dependent, because biomass determined the relationship between costs of harvest and revenues. He also recognised, however, that technological change could influence relative profitability and the exit from or entry to the fishery.

These 'industry-wide' models ignore the variant decision-making behaviour of fishers (Hanna and Smith 1993; Ward and Sutinen 1994) and are considered inappropriate for many fisheries. This is especially so of small-scale[29] inshore or artisinal fishery's, or those with a high component of owner-operator participation and a high level of firm diversity such as the GBR RLF, because they demand unrealistic assumptions of homogeneity among the fleet participants (Durrenberger 1997; Whitmarsh 1998; Maurstad 2000). Such general models do not take into consideration the different capital

[29] See Kurien (1998) for a comprehensive discourse on the characteristics of small-scale fisheries and the conflicting management problems faced by these fisheries.

configuration of individual firms, nor do they examine the link between these configurations and income expectations from new technologies, and they ignore the fact that many small firms operate with quite low levels of annual investment (Boncoeur et al. 1998). Fisheries policy and regulations will need to account for heterogeneity in fisher motivations with respect to investment responses to changing economic conditions (Wilen 1979; Kirkley and Squires 1988; Hanna and Smith 1993). Failure to do so may result in disproportionate impacts of policies on fishers or greater than expected propensity for fishers to ignore or subvert policy.

Lastly, investment leading to increased fishing capacity need not be confined to entry of new vessels. Understanding the investment process is one of the most important issues in fisheries research (Hilborn 1985a). With developments in technology and demand for fishery products being seen as the main drivers of increased efficiency in fishing and increased value in fishery products, there is a need for greater emphasis on the individual determinants of investment. By virtue of it contributing to a more profitable operation, however, innovation in the short term raises the spectre of increased capacity utilisation (Ward 2000). The link between innovation, investment and excess capacity, particularly latent capacity, is the focus of the next section.

2.4 Fishing Capacity and Latent Effort

Excess capacity in fishing fleets is recognised as the main obstacle to achieving sustainable harvests of fish stocks (Kirkley and Squires 1999a; Dupont et al. 2002; Kirkley et al. 2002b). The trend in most fisheries for harvest capacities (vessels and equipment) to exceed the reproductive capacity of the resource stock prevents fishers from realising the full economic benefits from a fishery (Hannesson 1993b; Holland 2000b). According to Greboval (1999), it is a lack of universal accord on definitions of capacity, and to a lesser extent capacity utilisation, that has hampered progress in dealing with the problem of excess capacity. Although much of the discourse surrounding capacity and its measurement is outside the scope of my research, a review of the main points will prove useful for the ensuing discussion.

Capacity definitions will generally fall into one of two groups: those based on technical criteria (e.g., vessel characteristics); and those based on economic criteria (e.g., cost and revenue structures) (Lindebo 1999). Technical capacity definitions are based on target levels of inputs into or outputs from the fishery, such as effort days or catch quotas respectively. Under this approach, capacity is based on potential inputs (i.e., physical capacity) and represents the potential outputs producible from available resource stocks and full utilisation of these inputs (Terry et al. 2000; Ward 2000; Pascoe et al. 2001). In contrast, economic capacity is premised on economic efficiency principles of cost minimisation or profit maximisation, neither of which necessarily equates to maximum utilisation of inputs and associated outputs.

Ideally, empirical estimates of capacity should be based on the economic definition (Ward 2000). Understanding the underlying economics is essential to defining, measuring and controlling fishing capacity (Greboval and Munro 1999). Economic concepts require that for a given state of technology, fishing firms will operate at the output level that can be produced at lowest cost[30]. Because of the difficulty in obtaining necessary cost and revenue data sets, however, few studies developing economic based estimates of capacity have been undertaken in fisheries (Segerson and Squires 1993; Hannesson 1993b; Segerson and Squires 1995). Economic definitions are preferred to technical ones[31], given that the former recognise fishers' behavioural responses to changing market and resource conditions (Lindebo 1999). The paucity of economic data, however, has meant that most studies have addressed capacity from a technical standpoint (Smith and Hanna 1990; Smit 1996; Maurstad 2000; Pascoe et al. 2001; Dupont et al. 2002; Kirkley et al. 2002b).

Consideration must be given to more than just physical capacity such as engine power and vessel tonnage for technical measures to be representative (Valatin 1994). Harvest measures based on hold capacity, for example, appear unrealistic given constraints such as weather, fish quality and market prices will dictate trip lengths more often than hold capacity. Technical capacity measures tend to assume away the effect of these economic or environmental conditions or non-pecuniary motivations in a heterogeneous fleet

[30] In the short-run (capital inputs are fixed) the optimum output level is indicated by the minimum cost position on the short-run average cost curve (SRAC). In the long-run (capital inputs are variable) optimum economic capacity is where long-run average costs, and associated SRAC, are minimised.
[31] Most technical measures assume that firms are operating at a *technically efficient* level leading to an upward bias in capacity.

(Kirkley et al. 2001; Pascoe et al. 2001). For practical reasons, however, capacity is most often measured as an aggregate of physical vessel characteristics (Valatin 1994).

Capacity utilisation (CU) is defined as the ratio of actual output to output capacity (Nelson 1989; Kirkley and Squires 1999a). As an efficiency measure, it may be an indicator of improvements in the economic efficiency or productivity of vessels through technological improvements (Berndt and Fuss 1986; Squires 1992)[32]. As with capacity, economic and environmental factors will likely limit the activity of individual vessels, implying capacity is unlikely to be fully utilised in any year (Smith and Hanna 1990:2089)[33]. Under such conditions CU may best be measured by comparing the potential number of days at sea (potential effort)[34] to the actual number of days at sea (realised effort) for each vessel class in the fleet (Smit 1996; Maurstad 1998).

Latent capacity or '*latent effort*' is a particular form of capacity under-utilisation that has received considerably less attention yet has major implications for resource sustainability (Thunberg 2000; Holland 2000b). Latent capacity is usually associated with limited licence fisheries and describes the potential for increases in effort allocation when a percentage of licensed participants are inactive or active at low levels of variable input utilisation (Kirkley and Squires 1999b; Ward 2000). Latency typically indicates the potential for excess capacity to develop in response to improved economic conditions[35] or regulation changes (Maurstad 2000) in a fishery and is generally a pointer to fishers being active in more than one fishery or in other industries (eg agriculture). This multi-endorsed nature of fisheries implies that in addition to containing the capacity of the active fleet, consideration must given to the latent capacity that returns to or enters the fishery when the opportunity cost of remaining outside the fishery increases (Smith and Hanna 1990:2089).

Latency in the fleet compromises efforts to manage capacity since individual vessels will respond differently to environmental constraints and economic conditions. Latent

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[32] Declining CU is usually an indicator of decreased economic efficiency, except in cases where high prices may be paid for smaller volumes of high value fish.

[33] See Smith and Hanna (1990) for a good summary of the factors impeding full capacity utilisation

[34] Vessel size and storage facilities will influence the number of days a boat can potentially remain at sea.

[35] In fisheries where latent effort exists, the prospect of increased rents may see the mobilisation of previously dormant licenses (Matthiasson 1996).

capacity will often comprise vessels whose participation in the fishery is dictated by the presence, or absence of certain market conditions. The transient nature of these 'latent' vessels will make obtaining capacity and CU data, at both an economic and physical scale, all the more difficult. Also, because these multi-fishery transients are likely smaller in size and hold capacity than the more dedicated single fishery vessels, weather conditions will place greater constraints on their fishing activity, further obscuring capacity estimates for these vessels. While on the whole fleet capacity measures based on "the maximum potential harvest from the existing fleet, given vessel characteristics" (FAO 1998) can identify the real problem of latent effort, these estimates will be less straightforward in fisheries where latent capacity causes variant effort levels among fleet segments with different physical characteristics.

Despite the difficulty in obtaining useable data by which to make capacity and CU assessments in fisheries exhibiting latent capacity, some understanding of the current activity levels is required if management of actual or potential over-capacity is to be effective[36]. Capacity management requires a measure of the existing level of fleet capacity, relative to some target level of capacity that accords with management objectives, usually stock size or catch level based (FAO 1998; Greboval and Munro 1999; Pascoe et al. 2001). Latent capacity could be estimated by attributing full variable input utilisation rates of active participants to currently partially or fully inactive participants on the basis of their capital stock information (See 9.1) (Kirkley and Squires 1999b).

Management of excess capacity is still largely accomplished through use of input controls that limit fishery access or reduce vessel numbers through buyback programs, although addressing over-capacity through the creation of individual harvesting rights is becoming a more contemporary approach (Grafton et al. 1996)[37]. Individual quotas may not be appropriate for all fisheries, however, such as those characterised by complex multi-species interactions, a limited ability to target specific stocks and heterogeneity in

[36] The importance of this is exemplified by Maurstad's study of the Norwegian Cod fishery (Maurstad 1998), in which she demonstrated the need to distinguish between vessels potential productive capacity, or *technical capacity*, and actual *capacity in use*.
[37] Proponents of Individual Transferable Quotas (ITQ) argue that fishers will choose fixed and variable inputs levels such that their catch allocation will correspond with full utilisation of inputs.

fleet-wide catch composition (Squires et al. 1998:135)[38]. Limited entry mechanisms remain a more pragmatic approach to management of fishing capacity and fisher numbers or fishing days a more tractable means by which to measure and address capacity levels in such fisheries.

While limiting vessel numbers will have a positive impact on effort control and capacity, incentives to increase the vessels catching power, technical efficiency and time spent fishing must also be considered (Smith and Hanna 1990; Charles 2001:95). Failure to do so may lead to overcapacity in individual vessels as the remaining fishers strive to garner as large as possible a share of the resource (see 2.2)[39]. In terms of time spent fishing, however, total number of days fished and trip length have been found to be the primary constraint on capacity output with a lesser role played by vessel characteristics (Smit 1996; Kirkley and Squires 2000; Thunberg 2000; Tingley et al. 2001; Kirkley et al. 2002b).

In limited entry fisheries grappling with continued excess capacity, a popular approach to capacity reduction is a vessel or licence buyback program (Holland 2000b). Accurate measurement of capacity and forecasts of capacity subsequent to a reduction program remain problematic, however, where data are limited. Further, in fishery's where significant latent effort exists, a reduction in vessel numbers need not equate to an equivalent or even tangible reduction in capacity (see 9.3.1) (Pascoe and Coglan 2000). Consequently, capacity management plans need to go beyond quantification of the level of excess capacity and identify the causes of excess capacity along with potential methods of removing these causes (Holland 2000b). In the case of latent effort, this may require a quantitative analysis of: entry to or exit from a fishery; changes in effort allocation for different classes of vessel or operation size based on historical fishing effort (see 8.4.3); or the link between costs, revenues and some form capacity indicator (Lindebo 1999). The following section places the issues of innovation, adoption or investment and capacity in the context of the GBR commercial RLF.

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[38] Fishery examples include coastal and inshore tropical multi-species fisheries, fisheries comprised of large numbers of small fishing firms and multi-fishery fleets that exploit multiple resource stocks.
[39] Excellent reviews may be found in (Rettig and Ginter 1978; Townsend 1990; Gimbel 1994).

2.5 Management of the GBR Reef-Line Fishery in the Context of Investment and Capacity

The GBR commercial (RLF) is a relatively low technology fishery with target species captured using hook and line methods operated manually by individual fishers usually working from 4-7m dories tendered to a main vessel, usually of 8-19m length. The RLF, like many other tropical food fisheries, is inherently multi-species with catch and effort distributed over a wide spatial scale. While the catch, by species composition for the entire fleet, shows more 125 different species caught annually (Mapstone et al. 1996a), demersal reef species (e.g., *Plectropomus leopardus* or common coral trout and *Lethrinus miniatus* or red-throat emperor) captured on offshore reef and shoal habitats dominate the harvest (Mapstone et al. 1996a) and so are of most interest to this research. The reefs and shoals where most fishing effort takes place range up to 140 nautical miles offshore, although the majority of fished reefs are within 70nm of the coastline, with the fishing grounds extending approximately 3500 kilometres along the coast of Queensland. The commercial fishery, with which I am concerned here, operates alongside both private, individual based and tourist, charter based recreational fisheries which have access to the same grounds and targets the same species as the commercial fishery.

Inshore multi-species fisheries, such as the GBR RLF, are not considered easily regulated via controls on total catch or by assigning of individual catch quotas. Excess fishing capacity has most often been addressed through direct input controls that regulate effort and catch such as entry restrictions, gear restrictions, and area or seasonal closures. Limited entry programs have exhibited a wide range of successful and unsuccessful outcomes (Sturgess and Meany 1982; Townsend 1990). A consistent conclusion of these studies is that economic success of entry limitations correlates with their restrictiveness. Their success was shown also to depend on the complexity of the fishery and the social and political support for proposed regulatory changes. Support for entry restrictions will usually be greatest when a positive net gain in private benefits accrues to those who expect to retain access to the resource (Karpoff 1989).

The RLF fishery is a limited licence fishery with a cap on the total number of commercial licences. Other management measures include minimum and maximum size limits for a range of species and, since July 2004, three categories of Total Allowable Commercial Catch (TACC) and Individual Transferable Quotas, with quotas allocated independently for coral trout, red throat emperor and 'other demersal species' (QDPI 2003). Area closures are also employed on the GBR as a conservation management tool, but are not instigated for fisheries management objectives. Fishers operating within the RLF generally hold multiple endorsements, known collectively as a "licence package" (Taylor-Moore 1998). The licence package is attached to the fishing vessel and permits the holder to participate in any fishery for which an endorsement is held. Despite there being more than 1800 valid "line" endorsements, only between 20-25% of endorsed vessels report catches of demersal reef species annually (Mapstone et al. 1996). Of these active vessels, less than 20% account for approximately 75% of the total catch of the main demersal species in any year. The remaining licence holders may either i) fish solely in another fishery (or fisheries), ii) fish part-time in both the RLF and other fisheries, or iii) be inactive in any fishery.

The method of fishing and licence structure has ensured that the potential for capital stuffing by individuals is minimal. Fishing is undertaken from dories (tender vessels) which work to a mother ship (primary vessel), to which the commercial line licence is attached. Because each primary vessel is only endorsed to support a given number of tenders, and fishing takes place from the dories, fishing mortality is directly related to the number of tenders active. As dories are occupied by a single fisher using passive handline capture techniques, catch rates are dictated by physical exertion of the fisher and not related to traditional measures such as catching power of the primary vessel. While these licences are transferable, the number of dories supported by the primary vessel is fixed, effectively setting a maximum capacity per licence.

Although the prospect of capital stuffing in individual vessels remains extraneous there is unquantified latent effort in the fishery that if activated could result in significant effort increases fleet-wide (QFMA 1997a). New innovative techniques in capture, handling and husbandry have been introduced to the RLF that have raised concerns over the mobilisation of latent effort that may lead to the development of excess capacity in the fishery.

Technological change in fisheries is traditionally weighted toward those innovations that increase the productivity of existing capital and labour inputs or decrease per unit production costs. Any short-term revenue gains tend to be dissipated in the longer term as stock levels are further depleted by the more efficient capture techniques. However technological progress in fisheries need not be consistent with greater throughput conveying instead increased economic returns through product enhancement that adds value to the existing catch or currently unused bycatch species.

Until recently, catch of demersal species in the RLF was processed as either whole chilled or whole or filleted frozen product and supplied both domestic and overseas markets. From 1993, fishing operators were being instructed in innovative capture and husbandry techniques by overseas buyers of reef fish, enabling them to store and transport their product alive for sale. This innovation was unique in that it added value to the market price through product enhancement, as opposed to offering increases in catching power or decreases in fishing costs. Improvements in vessel productivity in terms of higher revenue has seen a proportion of the fleet-wide catch of traditional target species now being marketed as live product to international markets in Hong Kong and China.

Concerns have been raised that significant latent effort that exists in the fishery may mobilise in response to potentially greater profits leading to excess fishing capacity. Improved profits, however, whilst they may be the principal determinant in the decision to adopt an innovation, are not likely be the sole contributing factor according to Sampson (1992). For example, Le Floc'h and Boude (1998) suggest that fishers will be reluctant to invest in quality enhancing innovations unless the stock is showing signs of over-exploitation. It has also been noted that the benefit stream from a new technology must not only exceed that of the technology it replaces but must also justify the investment cost which in turn depends on the existing capital endowments of the fishing operation.

Fishing firms that hold line endorsements, whether active in the RLF or not, exhibit broad heterogeneity in terms of size of main vessel, the number of tender boats attached to the main vessel, and the method and volume of storage capacity. These operational characteristics will determine the investment required for incorporating the innovation, which will in turn influence the timing and extent of adoption by those existing full-time operators. Of greater interest is the operator whose line endorsement was used sparingly, or not at all, prior to the advent of the live trade and which now shows increased fishing activity. Increased activity may be as a result of an existing licence holder responding to the increased opportunity cost of non-participation or by reactivation of the previously dormant licence by a new holder, for the same reason. Both cases illustrate the concern that fishery managers for the RLF have over mobilisation of latent endorsements. Despite regulatory restrictions on entry, the extent of latent capacity gives rise to open-access characteristics in the fishery (Homans and Wilen 1997). Without controls on fishing capacity in the RLF, the entry of new vessels may dissipate potential gains from the higher values of saleable catches. This may be the case even when added handling time and diminished holding capacity for the live product diminishes per-operation catches compared to those possible previously attainable when product was processed at sea and sold as frozen product (Mapstone et al. 2001).

The possibility of excess capacity within the RLF can be traced to the multiple endorsement nature of fishing licences (Taylor-Moore 1998). With the economic incentives to enter the market posed by the trade in live fish, increased participation and effort allocation in the reef line fishery may emanate from:

(i) vessels that are operating below full capacity and who will be motivated to augment existing levels of effort;

(ii) the activation of previously inactive licences by individuals or firms who do not currently participate in any fishery but may wish to enter the line fishery; or

(iii) the entry of multi-endorsed vessels, currently active in another Queensland fishery, who activate a previously dormant or under-utilised line fishing endorsement.

The majority of increased effort in the live fishery is likely to emanate from the first two sources. Effort increases from multi-endorsed vessels may be observed in the form of licence holders entering the RLF as regulations in other industry sectors are tightened or when the opportunity costs of not doing so increase sufficiently.

Where the catching ability of the fishing fleet is known to exceed the reproductive capacity of stocks, reducing capacity proceeds by removing vessels from the fleet so as to ease the competition for resources and improve allocative and economic efficiency among remaining vessels (Kirkley and Squires 2000). Assuming fleet capacity is reduced sufficiently, an indicator of this outcome would be greater per vessel capacity utilisation as catch rates improved.

The advent of the live trade sparked significant concerns of an expansion in fleet capacity in the RLF, as previously latent licences become more active. However, for those existing active vessels now participating in the live fishery, changes in capacity and CU are likely to be ambiguous. This can be illustrated by an example. Prior to 1993, when all catch was frozen, vessels rarely returned to port with full freezers. While due in part to weather, which restricted trip lengths, this was mostly due to superfluous freezer capacity of most vessels. With these existing operators switching to live fishing, incorporating live holding facilities may have required sacrificing freezer space. Where increased live capacity was offset by a reduction in freezer capacity, changes to overall capacity would be indeterminate[40]. Capacity utilisation levels for these 'live' vessels will likewise change both in response to targeting behaviour (less frozen product) and quality concerns of the live fish resulting in shorter trips, and the ratio of catch to capacity for each product type.

Technical measures of capacity have been recognised as inappropriate for labour intensive, small-scale coastal and inshore fisheries where physical vessel attributes such as engine power and hold capacity have far less relevance and where utilisation of resources is constrained socially and by physical capital endowments (Maurstad 1998). Where latent effort exists, such as in the RLF, capacity attributable solely to vessels' physical characteristics will be virtually inestimable. This constraint is somewhat ameliorated in the RLF where fishing effort is dictated not by the catching power of the primary vessel but by the number of dories attached to it. In addition, vessel use patterns will be diverse and may fluctuate widely in response to economic and market conditions. Under such conditions, categorising vessels on the basis of their historical

[40] A proportion of the catch of those vessels targeting product for the live market would comprise frozen product, either because the species type or its condition made it unsuitable for sale as live product. These multi-product firms would need to retain freezer space for these and market reasons.

activity levels in the RLF (days in which catch comprised certain target species) may obtain a preliminary comparative measure of capacity and CU over time in response to the emerging live fish trade (see 8.3.3 and 8.4.3).

2.6 Summary

Excess capacity has been recognised the world over as a major fisheries problem, from oceanic industrial fisheries to small-scale coastal and inshore artisinal fisheries. While technology is identified as a major cause of excess capacity in industrial fisheries (de Wilde 2002), small-scale fisheries are not impervious to negative impacts on fish stocks from adoption of improved technology's (Hamilton 2001). Technology need not be confined to process innovations that directly improve the productivity of, and returns to, factor inputs. Technology's that augment the value extracted per unit of the resource can likewise enhance a firm's profitability. Under the right conditions, such technologies can reduce the pressure on the resource stocks. In either case however, increases in effective effort may erode, in the short or longer term, any benefits to the firm arising from the adoption of that technology. In limited licence fisheries, the nexus between increases in fishing profits and increased effort can be exacerbated where inactive or under-utilised licences are present. The mobilisation of this latent effort in response to higher returns may impact on the economic and biological sustainability of the fishery.

The introduction of "live technology" to RLF offers a unique opportunity to understand the effect of a product enhancing innovation on resource rents, the adoption response of firms to this innovation and the potential impacts of reactivated latent effort on biological and economic sustainability. At present, little socio-economic information exists for either the whole of the line fishery or the live fishery component that would enable research into these phenomena. The following chapters explore emerging live fish trade in terms of these.

CHAPTER 3

THE USE OF SURVEYS TO DISCERN SOCIAL AND ECONOMIC CHARACTERISTICS OF THE GBR REEF-LINE FISHERY

3.1 Introduction

Data on biological components of fisheries is generally readily available for many fisheries while data addressing human aspects are not (Matlock 1991), largely reflecting the tendency for fisheries management to be biologically or ecologically focused. It has become more widely accepted in recent years, however, that fisheries management is not just limited to the management of fish stocks via harvest regulation but must incorporate an understanding of human dimensions, such as motivations, behaviours, responses to regulation, etc, into the management planning process (Matlock 1991; Wilde et al. 1996; Ditton and Hunt 2001). Recognition of the importance of people management in fisheries has brought increased need for social and economic data to guide management decisions.

Socio-economic information can be collected through a range of fishery-wide survey methods or via designed sub-sampling strategies from which fishery-wide characteristics are inferred. Surveys require the use of a survey 'instrument', usually a questionnaire, which facilitates establishing an understanding of fishers' behavioural and demographic characteristics (Robinson and Pascoe 1997), their opinions and attitudes (Hanna and Smith 1993) and estimation of economic performance (Boncoeur et al. 1998). The survey method employed will depend on a number of factors including the type of data sought, length of the survey instrument, the survey timeframe, the subject population, sample size required for robust inferences, the geographic area of interest, and resource limitations (Essig and Holliday 1991). Further consideration must be given to the accuracy and precision offered by the various survey methods (Pollock et al. 1994). Finally, the method employed may be dictated by whether the survey is a follow-up of earlier surveys undertaken in the fishery.

Questionnaires have been recognised as a suitable survey instrument to use to gather data on the human dimensions of a fishery where there is little or no such information available (Ditton and Hunt 2001). The reef-line fishery (RLF) is notable for the paucity of socio-economic information available to assist managers in formulating management decisions. This is all the more pertinent given the structural changes in the fleet and behavioural changes of its participants since the mid 1990s in response to the emerging live reef fish trade. Consequently, the questionnaire employed in this research is complex, collecting both qualitative and quantitative information on operational, historical, behavioural and economic aspects of the commercial fleet through the use of open-ended and close-ended questions and likert scale measurements. These data are a primary source of information by which to address the research questions posed in this thesis. This chapter provides a description of the design and implementation of the survey program and the development of the associated interview questionnaire. Given the paucity of information available on the RLF, this questionnaire aimed to collect the data necessary to describe and compare operational, behavioural and economic characteristics of the RLF following the emergence of the LRFF fishery

3.2 Survey Description

Interview methods in fisheries can be either off-site (mail and telephone surveys, logbooks or diaries) or on-site, such as face-to-face interviews and creel surveys (Pollock et al. 1994). Offsite techniques are preferred by many researchers because they are relatively simple and cost effective to administer. Face-to-face interviews, however, are more effective when the questionnaire is complex as they permit more in-depth interviews and greater flexibility (e.g., response choice cards) and the opportunity for immediate discourse to elaborate points of interest.

Data on individual operations for my work were obtained from face-to-face interviews. Face-to-face interviews were a more appropriate method of data collection for this research because of the questionnaire length and scope and the small number of respondents. The flexibility of this method also enabled item non-responses and misinterpretation errors to be minimised and to aid response clarification, particularly with regard open-ended questions. A less orthodox reason for preferring this approach related to the political sensitivities that prevailed at the time of data collection, meaning that many fishers were reticent to respond to off-site surveys. These arose from:

(i) the recent release of a draft management plan for the RLF that had fostered distrust of researchers and managers among target respondents;

(ii) the administration of two (2) other surveys in close proximity to this one, one of which was conducted by a government agency; and

(iii) the sensitive nature of the data being sought (e.g., cost and revenue figures).

Given these potential impediments to the success of the interview program, it was essential that rapport be established with the respondents to enhance the quantity and quality of responses. Face-to-face interviews would facilitate the establishment of this rapport and increase the likely success of the interview program through improved cooperation.

Data quality is usually considered in terms of its reliability, or precision, and validity, or accuracy (Bryman 2001). The problem of recall bias has been identified as compromising the quality of data collected from interviews because of the artificiality imposed on respondents in requiring them to recollect past actions or speculate on future hypothetical actions (Babbie 1999). The ‘quality’ of the data and the reliability (precision) of responses is strongly linked. Reliability can be improved by use of a standardised questionnaire and by careful consideration of the relevance of questions. Reliability does not necessarily ensure validity (accuracy), however, because of the potential for biases imposed by the subjectivism of the interviewer (Babbie 1999; Bryman 2001). While having a single person administer the questionnaire can further enhance reliability, there may be an increased risk of interviewer-subjective bias. The potential for subjective bias was minimised through limited use of open-ended questions (Pollock et al. 1994). Poor validity is in part a product of the artificiality of using questionnaires to elicit responses. Validity can be compromised where the questions, typically closed, are irrelevant or they constrain the respondent’s options (Arksey and Knight 1999). Validity concerns in regard to these closed questions have been addressed through use of: i) field observations of vessel construction and operation; ii) pilot testing; iii) qualitative discussions with stakeholders; and iv) extensive literature searches. Reliability and validity issues will be further addressed in chapter 7.

3.2.1 Survey Response and Interview Program

The multi-endorsed nature of the fishing licences in Queensland (section 4.4) demanded a two-stage process be employed to successfully sample the RLF fleet. These steps were to:

(i) determine those licence holders who fell within the surveys scope prior to commencing the interview program, through a telephone survey; and

(ii) coordinate face-to-face interviews with in-scope fishers who agreed to participate in the survey, when and wherever practicable.

The existence of multiple endorsements meant some holders of line fishing endorsements fell outside the scope of this survey. For example the holder of a line endorsement may be active in another fishery such as trawl, net or crab for which they hold an endorsement but not be active in the RLF (even though endorsed for the RLF), or they may be using their line endorsement predominantly to target pelagic (mackerel) rather than demersal species (Taylor-Moore 1998). In the first instance, names, addresses and telephone contact details of the sampling frame were obtained from the then Queensland Fisheries Service (QFS), with the support of the Queensland Seafood Industry Association (QSIA)[41]. From this list, fishers falling within the scope of the survey were determined on the basis of three criteria, these being that they:

(i) were holders of a licence including an L2 endorsement;

(ii) nominated the demersal reef-line fishery as their principal fishery; and

(iii) targeted primarily coral trout (*Plectropomus spp.*) within the Great Barrier Reef region north of 24º 30’ S on at least 50% of all fishing trips.

Setting the scope in such a way was felt appropriate because in the first instance it would be the more active vessels that would likely respond to any changes in the fishery (section 2.4).

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[41] From 2003 Queensland Fisheries Service was incorporated into the Queensland Department of Primary Industries and Fisheries, becoming the Fisheries section within that organisation. Likewise from July 1, 2000 the Queensland Commercial Fishermen’s Organisation was renamed the Queensland Seafood Industry Association.

As at June 1999, when initial contact was made, there were 228 licensed commercial operators holding an L2 endorsement (section 4.4). Sixteen of the license holders were identified as falling outside the geographical survey area, from Cooktown in the north to Bundaberg in the south (see Figure 3-2). In June 1999, a mailout was conducted formally inviting each of the remaining 212 license holders to participate in the research and advising them to anticipate a telephone call to confirm their willingness to participate. Each mailout consisted of a cover letter introducing myself, my institutional affiliations, confirmation of industry support and a two page information brochure outlining the benefit to industry, information needs and data requirements and data confidentiality issues (Appendix 1). The mail-out was followed after two weeks by a telephone call and where a licence holder was not contactable by telephone on the first attempt, 5 further attempts to contact them were made. A major aim of the follow-up telephone call was to informally speak with the licence holder regarding the nature and purposes of the research, to address any concerns they had and improve respondent participation. If no contact was made after six attempts, these licence holders were identified as ‘not contactable’.

The 212 licence holders were subsequently divided into those within the scope of the survey (n = 85), those that fell outside the scope (n = 83), or those that could not be contacted by telephone (n = 44) on the basis of the mailout and subsequent telephone contact. The majority who fell outside the survey did so because they were not actively using their line endorsement at the time of the survey or they targeted mainly pelagic species. Only 73% (62 out of 85) of those within the scope of the survey agreed to participate in face-to-face interviews. Those license holders who had leased their licence to a third party but would not provide contact details for the lessee were treated as unwilling to participate. Only 81% (50 out of 62) of willing participants were interviewed, primarily due to time and funding constraints but also because of difficulties in arranging a suitable time to interview some ostensibly willing participants. Table 3.1 shows the results of the scoping phase of the survey program by the fishers’ designated homeports. Sampled ports were divided into northern (Cooktown, Cairns, Innisfail and Cardwell, Townsville, Bowen) and southern (Mackay, Rockhampton, Gladstone, Bundaberg) regions comprised of 36 and 49 respondents respectively.

Table 3-1: Summary of the scoping phase of the survey program. Telephone surveys determined those units within the sampling frame who fell within survey scope and who indicated a willingness to participate in a face-to-face personal interview.

Region	Port [1]	No. Licenses	No. Contacted	Within scope of survey [2]	Willing to Participate [3]
Northern	Cooktown	2	-	-	-
	Cairns	50	44	16	7
	Innisfail/Cardwell	19	16	3	2
	Townsville	15	13	7	6
	Bowen	21	18	10	8
Southern	Mackay	61	47	34	28
	Rockhampton	5	1	1	1
	Gladstone	24	19	8	6
	Bundaberg	15	10	6	4
	Total	**212**	**168**	**85**	**62**

[1] Designated homeport in Queensland Fisheries Service contact details;

[2] Those outside the scope of survey included those fishing in other fisheries, not active or unable to be contacted;

[3] Discrepancies between those willing to participate and those for which interviews were conducted were due to survey time limits.

The RLF fishing fleet's activities were principally determined by weather patterns, which necessitated that interviews be arranged opportunistically at short notice, meaning that probability sampling techniques were inappropriate (Pollock et al. 1994). This weather dependence resulted in interviews being conducted in blocs of 3 or 4, coinciding with times when vessels were confined to port due to poor weather. The survey goal was to interview more than 50% of boats in each region with the sample being a representative one, reflecting the number of each type of operation (live or frozen) identified as within the scope of the survey within these regions. The issue of potential biases in sampling estimators is addressed briefly in section 3.2.4.

Interviews were conducted from October 1999 to May 2000. Owners of 50 vessels were interviewed in ports from Cairns to Mackay, representing an overall survey participation rate of 59% of in-scope licence holders. Twenty one (58%) of the 36 licencees operating from the northern region and 29 of 49 (59%) licencees from southern region were interviewed. Sixty-six percent of respondents had converted their operations to supply the live market, while 34% continued to market frozen product only (Figure 3-1).

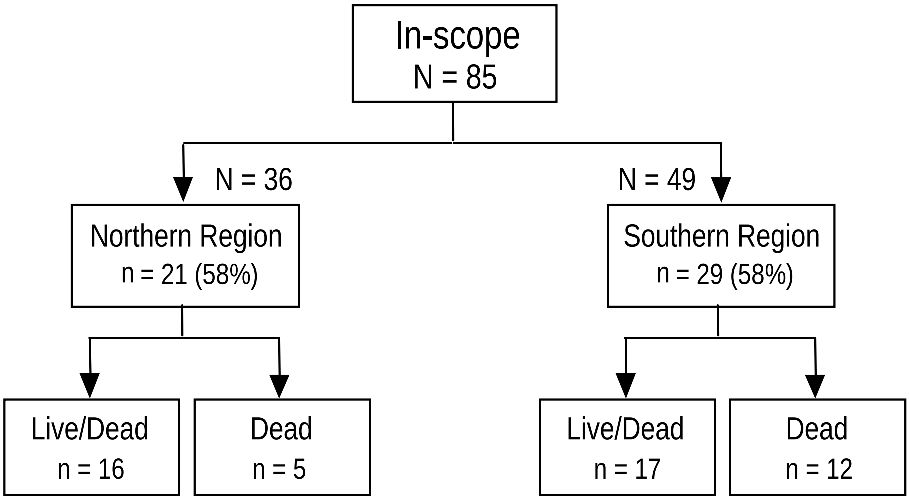

Figure 3.3-1: Sampling outcome for in-scope licence holders in the Reef-Line Fishery based on initial telephone contacts. Numbers (n) of respondents for each subgroup are identified by region and operation type.

3.2.2 Interview Questionnaire Development

An affiliation with the Effects of Line Fishing project (Mapstone et al. 1996a; Mapstone et al. 1997; Mapstone et al. 2001) presented an opportunity to meet with fishers active in the RLF prior to the development of the questionnaire to gain an overview of the operational aspects of the fishery. These meetings, in conjunction with study objectives, guided the survey instrument's design, particularly in terms of closed questions (see below). General guidelines for the design, format, order and wording of individual questions, as well as the overall construction of the questionnaire followed principles set out by Pollock (1994), Babbie (1998) and de Vaus (1995). Technical and jargon terms that might have polarised respondents were avoided as were ambiguous, complex, overlong, double-barrelled or negative questions (Arksey and Knight 1999; Bryman 2001).

Questions were a mix of open, closed and likert-scale type questions. Likert scales usually measure peoples' responses along a continuum ranging from a strongly negative position to a strongly positive one, with a neutral mid-point. In contrast, the likert scales used in this survey measured the importance or intensity of either a favourable or unfavourable attitude to the issue in question; in effect one half of the continuum[42]. This variation was supported by DeVellis (1991:70) who maintained:

> *"...it is neither necessary nor appropriate for this (sic) type of scale to span the range of weak to strong assertions of the construct. The response options provide the opportunity for graduations..".*

Consideration was given to the question order where likert-type questions were grouped in matrices to minimise the likelihood of response set bias (Babbie 1999). The use of closed questions was favoured due to ease of analysis, to minimise misinterpretation and coding errors typically associated with open questions and to facilitate quantitative analysis of responses (Pollock et al. 1994; Bryman 2001).

The interview survey was pre-tested in two stages: the first with a non-representative sample of 4 academics from James Cook University familiar with the use of survey instruments and the second with a representative sample of 4 line fishing operators, 2 of whom marketed their product live. The purposes of pre-testing the surveys were to: i) familiarise the interviewer with its format and use; ii) eliminate redundant questions; iii) gauge the time taken to administer the interview; iv) assess questions for interpretation, clarity, relevance, ambiguity and ordering; and v) estimate the range of answers for individual questions (Babbie 1998; Arksey and Knight 1999; Bryman 2001). The objective of this last point was twofold: to ascertain whether closed question response categories were *exhaustive* and *mutually exclusive* and to minimise the number of open-ended questions. The pilot testing brought about numerous changes to the questionnaire including: a reordering of questions into more obvious groupings to facilitate the flow of conversation; replacing categorical measures with ordinal measures; the removal of redundant questions and inclusion of additional ones; and replacing some open-ended with closed questions. The final questionnaire is provided in Appendix 2.

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[42] For example, rather than eliciting a response on whether the respondent's attitude to set of statements ranges from agreement to disagreement they may be asked to indicate whether a certain states influence on an outcome ranged from extremely important to not important to as opposed to extremely unimportant.

3.2.3 Questionnaire Components

The survey instrument was divided into six sections: (i) fishing history; (ii) operational characteristics; (iii) live fishing history; (iv) investment decision–making; (v) management and research; and (vi) business operations. Each chapter in this thesis has drawn independently on data from questions from one or more of these sections as well as a range of secondary data sources. The sections and associated questions pertinent to each chapter's line of inquiry will be acknowledged in their respective methods sections.

3.2.4 Interview Administration and Data Analyses

Interviews were arranged opportunistically via telephone contact with those fishers who had earlier agreed to participate in the survey. Participants were reminded of the survey data requirements, how the data would be used and the confidential treatment of the data, thus ensuring that respondents had time to locate any information needed for the interview and alleviating fears of misuse of information.

There is a potential for biases in the sample estimators when using non probability-based sampling techniques such as in this survey (Stephan and McCarthy 1958; Kish 1965). The first step in minimising such bias is sampling frame accuracy. The management of the RLF through limited entry ensures the population of potential respondents is explicit. Estimator biases were further counteracted during the follow-up telephone call through culling out-of-scope fishers and clarifying relevant characteristics of those within scope (e.g., business size, geographic location). Lastly, the large sample size relative to the in-scope population size increased the likelihood that the sampled fishers were representative of the range of active fishery participants.

Interviews were conducted face to face, usually at the participant's residence. It was recognised during pre-testing that respondents felt more comfortable in their own homes and valued the time away from their vessels. A structured interview format was used with the wording and ordering of questions administered identically to all respondents. While a structured interview approach reflects the positivist approach to scientific inquiry, it goes some way to addressing validity concerns and reducing error or bias

(Bryman 2001). The interviewer recorded all responses. Prompt cards were used for questions where respondents were asked to choose from a large number of categories and for all likert-scale questions.

Interviews were conducted in two stages in most cases, with the average interview taking approximately 3-4 hours to complete. It was decided after pre-testing to divide the interview into stages to minimise response errors and improve the reliability and validity of the data (Moser and Kalton 1979; de Vaus 1995). Stage one, [sections (i) to (v)] of the questionnaire (Appendix 2) gathered data on fishing history, operational characteristics and decision-making. Questions on the financial aspects of the fishing operations were gathered in stage two.

Time spent with the respondent during stage one also was aimed at improving rapport and gaining the respondent's confidence. With the intention of this survey to obtain highly accurate data on costs and revenues, in most instances interview participants needed time to locate relevant financial statements from the business's financial records. At the completion of stage one, the respondent was asked if they wished to continue participating. At this time, the confidential treatment of all data was again stressed and participants were advised that identification of individual operator data would not be possible. A suitable appointment time was arranged for those that agreed to provide financial data. Although reinterviewing is often seen as undesirable (Sheatsley 1983), the distinction in the data made this separation seem logical, methodologically acceptable and advantageous in allowing participants to gather relevant information prior to stage two that they might have been reticent to provide on the initial interview. Data collection occasionally was finalised in one sitting, but for the reasons noted above and the sensitive nature of the data, multiple visits were the norm.

Processing of survey data typically requires the classification, or *coding*, of responses before data entry, which is performed by 2 or more persons independently to minimise recorder bias (Babbie 1999). Entry of interview data into a customised Microsoft Access database eliminated the need for manual interpretation of categorical responses, however, through the use of "lookup" tables and "check-boxes". Statistical analyses of these data were done using SPSS and Microsoft Excel software.

3.3 Summary

In many fisheries there are few data available on the human dimensions of the fisheries to inform decision-making processes or support management programs which, ultimately, involve regulating human behaviour or activity. Rectifying this situation becomes more important as fishers' activities change over time in response to environmental and market forces or prior management decisions. Survey instruments such as questionnaires facilitate the collection of information on a wide range of attitudinal, behavioural and operational aspects of fishery participants simultaneously. They are especially useful in fisheries such as the RLF where generally accessible data are not available at the level of the fishing firm and do not elucidate fishery drivers at operational levels.

CHAPTER 4

THE FLEETWIDE RESPONSE OF THE COMMERCIAL REEF-LINE FISHERY TO THE EMERGING LIVE REEF FISH TRADE

4.1 Introduction

The practice of keeping reef fish alive until moments before they are cooked has been a Chinese custom for centuries (Li 1996). Countries where large enclaves of Chinese ethnic groups reside, particularly Hong Kong, have become increasingly wealthy in recent decades and the demand for 'live' food fish has grown (Johannes and Reipen 1995). The premium paid by consumers for live, as compared to frozen or chilled, reef fish provides considerable incentive for live fish to be landed by the artisinal fishers of South-east Asia and the Indo-west Pacific as well as the capital intensive operations of more developed fishing nations, including Australia (Johannes and Reipen 1995).

The Great Barrier Reef commercial reef-line fishery (RLF) in Australia has traditionally marketed its catch of coral reef fin fish to domestic and international markets as either frozen fillets, frozen whole gilled and gutted fish or whole chilled fish. The introduction into the fishery in 1993 of innovative techniques for keeping fish alive for export, however, came with the promise of increased revenue returns per unit of effort and was the prompt for existing fishers to become part of this lucrative international trade.

This chapter provides an overview of the international trade in LRFF and the impact of the emerging LRFF on catch and effort composition within the whole of the commercial RLF. The information presented in this chapter provides a context for the results of my research presented in succeeding chapters. The purpose of this chapter, therefore, is to:

(i) highlight the main features of the global trade in live reef fish (LRFFT);

(ii) describe the history and development of the GBR live reef fish fishery (LRFF) as a development of the existing frozen-product commercial (RLF); and

(iii) emphasise where possible, through descriptive data, the unique aspects of the developing LRFF that call for further research;

4.2 Methods

4.2.1 Data Sources

Data were compiled from a number of secondary sources and from face-to-face interviews with fishers (see Chapter 3). Secondary data were obtained from national and international government agencies and non-governmental organisations (NGOs) whose activities were relevant to the LRFFT and the RLF. Data on demand and prices for selected live reef fish species in Hong Kong were made available by the Hong Kong Census and Statistics Department (HKCSD) and the Hong Kong Agricultural, Fisheries and Conservation Department (AFCD). Additional pricing and volume data were provided by the International Marinelife Alliance (IMA), The Nature Conservancy (TNC) and TRAFFIC – part of the World Wildlife Fund organisation (WWF). Relevant data on the commercial reef-line fishery and the expansion of the LRFF were obtained from the Department of Primary Industries and Fisheries (DPI & F) in Queensland [43], and the Effects of Line Fishing (ELF) project at James Cook University. Historical data on domestic beach prices for frozen whole, filleted and live Coral trout (*Plectropomus leopardus*) were collected from local wholesale fish buyers. The Australian Quarantine Inspection Service (AQIS) provided data on the quantities of live reef fish exported from Australia.

4.3 The International Live Reef Food Fish Trade

The demand for "live" fish is centred mainly in Hong Kong and Southern China and has grown considerably since the late 1960's. The traditional sources of live reef fish were the inshore reefs surrounding Hong Kong and those in the South China Sea. Hong Kong fishers began to move farther afield as fish stocks on those reefs began to show signs of depletion. There has been a gradual infiltration of the live fish trade into other South East Asian and Indo-west Pacific countries, beginning with the Philippines in about 1975 (Figure 4-1). Hong Kong based companies have been at the forefront of locating new sources of live fish throughout South East Asia, although companies from Malaysia, Taiwan and China also have been active (Johannes and Reipen 1995). Industry expansion occurred by way of foreign, typically Hong Kong based, companies

[43] Formerly known as the Queensland Fisheries Management Authority (QFMA) until 2000 and the Queensland Fisheries Service (QFS) until 2003

negotiating with governments of the source countries for access to the resource. Local fishers were then recruited to supply fish to the foreign-owned companies that exported live product to markets in Hong Kong (Squire 1994).

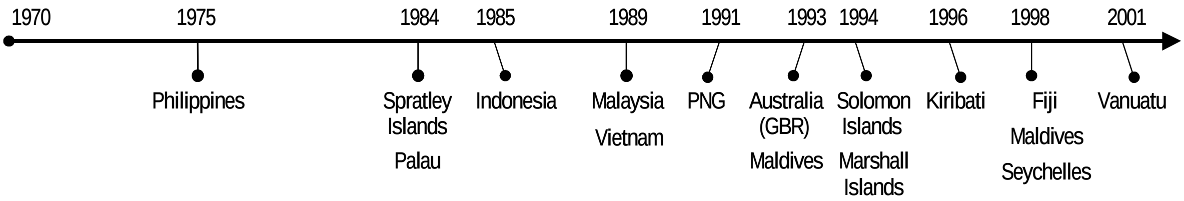

Figure 4-1: Entry year of countries participating in the live food fish export trade

† The governments of Palau (1988), Papua New Guinea (1997) and the Solomon Islands (1998) imposed moratoriums on live fishing practices. Live reef fish trade activities in both Papua New Guinea and Solomon Islands did recommence in 2001 on trial bases. Shipments from Fiji, PNG, the Marshall and Solomon Islands, the Maldives and Seychelles and other Pacific Island nations continue to be sporadic and infrequent.

Indonesia, Malaysia, the Philippines, Australia and Vietnam are the major exporters of wild-caught reef fish. Historically, small quantities of live fish have been exported from the Maldives, Papua New Guinea, Fiji and the Solomon Islands, although political, operational and transport difficulties tended to beset the trade in these countries (Shakeel and Ahmed 1997; Smith 1999; McGilvray and Chan 2001)). There are also reports of developing wild-caught live reef fish export operations in Tonga, Kiribati and Vanuatu in the Indo-west Pacific (Sommerville and Pendle 1999; Donnelly et al. 2000). While small quantities of wild-caught live reef fish are also exported from Thailand and Vietnam direct to Hong Kong markets, these countries export mostly wild-caught fry and fingerlings for grow-out (Bentley 1999; McCullough and Hai 2001). Only Chinese Taipei (Taiwan) exports hatchery reared fingerlings for grow-out (Sadovy 2001).[44]

Fishery resources of many SE Asian and Pacific countries have been heavily overfished in part as a result of the quest to supply the lucrative market for live fish. The combination of inadequate management, made more difficult by fragmented fishing grounds often governed under customary tenure and unsustainable fishing practices has seen fish stocks dramatically depleted and habitat devastated in several areas. The use of cyanide and dynamite and targeting of spawning aggregations have been acknowledged as destructive fishing techniques occurring throughout south-east Asia

[44] See Johannes and Reipen (1995), and Bentley (1999) for a more detailed profile of source countries and discussion as to the development of the live fish export trade within these countries.

having ecological and economic implications (Barber and Pratt 1997; Pet-Soede and Erdmann 1998; Sadovy and Pet 1998a; Johannes and Lam 1999a).

4.3.1 Traded Volumes of Live Reef Food Fish through Hong Kong

Hong Kong is the main centre for the global live reef fish trade and the largest market for Australian live reef fish, with approximately 95% of all live product captured on the GBR being exported to Hong Kong (Muldoon, 2001 *unpublished data*). Reported estimates of total imports of live product into Hong Kong vary widely. McDonald and Jones (1998) estimated that from 1989 to 1994 imports of all live fish into Hong Kong ranged between 38 200 to 54 140 tonnes, of which more than 75% was supplied from China. The HKCSD estimated that annual imports of live reef fish into Hong Kong from 1997 to 2000 ranged from 21 700 to 17 100 tonnes. The reliability of these estimates is questioned by Lau & Parry-Jones (1999), however, because of inadequate reporting mechanisms. They point to likely under-recording of imports and re-exports of live fish as a result of there being no requirement for the approximately 100 Hong Kong registered live transport vessels (LTVs) to declare imports entering Hong Kong by sea. These LTVs mostly bring in live product from South-east Asia and the Indo-west Pacific. Monthly estimates of live marine fish transported into Hong Kong are available from the AFCD, although these figures are thought to capture only about 50% of all shipments of live reef fish into Hong Kong (McGilvray and Chan 2001). Further, these figures, while disaggregated to the species level, are aggregated across multiple source countries. Increased use of air transportation has been promoted to facilitate improved accuracy of import records (Chan 2000). Taking into consideration fish brought in via LTVs, imports of live reef fish into Hong Kong were estimated to be 32 000 tonnes in 1997 by Lau & Parry-Jones (1999) and 30 000 tonnes in 1999 by McGilvray & Chan (2001)[45]. Hence, officially declared imports may be under-reported by roughly half. These estimates are still considerably lower than those of McDonald and Jones, mainly because McDonald and Jones' estimates included non-coral reef finfish species. Table 4-1 summarises imports "recorded" by the HKCSD and AFCD for live reef fish species for the period 1997 to 2001. Inter-annual discrepancies are likely

[45] Estimates were based on monthly import data obtained from surveys of live reef fish traders. The discrepancy (~11 000 tonnes) between these data and those collated by the CSD for total reef fish imports was attributed to inadequate reporting mechanisms by the CSD regarding mode of transport of live imports.

to be as much a product of inadequate reporting as changes in supply, consumer preferences or demand.

Table 4-1: Estimates of annual live fish imports into Hong Kong from 1997 to 2001. Bracketed figures are AFCD estimates of total live fish of all species transported into Hong Kong by LTVs. AFCD estimates for 1997 are not available

Species	Quantity (t)				
	1997	1998	1999	2000	2001
Coral trout (*Plectropomus spp.)*	840.2 (n/a)	1 136.9 (307.5)	1 496.2 (505.6)	2 142.7 (708.9)	2 101.1 (457.2)
Highfin grouper (*Cromileptes altivelis)*	14.5 (n/a)	11.9 (20.9)	4.6 (11.5)	4.4 (10.6)	7.8 (10.4)
Humphead wrasse *(Chelinus undulatus)*	1.7 (n/a)	4.3 (127.5)	4.6 (85.4)	42.9[a] (38.7)	12.3 (24.6)
Other Groupers	4 860.3 (n/a)	5 406.2 (977.3)	3 777.1[b] (1 481.9)	3 650.6[b] (2 740.5)	3 693.2[b] (1 049.7)[c]
Other Marine Fish	15 350.1 (n/a)	12 818.8 (885.2)	5 824.4[b] (1 536.2)	6 047.1[b] (1 719.7)	5 903.6[b] (578.2)
TOTALS	**21 066.8**	**19 378.1** (2 318.4)	**11 106.9**[b] (3 620.6)	**11 887.7**[b] (5 218.4)	**11 718.0**[b] (2 120.1)

[a] The significant increase in recorded imports is attributed to an increase in the use of air transport by SE Asian exporting countries.

[b] The significant decline in total recorded imports cannot be readily explained. Efforts by the HKCSD from 1999 onwards to improve market information by enabling imports to be identified by species type (eg flowery grouper) as opposed to species categories (e.g., other grouper or other marine fish) may be partly responsible. A more plausible explanation might be the impacts from a downturn in the Asian economy during 1997 and 1998.

[c] The overall decline in recorded imports is due to a significant decline in green grouper imports

Source: Hong Kong Census and Statistics Department; Agriculture Fisheries and Conservation Department, International Marinelife Alliance

4.3.2 Demand for Live Reef Food Fish from Hong Kong Markets

Demand for live fish coincides closely with events on the Chinese lunar calendar and is observed to peak on traditional Chinese festivals, notably: Chinese New Year (January/February), Mother's day (May), Mid-Autumn festival (August/September) and Winter Solstice (December) (Li 1996; Lau and Parry-Jones 1999). These festive periods correspond with higher beach prices for Australian fishers and a subsequent increase in the live catch as a proportion of total catch (section 5.4.2).

The live fish retail market in Hong Kong is dominated by the relatively steady demand from consumers for low and medium-priced species, the latter encompassing a number of species in the grouper complex (Sadovy and Lau 2002).The main source of demand for high value live fish imports are the medium and premium-priced restaurants with the most highly valued species being the humphead (Maori) wrasse (*Chelinus undulatus)*, highfin grouper (Barramundi Cod, C*romileptes altivelis),* Coral trout[46] (*Plectropomus leopardus)* and the large groupers (*Epinephelus fuscoguttatus* and *E. polyphekadion)*. This list accords with the main target species of live fishing operations in Australia. Table 4-2 lists the Hong Kong wholesale prices for these preferred species of the Hong Kong restaurant trade. Average annual wholesale prices (in Hong Kong) began to fall in the latter stages of 1997 and, with the exception of flowery cod, most species' prices had failed to recover from these declines up to and including 2001.

Table 4-2: Annual mean wholesale prices for live reef fish for consumption in Hong Kong from 1997 to 2001. Prices are shown in both Hong Kong and Australian dollars

	Mean Annual Wholesale Price (kg)									
	1997		1998		1999		2000		2001	
Preferred Species	($HK)	($A)[1]	($HK)	($A)[1]	($HK)	($A)[1]	($HK)	($A)[1]	($HK)	($A)[1]
Coral trout (*P leopardus.)*	325.80	57.20	277.10	57.90	275.70	55.20	291.50	64.80	266.40	65.10
Maori wrasse (*C. undulatus)*	605.00	106.20	435.20	88.20	464.20	93.00	423.85	94.40	431.50	105.50
Barramundi Cod (*C. altivelis)*	571.60	100.30	539.30	112.00	513.70	102.90	519.05	116.20	518.30	126.70
Flowery cod (*E. fuscoguttatus)*	219.90	38.60	149.40	31.00	144.10	29.90	187.70	42.00	188.00	45.90
Camouflage Cod (*E. polyphekadion)*	234.80	41.20	167.00	34.60	156.30	31.30	172.65	40.60	164.40	40.20

[1] A$ prices have been calculated on the basis of its mean average monthly performance against the HK$ using Australian Bureau of Statistics (ABS) exchange rate conversions.

Source: Agriculture Fisheries and Conservation Department, Hong Kong, ABS.

The mean annual wholesale prices, shown in Table 4-2 fail to adequately represent the large mean monthly price fluctuations that characterise the Hong Kong live fish markets within a calendar year. For example, while the average annual wholesale price of Maori wrasse fell 28% from 1997 to 1998, its price was relatively stable between January and

[46] Unless otherwise stated, coral trout refers only to the species *Plectropomus leopardus.*

December of 1998 as shown by the range in prices and the standard deviation for that year (Table 4-3). This difference is explained by large declines in average monthly price from October to November 1997 (13%) and December 1997 to January 1998 (20%), followed by a small recovery throughout 1998 (Figure 4-2). Contrasting, and more normal, patterns emerge in subsequent years for all species except the large cods, for which prices in 2000 rose sharply on the back of stronger demand. These discrepancies in between- and within-year price changes seem largely due to the seasonal trends in demand related to festival events. Significant increases in prices in January and February (Chinese New Year) are followed by equally large declines in March and April, before a year end recovery (Figure 4-2) (see also Appendix 3)

Table 4-3: Mean annual wholesale fish prices ($HK/kg) for the five principal species exported live from Australia from 1998 to 2000. Standard deviations of mean annual wholesale prices are in parentheses. Between years variations (Column 2) are expressed as the percentage change from the previous year. Yearly range in price (Columns 3) is based on mean monthly prices for that year.

	1998			1999			2000			2001		
Species	Mean Annual Price ($HK)	Change mean price (%)	Yearly Price Range ($HK)	Mean Annual Price ($HK)	Change mean price (%)	Yearly Price Range ($HK)	Mean Annual Price ($HK)	Change mean price (%)	Yearly Price Range ($HK)	Mean Annual Price ($HK)	Change mean price (%)	Yearly Price Range ($HK)
Coral trout (*P leopardus.)*	285.8 (19.3)	-12.3	67.4	275.7 (29.0)	-3.5	101.1	291.3 (39.7)	5.7	111.5	266.4 (28.2)	-8.6	88.3
Maori wrasse (*C. undulatus)*	435.2 (18.3)	-28.1	52.2	464.2 (32.5)	6.7	114.2	423.9 (41.2)	-8.7	172.7	431.5 (30.5)	1.8	102.3
Barramundi Cod (*C. altivelis)*	539.3 (29.5)	-5.7	89.6	513.7 (22.3)	-4.8	79.8	519.1 (25.9)	1.1	100.9	518.3 (56.0)	-0.2	243.8
Flowery cod (*E. fuscoguttatus)*	149.4 (25.6)	-32.1	67.9	144.1 (13.7)	-3.6	44.8	187.7 (14.6)	30.3	44.1	188.0 (15.2)	-0.1	54.5
Camouflage Cod (*E. polyphekadion*	167.0 (6.7)	-28.6	22.0	156.3 (14.3)	-6.4	44.1	172.6 (15.6)	10.4	65.8	164.4 (14.2)	-4.8	44.5

Source: Agriculture Fisheries and Conservation Department, Hong Kong, International Marinelife Alliance

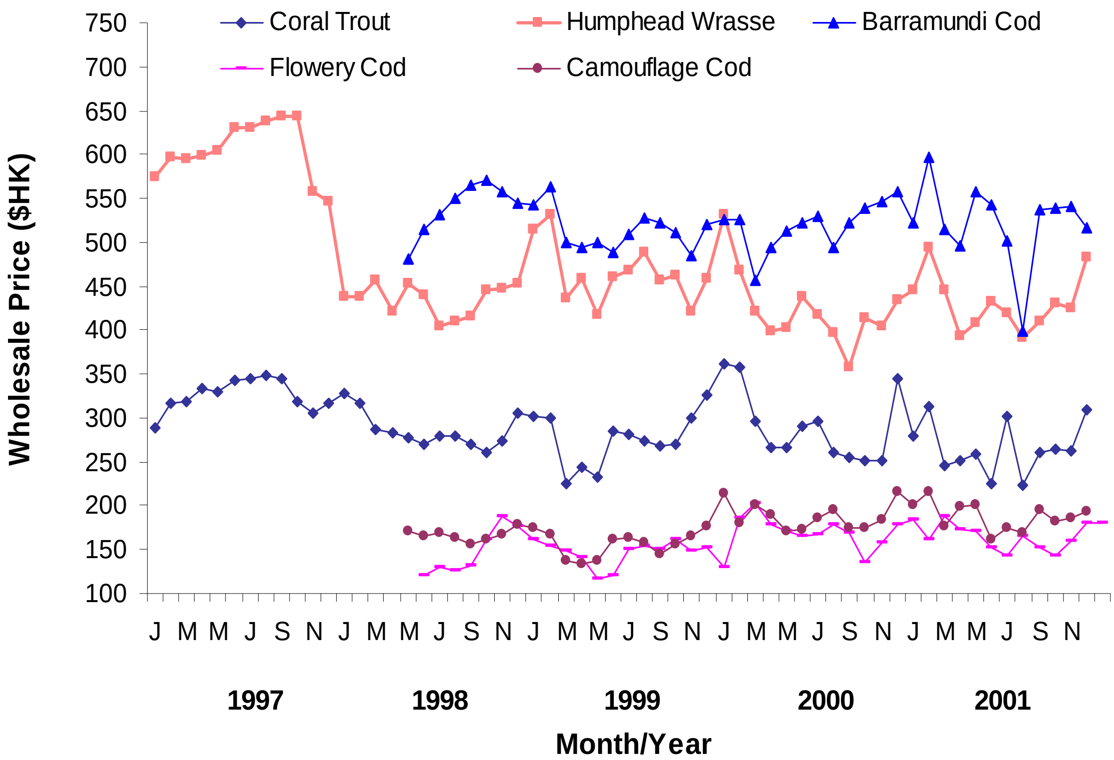

Figure 4-2: Mean monthly wholesale fish prices ($HK/kg) for the five principal species exported live from Australia from January 1997 to December 2001. Mean monthly prices were not available for three species (Barramundi Cod, Flowery Cod and Camouflage Cod) for the period January 1997 to April 1998 inclusive.

Source: Agriculture Fisheries and Conservation Department, Hong Kong, International Marinelife Alliance

One of the most popular higher-priced live fish species in the region is common coral trout (*Plectropomus leopardus*). While other coral trout species (*P. areolatus, P. maculatus, P. laevis*) are also preferred for the texture and taste of their flesh, *P leopardus* is favoured because of its red skin colour, which signifies 'good fortune' among Chinese (Chan 2000). Plate-sized specimens ranging from 0.5kg – 1.5kg are the preferred sizes for live fish, with fish above this size range generally being sold for less per kilogram, or by piece rather than weight. Lower prices paid by Hong Kong importers are reflected in the prices received by fishers from wholesalers in Australia (section 5.4). Although Barramundi Cod and Maori wrasse remain 'signature' species of the live reef fish trade, they do not attract the high levels of demand they once did partly because of their premium price, arising from limited supply (Chan 2000; McGilvray and Chan 2001).

While Hong Kong remains the major importer of live reef fish, the composition and volume of imports has fluctuated in recent years. According to Bentley (1999), whose data spans the years 1990 to 1996, the total volume of recorded annual exports of reef fishes from Southeast Asia rose continuously from 1991 to 1995 before declining by more than 20% in 1996. Exports to Hong Kong from the three major source countries of wild-caught species of Indonesia, Malaysia and the Philippines reflected this trend (Bentley, *ibid*.). Data compiled for the period 1997 to 2000 by the HKCSD (HKCSD, *unpublished data*) however, is ambiguous. All the major source countries (excluding Australia) were reported as showing substantial declines in volumes traded (40%-60%) during 1999, yet data in subsequent years shows no discernible trends, although volumes remain below historical levels (Figure 4-3). While this dip in volumes closely follows the Asian economic downturn of 1997 and 1998, there is insufficient evidence to suggest that it may be a lagged response to these economic events. Comparison between the two data sources is impractical as Bentley's data is based on official government estimates of live reef fish exports from the respective countries, by sea and air transport, while the HKCSD data is based on imports into Hong Kong from the respective countries by air only[47]. Suggestions by some authors of downward trends in imports of live reef fish into Hong Kong, particularly high value species, from the main source countries (Barber and Pratt 1997; Bentley 1999 ibid; Lau and Parry-Jones 1999) are not borne out by HKCSD data. The data don't necessarily contradict claims, however, that declining supplies of high value species are an indication of widespread over-exploitation of stocks important to the live trade as no data is available on trends in average size of imported fish, which may be evidence of localised depletions of target species (Padilla et al., 2003)[48].

[47] Recall the reporting system inadequacies for live reef food fish imports discussed earlier in this section.

[48] There is evidence of increasing numbers of juvenile fish being retained for grow-out until they reach market size (G. Muldoon, Y Sadovy; personal observations)

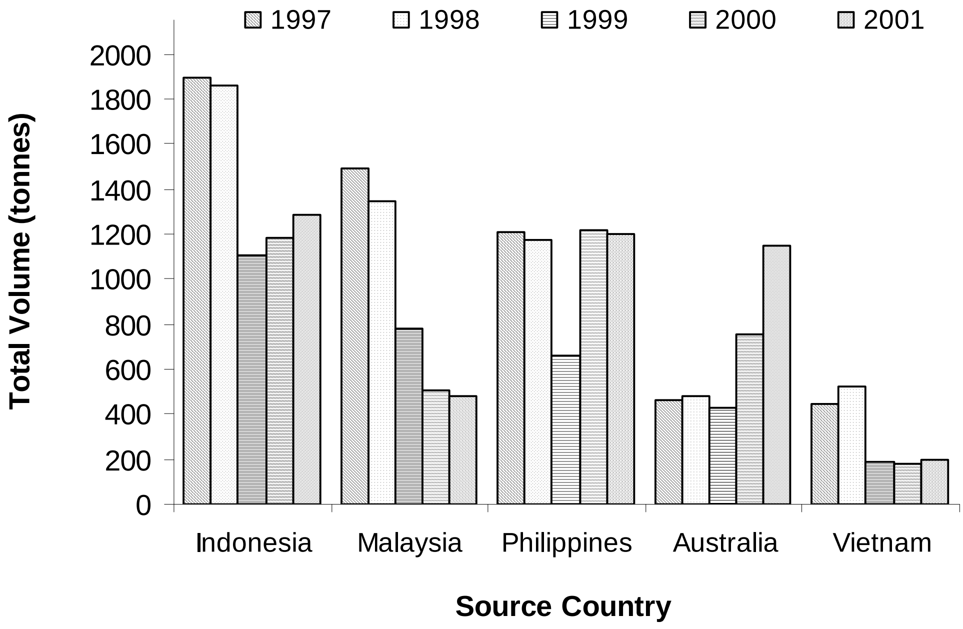

Figure 4-3: Recorded imports into Hong Kong from major source countries of wild-caught live reef fish for the years 1997 to 2001. Historically lower import volumes in years subsequent to the large decline in volumes in 1999 reflect the continual depressed demand for live reef fish in those years. Imports by sea are not able to be included due to reporting system inadequacies.

Source: Hong Kong Census and Statistics Department (HKCSD), (unpublished data).

In contrast to the irregular trends in live reef fish imports by country into Hong Kong from 1996 onward, total imports of coral trout species *Plectropomus spp.* increased. A considerable proportion of this increase was being sourced from Australia, and to a lesser extent SE Asia and the Indo-west Pacific, through increased effort in existing fisheries and exploitation of new fishing grounds (Lau and Parry-Jones 1999; Yeeting 1999; Johannes and Lam 1999a). Between 1998 and 2001, total imports of coral trout into Hong Kong increased by 963 tonnes or 85%. Australian exports made up 828 tonnes or nearly 86% of this increase so that by 2001, Australia supplied nearly 49% of all shipments of live coral trout into Hong Kong by air, a marked increase on the 17% of all imports it supplied in 1998 (HKCSD, *unpublished data*) (Table 4-4).

Table 4-4: Total imports of coral trout (*Plectropomus spp.)* into Hong Kong by air by source country for the years 1997 to 2001. Yearly changes in source country imports are shown as percentage of previous year's imports.

	Quantity (tonnes)									
	1997		1998		1999		2000		2001	
Source Country	(t)	Change (%)	(t)	Change (%)	(t)	Change (%)	(t)	Change (%)	(t)	Change (%)
Indonesia	298	-	451	51.3	366	- 18.8	516	40.9	286	- 44.6
Philippines	45	-	84	86.6	357	325.0	539	50.9	439	- 18.6
Malaysia	248	-	238	- 4.0	253	6.3	260	2.8	230	- 11.5
Thailand	95	-	72	- 24.2	13	- 81.9	1	- 92.9	37	-
Vietnam	32	-	53	65.6	56	5.7	56	0.0	35	- 37.5
Singapore	0	-	21	-	17	- 19.0	1	- 94.1	-	-
Australia	345	-	198	- 42.5	410	107.2	722	76.2	1,026	42.1
TOTALS [a]	**1,083**	**-**	**1,137**	**5.0**	**1,496**	**31.5**	**2,143**	**43.2**	**2,100**	**- 2.0**

[a] Totals represent all imports of Coral trout into Hong Kong, not just those countries included in the table.

Source: Hong Kong Census and Statistics Department; International Marinelife Alliance.

Several factors are proposed for this increase in 'recorded' volumes of coral trout flowing into Kong Kong.[49] The first is the increased demand for live reef fish in China (Bentley 1999). Since the early 1990s, live reef fish imported to Hong Kong have been re-exported to China to supply the growing demand, originally in the south but more recently also in northern cities (Li 1996; Chan 2000). Re-exports of wild caught live fish into China have increased from zero percent of Hong Kong imports in 1990, to 30% in 1995, [50] to 60% in 2000 (Johannes and Reipen 1995; Chan 2000). Secondly, during the Southeast Asian economic crisis of 1998, high-priced reef fish, such as Maori wrasse and barramundi cod, became less popular as consumers switched their preference to lower-priced coral trout. The last, and perhaps most important, is that the increased supply is a result of Australian fishers increasing supply of live coral trout in response to the higher domestic beach prices paid for live fish. Coral trout has remained the most popular eating fish at festivals and celebration dinners in the wake of the economic crisis (P Chan*, personal comment, 2001*).

[49] Recall that underreporting may be as high as 50% due to the imports by sea using Hong Kong registered vessels (Lau and Parry-Jones, 1999).

[50] According to Bentley (Bentley 1999), Indonesian exports of live reef fish directly in to China increased from zero to 27% of total live reef fish exports in the period 1991 to 1995

4.4 The GBR Live Reef Fish Industry

The LRFF is wholly contained within the commercial RLF and is distinguished only by the form in which the product is sold to the wholesale market. The primary operations licensed to fish within the commercial RLF are permitted to catch their product and market it in frozen, fresh or live form. A separate licence is not required to market live product and similar management measures apply regarding minimum fish sizes, gear restrictions and vessel sizes. The decision to upgrade their vessel to catch and store live product[51] is the operators', as is the decision to direct fishing effort at supplying fish for either the frozen or live markets. This is the main distinction between live and frozen operations. Live operators will retain *both* live and frozen product, the latter because some landed fish will be unsuitable for the live markets due to their size, quality or species.

Virtually all live product landed by the commercial sector in the GBR is exported as airfreight, through wholesalers, to the live fish markets in Hong Kong. Transporting fish by sea on live transport vessels (LTVs) is uncommon on the GBR because the use of LTVs within the GBRMP is restricted, transit times to Hong Kong are lengthy and there is a considerably higher risk of mortality than with air transport. The higher mortality rates suffered during sea transit, in conjunction with the potentially lower market price in Hong Kong as a result of 'flooding' the market with the LTV consignment, effectively offsets the nominally lower unit costs of transporting fish by sea from the GBR and ultimately makes transporting fish by air more cost effective per unit (P Chan 2001, pers. comm.). Live product unloaded at any of the main ports within the GBRMP is transported by road to either Cairns or Brisbane from where it is air freighted to Hong Kong in specially constructed transport bins. These bins hold up to 1200 litres of water and 300 fish for up to 24 hours at a time (L Peterson 2001, pers. comm.).

Existing research (Mapstone et al. 1996a; Mapstone et al. 2001), has identified variation in the temporal and spatial distribution of catch and effort between selected regions[52]

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[51] Most vessels that are set up to store live product retain freezer space to enable the storage of frozen product. Some may have the capability to store their catch fresh on ice as well as in frozen or live form.

[52] The authors analysed the reef-line fishery in terms of 11 regions with some of their regional boundaries corresponding with section boundaries of the GBRMP. While not wholly consistent, their regions; Cairns, Townsville, Mackay and the Swains correspond fairly closely to the Cairns, Central and Mackay / Capricornia section boundaries of the GBRMP.

for vessels targeting coral trout, both prior to and since the advent of the trade in live fish. From 1989 to 1995, coral trout comprised 30-40% of annual catch in the Cairns region, 35-50% in the Townsville region and greater than 50% in most years in the Mackay and Swains regions (Mapstone et al. 1996b). In the period since 1995, coral trout has continued to comprise 40-55% of total annual catches in the reef-line fishery, but the form in which it has been marketed has changed.

Marketing of catches of reef fish alive from the GBR was first reported in 1993. In 1994, landings of live fish accounted for approximately 8% and 2% of total landings of coral trout from the Northern and Central regions respectively[53]. By 1995 the percentage of total reef-wide live catch had almost doubled, and comprised over 20% in some regions. Data for the period 1995 to 1997 indicated that live catch as a percentage of total catch of coral trout in the GBRMP rose to nearly 40% in some regions and more than 20% for the whole of the commercial RLF. This aggregate percentage for the whole commercial RLF remained steady in 1998, but rose again in each of the years 1999 to 2001 to comprise approximately 35%, 55% and 60% respectively of the total fishery catch of coral trout (QFS, *unpub. data*). During this same period, the proportion of live catch rose in all regions with the largest change in marketing being exhibited in Central and Southern regions of the GBR where live catch was almost 70% of total catch of coral trout (Figure 4–4; 4–5).

[53] The regions used by QFS (Far Northern, Northern, Central and Southern) correspond closely with the section boundaries of the Great Barrier Reef (Far Northern, Cairns, Central and Mackay/Capricorn respectively). The slight discrepancies between the two will not affect the general trends described herein.

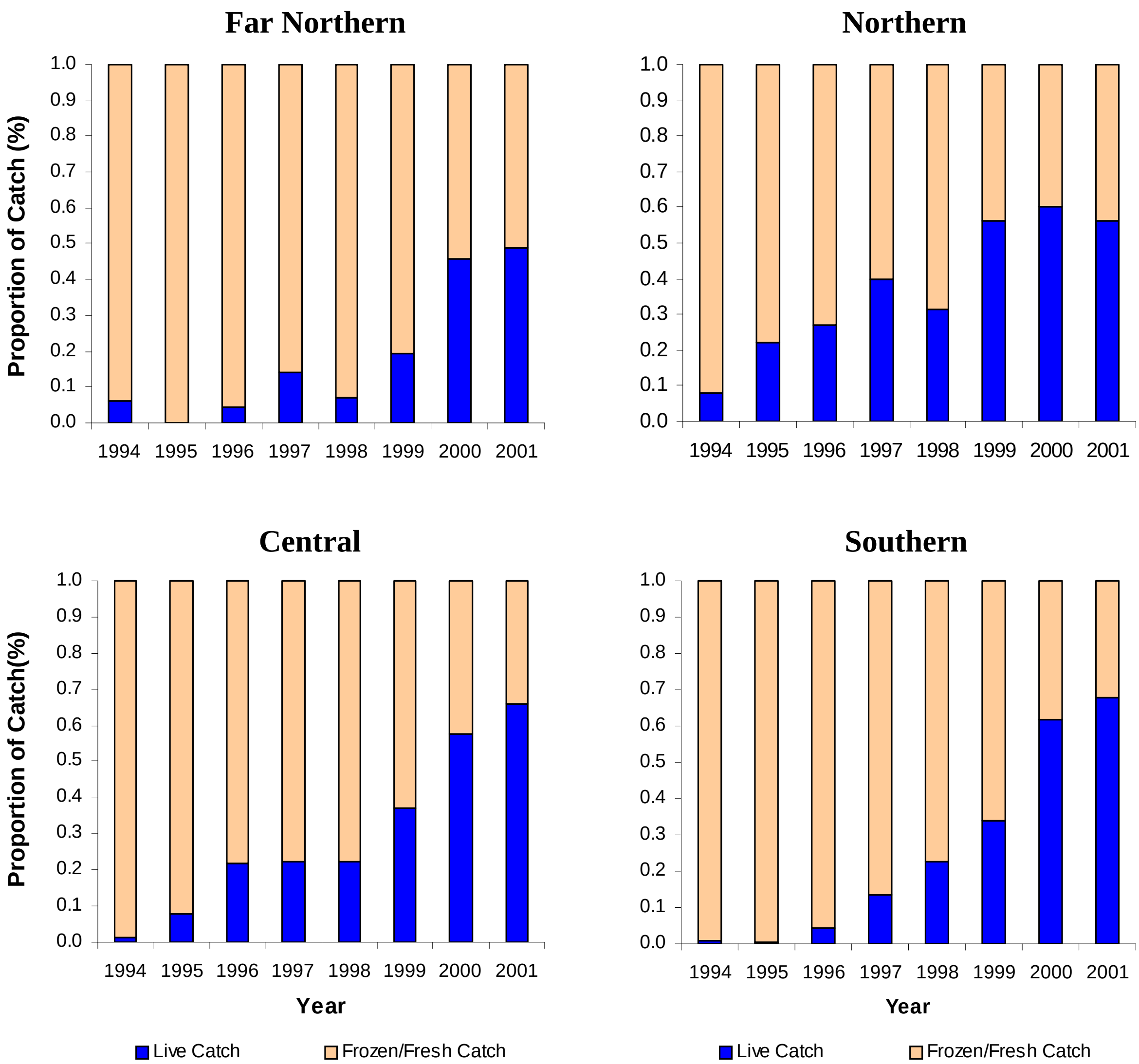

Figure 4-4: Regional variations in annual landings of (live) Coral trout as a proportion of total annual catch of Coral trout for years 1994 to 2001. These regions correspond very closely with the section boundaries of the Great Barrier Reef (Far Northern, Northern, Central and Southern regions correspond with the Far Northern, Cairns, Central and Mackay – Capricorn sections respectively). The slight overlaps between GBR sections and QFS regions will not affect the general trends described herein.

Source: Queensland Fisheries Service

Annual exports of coral trout have increased from 97 tonnes in 1995 to 1026 tonnes in 2001. The levelling off of annual exports in 1998 is likely a product of the combined effects of a depressed Asian market on Australian beach prices and declining catch rates in the wake of a large scale cyclone disturbance, although inaccurate reporting of catches by fishers may also be a factor.[54] The higher domestic beach prices offered for

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[54] Prior to 1997 there was no requirement for operators to discriminate between live and fresh/frozen product in compulsory logbooks, with the result that many fishers would have recorded live catch as

live fish following the end of Asian crisis, in concert with improved catch rates, is reflected in increases of 76%, 81% and 36% respectively in exports of coral trout in the years 1999, 2000 and 2001 (Figure 4–5).

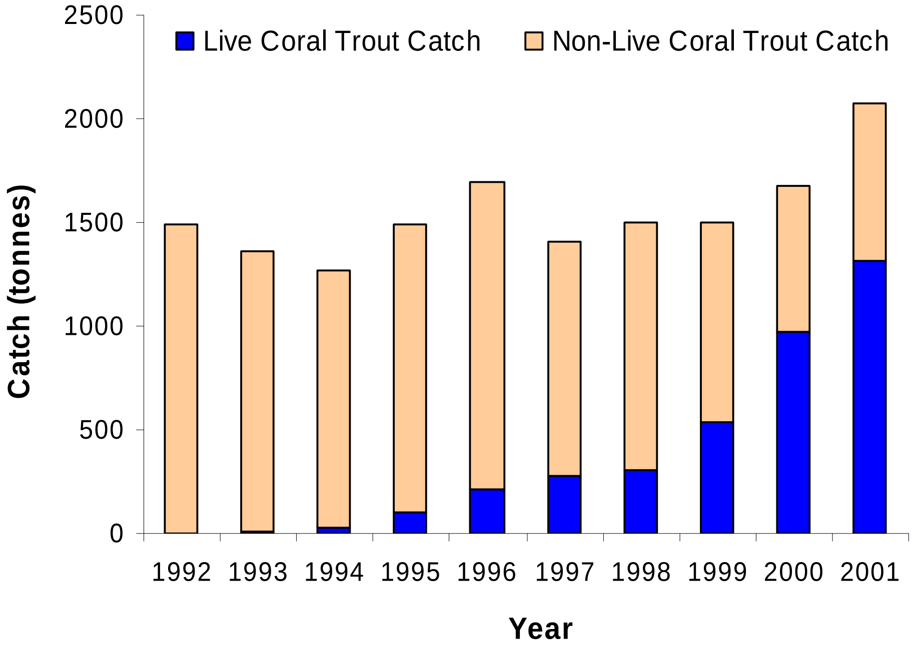

Figure 4-5: Landings of live coral trout and total catch of coral trout, in tonnes, from all regions within the GBRMP for the years 1992 to 2001. Note the stabilisation in live catch during the Asian economic downturn of late 1997 and 1998 and subsequent increase as Asian economies recovered.

Source: Queensland Fisheries Service, Australian Quarantine Inspection Service.

Coral trout (mainly *P. leopardus*) historically has made up 90-95% of all live reef fish exports from the GBRMP. Comparatively minor quantities of barramundi cod (*C. Altilevis)*, Maori wrasse (*C. Undulatus)* and larger cods (*Epinephelus spp)* also were exported. While exports of barramundi cod and Maori wrasse have varied over time, exports of cods and mixed species have grown considerably since 1996, increasing by 1200% and 480% respectively (Table 4–5), though the composition of these live export categories is unclear (Mark Elmer, QFS, *pers. comm.*). Commercial catches of passionfruit (*P. areolatus*), chinese footballer or blue-spot (*P laevis*) and bar-cheeked

whole fresh/frozen catch. Revised logbooks incorporating specific requirements for live catch to be recorded separately were introduced only in 1999. No directives were given by QFS in the intervening period between 1997 and 1999 as to how fishers should report live catch in their logbooks.

trout (*P. maculatus*) on the GBR are incidental[55] even though they are a desired species in Hong Kong.

Table 4-5: Annual exports (kg) of live reef fish from the Great Barrier Reef reef-line fishery between 1995 and 2001.

Year	Coral Trout	Barramundi Cod	Maori Wrasse	Cod (other)	Mixed Species	Totals
1995	97 735	650	70	1060	2165	101 680
1996	431 935	1 185	555	4 540	10 605	448 820
1997	345 030	715	545	4 345	2 425	353 060
1998	198 095	555	3 725	2 230	10 405	215 010
1999	493 300	1 250	6 865	10 580	27 530	539 525
2000	721 021	3 560	5 170	11 160	44 590	785 501
2001	1 026 442	887	2 651	59 040	61 725	1 150 745

Source: Australian Quarantine Inspection Service (AQIS), Queensland Fisheries Service (QFS).

A stable, albeit slightly increasing, effort pattern prevailed in the commercial RLF from 1989 to 1995 with substantial increases in total effort and catch being experienced in subsequent years (section 1.6.2). Much of this increase has been attributed to excess or latent capacity in the fishery being mobilised as a result of the developing live fish trade (section 2.5). This view is only partially supported by data which shows substantial increase in the effort associated with landings of live product, mainly coral trout, in all sections of the GBR, from less than 100 days in 1993 to over 19400 days in 2001. The association of increased effort with growth of live reef fish exports after 1993 is confounded by the announcement and development of revised management arrangements over the same period that may have stimulated some activation of latent effort. Hence, the contribution to overall increases in fishing effort attributable to increased targeting of product for live markets remains uncertain. For example, from 1995 to 1996 the total number of days on which landings of live fish was reported increased by 155% from 1290 to 3300 days (2010 days). The total number of days on which coral trout in any form was reported in that year, increased 25% from 18155 to 22605 days (4450 days). While live days fished as a proportion of total days fished on

[55] Average wholesale prices of these species were approximately 35% less than for *P. leopardus* over the period 1999–2000 (IMA, *unpublished data*).

which coral trout were targeted increased from 7.1 % to 14.6 %, the increase in live effort made up at most only 50% of the increase in total days fished. During 1997, total live effort increased a further 56% (1870 days) to 5150 days while at the same time total days on which coral trout in any form was reported increased 10.9% (2470 days) to 25075 days. As a proportion of total days, live days fished increased from 14.6 % to 20.5% of total days fished over the same period. Thus, more than 75% of the total effort increase during 1997 could be attributed to increases in live fishing effort if the assumption was made that all that increase in live effort was by operators who had not previously been fishing. In 1999 and 2000, after the Asian economic crisis had passed, live days fished increased by 45% and 63% respectively while total effort fell by 7% in 1999 and rose again by 8% in 2000. In contrast, live and total effort days in 2001 were 52% (6700 days) and 32% (7600 days) higher respectively with live days fished reaching 60% of the total days fished on which coral trout were landed (Figure 4–6).

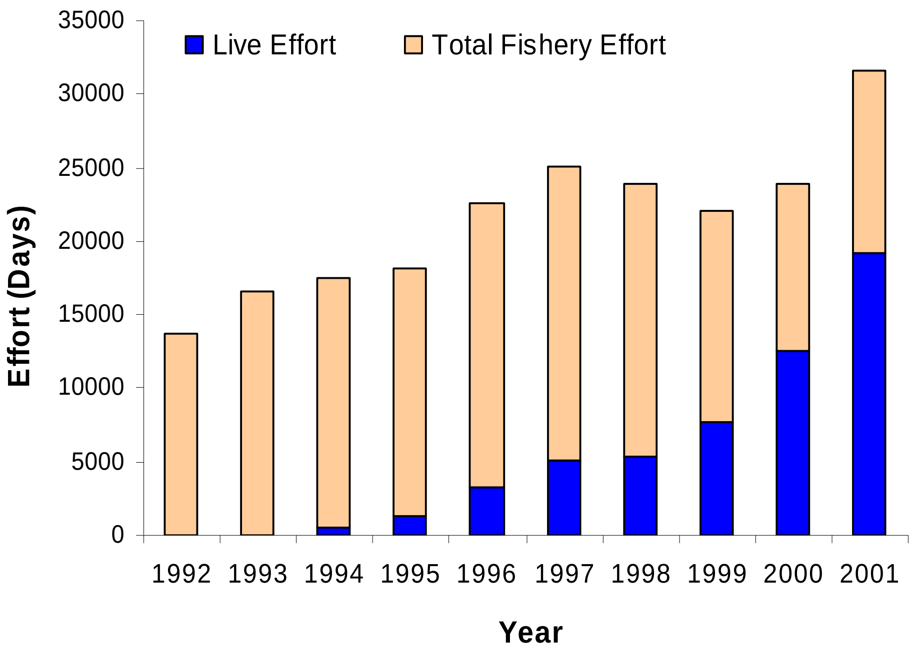

Figure 4-6: Total fishing effort and effort resulting in landings of at least some live fish within the GBR reef-line fishery (excluding Eastern Torres Strait) for days on which catch of Coral trout was recorded for the period 1992 to 2001.

Sources: Queensland Fisheries Service; Mapstone (unpublished data, 2000).

The difficulty faced in making the link between live and total effort has been attributed in part to inadequate and erroneous reporting in the QFS logbooks (see above) and also in differentiating between the potential sources of total effort increases. Firstly, prior to

1997 there was no requirement for operators to discriminate between live and fresh/frozen product in compulsory logbooks, with the result that many fishers would have recorded live catch as whole fresh or frozen catch (Mapstone et al. 2001). The likely result would have been an under-reporting of live effort days and an over-reporting of effort associated with fresh/frozen product. A second logbook intended explicitly for recording of live catch was introduced only in 1999, but limited directives were provided by QFS in the period between 1997 and 1999 as to how fishers should record live catch in their existing logbooks. Finally, fluctuations in overall effort and live effort as a component of it will be a product of existing operators who convert their vessels to hold live fish and the entry to the fishery of previously dormant licences for the purpose of supplying either live or fresh or frozen markets. The activation of these latent reef-line endorsements may be attributed to:

(i) individuals or firms, either existing licence holders or holders of a newly acquired licence, responding to economic incentives posed by the live trade or the threat of a proposed review of management arrangements in the RLF; or

(ii) multi-endorsed vessels active in another Queensland fishery who activated a previously dormant line endorsement in response to effort reduction programs (e.g.. in spanner crab and east coast trawl fisheries) or area closures (e.g. dugong protection areas in the inshore net fishery).

While increased activity by the latter group of fishers would directly translate to increases in total effort, the contribution of those existing operators to fluctuations in total effort is less distinct because while the number of live effort days would certainly have increased, their total annual effort days may have either increased or decreased[56].

Despite the inconclusiveness of the effect of the growing live fish trade on total effort in the RLF, stakeholder groups expressed concern over the potential impacts on the biological resource arising from increases in the allocation of effort to the fishery (QFMA 1997a; Mapstone et al. 2001). The presence of latent effort, which fomented

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[56] A currently active operation that converts to live will exhibit either an increase in effort associated with landings of live product fishing, but a decline in total days effort or an increase in effort associated with landing live fish, and an overall increase in total days fished.

these concerns, will be discussed in the context of management implications and economic incentives in the next chapter.

Other specific issues of concern raised by increase in effort directed toward capture of fish for the live market related to the perception that live operations would:

(i) localise fishing pressure on inshore reefs, closer to offload ports;

(ii) fish the one area for extended time periods, as higher prices for live product would offset diminishing catch rates;

(iii) target smaller coral trout due to higher prices paid for plate sized fish;

(iv) concentrate their fishing effort in shallower depths to avoid embolisms and improve survival rates of captured fish; and

(v) target spawning aggregations of some species because of the higher market prices.

(Squire 1994; QFMA 1996; QFMA 1998; Mapstone et al. 2001).

Mapstone *et al.* (2001) confirmed that live operations did remain closer to port, thereby inferring increased pressure on inshore reefs, but more recent analyses indicated that that concentration was a transient phenomenon, probably associated with early problems with husbandry on the primary vessels and reticence of fishers to be too far from offloading points with high valued catch susceptible to unpredictable on-board survival rates. Their data did not support the notion that live operations were less mobile, however, showing that operations spent less time at fishing sites while dories moved more frequently during fishing sessions. Their results in relation to (iii) and (iv) above were ambiguous, showing that live operations fished both deeper and shallower on average than dead operations depending on and season. Further, the proportion of small but legal sized coral trout in the catch were also both more and less than in the catches of non-live operations, again depending on the time of year. Finally they found little evidence to suggest consistent targeting of spawning aggregations of coral trout by vessels supplying either live or frozen markets.

4.5 Discussion

Increasing demand for live reef fish, initially from Hong Kong and more recently China[57], coupled with depletion of stocks from the near waters of the South China Sea has seen Hong Kong importers look increasingly farther afield for new supply sources. By 2000, 27 countries were exporting live reef fish into Hong Kong, although almost 98% of imports were accounted for by only 8 exporting countries: Mainland China, Thailand, Taiwan, Philippines, Indonesia, Malaysia, Vietnam and Australia (HKCSD, *unpublished data*). More than 70 species of live food fish are sold at wholesale markets in Hong Kong and China, the majority (>80%) of which are lower priced fish for household consumption (Lau and Li 2000). The higher priced species, distinctive of the trade, which supply mainly restaurant demand (maori wrasse, barramundi cod and coral trout), have historically made up less than 20% of total imports.

The downturn in the SE Asian economy from 1997 is credited with having a significant impact on demand patterns for LRFF (Cesar et al. 2000). This is evidenced by several key Hong Kong economic indicators all moving adversely from early 1998, with the Consumer Price Index and restaurant receipts falling, the unemployment rate rising and nominal wages stagnating (Hong Kong Census and Statistics Department, *unpublished data*). Moreover, during this period consumer demand shifted away from the very high priced reef fish (Maori wrasse, barramundi cod, giant grouper) toward slightly lower-priced species, such as coral trout (P Chan 2001, pers. comm.). In the wake of the SE Asian economic downturn, the market for LRFF in Hong Kong has not recovered, with prices for higher priced species remaining well below historical levels, despite ongoing forecasts of rising demand for high-value species from an increasingly wealthy mainland Chinese population, mainly in Southern China, which would result in higher prices for these species (Bentley 1999; Chan 2000).

Analysis of import trends of live fish into Hong Kong is complicated by reporting inadequacies bought about by the modes of transport used (section 4.3.1, Table 4–2 and Figure 4–3). Nonetheless, trends indicate that while the volume of imports of the high priced species may have declined, imports of live coral trout increased considerably

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[57] Since the early 1990's re-exports of live fish into China has grown from nil to almost 60% of all live fish imported into Hong Kong.

between 1996 and 2001. These outcomes seem likely to have been influenced by a combination of demand and supply events.

The view that higher volumes of coral trout being traded are a result of increased demand, whether due to expanding consumer markets in Southern China or as a substitute for increasingly unavailable more highly prized species, may be misleading. It is perhaps more likely that the sharp rise in imports of live coral trout into Hong Kong is being supply driven. Prior to the advent of the LRFFT in Australia, the annual catch of coral trout for fresh and frozen markets on the GBR was already substantially greater than every Southeast Asian country supplying live coral trout to markets in Hong Kong. From 1997, as the re-allocation of fishing effort toward the capture and marketing of live fish in the RLF began to rise significantly, the volume of live coral trout exports from Australia likewise increased, almost doubling imports into Hong Kong. It is therefore highly plausible that the supply of live coral trout being offered to the market has been surplus to demand. The subsequently lower wholesale and retail prices in Hong Kong have made consumption of live coral trout increasingly available and attractive to the conspicuous consumer. Coral trout (mainly *P leopardus*) is by far the most popular species comprising between 90-95% of higher priced imports.

On the supply side, Australia is playing an increasingly important role in the LRFFT. In contrast to other high-priced species, imports of coral trout into Hong Kong have increased significantly since 1997. Australia, whose exports have made up more than 85% of this increase, is now the predominant supplier of live coral trout. Exports from all other major suppliers of coral trout (see Table 4–5) have stabilised or decreased with the exception of the Philippines, whose increases are most likely from exploitation of new fishing grounds (Lau and Parry-Jones 1999). Concerns have been raised that these countries' export levels are being sustained through the capture and culture of immature juvenile fish for export, raising the spectre of growth and recruitment overfishing (Sadovy and Pet 1998b; Sadovy 1999).

There has been a considerable change in fleet behaviour in the RLF in response to the value-adding of an existing target species, although the diffusion of live technology throughout the fishery has not been uniform. The irreversible nature of investment (Clark et al. 1979, Charles et al. 1985) means the speed at which new technology disseminates amongst the fleet will be dictated by its superiority (e.g. profitability) and reliability. Another factor inhibiting adoption is risk, in terms of exogenous factors such as prices and catch rates. These factors appear to have relevance to the rate of adoption in the RLF (see Chapter 7).

Following the initial introduction of new technology to store fish catch alive, the major improvement has been an increase in the number of days live operators are able to maintain healthy live fish on board; from an initial 5-6 days to the current 10-12 days (Mapstone et al. 2001). These improvements permitted longer trips to be taken further from port and reduced the need to return to port as often. They would have enabled fishers in southern regions, where fishing grounds are much further from port, to undertake the longer trips necessary to make a trip commercially viable, in that they would lower annual steaming costs and per unit production costs and increase supply opportunities via increased time spent on the fishing grounds. Despite these improvements in on-board husbandry, more widespread and rapid adoption of live technology was likely retarded by the combined forces of the SE Asian economic crisis and a decrease in catch rates following a large scale cyclone event. Improved beach prices, a perceived diminution of market uncertainty, and dissemination of knowledge of the benefits of this innovation would appear to have been responsible for a surge in the number of operations that retained fish alive in the wake of these events.

The influence of these factors over time is borne out in regional variations in landings of live as a proportion of total catch of coral trout. Up to 1998, live as a proportion of total catch was highest in the Northern region. While proximity to fishing grounds was a key factor, proximity to the international airport in Cairns, from where live fish could be transported to Hong Kong, would also have been an influence. While live as a proportion of total catch increased in all regions after 1998, increases were particularly evident in the Central and Southern regions, where rapid rates of adoption have seen almost ¾ of the total catch of coral trout retained alive in 2001 in comparison to the Northern region which only retained just over ½ their catch alive in 2001 (Figure 4–4).

What is not clear from the data, however, is the source of the increase in effort allocated toward catch and retention of live product. In the early years of the trades influence, increases in the number of days on which live catch was retained (live days) were considerably less than increases in total days on which coral trout in any form was retained. These additional days may be evidence of some boats entering the RLF from another fishery, initially to catch live fish during periods of high live prices, and then continuing to use their line endorsement and retaining frozen or fresh fish - thereby expanding their total effort input more than their live input. Increases in live days fished in 1999 and 2000 exceeded increases in total days, suggesting that many boats already active in the fishery and retaining only frozen product installed live technology and concentrated their effort on retaining live product., Increases in total days fished in 2001 were only slightly more than for live days[58] suggesting another influx of latent effort.

If demand for coral trout did, as predicted (Briones 2007), trend upwards due to growing incomes in mainland China, and if unsustainable fishing practices[59] continue to impact adversely on other countries' abilities to maintain levels of supply of coral trout, Australia may well play an increasingly important supply side role in the LRFFT. The willingness of fishers in the RLF to meet growing demand however, may depend on macroeconomic conditions such as exchange rate fluctuations, which have the potential to either mitigate or exacerbate price. Continual price deflation in Hong Kong since early 1997 has depressed prices of all LRFF species there (International Marinelife Alliance, *unpublished data*). The impact of these price declines has been mitigated by favourable exchange rate fluctuations to source countries[60]. The wholesale price of coral trout in Hong Kong in November 1999 was HK$300/kg - equivalent to A$61/kg (A$1 = HK$4.95), but by November 2000 had fallen to HK$252/kg - equivalent to A$62/kg due to a weaker Australian dollar (A$1 = HK$4.07). A strengthening Australian dollar in concert with static or lower wholesale prices for coral trout in Hong Kong should, all else being equal, translate to lower beach prices being offered to fishers in the RLF. How fishers respond to such trends (e.g., by switching between different product forms) will depend on the relative prices of live and frozen fish.

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[58] The increase in live days fished was approximately 90% of the increase in total days fished

[59] The widespread adoption of unsustainable fishing practices (sodium cyanide, targeting of spawning aggregations) has been blamed for extensive localised depletion of high-priced species and subsequent declines in their availability (Johannes and Reipen 1995; Barber and Pratt 1997; Bentley; 1999)

[60] The Hong Kong dollar is pegged against the US dollar at a rate of HK$7.80 = US$1.00 and the US dollar has strengthened against all currencies supplying the LRFFT.

4.6 Summary

The emergence of Australia as a reliable new source of LRFF will have wide-ranging implications for the traditional commercial RLF. While overall, the catch and effort data point to a significant transformation within the fishery, the likely extent and longevity of this transformation are not well understood at either a fishery or fishing firm level. A more thorough examination of the behaviour and profiles of fishing firms, and of their decision-making in respect of whether or not to market LRFF will provide input into the future management of the RLF.

CHAPTER 5

THE FISHING FIRM RESPONSE TO THE VALUE ADDING OF AN EXISTING TARGET SPECIES IN THE GREAT BARRIER REEF REEF-LINE FISHERY

5.1 Introduction

The live reef fish trade represents an alternative high 'value-added'[61] market to traditional frozen and chilled fisheries. An example of adding value to an existing target species through product differentiation has occurred within the Great Barrier Reef (GBR) reef-line fishery (RLF). The Live Reef Food Fish Fishery (LRFF) as part of the RLF is unique compared with traditional value-adding scenarios in that it involves adding value to the main target species with minimal changes to existing fishing methods (hook and line) and without promoting increased productivity.

The advent of the LRFF in Australia can be examined in terms of the structure and operational behaviour of the reef-line fishing fleet in response to the emerging live fish trade, with particular emphasis on changing market conditions (beach price) and how they have influenced the adoption of new technology (investment). In cause and effect parlance, this increased price (cause) will have two concurrent effects on the fishing firm: an investment response and a supply response.

This chapter describes the response of existing fishers in RLF to the emergence of the live fish trade in Australia in terms of the key market drivers; increased prices for existing target species and high demand for live fish; that would likely motivate a shift to live fishing.

[61] Value-added is the difference between the revenue earned through the sale of the product and the amount paid by that firm for products supplied by other firms that are required as intermediate inputs.

The purpose of this chapter, therefore, is to:

(i) examine the business unit response to the emerging LRFF as part of the commercial RLF, in terms of investment and allocation of effort to the marketing of either live or fresh/frozen product; and

(ii) emphasise where possible, through descriptive data, the unique aspects of the developing LRFF that call for further research;

5.2 Theoretical Background

Increases in prices for fishery products will, *ceteris paribus*, improve industry profits and may generate an economic incentive for increased capital investment and fishing effort[62] (Bjorndal and Conrad 1987b; Kirkley and Squires 1988; Sampson 1992). This broad premise is based upon the neoclassical theory that all firms will choose to operate so as to maximise profits[63]. Although a detailed theoretical discourse of profit maximising behaviour is beyond the scope of this chapter, a summary of the main points would be useful in contextualising the economic forces at work within the LRFF.

The premise of profit maximisation as the underlying motivation for a firm's behaviour is considered appropriate, regardless of the market structure within which the firm is operating [McConnell and Brue, 2004]. Pure (perfect) competition provides the benchmark that can be used to evaluate the functioning of markets and efficient allocation of resources (Braff 1969; Varian 1990; Cyert and March 1992). Pure competition in a fishery context implies that: 1) no one firm is able to influence the price of factors (i.e. labour and capital) employed or product sold; 2) products are homogeneous; 3) all firms have complete information about the prices each faces; and 4) there are no barriers to entry into and exit from the industry[64] (Anderson 1976; Lawson 1984; Clark 1990,; Common 1995; Ward 2000).

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[62] The incentive for increased capital investment and effort arises from additional 'resource rents' accruing to inputs to production. Rent is the surplus after all costs of production have been deducted from the price of the resource, including the opportunity cost of labour and capital. While fishery rents generally attributable to resource scarcity, they may also reflect short-term supply and demand imbalances, with above normal profits being the market signal that induces greater investment.

[63] There may be many dimensions to a firm's output choice such as ensuring long term survival (Rothchild 1947); maximising sales revenue (Baumol 1962) or pursuing satisfactory profits, *satisficing*, (Cyert and March 1992).

[64] Entry (and exit) into (from) the market must be free and unimpeded but not necessarily frictionless or instantaneous as in a perfectly competitive market (Braff, 1969)

5.2.1 Price and Investment

Empirical data indicates that consistent differences in profitability between segments of industry persist over time (Geroski et al. 1990:84). These difference, which are evidence of the 'non-competitiveness' of an industry, can be explained by the existence of a number of barriers to entry that allow some firms to enjoy a degree of market power for appreciable lengths of time. These entry barriers include: regulatory constraints; technical or physical specifications of capital; production (supply) and consumption (demand) uncertainty; and imperfect knowledge with respect to profitability comparisons (Le Gallic 2000). Each of these barriers has application to the RLF.

Under the traditional assumptions of competitive markets, producers will base their production strategies on the principles of profit maximisation. The competitive firm will maximise profits by choosing the output level, at given prices, at which total revenues exceed total costs by the largest amount (Braff 1969; McTaggart et al. 1999). Under certain conditions[65], an increase in the price(s) of good(s) produced will see profit maximising firms choosing to increase their output. This is achieved by adjusting the combination and level of inputs into the production process. These inputs will be either fixed (capital, plant and machinery, etc.) or variable (labour, fuel, etc). The extent to which the firm can alter its output will depend on the time scale under consideration. These time scales, described as either short or long-run[66], will determine the firm's ability to adjust inputs in response to price changes (Sampson 1992:37).

In the short run, the firm's capacity is considered static and any increases in output can only be achieved by varying the level of variable inputs – to the point where additional revenues from higher prices are matched by additional costs associated with greater inputs to production. In contrast, long-run implies that the firm is able to increase, or decrease, it's productive capacity or fixed inputs (McGaw 1981; Sampson 1990; Varian 1990). Investment is regarded as a long run response to a change in prices. Where

[65] If marginal revenue from an additional unit of output exceeds the marginal cost of producing that unit of output, additions to total revenue are greater than additions to total cost and profits will increase by expanding output.

[66] The concept of long-run and short-run is ambiguous with no set time limit that distinguishes between the two. For some firms the long-run may be defined as a few months whilst for others adjusting capital stocks may require several years.

expected future incomes from a price increase are considered sufficiently great, the firm can profitably undertake investment to expand its productive capacity.

The validity of the profit maximising hypothesis has been repeatedly questioned in the fisheries economics literature[67], with many authors arguing that non-monetary factors will have a large, and in some cases dominant, influence on fishing behaviour (Anderson 1980; Gatewood and McCay 1990; Hanna and Smith 1993). The existence of non-monetary benefits, however, does not preclude the possibility of profit maximising behaviour and several authors have reasoned that fisher responses, while reflecting predominantly profit maximising behaviour, encompass other non-monetary goals (Bockstael and Opaluch 1984; Allen and McGlade 1986; Charles 1994; Robinson and Pascoe 1997).

If we assume that all active firms under examination in this fishery are behaving primarily as profit maximisers, what relevance does this discussion have to commercial reef-line fishers participating in the LRFF? Firstly, have firms reacted as expected to a change in the price of production-related goods, in this case the price received from marketing the fish in live as opposed to frozen or fresh form? Second, do the conventional short and long run relationships accurately reflect the chronological order of events that dictate supply? For the firm to participate in the LRFF, it must first undertake investment (a typically long-run phenomenon) that not so much increases its capacity to catch more fish, but provides it with the ability to *'produce'* the new product (live fish)[68]. The firm must make a long-run decision to invest in a new technology that enables it to retain live product for sale before it can make any short-run decision regarding the amount and combination of its variable inputs.

5.2.2 Price and Supply

The quantity supplied of a particular good by individual firms and the market as a whole in any given period can be depicted through the use of supply curves. A supply curve

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[67] Generally, the description of the traditional 'competitive' theory of the firm is regarded as inappropriate for the fishing firm. This is because profit maximisation is complicated by the common property nature of the resource. Also while the fishing firm has some control over it's input of effort, it has much less control over it's output in the face of catch rate uncertainty and weather impediments.

[68] In some instance, firms who have re-configured their vessels to store live fish have reduced their total catch capacity through sacrificing existing freezer or brine space in favour of holding space for live fish.

will show the quantities offered for sale by producers over a specified time period, at various prices. The supply curve normally slopes upward and to the right reflecting the assumption that producers will supply more of a product if offered higher prices (Anderson 1986; Eckert and Leftwich 1988; Common 1995). That is, the firm's response to changes in the market price of a commodity will be to change the quantity supplied, depicted as a movement along a supply curve. The quantity of a given product a firm intends to offer for sale may be influenced by numerous other determinants including: the price(s) of related goods; the costs of inputs into the production process; expectations for future prices; the number of suppliers; and the state of technology (Harris 1990; Thomas and Weber 1990; McTaggart et al. 1999). A change in any one of these determinants, with price remaining constant, will lead to an inward or outward shift of the supply curve. Each of these supply determinants has direct and occasionally unique relevance to the advent of the LRFF. Although a detailed treatise of these determinants is outside the scope of this chapter, the key points are summarised in comparing the shift in supplying product for the traditional frozen fish market to supplying fish to the live fish market.

5.2.2.1 Product Differentiation and Relative Product Price

Frozen or fresh product and live product can be considered as production related goods, or *substitutes in production*[69] (see 4.4.2). Assume in the first instance that the firm is capable of producing only frozen product and produces output of X_{F1} at price P_{F1} (Figure 5–1(a)). In response to the value adding of an existing target species, however, the firm invests in live storage capability enabling it to retain fish for either the frozen or live markets. Once the fishing firm has become "live capable", it will allocate resources toward the capture of either live or frozen product, or both, depending on their respective beach prices and market demand. If we assume that fishing costs remain relatively constant once the initial investment in conversion has been made, the most likely outcome would be that the fishing firm allocates more, or all, of its resources toward catching fish for the live market. This is shown by a rightward shift of the supply curve in 5–1(b) from S_L (where it was producing no live fish) to S_{L1} where it may initially produce X_{L1} live fish at price P_{L1}. Correspondingly, the firm will produce

[69] A *substitute in production* refers to a product that competes with another for available factor inputs. Changes in prices of one product will lead to a re-allocation of these scarce resources.

less frozen fish, shown by an inward shift of the supply curve in Figure 5–1(a) from S_F toward S_{F1}.

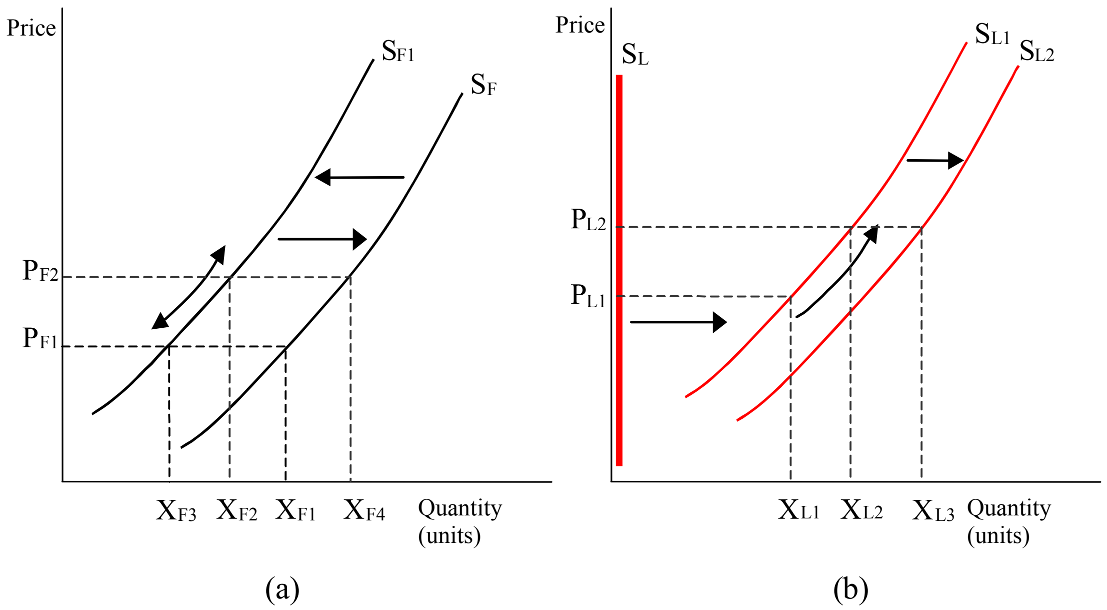

Figure 5-1: Fishing firms short-run and long-run supply response to changes in prices of substitute products in the markets are shown for (a) frozen and (b) live fish. The advent of the live fish trade is reflected by the appearance of the supply curve for live fish (S_{L1}) from S_L (where the firm produced no live fish). Continued higher prices for live fish will lead to a further re-allocation of resources among existing fishing vessels and the entry of new fishing vessels. These combined events will cause an outward shift in the supply curve for live fish (to S_{L2}) and simultaneous inward shift of the supply curve for frozen fish (toward S_{F1}). Longer run transformations of live and frozen markets are not explicitly addressed in this diagram, except for the potential increase in price for frozen fish, brought about by excess demand. This may lead to some vessels reallocating resources in order to supply more frozen fish, shifting the supply of frozen fish outward (toward S_F). Assuming constant costs, long-run supply curves are infinitely elastic (horizontal) at P_{F1} and P_{F2} where prices equal minimum average total costs.

Any further increase in the beach price for live fish relative to frozen fish will likely be characterised by both movements along the supply curve, and further rightward shifts of the supply curve for live fish and a simultaneous leftward shift of the supply curve for frozen fish. If the price for live fish increases to P_{L2}, existing live fishers will allocate more effort towards the capture of live product increasing their output to X_{L2}. In addition, more fishers may convert their vessels to live, causing the supply curve for live fish to shift out to S_{L2} producing X_{L3} live fish at price P_{L2} . There will likely be a corresponding further inward shift of the supply curve for frozen product toward S_{F1}.

This pattern will continue as more of the existing fleet converts to live, and as new firms enter the market.

5.2.2.2 The Cost of Inputs to the Production Process

In traditional industries a negative relationship exists between the price of inputs to the production process and market supply with cost decreases (increases) denoted by outward (inward) shifts in the supply curve. In fisheries, this simple relationship is distorted by the stochastic nature of the fish stock. For example, declining per unit costs from improvements in technology that increase productivity may enhance fishery rents and lead to an increased supply of effort to the fishery. This can create a perverse long-term outcome as the increased fishing effort reduces stock abundance and increases per unit fishing costs (Whitmarsh 1998). This stock dependent nature of fishing, whereby the individual vessel, while controlling its production of fishing effort, has only indirect control over its catch rates, has seen it described as an *increasing cost industry* (Anderson 1985a; Doll 1988).

As earlier recognised, innovation in the RLF has led to an increase not necessarily in productive throughput per vessel but in the value of a unit of production. While the combination of variable inputs into the production process remains relatively unchanged, variable costs may differ between those vessels supplying live or frozen markets due to the dynamics of different operation types. Live operations on average do shorter trips and tend to fish closer to port throughout the trip duration, but make substantially more trips annually and carry a greater cargo weight (fish plus water in onboard tanks) per trip (Mapstone et al. 2001). So, while more trips and heavier loads on both the primary and tender vessels may increase fuel use, reduced overall steaming distances may decrease aggregate fuel costs. Furthermore, costs associated with holding live as opposed to frozen fish are likely to be higher due to the need to have water pumps running constantly in addition to the existing costs of running a freezer(s). Any positive net outcome (i.e., increased per day fishing costs being offset by relatively larger increased per day revenues) will provide an incentive for increased effort among existing and potential licence holders.

5.2.2.3 The State of Technology

The state of technology generally sets the upper limit on the amount of a particular product that can be produced from a given amount of resources. In the sense that technology improvements may lead to increases in output, new technologies can lower the cost of producing that product (Sampson 1992; Whitmarsh et al. 1995; Rosseger 1996). This implies that more of a product will be offered at that price (an outward shift in the supply curve), but requires us to make certain assumptions regarding the fishery resource and capital employed[70] (Anderson 1976; Pascoe and Mardle 1999). As recognised in Chapter 2, the innovation that has enabled the retention of live fish for sale does not conform to standard technological outcomes in the sense of increased production. Although this research does not encompass the wholesalers and processors responsible for export of live fish to Hong Kong, they have been the beneficiaries of improvements in transportation technology. The introduction of purpose-built transportation bins has led to efficiency gains in terms of transportable volumes as well as reduced mortality rates and improved quality of fish products (Sadovy et al. 2004).

5.2.2.4 Number of Suppliers

In 5.2.1 above, it was acknowledged that live and frozen fish were substitute goods because they competed for the available harvesting resources (labour, capital). Higher prices for live fish would see a re-allocation of resources toward supplying live product, resulting in lower retention of fish for frozen markets. In the long run this relationship would likely be stronger, because of the time lags associated with re-allocating capital stocks. As more fishers switch to supplying fish to live markets, the market supply of fish supplied to frozen markets will decline. The long-run response to excess demand for frozen fish may be an increase in the frozen price (an upward movement along the supply curve S_{F1} in Figure 5–1 (a)). Any subsequent incentive for fishers to increase the supply of frozen fish would be reflected by an outward shift in the market supply curve for frozen fish toward S_F in Figure 5–1 (a).

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[70] These include constancy in catch-per-unit-effort (CPUE) and the potential for effort increases. Any effort increases that have a detrimental effect on species abundance will affect the ability of fishers to increase supply in response to changes in price. Opportunities for individual vessels to increase effort may be subject to weather constraints, although where access to the resource cannot be restricted, additional effort may emanate from entry of new vessels.

5.3 Methods

5.3.1 Data Sources

Primary interview data drawn from sections (i), (ii), (iii) and (iv) of my interview questionnaire (Appendix 2) were used to explore fishers' responses to the opportunities presented by the market in live fish and their decisions to incorporate live fishing practices into the fishing business (Table 5-1).

Table 5-1: Questions used to describe fisher's responses to the advent of live fish trade.

Section	Question #	Question description
Fishing History	Q2	Year entered reef-line fishery
	Q7, Q8	Licence details
Operational Characteristics	Q13	Primary vessel characteristics
	Q17	Market value of fishing operations
	Q20	Value of licence package [1]
Live Fishing History	Q35	Year entered live reef fish fishery
	Q35	Live catch as proportion of total catch
	Q36	Vessel conversion category
	Q37	Year of conversion to live
	Q37 b)	Existing vessel - upgrade details and costs
	Q38, Q39	New vessel - upgrade details and costs
	Q40	Construction of new vessel - costs
	Q43	Fishing trip targeting behaviour
	Q44	Targeting behaviour determinants
	Q45 - Q47	Effort allocation toward capture of live product
	Q48	Minimum acceptable fish price
Investment Decision-making	Q54	Satisfaction with operation size
	Q70	Risk of investing

[1] Questionnaire responses cross-referenced against broker supplied licence value data to check for validity of respondent data.

Both primary and secondary data collected are presented in descriptive form in section 1. Interview data, used to examine fishers' responses to the emergence of the LRFF, are explored in section 2 in the context of economic theory of investment and supply. Historical data on fishing licence values were provided by local brokers whose businesses dealt primarily with the trading of commercial fishing licences

5.3.2 Data Analyses

Firms usually adjust output according to market prices of goods they produce. The supply response to changes in price, particularly in fisheries, often is not instantaneous but occurs with a lag of one or more periods (Holland and Sutinen 1999). Recognising that supply in any given period depends on prices in the current *and* previous periods, a lagged log linear[71] regression model was used to estimate the relationship between the monthly wholesale price of live coral trout (X_t) and the propensity of vessels to market their product live in that month (Y_t). This propensity is measured as a proportion of the live requisite vessels in my sample who have actively marketed live product in a given month, across a 30-month period between July 1997 and December 1999. A hierarchical model, which requires predictor variables be entered sequentially into the model according to principles of causal priority and relevance, was preferred over other stepwise regression procedures [Cohen, 1983 #724: 120-124]. The full log-linear model was hypothesised as:

$$\ln Y_t = \alpha + \beta_1 \ln X_t + \beta_2 \ln X_{t-1} + \beta_3 \ln X_{t-2} + \cdots + \beta_k \ln X_{t-k} + \varepsilon_t \quad [1]$$

There frequently will be correlation between residual terms (μ_t) with multiple regression models involving the use of time series data. This *autocorrelation* will affect the accuracy (i.e., overestimation of variance), but not the precision, of coefficient estimates leading to a possible Type *II* error. The Durbin-Watson *d* test was used to detect for autocorrelation in the model. Where detected, dependent and independent variables were transformed using ρ, the *Markov first-order autoregressive*[72], estimated from the Durbin-Watson *d* statistic and applied using the Cochrane-Orcutt iterative procedure (Gujarati 1988:375) to correct for that autocorrelation. Squared residual estimates were plotted against all explanatory variables to test for heteroscedasticity but no systematic patterns were detected implying heteroscedasticity was not present in the data. The transformed model can be written as:

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[71] A log-linear model was preferred so as to provide estimates of supply elasticity directly. Moreover, a straight linear regression models would imply a positive supply with a zero price.

[72] ρ can be interpreted as the *first-order coefficient of correlation* that corrects for the effect of the systematic shift in the disturbance term ε_t due to ε_{t-1}.

$$(\ln Y_t - \rho \ln Y_{t-1}) = \alpha(1-\rho) + \beta_1(\ln X_t - \rho \ln X_{t-1}) + \beta_2(\ln X_{t-1} - \rho \ln X_{t-2}) + \beta_3(\ln X_{t-2} - \rho \ln X_{t-3}) + (\varepsilon_t - \rho\varepsilon_{t-1}) \quad [2]$$

Using SPSS software, three lagged models were estimated and analysed using current period price (X_t) and successively price lagged by one (X_{t-1}), two (X_{t-2}) and three (X_{t-3}) periods. The second model, where Y_t was regressed against X_t , X_{t-1}, and X_{t-2}, significantly improved the models predictive ability, as measured by the adjusted R^2. A third model, regressing Y_t against X_t , X_{t-1}, X_{t-2} and X_{t-3} did not significantly improve the models predictive ability and X_{t-3} was dropped from the model.

One-way Analysis of Variance (ANOVA) was used to test for changes in various characteristics of fishing effort and catch. One-way ANOVA tests were performed on the metric 'percentage of months in which fish were marketed live' estimated from the survey data to test for equality of means by year of entry to the live fishery. Planned comparisons were used to test the hypothesis that later entrants (post-1996) to the live fishery would have a heightened response to downward movements in prices than did earlier entrants (pre-1997)[73]. One-way ANOVA was also used to test for the impact of price changes on the proportion of total catch retained alive aggregated across all vessels for all years. Planned comparisons were again used to test the hypothesis that earlier entrants (pre-1997) to the live fishery retained more of there catch alive during times of lower prices than did later entrants.

5.4 Results

Underpinning the investment and supply responses by fishers in the RLF has been the value-adding of an existing target species. The wholesale beach price for live coral trout has consistently exceeded the equivalent beach price for the same species presented in frozen and fresh form, with the price of live product ranging between 40% and 300% higher than its fresh or frozen counterpart (Figure 5–2). The following two sections present survey data of the impact of price variation on investment in live technology

[73] Planned comparisons are an alternative to using multiple t-tests to compare all pairs of groups that lessen the probability of making a type *I*, or *familywise*, error [Field, 2000 #725].

and supply of live product, while section 5.4.3 explores the impact of this product value-adding on expected future returns through the capitalisation of fishing licences.

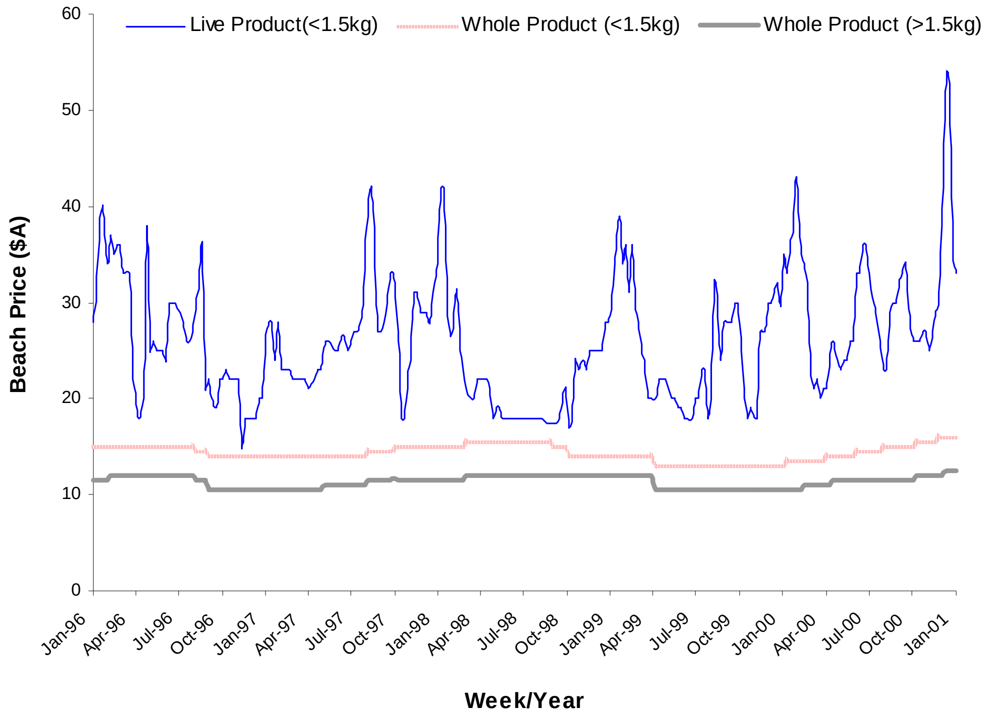

Figure 5-2: Comparison of wholesale beach price for live trout of less than 1.5kg in weight and frozen coral trout of less than and greater than 1.5kg in weight for the period January 1st, 1996 to December 30th, 2000.

Source: unpublished wholesale trader data

5.4.1 Price and Investment

The fleets' response to the value-adding of an existing target species has been a comprehensive investment program undertaken by both existing fishers with a fishing history predating the LRFF as well new entrants to the fishery. Of the 50 interviewees, 33 (66%) had adopted the means to catch and store live product since 1994, following the emergence of the LRFF fishery (Figure 5–3)[74]. Mapstone et al. (1996a) observed that the most active 60 vessels in the fleet accounted for ~70% of fleet-wide effort directed at catching coral trout. Based on the scoping phase of my survey program (Table 3–1), and evidence of an increase in the number of vessels targeting mainly coral trout since 1994 (Mapstone et al. 2001), this conversion rate is assumed representative of the response of the most active vessels in the fleet to the LRFFT. The pulse of vessels

[74] Ongoing contact with the sampled fishers revealed that a further eight (8) vessels have converted to live since the completion of the interview program. This represents 82% of sampled vessels.

adopting live capability during 1997 is thought to be a direct response to increasing prices and demand for live product and high catch rates in the fishery at that time. The subsequent levelling off in the rate of diffusion was correlated with a downturn in prices in 1998 (in response to a declining Southeast Asian economy which flowed through to fishery imports) and decline in catchability (following a major cyclone event in 1997).

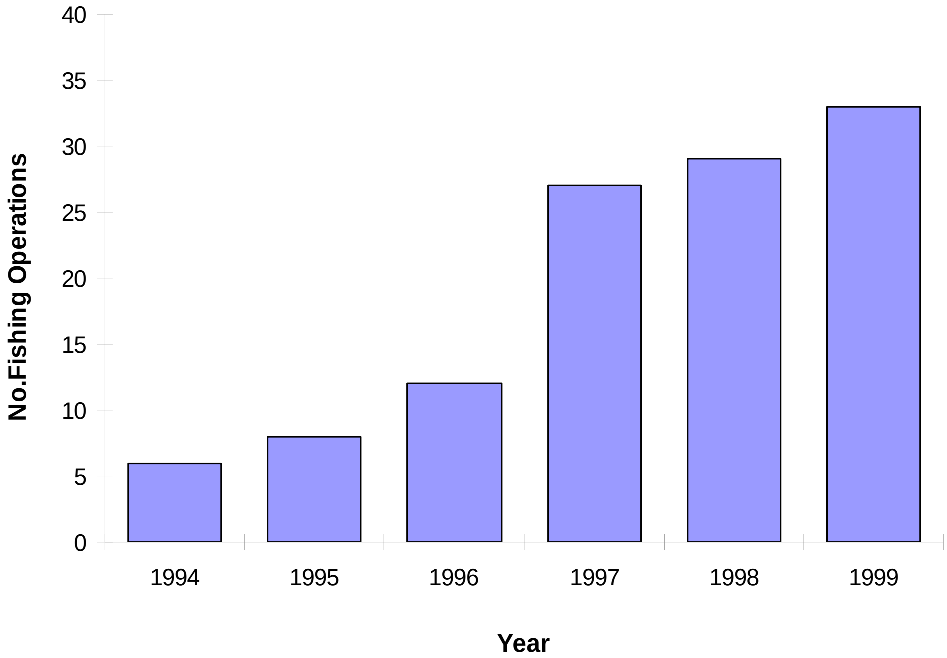

Figure 5-3: Adoption of live capture and storage capability among sampled fishers between 1994 and 1999 inclusive (n = 50).

The magnitude of investment required to participate in the live fishery will vary with origin of the decision-maker: as the owner of an existing fishing operation or an intended entrant to the fishery. For the owner of the existing operation, the decision faced is whether to modify the existing vessel or upgrade to a new vessel. The physical characteristics and configuration of their existing fishing vessel may influence this decision. Of the 33 respondents who adopted live capability, 25 were licence holders with an operational history in the RLF targeting fish for the frozen market, while the remaining 8 vessels entered the live fishery directly with no prior history with that operator in the RLF. Of those 33 respondents who were engaged in the live fishery, 17 had converted their existing vessels, 14 had purchased new vessels, and 2 had vessels' purpose built to participate in the LRFF (Figure 5–4).

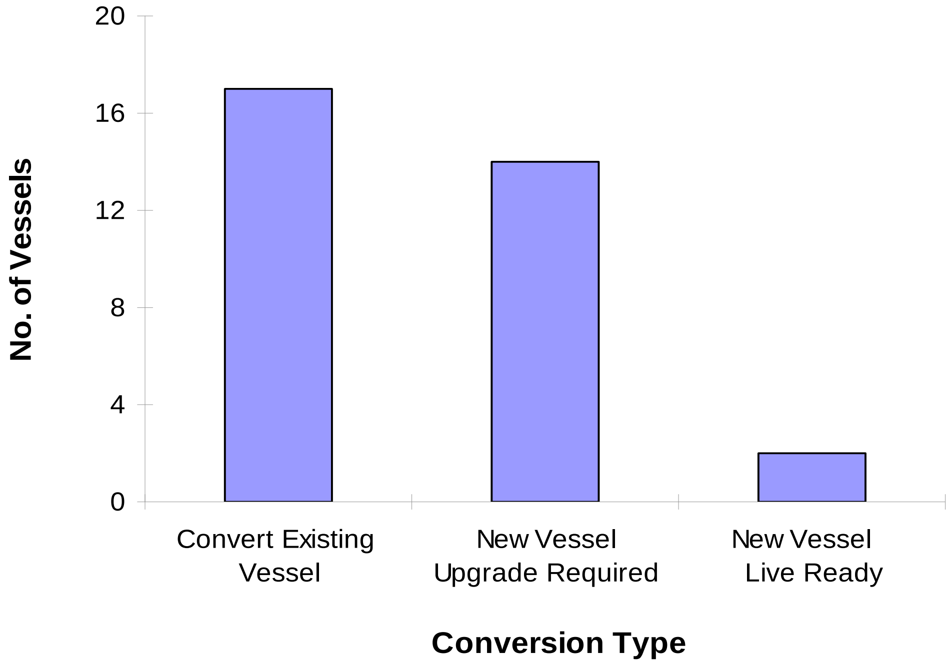

Figure 5-4: Summary of modes of operations' entry into live fishing by conversion type (n = 50). Of the 14 new vessel upgrades, 6 were derived from the existing fleet with the remainder representing new boats entering the fishery. All 17 conversions of existing vessels were active in the RLF prior to the advent of the live trade.

Expenditure undertaken to adopt live capacity varied widely across the respondents surveyed in accordance with conversion type. For those who converted an existing vessel, expenditure ranged from $5 000 (for installation of simple above deck tanks) to $70 000 (for structural modifications to vessels below deck, freezer or storage capacity). The average cost of entry into the LRFF of $24 440 for those operators upgrading their existing vessel was low compared with those who purchased a new vessel. Those existing fishers who replaced their old vessel to enter the LRFF spent an average total cost of $210 000 in the action. Licensees with no history in the RLF, for whom entry necessitated the purchase of both a vessel and a licence, spent an average total amount of $438 875 to enter the LRFF (Table 5–2). These results provide some insight into the greater barriers to entry, in terms of capital acquisition costs, faced by those intending live fishery participants without existing facilities (licence and vessel).

Table 5-2: Mean total upgrade costs for existing and new operations (new operations include both live ready vessels and vessels requiring additional upgrade or conversion).

	Existing Vessel Conversion			New Vessel Purchase			
	Boat Costs	Upgrade Costs	Total Costs	Boat Costs	Upgrade Costs	Total Costs[1]	Licence Costs[2]
Mean	–	24 440	24 440	250 940	48 440	299 375	89 500
Minimum	–	5 000	5 000	100 000	0	135 000	44 000
Maximum	–	70 000	70 000	650 000	150 000	730 000	160 000
95% CI	–	10 795	10 795	89 110	19 720	97 005	36 620

[1] Excludes the cost of purchasing a licence which contains a line fishing endorsement.

[2] Of the 16 new vessel purchases, 10 survey respondents had entered the live fishery from outside the fishery. Of these, 8 purchased a licence while 2 were leasing licences at the time of the survey.

Some insight into potential barriers to entry also may be gleaned from operator satisfaction with current operation size or type (Table 5–3). Overall satisfaction with fishing operation size was 62%. A significant difference in satisfaction levels occurred between live (75.8%) and frozen (35.3%) operators (Log-likelihood Ratio = 7.777, $p < 0.01$). Furthermore, 81% of all operators expressing satisfaction with operation size were those engaged in live fishing. Conversely, of those operators expressing dissatisfaction with operation size or type, 58% supplied only frozen product. Of the 11 frozen operators signalling dissatisfaction with their current business size, 9 indicated upgrading to a larger vessel to facilitate the switch to live fishing or the installation of live tanks as their main priority. This appears to support the notion that access to capital was a barrier restricting these operators from realising the switch to live fishing.

Table 5-3: Satisfaction with size (or type) of fishing operation by operator type

Operator		Satisfaction with size of fishing operation		
Type	Group characteristic	Satisfied	Dissatisfied	Total
Live	Count	25	8	33
	% within live operations	75.8%	24.2%	100.0%
	% within satisfaction with size of fishing operation	80.6%	42.1%	66.0%
Frozen	Count	6	11	17
	% within frozen operations	35.3%	64.7%	100.0%
	% within satisfaction with size of fishing operation	19.4%	57.9%	34.0%

5.4.2 Price and Supply

Fishing firms within the RLF who have invested in the requisite live technology will likely base their production decisions on relative prices of frozen and live product forms, in similar fashion to a multi-species fisheries where fishing firms' targeting behaviour is determined by relative prices of alternate target species (Ward and Sutinen 1994). Cyclic fluctuations in the beach price for live fish landed in Australia (Figure 5–2), as dictated by seasonal demand in Hong Kong (see 4.3.1), and longer-term trends in these beach prices both influenced the targeting behaviour of live capable operations in the RLF. The allocation of effort towards the capture of live product corresponded well with seasonal pricing patterns, increasing and decreasing in concert with price variations. These effort and catch patterns are presented below.

5.4.2.1 Price and Effort

At the time of the interview, respondents who had converted their operation were asked to indicate those months, in the period from July 1997 to December 1999, when their catch comprised coral trout to supply the live export market. For those who converted prior to July 1997, the maximum number of months able to be fished was 30, with this number declining in accordance with the proximity of entry to December 1999 (Figure 5–5). Using the sequential procedure described in section 5.3.2, model [1] was used first to analyse this relationship between live price and effort. Autocorrelation was detected between error terms ($d_{29,2}$ = 0.622, d_L = 1.054, d_U = 1.332) and the model transformed using the coefficient of correlation, ρ. Using the same sequential procedure, the transformed model [2] supports the hypothesis that vessels react positively, albeit slightly, to increases in price of live fish ($F_{3, 24}$ = 5.978, p = 0.003). No autocorrelation between error terms was detected in the transformed model ($d_{29, 2}$ = 1.746). The model coefficients provide information on supply elasticity's directly with the results indicating that fishers' decisions to market live product will be influence by wholesale prices in the previous (X_{t-1}) and current (X_t) periods, with wholesale price lagged by one period being a slightly better predictor of a vessels propensity to catch fish for live markets. Generally, decisions of "live capable" fishers who may at any given time be marketing only frozen product to revert back to marketing live product will be influenced by higher price levels in more than one period. The parameterised transformed regression model is (t-values are in parentheses):

$$Y_t = -0.627 + 0.249 X_t + 0.334 X_{t-1} - 0.060 X_{t-2}$$

$$(-4.305, p < 0.001) \quad (2.251, p = 0.034) \quad (2.949, p = 0.007) \quad (-0.998, p = 0.328)$$

$R^2 = 0.428$ Adjusted $R^2 = 0.356$

The aggregate outcome depicted in figure 5–5 is consistent with short-run movements along the supply curve for live fish. As new firms enter the fishery, outward shifts of the supply curve would be expected at all price levels.

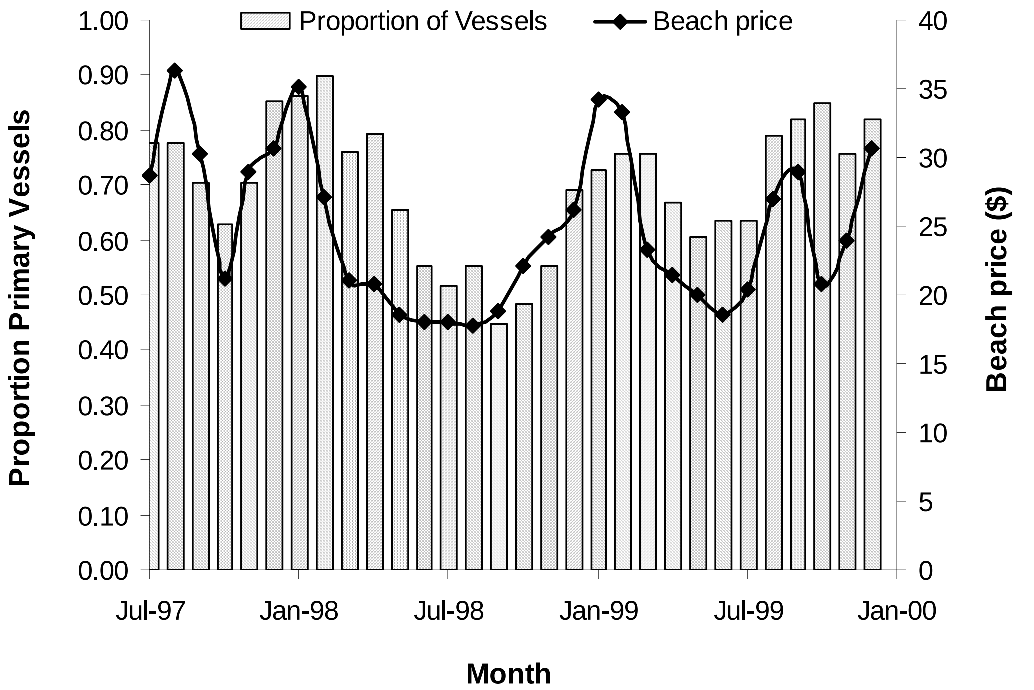

Figure 5-5: Effort allocated toward the capture and sale of live Coral trout, measured as the proportion of all vessels who targeted live product in that month, (LH axis) and the corresponding wholesale beach price in $A (RH axis) from July 1997 to December 1999

Examining the monthly behavioural responses of cohorts of new participants in the live fishery to relative changes in price, however, can provide improved insight into the effect of price on supply. When examining monthly responses by year of the vessel's entry to the live fishery (Figure 5–6), the proportion of months for which respondents reported marketing live product was significantly different across cohorts ($F_{5, 27}$ = 3.347, $p = 0.018$). Planned comparisons of those vessels who converted their operations pre-1997 against those who converted their operations post-1996 showed the latter to have retained live product for a significantly lower proportion of all possible months (t

$_{0.05, 27}$ = 3.062, p = 0.005). The decline in proportion of all possible months fished live in 1997 and 1998 corresponded with a large jump in the number of vessels in the sample who began marketing their catch alive during those years (Figure 5–3). Those years corresponded with a downturn in prices experienced in the live export market in the wake of the Asian economic crisis, which would have significantly influenced the 'aggregate' results presented in Figure 5–5.

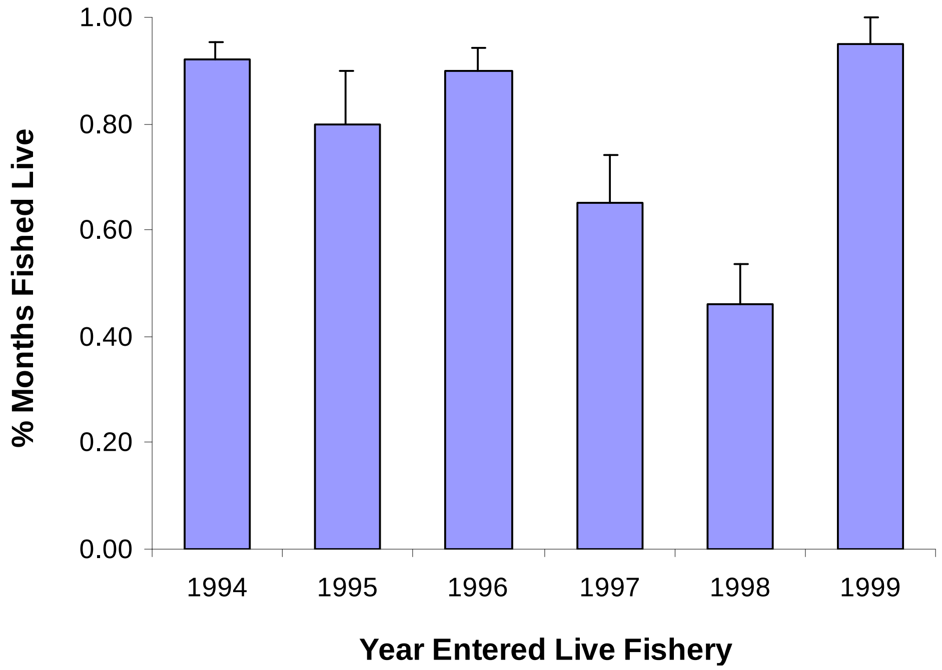

Figure 5-6: Mean proportion of months fished live between July 1997 and December 1999 by year of entry for all live operations. Mean is calculated by dividing the actual by the maximum possible number of months a vessel fished live. Note that vessels almost solely entered the fishery in either late December of the preceding year or January of the current year, generally coinciding with peaks in annual prices (see Figure 5–2). Error bars are standard errors.

5.4.2.2 Price and Catch

Survey respondents were asked to indicate the mean annual proportion (%) of their total catch of coral trout that was marketed live for all years in which fish were marketed live., Respondents were presented with ten categories for ease of recall, each representing a decile ranging from less than 10% to greater than 90%. The mid-point of each category served as the statistic upon which to measure the mean for all respondents (e.g. for the category 21-30%, the midpoint of 25.5% was the statistic applied). When aggregated across all respondents regardless of the year the operation entered the live fishery, the mean annual proportion of live to total catch of coral trout showed no significant difference among years ($F_{5,110} = 2.057$, $p = 0.076$) (Figure 5–7).

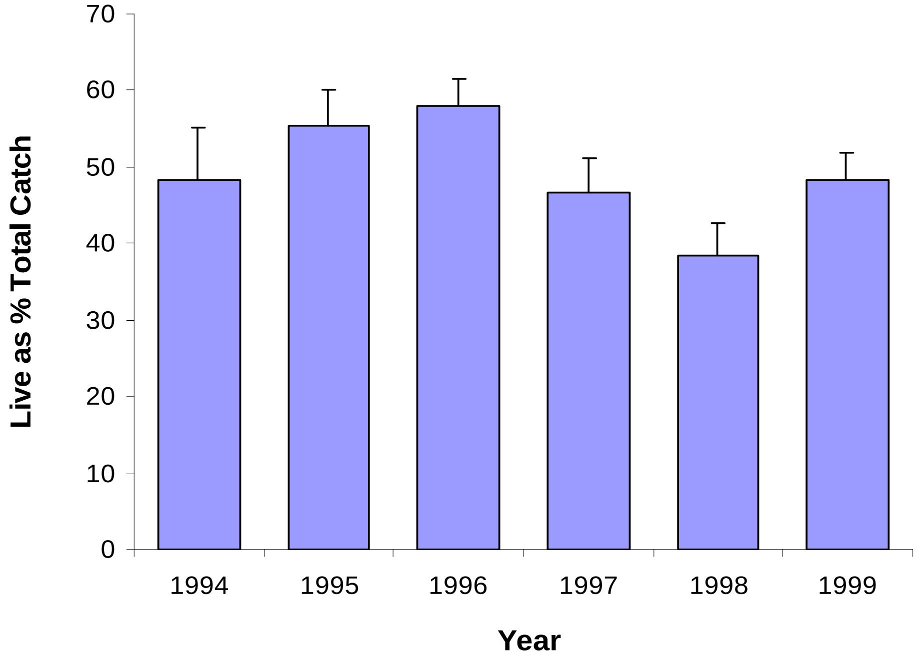

Figure 5-7: Mean annual catch of live as a proportion of total catch of coral trout for the years 1994 to 1999. Year bars are cumulative and represent the aggregate percentage for all boats supplying live product during that year regardless of year in which that vessel first supplied coral trout alive for export markets. Error bars are standard errors.

While evidence suggests the supply response to a lower relative beach price for live coral trout was consistent across all years, these aggregate supply responses may mask stronger differences between cohorts of new entrants to the live fishery. To isolate these supply trends, planned comparisons were made between vessels who had converted their operations to live pre-1997 and post 1996 for each of the years 1997-1999. Later entrants (post-1996) to the live fishery retained a significantly lower proportion of their catch alive in both 1998 ($t_{0.05,\ 11.34} = -5.031$, $p < 0.001$) and 1999 ($t_{0.05,\ 24} = -3.054$, $p = 0.005$) but no significant difference was detected for 1997 ($t_{0.05,\ 23} = -1.508$, $p = 0.145$) (Figure 5–8). The combination of lower average beach prices for live coral trout during 1998 and 1999 (see Figure 5–2) and declining catch rates[75], may have influenced the targeting behaviour of these newer converts.

[75] Anecdotal evidence obtained from fishers during the survey program suggested that catch rates for target species declined considerably following a large scale cyclone event in early 1997.

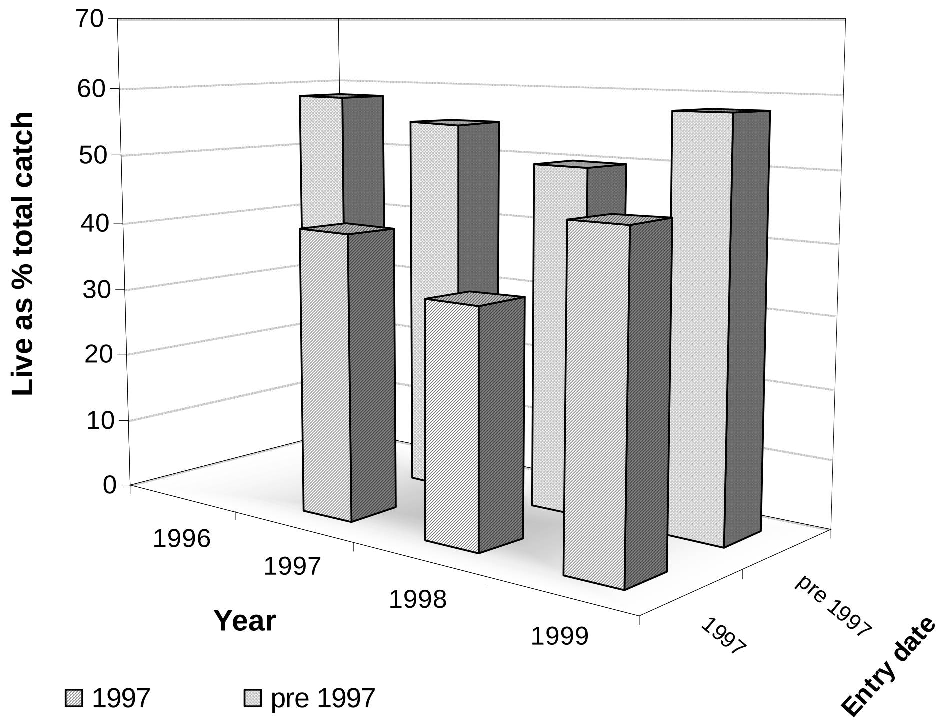

Figure 5-8: Average live catch as a proportion of total catch of coral trout for the years 1996 to 1999 by the date at which the vessel first began marketing live product. Pre-1997 vessels include all those who commenced live fishing between 1994 and 1996. Only vessels commencing live fishing during 1997 were included in the second data series. Vessels commencing live fishing in 1998 and 1999 were excluded in view of their late entry to the fishery.

Further evidence of this supply response can be observed from the monthly quantities of live fish exported from Australia to Hong Kong, collected by the Australian Quarantine Inspection Service (AQIS). These 'official' figures validate to some degree data procured from fisher interviews as presented above. As most live product is consigned soon after purchase by wholesale exporters and not stored for any lengthy periods (Lance Peterson, *personal communication*), the volume of monthly exports would correspond fairly closely with monthly catches. Monthly export volumes appear to correspond well with movements in the wholesale beach price (see Figure 5–2), highlighted by the downturn in these prices from throughout late 1997 and all of 1998, and to some extent, Chinese festival months. As noted earlier, coral trout predominates in total exports, with monthly increases in export quantities reflective only of higher exports of coral trout (Figure 5–9).

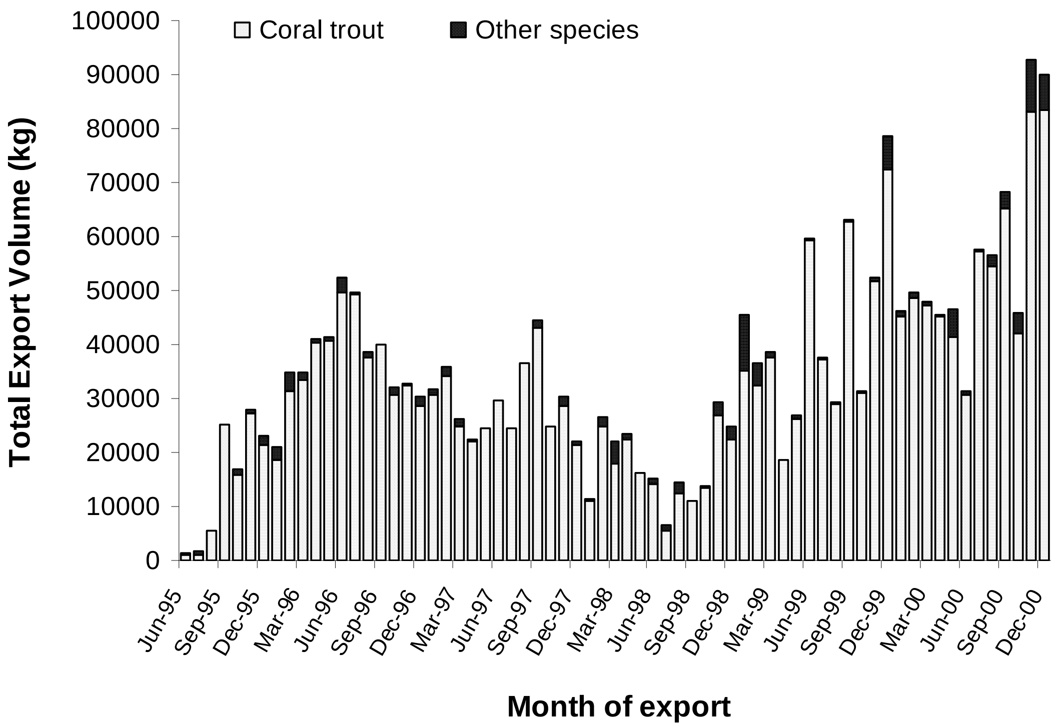

Figure 5-9: Monthly volumes in kilograms of live reef fish exported to Hong Kong from the Great Barrier Reef Marine Park waters from June 1995 to December 2000. The main Chinese festival months in Hong Kong are Chinese New Year (Jan-Feb), Mother's day (May-Jun), and the Mid-Autumn festival (Aug-Sep)

Source: Australian Quarantine Inspection Service, Queensland Fisheries Service.

5.4.3 License Values

In limited licence fisheries, such as the RLF, the licence value where the licence is attached to a vessel represents the capitalised net present value of expected future returns from fishing (Campbell and Haynes 1990; Flaaten et al. 1995)). Despite Wilen's (1979) claim to the contrary, considerable evidence exists that licence values do capture rents and reflect expectations of future earnings (Schelle and Muse 1986; Karpoff 1989). Any developments in a fishery, such as value-adding or reductions in fleet capacity, that contribute to improved economic returns should normally be reflected in an increased value of licences (Byrne 1982).

Expectations of high returns from the fishery due to elevated beach prices for live as compared to fresh or frozen product appear to have been capitalised into licence values. The increase in market values of L2 endorsements appears to have been driven by new entrants to the live fishery who had to purchase a line endorsed licence package as a means of entry to the RLF (Muldoon, 2001; *personal observation*.). Prices of licence packages comprising L2 endorsements rose substantially following the advent of the live fish trade with market values of 2, 3 and 4 dory endorsements increasing by 60%, 65% and 75% respectively between 1993 and 1998 (Figure 4.17). Despite a lack of formal data, anecdotal evidence indicates licence values have continued to escalate since 1998 with a licence incorporating a 4 dory line endorsement sold for approximately $120,000 in 1999 (Terry Must; *personal communication*).

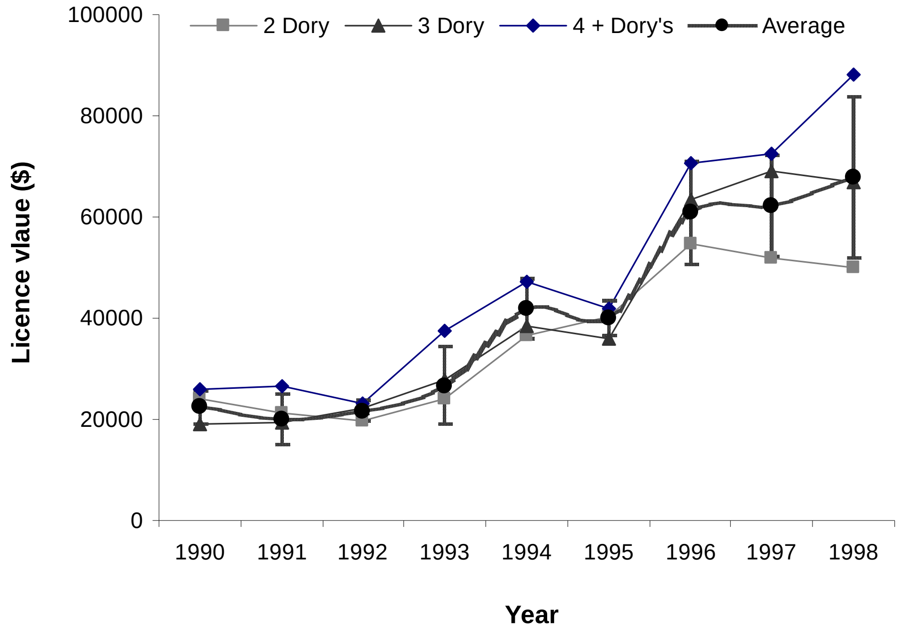

Figure 5-10: Average annual market value of L2 (2 or more tender vessels) licences for 2, 3 and 4 dory licences packages including average annual aggregate values across all marketed licence packages from 1990 to 1999. Error bars are standard deviations

Source: unpublished broker data

5.5 Discussion

In contrast to the traditional sequence of short and long-run responses to an increase in the price of a good and potential increase in profits, firms in the RLF display notable anomalies. The 'notionally' long-run response of investing in requisite technology to enable storage of live product necessarily precedes the short-run response of adjusting variable inputs[76]. While fishers do respond to economic incentives they also exhibit a strong inclination to remain within the same fishery over time (Bockstael and Opaluch

[76] For those not currently active in the RLF or any other fishery, the investment decision will likewise necessarily occur first

1984). Strong evidence of higher returns in the long term is usually required before a fisher will undertake capital expenditure that either increases capacity to expand existing output or permits entry into new product markets.

Certain necessary tenets required of competitive markets appear not to prevail in the RLF, and the LRFF as a component of it. While no one firm is able to exert market influence over the prices of landed product and knowledge of these prices is freely available to all[77], the emergence of the LRFF has countermanded the assumption of product homogeneity. Participants in the LRFF are using very similar inputs to produce a new output to supply a separate market. This "product differentiation" may confer a competitive advantage upon those fishers supplying live markets such that they experience super-normal profits[78]. Under perfectly competitive conditions of unrestricted entry and exit, these pecuniary market signals should lead to the entry of new firms into the fishery (Sampson 1990; Perman and Scouller 1999)[79]. Certain 'barriers to entry' may exist, however, that preclude the free movement of capital into and within the RLF.

When considering entry barriers, one needs to distinguish between: i) whether an operator is currently endorsed to remove product from the RLF; and ii) the endorsed operators decision to switch between targeting fish for either the fresh, frozen, or live markets. Outlays to overcome the former and enter into the live fishery need not be substantial for existing active line fishers but will be considerably greater for presently inactive fishers holding a line endorsement and more so for those faced with vessel upgrade decisions or who must purchase a suitably endorsed licence and vessel. The major entry restrictions is thus likely to be access to capital markets (Whitmarsh 1990; Le Gallic 2001).

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[77] While complete price information prevails in both markets, a lack of perfect knowledge as to the spatial effort allocation of other fishers is likely leading to effort being applied to areas recently fished. As such, Gates (1984) and Pascoe and Mardle (1999) regard perfect knowledge as an unrealistic assumption

[78] In perfectly competitive markets, firms will enter an industry until all excess resource rents are extirpated and the opportunity costs of variable and fixed inputs are just being met; and profits are said to be normal. Profits are said to be super-normal when the return exceeds the opportunity costs of capital.

[79] Under perfect competition, resources will be able to move freely within and between firms in response to pecuniary signals.

A limited licence regime will erect barriers to entry insomuch as the licence value embodies the discounted value of expected future rents (Huppert and Odemar 1986; Thomas and Weber 1990; Ward 2000). The large number of unused licenses that characterise the RLF suggests that entry *per se* is not overly restrictive. Physical vessel characteristics may also be a barrier where vessel size determines the ease with which live technology can be incorporated and will dictate the capital outlay required to acquire a suitable vessel. This barrier will influence the timing of the decision to switch to live fishing, in the case of existing fishers, or enter the fishery, in the case of potential entrants. Of the survey respondents in this study, 65% of the active frozen only operators expressed dissatisfaction with their business size with 80% of these nominating the size of their present primary vessel as being too small to incorporate live technology. The absence of restrictions on a fisher's targeting behaviour infers that once an operator is suitably configured, no entry or exit barrier's exist to the LRFF and the operator can switch freely between supplying fish for either live or frozen markets.

A characteristic of *multi-product* firms is that production processes (inputs) can be reorganised to alter their relative quantities of outputs in response to market conditions (Laitinen 1980; Smith and McKelvey 1986). Multi-product fishing firms can be restricted in the extent to which input reorganisation can occur. Output decisions for such firms, are usually made prior to a fishing trip based on weather, resource abundance and market conditions, and will determine the combination of factor inputs for the trip. Those inputs are largely fixed for the duration of the trip (Squires 1987; Segerson and Squires 1993). Such constraints do not prevail in the RLF. Although they are discrete products, fish for live and frozen markets, are derived from the same species and, apart from handling and storage methods, employ the same factor inputs. Decisions by live operations to retain more or less of either product form can be made prior to and during fishing trips, including after fish are caught[80].

Fishers in general respond positively to economic incentives such as price by switching between fisheries, although with a time lag (Bockstael and Opaluch 1983). This lag is often a consequence of time and cost constraints associated with reorganising fishing inputs. The lag period has been shown to shorten with price increases over time

[80] Coral trout is the main target species for most frozen and live operators. While other species are targeted sporadically within the year on the basis of abundance, these are usually deemed by-product.

(Botsford et al. 1983), or lengthen as variability in resource availability or expected revenues increases (Eggert and Tveteras 2004). My results show that live operators adjust their targeting behaviour in response to the relative price of live coral trout, with a slight effort response lag (Figure 5–5). The similarity in factor inputs limits such constraints on output decisions for live capable vessels in the RLF. The short response lag to changes in price may be due to either an expected minimum price for live fish needed to meet slightly higher variable costs or price variability and instability (Eggert and Tveteras 2004).

Further insight into operational responses to price was gained from comparisons to live fishing activity by year of entry to the live fishery, both in terms of the proportion of months that an operation retained coral trout alive and the proportion of live to total catch of coral trout. Those operations that entered the live fishery prior to 1997 were significantly more active, both in terms of months fished and the percentage of total catch retained alive for sale. Not unexpectedly, these responses coincided with declines in live wholesale prices, attributed to the SE Asian economic downturn. Anecdotal reports of declining catch rates in the wake of a large-scale cyclone disturbance in early 1997 may also have contributed to lower retention of live product by these later convert's. These results suggest that operators who had been fishing live prior to 1997, responded with less alacrity to price declines. Their acceptance of a lower price for live fish may be explained by a better understanding of the comparative cost and revenue structure of their fishing firm than the understanding of 'younger' entrants to the LRFF.

According to the Food and Agriculture Organisation, more than 75% of the world's fisheries are fully or over-exploited (FAO Fisheries 2002). Within this environment, researchers and fisheries managers have identified value-adding of fishery products through improved processing and handling and better resource utilisation as of increasing importance (FAO 1998; Boude et al. 2000a). Ideally value-adding would maintain or increase the profitability of fishing operations while stabilizing, or even reducing, catches (Fornshell 2002). Any long-term benefits from changing fishing practices however, will be contingent on adequate regulation of effort in the fishers and may be undermined by too many new firms entering the fishery (Hilborn 1985a; Seijo et al. 1998; Holland and Sutinen 1999; Mapstone et al. 2001).

The remaining chapters of my thesis will aim to address these issues by examining the impacts of value-adding on financial and operational characteristics of the RLF (Chapter 6); the factors influencing investment in live technology among a sample of fishers (Chapter 7), a comparative analysis of the outcomes from the uptake of live fishing on vessel efficiency and fleet capacity and of latent effort as a potential source of substantial excessive harvesting capacity (Chapter 8). Capacity and sustainability are subsequently addressed in the general discussion (Chapter 9)

5.6 Summary

Results presented in this chapter indicate that the RLF does not conform to the definition of a competitive industry with respect to product homogeneity and barriers to entry. A root cause for this non-competitiveness is the need for the fishing firm to undertake investment in the requisite technology to maintain live fish before being able to make decisions as to the allocation of fixed and variable inputs. While profit maximisation in the RLF is tempered by the existence of financial and capital barriers to entry, these allocative decisions are the basis for assessing whether fishers are behaving in a profit maximising manner.

According to accepted theory, changes in relative prices will see profit maximising firms choosing to increase or alter their output mix. There is evidence from these results that firms, capable of marketing both live and frozen fish, are thus behaving as profit-maximisers. As prices of live fish declined relative to frozen fish prices, operators showed a tendency to switch to marketing frozen fish, once a “floor” price for live fish was exceeded. That those fishers who had been engaged in live fishing for less time, displayed an inclination to revert to marketing frozen more quickly (i.e. a higher floor price) is further evidence of the profit maximising motivation of fishers in the RLF.

Differences in profitability, should they exist will be further confirmation of the non-competitiveness of the industry. Comparisons of financial profiles are addressed in detail in the next chapter.

CHAPTER 6

FINANCIAL AND OPERATIONAL CHARACTERISTICS OF THE GBR REEF LINE FISHERY OPERATORS

6.1 Introduction

A constant theme running through the chapters of this thesis is the effect on the reef-line fishery fleet of the emerging live reef food fish trade (LRFFT), including the requirement to take-up apposite technology. The subsequent chapter describes the economic and non-economic factors dictating the adoption of this innovation. Following on from historical fleet-wide perspective given to the LRFFT in the previous chapter, this chapter focuses on operational and economic characteristics of a commercial fishing fleet comprised of individual adopters and non-adopters of technology that enables coral reef fish to be marketed alive.

It is acknowledged that management of commercial fisheries is as much about managing fishers and their dynamic relationship with the resource as managing fish populations per se (Hilborn 1985a). Fisheries management is often confounded by conflicting objectives and the need to arrest conflict between conservation of fish stocks and meeting social objectives of a fishery (Mardle and Pascoe 1999), as well as responding to the evolution of harvest technology. Fishery managers require information on economic and behavioural characteristics of fishery agents as well as biological aspects of the fish stock in order to consider broader impacts of proposed management strategies (Charles 2001).

The standard theory of the firm which assumes myopic profit maximisation behaviour and homogeneity amongst fishing operations (firms) has been widely applied to fisheries. While the validity of the former remains unresolved (Doll 1988; Ward and Sutinen 1994; Robinson and Pascoe 1997), heterogeneity amongst firms within fishing fleets is more widely accepted (Hilborn and Walters, 1987; Kirkley and Strand, 1988; Holland and Sutinen, 1999). Different fleet components may be affected differently and react disparately to different management options where heterogeneity exists. Diversity among fishing operations necessitates an understanding of the operational profile of the fishing fleet to manage how the fleet accesses and impacts on the resource. Operations within the commercial RLF marketing product alive or frozen potentially represent significantly different firms but there is limited empirical research into the operational profiles of these different operation types in the reef line fishery.

Effort control is an important consideration in fisheries management, and may be achieved through a range of regulatory alternatives. Whilst regulators tend to manage for stock protection first, regulation will impact on the operating costs and revenues of fishers harvesting the resource (Boyce 2000). Data enabling assessment of economic effects of management regulations, however, invariably are limited. Effective management requires an understanding of economic profiles of the fishing fleet which in turn requires the collection of basic descriptive information, ideally at the individual fishing operation level (Anderson 1976; Waugh 1984). Such data enable a range of management problems to be addressed: Is the fishery economically overfished? Do incentives exist for changing behaviour from existing operations or effort increases from new entrants? What are the capital requirements for entry to the fishery and are there financial barriers to entry? Financial data allow for empirical analysis of the impacts of policy decisions on fishing costs and revenues and the potential effort dynamics with which management plans must cope. Again, there is a paucity of business-unit level data for the reef line fishery, with the only financial data collected to date being highly aggregated (Taylor-Moore 2000).

The purposes of this chapter are to, firstly, explore structural and financial aspects of the RLF, and the LRFF fishery as a component of it, including capitalisation and profitability and, secondly, examine the operational characteristics such as trip frequency and length, annual days fished, trip determinants, and home port affinity of operators in the RLF supplying the traditional frozen markets and those who have converted their operation in order to supply the live food fish export market.

Accordingly, the specific aims of this chapter are to:

(i) test for financial and economic differences between frozen and live vessels in the GBR reef-line fishery as a basis for hypothesising what factors might encourage or discourage either adoption of new technology by existing vessels or entry of new participants; and

(ii) test for differences in operational characteristics of frozen and live vessels in the GBR reef-line fishery that might signal specific consideration for management of the RLF in response to changed behaviour of fishers who move into the LRFF.

6.2 Methods

6.2.1 Data Sources

The two principal data sources for this chapter were the survey questionnaire administered to commercial fishers and secondary data on fishing effort and catch of the commercial reef-line fishery obtained from the Department of Primary Industry and Fisheries (DPI & F)[81] C-FISH database through the Effects of Line Fishing (ELF) project. C-FISH data were aggregated across operations to maintain confidentiality and prevent catch and effort records from being able to be linked to individual fishing operations.

Primary interview data were drawn from sections (i), (ii), (iii), (iv) and (vi) of my interview questionnaire (Appendix 2). Operators were asked to respond to questions on capital structure, fixed and variable costs and revenues, and operational aspects such as trip frequency and length, number days fished and trip related decision criteria (Table 6–1). Where possible these data were used in conjunction with C-FISH data to support analyses of both financial and operational characteristics.

[81] At the time these data were obtained, the Queensland Fishery Service was the agency responsible for maintaining the C-FISH database and handling information requests.

Table 6-1: Survey questions used to investigate the operational and economic characteristics of frozen and live operations within the GBR reef-line fishery.

Section	Question #	Question description
Fishing History	Q1	Fishing operation ownership
	Q2	Year of entry into line fishery
	Q7	Licence purchase details
	Q8	Endorsement characteristics
Operational Characteristics	Q10-Q12	Port usage
	Q13a	Primary vessel characteristics
	Q13b	Tender vessel characteristics
	Q17 – Q20	Business values
	Q21	Annual effort history
	Q24-Q25	Trip length and trip length determinants
	Q26	Wind speed influence on trip departure
	Q27-Q32	Crew details (age, experience, years employed)
	Q33	Capacity utilised per trip
Live Fishing History	Q35	Live catch as proportion of total catch
	Q36	Vessel conversion
	Q37 a)	Year of conversion to live
	Q37 b)	Conversion undertaken and costs
	Q43	Fishing trip targeting behaviour
	Q44	Targeting behaviour determinants
	Q45	Effort allocation toward capture of live product
	Q48	Minimum acceptable fish price
Investment Decision-making	Q54	Satisfaction with operation size
	Q62	Volatility of market and fishery determinants
Business Operations	Q74	Annual costs
	Q75	Replacement and capital costs
	Q76	Variable costs
	Q77	Annual catch and revenue

6.2.1.1 Measures of Fishing Effort and Fleet Characteristics

A measure of effort must be developed that enables productivity comparisons of various vessel configurations. Effort, in an economic context, is a multi-level concept where factors of production, such as capital, labour and energy, are aggregated to form a composite index, typically represented as some variant of fishing time or days at sea (Anderson 1986; Squires 1987). This index can be adjusted or ‘standardised’ by a measure of productivity (fishing power) to enable comparison across heterogeneous vessels (Sathiendrakumar and Tisdell 1987; Smit 1996) [82].

In many commercial fisheries (e.g., trawl, purse seine or net), fishing power is determined by engine power of the main vessel and fishing gear controlled from it. The "power" of fishing operations in the RLF, however, is determined both by the size of the main vessels and the number of tender vessels they support. While larger vessels usually support more tenders, regardless of operation type[83], the size of the main vessel also may constrain inputs directly in that larger vessels are able to travel or remain at sea in more adverse weather conditions than smaller vessels and generally will have larger holding capacities and so be able to support longer fishing trips. Main vessel size also may affect operational efficiency with larger vessels, supporting more tenders, able to justify additional costs incurred in travelling longer distances to fishing grounds. For the purposes of this chapter operational characteristics are compared using primary days fished (see 1.6.2), or days fished by the main vessel regardless of number of tenders supported. Data were standardised for financial and economic comparisons, however, as costs and revenues per dory day fished. That is, aggregate costs and revenues of fishing operations were divided firstly by the number of days the operation fished and then the number of tenders (dories) supported during that time. Thus, for a primary vessel that fished a total of 120 days and supported 4 dories, total revenues and costs were divided by 480 to obtain per dory day values.

6.2.1.2 Financial Performance Measures

Data on annual costs and revenues were collected from business' annual financial statements, made available by respondents at face-to-face interviews (see Chapter 3). These data were used to compare financial profiles and to measure overall economic performance of live and frozen operations.

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[82] The literature acknowledges that constructing such a capacious measure of fishing effort is problematic in that vessels are often not homogenous in terms of vessel size or technology (Hannesson 1993a)

[83] There is a significant correlation between size of the main vessel and the number of tenders supported ($r_p = 0.336$, $p = 0.009$).

Costs

Costs were divided into annual and variable costs. *Variable costs* were those associated with a fishing trip and which were dependent upon trip length and effort input. These costs included: fuel for main and tender vessels, bait, fishing gear (hooks, lines, sinkers etc.), provisions, ice, packaging, wages and superannuation and communication costs. Approximately 40% of boats, for which data were collected, employed skippers over the three years, with the remainder owner-operated (Table 5–5). Skipper wages were excluded to enable meaningful running cost comparisons to be made on the basis of owner-operator equivalent costs (Coglan and Pascoe 2001). *Annual costs* were incurred regardless of trip activity and usually were associated with capital investment (Doll 1988). They comprised *maintenance costs* for primary and tender vessel (hull, freezer, engine etc.) and *fixed costs* including mooring fees, insurance costs, licence renewal fees, interest and administrative costs such as on-land utilities and phones charges. *Total cost* was the sum of variable and annual costs.

Revenues

Gross Revenues were total returns derived from sales to wholesalers of all reef fish products, either live or frozen. *Net Revenue* was akin to operation gross profit in the sense that it was gross revenue minus variable and annual costs, but before payment of taxes. Wages to skippers were re-included as a variable cost in the calculation of net revenues (Coglan and Pascoe 2001). In order to properly compare financial performance across vessels, however, compensation for owner-operators' labour was also included as a variable cost[84]. Skipper wages and imputed labour costs were deducted from net revenues to derive *adjusted net revenue*. Adjusted net revenues were used to compare both financial performance and returns to capital (see below).

Productivity

Two measures of overall economic performance were calculated for each operation type: variable costs as a percentage of gross revenue, expressed as values per dory day; and rate of return to capital. Variable costs were an appropriate measure in these calculations as they were representative of costs incurred in catching fish while gross revenues

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[84] The average skipper wage for live (15%) and frozen (20%) vessels, across all years of the study, was calculated as a percentage of gross revenue and was used to impute owner-operator salaries.

represented the income from catching fish. Return to capital was a ratio of *adjusted net revenue*[85] to *capital value*. Adjustments made to net revenues to recognise returns to labour for owner-operators' and skippers' wages were carried over to enable comparison of rates of return between vessel ownership types (Poffenberger 1985; Boncoeur et al. 1998).

6.2.2 Data Analyses

The interview data consisted of both nominally scaled and discrete data with the former used mainly to describe differences in operational characteristics of the fleet. Four common factors were used, although not necessarily simultaneously, for comparisons between operations in all statistical analyses:

1) Operation type (live, frozen, 'changer'[86]);
2) Operation home port region (Northern, Southern);
3) Financial Year – Financial and economic characteristics (1996-97, 1997-98, 1998-99); and
4) Calendar Year – Operational characteristics (1996, 1997, 1998, 1999).

Operations were classified by whether they retained product for live and frozen markets[87], or frozen markets only. Given the small sample size, home port region was determined subjectively to allow for an approximately equal sample size in each region and so maximize the power of statistical tests (see Table 3-1). Nevertheless, the boundaries recognised the geography of the GBR, which determines proximity of fishing grounds to the coastline. Operation years, unless otherwise stated, were from 1996 to 1999 inclusive. Comparisons of operational characteristics were based on calendar years in accordance with how fishers discriminate their operations, while financial comparisons were carried out on a fiscal year basis (e.g. 1998-99), consistent with the financial records usually provided by owners.

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[85] Convention implies that adjusted net revenue is equivalent to full equity profits in that it assumes income to the boat owner with no allocation to debt retirement.
[86] Changer operations were those that were classified as frozen at the start of the period of analysis and which became live operations at some point during the period being analysed.
[87] Not all catch is suitable for retention for live markets due to fish size (too large), poor quality or it being a non-target species. Moreover operations will experience occasional post-capture mortality.

6.2.2.1 Statistical Tests

The effects of operation type and region on the capital structure (primary vessel attributes, number of licensed tenders, tender attributes), capital value (primary vessel, tender vessels, licence and total business value) and length of trips were analysed using two-factor Analyses of Variance (ANOVA). The null hypotheses were that there were no significant differences in any metric between live and frozen operations or between northern and southern regions or across the interaction of the two factors. Effects were considered significant if $p \leq 0.05$. A full-factorial ANOVA model was used that tested for main and interaction effects. Where region effects and the interaction of region with operation type were non-significant and $p > 0.250$, data were pooled and a one-way ANOVA done to test for effects if operation type with greater statistical power (Winer 1971). Type III sums of squares, which are relatively insensitive to non-homogeneity of cell frequencies, were used in the analyses since cell sizes generally were unequal. Levene's test was used to examine the assumption of homogeneous variances for all data prior to analysis. Where the Levene's test suggested heterogeneity among variances, residual plots were used to examine the data and data Log_{10} transformed.

Effects of operation type and region (between subjects factors) and Year of operation (within subjects factor) on the financial and economic characteristics (costs, revenues operation productivity) and operational characteristics (number of trips, number of days fished, port affinity (number of ports from which catch unloaded, time spent in home port) were analysed using a full rank factorial Repeated Measures (RM) Analyses of Variance. Type III sums of squares were used in the analyses. Mauchley's test of Sphericity was used to test for homogeneity of variance-covariance matrices in the repeated measures error terms. Levene's test was used to test for homogeneous variances for each dependent variable for all levels of the between-subjects factors, for between-subjects factors only. Where Mauchley's test suggested a violation of the Sphericity assumption (number of fishing trips), or the Levene's test suggested heterogeneity among variances, the data were Log_{10} transformed, which then satisfied the assumptions of the analysis (Zar, 1984).

An additional operation type, "changer", was incorporated into the RM analysis to examine for evidence of change attributes within these operations across time (see 6.2.2). Changer operations were included as cohorts in the model, based on the year they switched to supplying the live fish market. Where inclusion of the changers did not enhance the results, in that they were indistinguishable from frozen operations, the full RM ANOVA analysis was redone using only the original operational classifications (live and frozen).

No data for financial and economic characteristics were available for changer operations in the northern region and so only the effects of operation type and year for vessels from the Southern Region were analysed in the RM ANOVA that included the changer type. The cohort of changer operations available for these analyses operated as frozen vessels in the first financial year (1996-1997) and live vessels in subsequent years (1997-1998, 1998-1999).

Data on operational characteristics were available for changer operations in both regions, enabling analysis of all three effects in the RM ANOVA. Further, operational data allowed for the analysis of multiple cohorts of changer vessels, representing separately those operations that switched to live fishing in either 1997 or 1998. Discrete RM models were used to examine operational behaviour of these two cohorts by including firstly only those who switched in 1997 and then those who switched in 1997 and 1998. Analysing both cohorts concurrently did not yield additional useful information and a subjective decision was made to incorporate only the 1997 cohort into the analysis, with changer operations operating as frozen vessels in 1996 and live vessels in subsequent years (1997, 1998, 1999).

6.3 Results

6.3.1 Capital Structure

Capital structure is presented in terms of physical details of the primary vessel by operation type. Other business aspects such as ownership, including fishing license, and skipper arrangements are also presented by operation type (Table 6–2).

6.3.1.1 Primary Vessel

The typical primary vessel of live operations is significantly longer ($F_{1,48} = 6.661$, $p = 0.013$) and wider ($F_{1,48} = 7.995$, $p = 0.007$) than frozen vessels, and is also significantly newer ($F_{1,48} = 4.772$, $p = 0.034$). Engine power and fuel capacity for live vessels tended to be greater than those of frozen vessels, although neither result was statistically significant. Despite having to sacrifice some freezer space to install live tanks, live vessels retained freezer space comparable to that of frozen vessels, indicating they retained the flexibility to switch back to marketing only frozen product should the market for live product move adversely. This is most likely correlated with the larger size of live vessels (Table 6–2)

Table 6-2: Physical details of primary vessel by operation type

	Mean	
Detail	**Live Operations**	**Frozen Operations**
Boat length (m)	14.7 *	12.7 *
Draft (m)	1.85	1.75
Beam (m)	5.00 *	4.25 *
Age of vessel (yrs)	20.6 *	27.3 *
Main engine (hp)	255	170
Fuel capacity (L)	5500	3600
Steaming Speed	8.1	7.2
No. Berths	7.4	5.6
Water (L)	2400	1600
Auxillary (% Yes)	100	30
2nd Aux. (% Yes)	18	0
Snap (kg)	330	300
Hold (kg)	3740	3800
Brine Tanks (% Yes)	55	76
Brine (kg)	290	460
Fresh (% Yes)	45	6
Fresh (kg)	1130	
Internal Live Tanks (% Yes)	58	
External Live Tanks (% Yes)	82	
External & Internal Tanks (%Yes)	39	
Live internal (l)	5800	
Live internal (kg)	930	
Live external (l)	4100	
Live external (kg)	600	
Live Total (l)	6690	
Live Total (kg)	1060	

* *$p < 0.05$ (One-way ANOVA)*

6.3.1.2 Tender Vessels

There were no significant main or interaction effects of operation type or region on the number of tender vessels live or frozen operations were licensed to support ($p < 0.05$)

(Table 6–3). There were significant main effects of operation type and region for both the length (meters) and power (outboard horsepower) of tender vessels used, both of which were greater for live operations than for frozen operations (Tables 6–3, 6–4).

Table.6-3: Average number of tender vessels supported by primary vessels by Operation Type (frozen, live) and Region (northern, southern).

Operation Type	Region of Operation	Tender Attributes		
		Number	Length	Power
Frozen Operation	Northern Region	3.60	4.47	31.6
	Southern Region	4.42	4.27	25.7
	Total	4.18	4.34	27.7
Live Operation	Northern Region	4.07	4.82	35.2
	Southern Region	4.17	4.54	31.3
	Total	4.12	4.67	33.1
Total	Northern Region	3.95	4.73	34.3
	Southern Region	4.27	4.44	29.2
	Total	4.14	4.56	31.4

Table 6-4: Analysis of variance comparing length (meters) and power (horsepower) of tenders vessels. Operation type (frozen, live) and Region (northern, southern) are fixed factors. Results of Levene's Test also are presented. df = degrees of freedom, MS = mean square, *F* = *F*-ratio, *p* = probability of the data if no difference existed. Significant results (P<= 0.05) are in bold.

Source of variation	Tender Length (mts)			Tender Power (hp)		
	df	*F*	*p*	df	*F*	*p*
Operation Type	1	11.852	**.001**	1	5.295	**.026**
Region	1	9.111	**.004**	1	6.024	**.018**
Operation Type* Region	1	.369	.547	1	.249	.620
Residual (error)	44			43		
	Levene's Test (F = 2.688, p = 0.058)			Levene's Test (F = 1.672, p = 0.187)		

6.3.1.3 *Ownership Details*

The advent and expansion of the live fish industry in Queensland has resulted in substantial change in ownership patterns in the reef-line fishery. Whereas the majority of frozen operations remain as partnerships, more than 30% of all live operation were trading as private companies by 2000. Furthermore, while all frozen operations interviewed owned their licence, 9% of live operations had leased a license in order to commence fishing (Table 6–5).

Table 6-5: Comparison of operational details for frozen and live fishing operations

Operational Detail	Percentage (%)	
	Live	Frozen
Vessel Ownership		
Sole Proprietor	9.1	11.8
Partnership (family)	54.5	76.5
Partnership (non-family)	6.1	11.8
Private Company	30.3	0.0
Leased (Vessel & Licence)	0.0	0.0
Skipper		
Self	57.6	58.8
Contract Skipper	42.4	41.2
Licence Ownership		
Owned	90.9	100.0
Leased	9.1	0.0

6.3.2 Capital Values

There were no significant main or interaction effects of operation type or region on the value of tender vessels or licences values. There was a significant main effect of operation type on primary vessel value and total business value, with mean values for frozen operations being $140,300 and $260,400 respectively while for live operations the mean values were $245,300 and $366,800 respectively[88]. These were, given the contribution of primary vessel value to total value, highly correlated ($r_p = 0.988$, $p < 0.001$). Average primary vessel ($F_{1,48} = 5.991$, $p = 0.018$) and total business capital values ($F_{1,48} = 4.791$, $p = 0.034$) were significantly greater for live than for frozen operations (Figure 6–1).

[88] Amounts are based on owner(s) assessment of the market value of business components at the time of the interview

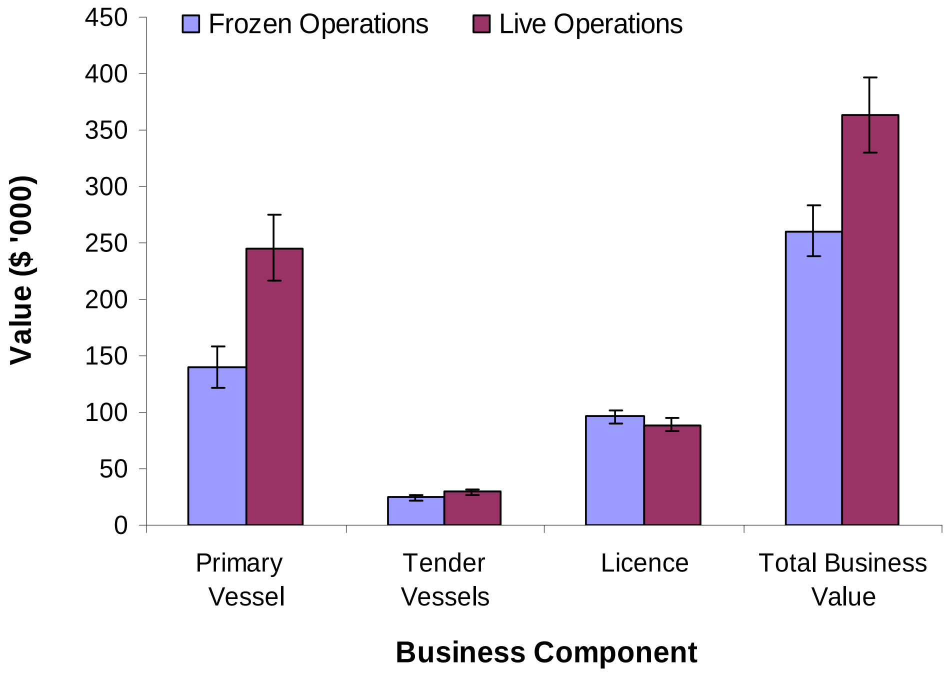


Figure 6-1: Mean business values ($ ‘000) by business component by operation type. Error bars are Standard Errors

An exponential trendline was used to describe the relationship between primary vessel length and primary vessel value [89] (Figure 6–2). These data showed that almost 70% of the variation in primary vessel value was explained by vessel length (R^2 = 0.69). The average expected outlay to purchase a primary vessel of length 14.7m to commence fishing for live product would be approximately $193, 500.

[89] Data pertaining to asset values can be exponentially distributed, whereby values rise or fall at increasingly higher rates.

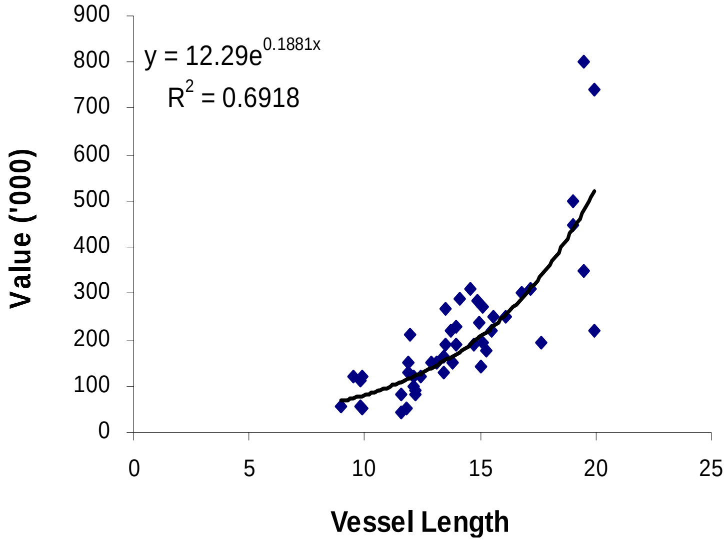


Figure 6-2: Relationship between owner estimate of primary vessel value ($ '000) and length of primary vessel

6.3.3 Financial and Economic Performance Indicators

6.3.3.1 Costs and Revenues

Financial parameters were initially analysed for three operation types (live, frozen and changer) in the southern region across four annual financial indicators (annual costs, variable costs, gross revenue and net revenue). ANOVA results showed no significant interaction effects between Operation Type and Year on any of the above indicators, but a significant main effect of Operation Type on both gross revenue ($F_{2,14} = 10.367$, $p = 0.002$) and net revenue ($F_{2,14} = 20.134$, $p < 0.001$). Post hoc tests, using the Bonferroni method[90], showed live operations grossed significantly higher revenues than both frozen (p = 0.003) and changer (p = 0.012) operations, with net revenues for live operations also significantly greater than frozen (p < 0.001) and changer (p = 0.009) operations. Results suggested that changer operations more closely resembled frozen operations than live operations, both before and after their switch to marketing live product (Figure 6–3). Subsequently, RM ANOVAs of costs and revenues were conducted (see below) for live and frozen operations only, but with the exclusion of changer operations regional effects were added to the analysis.

[90] The Bonferroni method is regarded as the most robust of the univariate techniques in terms of statistical power and control of Type I error rates (Field 2000).

Figure 6-3: Estimates of average gross and net revenues per dory day, pooled across years, and results of Bonferroni multiple comparisons among operation types. Similar operation types are those where p > 0.050 and are connected by underlying solid bars.

	Operation Type		
Financial Indicator	**Frozen**	**Changer**	**Live**
Gross Revenue per dory day	321.75	262.35	518.95
Net Revenue per dory day	105.95	119.75	230.30

There were no significant interaction effects between Operation Type and Region or main effects of Region for any of the financial performance indicators examined. There were no significant interaction effects between Year and Region or Year and Operation Type and Region for any indicator and nor did any indicators show a significant main effect of Year. Lastly, there were no significant interaction effects between Year and Operation Type for either annual or variable costs or adjusted net revenue (Table 6–7). Variable costs per dory day were ranked higher for live than frozen operations in all years but were significantly greater only in financial years 1997-98 and 1998-99. While variable costs per dory day rose steadily for live operations over the three years, variable costs for frozen operations in 1997-98 and 1998-99 were 17% and 9% lower respectively than in 1996-97 [Figure 6–4(a)]

There was a significant interaction between Year and Operation Type for both average gross and average net revenues per dory day (Table 6–7).. Annual gross and net revenues per dory day for live operation were significantly higher than frozen operations in all years. Gross revenues rose steadily over the three years for live operations, while gross revenues were lower in both in 1997-98 and 1998-99 than in 1996-97 for frozen operations [Figure 6–4(b)]. Net revenues of frozen operations declined over the three years but net revenues of live operations were initially stable before rising in 1998-99[Figure 6–4(c)].

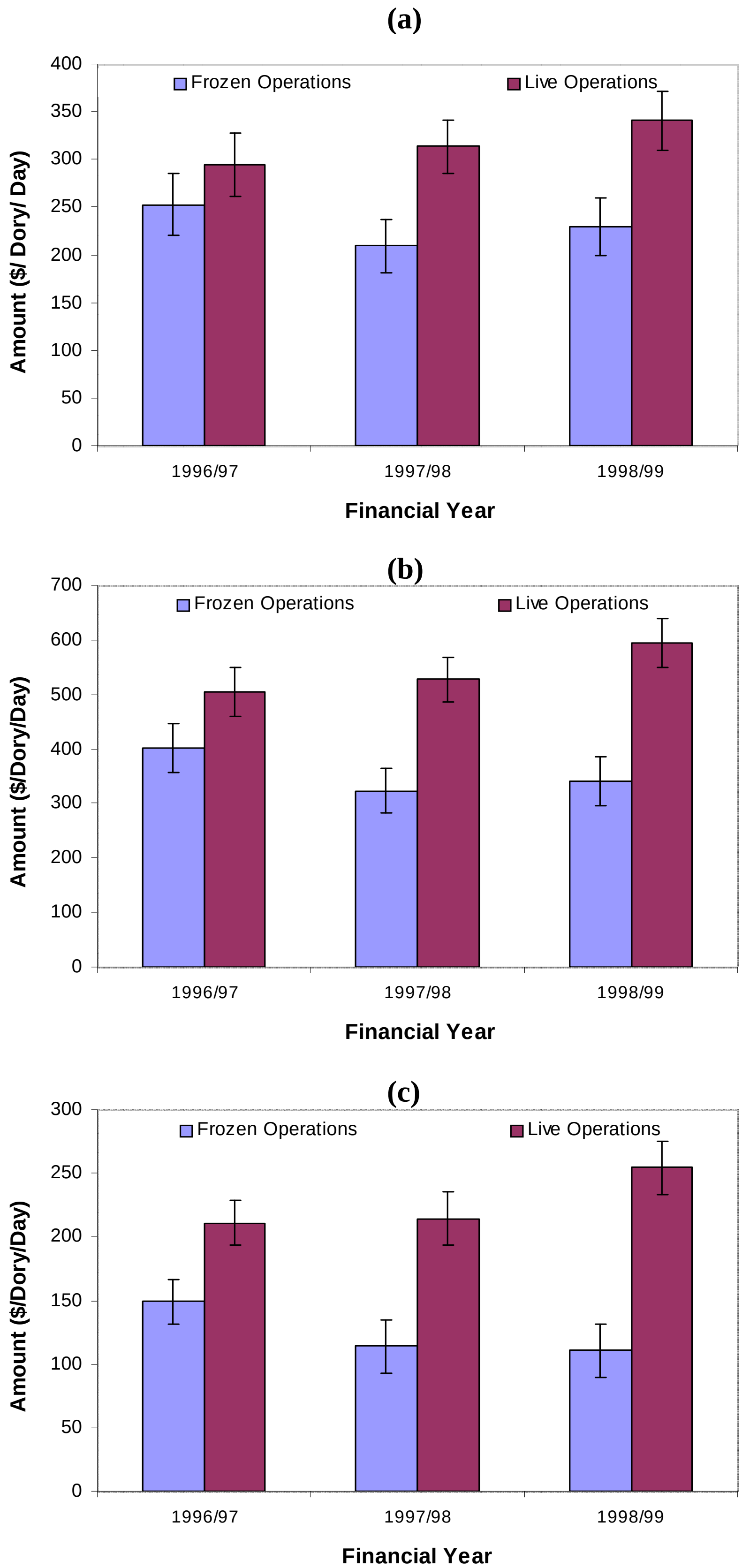


Figure 6-4: Mean value per dory/day for financial performance indicators; a) annual variable costs, b) annual gross revenue and c) annual net revenue by Operation Types (frozen and live) for the years 1996-97, 1997-98 and 1998-99. Error bars are standard errors.

There was a significant main effect of Operation Type for all financial indicators. Average annual and variable costs [Figure 6–5(a) & (b)] and gross, net and adjusted net revenues [Figure 6–5(c), (d) & (e)] per dory day were all significantly higher for live than frozen operations. Net revenue, which included skipper payments but no imputed salary for owner-operators, was highly significantly different between live and frozen operations and remained highly significant with the inclusion of returns to labour for owner-operators (adjusted net revenue) (Table 6–7).

6.3.3.2 Productivity and Efficiency

Variable Costs as a Percentage of Gross Revenue

Results of a three-factor ANOVA comparing average variable costs as a percentage of gross revenue per dory day indicated that there were no significant effects of the interactions between operation type, region and year or the main effects of region and year. When pooled across years and regions, however, the variable varied significantly among operation types ($F_{1,88}$ = 5.265, p = 0.024) with relative variable costs per dory day being lower for live (58.9%) than for frozen operations (64.9%).

Return to Capital

Returns to capital were computed for the financial year 1998-99 as non-stationary capital values (Figure 4–17) which under normal conditions may make comparisons across years difficult. With an average vessel age of 21 and 27 years respectively for live and frozen operators however, depreciation was able to be ignored. While overall, live operations higher rates of return to capital than did frozen operations, there were no significant main or interaction effects of operation type or region (p>0.05) on return to capital both with and without licence values included (Table 6–6).

Table 6-6: Rate of return to capital with and without license values included in total business value by Operation Type (frozen, live) summed across regions.

Operation Type	Returns to Capital (%)	
	Include License Value	Exclude License Value
Frozen Operation	4.53	9.00
Live Operation	11.75	17.78
Overall	8.82	14.22

Table 6-7: Repeated measures analysis of variance comparing annual fixed and variable costs, gross revenue and net revenue per dory day across financial years 1996-97 to 1998-99. Year (Y, 1996-97, 1997-98, 1998-99) is the repeated measures effect. Region (R, Northern, Southern), Operation Types (OT, Live, Frozen) are between-subject fixed factors. Significant p values ($p < 0.05$) are in bold. Results of Mauchley's Test of Sphericity for each financial measure are also presented. df = degrees of freedom, MS = mean square, *F* = *F*-ratio, *p* = probability of the data if no difference existed.

Source of variation	Annual Costs [a]				Annual Variable Costs				Gross Revenue				Net Revenue [b]				Adj. Net Revenue [c]			
	df	MS	*F*	*p*	df	MS	*F*	*p*	df	MS	*F*	*p*	df	MS	*F*	*p*	df	MS	*F*	*p*
Operation Type	1	28270.73	6.247	**0.021**	1	145855.15	6.187	**0.022**	1	600777.75	12.773	**0.002**	1	66706.729	16.665	**0.001**	1	20408.02	11.443	**0.003**
Region	1	2441.477	0.539	0.471	1	8076.362	0.343	0.565	1	47173.93	1.003	0.329	1	250.925	0.063	0.805	1	17.741	0..010	0.922
OT *R	1	70.493	0.16	0.902	1	608.791	0.26	0.874	1	3006.811	0.064	0.803	1	11870.600	2.966	0.100	1	51.532	0.029	0.867
Between-subjects error	20	4525.561			20	23575.71			20	47036.469			20	4002.858			20	1783.383		
Year	1.42	255.492	0.14	0.892	2	1877.980	0.812	0.451	2	10793.485	1.673	0.201	2	3025.763	2.359	0.108	2	604.332	0.371	0.693
Y * OT	1.42	316.680	0.142	0.795	2	6580.180	2.844	0.070	2	27646.493	4.286	**0.021**	2	4957.41	3.865	**0.029**	2	1334.904	0.819	0.448
Y * R	1.42	555.061	0.249	0.781	2	1113.42	0.481	0.622	2	3590.633	`0.557	0.578	2	837.609	0.653	0.526	2	426.717	0.262	0.771
Y * OT* R	1.42	364.70	0.231	0.795	2	2749.939	1.188	0.315	2	6902.089	1.070	0.353	2	527.344	0.41	0.666	2	27.742	0.017	0.983
Within -subjects error	34.44	1837.229			40	2313.925			40	6451.100			40	1282.685			40	1629.067		
	Mauchley's Test of Sphericity (W = 0.588, p = 0.006)				Mauchley's Test of Sphericity (W = 0.751, p = 0.066)				Mauchley's Test of Sphericity (W = 0.946 p = 0.589)				Mauchley's Test of Sphericity (W = 0.886, p = 0.315)				Mauchley's Test of Sphericity (W = 0.886, p = 0.338)			

[a] Because Sphericity assumption is violated the Huynh-Feldt estimate is used to test for significance for repeated measure main and interaction effects.

[b] Net revenue is derived from gross revenues less total costs. Total costs include wages paid to skippers but do not include imputed salaries to owner-operators.

[c] Adjusted net revenue is the same as above except where relevant, returns to owner-operators labour have been imputed and included in total costs deducted from gross revenue

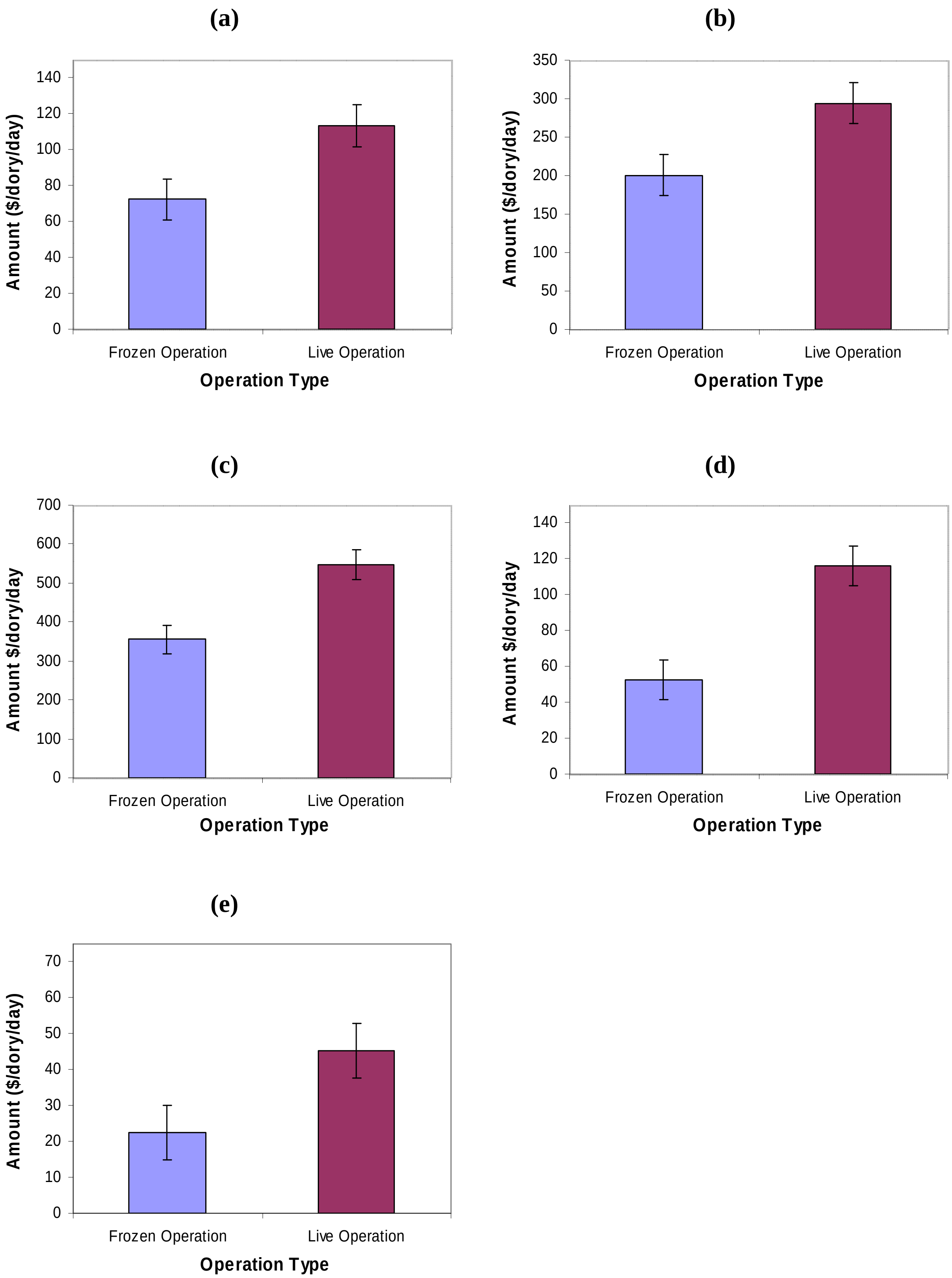


Figure 6-5: Mean value per dory/day for financial performance indicators a) annual fixed costs, b) annual variable costs, c) annual gross revenue, d) annual net revenue and e) adjusted annual net revenue by Operation Types (frozen and live). Values are aggregated across Years and Regions. Error bars are standard errors

6.3.4 Operational Characteristics

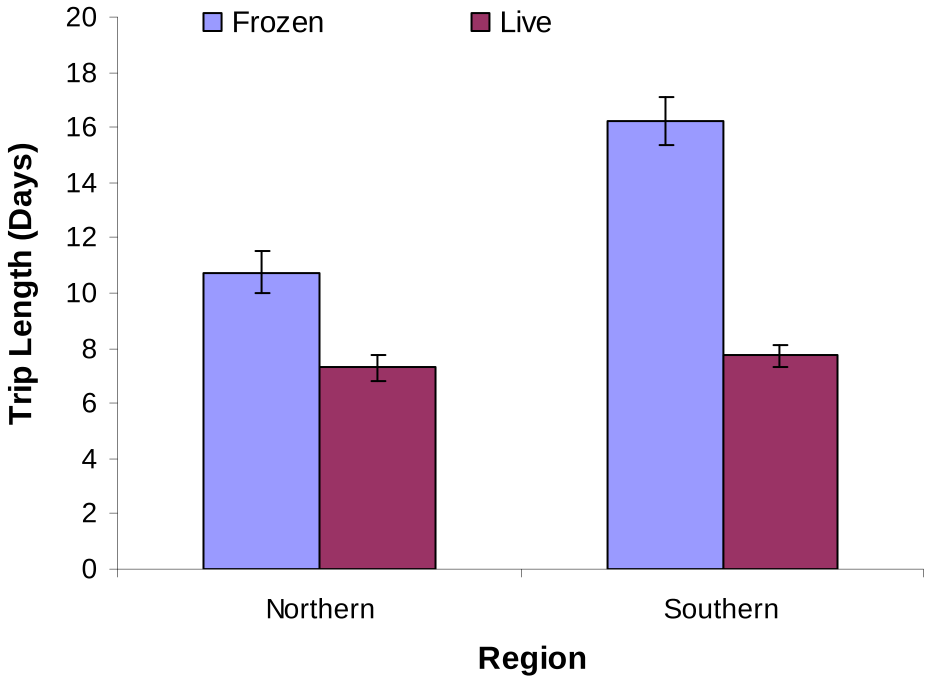
6.3.4.1 Trip Length and Port Turnaround Time

Interview data on trip length, time in port between trips (turnaround time) and the number of trips undertaken annually were collated across all years of operation. Consequently, only two factors, Region and Operation Type, were examined for main and interaction effects. There were significant interaction effects between Operation Type and Region on both trip length and turnaround time (Table 6–8). Frozen operations undertook significantly longer trips than live operations in both northern and southern regions. While trip lengths were comparable for live operations across both northern and southern regions, frozen operations in the southern regions undertook significantly longer trips on average than their counterparts in the northern region [Figure 6–6 (a)]. There was little difference in average turnaround times between frozen and live operations in the northern region, whereas turnaround times for live operations in the southern region were slightly, but not significantly, higher than either operational type in northern region. Frozen operations in southern regions spent significantly more days in port between trips than frozen operations in the north or live operations in either region. [Figure 6–6 (b)]

Table 6-8: Analysis of variance comparing the length of fishing trip and turnaround time in port. Region (Northern, Southern) and Operation Type (Live, Frozen) are fixed factors. Results of Levene's Test of Equality are also presented. df = degrees of freedom, MS = mean square, F = F-ratio, p = probability of the data if no difference existed.

	Trip Length (Days)				**Port Turnaround (days)**			
Source of variation	**df**	**MS**	***F***	***p***	**df**	**MS**	***F***	***p***
Operation Type	1	314.928	69.98	**<0.001**	1	12.296	3.420	0.071
Region	1	76.989	17.108	**<0.001**	1	36.293	10.094	**0.003**
Operation Type* Region	1	56.599	12.57	**0.001**	1	25.735	7.157	**0.011**
Residual (error)	202.5	4.500			202.5	3.596		
	Levene's Test: F = 1.474, p = 0.234				Levene's Test F = 1.235, p = 0.309			

(a)



(b)

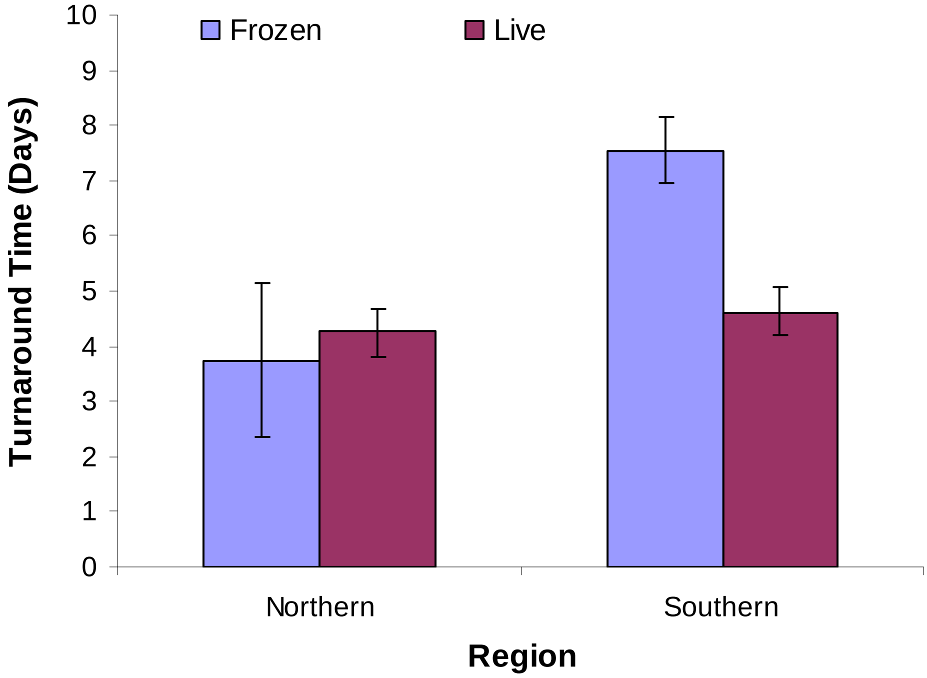


Figure 6-6: Average time in days for a) length of fishing trip and b) turnaround time in port between fishing trips by Region (northern and southern) and Operation Type (live and frozen). Error bars are standard errors.

6.3.4.2 Trip Length Determinants

Factors affecting trip length varied across operator types and determinants. Bad weather was acknowledged as a trip length determinant significantly more by live than frozen operators ($F_{1,46} = 5.075$, $p = 0.029$), as was hold capacity ($F_{1,46} = 5.019$, $p = 0.030$) [Figure 6–7(a)]. Trip profitability was a significantly greater determinant of trip length for both live and frozen operation in the southern region than their counterparts in the north ($F_{1,46} = 12.365$, $p = 0.001$) [Figure 6–7(b)].

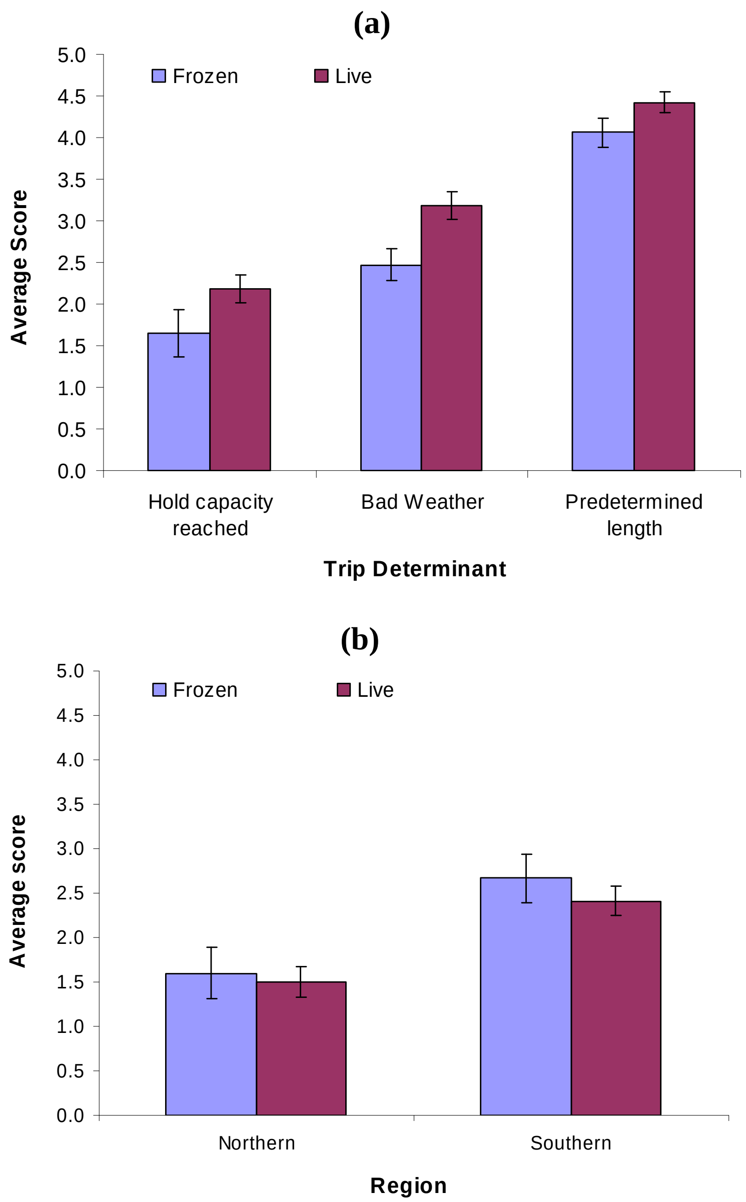


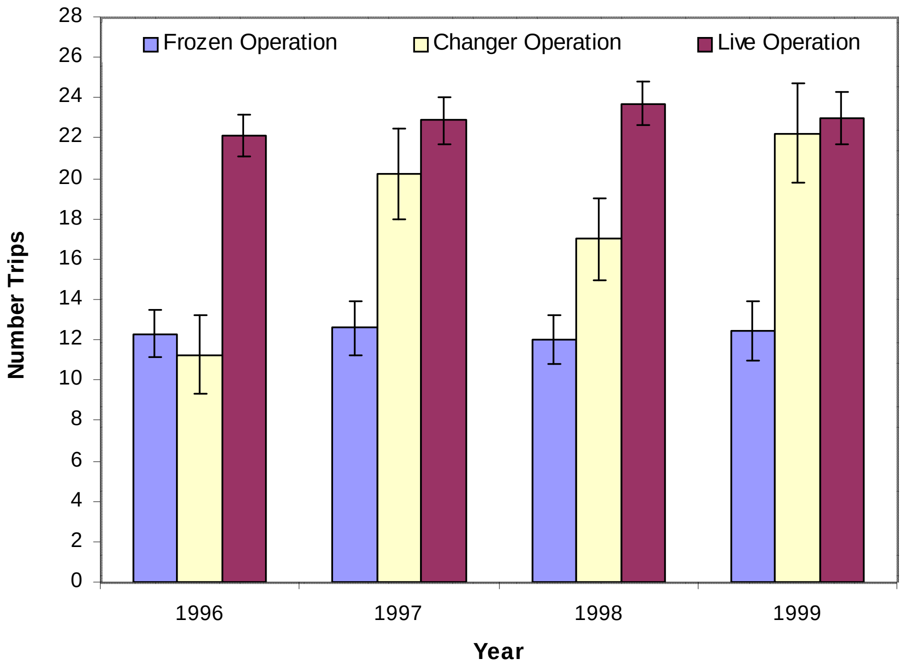
Figure 6-7: Trip length determinant response by operation type (a) and for operation type by region (b) with the scoring range being: 1 = Never; 2 = Hardly ever; 3 = Occasionally; 4 = Regularly; 5 = Consistently. (Error bars are standard errors).

Reaching a predetermined length was the main impetus for terminating a fishing trip for both operation types, while neither operator type identified reaching holding capacity as a major determinant of trip length (Figure 6–7).

6.3.4.3 Number of Trips and Total Days Fished

Number of Trips

Results of the RM ANOVA indicated no significant interaction effects between Region and Year or Operation Type, Region and Year. There were, however, significant interaction effects between Operation Type and Year and Operation Type and Region (Table 6–9). 'Changer' operations did significantly more trips in 1997 and 1999 than in 1996, but not so in 1998. As anticipated, the number of trips undertaken by changer operations prior to their switch to marketing live product was comparable with other frozen operations, while in the year they switched to marketing live product (1997), it was consistent with other live operations. In 1998, these live capable changer operations did significantly fewer trips than other live operations and a significantly greater number of trips than frozen operations [Figure 6–8(a)]. Frozen operations in the southern region did significantly fewer trips than those in north but there are no significant regional differences for other operation types. Moreover, while the number of trips undertaken by changer operations in the southern region was significantly fewer than live operations and significantly greater than frozen operations in south, this pattern was not evident in the northern region [Figure 6–8(b)]



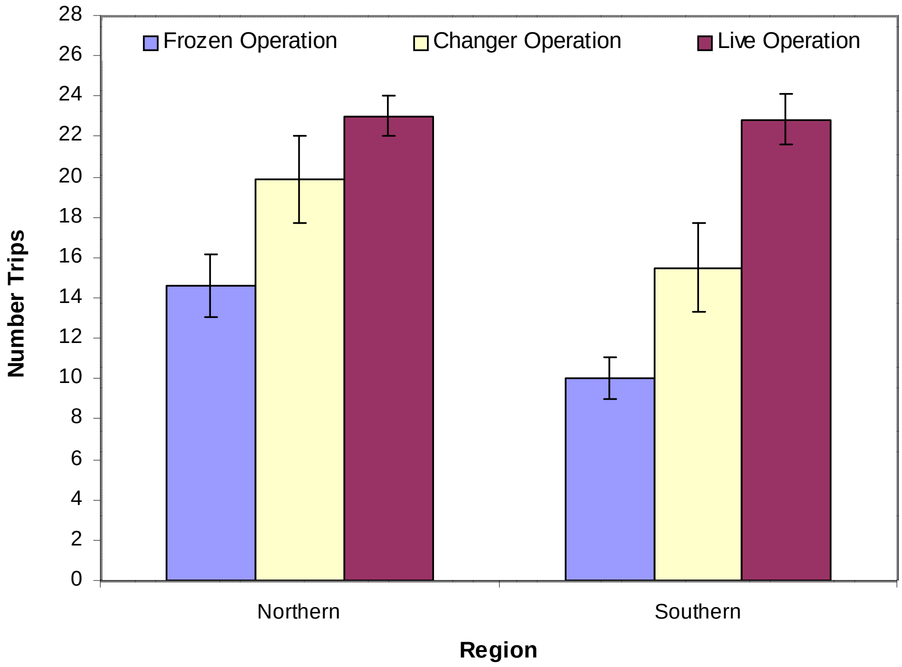


Figure 6-8: Mean number of trips per calendar year by a) Operation Type (Live, Frozen and Changer) for the years 1996, 1997, 1998 and 1999 and by b) Operation Type (Live, Frozen and Changer) by Region (Northern and Southern). Error bars are standard errors

Total Days Fished

Results of the RM ANOVA indicated neither significant main effects of Year, Operation Type or Region nor any significant interaction effects between Operation Type and Year or Operation Type, Region and Year or between Operation Type and Region. There was however a significant interaction effect between Year and Region (Table 6–9). In both 1996 and 1997, the mean numbers days fished did not differ significantly with region but in 1998 southern operations fished for significantly more days than those operations in the north. (Figure 6–9)

Table 6-9: Repeated measures analysis of variance comparing number of trips undertaken and number of days fished during a calendar year. Year (Y, 1996, 1997, 1998) is the repeated measure variable. Region (R, Northern, Southern), Operation Types (OT, Live, Frozen, Changer) are between-subject fixed factors. Significant p values ($p < 0.05$) are in bold. df = degrees of freedom, MS= mean square, F = F-ratio, p = probability of data if no difference existed.

	Number Trips per Year [a b]				Days Fished per Year [a]			
Source of variation	**df**	**MS**	***F***	***p***	**df**	**MS**	***F***	***p***
Operation Type	2	0.23929	48.871	**0.000**	2	118.851	0.259	0.774
Region	1	0.03877	7.917	**0.009**	1	42.091	0.092	0.764
OT * R	2	0.01996	4.076	**0.029**	2	53.270	0.116	0.891
Residual (error)	26	0.00490			26	458.889		
Year	3	0.0050	6.454	**0.001**	2	38.901	0.070	0.932
Y * OT	6	0.0026	3.387	**0.005**	4	1054.307	1.897	0.125
Y * R	3	0.0026	0.338	0.798	2	2387.064	4.296	**0.019**
Y * OT * R	6	0.0019	0.248	0.959	4	252.790	0.455	0.768
Within -subjects error	78	0.00776			52	555.696		
	Mauchley's Test of Sphericity (W = 0.646, p = 0.055)				Mauchley's Test of Sphericity (W = 0.937, p = 0.445)			

[a] Number of trips and number of days fished are for calendar years.

[b] Data were Log_{10} transformed to satisfy the Sphericity assumption of the analysis.

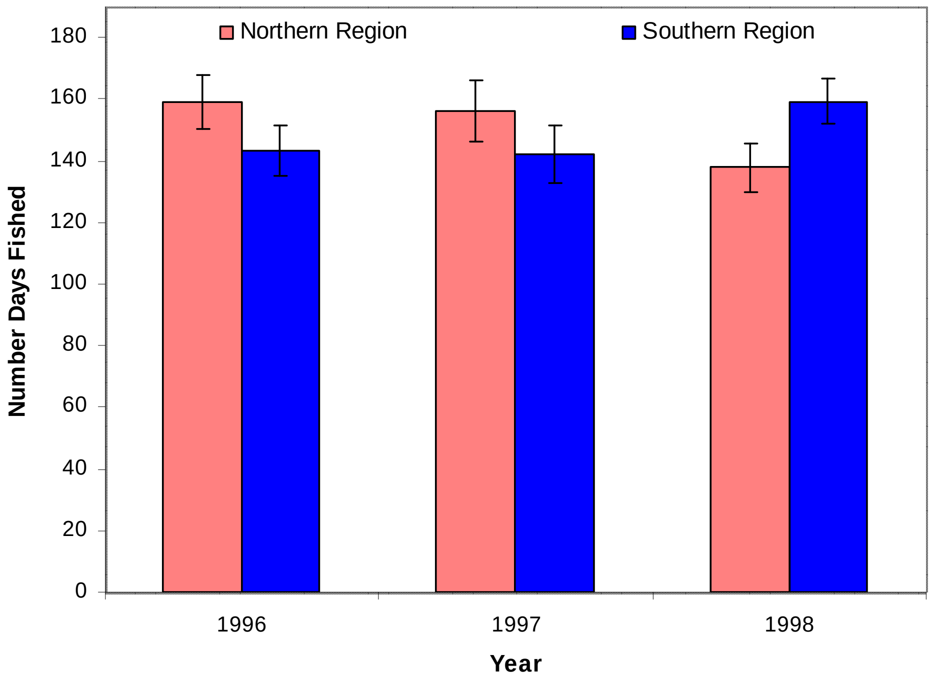


Figure 6-9: Mean number of days fished by primary vessels per calendar year by Region (northern and southern) for Operation Type for the years 1996, 1997 and 1998. Values have been aggregated across Operation Type (frozen, live and changer). Error bars standard errors

6.3.4.4 Port Operations

Results of the RM ANOVA indicated no significant interaction effects between Year and Operation Type, Year and Region, Year, Operation Type and Region nor Operation Type and Region on the number of ports used by fishing operations in a calendar year. There were however, significant main effects of Year and of Operation Type on this measure of vessel mobility (Table 6–10). Port use, pooled across all operation types, was significantly higher in both 1998 (p = 0.046) and 1999 (p = 0.020) than in 1996 [Figure 6–10(a)]. On the whole, live operations had less affinity to their home port than either frozen or changer operations and used a significantly greater number of ports to unload their catch than did frozen operations. Changer operations, which operated as frozen vessels in 1996 and live vessels in 1998 and 1999, used more ports on average than frozen operations and fewer ports than live operations but not significantly so in either case (Table 6–10) [Figure 6–10(b)].

Table 6-10: Repeated measures analysis of variance comparing number of ports utilised, including the operators home port during a calendar year. Year (Y, 1996, 1998, 1999) is the repeated measure variable. Region (R, Northern, Southern), Operation Types (OT, Live, Frozen, Changer) are between-subject fixed factors. Significant p values ($p < 0.05$) are in bold. df = degrees of freedom, MS= mean square, F = F-ratio, p = probability of data if no difference existed

	Number Ports Utilised per Year [a]			
Source of variation	**df**	**MS**	***F***	***p***
Operation Type	2	1.533	3.426	**0.047**
Region	1	0.126	0.281	0.600
OT * R	2	0.285	0.636	0.537
Residual (error)	28	0.448		
Year	2	0.882	5.862	**0.005**
Y * OT	4	0.251	1.665	0.171
Y * R	2	0.005	0.033	0.968
Y * OT * R	4	0.114	0.759	0.557
Within -subjects error	56	0.150		
	Mauchley's Test of Sphericity (W = 0.858, p = 0.127)			

[a] Number of ports utilised is over a calendar years. Operations are deemed to have utilised a port other than their home port when catch is unloaded at that port and a new fishing trip originates from that same port.

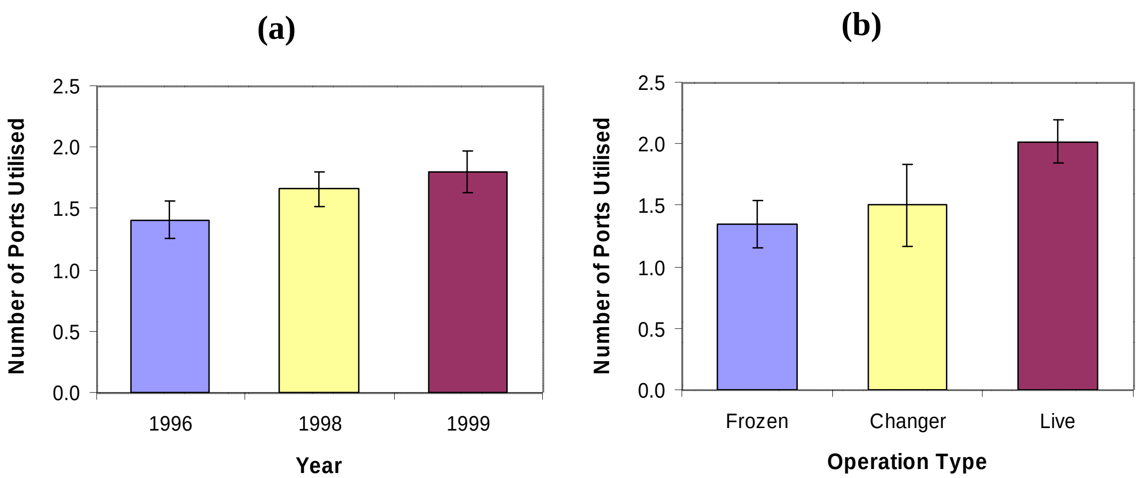


Figure 6-10: Average number of ports utilised per calendar year by a) year (1996, 1998, 1999) and by b) Operation Type (frozen, live and changer). Error bars are standard errors.

6.4 Discussion

Prior to the advent of the live reef food fish (LRFF) fishery, descriptions of financial and operational profiles of operators within the reef-line fishery, while limited, indicated the fleet to be relatively homogenous (Gwynne 1990). The results of my analyses provide preliminary evidence that the emerging LRFF fishery has significantly transformed financial and operational profiles of fishery participants, with the RLF now comprising two distinct sectors; live and frozen operators. Live operations are significantly different from frozen operations in three main areas:

1. Live operations are more highly capitalised than frozen operations, primarily as they fish from a larger primary vessel;
2. Live operations, while incurring higher fishing costs, generate significantly higher gross and net revenues and are more economically efficient than frozen operations; and
3. Live operations differ from frozen oprations at the micro-operational level (trip length, port utilisation, port turnaround, number of trips) but not at an aggregate level (days fished).

The implications of these results for management of the RLF are not conclusive. Given the latent effort identified in this fishery (see 2.5; 4.4), the superior economic and financial performance of live operations suggests incentive exists for effort increases from both existing and new operators. Annual fishing effort applied to the fishery at the business-unit level is comparable across the two fleet sectors. Management that restricts access to fish resources without attention to the differences between live and frozen operations may cause these components to respond differently to changing cost and revenue structures with outcomes not anticipated in the management provisions.

Barriers to Investment for Profit-maximising Firms

The objective of profit maximisation is central to most firms' production strategies (Doll 1988; Dupont 1993), even though it is generally accepted that firms also may have other objectives (Hanna and Smith 1993). An increase in product prices will see profit maximising firms choosing to increase their output by adjusting their fixed or variable inputs. Fishing operations must first undertake investment to enable them to catch and hold live product for markets in order to participate in the LRFF. The magnitude of investment required to participate in the LRFF will vary with the status of the decision-maker: existing fisher or an intended entrant to the fishery. Survey data showed that investment undertaken to adopt live technology ranged from $5,000 to $70,000 for those firms converting an existing vessel to more than of $400,000 for those with no history in the RLF who had to purchase both a vessel and a licence (see 5.4.1). Data on capital values collected from this sample of fishing operations suggests that the costs to a currently non-active fisher to enter the LRFF fishery would be up to $225,000 for the primary and tender vessels and up to $90,000 for a four dory license. These results provide some insight into the progressive financial barriers to entry faced by existing and intending new live fishery participants. Entry barriers can take many forms, however, including regulatory, technical or physical capital requirements, supply and demand uncertainty, or informational (Le Gallic 2000).

Differences in profitability between existing RLF operations in different segments of industry are evidence of a general 'non-competitiveness' in the RLF, or parts of it. and support the existence of entry barriers (Le Gallic 2000). The costs of adopting a new fishing technology would usually be weighed against the knowledge of resource availability and revenues generated from that new activity (Salas et al. 2004). A lack of information on economic performance will hinder the speed at which the new technology is 'taken-up' by the existing fleet (Whitmarsh 1990). Entry barriers will be greater still for potential fishery participants, who are either currently operating in another fishery or not engaged in any fishery activity. Increased investment costs faced by these groups are compounded by the fact that fishing capital is non-malleable and irreversible, having few, if any, alternative uses (Charles and Munro 1985). The fishing industry is characterised by many types of uncertainty, including economic uncertainty and informational impediments (Gates 1984). Obstacles to obtaining information on profitability and markets will be compounded for non-fishery prospective participants, particularly in the case of new technologies for which there is not a well established track record.

A firm can profitably undertake investment to initiate or expand its productive capacity where expected incomes from increased prices are sufficiently great. Prices for live Coral trout (*Plectropomus leopardus*) exceed, on average, those for the same species in frozen and fresh form by a factor of up to 3 (see 5.4). The question for both entrant types then becomes whether the economic and financial incentive to undertake this investment exists.

Comparisons of Financial and Economic Performance

The financial and economic data collected for the years 1996-97 to 1998-99 provide an excellent baseline for comparisons between live and frozen operations within the RLF. Live operations, while incurring significantly higher annual and operating (variable) costs than frozen operations, also earn significantly greater gross revenues from fish sales. Two measures of profitability were used in the analysis of financial performance; net revenues including only wages paid to skippers and adjusted net revenues incorporating skipper wage and returns-to-labour for owner-operators. Data collected in this study show that an equivalent percentage (~60%) of both operation types employ skippers and both remunerate skippers on the basis of percentage of catch value. Imputed wages accruing to owner-operators should be estimated using average wages paid to skippers of other vessels (Holland 2002), suggesting that the opportunity cost of labour for owner-operators should be adjusted according to operation type.

In general, increased per day fishing costs are offset by relatively larger increases in per day revenues. Along with higher gross revenues, net revenues inclusive of skipper wages only and adjusted net revenues are both significantly greater for live than frozen operations. Despite the significant differences in gross revenues, the absolute value of skipper wages is comparable for both operation types, which may be attributable to several factors. Firstly, live boat skippers receive on average a smaller percentage (15%) of catch value than frozen boat skippers (20%). Secondly, catch rates, and hence total catch, of most species groups tended to be lower for live operations, with catch rates for coral trout as much as 30% lower and catch of demersal by-product as much as 50% less (Mapstone et al. 2001). Lastly, the contribution of fisher skill as a determinant of fishing success needs to be recognised (Hilborn and Ledbetter 1985b). The crew of frozen operations, with significantly greater experience ($p < 0.01$) than those of live operations, would add value to their skipper's wage, regardless of differences in catch rates.

Despite beach prices for live coral trout declining sharply during 1998 (see 5.4), revenues of live operations rose over the period whilst revenues for frozen operations remained steady. One reason for this may have been the improvements in on-board husbandry of live fish, which increased the number of days for which live fish could be retained onboard and in healthy condition from 5-6 to 8-10 days (Mapstone et al. 2001). These improvements, while benefiting live operations in both the northern and southern regions, would have had greater benefits for southern based vessels which were faced with much greater distances to fishing grounds than those in the north. With improved husbandry and more secured survival of live fish, live operations could venture farther from port and access more isolated reefs subjected to less fishing pressure than inshore reefs (Mapstone et al. 1996; Ayling et al. 2000). The ability to undertake longer fishing trips would also have improved the efficiency of live operators. In the RLF variable costs such as fuel and repairs and maintenance are influenced by the steam time and distance to fishing grounds and are independent of trip lengths[91]. Live operations in the southern region, faced with much greater steaming distances to fishing grounds, would be able to distribute such fishing costs across larger catches and hence revenues by undertaking longer trips. Improved husbandry skills which result in greater efficiencies will provide further impetus to the widespread adoption of live technology and ultimately reactivation of latent effort from prospective non-fishery participants.

The differences in financial characteristics between operation types can be reinforced by looking at measures of economic performance. A key indicator of performance from a fisheries management perspective is the level of resource rent being generated in the fishery. Comparing the rate of return on capital to the opportunity costs of that capital is indicative of the level of resource rents in the fishery. Pascoe et al. (1992) argued that where limited entry prevents access to alternative fisheries, the opportunity cost of capital is low. The opportunity cost of capital is also low where multiple endorsements permit vessels to access other fisheries, as in the case of the RLF (see 2.5, 4.4), but the relative returns from these fisheries are inferior[92].

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[91] Data indicates that fuel and repair and maintenance costs comprise approximately 15-20% of total variable costs of fishing.

[92] See Taylor-Moore (2000) for an overview of fishing returns for a range of fisheries in Queensland.

Rates of return as a measure of economic performance also need to be evaluated with capital structure and capital values in mind. The capital structure of a line fishing operation comprises capital items (primary and tender vessels) and a license. There are opposing views as to whether the value of a licence should be included as a capital value. One view is that dedicated fishing endorsements have no value outside the fishery and should be excluded from the capital value of the fishing firm (Holland 2002; Hundloe 2002). Another is that where licences in a limited entry or quota fishery are tradeable, they need to receive a suitable return and should be treated as a capital item (Boncoeur *et al.* 1998). Using capital structure to measure net returns to the fishery is dependent on trends in that capital structure. Declining capital values may indicate a fishery is overcapitalised and inclusion of cost of current capital may mean measures of net returns overestimate long term rent. Constant capital values imply current net return to fishery is a reasonable measure of rent (Rose et al. 2000b). Given an average vessel age of >21 years for both operation types and restrictions on verifying actual vessel values, capital values are assumed to be constant based on values supplied from interviews (Rose et al. 2000b).

The return to capital calculated for live fishing operations in the RLF is attractive in contrast to other comparable smaller-scale Australian fisheries for which data exists. For example, rates of return of inshore boats in the South East Trawl Fishery in 1999-2000 were 11.4% excluding the license value and 4.1% including the licence value (Galeano et al. 2002a). Galeano et al. (2002b) reported returns in the Eastern Tuna and Billfish Fishery of 9.4% excluding the license value and 5.8% including the licence value and in the Southern Shark Fishery of 10.8% excluding the license value and 3.1% including the licence value in 2000-2001. The high returns to capital I document for live boats (17.8% excluding the license value and 11.7% including the licence value) reflect the value-adding of an existing product and manifests itself as increased productivity[93] of live operations compared to their frozen counterparts.

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[93] Productive efficiency is a measure of the amount of output (gross revenue) extracted per unit of cost (variable fishing costs) given available technology and input prices ((Rose et al. 2000b)

Comparisons of Operational Behaviour

To more fully understand the implications of any regulatory changes imposed on the RLF, however, operational characteristics also need to be reviewed in terms of the extent to which heterogeneity exists between operation types. Comparison of the fishing practices of live and frozen operations in this study showed that trip parameters (trip length, time in port between trips, number of trips) differed variously between operation types and regions and for operation types across years. In contrast, individual live and frozen operations fished on average a similar number of days per year across all years of this study, although there were regional differences across years, which again might be indicative of improvements in on-board husbandry.

Despite improvements in on-board husbandry enabling live operations to almost double the maximum possible length of their fishing trips, frozen operations still undertook significantly longer trips than live operations in both regions and more than twice as long in the south[94]. As previously noted, longer trips in the south may be a fishing strategy to negate the higher costs associated with accessing more distant fishing grounds and to improve trip profitability from larger per trip catches (Sampson 1992). Indeed, while fishing trips tended most often to be of a predetermined length, both frozen and live operations in the south identified profitability as a significantly more important trip length determinant than their respective counterparts in the northern region [Figure 6–7 (a), (b)]. While there were insufficient data to isolate causal effects of such a fishing strategy, variable costs were lower for both frozen and live operations in southern regions for all years for which data were collected.

Market Influence on Adoption Decisions

Fishing behaviour should respond to changes in costs and revenues (Robinson and Pascoe 1997). Where more than one type of fishing technology is available or alternative species are targeted, vessels would be expected to base their fishing decisions on the relative profitability of available options (McKelvey 1983; Sampson 1992). This in turn will be based on information on revenues generated from prior trips and potential costs, with these costs being monetary (e.g. fuel, wages) or non-monetary (e.g. fisher skill) (Salas et al. 2004). Fishermen are inherently risk averse and tend to

[94] Trips for frozen operations in the south are on average 6 days longer than their northern counterparts.

react positively to increases in expected returns and negatively to variability of uncertain returns (Bockstael and Opaluch 1983).

As this study showed, adoption of live technology did not result in operators sacrificing all usable freezer space, with all live operations in this study retaining frozen capacity. That they did was likely due to logistical reasons and a market decision to retain the flexibility to store frozen product in the event of a downturn in live prices (see 5.4.2.2). Of less but still influential concern would be the capability to freeze by-catch and target species not suitable for live markets.

Although the results from this study are based on a small sample size, the operational behaviour of the 'changer' operations provides an insight into the influence of market conditions following the adoption of a new technology. In 1997, their first year of operation after incorporating live technology, changers undertook a similar number of fishing trips to existing live operations across both regions. Demand fluctuations in overseas markets, however, saw beach prices for live fish depressed for most of 1998. Changers responded by undertaking significantly fewer total trips than established live operations in 1998 [Figure 6–8(a)] and offering a greater proportion of their catch to the market as frozen product (see 5.4.2), implying they were switching between marketing live and frozen product as dictated by price, perception of risk, or experience. As recent adopters of live technology, changers would have imperfect knowledge of the relative profitability of trips when marketing live versus frozen product (Mapstone et al. 2001). In contrast, established live operators exhibited a higher degree of fidelity to past fishing patterns (Holland and Sutinen 1999) and continued to market their product alive during the market downturn.

The superior financial and economic returns from improved technology enabling marketing of live as opposed to frozen product provides ample incentive for an increase in fishing effort (Asche and Aarland 2000). Over time, as adoption risk diminishes and the superiority of the new technology becomes more evident, adoption will likely be more widespread[95]. The possible source of effort increases is less obvious and may

[95] The minimum" size for the adopting firms usually declines over time as knowledge of relative costs and revenues diffuses among fishery participants with more widespread adoption likely (see 6.2.1)

emanate from either existing or intending new fishery participants[96]. The possible implications of these findings for management of effort in the reef-line fishery are referred to in subsequent chapters and discussed in detail in the general discussion

6.5 Summary

The results from this chapter represent that first attempt to present the financial and operational profiles of both frozen and live operations in the RLF. They demonstrate heterogeneity between fleet components on both counts. In particular the results have quantified the significantly higher returns generated by live operations in the RLF. Over time it would be expected that more currently frozen only operations would move to maximise profits by investing in requisite technology to market their product alive. This outcome had particular relevance for the RLF in the late 1990s which retained substantial latent effort that could, given the market conditions, be mobilised. These conditions have been only partially ameliorated by effort reductions and the introduction of catch quotas in 2003-04. Despite being license limited, the extent of this latent effort meant that the RLF exhibited many of the characteristics of a regulated open-access fishery (Homans and Wilen 1997). As such any short-term benefits accruing to fishers from the value-adding an existing target species could be eroded by longer-term effort increases.

Given the heterogeneous financial and operational profiles in the RLF, management regulations that aim to safeguard against excessive effort or catch will need to consider the varying burdens that such regulations may impose on the efficiency or profitability of either operation type (Grafton 1995). At first glance, given the aggregate effort input of live and frozen operations is comparable; regulations aimed at reducing effort in the RLF are unlikely to be discriminatory. Both operation types would retain sufficient flexibility to reallocate effort to maximise returns. Regulations that restrict the days that can be fished by ‘active’ operations however, would tend to increase fishing costs and reduce the economic efficiency of those vessels (Townsend 1990). Regardless of adoption risk, input-based regulatory changes may expedite the number of existing frozen operations switching to the more profitable marketing of live product (Wilen and

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[96] The source of new effort will depend on entry barriers such as access to capital and the individual’s assessment of the risk and return associated with that investment.

Homans 1994). This chapter also highlights the investment options and progressive barriers to entry faced by those wishing to participate in the live fishery. Further research needs to be undertaken into the motivations and drivers of investment behaviour in the RLF and these will be addressed in the following chapter.

In the context of fisheries management, this chapter highlighted several other areas for future research. These include; the opportunity for product enhancement innovations to lower the social costs of effort reduction strategies, the biological implications for target and non-target species of a greater number of vessels retaining live product given live vessels have lower catch rates and retain less by-product (Mapstone et al. 2001), and the potential impact on frozen product prices from changes to economic conditions in essential markets.

CHAPTER 7

INNOVATION AND INVESTMENT IN PRODUCTIVITY ENHANCEMENT: GBR LIVE FISHERY AS A COMPONENT OF THE GBR REEF-LINE FISHERY

7.1 Introduction

Occasionally a new fishery develops that makes better use of by-catch species (Meyers 1994; Perez and Pezzuto 1998) or adds value to current target species as a new product supplying existing or new markets (McElroy 1993; Drouin 1999). Among the drivers for alternative uses of currently exploited stocks or by-catch, is growing consumer demand or changing consumer preferences (Smith *et al.* 1992; Edwards 1999). An inability of a country to meet domestic consumer demand from it's own resources often will necessarily lead to an increase in imports from other countries (Sonu 1997; Sonu 1998). It is likely that as part of the process of satisfying this consumer demand through imports, the importing country will need to make supplier firms aware of specific consumer preferences. This may in turn require the introduction and diffusion[97] of a new technology in the supplier country. Consumer preference, new or emerging markets and take-up of process or product innovation are certain to be linked.

The reef-line fishery (RLF) on the Great Barrier is one such example of a fishery experiencing a product enhancing innovation driven by changing consumer demand. Increased demand[98] for imported live reef fish in Hong Kong and Southern China has precipitated the introduction into the existing fishery of a new technology enabling fishers to store and transport their product alive for sale (Squire 1994). This technology has added considerable value to an existing targeted species, with minimal change to methods of capture. These developments have led to concerns over potential effort

[97] Throughout this chapter, *diffusion* refers to the spread of a specific technology among potential adopters

[98] See Chapter 4 for a detailed discussion on the main sources of demand for live reef fish and the causes of the spread of the live reef food fish trade into Southeast Asia and the Indo-west Pacific.

influx through mobilisation of latent effort[99] (see 2.5) (QFMA 1997a; Taylor-Moore 1998). Investigating the adoption determinants for such product enhancing innovations may provide some insight into the motivations, pecuniary or otherwise, of fishers in the RLF and the conditions under which new harvesting capital is likely to enter the fishery. Thus the aims of this chapter are to:

(i) describe the economic and non-economic factors dictating the adoption or non-adoption of a direct revenue enhancing innovation;

(ii) develop an adoption model to address links between innovation, diffusion and investment;

(iii) Use these findings to conceptualise the link between innovation and excess fishing capacity in the presence of latent effort.

7.2 Theoretical Aspects of Innovation Adoption and Diffusion

Three categories of variables are recognised as important in predicting adoption or non-adoption of an innovation. These are personal characteristics of the potential adopter (or firm), attitudes to the state of potential adopters' specific sector, and the perceived attributes of the innovation (Tornatzky and Klein 1982; Rogers 1995).

Although the literature on technological innovation addresses adoption and diffusion collectively, there are differences between the two. Diffusion studies tend to focus on determinants of the spread of an innovation following it's initial adoption (Rogers 1995)[100]. Adoption studies on the other hand study which factors determine the uptake of a given technology by a firm at any point in time. The focus of this chapter is on those factors determining the adoption or non-adoption of innovative technology.

7.2.1 Characteristics and Attitudes of the Firm

There are relatively few empirical studies of innovation adoption in fisheries. There is considerable empirical research into the adoption or non-adoption of innovation within

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[99] *Latent effort* is a combination of unused and under-used fishing endorsements. In this instance, I refer only to the unused licences.

[100] The rate of diffusion of an innovation throughout an industry is best described by the sigmoid or logistic diffusion curve (Griliches, 1957; Mansfield, 1961).

resources based activities, however, from the agricultural sector. Technology adoption literature tends to be divided into two broad streams: 1) analysis of adoption behaviour of individual firms; and 2) aggregate adoption models that emphasise technology diffusion over time (Kennedy and Thirlwall 1973; Feder *et al.* 1985; Dorfman 1996). Technology adoption studies can focus on either a single new technology or a set of new technologies considered as a single indivisible unit adopted simultaneously (eg. high yield seed varieties *and* fertiliser or irrigation techniques) (Rauniyar and Goode 1992). Fisheries innovations, however, tend not be bundled, with each performing separable functions, so that interactions between packages of interrelated technologies rarely confound the decision-making process (Acheson and Reidman 1982). My research is concerned with the behaviour of a fishing firm faced with an innovation adoption choice for a single new technology – the capability to keep fish alive for sale.

A review of empirical studies of resource industries shows adoption decisions as being influenced by a suite of adoptee attributes. Firm size is the major factor dictating the uptake of a new innovation and has been shown to be positively related to adoption (Just and Zilberman 1983; Feder and Umali 1993; Rogers 1995; Barham 1996; Rauniyar 1998). Other key determinants widely recognised as influencing the initial adoption decision are capital requirements (Sturm and Smith 1993), liquidity constraints (Chacko 1998), risk or uncertainty (Feder 1980; Binswanger and Sillers 1983; Tsur *et al.* 1990), availability of labour (Shields *et al.* 1993), access to markets (Rauniyar 1998), output prices (Shields *et al.* 1993) and, in the case of resource-based industries, environmental conditions (Cary and Wilkinson 1997).

It also has been recognised that those with higher levels of education are more likely to adopt innovations (Saha *et al.* 1994; Rikoon *et al.* 1996; Rauniyar 1998) as are younger decision-makers (Sturm and Smith 1993; Boahene *et al.* 1999). It has been argued that external income sources enhance the likelihood of adoption by overcoming capital constraints and partially insulating the enterprise from adverse economic or environmental conditions associated with adoption (Shields *et al.* 1993). Wozniak (1993) and Dorfman (1996) argue that being part-time in an industry can reduce the likelihood of adoption. Lastly, geographical proximity to other adopters has been identified as a strong determinant, especially in the early stages of the innovation's introduction (Lindner *et al.* 1982; Fischer *et al.* 1996; Baptista 2000).

A wide variety of empirical results suggest close correlations exist between firm size and other factors influencing adoption behaviour, such as adoption costs and credit constraints (Feder *et al.* 1985). Larger firms will have better access to credit and can apportion investment costs over more output units, leading to lower relative fixed costs of acquiring a new technology, giving them a relative advantage for innovations with higher fixed adoption costs. Often, however, these factors, while critical determinants in the initial phases of adoption, become less significant in the latter stages of the diffusion cycle, implying that the "minimum" size for the adopting firm declines over time (Feder and O'Mara 1981; Alauddin and Tisdell 1988; David and Otsuka 1990).

The influence of economic factors on adoption is sometimes seen as an indicator of the divisibility of an innovation (Feder *et al.* 1985). An innovation is divisible if it can be partially adopted, or used more or less intensely (Saha *et al.* 1994)[101]. Adoption can be seen as either a dichotomous (adoption/non-adoption) or continuous variable. In the latter case, adoption behaviour is a continuum, rather than a discrete event, along which use intensifies over time. (Rauniyar and Goode 1992). The relationship between firm size, adoption cost and access to credit is more apparent with indivisible technologies, that require a large initial investment (Feder and Slade 1984; Chacko 1998). Also, risk aversion and uncertainty are likely to be higher when the technology to be adopted is indivisible (Feder and O'Mara 1982), often preventing smaller firms from adopting more quickly (Feder and O'Mara 1981; Shields *et al.* 1993; Sturm and Smith 1993).

Most models of technology adoption under uncertainty predict that risk aversion delays adoption (Feder and Umali, 1993:220). Larger, more profitable firms may cope better with adoption risk and be more inclined to innovate with indivisible technologies (Feder and O'Mara 1981)[102]. The extent to which the innovation modifies existing production techniques and the extent to which investment in a new technology is irreversible will, in the presence of uncertainty, influence the propensity to adopt (Purvis *et al.* 1995). Uncertainty declines over time as information about the new method becomes more widely disseminated (Whitmarsh 1990; Rogers 1995) and the adoption experiences of

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[101] An example in agricultural applications would be the area of total farm under high yield seed varieties cultivation or the quantity of fertiliser applied per hectare.

[102] This relationship didn't hold in the case of divisible technology (Feder, 1980; Just and Zilberman, 1983) but risk did influence extent of adoption where a decision had been made to adopt (Saha et al., 1994)

others are observed (Kapur 1995). The minimum firm size below which adoption is rejected also is expected to fall over time and the number of firms in the industry using the new technology will rise (Stoneman 1983).

Economic considerations remain the most important determinants of adoption decisions for innovations oriented toward resource conservation within resource dependent industries (Pannell 1999). Innovations with environmentally beneficial outcomes will only be adopted if there is an economic benefit to be had and the economic advantages of doing so can be clearly demonstrated (Weaver 1996; Robins *et al.* 1999). Adverse fluctuations in resource stocks or increased resource competition may increase the likelihood of adoption, particularly where the level of existing financial returns may be jeopardised by non-adoption (Frank 1995). In such circumstances adoption may reduce undesired risks through diversification (Just and Zilberman 1983; Tsur *et al.* 1990). Conversely, uncertainty over future returns (e.g. fish catch) can delay adoption (Whitmarsh 1989)[103].

7.2.2 Perceived Attributes to Innovations

Most innovation adoption research has centred on two central questions: (i) who adopts innovations and why; and (ii) which innovations are more likely to be adopted and when. Most studies have acknowledged, however, that no general theory of innovation adoption or rejection has emerged (Rogers 1995). Two explanations have been posited for this lack of a universal theory: i) innovation research embraces a wide variety of disciplines and typologies and so uniformity is unlikely; and ii) a unique relationship exists between innovation(s) and individual adopter(s), also meaning that standard responses are unlikely (Downs and Mohr 1976).

According to Downs and Mohr (1976:702-704), each innovation can be classified according to either its *primary* or *secondary* attributes. They posited *primary* attributes as those intrinsic properties of an innovation that all potential adopters perceive of similarly (e.g. cost). Others dispute this view, however, arguing that regardless of whether a particular innovation costs a fixed amount or not, that cost will be evaluated

[103] Despite being shown to respond to economic incentives, fishers are inherently risk averse (Andersen, 1982; Bockstael and Opaluch, 1983)

relative to the potential adopter's financial resources and thus there can be no primary (common) attributes of an innovation (Tornatzky and Klein 1982). Downs and Mohr (*ibid*) argued that s*econdary* attributes (e.g. compatibility or complexity of innovation) depend on the "relationship" between the innovation and the potential adopter and the perceived extent to which the innovation does or doesn't meet the adopter's needs. As such, they maintained that no one subset of secondary attributes would consistently explain the adoption of all or most innovations across sectors[104]. They based their observations on a meta-analysis of numerous studies, whereby factors found to be important for adoption of an innovation in one study were less so or not at all important in others. These contradictory results suggest that cross-sectoral comparisons are not likely to be fruitful and that individual human behaviours outweighed sector specific issues or priorities in the innovation adoption processes.

A number of studies in the fisheries sector have examined the factors dictating adoption of several innovations separately by single firms. All studies found very few secondary attributes (e.g. compatibility, profitability, complexity of innovation) to be consistently linked to the adoption of more than one innovation, either within or between firms (Acheson and Reidman 1982; Bingham *et al.* 1984; Levine and McCay 1987; Dewees and Hawkes 1988). This suggests a fishing firm faced with the decision to adopt one or all of a suite of innovations will adjudge each separately based on how well it meets their needs or solves a problem, and that adoption of fisheries innovations should be examined independently. These studies also confirm that attempts to generalise across suites of innovations won't necessarily lead to a more comprehensive understanding of innovation behaviour. These findings support my intention to focus on a single-innovation in the RLF.

7.2.3 Innovation and Investment

The expectation of improved profits, whilst posited as a principal determinant in the decision to adopt an innovation is not likely be the sole contributing factor (Sampson 1992; Pannell 1999). Regardless of the nature of an innovation, adoption of new technology normally requires an initial capital outlay. Thus, innovation can be

[104] The assumption here being that all innovations, be they technological, economic or institutional, are essentially the same and therefore treated alike.

considered an investment decision by the firm in that it involves expenditure now in anticipation of a stream of benefits over future periods (Whitmarsh 1990; Rosseger 1996). *A priori*, the main factors determining investment will be (Solomon 1976; Lipsey and Harbury 1992; McTaggart *et al.* 1999):

(i) *expected future profitability* which is partitioned into expectations of price or price stability, demand for product and the source of supply;

(ii) *expected costs* comprising acquisition (opportunity) costs regardless of source of investment funds, availability of credit and expected production costs; and

(iii) *existing capital*, which recognises that the degree to which existing capital is utilised dictates flexibility to incorporate new capital and hence investment costs

7.2.4 Innovation Adoption within the GBR Reef-Line Fishery

Studies into the adoption of process innovations that increase the throughput of individual fishing firms and/or reduce input costs predominate in fisheries (see 2.3.1). The adoption of fishery innovations that enhance the quality of the catch (handling and storage) or improve the efficiency of resource conversion (the amount of value extracted per unit of resource), with little or no impacts on lowering fishing costs, are rare, despite the latter innovations being advanced as potentially offsetting the decline in fish stocks and associated fishery rents arising from technology induced overfishing (Le Floc'h and Boude 1998; Boude et al. 2000a).

The adoption of live fishing practices by fishing operators within the RLF is an example of such an innovation. Firstly, the adoption of live fishing practices does not lead to greater volumes of output, through increased catching power, but in fact may result in lower overall catch rates in the fishery (Mapstone *et al.* 2001). Second, the innovation does not offer reductions in per unit production costs through improvements in productivity. In fact, it may increase variable costs by virtue of reduced holding capacity and increased steaming costs due to shorter, more frequent trips and greater cargo loads because of having to carry large quantities of water in which the fish are kept alive. Any improvements in vessel productivity manifest themselves in a revenue sense only through adding value to a unit of output. Further, it may be argued that there is an absence of increased pressure on fish stocks from individual fishing firms adopting this innovative technique. This contrasts with innovations that improve the productivity of factor inputs (i.e. catching power, catch volume). While generating increased profits in the short term, such innovations may, in the long-term, drive stock levels down even further, ultimately eroding long-term profits (Whitmarsh 1998). The presence of significant latent effort in the RLF, however, which may mobilise in response to potentially greater profits, may impose similar negative spillover effects from the adoption of trade in live reef fish if aggregate, rather than individual, effort is permitted to expand sufficiently beyond current levels.

This research differs from other fisheries adoption research in that it examines an innovation that impacts positively on output price as opposed to output volume, and makes a distinction between *attributes* of the innovation that influence its adoption and *investment determinants* that dictate the extent to which it is adopted. In order to examine the adoption behaviour toward a product innovation and to explore this innovation-investment link further, three discrete models were developed:

(i) a logistic regression model using personal and attitudinal characteristics of both adopters and non-adopters to predict likelihood of adoption;

(ii) factor analysis to confirm hypothesised innovation attributes influencing take-up by adopters only; and

(iii) factor analysis to explore the link between adoption (implementation) and non-adoption and investment determinants.

7.3 Methods

This chapter focuses on the decision of operators to participate, or not, in the live fishery. Face-to-face interviews conducted with a sample of 50 vessel owners actively participating in the reef-line fishery (see Chapter 3) were used to categorise respondents as either adopters or non-adopters. Individuals in each category were asked to respond to a unique set of questions, formulated to educe their reasons for either adoption *or* non-adoption. This contrasts with most innovation studies where respondents, regardless of their adoption status, are asked a homogenous set of questions (Acheson and Reidman 1982; Levine and McCay 1987; Dewees and Hawkes 1988).

7.3.1 Data Collection and Model Considerations

Interview data drawn from sections (i), (ii), (iii) and (iv) of the questionnaire (Appendix 2) were used to explore fisher responses to the opportunities presented by the market in live fish and their decisions to incorporate live fishing practices into the fishing business (Table 7–1). Prompt cards were used for questions where respondents were asked to choose from a large number of categories and for all likert-scale type questions.

Table 7-1: Questions used to describe the personal characteristics, attitudinal variables and attributes of the innovation influencing the adoption or non-adoption decision. Questions 41, 42, 50 and 67 are likert-scale type questions (see Chapter 4).

Section	Question #	Question description
Fishing History	Q2	Year entered fishery
	Q9	Home port of vessel
	Q8	Number of dories permitted
Operational Characteristics	Q13	Primary vessel characteristics
Live Fishing History	Q35	Live or fresh/Frozen fishing operation
	Q37	Year of conversion to live fishing
	Q41	Importance of multiple variables in decision to upgrade
	Q42	Importance of multiple variables in determining level of investment undertaken
	Q50	Importance of multiple variables in influencing decision not to upgrade
Investment Decision-making	Q67 a)	Opinion on status of reef stocks in region fished
	Q67 b)	Opinion on commercial fishing effort in region fished
	Q67 c)	Opinion on impact of live fish industry on RLF
	Q70	Risk of investing in line/live fishery

Personal and attitudinal data about adoption and non-adoption behaviour can be rigorously analysed for both operation types using logit analysis. Developing a model of technological innovation for the reef-line fishery for both operation types simultaneously is more problematic with respect to perceived attributes. I explore not only the dimensional aspects of the perceived attributes of live fish technology, but also the innovation-investment link. To do this, three discrete factor analytic models are developed to firstly measure the features of live technology important in the adoption/non-adoption decision and secondly the economic determinants that dictate this decision. For each factor model, respondents were asked a series of statements with responses recorded using a five point Likert-type scale from 1 (not at all important) to 5 (very important). Likert scale questions traditionally employ a bipolar symmetrical scale around a neutral point (favourable - neutral - unfavourable) to elicit responses (DeVellis 1991; Arksey and Knight 1999). Rating response formats however, need not span the range of weak to strong assertions of the construct and may be uni-polar, from zero to a high positive or high negative value (Dawis 1987; DeVellis 1991; Spector 1992) In this study, groups are treated independently, so that the scale measures only the intensity of the decision to either i) adopt or ii) not adopt; in effect one side of the scale.

7.3.2 Logit Model

Logit analysis was the primary statistical technique used to test a 10 variable model of adoption/non-adoption of a single innovation using personal and attitudinal characteristics of the respondents. The maximum-likelihood logit technique has been shown to be appropriate in the case of a dichotomous dependent variable, where data are non-aggregated and independent variables are both categorical and continuous (McFadden 1974; Aldrich and Nelson 1988; Fox 1997). The logit model was preferred as being more appropriate for distributions with heavier tails (Liao 1994). Logit models have been widely used to investigate binary decision choices in fisheries, including consumer preference (Engle and Kouka 1995; Nauman et al. 1995), entry-exit behaviour (Ward and Sutinen 1994) and investment decisions (Acheson and Reidman 1982; Dewees and Hawkes 1988)[105]. The logistic regression model is a transformation of the linear probability model (LPM):

$$P_i = E\,(Y_i = 1 \mid X_k) = \alpha + \beta_k X_k + \varepsilon_k \qquad [1]$$

Where; P_i is the *conditional probability* of Y_i occurring given X
α is an unknown constant
β_k is a vector of unknown parameter estimates
X_k is a vector of independent or explanatory variables
ε_k is a vector of error terms

[105] See Feder *et al.* (1985) for a comprehensive review of the use of logit models to describe adoption behaviour in agricultural studies.

The LPM expresses the dichotomous decision variable Y_i as a linear function of the explanatory variables X_k, where 1 = adoption and 0 = non-adoption of the innovation, the output being the probability that adoption will/will not occur given certain values of X. The probability that $Y_i = 1$ will equal P_i and the probability that $Y_i = 0$ will equal $1 - P_i$.

In this research, the *logistic regression* or logit model is preferred over the LPM for three reasons. First, in the logit model, unlike the LPM, as X_i increases, $P_i = E(Y_i = 1 \mid X_i)$ also increases but the condition $0 \leq P_i \leq 1$ holds. Secondly the relationship between P_i and X_i becomes non-linear in that as X_i gets very large (or small), the value of P_i approaches 1 (or 0) at slower rates respectively[106]. Lastly it calculates the log of the odds of the fisher adopting live technology. An important assumption of *ordinary least squares* is that there is linearity in model parameters. If the probability of adopting live technology (Pi) is given by ($1/1 + e^{-zi}$), then the probability of not adopting live technology ($1 - Pi$) will be ($1/1 + e^{zi}$). Subsequently the odds ratio in favour of the adoption of live technology is given by $Pi / (1 - Pi)$. By taking the natural log of this we obtain the *logit model*, an expression of the *log* of the odd*s* ratio and importantly, from an estimation point of view, is linear in the parameters α and β (Gujarati 1988):

$$L_i = \text{Ln}\left(\frac{P_i}{1 - P_i}\right) = Z_i$$

$$= \alpha + \beta_1 X_{1i} + \beta_2 X_{2i} + \cdots + \beta_k X_{ki} + \varepsilon_{ki} \qquad [2]$$

Although my interview program included a large proportion of the active fleet (~25%), the small absolute sample size (N = 50) required that careful consideration be given to the number of parameters included in the model as the robustness of parameter estimates and the explanatory power of the statistical tests is limited with small sample sizes (Long 1997). According to Acheson and Reidman (1982), collinearity exists in a number of innovation studies because of too large a number of independent variables. I earlier noted little uniformity or generality among the subset of explanatory variables that could consistently describe adoption behaviour, either for independent innovations

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[106] Geometrically the model is a sigmoid or S-shaped curve with the model essentially linear over the probability range 0.2 to 0.8 (Fox, 1997).

within a specific sector or a specific innovation across sectors (Tornatzky and Klein 1982). A review of the adoption literature in fisheries, however, identified that some variables regularly were or weren't significant in describing fisher's adoption practices. This information was used to guide my model development, most specifically to reduce the number of variables included in analyses. A large number of personal (kinship, education level, and full or part-time status) and attitudinal (loan access, financial commitment) variables have been shown to be of limited significance in explaining adoption decisions in fisheries (Acheson and Reidman 1982; Dewees and Hawkes 1988). Other variables found to be significant, such as membership of cooperatives, were not relevant to my sample, while details on alternative income sources were not recorded[107] (Acheson and Reidman 1982; Levine and McCay 1987; Dewees and Hawkes 1988). Age of operation owner in years is a common explanatory variable in these innovation models, but age was found to be correlated with years in the fishery (r_S = 0.305, p = < 0.05), and so I used the latter. Firm size is typically a significant variable in adoption models and is usually included as a business value (Dewees and Hawkes 1988; Barham 1996) or vessel size (Whitmarsh 1978). In the RLF, primary vessel length and number of tenders supported are seen as more indicative of firm size[108] as they determine current and future capacity and effort and catch respectively. Proximity to other adopters and markets has been identified as a strong determinant during the early stages of adoption across a sector, in terms of information acquisition. Using the proportion of total catch retained alive as a simple adoption indicator within the RLF, it can be shown that live technology diffused longitudinally south from Cairns, the main exit point for live fish exports (see Figure 4.4). Similarly, vessels unloading catch at multiple ports would likely enhance their knowledge of new innovations (Stephenson 1980; Acheson and Reidman 1982). Limits on access to credit are acknowledged as impediments to adoption, which can be exacerbated by existing debt levels (Dewees and Hawkes 1988; Whitmarsh 1990). Future expectations of fishing conditions will likely influence innovation adoption decision, although those who are pessimistically inclined are as likely to adopt as those who have a positive outlook (Levine and McCay 1987;

[107] Several respondents observed that whilst relationships did develop between small groups (2 or 3) of fishers, usually from the same home port, prior attempts to establish cooperatives within the RLF had been unsuccessful. Whilst, nearly all respondents nominated the RLF as their sole source of income for, details were not sought during interviews regarding spousal incomes, although in many cases fishing businesses were family operated.

[108] Vessel length correlated well with estimated value of primary vessel (R^2 = 0.6918) (see Figure 5–2).

Dewees and Hawkes 1988; Whitmarsh 1990). Lastly, there is an investment risk associated with innovations that implies firms are likely to postpone adoption until they are more certain about potential benefits of adoption (Whitmarsh 1978). On the basis of this review and knowledge of the idiosyncrasies of the RLF ten variables were identified as potentially useful in defining a model of live fish technology adoption. The full specification of the model was:

$$\text{Ln}\left(\frac{P_i}{1-P_i}\right) = \alpha + \beta_1(\text{YEARS}) + \beta_2(\text{HOMEPORT}) + \beta_3(\text{NUMPORTS}) + \beta_4(\text{BOATLENG}) + \beta_5(\text{NUMTEND}) + \beta_6(\text{MORTGAGE}) + \beta_7(\text{STKSTATUS}) + \beta_8(\text{EFFSTATUS}) + \beta_9(\text{LIVEFISH}) + \beta_{10}(\text{INVRISK}) + \varepsilon_{ki} \quad [3]$$

where the coefficients β_k, reflect the effect of a change in the independent variable(s) on a change in the odds ratio, as defined in equation [2], of the fisher adopting live technology. The independent variables are described in Table 7–2 below.

The estimation of coefficients and statistical results were derived using SPSS software. Stepwise backward regression was used to derive the most parsimonious model, by iterative removal of the least significant variable (i.e. highest *p*-value). Log-likelihood statistics were generated to test for relative goodness of fit of the model at each step. The log-likelihood ratio was preferred over R^2 as R^2 is not well suited to dichotomous dependent variable models as a measure of the goodness of fit (Aldrich and Nelson, 1988). This ratio, through transformation, approximated the chi-square distribution (Zar 1996) and the χ^2 statistic was used to test the overall model's ability to predict adoption/non-adoption at each step following removal of the variable of least significance as well as whether removing this variable significantly reduced the model's predictive ability. The Hosmer-Lemeshow statistic was used to test the hypothesis that the model predicted values were not significantly different from the observed data. The Wald statistic, which has a chi-square distribution, was used to test whether the β coefficients for each predictive variable in the model were significantly different from zero. Finally the terminal model was tested for multicollinearity and autocorrelation using SPSS generated diagnostics tests and the Durbin-Watson test statistic.

Table 7-2: Personal and attitudinal characteristics included in logit model

Variable Name	Variable Description	Comments
Personal		
YEARS	Number of years operator has fished including years since converting to live	Innovation involving changes to existing operations may be less likely to be adopted by those with longer fishing histories. Accordingly, years fishing and adoption should be negatively correlated.
HOMEPORT	Vessels homeport	Homeports were classified as falling in either Northern (0) or Southern (1) regions. Ports closer to location of early adopters may benefit from improved information networks and lead to them being positively related to adoption
NUMPORTS	Average number of ports visited in 1996, 1998 and 1999	For operations who had converted to live, an average was taken of the number of ports used, regardless of date of conversion. Number of ports would be consistent with 'entrepreneurial' behaviour and positively related to adoption
BOATLENG	Length of primary vessel	Vessel size will determine the relative ease of incorporating technology into existing business and consequently will influence costs of adoption. Larger vessel size should be consistent with and hence positively related to adoption
NUMTEND	Number of tenders primary vessel is licensed to support	More tenders will increase the costs of adopting live technology although economies of scale will enable the spreading of investment costs across firm outputs. Depending on primary vessel upgrade costs, the number of tenders supported may be positively or negatively related to adoption.
MORTGAGE	Is mortgage held over primary and tender vessels	Mortgage variables classified as either 0 = no mortgage or 1 = mortgage. Amount of mortgage and mortgage payments not considered
Attitudinal		
STKSTATUS [a]	Measure of the operator's judgement of exploitation level of the target species	Respondents were asked to assess the status of fish stock on a scale of 1 (under-utilised) to 5 (over-utilised) as compared with 3 years earlier. Higher scores reflect a more pessimistic outlook for fish stocks and should be positively related to adoption.
EFFSTATUS [a]	Measure of the operator's judgement of effort levels in fishery	Respondents were asked to judge effort levels in the fishery on a scale of 1 (very low) to 5 (very high) as compared with 3 years earlier. Higher scores reflect a more pessimistic outlook and should be positively related to adoption.
LIVEFISH	Measure of the operators assessment of the impact of live fishing to the RLF	Respondents were asked to assess the impact of the live fish trade in the RLF (positive or negative) on a scale of 1 (adverse impact) to 5 (favourable impact). Higher scores should be positively related to adoption
INVRISK	Risk of investing	Risk was measured in three categories (low, medium and high). Those assessing the risk to be low are more likely to adopt live technology. The relationship between risk and adoption should be negative for risk-averse operators and positive for those less risk averse. Higher levels of risk aversion should be negatively related to adoption.

[a] Fisher attitudes were measured using a Likert-type scale ranging from 1 (the most favourable assessment) to 5 (the least favourable assessment). The influence of attitude on adoption decision may be ambiguous. One argument may be that those with a favourable assessment would be more likely to adopt because a robust fishery offers greater security in terms of return on investment. Another may be that those with favourable assessments may opt to maintain the status quo and not adopt (Levine and McCay 1987). Conversely, those with an unfavourable assessment may be more likely to adopt in order to offset perceived or anticipated poor economic conditions in the fishery

Results from the full model were meaningless with extremely low (< 0.01) Wald statistics generated for all predictive variables and a 'non-unique' perfect fit solution detected. Pearson's coefficient of correlation was used to test for correlations between pairs of independent variables. Two model parameters showed significant correlations with one or more other parameters: mortgage on primary vessel with boat length (r_p = 0.466, p < 0.001) and number of tenders (r_p = 0.331, p < 0.019); and changes in effort levels with changes in stock status (r_p = 0.473, p < 0.001). Thus, the parameters, *MORTGAGE* and *STKSTATUS* were deleted from the full model. *EFFSTATUS* was retained over *STKSTATUS*, as respondent's answers to the latter may have been biased by a large scale cyclone event occurring in 1997 which was followed by large declines in catch rates. The squared residual estimates from the refined model were generated and plotted against all explanatory variables to test for heteroscedasticity (Gujarati 1988). No systematic patterns emerged between residual estimates and explanatory variables, suggesting heteroscedasticity was not present in the data. Lastly, in order to more accurately estimate the "marginal impact"[109] of the variables on the probability to adopt, adjusted odds ratios were calculated.

7.3.3 Factor Analysis

Factor analysis has been widely used in innovation adoption studies (Dewees and Hawkes 1988; Rauniyar and Goode 1992; Grover 1993; Rauniyar 1998; Karahanna *et al.* 1999). Factor analysis is used to describe the relationships among variables through a few underlying, but unobservable, quantities or *factors*. Each factor is represented by a unique set of variables that are highly correlated among themselves and exhibit small correlations with variables in other factors. The correlation between variables and factors is expressed as a weight or *factor loading*. In notational form, factor analysis expresses *p observed random variables* as **x** linear functions of *m* (< *p*) unobserved variables or factors (Jolliffe 1986). If $x_1, x_2, \ldots, x_p$ are the variables and $f_1, f_2, \ldots, f_m$ the unobserved factors, then:

[109] The marginal effect is the independent effect of a change in variable X_t, with all other variables held constant, on the probability that an individual will choose to either adopt or not and is calculated as:

$$\frac{dP}{dx} = \phi'(Z)\frac{dt}{dx}$$

$$
\begin{aligned}
x_1 &= \lambda_{11} f_1 + \lambda_{12} f_2 + \cdots + \lambda_{1m} f_m + e_1 \\
x_2 &= \lambda_{21} f_1 + \lambda_{22} f_2 + \cdots + \lambda_{1m} f_m + e_2 \\
&\vdots \\
x_p &= \lambda_{p1} f_1 + \lambda_{p2} f_2 + \cdots + \lambda_{1m} f_m + e_p
\end{aligned} \qquad [5]
$$

Where; λ_{jk}, $j = 1, 2, .., p$; $k = 1, 2, ., m$ are loadings of variables on each factor and e_j, $j = 1, 2,.., p$ are error terms specific to each variable.

Initial factor loadings will be imprecise as variables load highly against more than one factor. A process of orthogonal rotation is used to secure a less ambiguous association between variables and factors, while leaving covariance estimates unchanged.

7.3.3.1 Factor Model Development

I earlier noted the likelihood that factors influencing the decision to innovate may differ from those affecting the decision not to innovate making comparisons between the two difficult. This survey thus considers adopters and non-adopters independently, contrasting with most innovation studies where respondents, regardless of adoption status, are asked a homogenous set of questions. Moreover, Tornatzky (1982) recommends the adoption model distinguish between those factors important in the decision to adopt and those affecting the extent of implementation. For these reasons, I have developed two discrete factor analytic models. The first model (model 1) identify's the perceived innovation attributes that influence an adopter's commitment to innovate. A subsequent model (model 2) is used to test for the importance of investment determinants in encouraging the adoption of live fishing techniques among innovators or rejection among non-innovators.

Innovation literature has identified the main attributes influencing adoption behaviour as being: compatibility, relative advantage, complexity or simplicity and risk, trialability, observability, communicability and prestige (see Table 7–3 for definitions) (Tornatzky and Klein 1982; Dewees and Hawkes 1988; Rogers 1995; Baldwin and Rafiquzzaman 1998; Karahanna *et al.* 1999). Of these, Tornatzky and Klein's (1982) meta-analysis indicated that only relative advantage, compatibility and complexity as more consistently related to adoption, while Dewees (1988) study showed trialability and prestige as attributes of limited importance. Relative advantage is often regarded as too indistinct, and is better signified by identifying specific characteristics reflecting that advantage, such as improved economic outcomes.

Trialability was excluded on the basis of personal observations. In terms of the adoption decisions, trials usually culminate, over time, in moving to a new technology at the expense of being able to implement the old process. Regardless of its complexity[110], live technology was fully incorporated into fishing operations from the outset of a decision to adopt and in many cases adoption did not require sacrificing usable frozen space (see 6.3.1.1).

Table 7-3: Factor Model 1 – Perceived attributes of innovation adoption influencing adopter's commitment to innovate

Attribute	Description
Compatibility	The degree to which an innovation is consistent with past practices or meets the needs of a potential user. In this study it describes the ease with which the innovation can be incorporated into existing capital structure
Relative advantage	The degree to which an innovation surpasses the process/idea it replaces. It can be measured in terms of monetary or social improvements
Complexity	The degree to which an innovation is considered simple to understand and use. In this study it refers to the knowledge requirement for successful installation
Trialability	The degree to which an innovation can be partially adopted, or experimented with on a limited basis before full adoption, while also allowing easy reversal to a previous state.
Observability	The degree to which results of an innovation can be seen by others. It may manifest itself as higher yield or improved profits. Its 'interdependence' is often clouded by overlap with other attributes.
Communicability	The degree to which aspects of the innovation are able to be shared with others
Prestige	The degree to which the innovation can enhance an individual's status among their fellow fishing operators
Risk	The degree to which the innovation is considered economically risky

Based on pre-testing and an understanding of the market orientated nature of the innovation and its significance to the fishery, likely attributes (factors) of the innovation were hypothesised for model 1 as expected income, compatibility, relative advantage,[111] complexity and risk. Likert-scale questions used in the analysis were framed accordingly. The objective of this phase was to test the importance of economic

[110] This assumption contrasts with much of the agricultural literature that regards the ability to parsimoniously 'trial' an innovation as an important element in the adoption decision process.

[111] Relative advantage can describe the degree to which the adopting live fish technology represents an overall gain in firm profitability (e.g. competitive advantage, employment conditions) as distinct from income expectations, as well as social improvements.

attributes of the innovation to explain adoption decision model variance and to provide support for the innovation-investment link.

Confirmatory factor analysis was used in model 2 to examine underlying factor structures in the context of investment decision determinants. In the context of this research, indicator variables have been selected on the basis of prior theory and confirmatory factor analysis used to test whether each variable loads as predicted against the hypothesised factor[112]. The three investment attributes hypothesised as influencing the implementation decision were expected income or expected future profitability, expected costs and existing capital structure. The same three attributes were assumed to dictate the decision not to adopt live technology (Table 7–4). Independent factor analyses were conducted for adopters and non-adopters.

Table 7-4: Factor Model 2 – Hypothesised factor structure for the investment/non-investment models with investment decisions for adopters and non-adopters of live technology presumed to be analogous (see 7.2.3).

Factor	Variables
Expected Income	Expected market price stability for live fish Expected future demand for live product Sustainability of returns from live fishing
Expected costs	Cost of borrowing/upgrade cost Current debt levels Availability of credit/borrowing
Existing Capital	Condition or size of primary vessel Costs to maintain vessel safety/competitiveness Freezer space available for conversion [1] Age of owner-operator [2]

[1] Freezer space available for conversion was specific to adopters and was intended to capture opportunity cost

[2] Age of owner operators was specific to non-adopters and was intended to capture opportunity cost

The factor loadings generated by the independent factor models for adoption and non-adoption were used to explore variations in innovation-investment behaviour between adopters and non-adopters. A new factor loading matrix was constructed to do this, based on the average loading value for each variable within each factor across both groups. These average factor loadings were then multiplied by a respondent's corresponding Likert-scale response for each variable and summed across all variables to produce a single respondent score for each of the three factors (income, cost and

[112] A minimum requirement of confirmatory factor analysis is that the number of factors in the model and expectations about which variables will load on which factors are hypothesized beforehand.

capital). This process was repeated for all adopter and non-adopter respondents to generate a mean for each group. T-tests were used to test for significant differences between adopters and non-adopters. Levene's test was used to test for homogeneity of variances.

The SPSS statistical package was used to analyse data collected from personal interviews. Factor analysis (using Principal Component Analysis and Varimax rotation) was applied to the Likert-scale response variables to test the hypothesised dimensional structures of each of the models. Only factors with eigenvalues greater than 1.0 were extracted (Stevens 2002). Eigenvalue scree plots were also used to aid in the determination of an appropriate number of factors to use. In some instances, variables were deleted to enhance *construct* validity[113] and explanatory power of the factor models. Each model was assessed using statistical and heuristic goodness of fit indicators, namely *Kaiser-Meyer-Ohlin, Bartlett's Test of Sphericity*, *Cronbach's alpha*, *Goodness of Fit Indices* (GFI)[114] and the *Root Mean Square Residual* (RMSR) with the latter two used to assess the model of best fit.

7.4 Results

7.4.1 Logit Model

Summary statistics are shown in Table 6–5 for all explanatory variables considered for use in the logit model, including those later excluded. There were clear similarities between live and non-live operators for many variables, with some noticeable exceptions. Typically, owners and licence holders tended to be in their mid to late forties, with more than a decade's experience in the fishery. The majority of these owners or owner/skippers had been operating in the fishery prior to the advent of the live trade, resulting in comparable fishing histories between operation types. The average number of tender vessels supported by either operator type corresponded closely ($t_{0.05,\,48} = -0.08$, $p = < 0.469$). This was a largely unexpected result as it was believed that larger vessels supporting more tenders were more likely to adopt live technology (see 6.3.1.2)

[113] Construct validity refers to whether the factor dimensions are consistent with theoretical or empirical expectations (Carmines and Zeller, 1979)
[114] Both relative GFI and GFI adjusted for degrees of freedom were included.

Table 7-5: Descriptive statistics for personal and attitudinal characteristics used in logit model for live and non-live operations participating in the reef line fishery

	Live Operators			Non-live operators		
Variable	**Mean**	**Std. Dev.**	**Range**	**Mean**	**Std. Dev.**	**Range**
AGE [a]	46.24	9.90	29-74	48.53	8.06	33-60
YEARS [ϕ]	11.76	6.50	2 – 22	13.94	6.11	2 – 22
HOMEPORT [b ϕ] *North*	76%	–	–	24%	–	–
South	61%	–	–	39%	–	–
NUMPORTS [ϕ]	2.00	1.36	1 – 6	1.40	0.87	1 – 4
BOATLENG (m)	14.66	2.74	9.0 – 19.94	12.79	2.67	9.5 – 19.92
NUMTENDS	4.15	0.97	2 – 6	4.18	1.13	3 – 7
MORTGAGE [c ψ]	55%	–	–	30%	–	–
STKSTATUS [d ψ]	3.09	0.80	2 – 5	3.00	0.87	2 – 5
EFFSTATUS [d]	3.97	0.68	2 – 5	3.65	1.00	3 – 5
LIVEFISH [e]	4.33	0.92	1 – 5	2.71	1.16	2 – 5
INVRISK [ϕ]	2.67	0.54	1 – 3	2.53	0.62	1 – 3

[a] Age was deleted from the final logit model on the basis of significant correlation with years in the fishery.
[b] Dichotomous variable (0 = North, 1 = South). Value is percentage of operators per region.
[c] Dichotomous variable (0 = No, 1 = Yes). Value is percentage of operators having a mortgage.
[d] Likert-scale response variable from the most favourable (1) to least favourable (5) response.
[e] Likert-scale response variable from the least favourable (1) to most favourable (5) response.
[ψ] Explanatory variable deleted from the full-rank model analysis.
[ϕ] Explanatory variable deleted from the final model.

The terminal results of the stepwise backward logistic regression analysis are reported in Table 7–6. The terminal model chi-square statistic was highly significant ($\chi^2_{0.05, 4,}$ = 33.760, p = < 0.0001) indicating that the inclusion of these variable enhanced the predictive ability of the model where the constant only was included[115]. The step chi-square statistic, calculated after each stepwise deletion, indicated that the predictive ability of the model was enhanced by the iterative deletion of the least significant variable[116], while the model remained highly significant. The Hosmer-Lemeshow chi-square statistic ($\chi^2_{0.05, 8,}$ = 7.311, p = < 0.504) was correctly non-significant, indicating that the predicted model did not differ significantly from the observed data. The terminal results of the stepwise logistic regression analysis are reported in Table 7–6.

[115] *The* "model Chi-Square" provides a test of the null hypothesis that b1 = b2 = … = b*k* = 0 for the logistic regression model.
[116] The predictive ability of the terminal model (92%) was higher than that of the full model at 86%.

Table 7-6: Maximum Likelihood Estimates for Binary Logistic Regression Model of the probability that fishing operations will adopt live technology, excluding all correlated variables. Significant p values ($p < 0.05$) are in bold. Adjusted Odds Ratio's are in Column 5

Variable	β	**Wald** χ^2	**df**	p	**Adj** (β)	**Std. Error**
Constant	– 15.603	7.703	1	**0.006*****	0.000	5.622
BOATLENG	0.512	4.835	1	**0.028****	0.071	0.233
NUMTENDS	– 0.953	2.632	1	0.105	– 0.132	0.575
EFFSTATUS	1.346	2.744	1	**0.098***	0.186	0.829
LIVEFISH	2.333	7.973	1	**0.005*****	0.322	0.862
ML Estimates	**(n = 50)**					
Initial Log-Likelihood (-2LL)	64.110					
Terminal Log-Likelihood (-2LL)	30.343					
Model χ^2	33.760		4			
Hosmer-Lemeshow χ^2	7.311		8			
% predicted correctly	92 %					

* *p < 0.10*
** *p < 0.05*
*** *p < 0.01*

The attitude toward live fishing (*LIVEFISH)* was the most significant explanatory variable in the model, with the other significant variables being primary vessel length (*BOATLENG*) and perception of changes in effort (*EFFSTATUS*). Those adopting live technology commonly perceived live fishing techniques to be environmentally superior, as fewer fish and lower by-catch were caught per trip/annually, while contributing to improved economic returns per fish. Comments proffered by live operations included:

> *"....fishers' are taking less fish overall, fishing fewer days per year but receiving a greater return per fish"; and*
>
> *"....live fishers are targeting a specific type of product as opposed to 'pulling in' a whole range of species"*

In contrast, non-adopters perceived live fishing to be a less sustainable practice because of its selective targeting and acceptance of lower site-specific catch rates with comments from non-live operations suggesting:

> *"....live boats target only one species and place greater pressure on smaller trout by fishing the shallows"; and*

> *"….live fishers will accept lower catch rates then fishers targeting dead and will stay* fishing on the reef longer, rather than moving on"

All variables significant in explaining adoption/non-adoption were significant in the direction hypothesised, with the exception of NUMTENDS, with the model predicting an increase in the number of tenders would slightly decrease the odds of adoption. The significant result for EFFSTATUS may also be ambiguous as live operations were only slightly more pessimistic than frozen operators on EFFSTATUS (see Table 7–5), and not significantly so ($t_{0.05,\,48} = -1.198$, $p = 0.243$).

7.4.2 Factor Analyses

The factor analyses are presented in two parts. First, those fishing operations that adopted live technology are examined to test for the existence of the hypothesised four-attribute structure to describe the adoption decision. Second, I extend the analysis to examine the underlying factor structure that best describes the operator's decision to either adopt or not to adopt, in the context of investment decision determinants

7.4.2.1 Adoption Decision

The results of the exploratory factor analysis are summarised in Table 7–7. The underlying latent structure is best described by four hypothesised attributes. The rotated factor model explains 70% of the variance between the fitted and sample correlation matrices. Varimax rotation ensured none of the four factors extracted was significantly correlated to one another. The mean value of communalities for all variables was ≥ 0.70, lending further support to the choice of the four-factor model (Stevens, 2002).

The Kaiser-Meyer-Ohlin measure of sampling adequacy, although relatively low (KMO = 0.525), suggested the correlation matrix was suitable for factoring (Sharma 1996). The Bartlett Test of Sphericity (BTS = 139.976, $p < 0.001$) supported the appropriateness of the factor model[117].. The Cronbach's alpha estimates were

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[117] Bartlett's test examines the extent to which the correlation resembles an identity matrix (i.e. orthogonal), implying no correlation between variables. A significant score ($p < 0.05$) implies the correlation matrix is non-orthogonal (i.e. variables are correlated) and the model is appropriate for factoring (Sharma, 1996).

sufficiently high for factors 1-3 (Peterson 1994)[118]. Despite a lower reliability estimate for factor 4 (α = 0.599), high single factor loadings impied the factor's structure was sound (Grover 1993), and worthy of retention. I did not reject the null hypothesis Using the SPSS generated goodness of fit test ($\chi^2_{0.05, 24}$, = 18.889, p = 0.757), indicating the hypothesised model fitted the data. The Relative GFI (p = 0.929) further supported the model fit, while the root mean square residual score (RMSR = 0.060) indicated small residuals and a good model fit (Sharma 1996).

Table 7-7: Factor loading[a] patterns for perceived attributes of live technology based on responses to the importance of selected variables in determining the adoption decision.

	Factor 1	Factor 2	Factor 3	Factor 4
Statement	Relative Advantage	Expected income	Compatibility	Complexity / Risk
Compensation for low frozen fish price	**0.921**	0.111	0.088	-0.097
Shorter trip lengths	**0.727**	0.000	0.043	0.009
Retention & employment of decent crew	**0.699**	0.201	-0.102	0.246
Expected market price for live fish	0.033	**0.863**	-0.139	-0.128
Expected demand for live fish	-0.017	**0.800**	0.014	-0.080
Expected return on investment	0.253	**0.742**	0.165	0.389
Potential for downturn in live fishery	0.234	**0.516**	-0.282	0.156
Diversification of existing operation	0.166	0.102	**0.878**	-0.129
Easily incorporated into existing business	-0.294	-0.107	**0.806**	-0.098
Little change to existing capture methods	0.135	-0.156	**0.738**	0.159
Probability of live system's success	-0.174	-0.037	-0.067	**0.903**
Acquisition of information from other live operators	0.403	0.073	0.006	**0.687**
Eigenvalue:	2.311	2.307	2.117	1.608
Cronbach's alpha:	0.738	0.717	0.746	0.599
Variance explained (%):	19.257	19.226	17.642	13.404

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization
[a] The factor upon which each variable loaded most strongly has been indicated in bold

Factors 1 (relative advantage) and 2 (expected income) collectively capture the economic benefit associated with this innovation and account for ~40% of the total explained variation between the estimated and sample matrices., Factor 3 (compatibility) was also important in the adoption decision[119] while factor 4

[118] Values of Cronbach's alpha of 0.7 and above are generally considered acceptable; however, it is not uncommon for scales with less than 10 items to have values below 0.7 (Pallant, 2001).
[119] Orthogonal rotation has the effect of optimising the factor structure, which, as a consequence leads to an equalisation of the relative importance of the model factors in terms of variance explained.

(complexity/risk) was the least influential in terms of variance explained. All variables loaded highly[120] against their respective factor and were below cut-off levels against all others, except for *acquisition of information* which loaded positively against factor 1 (0.403) as well as factor 4 (0.687) (Stevens, 1992: 382-384).

7.4.2.2 Adoption Implementation – Non-Adoption Decision

The final rotated factor solutions for the second stage factor analyses results are summarised in Tables 7–8 (a) and (b). These analyses verified the latent structures of the factor model(s) were consistent with underlying investment theory.

Table 7-8: Factor loading[a] pattern of (a) investment determinants for vessel owners adopting live technology and (b) non-investment determinants for vessel owners not adopting live technology.

(a)

Statement	Factor 1 Expected Up. Costs	Factor 2 Expected Income	Factor 3 Existing Capital
Cost of borrowing for upgrade	**0.900**	0.205	0.061
Current debt levels	**0.888**	0.081	-0.010
Availability of Credit/Borrowings	**0.885**	0.042	0.011
Sustainability of returns from live fishing	-0.004	**0.793**	0.220
Expected market price stability for live fish	0.199	**0.774**	-0.259
Expected future demand for live product	0.147	**0.710**	-0.276
Condition or size of primary vessel	0.016	0.042	**0.862**
Costs to maintain vessel safety and competitiveness	0.051	-0.249	**0.796**
Eigenvalue:	2.446	1.846	1.571
Cronbach's alpha:	0.882	0.695	0.651
Variance explained (%):	30.579	23.078	19.637

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization

[a] The factor upon which each variable loaded most strongly is indicated in bold

[120] The literature doesn't define how high is 'high', although researchers have used cut-off values as low as >0.30. Stevens (1992) recommends that for a sample sizes of 50 loadings of ~0.7 are considered significant while for sample sizes of 100 loadings should be >0.50. For my purposes, a variable should have one factor score of >0.50 to load against any factor. Based on Stevens' recommendation, cross-dimensional loading patterns are examined where any variables loading against a second factor is >0.40.

(b)

Statement	Factor 1 Expected Income	Factor 2 Expected Up. Costs	Factor 3 Existing Capital
Expected market price stability for live fish	**0.914**	.138	-0.045
Sustainability of returns from live fishing	**0.887**	-.034	0.042
Expected future demand for live product	**0.745**	.051	-0.118
Current debt levels	-0.148	**0.928**	-0.029
Availability of Credit/Borrowing	0.275	**0.834**	0.137
Cost of borrowing for upgrade	0.083	**0.645**	**0.512**
Costs to maintain vessel safety and competitiveness	0.101	0.074	**0.855**
Condition or size of primary vessel	-0.350	0.111	**0.789**
Eigenvalue:	2.414	2.013	1.654
Cronbach's alpha:	0.827	0.773	0.640
Variance explained (%):	30.174	25.161	20.674

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization

[a] The factor upon which each variable loaded most strongly is indicated in bold

The explanatory powers of two factor models of adoption expenditure were tested. Model one included all variables, while model two deleted *freezer space available for conversion* (see Table 7–4). The justifications for deleting *freezer space* from the model were several. Firstly, the full model generated a four-factor model showing freezer space as uncorrelated with any other variable. Secondly, the expectation that freezer space would influence the adoption expenditure decision proved tenuous due to excess freezer capacity of most vessels (see 6.3.1.1 and Table 6–2) and, lastly, sacrificing freezer space was only one of several options for incorporating the live technology. Moreover, constraining the model to a three factor solution, with freezer space loading against factor 3 (capital), reduced the variance explained by the model and distorted indicators of model fit. Model two [Table 7.8(a)], which excluded freezer space, produced a better fit on the basis of statistical and heuristic tests.

The explanatory powers of two factor models of non-adoption were used to test whether non-implementation factor models were consistent with investment theory. Model one included all variables while model two deleted *age of owner-operator* (see Table 7–4). Both models produced three factor results, but factor indeterminacy existed in model one such that factor loadings were incongruous and misleading (MacDonald, 1991). In model one, C*osts of upgrade* loaded equally against factors 2 (costs) and 3, (capital) while *age of owner operator* loaded negatively against factor 2. Moreover, the Cronbach's' alpha estimate of 0.339 for factor 2 (costs) was unacceptably low[121]. Model two (Table 7.8(b)) produced the best fit on the basis of factor structure, and statistical and heuristic tests.

The final factor model for adopters of live technology explained 73.3% of the model variance between the fitted and sample correlation matrices. Varimax rotation ensured the three factors extracted were not significantly correlated. The Kaiser-Meyer-Ohlin measure of sampling adequacy (KMO = 0.656) indicated the correlation matrix was appropriate for factoring as did the Bartlett Test of Sphericity (BTS = 83.242, $p < 0.0001$). The Cronbach's alpha estimates were sufficiently high for all three factors (Peterson 1994). The SPSS goodness of fit index showed the model fitted the data well ($\chi^2_{0.05, 7,} = 4.321$, $p = 0.742$) and so I did not reject the null hypothesis. The Relative GFI ($p = 0.873$) further supported the model fit, as did the root mean square residual score (RMSR = 0.080) [Table 7.8 (a)].

The factor model for non-adopters of live technology explained 76.0% of the model variance between the fitted and sample correlation matrices. Varimax rotation ensured the three factors extracted were not significantly correlated. The Kaiser-Meyer-Ohlin measure of sampling adequacy, (KMO = 0.566) was just below the suggested cut-off point of 0.60 suggesting the results should be interpreted with caution, but the Bartlett Test of Sphericity (BTS = 46.915, $p = 0.014$) supported the use of this factor model and the Cronbach's alpha estimates were sufficiently high (Peterson 1994) for all three factors. The goodness of fit index indicated this model fitted the data well ($\chi^2_{0.05, 7,} = 5.211$, $p = 0.634$) and so the null hypothesis was not rejected. The relative GFI ($p = 0.913$) was well above suggested cut-off values, implying this model fitted the data well. Lastly, the root mean square residual score (RMSR = 0.091) indicated small residuals and a good model fit. All variables loaded highly against their respective factor and low against all others, except for *cost of upgrade*, which loaded positively against factor 3 (0.512) as well as factor 2 (0.645) (Table 7.8 (b)).

Explained variance is indicative only of a factors importance in determining the factor structure, and not the perceived importance of the individual variables loading against

[121] Nunnally (1967, 1978) is the most widely cited author in terms of reliability coefficients. His minimum acceptable alpha coefficients for preliminary research are in the range 0.6 – 0.7.

that factor. A factor mean based on the average of each respondent's likert-scale (likert-scale mean) response to variables within that factor is useful to compare the relative importance of each factor with regards innovation attributes that influence the adoption decision and the adoption implementation or non-adoption decision. (Table 7–9)[122].

Table 7-9: Summary statistics for perceived attributes that determine both the adoption and non-adoption of live technology. Likert-scale mean (μ), is calculated as the average of the horizontal sums of the respondents' likert-scale response scores for those variable groupings identified by factor analysis as best describing the underlying or 'latent' factor structure where (1 < μ > 5).

	SUMMARY STATISTICS		
Perceived Attributes (Factors)	Mean[a]	Std Deviation	Std Error
(1) ADOPTION			
(i) Adoption Decision			
Relative economic advantage	3.81	0.73	0.13
Expected income	2.87	1.09	0.19
Compatibility	3.34	0.69	0.12
Complexity/risk	3.00	0.94	0.16
(ii) Implementation Decision			
Expected income	4.17	0.58	0.10
Expected upgrade costs	1.97	1.18	0.21
Existing capital structure	3.23	1.05	0.18
(2) NON-ADOPTION			
Expected income	3.12	1.05	0.25
Expected upgrade costs	1.98	1.03	0.25
Existing capital	2.26	1.21	0.29

Mean respondent scores based on factor loadings (factor loading mean) and derived from the combined factor loading matrix for adopters and non-adopters were tested for significant differences across each of the three factors. Factor loading means were significantly greater for adopters than non-adopters for expected income ($t_{0.05,\ 21.54} = -3.289$, $p = 0.003$) and existing capital ($t_{0.05,\ 48} = -2.214$, $p = 0.032$) suggesting these factors were stronger motivators in the decision to invest, than to not invest, in live technology (Figure 7-1).

[122] These statistics reinforce the importance attached to each factor dimension derived by the factor analysis

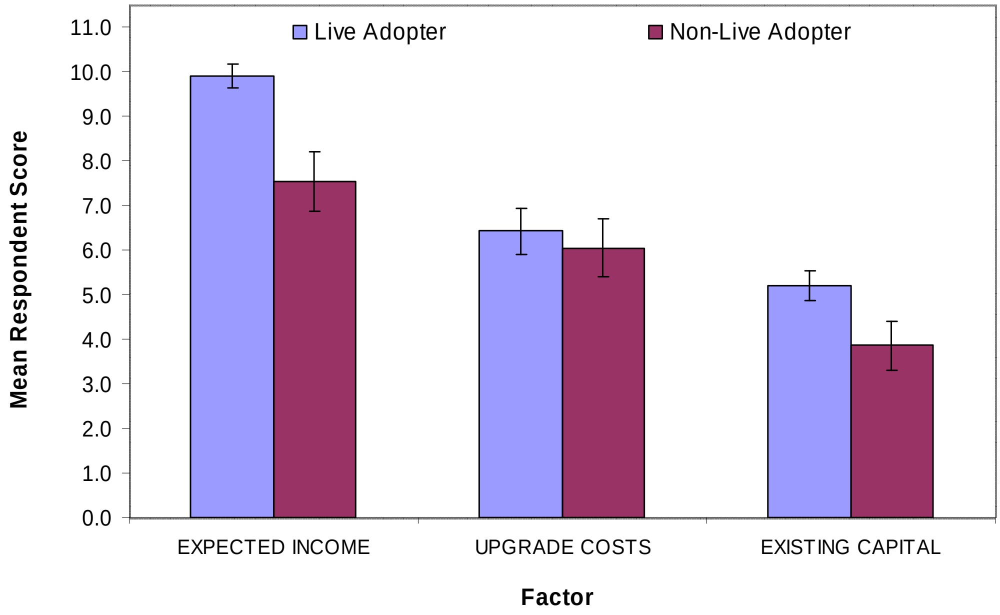

Figure 7-1: Factor loading mean for each of three (3) latent factors (income, costs, capital) hypothesised to influence innovation-investment decision based on respondent likert-scores and corresponding factor loadings for that factor. Error bars are standard errors.

7.5 Discussion

Innovation and technology adoption are widely recognised as contributing to problems of over-capacity and over-fishing, from large industrial to small-scale artisanal fisheries of both developed and developing countries (Greboval and Munro 1999; Stobutzki et al. 2006). Adoption studies in fisheries have focussed squarely on those process innovations designed to improve productivity and increase throughput by way of bigger nets, more powerful engines and better fish finding equipment. Such technology improvements are often a response to lower catch rates, often brought about by the absence of property rights in the fishery (de Wilde 2002). There is tendency for a vicious cycle to develop whereby new technology leads to improved fishery rents in the short-term with these rents eroded as the technology is more widely adopted and target stocks further depleted, leading to searches for new and even more superior technology (Whitmarsh 1998). Even where adequate management systems are in place, new technology can lead to over-capitalisation and lower economic returns (Whitmarsh et al. 1995).

Product innovations that add value to existing target species' with little or no discernible improvement in catchability or catches are absent from the literature, despite recognition that improvements in resource recovery rates can, in the presence of good management, contribute to the long-term sustainability of some fisheries (FAO 1998). In this chapter I sought to address this gap in the fisheries literature using the live reef fish trade as part of the RLF as a case study. Results are discussed in terms of those economic (expected income and costs and existing capital) and non-economic (personal and attitudinal) factors affecting adoption. The results are used to explore the implications of this revenue enhancing innovation for current and future capacity in the fishery.

It should be noted that despite a clear connection between innovation and investment decisions (Whitmarsh 1990), fisheries innovation studies have failed to distinguish between the adoption and implementation decision phases as advocated by Tornatzky and Klein (1982). In testing for the existence of a specific factor structure for a product as opposed to a process innovation here, only the responses of eventual adopters have been considered. In several innovation studies, both adopters and non-adopters have rated specific innovations highly in terms of economic advantage with the reason for non-adoption being financial constraints (Dewees and Hawkes 1988). So while adopters and non-adopters may perceive specific attributes of an innovation similarly, other personal or attitudinal characteristics may be the barriers to adoption. Accordingly, only the adopter perception is useful to resolve such influences. Moreover, no study I am aware of has explored the link between innovation and traditional investment determinants. The scale of implementation and non-adoption decisions both can be considered in terms of investment, with non-adoption of an available technology akin to the decision not to undertake new investment.

Overall, the results of my research show that firm size and expected income were principal determinants in the decision of some operations to convert to live and others to remain as frozen, during both the decision-making and, in the case of adopters, the commitment to innovate stages. Firm size (i.e. vessel length) was identified as the characteristic most likely to influence the adoption of live technology while existing capital was significantly more important in the decision of eventual adopters to undertake investment than it was for non-adopters to reject it. Income expectations were likewise shown to be an important attribute of the innovation that shaped the adoption decision as well being a significantly more important in the investment decision.

The results of the logistic model conformed to expectations. With the exception of the number of tenders, the signs on variables were consistent with their hypothesised influence on the adoption of live fishing technology. While not significantly different regionally, operations overall in the northern region had longer vessels but supported fewer tenders suggesting this variable was determined more by the distance to fishing grounds than any differences in operation type (see 6.3.1.2).

Perceived environmental and economic benefits of fishing for live, as opposed to frozen, product–an attitudinal characteristic–was best able to describe the probability of adoption of live technology. There were some concerns over the efficacy of this explanatory variable in that it may have captured multiple attitudinal aspects–favourable and unfavourable–of the impacts of live fishing simultaneously[123]. The potential for biased responses also exists in that post adoption, adopters would likely have a more favourable attitude through the impact of the new technology on their operation. Removing this variable from the model significantly reduced the models explanatory power, however, while its retention accounted for the dichotomy of attitudes to live fishing by the respective operational groups.

Operators who perceived current fishery effort to be higher than historic effort levels were also more likely to have adopted live technology. According to Le'Floch and Wilson (1998), fishers will be more likely to invest in quality enhancing innovations where the stock is showing signs of over-exploitation. A less favourable outlook toward effort levels, and hence catch rates, by adopters may have compelled them to compensate for excessive effort by embracing the opportunity to add value to their catches. Alternatively, a decision not to adopt may have been influenced by the prospect of undertaking capital investment at a time when the future of the fishery was regarded as uncertain or pessimistic, both in terms of fishery productivity and market demand. Studies suggest that under conditions of uncertainty, the probability of adoption increases the better is the state of the resource or environment (Feder et al. 1985). As

[123] This variable was intended to denote fisher attitudes to the impact of live technology on the existing fishery through a single score.

with attitudes to live fishing, attitudes toward effort may also have captured concerns of operators displeased with on-site fishing behaviour of live operations, as opposed to overall effort increases *per se*.

The significance of vessel length was expected, as early discussions with vessel owners indicated installation of the requisite live technology was contingent on the i) availability of space to install live tanks and ii) capacity of the vessel to carry an additional 2-8 tonnes of water in these tanks. Both would be positively related to vessel length and critical to the operation's ability to incorporate the innovation into their fishing operation. While vessel length is positively related to adoption, the model is not retrospective and doesn't distinguish between active operations that upgraded an existing vessel or those that purchased a new vessel in order to enter the fishery (see 5.4.1). This is an important distinction in understanding the innovation-investment link, as the ease with which live technology can be incorporated into the existing business (i.e. vessel) will influence adoption costs. Identifying those 'economic' factors that influenced the adoption decision and the investment decision was the basis for the subsequent factor analyses.

The importance of retaining freezer space would also have been an economic consideration. Despite sacrificing freezer space, newly converted live operations retained adequate space to store a substantial non-live catch component; mainly coral trout (see Table 6–2). As evidenced by fleet responses to price changes (see Figure 5–5), retained freezer space offers economic surety in the event of lower returns from marketing live product as operators can switch to targeting frozen product (McKelvey 1983). Again, over time, as the economic uncertainty of marketing live product diminishes and fishers better understand the cost and revenue structure of their business, adoption rates may increase through smaller firm's incorporating live technology and an acceptance of the need to incur higher adoption costs (i.e. purchase larger boats).

The objective of the first factor analytic model was twofold. The first was to test for 'secondary' innovation attributes of a value-adding product innovation against innovation attributes typically associated with process innovations (Downs and Mohr 1976; Tornatzky and Klein 1982). The second was to substantiate the importance of performance attributes of the innovation to explain the adoption decision. It should be remembered that factor analysis describes only the underlying structure of unobserved 'factors'. This structure is determined by the strength of correlations between variables with the magnitude of factor loadings determining the variance explained by each factor. Explained variance in and of itself is indicative only of a factors importance in determining the factor structure, and not necessarily the perceived importance of the individual variables loading against that factor (Kline 1994).

As anticipated, the expectation of higher returns, (price and demand for live fish) and the potential relative advantage offered (higher relative prices, improved labour productivity and operational flexibility associated with shorter trips)[124] when fishing for live product were both confirmed as factors describing the adopters commitment to innovate. These economic performance attribute's collectively accounted for most of the model variance, no doubt a response to the market oriented nature of innovation. The factor likert-scale mean score of 3.81 (out of 5) confirmed the importance of expected income in the decision whether or not to adopt. Those variables expected to load highly against the compatibility factor did so. Despite explaining less model variance, its factor likert-scale mean score of 3.34 (out of 5) was higher than that of the relative advantage factor of 2.87, indicating it played an important role in the initial decision to adopt. The complexity/risk factor explained the least amount of model variance, but again the factor likert-scale mean score of 3.00 (out of 5) suggests the perception of economic risk was important. The results of the logit model, however, showed risk to be not a useful predictor of the probability of adoption. This suggests that if risk plays any role in preventing adoption of live technology it is related to firm size and the impediments that places on funds available for investment, the ability to retain product diversity, the physical characteristics of the vessel that facilitate or inhibit the technology adoption and the subsequent level of investment required (Feder 1982; Just and Zilberman 1983; Tsur et al. 1990).

While factor analysis works to reduce interdependencies between dimensions (attributes), some dimensions may absorb elements of other innovation attributes (Pannell 1999). For example, it is quite likely that of those variables comprising compatibility, incorporation of requisite live technology into the existing business

[124] In compensating for low frozen price fuel, wages and maintenance have all increased over last 3-4 years but price frozen has remained stable. Higher live prices effectively reduce relative per unit production costs.

captures cost elements, principally the magnitude of investment required. Several fishers indicated that upgrading their vessels to hold live product required them to first lengthen the vessel to be able to carry the extra weight of water in live holding tanks. While the on-board live tank configuration is a cost based on the preference of the owner, the safety aspect that requires the vessel to be lengthened is in this instance an unavoidable cost. Moreover, the ease of incorporation may represent a reduced risk of adopting through potentially lower investment costs.

Costs of upgrade were excluded as an 'economic' determinant in the adoption decision stage for several reasons. Firstly, costs have been found to be insignificant in other studies (Tornatzky and Klein 1982). Secondly, upgrade costs vary widely depending on the degree of incorporation into the vessels structure (see 5.4.1) and lastly they appear to be a matter of preference and resource availability. In the RLF, costs of incorporating live technology seem to have little bearing on the decision to pursue adoption, either because cost is regarded as relatively fiscally reasonable or the expectation of enhanced future profits as a motivating factor was seen to more than offset considerations of costs as a prohibitive factor (Whitmarsh 1990). An exploration of the link between innovation and investment may add further insight to these tradeoffs.

Results of the second factor analysis confirm that existence of the three hypothsised factors influencing the implementation (investment) or non-adoption (non-investment) decision., Expected upgrade costs explained most of model variance for adopters of live technology, while for non-adopters income expectations explained most variance. Existing capital explained the least amount of model variance for both adopters and non-adopters.

Factor loading means and likert–scale means provide additional insight into the investment/non-investment decision. Results of t-tests on factor loading means showed that income expectations were significantly more important for adopters than non-adopters. The expectation of higher productivity or profitability however, does not in itself justify the adoption of an innovation. According to Whitmarsh (1990), fishers must perceive there to be an adequate return on the investment costs. To that end these results may be suggesting that non-adopters of live technology currently don't perceive the potential returns from marketing live product to be adequate to counter the costs of investment. Intuitively, these upgrade costs will depend heavily on the existing capital stocks. Fishers who wish to innovate may be prevented from doing by a combination of capital stocks; financial wherewithal or both (see 5.4.1). This is a coherent result given existing capital structure will to some extent dictate the expenditure required to incorporate the new technology. In some instances, the purchase of a new, larger vessel may be the only option available.

The likert–scale means for expected upgrade costs (out of 5), were equally low for both adopters (1.97) and non-adopters (1.98) while the results of t-tests on factor loading means showed no significant differences between the two groups. These results imply that costs exert a similarly minimal influence for both groups but probably for different reasons. In the case of adopters, it could be that anticipated higher incomes following investment relative to upgrade costs serve to make these costs irrelevant or, that the anticipated investment costs were regarded as modest relative to current and future incomes[125]. For non-adopters, the low importance probably reflects recognition of financial barriers to adoption caused by limited capital stocks and the subsequent high costs required to enter the live fishery.

This disparate view of cost and its influence on adoption/non-adoption decisions suggests Downs and Mohr's (1976) notion of cost as one of the "primary" innovation attributes perceived of similarly by all potential adopters is far from settled. In describing cost as a primary attribute perceived of identically by all adopters, they are implying that adoption costs are essentially static with adoption/non-adoption decisions determined by variables such as firm size or income. Innovations however, may not easily be cast as being of a high or low cost. Choice in terms of the technical aspects of the innovation employed as well as the extent of its divisibility can provide potential adopters with flexibility as to the cost outlaid to incorporate a new innovation into their existing operation. Much in the way that Acheson and Reidman (1982) acknowledge that innovations and innovators are not independent of one another, I would argue that cost and its relationship to capital stocks affect rates of adoption and by whom. Moreover, the adoption decision is not being dictated by whether the innovation is either 'high' or 'low' cost but evaluated according to the potential adopters existing

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[125] The average upgrade cost for active operators with an existing vessel was ~$24,000. In contrasts the average investment costs for active operators who had to upgrade to a new vessels was ~$210,000.

capital and financial resources. The discussion above does lend support to the contention that there can be no primary attributes of an innovation (Tornatzky and Klein 1982).

Methodological Considerations

Methodological limitations of innovation adoption research have been identified as arising from the post-hoc nature of data collection (Tornatzky and Klein 1982). Conventional adoption studies rely on cross-sectional data, collected at a single point in time from those who have already undergone the adoption process, to describe the diffusion of innovations. This approach is seen as contributing to a *pro-innovation* bias and to innovations being historically 'laden with positive value' (Rogers 1995). Hence more is known about adoption than rejection.

The use of longitudinal data is posited as one solution to addressing these biases and to better understand adoption decisions (Tornatzky and Klein 1982). Over time, changing conditions such as improved fishery catch rates, prices expectations and perceived risk may alter the potential adopters' situations and the perception of the innovations suitability (Levine and McCay 1987; Feder and Umali 1993). Sequential data collection programs would enable exploration of these dynamic aspects of adoption decisions, especially in relation to firm size, uncertainty investment risk and accumulation of evaluative information as well as the link between expected income and costs. Unfortunately, sample size, time constraints and timing of the survey relative to the innovations' introduction have precluded this study from employing a longitudinal survey method.

Implications of Innovation Adoption for Latent Effort in the RLF

The prospect of greater returns is often characterised by a ratcheting up of effort from existing operators or an influx of effort from vessels new to the fishery (Ward and Sutinen 1994; Asche and Aarland 2000). The RLF on the GBR has been identified as potentially vulnerable to such an outcome. Latent effort has been shown to exist in several forms in the RLF (see 2.5, 4.4). The multi-endorsed nature of many Queensland fishing operations has meant that this latent effort may mobilise in response not only to economic incentives to switch between fisheries but also to changes to existing management arrangements in this or other fisheries. Latent effort consigns the RLF to facing the open-access fishery problem of excessive entry of new harvesting capital (Scott 1988). Under these conditions, innovation that contributes to more profitable operations in the short term raises the prospect of excessive fishing effort and fleet capacity in the medium to long term (Ward 2000).

The previous chapter showed that despite incurring higher fixed and variable fishing costs, live operations were significantly more profitable than frozen operations and had higher rates of return to capital. The superior financial performance of live operations suggests there is sufficient incentive to switch from marketing frozen to live product and depending on returns from other fisheries, switch to the RLF. Barriers restricting entry to the live fishery also have been addressed previously. This chapter has explored further those motivations for the uptake of live technology by looking at the personal and attitudinal characteristics of adopters and non-adopters as well the attributes of the innovation that dictate decisions to undertake investment in the new technology or not.

This research shows that vessel length, as a proxy for firm size, is positively related to adoption. Other studies have shown there to be a relationship between firm size and costs of adoption and firm size and uncertainty[126] or economic risk[127] such that in the early stages of an innovations' diffusion, a "minimum" size exists for adopting firms. Over time, this "minimum" size for the adopting firm is likely to decline as uncertainty decreases (Feder and Umali 1993). This research also showed that income expectations of non-adopters were significantly less than those who adopted while income expectations of non-adopters don't sufficiently compensate against their upgrade cost expectations. As uncertainty over the technological capabilities and requirements decline and observable benefits become more obvious and as the gap between profitability expectations and economic risk of investment closes, adoption could become more widespread. This has resonance for firms currently active in the RLF, for small and large firms currently endorsed to participate in the RLF but who are either active in other fisheries or occasionally active in the RLF and for those who neither hold an endorsement in the RLF nor participate in another fishery.

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[126] Most innovations are synonymous with uncertainty. Uncertainty will be shaped by the extent to which the innovation modifies existing production techniques, which will in turn influence technical uncertainty and financial risk. The innovation at the centre of this research is not a radical departure from existing production processes, translating to a low degree of technical uncertainty. In terms of financial uncertainty, the value increase in the product targeted may reduce uncertainty in returns from fishing

[127] Risk delays adoption with larger firms better able to absorb risks of investing in new technology

Given the latent effort in the RLF, the question for management is at what point will those vessels who currently have not innovated choose to innovate and under what conditions will currently inactive or less active licenses be reactivated and what are the effort implications for that activation? For those operations wholly active in the RLF, total annual effort days may increase or decrease while partially active licenses would likely become more active where an existing owner commits to live fishing and undertakes investment in requisite technology. Similarly, holders of newly acquired licenses that were previously partially active or inactive would be expected to increase annual effort. These latter two categories will contribute most to the amount of new effort applied to the fishery and give rise to implications for the fishery's economic and biological sustainability. So long as the impetus for entry to the fishery continues and entry is not restricted, the aggregate opportunity costs of fishing may eventually rise[128]. leading to diminished returns to individual fishers because of reduced stocks and increased variable costs (Munro and Scott 1985; Charles 1994).

7.6 Summary

Unlike previous fisheries innovation research, this research has focussed on a product innovation that improves resource recovery through value-adding as opposed to a process innovation that increases resource throughput. In doing so, it has considered some of the methodological limitations identified within the literature and attempted to account for these where possible.

By surveying adopter and non-adopter investment decisions independently, this research has been able to explore some of the reasons for the innovations rejection by non-adopters, and address to some extent the pro-innovation bias identified by previous research. In addition to the temporal problem above, adoption studies are hampered by their dependence on recall data (Rogers 1995). Problems of recall are deemed negligible because live technology: i) has diffused rapidly in a recent timeframe; and ii) is a radical innovation of great salience to potential adopters (Coughenour 1965). Using non-

[128] Potential returns from investing in a fishery facing improved profit margins may surpass profits from alternative investments. Improved economic profits may lead initially to a fall in the opportunity cost of capital.

adopters' responses has provided insight into the conditions under which adoption may occur at a later date.

This chapter represents a first attempt, however, to explore the link between innovation and investment and to recognise the potential for excessive harvesting capacity arising from latent effort in the fishery. This is in contrast to more usual reason for over-capacity that arises from over-investment in the fishing fleet, to counter declining resource rents. The next chapter explores further the implications of mobilisation of latent effort in all forms.

CHAPTER 8

THE IMPACT OF TECHNOLOGY ON EFFICIENCY AND CAPACITY IN THE REEF-LINE FISHERY

8.1 Introduction

Fishing capacity has become a management issue of great significance in recent years (FAO 1998) with surplus capacity in fishing fleets recognised as the main obstacle to achieving sustainable harvests of fish stocks (Kirkley and Squires 1999a; Dupont et al. 2002; Kirkley et al. 2002b). The trend in most fisheries has been for fishing, or harvest, capacity in the fleet and associated inputs to exceed the reproductive capacity of the fish stock (Holland 2000b). The growth of harvesting capacity is widely recognised as a product of the continuous cycle of improving technology, catching power and fishing gear to compensate for ever declining fish stocks (Whitmarsh 1998; Edwards 1999). Compounding the problem of active fishing capacity is that of excess capacity, which is over-investment in both capital stocks and variable inputs[129]. Excessive harvesting capability and excess capacity result in inefficient allocations of economic resources, leading to below normal profits; outcomes that are exacerbated where property rights are poorly defined (Mace 1997).

Measurement of capacity in fisheries has to date been mostly concerned with physical measures of capacity that define maximum outputs possible from a given vector of inputs (Pascoe et al. 2001; Kirkley et al. 2002a). Since fishing is an economic activity, a more appropriate measure of capacity might be one that focuses on that level of output which minimises costs or maximises revenues (Kirkley et al. 2001). Economic measures of capacity, however, require the application of economic data, and such cost and revenue data are typically not available for fisheries[130]. Consequently, only a few fisheries studies have used economic data to investigate capacity issues (Squires 1987;

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[129], The emphasis in fisheries historically has been on overcapitalisation, a term that usually refers to excessive amounts of capital stocks but not other variable inputs such as labour and fishing effort, which may likewise be allocated in excessive amounts.

[130] Economic capacity is measured by employing cost or profit functions. The estimation of a cost function requires data on the level of output and input prices for each decision-making time period (eg. trip).

Segerson and Squires 1993; Hannesson 1993b) (see 1.1 Capacity and Excess Capacity)[131].

It is often assumed that most, but not all, fishers operate with the objective of maximising the volume as opposed to the value of catch, particularly where fishers tend to be more risk averse than risk taking (Herrero and Pascoe 2003). The absence of data on input and output prices has meant most studies have sought to derive measures of 'primal' capacity which assume this objective of maximising the quantity of outputs produced. Ignoring the relative prices of multiple outputs, however, overlooks the possibility that fishing operations with lower catch volumes may generate higher revenues by providing product with higher per unit value. These operations may be inaccurately ascribed as being less efficient (Pascoe et al. 2003).

Appropriate management of capacity requires an estimate of the fishing capacity in the fleet and of the excess capacity in the fishery at both the individual and fleet-wide levels. While the problem of latent effort principally arises due to catching capacity not being fully employed, excess capacity issues can be further confounded where vessels are endorsed to participate in multiple fisheries. Consideration must given to the prospect of latent capacity that returns to or enters the fishery when the opportunity cost of remaining in another fishery increases (Smith and Hanna 1990; Vestergaard et al. 2003). A fishery that exhibits significant latent effort will face similar common-property problems to that of an open-access fishery.

In previous chapters of this thesis the advent of a market innovation (marketing fish alive) that has added value to an existing target species has been explored in terms of costs and economic incentives associated with the decision to adopt, or not, the requisite technology and comparative performances of operations marketing either frozen or live product. The purpose of this chapter is to again draw a distinction between live and frozen operations, this time through the use of capacity analysis. Differences in price between live and frozen forms of the main target species, and the fact that not all firms in the fishery have chosen to configure their operations to market live product, provides

[131] These studies have mostly employed a production function approach which is restrictive in applications where there are multiple outputs and more than one fixed factor of production.

an opportunity to compare the efficiency of vessels based on both catch volumes and catch value.

The potential for the live fish trade to encourage the entry of new firms or increased activity from existing firms suggests a need to examine capacity and capacity utilisation of the existing active vessels and to use these results to infer implications of mobilising latent effort, which is present in the reef-line fishery (RLF) to a significant extent.

One approach that is becoming more widely accepted as a method of estimating capacity in fisheries is *data envelopment analysis* (DEA). No studies I am aware of have used the DEA approach to explore impacts of latent capacity in the form of both unused and under-utilised fishing units on the management of fishery stocks.

Accordingly, the aims of this chapter are to:

(i) Undertake economic capacity analysis to compare the efficiency of frozen and live operations in terms of catch volume and catch value;

(ii) Measure capacity and capacity utilisation of a sample of active fishing vessels and use these results to investigate potential capacity implications for the commercial RLF; and

(iii) Discuss the potential outcomes of these efficiency and capacity results in view of available evidence of mobilisation of previously latent effort..

8.2 Theoretical Considerations

8.2.1 Capacity and capacity utilisation

Johansen (1968) defines capacity in physical or 'primal' terms as the "maximum amount that can be produced per unit of time with existing plant and equipment provided the variable factors of production is not restricted" (p. 57, cited in Fare et al. 1994). Johansen's concept of capacity is unbounded, implying output is not constrained by limitations on resource stocks or other confounding factors that may restrict the maximum utilisation of variable inputs. This notion of capacity from production theory as some physical maximum is inconsistent with the economic motivations of firms, in that it implies production may exceed the point at which the marginal costs of additional variable inputs are greater than the marginal profit from additional output. Capacity should therefore represent some *sustainable* maximum level of output that takes into account usual operating procedures (Klein and Long 1973). Accordingly, a technological-economic measure of capacity has been specified by Fare *et al*. (2001) that is primal in its representation but which is empirically constrained not to impute production points outside those observed in the actual data[132].

Technological-economic measures of capacity are a primal notion based on output *maximisation* or input *minimisation* given the current technology, capital stocks and other factors affecting productive performance (Kirkley et al. 2002a). Economic measures of capacity on the other hand, are founded on the idea of *optimising* inputs allocated or outputs produced in terms of minimising costs or maximising profits given current technology and capital stocks, but also taking into account the economic decision-making behaviour of firms[133]. Neither cost minimisation nor profit maximisation necessarily equate to maximising input or associated outputs. One widely used economic measure of optimal capacity is the output level that corresponds with the point of tangency between short-run and long-run average costs curves (Kirkley et al. 2001) [134]. Bound within this notion of economic capacity, is the concept of minimum efficient scale, which denotes the size of the firm and the smallest output that firm can produce such that its long-run average costs are minimised (Lindebo et al. 2007).

Economic measures of capacity are preferred by economists as being more reflective of agents' behavioural responses to changing market and resource conditions (Ward 2000). The economic, or cost-minimisation, approach may be inappropriate, however, where there are multiple outputs and more than one fixed factor of production (Berndt and Fuss 1989). Moreover, the general unavailability of data on input and output prices has meant the primal measure of maximum output, tempered by recognition of limitations associated with usual operating conditions, is preferred as the measure of capacity by fishery managers.

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[132] This specification is defined as technological-economic because while it does not specifically embrace economic motivations it does recognise observed behaviour that takes into account economic factors, such as those which would constrain output.
[133] One such example of capacity output might be the level of catch that maximised profit.
[134] In the short-run (capital inputs are fixed) the optimum output level is indicated by the minimum cost position on the short-run average cost curve (SRAC). In the long-run (capital inputs are variable) optimum economic capacity is where long-run average costs, and associated SRAC, are minimised.

Physical capacity can be thought of in a fisheries context as the maximum amount of fish that can be produced over a period of time (e.g. year or season) by a vessel or the fleet if fully utilised, given resource conditions (FAO 1998) [135]. Full utilisation in the fisheries context represents the maximum number of days a boat could reasonably be expected to operate taking into account customary and usual operating conditions (i.e. allowing for breakdowns, loading and unloading, repairs and maintenance, other normal non-fishing days and weather constraints) rather than the maximum possible based on the number of days the fishery is open (Tingley et al. 2003).

A measure of maximum potential output is not the most useful measure of performance for fisheries managers. Management of fishing capacity also requires some measure of the level of utilisation of inputs relative to outputs, or excess capacity in the fishery. *Capacity utilisation* (CU), now widely applied as a measure of excess capacity in fisheries, is the ratio of an individual vessel's (or fleet's) actual output to its potential output. Where potential output exceeds actual output, such that $CU < 1$, there is capacity under-utilisation or 'excess capacity' in the vessel or fleet[136]. This implies that the fleet, if fully utilised, could increase outputs or conversely the same level of output could be produced by a smaller, more active fleet.

An output-oriented approach to capacity and capacity utilisation is regarded as a more intuitive to fisheries where observed and potential production is of most interest. The weaker technological-economic concept of capacity is more suited to fisheries where costs are related to levels of fishing effort and resource stocks, because output levels that can be realised only through unrealistic levels of input are excluded. Capacity output is measured relative to a "best-practice" frontier based on observed input and output levels (Vestergaard et al. 2003) and expressed as the maximum feasible catch given existing physical, environmental and economic conditions and state of technology. Rather than identifying the "maximum feasible" catch if the level of variable inputs is unconstrained, the issue of interest may be identifying whether the

[135] By stipulating the relationship between the maximum feasible catch and the given existing physical, environmental and economic conditions, this definition recognises the association between productive and economic efficiency (Dupont et al. 2002).

[136] Capacity utilisation as an indicator of excess capacity is a short-run measure in that only variable inputs to production can change

observed outputs are being efficiently produced given existing observed inputs. That is, are observed outputs being produced in a technically efficient manner.

8.2.2 Technical Efficiency

Technical efficiency (TE) is a measure of whether the firm is using the minimum inputs necessary to produce a given level of output (input-oriented efficiency) or whether the firm is producing the maximum level outputs holding fixed and variable inputs constant (output-oriented efficiency) (Farrell 1957). Estimates of technical efficiency are based on the performance of an individual firm relative to a best-practice production frontier derived from the performance of all firms of interest (Coglan et al. 1998). Holding inputs fixed, firm specific technical efficiency is a measure of how far that firm's outputs deviate from the best-practice frontier.

In Figure 8–1 a production possibilities frontier is defined by vessels A, B, C and D. These vessels are said to be operating in a technically efficient manner. Vessel E is producing at a point inside the frontier and is said to be technically inefficient. The radial distance *0E/0E** is the measure of output-oriented technical efficiency, the inverse of which is the amount by which vessel E can increase outputs, holding inputs constant, in order to become efficient. For example, $TE = 0E/0E^* = 0.80$ implies outputs will need to increase by *1/TE*, or 1.25, holding inputs constant, for vessel E to move onto the frontier. A TE score of 1.0 indicates that firm is technically efficient and thus on the frontier. (Walden and Kirkley 2000).

The shape of the frontier will depend on the scale assumptions that underlie the model. Two scale assumptions may be incorporated into the analysis: constant returns to scale (CRS); and variable returns to scale (VRS)[137]. CRS implies that a doubling of *all* inputs would exactly double output whereas VRS describes a situation whereby an increase in variable inputs (e.g. days fished) of x% will lead to an increase in output of less than x%. There are generally *a priori* reasons to assume fishing would be subject to variable returns and in particular decreasing returns to scale, namely that an increase in inputs of

[137] Variable returns to scale encompass both decreasing and increasing returns to scale. Use of VRS will avoid technical efficiency scores being confounded by scale efficiencies by ensuring only vessels of similar scale are compared. Scale efficiency refers to further improvements in firm efficiency through changing their scale of operations, i.e., to keep the same input mix but change the size of operations.

(Pascoe et al. 2001). Furthermore, VRS envelop the data points more tightly and tend to generate higher efficiency scores.

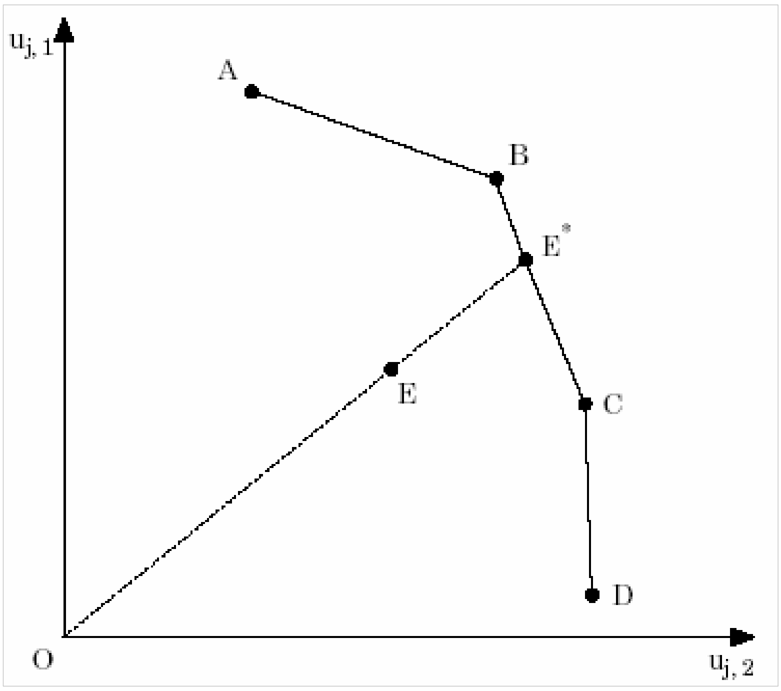

Figure 8-1: Output-oriented technical efficiency

Source: Pascoe et al. (2001)

Capacity utilisation as described in 8.2.1 may be a downward biased measure that over-estimates capacity under-utilisation. This is because observed outputs may not be being produced efficiently, so that some of the apparent capacity under-utilisation is due to production inefficiencies given the level of fixed and variable inputs. Technical inefficiency implies an increase in outputs for a given level of variable input is possible. A more appropriate measure of CU is the ratio of technically efficient output to capacity output[138] (Fare et al. 1989). This approach, now widely endorsed in fisheries literature, enables the effects of efficiency to be separated from those of capacity under-utilisation.

8.2.3 Revenue Efficiency

Fishing is an economic activity. Hence it may be more appropriate to assume that fishers pursue objectives other than maximising physical outputs. With the availability of price information and assumption as to a firm's behavioural objective (e.g. revenue maximisation), the firm's allocative efficiency, which reflects the ability of firms to

[138] Technically efficient output is that level of output attainable holding inputs constant.

produce the optimal mix of outputs given their respective prices, can also be examined. One such economic output efficiency measure is *revenue efficiency*, which is a measure of observed revenue to maximum revenue, given variable inputs are fixed but allowing for fixed inputs to vary (Coelli, 1999).

As with Figure 8–1, technical inefficiency is represented in Figure 8–2 as the distance AB, or the amount outputs could be increased without requiring extra input. Revenue efficiency can be defined for any observed output price vector p represented by the line DD′ and q , $\hat{q}$ and $q*$ represent, respectively, the observed output vector of the firm at point A, the technically efficient production vector associated with *B,* and the revenue efficient vector associated with point *C*.

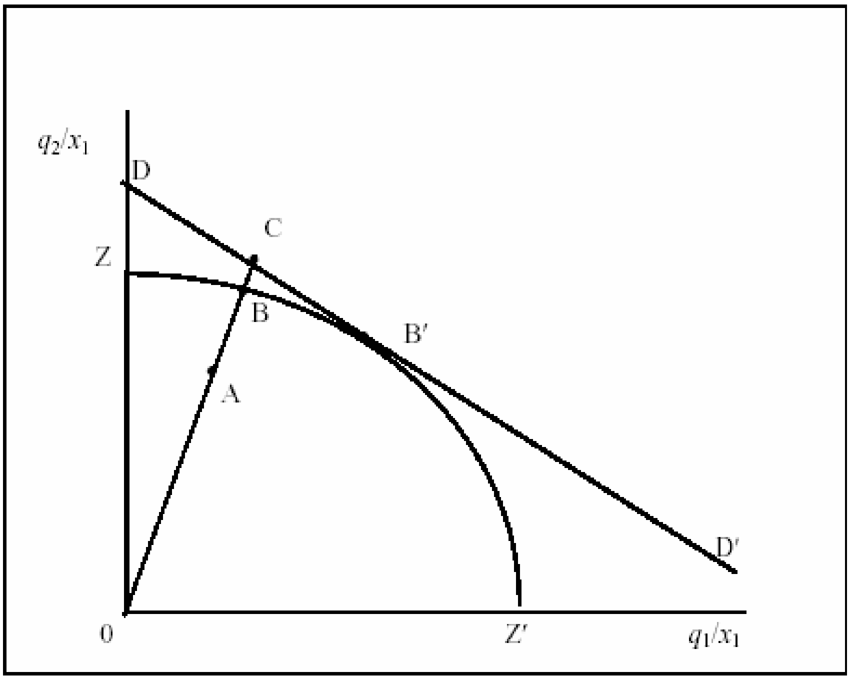

Figure 8-2: Output-oriented technical and allocative efficiency

Source: O'Donnell C (2004)

We can define technical efficiency (TE) and allocative efficiency (AE) from the isorevenue line DD*'*, derived from price information, respectively as:

$$TE = \frac{p'q}{p'\hat{q}} = \frac{OA}{OB}, \quad \text{and}$$

$$AE = \frac{p'\hat{q}}{p'q^*} = \frac{OB}{OC} \qquad (1)$$

Furthermore, we define overall revenue efficiency as the product of these measures. All these measures are bounded by zero and one.

Technical efficiency reflects the ability of a firm to obtain maximal outputs from a given set of inputs. Consideration should be given to the prospect that the operations performance can be improved by reallocating inputs to produce a new, more profitable, mix of outputs. For example, fleets may consist of a mix of operations with some preferring to land a lesser quantity of high quality product and others preferring a higher quantity of catch in spite of a lower per-unit value. In such cases, capacity estimates will be driven by the latter, with boats landing the higher quality catch being deemed to be operating at less capacity, or more inefficiently. This can be overcome by using output price data to construct an estimate of revenue as opposed to output maximisation.

8.2.4 Technology, Efficiency and Time-Scales

Measures of capacity and efficiency are short-run concepts describing the performance of a firm when faced with constraints on capital stocks and fixed inputs but where variable inputs can change (Squires et al. 2003). The concept of short- and long-run is ambiguous, however. In fisheries, the short-run may be defined by a single trip while the long-run, which provides for adjustment of fixed inputs and/or capital stocks, may be as short as a few months. The extent to which fixed inputs constrain output in the short-run may be determined by the ‘lumpiness’ or fixity of capital stocks (Weninger 2004). Capital fixity will be determined by costs and time required to adjust capital inputs in order to increase outputs. When capital is highly variable, the firm is able to more quickly adjust capital stocks to its target value (McGuckin and Zadrozny 1988). Capital fixity is likely to be more restrictive in industrial fisheries, where vessel attributes (engine horsepower, hold capacity) dictate catch quantities and lead to high adjustment and time costs.

As previously proposed, adoption of new technology is considered a capital investment decision. The convention in capacity and efficiency analysis is for different technologies to be treated separately (Johansen 1968). In fisheries, this notion is premised on the basis of highly distinct technologies (fishing gears), differences in labour requirements within the fleet and non-jointness in inputs, such that effort and associated costs of a vessel may be allocated across fisheries that are seasonally and geographically distinct or involve using different gears or métiers (Pascoe et al. 2003).

In contrast, the LRFF, as part of the RLF, is distinguished only by the form in which product is sold and vessels wanting to market live fish need only to incorporate requisite technology. Capacity and technical efficiency estimates are short-run measures with fixed inputs held constant and outputs of live and frozen operations restricted to their current mix (i.e. frozen operations produce only frozen product over the time-scale of interest). So despite differences in husbandry technology, live and frozen operations can be pooled into the one analysis. This will enable comparison of efficiency of the two operation types where variable inputs are held constant and comparison of capacity and CU[139] across all operations where variable input utilisation increases. Revenue efficiency provides for a medium- to long-term outcome by allowing for reallocation of fixed inputs such as incorporating live holding technology into existing capital to produce a new mix of outputs. In terms of this analysis, capital is, in most instances, not highly fixed with 'live technology' able to be incorporated in a relatively short period (< 6 months) and at comparatively low cost (see 5.4). As such, this distinction between short and medium- to long- term efficiency estimates should not compromise the veracity of analysis results.

An important issue pertaining to the underlying technology of the fishing vessels is that of disposability. Disposability for a multi-output firm describes how changes in the level of one output manifest on other outputs. In my analysis I assume strong disposability in outputs, which permits reductions in one output to be accompanied by increases or decreases in the level of other outputs (Fare et al. 2001). This accommodates both technological and economic decisions made by live operations to 'switch' between producing live and frozen product during a given period of time and permits aggregation of data (Vestergaard et al. 2003).

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[139] CU defines the extent to which production can increase without the need for major expenditures for new capital and equipment

8.2.5 Capacity Management and Latent Effort (Capacity Utilisation)

A further issue that frustrates the measurement of capacity in fisheries is latent capacity. It often manifests where their participation in a specific fishery is dictated by prevailing market conditions, and especially so when vessels are endorsed to access multiple fisheries. The often transient nature of these 'latent' vessels can make obtaining usable data problematic (FAO 1998). Assumptions of fleet homogeneity in the absence of adequate data can compromise capacity estimates of the entire fleet and lead to sub-optimal management outcomes (Kirkley et al. 2001). The dangers of ignoring heterogeneity and technological variety in a fleet comprised of large and small-scale vessels, some of which are more active than others, is ably demonstrated by Maurstad (1998)[140].

A popular approach to capacity reduction is a vessel or licence buyback program, but accurate measurement of forecast capacity subsequent to a reduction program remains problematic (Holland 2000b). In fishery's where significant latent effort exists, a reduction in vessel numbers need not equate to an equivalent reduction in capacity (Pascoe and Coglan 2000). The effect on output levels of reducing inputs will depend of the level of input utilisation across the fleet[141]. The effectiveness of fleet reduction programs will be determined by the extent to which *effective* effort is removed, especially where specific fleet segments[142] are characterised by low input utilisation. Capacity reduction targets are primarily set on the basis of the level of overexploitation of stocks harvested by different fleet segments, and assume a percentage decrease in physical inputs will result in a proportional decrease in potential outputs given the stock size. This is effectively assuming CRS, whereas as earlier noted is fisheries are generally characterised by VRS. Moreover, attributing full variable input utilisation rates of active participants to currently partially or fully inactive participants to estimate latent capacity, however, ignores the heterogenous nature of fleet segments (Kirkley and Squires 1999b). Controls on vessel numbers alone may overlook different environmental and economic constraints faced such as by smaller, less active and less efficient vessels. Removal of the less efficient vessels could result in reductions in

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[140] Maurstad's study of regulation within a small-scale Cod fishery showed how management regulations that ignore fleet heterogeneity can provide incentives to increase effort and catches overall.
[141] Input-based CU measures with values less than one implies the existence of latent effort.
[142] 'Fleet segment' is used to define effort categories of vessels in the RLF (Mapstone et al. 1996a).

effective capacity being less than that of nominal capacity (Thunberg 2001; Tingley and Pascoe 2005). Conversely, removing the most active vessels may result in greater initial reduction in fishing pressure, but may encourage the reactivation of latent capacity in the medium-long term. If a reduction in fleet size also creates incentives for remaining vessels to increase their CU or, in the case of 'latent' vessels, to mobilise, then the effectiveness of such programs will be further diminished (Tingley et al. 2003). Vessel buyback schemes are often only a second-best solution to fishery management where defined property rights or other economic instruments are not in place (Lindebo and Soboil 2002).

Despite the difficulty in obtaining useable data by which to make capacity assessments in fisheries with latent capacity, some understanding of the variant fleet-wide activity levels is necessary to understand excess capacity and its effect on resource stocks.

8.3 Methods

Data Envelopment Analysis (DEA) is a mathematical programming technique that enables measurement of capacity outputs relative to some optimum. It can be applied when data are available on levels of production inputs and outputs only or when economic price data also are available (Kirkley et al. 2001). In addition to overcoming data limitations on prices, DEA has other advantages in that it accommodates multiple outputs and inputs, heterogeneous capital stock and zero-valued outputs or inputs typical of multi-product fisheries. Also, DEA does not impose any specific functional form on the underlying technology, enabling the various scale assumptions to be applied (Kirkley et al. 2002a). A disadvantage of the technique is that it does not account for random variations in outputs, thereby attributing any shortfall in output to capacity under-utilisation or technical efficiency rather than stochastic variation.

DEA studies have examined capacity issues using physical data (Fare et al. 2000; Kirkley et al. 2001; Pascoe et al. 2001; Squires et al. 2003; Vestergaard et al. 2003) or economic cost data (Tingley and Pascoe 2003). DEA has also been applied to multi-specific, multi-métier fisheries (Dupont et al. 2002; Tingley et al. 2003) and those fisheries where data are limited (Kirkley et al. 2001). With the exception of Kirkley (2003) and Squires *et al.* (2003), developing country fisheries are absent from the literature. Moreover, all studies I have been able to identify use data from capital-intensive trawl and net fisheries as opposed to the more labour-intensive inputs that typify tropical inshore and reef-based fisheries.

8.3.1 Capacity and Technical Efficiency

In estimating capacity outputs, we designate the vector of outputs u and the vector of inputs x. There are m outputs and n inputs (where $n \in \alpha$ is the subset of fixed inputs and $n \in \hat{\alpha}$ is the subset of variable inputs) and j observations or firms. An estimate of capacity outputs requires solving for the following set of equations.

$$\underset{0,\mathbf{z},\lambda}{\boldsymbol{Max}}\, \theta_1$$

subject to:

$$\sum_j z_j u_{jm} \leq \theta_1 u_{0m} \qquad \forall m$$

$$\sum_j z_j x_{j,n} \leq x_{0,n} \qquad n \in \alpha$$

$$\sum_j z_j x_{j,n} = \lambda_{0,n} x_{0,n} \qquad n \in \hat{\alpha}$$

$$\sum_j z_j = 1$$

$$z_j \geq 0 \quad \forall j \qquad \lambda_{j,n} \geq 0 \qquad n \in \hat{\alpha} \qquad (2)$$

Where:

θ_1 (≥ 1) is a scalar showing how much the output of each firm can increase;

$u_{j,m}$ is the output m produced by firm j;

$x_{j,n}$ is the input n used by firm j;

z_j is a weighting factor such that capacity output is the weighted sum of the output of other vessels in the data set;

The value of θ_1 is estimated for each vessel separately with the target vessel's outputs and inputs being denoted by u_{0m} and $x_{0,n}$. Inputs are divided into fixed (α) and variable ($\hat{\alpha}$) factors. The problem allows for full utilisation of variable inputs through the parameter λ, which is the optimal use of the variable input, but constrains output with the fixed factor. The level of capacity output is given by $u*_{0m} = \theta_1 u_{0m}$ for each species and assumes catch composition remains constant but that catch levels can increase through increased use of variable inputs. This assumption is a fairly realistic one in fisheries. $\sum_j z_j = 1$ imposes variable returns to scale on the production technology (Fare et al. 1989). In the case of the RLF, this restricts frozen operations to increased outputs of only frozen product. Capacity output $u*$ is determined by multiplying each observed output u by θ_1. Capacity utilisation (CU) based on observed outputs is:

$$CU = \frac{u}{u*} = \frac{1}{\theta_1} \tag{3}$$

where $0 \leq \boldsymbol{CU} \leq 1$ and values less than 1 indicate a firm is operating at less than full capacity given fixed inputs.

This approach converts the multiple-output problem to a single-output problem and provides for a fixed radial expansion of outputs (Vestergaard et al. 2003). Estimates of CU are likely to be biased downward for two reasons. Because the DEA technique does not account for random variations in catch (outputs) any apparent shortfall in output is attributed to either capacity under-utilisation or to technically inefficient production of observed outputs (i.e. not producing to the full potential given the level of both fixed and variable inputs), rather than stochastic error (Fare et al. 1994; Tingley et al. 2003).

A measure of technically efficient (TE) output corresponding to a given level of fixed and variable inputs can correct for this bias and separate the effects of inefficiency from those of capacity under-utilisation (Kirkley et al. 2001; Tingley and Pascoe 2005). Given the random variability in the data will upwardly bias both capacity output and technically efficient output, the ratio of these can be considered an “unbiased” capacity measure (Holland and Lee 2002). An estimate of technically efficient output requires solving for the following equations:

$$\underset{\theta,\mathbf{z}}{Max}\,\theta_2$$

subject to:

$$\theta_2 u_{0,m} \le \sum_j z_j u_{j,m} \qquad \forall m$$

$$\sum_j z_j x_{j,n} \le x_{0,n} \qquad \forall n$$

$$\sum_j z_j = 1$$

$$z_j \ge 0 \tag{4}$$

where θ_2 is a scalar showing how much the output of each firm can increase if all inputs are used in a technically efficient manner and all other terms are as for equation (3). The technically efficient level of output u^*_{TE} is defined as θ_2 multiplied by observed output u and the technical efficiency of the firm given by:

$$TE = 1/\theta_2 \tag{5}$$

where $0 \le TE \le 1$ and values less than 1 indicate a firm is operating in technically inefficient manner given current use of fixed and variable inputs. The "unbiased" measure of capacity utilisation CU^* is a ratio of technically efficient output to capacity output and is given by:

$$CU^* = \frac{1}{\theta_1}\bigg/\frac{1}{\theta_2} = \frac{\theta_2}{\theta_1} \tag{6}$$

As the level of all inputs is constrained, the TE multiplier θ_2 is less than capacity output multiplier θ_1 and both are less than 1 and therefore $CU \le CU^* \le 1$.

8.3.2 Revenue and Allocative Efficiency

According to Fare *et al*. (2000) the capacity output models outlined above can be adapted to represent a revenue maximisation problem that allows for substitution in outputs. A model of revenue efficiency (RE) is proposed that differs from usual models in that while it restricts variable inputs (e.g. days fished, number of tenders) to current levels, it allows for non-live operations to reallocate fixed inputs by incorporating live technology in the short-run. This outcome assumes adoption of live technology is low cost and time neutral. This revenue maximisation problem can be formulated as:

$$\underset{\tilde{y}_{jm},z,\lambda}{Max} \sum_m p_m \tilde{y}_{jm}$$

subject to:

$$\sum_{i=1}^{N} z_i y_{im} \geq \tilde{y}_{jm} \qquad \forall m$$

$$\sum_{i=1}^{n} z_i x_{in} = \lambda_{jn} x_{jn} \qquad n \in \alpha$$

$$\sum_{i=1}^{n} z_i x_{in} \leq x_{jn} \qquad n \in \hat{\alpha}$$

$$\sum_j z_j = 1 \tag{7}$$

where p_m is the output price for output *m*, $\tilde{y}_{jm}$ is the revenue maximising level of output *m* produced by firm *j*, given output prices p_m and input levels x_{jn}, and all other terms as for equation (3). This model allows for substitution in outputs (Cooper et al. 2000) and price data can vary among firms. Having solved for the above, revenue efficiency (RE) is calculated by:

$$RE = \frac{\sum_m p_m y_{jm}}{\sum_m p_m \tilde{y}_{jm}} \tag{8}$$

where $0 \leq RE \leq 1$ when $p_m y_{jm} > 0$ and values less than 1 indicate a firm is operating in a revenue inefficient manner given current use of fixed inputs. If we accept revenue maximisation as a behavioural objective, this ratio of maximum to observed revenue can be used in conjunction with TE to calculate allocative efficiency (AE). Given that TE and RE models hold variable inputs at their current levels, AE can be calculated as

$$AE = RE / TE\,. \tag{9}$$

DEA outputs for TE, RE and AE were tested for significant differences between live and frozen operations. All efficiency measures for each operation type were tested for normality using the Kolmogorov-Smirnov test and homogeneity of variances using Levene's Test prior to analysis. Where tests suggested non-normality and/or heterogeneity among variances data were Log_{10} transformed. Because test for significance were conducted using same data input, critical significance criterion were revised using a Bonferroni adjustment.

8.3.3 Data Sources

The dataset for the DEA analysis comprises 50 vessels active in the RLF during 1999 and includes 17 frozen-only operations and 33 live operations who marketed frozen and live product. Trip level logbook data have been aggregated to provide monthly levels of inputs and outputs by vessels for the year 1999. These vessels represent some of the most active in the fleet, making up approximately 42% of the total catch (frozen and live product) and 55% of the total live catch of coral trout from the RLF during the period of interest. Data on fishing effort (inputs) and catch (outputs) for these commercial vessels was derived from the Department of Primary Industry and Fisheries (DPI & F) C-FISH database through the Effects of Line Fishing (ELF) project. Data on beach prices (i.e. price paid by processor to fishing boat owner) for each output type (product) was provided by fish processors operating out of Cairns, Bowen and Mackay.

The basic DEA model contained three inputs and three outputs. The fixed input into the model was vessel length while variable inputs were days at sea and number of tender vessels or dories. A primary vessel is licensed to support a maximum number of dories and fishing is also permitted from the primary vessel. The primary vessel and each dory is assumed to support only one fisher (one line), meaning that the maximum possible fishing effort each day is the number of dories plus one. Actual effort allocated on any fishing trip may be less than the maximum permitted from dories and the primary vessel combined where one or more dories are not used because of crew shortage, maintenance and breakdowns, or because one or more fishers choose not to fish. The model contains three outputs (product types): frozen coral trout; live coral trout; and "other species" sold as frozen product. "Other species" comprises mainly common emperor species such as red-throat emperor and red emperor for which there is a consumer market (for dead fish) but also includes small incidental catches of "other species" sold alive (typically small serranids or cods) . Catch of pelagic species have not been included in this analysis as their contribution to overall catch and revenue for the demersal RLF is minimal[143]. Frozen-only vessels will have zero-values in outputs of live product and live-only vessels (if there were any) would have zero values for frozen coral trout and "other species". As noted previously, DEA can accommodate these zero values.

While live product is sold whole, frozen products may be marketed as fillet, gutted, trunked (guts & head removed) or whole ("guts in") product with catch weights reported as processed catch weights. All logbook reported 'processed' weights have been converted to live weight equivalent values (LWE) based on known recovery rates for different product types[144]. These LWE estimates have been applied to the DEA model and capacity and capacity utilisation estimates.

Deriving price data for frozen product for use in the Revenue Efficiency (RE) DEA model required a multi-stage procedure. Firstly, the composition of catch for each vessel by species or species group (coral trout, other demersal) and product types (live and frozen) was determined. Next, frozen product for each species group was divided into market type (fillet, trunked, gutted, whole) and a 'price conversion-for-product' (PCP) multiplier[145] derived for each species group by market type. The PCP multiplier varied depending both on the breakdown of market type (fillet, etc.) and, in the case of other demersal species, catch composition[146] for each vessel. For example, a higher proportion of filleted product lowered the PCP multiplier in recognition of lower recovery rates on that product type. The last stage was to multiply beach price by the PCP multiplier to derive an estimate for each vessel of price gained from each product type per kilogram of whole fish. This approach was more complicated for other demersal species, which comprised frozen red-throat emperor (RTE), frozen other species and live other species. Thus, the adjusted price of the other demersal catch,

[143] Moreover, pelagic species are rarely, if ever, targeted by the vessels in this sample and are considered incidental bycatch for the purposes of this study.

[144] An average rate of recovery has been applied across all vessels that ignore differences in filleting skills between fishers.

[145] The PCP multiplier falls between 0 and 1 for all market types. A PCP multiplier of 1 implies the LWE is equal to weight of saleable product

[146] Catch composition had to be taken into account because of different recovery rates of various product types for the different body shapes of the different species.

given reported product composition and conversion rates from whole fish to each product type (fillet, etc) was calculated by:

$$DemP_{adj} = PCP_{RTE} * BP_{RTE_{Fillet}} * CP_{RTE_{Fillet}} + PCP_{FOTH} * BP_{FOTH_{Fillet}} * CP_{FOTH_{Fillet}} + PCP_{LOTH} * BP_{LOTH} * CP_{LOTH} \qquad (10)$$

Where $DemP_{adj}$ is adjusted fresh weight price and $BP_{RTE_{Fillet}}$, $BP_{FOTH_{Fillet}}$ and BP_{LOTH} are beach prices for RTE fillet, other demersal species fillets and other live species respectively and $CP_{RTE_{Fillet}}$, $CP_{FOTH_{Fillet}}$ and CP_{LOTH} represent the proportion of the non-trout catch comprised of by each of these product types such that $CP_{RTE_{Fillet}} + CP_{FOTH_{Fillet}} + CP_{LOTH} = 1$.

The Q-FISH database was analysed to explore the mobilisation of latent effort since the advent of the LRFF fishery and examine capacity implications of that mobilisation. This analysis assumed that the LRFF fishery was driving effort mobilisation and focussed only on those operations which recorded catch of coral trout in any product form, including live coral trout. Operations were divided firstly into four effort classes: < 3 lines, 4 lines, 5 lines and ≥ 6 lines. These classes accounted for one line being used from the primary vessel, and so the number of dories supported by an operation can be assumed to be the number of lines minus 1 (i.e. 5 line operations ≈ 4 dories), consistent with previous chapters. Each operational class was then further partitioned into annual operation-actvity groupings: 1-50 days, 51-100 days, 101-150 days and ≥ 150 days, where the number of days indicates the number of days the operation (i.e., primary vessel + tenders) was fishing. The variables of interest within these effort class and activity groupings were: i) the number of boats recording catches of coral trout and, as a subset of this, live coral trout; and ii) mean effort (line-days). These variables were compared across the years 1995 to 2001 to derive evidence of the take-up of latent effort, either through currently active vessels or newly activated licenses, and, by inference, the influence of the live fish trade on the mobilisation of latent effort[147].

[147] While there may have been other motivators for uptake of latent effort such as from multi-endorsed vessels entering the fishery as regulations in other fishing industry sectors become more restrictive, for the purposes of this analysis I have assumed these other influences to be minor compared to the influence of live fish prices.

The usefulness of DEA to examine capacity issues in fisheries with latent effort is limited. Firstly, DEA requires each firm employ a positive amount of at least one input (effort) to produce a positive amount of at least one output (catch) (Kirkley et al. 2001). Second, where fishing operations participate in multiple fisheries over the period of interest, data are needed on all inputs and outputs in order to produce accurate CU estimates for that period (Tingley et al. 2003). Both constraints are relevant to the RLF, where many licensed operations record low or zero levels of effort and catch over extended periods and data on the participation of RLF-endorsed operations in other fisheries over that time period are not readily available. According to Kirkley and Squires (1999b), however, fleet-wide estimates of capacity can be made by attributing capacity outputs associated with full variable input utilisation of active participants to currently partially or fully inactive participants on the basis of knowledge of their capital stocks.

I sought to apply the results of the DEA analysis of my sample data to estimate the capacity and potential latency of the whole of the RLF fleet, or at least that part of it satisfactorily represented by my sample. As a first step in estimating potential capacity, the mean lengths of primary vessels of the sample and the fleet in each effort class (1-3, 4, 5 & 6+ lines) were compared using two-factor Analyses of Variance (ANOVA), the null hypotheses being there were no significant differences in mean primary vessel length between the sample and fleet (group) in each of effort class. Effects were considered significant if $p \leq 0.05$. A full-factorial ANOVA model was used that tested for main and interaction effects. Type III sums of squares, which are relatively insensitive to non-homogeneity of cell frequencies, were used in the analyses given cell sizes generally were unequal. Levene's test was used to examine the assumption of homogeneous variances.

The next step was to apply average capacity estimates of the catch from the DEA results for each effort class to the respective frozen and live operations active in the fishery as at 1999. I chose to use only the catches of live and frozen coral trout in this step, excluding the catch of other species. The rationale for excluding catches of other landed commercial species was based on the high likelihood that all or most of that other catch would have been incidental bycatch whilst targeting coral trout and the importance of coral trout in driving fisher behaviour, as evidence by the fact it comprises around half the total catch of the commercial RLF. QFS data showing the proportion of operations in each effort class were used to estimate the number of live and frozen operations within each class for the 228 L2 endorsed vessels in 1999.

8.4 Results

8.4.1 Efficiency

Results of DEA analysis of technical, revenue and allocative efficiency for frozen and live operation are shown in Figures 8–3, 8–4 and 8–5. Whilst none of either the frozen or live operations had a TE score of less than 0.50, only ~28% of the frozen operations in the sample had a TE score less than 0.95 compared with 62.5% of live operations. [Figure 8–3(a)]. In contrast, 78% of frozen operations had a RE score of less than 0.5 compared with ~12.5% of live operations, while 72% and 78% of live or frozen operations respectively had a RE score below 0.95 [Figure 8–3(b)]. Lastly, 60% of live operations had an AE score of 0.95 or less while 80% of frozen operations had an AE score of 0.95 or less. None of the live operations had an AE score below 50%, whilst ~67.5% of frozen operations scored less than 50% [Figure 8–3(c)].

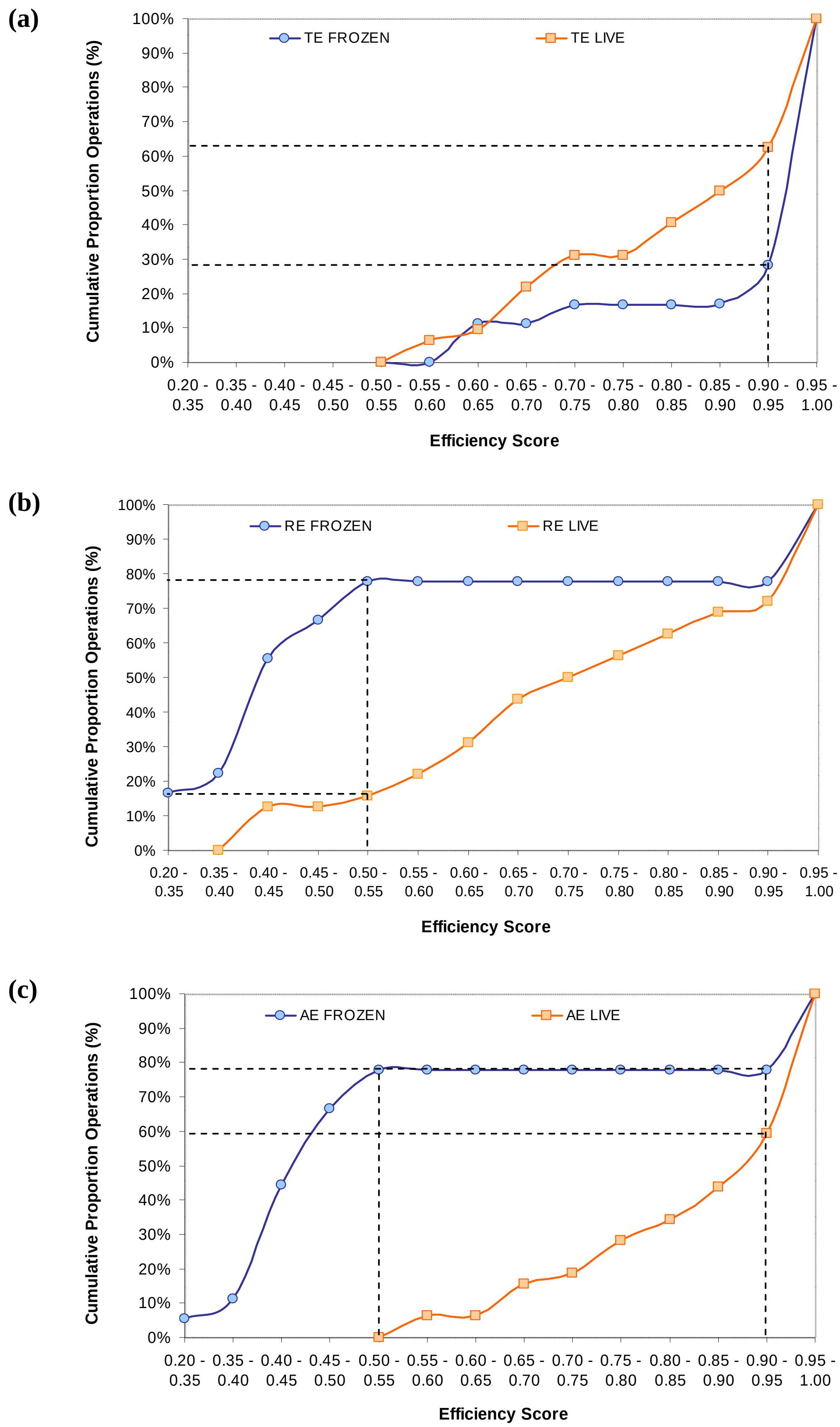

Figure 8-3: Distribution of efficiency scores for frozen and live operations within the reef-line fishery for (a) technical efficiency, (b) revenue efficiency and (c) allocative efficiency.

Normality tests showed TE, RE and AE outputs to be non-normally distributed for both frozen and live operations. Using Levene's test the null hypothesis of homogenous variance was accepted for TE and RE but rejected for AE (Table 8–1). Transformation of output data did not alter these outcomes. On the basis of these results, non-parametric Kruskal-Wallis tests were used to compare means. The Bonferroni adjusted critical value for *P* was equal to 0.0167[148].

Table 8-1: Tests for normality of distribution and homogeneity of variance for technical, revenue and efficiency score outputs for frozen and live vessels

Efficiency Criteria	Normality Test	Homogeneity Test
Technical Efficiency		($F_{1,48} = 1.893$, $p = 0.175$)
Frozen Operation	(K-S $_{0.05,\ 18} = 0.412$, $p < 0.000$)	
Live Operations	(K-S $_{0.05,\ 32} = 0.204$, $p = 0.002$)	
Revenue Efficiency		($F_{1,48} = 0.870$, $p = 0.356$)
Frozen Operation	(K-S $_{0.05,\ 18} = 0.267$, $p = 0.001$)	
Live Operations	(K-S $_{0.05,\ 32} = 0.157$, $p < 0.042$)	
Allocative Efficiency		($F_{1,48} = 7.006$, $p = 0.011$)
Frozen Operation	(K-S $_{0.05,\ 18} = 0.313$, $p < 0.000$)	
Live Operations	(K-S $_{0.05,\ 32} = 0.169$, $p < 0.021$)	

The average TE score for frozen and live operations was not significantly different ($\chi^2_{0.0167,\ 1} = 4.576$, $p = 0.032$) while the average RE score ($\chi^2_{0.0167,\ 1} = 8.234$, $p = 0.004$) and AE score ($\chi^2_{0.0167,\ 1} = 12.834$, $p < 0.000$) of live operations was significantly higher than that of frozen operations (Table 8–2).

Table 8-2: Summary statistics for technical efficiency, revenue efficiency and allocative efficiency for frozen and live operations within the reef-line fishery

	Technical Efficiency		Revenue Efficiency		Allocative Efficiency	
Statistic	**Frozen**	**Live**	**Frozen**	**Live**	**Frozen**	**Live**
Mean	0.932	0.857	0.535	0.754	0.562	0.871
Std Error	0.033	0.027	0.064	0.036	0.059	0.024
Std Deviation	0.138	0.151	0.273	0.202	0.251	0.134
95% Conf. interval	±0.069	±0.054	±0.136	±0.073	±0.125	±0.048

148 The Bonferroni correction is calculated as desired probability value (0.05) by number of significance tests conducted on the data, in this case 3 (Field, 2000).

8.4.2 Capacity and Capacity Utilisation

The distribution of observed and unbiased measures of capacity utilisation for each operation type is illustrated in Figure 8–4 (a) and 8–4 (b). Comparing observed and unbiased measures of capacity utilisation for frozen and live operations indicates a stronger downward bias on estimates of capacity output of live than frozen operations. Allowing for full utilisation of variable inputs (CU observed), almost 57% of frozen operations were operating at ≥ 90% capacity as compared with 28% of live operations. Based on technically efficient outputs, where current input levels are held constant (CU unbiased), almost 75% of frozen operations were operating at ≥90% capacity as compared with 66% of live operations. While the performance of live operations remained inferior under both observed and unbiased estimates of capacity utilisation, live operations showed a relatively greater improvement in the performance when holding current inputs constant. Accordingly, while 22% of live operations were operating at < 60% capacity utilisation based on the observed CU measure, only 3% of live operations had an unbiased capacity utilisation score of < 60%.

The higher degree of capacity utilisation among frozen operations is reflected in their rate of variable input utilisation (λ). Based on this sample, frozen operations were operating at their optimal number of days in 45% of observations, while only 25% of live operations were operating at their optimal number of days fished. Almost 70% of live operations could increase their variable input use as compared with less than 45% of frozen operations, with 22% of live operations able to increase inputs by more than 50% in order to operate at full capacity (Figure 8–5).

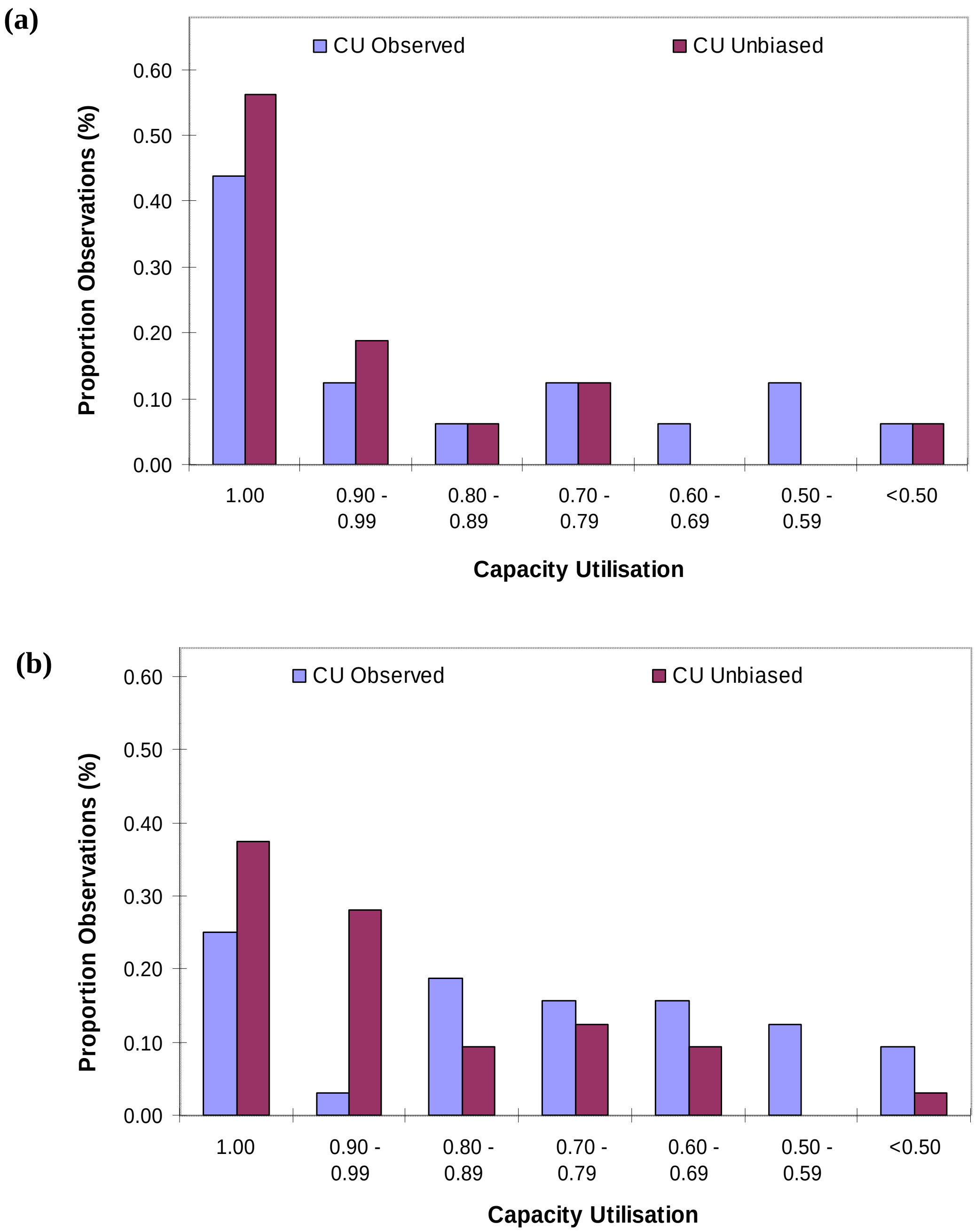

Figure 8-4: Distribution of observed and unbiased capacity utilisation scores for (a) frozen operations* and (b) live operations within the reef-line fishery.

** Operations where annual days fished <30 removed for purposes of analysis*

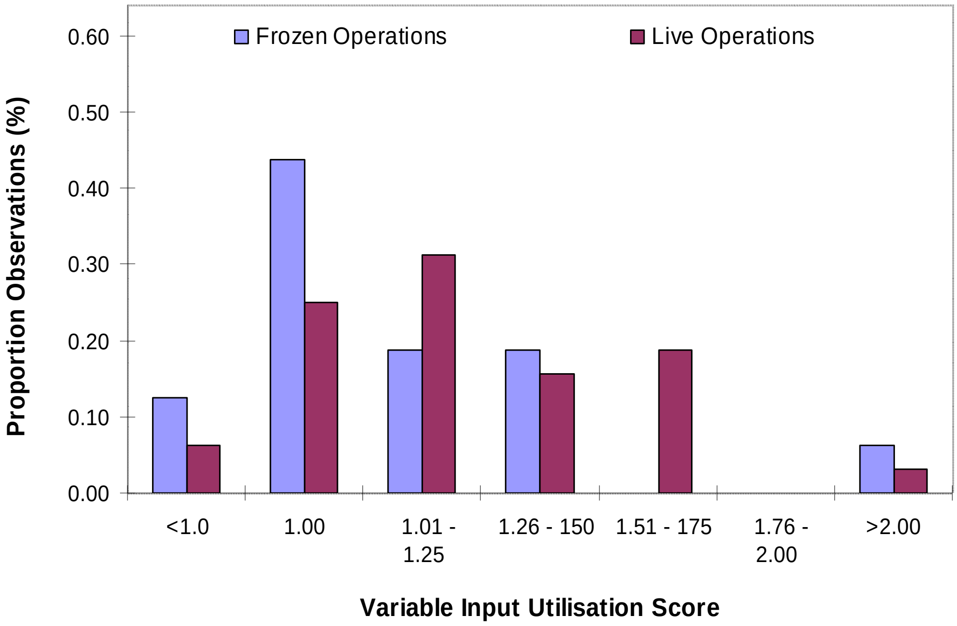

Figure 8-5: Distribution of variable input utilisation scores for frozen * and live operations within the reef-line fishery**.**

** Operations where annual days fished <30 removed for purposes of analysis*

This pattern of capacity utilisation and variable input utilisation among live and frozen operations was reinforced by average observed, technically efficient and capacity outputs by operation types for the main target catch, coral trout (Table 8–3). Average TE output of frozen coral trout for frozen operations was 8.8% higher than observed outputs, compared to live operations whose TE output of frozen coral trout was 32.5% higher than average observed outputs. Also, that live operations' technically efficient output of live coral trout was only 17.7% higher than observed catch suggested that inputs were being more efficiently applied to catching coral trout suitable for the live as opposed to frozen markets[149] (see 4.4). Live operations could have increased average total catch of both live and frozen coral trout by 34%, whereas frozen operations' capacity output was only 22.5% higher than observed output (Table 8–3).

[149] Fishers targeting fish for live markets tend to use 'view buckets' to enable them to look underwater to locate sites where coral trout are most abundant and bycatch will be minimised. The desire of live operations to avoid catches of fish not marketable alive sees them spend less time at each fishing location and move on from locations where less desirable species predominate (Mapstone et al., 2001).

Table 8-3: Average annual observed, technically efficient (TE) and unbiased capacity output (kilograms) for frozen and live coral trout by operation type in 1999. Technically efficient output was conditioned on variable inputs remaining static. Capacity output allowed for increases in days fished only. All estimates of technical and capacity output assumed constant stock abundance (CPUE).

	Frozen Operations		Live Operations	
Statistic	**Frozen**	**Live**	**Frozen**	**Live**
Observed catch	14,146	–	5,654	9,545
TE output	15,389	–	7,491	11,239
Increase TE (kg)	1,442	–	1,836	1,694
Increase TE (%)	8.8%	–	32.5%	17.7%
Capacity output	16,772	–	7,653	12,712
Increase capacity (kg)	2,626	–	1,999	3,166
Increase capacity (%)	22.5%	–	35.4%	33.2%

8.4.3 Latent Effort and Fleet Capacity

Data in Figure 8–6 and Figure 8–7 show for each effort class of operation the proportion of operations in that class that fall within one of four activity classes for each year from 1995 to 2001. ‘Activity’ here refers to the numbers of days per year that an operation reported fishing with the number of lines indicated by the ‘effort classes’. Values are expressed in Figure 8–6 as the proportion of operations reporting catch of coral trout in any product form while in Figure 8–7 values are the proportion of operations reporting catch of live coral trout. A take-up of latent effort has been assumed when, within a particular effort class, there is evidence of an increase over time in the proportion of operations attributed to higher activity groupings. Understanding the source of changing effort patterns, however, is confounded by the rate at which the vessel owner increased their activity and the extent to which activity patterns reflected increased participation in the LRFF fishery by previously inactive operations.

In general, there was a trend of increased activity levels across all operation effort classes, for vessels recording catches of coral trout in any product form, although the 6+ lines effort class was an exception. The proportion of operations that fished for >100 days per year in 1995 had increased to 2001 from 33% to 44% for operations using 1-3 lines, from 52% to 68% in the 4 line class and from 63% to 88% in the 5 line class

[Figure 8–6(a), (b) and (c)]. The comparisons between 1995 and 2001 activity levels were augmented for vessels recording catches of live coral trout. The proportion of operations in the 1-3 line class who fished for >100 days per year increased from 31% in 1995 to 54% in 2001, with analogous increases for the 4 and 5 line of 33% to 72% and 57% to 88% respectively [Figure 8–7(a), (b) and (c)]. While activity increases are likely a combination of increased activity and entry to the fishery by inactive licensees, the amplified results in the case of live operations suggests that the increased effort generally may have been driven by the reactivation of previously dormant licenses straight into the LRFF fishery.

General trends, such as those above, can overlook the more subtle transition of operations from lower to higher levels of activity over time that can add to evidence of the take-up of latent effort. The distribution of activity levels of operations in the 5-line effort class for years 1998 to 2000 serve as an example. In 1998, 10% of those operations fished for 50 days or less, 14% for between 51 and 100 days, 40% for between 101 and 151 days and 36% for >150 days. In 1999, the proportion of operations fishing 1 to 50 days and between 51 and 100 days fell to 7% and 10% respectively, while the proportion of vessels fishing for 101-150 days remained steady at 39% and activity in the >151 days group rose to 44%. In 2000, the proportion of operations fishing 1 to 50 days and 51-100 days again fell, to 4% and 7% respectively, while in the 101-150 and >151 days groups the proportion of operations increased to 40% and 49% respectively [Figure 8–6(c)]. Similar patterns prevail for other effort classes in successive years. These results suggest sequential movement of individual operations where, for example, operations becoming more active and moving into a higher activity group are being replaced by less active operations also moving upward from lower activity groups.

Before estimating potential capacity, the mean lengths of primary vessels of the sample and the fleet in each effort class were compared using a two-factor ANOVA. There was a significant main effect of effort class on mean length of the primary vessel, with vessel length increasing in line with effort class. There were no significant main or interaction effects on mean primary vessel length when comparing vessels from my sample with the whole fleet (group) either across all effort classes or between effort classes (Tables 8–4; 8–5). That no statistically significant differences were detected for any operation effort class, suggests the survey samples were representative of the RLF fleet and capable of being used to estimate potential capacity.

Table 8-4: Mean lengths of primary vessels for operation size classes for the survey sample and the commercial RLF fleet[1] as at 1999.

	1 - 3 Lines		4 - Lines		5 - Lines		6+ Lines	
	Fleet	**Sample**	**Fleet**	**Sample**	**Fleet**	**Sample**	**Fleet**	**Sample**
Mean (meters)	9.89	9.60	11.50	12.04	13.19	14.11	14.56	14.64
Std Error	0.319	2.067	0.391	0.882	0.345	0.553	0.731	0.925
95% Confidence interval	±0.314	±2.035	±0.384	±0.868	±0.339	±0.544	±0.719	±0.910

[1] Fleet statistics exclude the vessels comprising the survey sample.

Table 8-5: Analysis of variance comparing primary vessel length (meters). Effort Class (1-3, 4, 5 & 6+ lines) and Group (Sample, Fleet) are fixed factors. Results of Levene's Test also are presented. df = degrees of freedom, MS = mean square, *F* = *F*-ratio, *p* = probability of the data if no difference existed. Significant results (P<= 0.05) are in bold

	Primary Vessel Length (m)			
Source of variation	**df**	***MS***	***F***	***p***
Effort Class	3	77.490	9.064	< **0.000**
Group (Sample or Fleet)	1	1.919	0.224	0.636
Effort Class * Group	3	1.770	.369	0.891
Residual (error)	271	8.549		
	Levene's Test (F = 1.031, p = 0.409)			

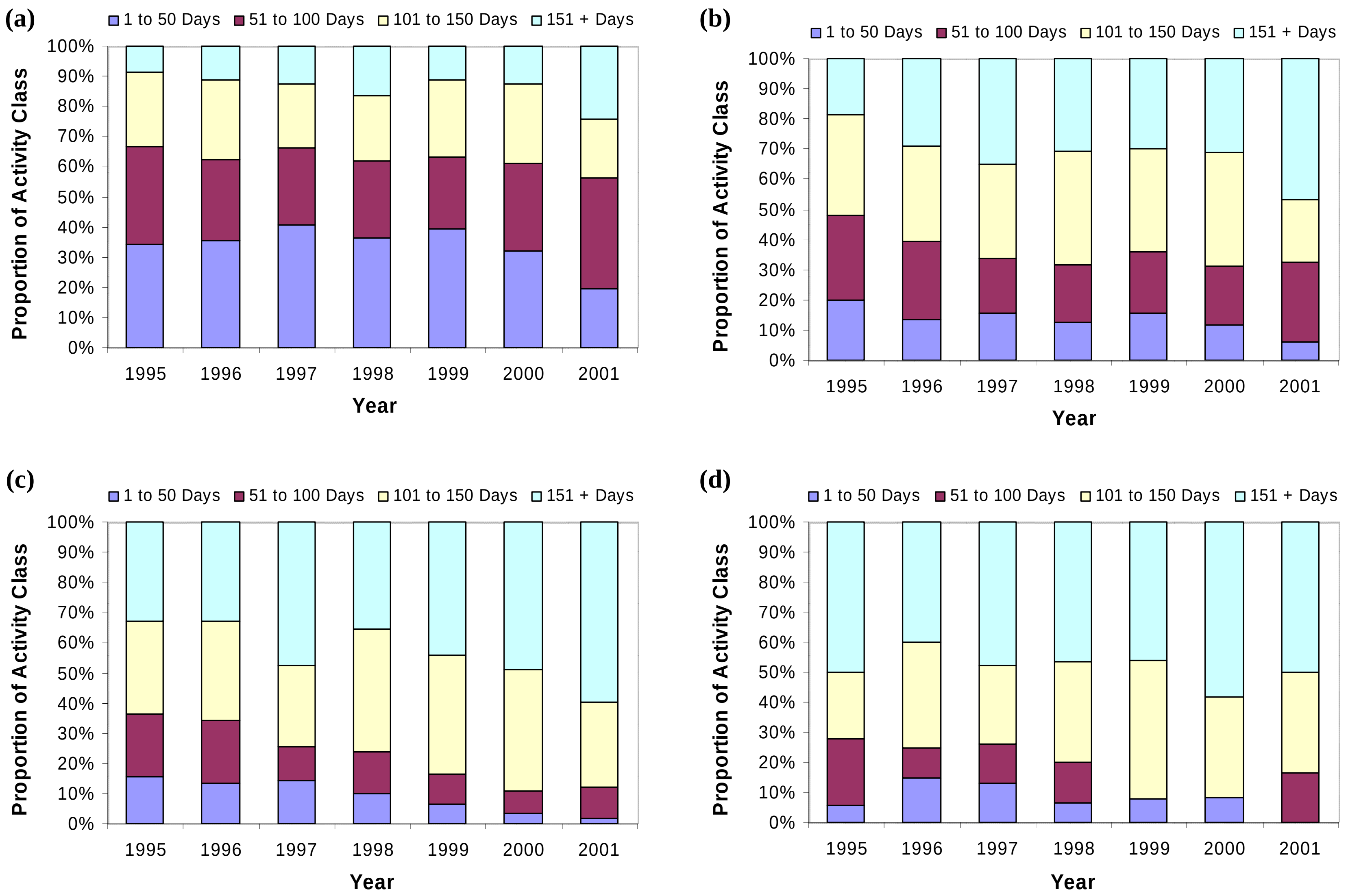

Figure 8-6: Commercial reef-line fishery endorsed operations reporting catch of coral trout for the years 1995 to 2001 by activity grouping (1 to 50 days, 51 to 100 days, 101-150 days and 151+ days) expressed as a proportion of vessels reporting catch of coral trout for operation effort classes a) 1-3 lines, b) 4 lines, c) 5 lines and d) 6+ lines.

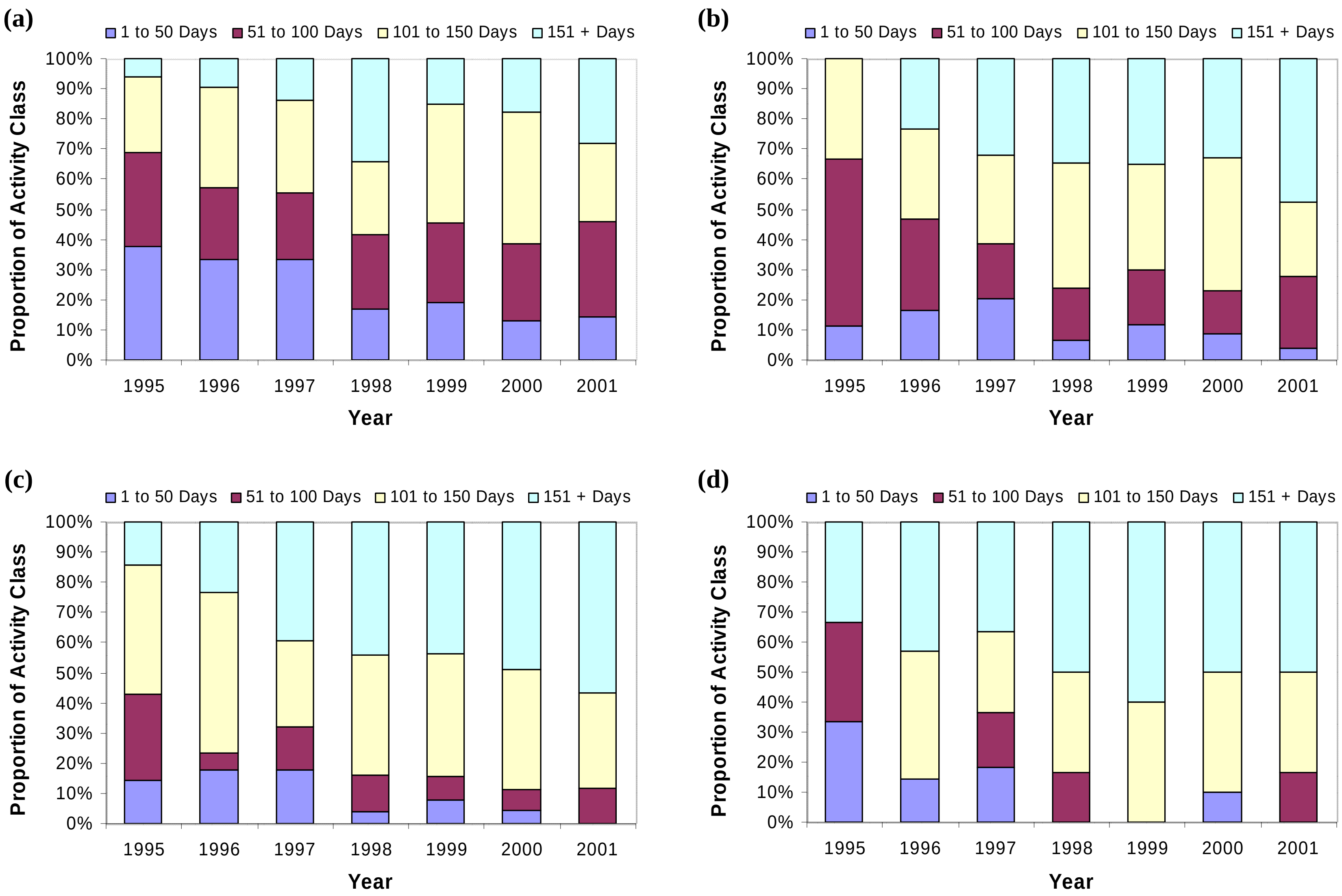

Figure 8-7: Commercial reef-line fishery endorsed operations reporting catch of live coral trout for the years 1995 to 2001 by activity group (1 to 50 days, 51 to 100 days, 101-150 days and 151+ days) expressed as a proportion of vessels reporting catch of live coral trout for operation effort classes a) 1-3 lines, b) 4 lines, c) 5 lines and d) 6+ lines.

Estimates of potential catch of coral trout for frozen and live markets from the fleet of frozen and live L2-endorsed operations were based on the combined results of the DEA conducted on my sample dataset (Sections 8.4.1 & 8.4.2) and QFS license data from 1999. These estimates are summarised in Table 8–6[150]. According to the QFS, approximately 110 vessels reported catches of live coral trout in 1998 (QFMA 1998). My estimate of 118 vessels seemed reasonable, therefore, particularly given the combined effects of former live operations reverting to frozen only production and the slowdown in adoption of live technology following the large scale cyclone in 1997 and the SARS events in South East Asia that affected catches and markets respectively during this period (see Chapters 4 & 5). The results shown below were based on the 1999 composition of frozen and live L2-endorsed operations and all estimates of potential capacity output were unconstrained by stock abundance or any impacts of increased harvests on CPUE. According to these results, live operations had the potential to harvest more coral trout in both product forms than did their frozen counterparts for each operation size class (Table 8–6). If all L2-endorsed operations mobilised fully into the reef-line fishery, the fleet would have had the capability to harvest substantially more than the actual 1999 harvest of 1,341,980 kg of coral trout, marketed as 821,821 kg of frozen and 520,159 kg of live product. If the fleet had fully mobilised into the reef-line fishery in line with the mix of frozen and live operations as at 1999, they would have had the potential to harvest pro-rata 2,403,054 kg of coral trout for the frozen market and 1,387,106 kg of coral trout for the live market, totalling 3,790,160 kg of catch (Table 8–6).

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[150] Catches of other mixed demersal species (product 3 in the DEA analysis) have been excluded for the purposes of this analysis on the basis that the value-adding of existing coral trout is the main driver of the mobilisation of latent effort.

Table 8-6: Average vessel capacity catch and estimated total potential fleet capacity catch of frozen and live coral trout product for frozen and live operations by operation effort class in 1999. Average capacity catch was calculated from survey sample of 50 vessels conditioned on flexible variable inputs (days fished). Total or maximum potential catch per operation effort class was estimated as the product of average capacity catch and the number of L2-endorsed vessels licensed to fish in the Great Barrier Reef RLF in each effort class.

	Operation Size Class (Lines)				
Variable	**1-3**	**4**	**5**	**6+**	**TOTAL**
Observed Catch/Fleet (kg)[1]					
Frozen Coral trout	180,590	319,114	260,932	61,185	821,821
Live Coral trout	90,474	200,844	186,640	42,201	520,159
Total	271,064	519,958	447,572	103,386	1,341,980
No. L2-Endorsed Operations[2]					
Frozen Operations	53	21	26	10	110
Live Operations	31	35	46	6	118
Total	84	56	72	16	228
Mean Capacity Catch/Vessel (kg)					
Frozen Operations					
Frozen Coral trout	8,753	16,545	17,272	23,112	65,681
Live Coral trout	0	0	0	0	0
Live Operations					
Frozen Coral trout	5,875	7,178	9,433	7,220	29,707
Live Coral trout	5,291	11,380	14,937	23,030	54,638
Total Potential Catch/Fleet (kg)					
Frozen Operations					
Frozen Coral trout	464,634	353,409	448,507	227,562	1,494,112
Live Coral trout	0	0	0	0	0
Live Operations					
Frozen Coral trout	181,637	248,646	434,226	44,433	908,942
Live Coral trout	163,579	394,205	687,601	141,721	1,387,106
Total Potential Capacity Catch	**809,850**	**996,260**	**1,570,335**	**413,716**	**3,790,160**

[1] Observed fleet catch was derived from QFS data of 315 reported vessels recording catches of frozen and live coral trout in 1999.

[2] Only L2-endorsed operations (228) were included in the analysis for the purposes of estimating potential catch of the fleet because I did not include any L3 vessels in my survey. The lower total number of vessels (n = 228) used to derive potential catch suggests total potential harvest of coral trout harvest from L2-endorsed frozen and live vessels is an underestimate of potential capacity of the whole fleet (315 vessels), though the extra 87 L3 operations would all have been in the 1-3 line effort class.

8.5 Discussion

I have used the two market-related sectors of the commercial RLF, comprising predominantly live or frozen operations, to examine differences between physical and economic based measures of efficiency and capacity. Capacity results estimated for an interviewed sample of operations were applied across the fishery to examine potential harvesting capacity outcomes arising from a fleet of vessels subject to hypothesised incentives to increase activity within certain logistic operational constraints.

The standard DEA approach in fisheries has been to derive physical capacity estimates, such as technical efficiency and capacity utilisation, on the basis of simple catch volumes. Assuming that fishers' primary motivations are to maximise value or return to capital, this approach encapsulates an implicit assumption that value and the quantity of catch are simply correlated. The approach overlooks situations in which the economic (i.e. profit maximising) ambitions of fishers may be imperfectly, or even poorly, correlated with the quantity of catch[151], such as in the RLF where value was increased through a market innovation that precipitated technology innovations that diminished catching capacity. An economic approach to DEA may provide a more cogent analysis of capacity in such situations, particularly in fisheries where outputs range widely in value based on species caught (e.g., coral trout, red throat emperor or other species) and the form in which product is sold (e.g. live or frozen whole or filleted). The case study presented here demonstrates that impacts of innovations that add value to existing fishery products by opening up new markets can have profound effects on the efficiency and capacity of fishing operations and the fishing fleet as a whole. If not accounted for, issues such as heterogeneity among the capital endowments of fishing fleets and the speed and extent to which new innovations are adopted (see Chapter 7) can confound capacity and efficiency estimates.

Comparison of technical (physical) and revenue (economic) efficiency measures for live and frozen operations provided an interesting set of results. Frozen operations on the whole demonstrated higher TE than live operations, although not significantly so, while live operations were shown on average to exhibit significantly higher RE than their frozen counterparts (Table 8–2). On the surface, these results were intuitively pleasing

[151] The fishers catch objective may be value, not volume based (Herrero and Pascoe 2003).

as they were consistent with assumptions in fisheries whereby some groups of fishers will aim to maximise the value and others the volume of their catches (Herrero and Pascoe 2003). When examined more closely, however, it can be seen that the higher TE of frozen vessels and the higher RE of live operations were not consistent with frozen operations taking larger absolute catches in order to offset lower catch values or live operations sacrificing catch throughput in order to maximise their catch value. The observed annual average coral trout catch of frozen operations was actually less overall than the combined average catch of live and frozen coral trout attributed to live operations in this sample[152]. Live operations had a combined coral trout catch ranging from 0.3% to 17% higher than frozen operations.

Estimates of TE and RE express the efficiency of the operation to produce a given quantity or value of outputs from a given level of inputs. The results of this study were consistent with frozen operations producing their catch more efficiently based on more limited capital endowments (see 6.3.1) and variable inputs, while the significantly higher RE of live operations was borne from the substantially higher prices they are receiving for live coral trout which, depending on operation effort class, made up between 46% and 79% of overall coral trout catch. Furthermore, these results lent support to those from previous chapters showing capital endowments as constraining some frozen operations from adopting live technology, as evidenced by frozen primary vessels being significantly smaller than their live counterparts (see Chapter 6).

Results generated from my sample showed that both for observed (biased) and unbiased capacity and CU estimates, frozen operations were operating at higher levels of utilisation and closer to their capacity output than live operations, although using the unbiased measure live operations performed comparatively better against frozen operations. These are not surprising results given what we know of differences in vessels sizes, and hence capacity, between frozen and live operations and modifications carried out by boat owners shifting to live[153]. This outcome is also notionally supported by the fact that lower TE will leads to greater difference between observed and unbiased CU measures. Typically, ‘live’ vessels retained on average similar freezer capacity to

[152] The average total catch per trip of live operations is less than that of frozen operations despite live operations holding both live and frozen catch onboard (Mapstone et al. 2001).

[153] ‘Live’ vessels in this study were significantly longer and wider than ‘frozen’ vessels (see 5.3.1.1)

'frozen' vessels even though freezer capacity was sacrificed in order to enable the storage of live fish and following the incorporation of live holding tanks (see 6.3.1). Moreover, few if any operations nominated freezer hold capacity as a determinant of trip length (see 6.3.4.2) with all vessels in this sample retaining sufficient excess frozen capacity to extend trip lengths well beyond the 1999 average. Trip lengths by live operations, however, were restricted to around 10-12 days by a combination of live hold capacity and maintenance of fish health. The flexibility would exist for live operations to more fully utilise their combined freezer and live capacity by doing longer trips, retaining only frozen product for the first part of a trip and live and frozen product of for the latter part of the trip. This outcome has been recognised in the results, with approximately 70% of live operations identified as being able to increase their variable input utilisation as compared with only 44% of frozen operations.

Tingley and Pascoe (2005), in a study of English Channel fisheries, found an atypical negative relationship between CU and fish price. Despite the prospect of falling fish prices from improved fishery productivity, price inelasticity encouraged increased CU, and hence landings, resulting in higher total revenues. My work provides a contrast to that result, but one that is not inconsistent with general theories. Technology and innovation in fisheries is usually associated with better fishing gear leading to increased throughput and hence CU (see 2.3.1). Innovations that add-value to a product such as through improvements in handling and husbandry or accessing new markets, however, may lower CU. Such is the case here, where live operations exhibit a lower CU despite a significant increase in the price of coral trout when marketed alive. One reason for the low CU of live operations might be that fishers are to some extent operating as 'satisficers'(Le Gallic 2001; Pascoe and Mardle 2005)[154]. That is, the opportunity for improved profits from better using their combined freezer and live capacity is being ignored based on historically higher profits being generated from live only fishing trips and increased utility from shorter live trips (see 6.3.3 and 7.4.2). A more obvious reason for this outcome is the 'non-malleability' of existing capital (see Charles and Munro 1985; Greboval and Munro 1999) in the short-term where, despite the addition of live

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[154] Satisficer's seek to achieve a certain level of profits rather than maximising profits. The satisficing assumption is not necessarily an appropriate one for considering fisher reaction to management change. In such cases, profit maximisation remains the most pertinent assumption for estimating the short run response to management change (see Anderson, 1999)

holding tanks, live and frozen operations retain similar levels of freezer capacity. Over the longer term, as the LRFF evolves and income uncertainty declines, these differences in CU between live and frozen operations are likely to diminish. Firstly, fishers will be able to better plan their investment decisions to match capital requirements to fishery needs (see Ward and Sutinen 1994), leading to higher CU among live operations. Second, declining uncertainty and improved information is often consistent with smaller firms adopting new technology or innovations (see 7.2.1 and Stoneman 1983). Over time this may lead to CU increasing in the live fleet and falling in the frozen fleet.

An expectation that over time this product innovation will be adopted more extensively by suitably endorsed operations who are either currently active or not in the commercial RLF is a reasonable one. Asche and Aarland (2000) illustrated fishers' responsiveness to market driven increases in prices under open-access that led to substantial increases in effort, both from the existing fleet and entry of vessels from other fisheries. Limited license fisheries with substantial levels of latent effort exhibit similar pitfalls to strictly open-access fisheries. My study has shown there to be a mobilisation of fishing licences within the commercial RLF. Although the source of that mobilisation is not certain, I have taken it as evidence of the fleet's reaction to higher prices, and hence revenues, within the LRFF. The relationship between revenue driven increases in effort and latent effort is one of overcapacity[155] as opposed to excess capacity (Holland 2000b; Ward et al. 2004).

Formally extending these capacity analyses to the whole commercial RLF fleet has been confounded by the high levels of latent effort and the multi-endorsed nature of fishing operations in the fleet. DEA requires that each firm of interest employ a positive amount of at least one input (effort, capital stock) to produce a positive amount of at least one output (catch) (Kirkley et al. 2001)[156]. A large component of the commercial RLF fleet currently records low or zero levels of effort and/or catch, while there is a paucity of data on the activities of RLF-endorsed operations participation in other fisheries over the period of interest that would bolster accurate estimates of CU and capacity (Tingley et al. 2003). In my study, capacity measures from the DEA applied to the sample of

[155] Overcapacity is a structural problem occurring in open-access or limited entry fisheries as a result of market failure, and one that is not self-correcting over time.
[156] Zero levels of activity are permitted for some inputs and outputs in a multiple input and output case.

vessels were used to "informally" estimate the potential harvesting capacity of a fully mobilised fleet (i.e. operating under usual conditions). Any such estimates of fleet-wide capacity need to be interpreted with caution as they assume the sample to capture the heterogeneity among capital stocks. While standard tests showed the heterogeneity among active operations to be adequately captured by the sample, the assumption that the sample adequately represented inactive operations and the assumption of homogeneity among fisher behaviours (i.e. profit maximisation) may still be causes for concern. It should be remembered that time spent fishing however, is regarded as a more important determinant of capacity output than vessel characteristics (Smit 1996; Kirkley and Squires 2000; Kirkley et al. 2002) (see 2.4). It should also be noted that no account was taken of the likely adverse impacts on stocks and catch rates from any substantial increases in effort (see Kirkley et al. 2002a). The inevitable dissipation of fishery rents would likely discourage new entrants to the fishery and impose a ceiling for the mobilisation of latent capacity and possibly lead to a negative feed-back that ultimately would result in reduced use of capacity.

Despite the above caveats being placed on any fleet-wide harvesting capacity estimates, the estimated potential catch of coral trout of 3,790 tons, were all L2-endorsed operations to fish in a manner consistent with those in my sample, is significantly higher than the 1999 observed catch of 1,342 tons. This result is a conservative one under the assumption of a stock capable of supporting increased capacity as it assumes a status quo with regards the present operational mix of vessels is retained. This is an unlikely scenario given any new entrants to the commercial RLF are likely to move immediately into the marketing of live product. Moreover, it excludes the sporadic participation of the L3 endorsed operations in the commercial RLF (see 1.6.1). The significance of this result can be found in research undertaken by the Effects of Line Fishing project which guided to some extent the decision by the then Queensland Fisheries Service[157] to implement a TACC for the commercial RLF from 2004, including a TACC for coral trout of 1,400 tons (see 1.6.2) (Mapstone et al. 2004). If, as the data in Figures 8–6 and 8–7 suggests, previously inactive license holders continued to enter the commercial RLF and active participants expand their effort, the potential harvesting capacity of L2-endorsed vessels would far exceed the proposed coral trout TACC, and probably the

[157] The Queensland Fisheries Service was incorporated into the Queensland Department of Primary Industries and Fisheries in 200?

capacity of the stock to sustain such catches (Mapstone et al. 2004). If I restrict capacity analyses to the study sample only, the potential harvest of coral trout from his sample of frozen and live operations is 944 tons annually, more than two-thirds of the proposed coral trout TACC.

8.6 Summary

The measurement of capacity and efficiency using DEA is still a relatively new area of investigation and despite a preference for economic measures, the paucity of data has meant few studies have adopted an economic approach (Lindebo 1999). Also, most studies of fisheries capacity are based on industrial fisheries where catching power is heavily dependent on vessel tonnage, engine power or net size and revenue is closely related to gross catch. An economic approach may be more consistent with fishers' behavioural aspirations in less industrialised fisheries and will give a more realistic portrayal of the 'efficiency' of operators in such fisheries. In this study, I have used a "labour-intensive" fishery exposed to changing market conditions to explore differences between technical and economic efficiency of a fleet comprising two distinct sectors, but for whom target species and fishing methods have remained relatively unchanged.

This chapter represents one of few studies producing an economic measure of efficiency, and the only study I am aware of that is based on a non-industrial fishery. The use of a value-adding innovation to illustrate the disparity between revenue and technical efficiency is likewise a novel approach and serves to highlight the potential consequence of using only physical (TE) measures as opposed to economic (RE) measures to guide fisheries management decisions and capacity reduction programs.

While recognising the deficiencies of measuring fishing capacity where there is substantial latency in the fleet, I have been able to identify the potential for very high levels of excessive harvesting capacity in response to enhanced fishery rents. These issues are further explored in the concluding chapter of this thesis in the context of positive and negative sustainability impacts of value-adding, capacity reduction programs and changes in the nature and extent of excess capacity in the face of changing management regimes, such as the introduction of TACC's and ITQ's.

CHAPTER 9

GENERAL DISCUSSION

9.1 Introduction

In the opening chapter of this thesis, it was noted that more 70% of the world's marine wild capture fisheries were estimated to be either fully or overexploited, with excess harvesting capacity seen as the major cause of this condition (Garcia and Newton 1997). A "crisis in fisheries management"[158] that is systemic across all fishery types from artisinal to industrial has been associated with this situation (Cochrane 2000; Buckworth 2001). Technological improvements in finding, catching, storage and transport of products (Valdemarsen 2001; Allison and McBride 2003) are seen as central to this "crisis", with a continuous cycle of investing in new technology to sustain catches from increasingly depleted stocks (Pitcher 2001). While technology improvements in developing fisheries are often more rudimentary than well established industrial fisheries (Hamilton 2001), the use of more effective gear (nets, poison, motorization) has enabled fishers in developing fisheries to expand the radius of their operations significantly (Pauly 1997). Coupled with low entry barriers and opportunity costs of labour and limited livelihood alternatives, these trends have led to massive expansions of effective effort (Pitcher 2001; Pauly et al. 2002).

This thesis opened with a discussion of the conflicts between biological (conservation) constraints, economic (rationalisation) and social (community) priorities (see 1.2). A key question in resolving at least some of those conflicts is whether value-adding can aid in the convergence of these overall sustainability goals and offset sub-optimal outcomes. Alternately, might the adverse impacts (e.g. high-grading) associated with fisheries with strong property rights regimes (ITQs) be magnified by adding value to particular product types. Value-adding of existing catch has been nominated as one way of mitigating problems of unsustainable use of fishery resources and generating positive

[158] The term is used to highlight the biological, social, economic and ecological imperatives arising from a failure to manage capacity and catch (Cochrane 2000). It can be succinctly summarised as arising from priority being given to protecting economic interests as opposed to protecting sustainability

sustainability and conservation benefits, by extracting greater value from a unit of resource (FAO 1998) rather than increasing value by extracting ever more resource., Value-added production and marketing also is seen as a strategy for enhanced employment and income generation as well as improved export earnings, particularly in developing countries (Jaffee and Gordon 1993). Regardless of the setting, however, any potential positive benefits from extracting greater value from the resource may be undermined by a poor fisheries management regime that allows unbridled expansion of fishery effort in response to incentives provided by prospective economic benefits from enhanced fishery rents.

In this thesis I have drawn upon a unique set of developmental circumstances within a specific fishery that have arisen solely from a value-adding innovation in production and used these innovations to explore a series of overlapping themes, presented as chapters. Each of these in turn demonstrates some novelty in terms of the data collected, the methodological approach applied or the prevailing theoretical view. Thus, the overarching themes of this thesis are: how do fishers respond to product or marketing innovations that add value to fishery products; what determines that response; and what are the potential economic and biological sustainability implications arising from those fishery developments.

The focus of this research has been on a product, as opposed to a process, innovation, which is unique in the fisheries literature as is the emphasis on a labour-intensive fishery (Chapter 2). In order to explore these elements further, I have focused on the commercial RLF within the GBRMP, which has undergone enormous change since the mid-1990's with the development of a market for live fish, with the offer of a substantial premium to the traditional frozen form in which their product was marketed. Research into innovations that impact positively on output prices is scarce and the fleet-wide and firm level response to the emerging live fish trade forms the basis of the descriptive components of the thesis (Chapter 4 and Chapter 5). The emergence of the LRFF within the RLF is used to examine the assumption of profit maximisation that underpins much of the economic theory applied to fisheries and also the sequence and duration of short- and long-run activities. In comparing the financial, economic and operational profiles of adopting and non adopting operations (Chapter 6), this thesis represents the first financial and economic analysis of the commercial RLF and its associated LRFF fishery. Few fisheries studies collect functional data at the level of the business unit. Comparing the operational profile of the two operation types is relevant to defining the management needs of these parallel fisheries. Understanding the investment decision behaviour of fishers faced with choice to adopt, or not, a new innovation is another sparsely researched area in fisheries. If there is sufficient evidence to indicate an innovation's fiscal advantage, why is it that not all business units adopt the superior innovation? Investigation of the economic and non-economic factors dictating investment decisions (Chapter 7) has provided insights peculiar to the fisheries literature, particularly with its focus on a product or market innovation and explicit links between innovation and investment decisions. Lastly, I examined efficiency and capacity issues that might have impacted on the consequences of diffusion of the uniquely value-adding innovation (Chapter 8). The recognition of latent effort as a special type of the property rights failure also represents the first explicit use of data to explore the potential for latent effort to result in overcapacity and excess capacity within the RLF fishing fleet, the results of which may have more far-reaching relevance to fishing fleets in general.

This chapter is a synthesis of the thesis results and is presented in three sections: 9.2) - a summary of the major findings of the thesis; 9.3) – discussion of emergent issues related to changing management strategies implemented within the commercial RLF; and 9.4) - recommendations for future research, particularly in relation to the impact of new management initiatives on efficiency and capacity within a restructured fishing fleet.

9.2 Major Findings

9.2.1 Financial, economic and operational aspects of the commercial RLF that influence fishing effort

Fishery managers tend to assume fishing fleets comprise an homogeneous set of fishers in terms of their behaviour (motivations and attitudes) and their financial and operational profiles (Doll 1988). If this assumption is inconsistent with reality, the impacts of management changes may be discriminatory toward some operation types and against others. Despite recognising the importance of the assumption of homogeneity, or the potential consequences if it is wrong, few fisheries studies have collected financial and operational information at the level of the fishing firm that would enable the assumption to be tested or guide fisheries management policies in the face of fleet heterogeneity (Griffin et al. 1976; Tettey et al. 1984; Poffenberger 1985; Ward 1988; Hamilton et al. 1996). This thesis represents the first comprehensive effort to collect data on the economic, financial and operational characteristics of the commercial RLF at the scale of individual firms. Moreover, this study has explicitly recognised the commercial RLF as comprising at least two distinct, heterogeneous groups, live and frozen operations, following the emergence of value adding technology. The question of most relevance, then, is are there differences in the financial profile of the two groups of fishers that might encourage reallocation or expansion of effort and if so are the operational profiles of the two groups of fishers sufficiently different to result in one or the other groups being more adversely impacted by changing management that aims to regulate effort?

There is clear evidence from the vessels I sampled that live operations incur significantly higher costs and that, despite inter-annual fluctuations between comparative prices of frozen and live products, they generate significantly higher gross and net revenues. Numerically then, incentives exist for increased participation in the LRFF by suitably endorsed license holders and to a lesser extent, those not engaged in any fishing activities. Indeed, effort supply in the RLF shows marked increases in years following the advent of the trade, despite the progressive barriers to entry into the LRFF faced by intending participants (see 5.4)[159]. In the five year period to 1995[160], effort days increased by 11.7% while in the five year period to 2000, effort days increased by 33.1%. Effort days in the RLF increased by a further 28.2% from 2000 to 2001 and more recent data suggests effort continued to increase until the introduction of effort reductions and catch quotas in 2003-04 (QFS, unpublished data).

Given the heterogeneity within the RLF fishing fleet, care needs to be taken to assess the various impacts of management options on each of the fleet components. Both effort and catch controls are capable of discriminating between fleet segments and both will provide additional incentive for non-live operations to innovate to retain live product.

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[159] Barriers include whether the intending participant is currently active within the RLF, active in another fishery or not engaged in any fishing activities; capital endowment, lack of information and fishing skill.
[160] Prior to 1995, the LRFF was limited in its scope and restricted mostly to Cairns region of the GBR.

My data suggest that while live and frozen operations operate differently at the trip level, they fish a similar number of days per year. Requirements to avoid management actions that provide unequal competitive advantages to sectors of an industry mean that regulations aimed at reducing effort in the RLF should not be discriminatory and allow both operation types comparable flexibility to reallocate effort to maximise returns[161]. Blanket regulations that restrict the days that can be fished by 'active' operations, however, would tend to increase fishing costs and reduce the economic efficiency of those active vessels (Townsend 1990). Regardless of adoption risk, these regulatory changes would be likely to increase the number of existing frozen operations switching to the more profitable marketing of live product (Wilen and Homans 1994).

In this study I have shown that value-adding innovations that retain the integrity of fishing methods can, despite imposing additional costs, increase the fisher's revenue base. Despite evidence that higher rents have, as anticipated, been accompanied by substantial fishery-wide effort increases, not all vessels I sampled adopted the new technology. This snapshot of the RLF fishery early in the innovation and diffusion process (Rogers 1995) has enabled me to probe more deeply into the decision-making processes that dictated the adoption, or not, of the value-adding innovation to hold fish alive for a new market.

9.2.2 Factors influencing investment and effort

There has been considerable debate in the literature as to whether fishers' behaviours are motivated by pecuniary or non-pecuniary interests. In general, and with few exceptions (see Kung 2001), the evidence suggests profit-maximisation remains the primary motive explaining fisher behaviour[162]. Responses to the emerging live fish trade suggest, based on the sample in this study, that most fishers in the commercial RLF do behave as profit-maximisers, as evidenced by their preparedness to undertake investment in the requisite technology to enter the live fishery (Chapter 5) (Bjorndal and Conrad 1987b). The rate of adoption of this new technology provides some further

[161] Both operation types in this survey retained sufficient excess capacity to extend trip lengths beyond the current average to improve economic efficiency. With improved husbandry, live operations have sufficient capacity to exceed the current maximum 'safe' trip length of 8–10 days.
[162] See (Robinson and Pascoe 1997) for a comprehensive review of the profit maximising assumption in a fisheries context.

insight into this interpretation. In broad terms, a majority of non-adopters in this study indicated a desire to incorporate the ability to catch and store live fish into their operation. These operators were constrained from doing so by a perception that their existing capital stocks (vessel) were inadequate (Chapter 5). It would appear, however, that not all fishers have profit maximisation as their main objective. While almost two-thirds of frozen operators expressed dissatisfaction with their current operations, the fact that some non-adopters were satisfied with their existing arrangements suggests that some fishery participants may place precedence on lifestyle given an acceptable level of profits rather than on maximizing profit over all other considerations (Hillis et al. 1997).

There is traditionally a clear distinction in economics between the short and long-run, usually defined with reference to the time required to adjust capital stocks to achieve economies of scale (see 5.2.1). The time distinction between the two in fisheries is often more arbitrary, but the transition is still typically presented as one of a short to long-run outcome, in that reallocation of existing variable inputs in response to market changes will precede the long-run investment needed to increase productive capacity (Sampson 1992). Under this assumption, profit maximising fishing firms faced with changes in stock abundance or prices will adjust their product mix in the short-run (Smith and McKelvey 1986). An ambiguity emerges, however, if a traditional long run activity, investment, necessarily precedes the opportunity to make short-run adjustments and that investment can confer a competitive advantage. The adoption of a profit-enhancing technology, incontrovertibly an investment decision, as has occurred in commercial RLF, is one example. The time and financial cost of incorporating the new technology in the RLF need not be great for existing license holders. Having equipped their operation with the ability to market either frozen or live products, live operations can reorganize inputs to retain more or less of frozen or live product as opportunities arise (McKelvey 1983). As multi-product firms, however, live operations are unique to fisheries in that input and output decisions need not be decided prior to a fishing trip and are not fixed for the trip duration. This gives live fishers in the RLF considerably more flexibility than frozen product fishers to adjust to prevailing market conditions.

This propensity for investment in value-adding innovations is likely to become more common in fisheries over time as agents seek to maximise profits in the face of declining stocks and the pressure of competition obliges firms to adopt innovations, and occupy new market niches, as soon as commercial circumstances allow. The rate of innovation adoption will depend in part on the risk averse nature of the individual but given the assumption of profit maximisation, improved information and knowledge of the investment's financial superiority will likely be a primary motivator to adopt a new technology (Robins et al. 1999).

9.2.3 Adoption and Innovation Decisions and their implications for fishing effort

Empirical evidence suggests that in general the adoption of new technology is slow initially followed by a period of rapid diffusion as (and if) the superiority if the new technology becomes more evident and then a slowing down as the innovation becomes widespread (Stoneman 1983). It has been argued for fishing technology that the adoption time process does not conform to this usual S-shape (Sampson 1992). Sampson implies that profitability of a given technology is a corollary of the interaction between stock abundance and the rate of harvest from the current mix of technologies. This is a production-centric view, and one that explicitly recognises the escalating long-term impacts of new technologies designed to maximise throughout to compensate for ever declining stocks. A unique aspect of the innovation central to my thesis is that the innovation has enhanced resource recovery (i.e. more $ per unit of resource extracted) and that this can, where management is adequate, have beneficial long-term outcomes economically and ecologically. If fishers in the RLF can increase profits by incorporating live holding technology into their fishing vessels, why then do some innovate and others persistently do not? Furthermore, can we expect there to be an accelerated take-up of this new technology over time?

One of the main tenets within the technology literature is that firm size will dictate the probability of either partial or full adoption and that over time the minimum firm size for adoption will decline (Stoneman 1983). Vessel length, as a proxy for firm size, was clearly pivotal to likelihood of existing RLF operators adopting live holding technology, at least within my sample of early adopters. Any escalation in take-up of live holding technology will be aided by declines in the uncertainty of the technology's success and by information about the relative advantage of the technology becoming more widely known (see Table 6–7), as well as the divisibility of the technology which allows for adoption on a limited scale[163] with smaller capital outlays (Feder and Umali 1993). An accepted barrier to entry into a new fishery is the perception of adequate returns on investment (Whitmarsh 1990). Initially, the fishers' existing capital endowments will heavily weight the decision to adopt or not, delaying the entry of smaller firms. Over time however, as evidence of the superior revenues (Smith 2000) from live fishing become more apparent we can expect an increase in adoption rates of smaller firms who are active in the fishery either part-time or full-time. These smaller active fishing firms may choose to incorporate live technology in a restricted fashion, compatible with their existing capital stocks. Alternately, the gap between profit expectations and investment risk may close to the extent that the purchase of a new, larger vessel is considered feasible.

It is not only firms currently active in the RLF who will likely contribute to the pool of those adopting live technology. Fishers within the scope of this study generally hold multiple endorsement licenses, permitting them to participate in any fishery for which they hold an endorsement (see 2.5). The opportunity cost of remaining outside the RLF fishery will increase as the fiscal superiority of live technology becomes more widely known and potential returns more assured (Whitmarsh 1978). At some point, suitably endorsed fishers who are currently participating part-time or not at all in the RLF and those potential participants currently not holding an endorsement may decide the fiscal advantages and comparative returns are sufficiently great to cover the opportunity cost of new investment (see 6.3.3 and 6.4). For fisher's who hold previously unused RLF endorsements, adoption will involve a reallocation of fishing effort to the LRFF fishery while for those without a RLF endorsement, adoption will involve substantial investment in capital as well as the purchase or lease of a suitable license[164]. While existing active vessels in RLF who switch to live fishing may not add to the cumulative effort, these latter two groups will likely contribute to overall effort increases in the RLF.

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[163] The complexity of live holding technology varies widely across the fishery, ranging from minimal outlays for simple temporary above deck tanks to sophisticated permanent below-deck modifications to purpose built vessels (see 5.4.1).

[164] As evidence of increasing profitability has emerged, demand forces have led to an increase in license values (see 5.4.3).

While no systematic data was collected on rates of adoption after 2000 that might have shown a proportional rise in the number of smaller vessels adopting, or of vessels entering the LRFF from outside, there is considerable anecdotal and observed evidence to suggest this was the case (see 8.4.3 and 9.2.4). Hence the case study of the RLF I have presented appears largely consistent with the literature on innovation adoption and technology diffusion.

9.2.4 Capacity and Sustainability

Data Envelopment Analysis (DEA) as an approach for estimating technical efficiency (TE) of production activities, capacity and capacity utilisation (CU) has been widely applied to a range of industries (Cooper et al. 2004) but its application to fisheries is relatively new (Fare et al. 2000). In fisheries as elsewhere, DEA is most often used to assess the TE of an existing technology relative to an ideal "best-practice" or reference technology to depict the maximum output possible from a given technology and level of inputs (Coelli et al. 1998). In the same way as most fisher's are assumed to be profit maximisers, they are also assumed to operate with the objective of maximising the volume as opposed to the value of catch (Herrero and Pascoe 2003). In fact, however, these two claims could be seen as contradictory, particularly in multi-species and multi-gear fisheries where seasonal price and abundance issues can dictate the effectiveness of effort allocation. Vessels that are the most technically efficient in terms of volume of catch need not be the most profitable if their catch of high value product is impacted negatively by efforts to maximize gross throughput.

To explore this paradox further, I used DEA analysis to compare technical and revenue efficiency of the two fleet sectors, live and frozen operators. Chapter 6 identified that live operations were significantly more profitable than frozen operations (see 6.3.3). These results accounted for one input to production by standardizing the measure of profitability as net revenue per dory/day. The results of the DEA analysis provide additional insight into performance by accounting for vessel length as an input and also by differentiating between three output product types; frozen coral trout, live coral trout and other demersal species. The results highlight the importance of using economic data rather than simple production data to explore efficiency questions, particularly in smaller scale, more labour intensive fisheries that prevail in the tropical inshore waters and on coral reefs.

It had been anticipated that the emergence of the LRFF as part of the commercial RLF would not only maintain or increase the profitability of fishing operations, but could also stabilise or even reduce catches at the level of the fishing unit (Fornshell 2002). In this way, it was anticipated that the shift to live fishing could, under certain conditions enhance the biological, social and economic sustainability of the RLF[165]. This outcome was not borne out, with the results showing live operations produced greater combined catches of the main target species, coral trout, than frozen operations. Reasons for this might include more selective targeting of coral trout, avoidance of bycatch[166] species and converging CPUE rates between live and frozen operations (Mapstone et al. 2001). While catch volumes may not have declined at the level of the firm, the higher value of catches (see 6.3.3) does suggest that any potential social and economic impact from regulations such as total allowable catches or individual quotas that seek to maintain or reduce current catch levels may be diminished as a consequence of the emergence of the live trade. This issue of changing regulations has great relevance to the RLF and is discussed in detail in the next section.

In the previous section, the innovation and investment literature was used to reinforce the prospect that over time, adoption of live technology would become more widespread and that this could lead to substantial increases in effort. DEA offers a convenient framework for estimating potential capacity at the scale of the fishing firm and, through benchmarking, to extrapolate to a fleet-wide level. Any long-term benefits from changing fishing practices, in this case value-adding, will be contingent on adequate regulation of effort by the fishers and may be undermined by too many new firms entering the fishery in response to increased rents (Hilborn 1985a; Seijo et al. 1998).

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[165] There was perception amongst live operators that switching to live would be beneficial overall, presumably from the viewpoint that less fish were being extracted for greater returns

[166] The term bycatch is used here to describe non-preferred species in terms of their unsuitability for live markets.

9.3 Emergent Issues with respect to Changing Management Strategies

The main regulations for directly controlling effort are catch quotas and limitations on boat numbers or effort (Townsend 1990; Grafton et al. 1996). Assigning property rights in the form of individual quotas or total catches are generally considered less suitable in multi-species fisheries such as the RLF, where problems of discarding and high-grading, monitoring and species specific targeting are exacerbated (Squires et al. 1998; Dupont and Grafton 2001)[167]. The most effective management tools in search fisheries such as the RLF are usually considered to be gear restrictions that influence catchability or direct controls on effort through closures or licensing or both (Wilen 1985).

The RLF was a limited–license fishery up until 2003, albeit one that harboured considerable latent effort from under–utilised or inactive licenses (see 2.4 and 4.4.2). The RLF until that point comprised a large number (~1,500) of multi-endorsed operations, many of which historically did not retain the main target species (coral trout) for either frozen or live markets. Around 15-20% of those that did retain coral trout accounted for between 75-85% of total catch. Limited entry fisheries that exhibit latent effort are especially prone to developing excess capacity where above normal profits prevail (Ward 2000) because, despite restrictions on entry, the extent of latent capacity can give rise to common-property characteristics whereby fishery rents are dissipated by an influx of effort (Anderson 1985a; Dupont 1990)[168]. In the case of the RLF, any potential rent gains from the value-adding of existing target species may be eroded in the longer term by the mobilisation of latent effort. A significant proportion of any latent effort must be removed from a fishery for capacity reduction programs to be successful (Holland 2000b).

The data presented in Chapter 8 indicated significantly greater harvesting capacity in the fleet then the catch at that time, which itself was higher than the catch limit being considered as part of the management review of the RLF[169]. In July 2004, a Total

[167] Quota management strategies may still have positive benefits for multi-species fisheries. These are discussed in more detail in the context of the RLF in Chapter 7.
[168] The RLF can be considered an open-access fishery because the amount of latent effort provides ample opportunity for the entry of new effort in response to above-normal profits.
[169] At the time data was being collected for this thesis, the Queensland Fisheries Service had issued an investment warning notifying stakeholders that the fishery was under review. As part of this legislative process, a total catch was being considered for the RLF, equal to 1996 harvest levels.

Allowable Commercial Catch (TACC) comprising Individual Transferable Quotas allocated independently for coral trout, red throat emperor and ‘other demersal species’ was introduced. Quota was allocated on the basis of historical catch, which led to the removal of a large number of multi-endorsed operations with little or no catch history, and the allotment of a large number of ‘minimum’ allocations (< 500kg), accounting for the bulk of the so-called ‘latent effort’. While the overall catch for these three product groupings was reduced by approximately 30%, anecdotal evidence suggests quotas allocated to some of the more active vessels in the fleet were more than 30% below historical catch levels. While these management changes may have reduced fleet-wide excess harvesting capacity, it is not clear what impact those changes had on the efficiency, capacity and capacity utilisation of individual vessels.

Introduction of quotas may discriminate against some or all fishers on the basis of incomes (Cunningham 1994), previous effort allocation decisions (Maurstad 2000) and vessel size. For example, firms who shifted to live fishing during any period upon which historical catch was being considered as the basis for quota allocation may have displayed lower catches and catch rates than when they fished only for frozen product (Mapstone et al. 2001). Quota allocation based on historical catches, therefore, would need to account for these catch rate and time of switching disparities. An allocation system that reduces allowable catch below historical levels may improve economic efficiency on the basis of revised catch allocations and increase resource rents (Grafton et al. 1996)[170]. While existing fishers do gain from the additional wealth conferred by their quota allocation, incomes (profitability) and rates of return (productivity) would decline. Such an outcome would discriminate against those remaining frozen operators who would face a substantial increase in barriers to entry to the live fishery because of quota limitations, despite the motivation to maximise returns on their catch allocation by marketing value-added live product.

9.3.1 Capacity and Capacity Reduction

Both the introduction of individual transferable quotas and license buyback programs are seen as instruments useful in encouraging the reduction of excess capacity at the

[170] Where stocks are overfished, reducing catches may improve productivity of the stock, thereby increasing economic efficiency

aggregate level (Grafton et al. 1996; Anderson 1998; Wakeford 2001). Both need to be considered with caution, however, in terms of their effectiveness in reducing the harvesting capacity of the fleet.

A study by Dupont *et al.* (2002) assessed capacity and CU in a multi-species inshore groundfish fishery prior to and after the introduction of ITQ's and this provides an interesting comparison for the RLF. The introduction of individual quotas led to a reduction in aggregate excess capacity in the fishery. There was little evidence of temporal changes to CU at the level of the individual vessel in the years before the individual quotas were introduced, but both small and large vessels operated at lower levels of CU following the introduction of private harvesting rights. Moreover, the larger vessels appeared to have coped better in the post-quota environment in maintaining their CU. One would expect that with their new catch allocation being around 30% lower than previous catch levels, most vessels in the RLF will operate at lower levels of CU. In some cases, catch reductions may reduce the scale of individual operations to the point where they cannot operate profitably and are faced with the decision of purchasing or leasing new quota, leasing out their existing quota or exiting the fishery. These outcomes will be exacerbated for frozen operators because the value of the product is significantly less than for live product whereas the cost of purchasing or leasing quota largely will be indexed to the income expected from live product. Further, frozen operators are faced with an additional choice as to whether to undertake investment in order enter the live fishery. While the introduction of ITQ's may give rise to undesirable equity and distributional outcomes for both live and frozen operations, (see Dupont and Phipps 1991; Copes 1997), the hands of frozen operations will likely be forced to either undertaken investment or exit the fishery.,

A further issue not widely discussed in the literature is the incidence of misreporting of catches when fishers expect to gain a significant advantage from doing so. This can lead to an overestimate of the efficiency and CU of a vessel prior to the introduction of a quota system, and a larger than actual decline in efficiency and CU following the introduction of the quota system. At a fleet level, apparent inefficiency and low harvesting capacity may be partly due to misreporting of historical output data.

Buyback programs are a popular tool for reducing fishing capacity in limited license fisheries (Holland et al. 1999; Clark et al. 2005). Oftentimes, however, fishery managers have limited or incomplete information about the levels of capacity for which a reduction is being sought. The use of DEA is becoming more widely employed to target vessels for decommissioning and to estimate the capacity being removed in order to obtain more optimal outcomes (Pascoe and Coglan 2000; Walden et al. 2003; Tingley and Pascoe 2005). The effectiveness of any fleet reduction scheme will be influenced by the nature of the vessel(s) being removed as in a heterogeneous fleet their impact on stock and effort will not be uniform.

A review of capacity reduction programs found that the programs often had a less than expected impact on capacity as there was tendency to focus on maximising the number of boats decommissioned with the fund available (Pascoe and Coglan 2000). Accordingly, the least technically efficient, least profitable vessels operating at lower levels of CU tend to dominate those being decommissioned. As a result, the reduction in effective capacity will not be as great as the nominal or expected reduction in capacity. By removing the least efficient vessels, the buyback scheme will increase average efficiency across the fishery but may not properly address total capacity concerns. Specifically targeting vessels with higher levels of efficiency would result in a greater reduction in harvesting capacity but would also lower the overall level of efficiency in the fleet, at least in the short-term. In the longer term, this strategy of sacrificing fewer more efficient vessels with higher CU may backfire since it is generally accepted in fishery economics that the removal of some vessels from the fishery results in the remaining vessels increasing their individual effort (analogous to remaining vessels increasing their CU) (Tingley and Pascoe 2005). If sufficient of the less efficient vessels became more efficient, harvesting capacity in the fishery could still increase and discount the initial gains from the buy-back program. Clearly then, there are trade-offs between improving short- and long-run efficiencies while controlling long-term harvesting capacity. In this regard, the use of physical capacity units for measurement of fishing capacity and as the basis for capacity reduction programs is inappropriate (Pascoe and Coglan 2000). Measures of efficiency, preferably in economic terms such as cost and revenue or profitability efficiency, will provide better insights into the heterogeneous nature of the fleet and enable buyback programs to target vessels or vessel types more effectively.

The issue of buybacks to reduce capacity and the extent of latent effort are inextricably linked, but often not considered (Walden et al. 2003). The issue of removing latent effort is a double edged sword. Similar to the issue outlined above, ignoring latent licenses and focusing on the most active vessels will reduce capacity in the short-term but in the longer term any conservation and economic benefits may be eroded by latent vessels increasing their effort and CU because of perceived under-exploitation of the resource following effort reduction. On the assumption that latent licenses are less profitable and hence less costly to buy back, buyout programs that focus too much on the removal of latent effort will not be as effective in reducing capacity. Technology induced changes in capacity and increases in effort, including those that are value-adding, where there is substantial latency in the fleet, contribute to the difficulties of measuring and managing fishing capacity and buyback programs.

9.4 Future Research Needs

Capacity reduction programs need to be targeted and backed up by reliable and robust methods to enable more vessels and more capacity to be removed with available funds so that capacity reduction programs are effective in the longer term. Developments within the RLF that saw the emergence of the LRFF fishery in the mid-1990's and the subsequent introduction of management changes in 2004 seeking to address the consequence of the LRFF fishery offer opportunities to extend the capacity research undertaken as part of this thesis.

Firstly, the analysis could be formulated as a profit maximisation problem such as in Coelli (2002), which would need specification of input prices as well as output prices used in this study. The relevance of this revised approach is to account for different variable costs of live and frozen operations (see 6.3.3.1). Secondly, capacity results have been estimated with limited knowledge of the less active and dormant operations within the commercial RLF. The existence of latent (or dormant) effort has been recognised as a confounding factor in capacity analyses (Holland 2000b; Thunberg 2001; Ward et al. 2004). A more complete dataset on these types of operations, which tend to be multi-fishery in nature, would enable a more meaningful analysis of potential capacity from a mix of fully and partially mobilised vessels and would provide a more accurate estimation of TE and CU scores for operations with multiple outputs[171]. Incorporating a measure of any vessels activity outside the metier of primary interest will increase unbiased CU scores. Apparent capacity under-utilisation in one fishery (e.g. the RLF) may be due to effort allocated to another fishery, whereas accounting for this other activity may reveal fully utilised vessel where activity in one fishery could only increase if effort was reduced in one or more other fisheries. A more cogent understanding of all fishing activities would improve the understanding of potential increases in effort arising from changing market conditions that could lead to more permanent switching of effort from one fishery to another. Also, a useful analysis from a management perspective would be to measure fishing capacity over time, as opposed to the single time period used in this study, in order to observe temporal patterns in efficiency and capacity. Consideration of either or both of these and formulate more effective capacity management programs.

Capacity and efficiency measures will differ under effort managed and TACC and ITQ managed fisheries. This research has identified levels of efficiency, capacity and CU in the pre-quota environment. The purpose of the management changes such as those introduced to the RLF in 2004 is generally to rationalise fishery effort and, by establishing property rights, improve economic efficiency. The application of DEA analysis to this fishery in a post-quota environment would provide valuable insights into the effectiveness of the ITQ program in improving efficiency, and uniquely so in a labour intensive, tropical inshore fishery.

Lastly, not all fishery economists are proponents of the value of capacity and efficiency analysis as tools to improve productivity and economic efficiency in fisheries, just as they regard not all fisheries to be suitable to the application of these tools to achieve optimal outcomes (Holland and Lee 2002). Some argue that the availability of excess capacity is crucial to the viability of the certain fisheries such as multi-gear, multi-species fisheries and those where effort allocation is heavily weather dependent (S. Cunningham, pers comm.). There is an opportunity for advanced DEA analysis to be more widely applied in a small-scale fisheries context to explore some of these issues.

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[171] Ignoring additional fishing activities of multi-fishery operations may lead to CU being underestimated.

9.5 Summary and Conclusion

The question posed at the outset of this thesis was whether or not value-adding of fishery products could improve rents and whether this could mitigate the prospect of overfishing. The premise that value-adding a unit of resource presents as a positive alternative to unsustainable use of fishery resources (FAO 1998) and can deliver more homogeny across social, economic and biological goals is unproven in circumstances where excess capacity exists that can capitalise on improved rents. The Live Reef Fish Fishery on the Great Barrier Reef presented an opportunity to empirically and theoretically coalesce the concepts of value-adding, innovation and adoption and capacity to examine fisher behaviour and long-term sustainability outcomes. The results from this thesis suggest that while value-adding can improve rents in the short-term longer term benefits will be undermined by sub-optimal management conditions in the fishery.

These results have relevance to the management of overcapacity in coral reef fisheries. The allocation of property rights and licence buyback schemes may, under certain caveats, effectively manage and reduce capacity within the better resourced fisheries of the developed world. Managing capacity in the artisinal and small-scale coral reef fisheries of the developing world however, represents a much more intractable problem due to a combination of limited entry barriers, very low or zero opportunity costs faced by fishers, limited enforcement capacity and the remoteness of many fishing locations from centres of governance.

The results from this thesis on the possible ramifications of value-adding induced over-capacity serves to highlight the likely sovereignty of spatial management – even recognising the difficulties associated with enforcement of protected areas – over conventional effort based management approaches for coral reef associated fisheries located in developing countries. This is especially so where the ever-expanding global footprint from major consuming nations regularly presents financial inducements to increasing number of fishers with limited livelihood alternatives.

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Appendices

Appendix A1 Initial Invitation to Participate in the Survey: Cover Letter and Information Brochure

EFFECTS OF LINE FISHING PROJECT

CRC REEF RESEARCH CENTRE
JAMES COOK UNIVERISTY
TOWNSVILLE 4811
Ph. (07) 4781 5253

6 September 2007

Dear «CLIENT_NAME»

The commercial fishing industry is currently operating in an environment where the management of fisheries in the Great Barrier Reef is undergoing considerable change. These changes are likely to have economic impacts on your fishing business. However little information is available to indicate just what the economic impacts of future management decisions may be. Important new research being undertaken by the Effects of Line Fishing project aims to help predict and evaluate the impacts of such decisions on individual reef-line fishing operations and the line fishing industry.

The purpose of this letter, which has been sent out with the assistance of the Queensland Fisheries Management Authority, is to notify you of the project so that all reef-line fishers have an opportunity for input. In the next few months I may be contacting you by telephone and inviting you to be part of this important survey of the industry. The information, which will be collected through personal face-to-face interviews with skippers and boat owners, will be used to demonstrate to reef and fishery managers the possible impacts of their management decisions on the line fishing fleet.

Information provided will remain ***absolutely confidential*** and will be managed according to established procedures within the ELF project. Any information you provide ***will not*** be shown to any other individual or agency, including QFMA. Information will be presented in aggregate form only to ensure individual fishers or vessels remain ***anonymous***. Please note that this project is independent from other studies, such as the recent DPI survey, but will add to our overall knowledge of how best to manage line fishing in the GBR

I hope you will participate in this worthwhile research project, which has the support of the QCFO.

Yours sincerely

Geoffrey Muldoon
Effects of Line Fishing

CRC Reef Research Centre — Science for sustainable use of the Great Barrier Reef

EXPLORING REEF SCIENCE

March 1999

The other side of the coin: economics of the reef-line fishery

An expanding live fish industry may lead to increased fishing effort. What does this mean for the long-term viability of the industry? New research on the economics of the line fishery aims to provide some answers.

An understanding of the biological effects of fishing upon fish stocks is essential for fisheries managers. Just as important is knowing how changes in management of the fishery may effect the profitability of commercial line fishers. To date, the financial and economic aspects of the line fishery have received little attention. The lack of socio-economic information can see fisheries management decisions based largely on biological information, with little consideration given to the economic or social costs of such decisions. Several new projects are under way that aim to provide improved social and economic information. One of these is focusing exclusively on the line fishery.

Commercial line fishers are being asked to participate in a socio-economic survey of the fishery.

HOW WILL YOU BENEFIT FROM THE INDUSTRY?

- comprehensive economic data showing the value of the fishery;
- a better understanding of the potential impacts of the entry of new licences on current fishers;
- improved socio-economic information to guide managers in achieving long-term biological sustainability and economic viability
- operators can compare their performance against industry averages for boats of different size, holding capacity and endorsement types, for both live and frozen product.

CONFIDENTIALITY OF DATA

Information provided will be held in strict confidence with no link to individual operators possible. Data will be used to generate industry totals and averages for the line fleet.

INFORMATION NEEDS

The information required for this project will be collected from personal interviews with skippers and boat owners. As the survey is intended to produce outcomes useful to both industry and managers, fishers are encouraged to come forward with any suggestions they may have.

WHAT WILL YOU BE ASKED FOR?

- A history of your fishing activity
- Your vessel and licence characteristics
- The costs of your fishing operation
- Your catch composition (live or frozen)
- What influences your investment decisions

CRC partners for protection and development:

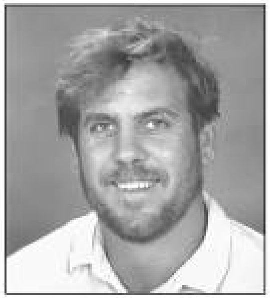
Co-operative Research Centre Program · James Cook University · AMPTO

CRC Reef Research Centre — Science for sustainable use of the Great Barrier Reef

continued

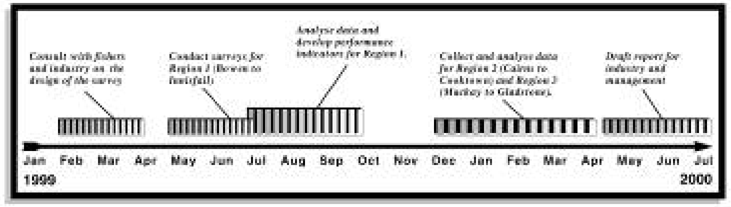
Geoffrey Muldoon, a post-graduate student working in cooperation with the Effects of Line Fishing project at the CRC Reef Research Centre plans to collect economic information on vessels' operations. The catalyst for his project has been the growth of the live fish trade and its potential to increase fishing activity in the reef-line fishery. The opportunity for greater profits may see formerly unused fishing endorsements reactivated, or sold to active operators, leading to an increase in fishing effort. This may ultimately impact on the profitability of those currently active in the industry. In order to better understand these issues, this research will investigate:

- differences in productivity between boats fishing for live or frozen product, and between boats of different size, holding capacity & endorsement types;
- variations in productivity between regions and throughout the year;
- the extent to which improved profits generate incentives for new fishers to enter the fishery;
- the impact of increased effort upon future profits of current participants



Geoffrey Muldoon aims to shed light on the economics aspects of the GBR line fishery.

TIMELINE



WHAT INFORMATION WILL YOU RECEIVE ?

During the course of this research, regular updates of the results will be presented to the Queensland Commercial Fishermen's Organisation (QCFO) for discussion and feedback. In addition the results of this research will be made widely available throughout the duration of the project in many formats such as popular fishing and trade magazines, the Effects of Line Fishing newsletters, direct to industry and management agencies, and in published reports. Over the next few months, Geoffrey hopes to introduce himself to line fishers between Cooktown and Gladstone.

For further information please contact Geoffrey Muldoon on (07) 4781 5253
The Cooperative Research Centre for Ecologically Sustainable Development of the Great Barrier Reef undertakes an integrated program of research and development, training and extension, to expand Reef-based industries and provide information for better science-based management and decision making.

Contact: CRC Reef Research Centre, James Cook University, Townsville, Qld 4811
Telephone: (07) 4781 4976 • Facsimile: (07) 4781 4099 • Email: crcreef@jcu.edu.au • Web: http://www.gbrmpa.gov.au/~crcreef/

Appendix A2 Interview Questionnaire

CRC Effects of Line Fishing Project
Owner/Skipper Questionnaire

Introduction

The Effects of Line Fishing Project (ELF) project is a multifaceted research project aimed at providing essential information for the management of the Great Barrier Reef reef-line fishery. The ELF project is funded by the Cooperative Research Centre for the Great Barrier Reef World Heritage Area based at James Cook University.

This survey forms one component of the ELF project and is designed to gather information on economic aspects of the reef line fishery. The survey will also provide information on fishermen's history in the live fish industry and on factors which influence their decision to enter the live fishery.

If future management of the GBR reef-line fishery is to be successful, it is very important to understand how the fishery operates and what factors affect its operation. In particular, it is necessary to understand what economic implications certain management strategies will have on a fishermen's livelihood.

The interview is divided into six sections; i) Fishing History ii) Operational Characteristics iii) Live Fishing History iv) Investment Decision–making v): Management and Research and vi) Business operations. You may find some of the questions, such as those about your financial arrangements, quite sensitive. Please feel free to refuse to answer any question.

IDENTIFICATION DATA

Interviewer:____________________ Interview Date:____________________

Interview #:____________________ Interview Location:____________________

Survey Region:____________________ Home Port:____________________

(City/Region)

Vessel Name:____

Vessel Registration No.:____________________ Owner:____________________

Endorsements held (please circle)

L1	East Coast Trawl	Spanner Crab
L2	Net - Barramundi	Crab
L3	Net - Inshore	Other

SECTION ONE: FISHING HISTORY

1. Are the vessel(s) and endorsement(s) owned by:

Sole Proprietor	☐	Partnership (family)	☐	Partnership (non-family)	☐
Private Company	☐	Public Company	☐	Leased	☐

2. In what year did you first enter the reef-line fishery? 19______

a) Why did you enter the reef-line fishery ? (open) ______________________________

____

3. Did you enter the reef-line fishery from another fishery?

☐ Yes ....

☐ No

If so, from which fishery ? ______________________ In what year did you leave that fishery ? 19______

Why did you leave the previous fishery ? (open) ______________________________

____

4. Do you regard the reef-line fishery as your primary fishery at present ?

☐ Yes

☐ No **(Go to End)**

5. Has it been your primary fishery since you first entered the reef-line fishery?

☐ Yes **(Go to Question 6)**

☐ No ....

List all fisheries, including reef-line, in which you have been commercially active since first entering the line fishery ?

Fishery	*Length of Time*		*Location(s)*
	From	*To*	

6. Please provide details of all vessels owned since entering the reef-line fishery.

Vessel	Name	Year built or purchased	Construction price	Upgrade cost	Year sold	Reason sold/upgraded
1.						
2.						
3.						

7. Did you need to purchase a licence package in order to enter the reef-line fishery ?

☐ Yes ....
☐ No, already held endorsement

a) In what year did you purchase that licence/licence package ? 19 _______

b) Was the line endorsement being used when you purchased it ? Yes / No

8. If you have multiple line endorsements, how many dories are permitted with each endorsement.

Licence Package	Endorsements	No. of dories permitted	No. of dories active
1.			
2.			
3.			

If, for any endorsement, the no. of active dories is less than the no. permitted. Why ? (open-ended)

____

____

9. What is the vessel's usual home port ? ______________________________

10. Within the last 5 years, in what other ports have you unloaded catch for periods of more than 1 month at a time ? (You may ☐more than one)

None (Go to Question 13)	☐	Bowen	☐	Cooktown	☐
Gladstone	☐	Mackay	☐	Port Douglas/Cairns	☐
Townsville	☐	Other	☐		

11. Why do you chose to operate out of (unload catch at) these ports as opposed to your usual home port ? (You may ☐more than one)

Port #1:

Improved catch rates	☐	Steaming time to reef	☐	Industry services	☐
Water Quality	☐	Weather	☐	Fishing for live product	☐

Other: ____

Port #2:

Improved catch rates	☐	Steaming time to reef	☐	Industry services	☐
Water Quality	☐	Weather	☐	Fishing for live product	☐

Other: ____

Port #3:

Improved catch rates	☐	Steaming time to reef	☐	Industry services	☐
Water Quality	☐	Weather	☐	Fishing for live product	☐

Other: ____________________

Port #4:

Improved catch rates	☐	Steaming time to reef	☐	Industry services	☐
Water Quality	☐	Weather	☐	Fishing for live product	☐

Other: ____________________

12. This next question looks at how port use has changed during the years from 1994-1999

	Percentage (%) used port to unload catch OR No. of trips from port			
Port	**1994**	**1996**	**1998**	**1999**
Bowen				
Cooktown				
Gladstone				
Innisfail/Mourilyan				
Mackay				
Pt Douglas/Cairns				
Townsville				
Other				

SECTION TWO: OPERATIONAL CHARACTERISTICS

13. Current Primary Vessel Characteristics

Specification		Specification		Specification	
Length	mts	Main Engine(s)	hp	Auxiliaries	
Draft	mts	Fuel Capacity	L	Berths	
Beam	mts	Max. Range	nm	Water Tank	L
Age	yrs	Steaming Speed	kts	Construction	

Specification				Specification	
Refrigeration Capacity				HF	Y / N
(i) Snap			kg	VHF/ UHF	Y / N
			cartons	GPS	Y / N
(ii) Holding			kg	Satellite Phone	Y / N
			cartons	GPS	Y / N
(iii) Brine/Fresh			kg	Radar	Y / N
Live Tank Capacity				Plotter	Y / N
Internal		External/Deck		Autopilot	Y / N
(i) Water	L	(i) Water	L	Sounder	Y / N
(ii) Fish	kg	(ii) Fish	kg	Computer	Y / N
	#		#	Weatherfax	Y / N

Specification		Specification						
Live Tank System		*Dory #*	1	2	3	4	5	6
Pumps		Length (m)						
Filter	Y / N	Outboard (hp)						
Sterilisation (UV/Ozone)	Y / N	Sounder						
Water Chiller	Y / N	Radio						
		Live Tank						

14. In what year did you purchase your current primary vessel ? 19 ______

15. What was the purchase price ? $________________

16. Do you have a mortgage on the primary boat or dories ?

☐ Yes (Approximately how much are your monthly repayments ?) ……

☐ No

< 250	☐	250 – 500	☐	500 – 1000	☐
1000 – 1500	☐	1500 – 2000	☐	> 2000	☐

17. What is your estimated market value for each component of your fishing operation?

Component		Estimated value
Primary vessel (including electronics, external live tanks & fishing gear)		$ ________
Live tank system (including pumps, filters, sterilisation, and chiller)		$ ________
No of tender boats:	[ ]	
Total value of tender boats (excluding electronic or fishing gear)		$ ________
Licence package (Total value of all fishery endorsements)		$ ________
Other (please specify)		$ ________

18. Your estimate of total market value of your fishing operation ? $ ________

19. The insured or replacement value of your primary and tender vessels ? $ ________

20. We require financial details of your licence packages (# should correspond with those in Q8).

Licence Package	Date Purchased	Purchase Price	Est. Current Market Value
1.	/ / 19	$	$
2.	/ / 19	$	$
3.	/ / 19	$	$

21. How many fishing trips did you do each year for the years 1994 to 1998 and what was the total number of days you fished in each year for the years 1994 to 1998?

Year	1994	1995	1996	1997	1998
Number Trips					
Total Days Fished					

22. Where number of trips for any of these years is less then the previous year, please indicate the main reason/s for this (ie > 25% less trips).

____

____

23. Where number of days fished for any of these years is less then the previous year, please indicate the main reason/s for this (ie > 25% less days).

____

____

24. In an average month, how much time do you normally spend on the following activities ?

Activity	Fishing	Steam to reef	Steam to port	Steam between sites	Turnaround in port
Time(Days)					

25. What most often determines the length of your fishing trips ? *(use flip cards*)

	Least Frequent				Most Frequent
Run out of outboard fuel	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Run out of bait	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Live tank filled to capacity	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Freezer filled to capacity	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Sufficient product to make trip profitable	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Difficulties with dorymen /**crew**	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Weather related influence	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

26. Above what wind or sea conditions won't you leave:

a) Port to steam to the reef ? __________ (knots) __________ (metres)

b) An anchorage on a reef to steam to another reef __________ (knots) __________ (meters)

c) An anchorage on a reef to steam to port __________ (knots) __________ (meters)

27. What is the age and experience of your present crew. How long have they worked for you ?

#	Age	Experience	Years Employed	#	Age	Experience	Years Employed
1.		(yrs)	(yrs)	4.		(yrs)	(yrs)
2.		(yrs)	(yrs)	5.		(yrs)	(yrs)
3.		(yrs)	(yrs)	6.		(yrs)	(yrs)

28. Do all dorymen receive the same payment?

☐ Yes ………………………………

☐ No

Fish Type	(% of catch value)		($/kg of landed catch)	
	Frozen/Chilled	Live	Frozen/Chilled	Live
CCT				
RTE				
MXA				
MWR				
BCD				
OTH				

29. Does the % payment received change as the market price changes ? (pre-test)

(For example, does the % each doryman receives decrease if the market price increase, and vice versa)

☐ Yes ……………………………..

☐ No, same throughout year

How does it change ? ____

____

30. How do you pay each dorymen ? (open-ended in pre-test)

____

____

31. Do you offer your dorymen bonuses based on total catch of Common Coral Trout ?

☐ Yes…………

☐ No

Kg required for trip bonus	Bonus (($/kg or % total catch)

32. Do you employ a contract skipper ?

☐ Yes (What are your contract arrangements?) ……….

☐ No

☐ % of landed value of catch

☐ % of profit.

☐ price per kilogram

☐ fixed salary

33. Answer the following questions regarding your freezer and tank capacity

Product Type	Total Capacity (kg or /#)	Most fish have held (kg or #)	Amt fish could hold (kg or #)	Average Capacity Used per trip (%)
Frozen/Fresh				
Live Tank				

34. What percentage of the year do you target:

a) Coral trout __________ (%)

b) Red Throat Emperor __________ (%)

c) Spanish Mackerel ……….. __________ (%)

In which month(s) do target them ? ______________________________

SECTION THREE: LIVE FISHING HISTORY

35. Did you sell live product in any of the years 1993 to 1998

☐ Yes (please indicate (□) which years) ….
☐ No **(go to Question 50)**

Year	1994	1995	1996	1997	1998
Live (□)					

% Total Catch	1994	1995	1996	1997	1998
< 5					
5 – 10					
11 – 20					
21 – 30					
31 – 40					
41 – 50					
51 – 60					
61 – 70					
71 – 80					
81 – 90					
> 90					

36. In order to participate in the live fishery, did you;

a) Convert an existing boat ? ☐ **(Go to Question 37)**

b) Purchase a new vessel already set up to catch and hold live fish ? ☐ **(Go to Question 38)**

c) Purchase a new vessel that required additional conversion work ? ☐ **(Go to Question 39)**

d) Construct a new purpose built vessel ? ☐ **(Go to Question 40)**

37. In what year did you upgrade the vessel to catch and store live fish ? 19 ________

a) What did the conversion involve ? (You may □more than one)

Installing deck tanks ☐
Freezer space conversion ☐
Pumps ☐
Closed system (filter, steriliser, chiller) ☐

a) How much were your conversion costs ? $ ____________________

38. What was the replacement cost (deducting sale price of old vessel)? $ ____________________

39. What was the replacement cost (deducting sale price of old vessel)? $ ____________________

a) How much were your conversion costs ? $ ____________________

40. Year constructed ? 19 __________

a) What was the replacement cost, after deducting sale price of old vessel ? $ ____________________

41. How important were the following in your decision to upgrade/replace your vessel?

	Not at all Important				Very Important
Expected market price of live fish *(price)*	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Costs of upgrade *(fixed costs)*	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Expected demand for live product *(output)*	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Expected costs of fishing *(variable costs)*	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Doing shorter but more frequent trips	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Involved little change to existing fishing methods	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Expected return on investment	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Diversification of existing operation	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Able to get information from existing live operators	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
To compensate for the low price of frozen product	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
The need to hold on to or employ decent crew	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Potential for live fishery to suffer downturn in future	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Would be easy to add in into existing business	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Good chance new live system would work properly	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Other:____________________________	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

42. How important were the following in determining how much you spent on conversion/ replacement

	Not at all Important				Very Important
Expected market price stability of live fish *(price)*	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Age, condition or size of main vessel	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Current debt levels (your assessment)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Expected future sales of live product *(output)*	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Freezer space available for conversion	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Rate of interest/cost of borrowing for upgrade	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Maintaining vessel safety and competitiveness	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Credit/Borrowing limit (bank assessment)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Expected future returns from live investment	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Other:____________________________	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

43. On an average trip, do you target live product from the beginning of the fishing trip ?

☐ Yes ....

☐ No ....

Do you target live for the entire trip ?

☐ Yes, dead product is by-catch not kept live

☐ No, Why ? ____________________

When do you switch to live (ie. when freezer full) ? ____________________

For how many days at the end of the fishing trip do you switch to live ? __________

44. How important are the following in determining whether you target live, as opposed to dead ?

	Not at all Important				Very Important
Market price of live fish	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Seasonal influences	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Changes in catch rates	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Weather conditions	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Distance from port to fishing grounds	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Other	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

45. The next question relates to your targeting of live fish since July 1997. We need to know where on the GBR you fished when targeting live fish, and at what times of the year you targeted live fish.

Month	**Jul 97**	**Aug 97**	**Sep 98**	**Oct 97**	**Nov 97**	**Dec 97**
Port						

Month	**Jan 98**	**Feb 98**	**Mar 98**	**Apr 98**	**May 98**	**Jun 98**
Port						

Month	**Jul 98**	**Aug 98**	**Sep 98**	**Oct 98**	**Nov 98**	**Dec 98**
Port						

Month	**Jan 99**	**Feb 99**	**Mar 99**	**Apr 99**	**May 99**	**Jun 99**
Port						

46. Have these fishing patterns remained the same since you began fishing live? (open ended)

☐ Different ....

☐ Same (How have they changed)

____

____

47. From January 1997 to the present, have you targeted dead fish more than in prior years ?

☐ Yes ... how important have each of the following been in your decision to fish dead ?....

☐ No

	Not at all Important				Very Important
Fluctuating market price for live fish	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Declining catch rates	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Decreased profitability (↑ costs)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
The stable market price for dead fish	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Other	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

48. What is the minimum price you would need to receive in order to fish live ? $_________kg

49. What do you base this assessment on ? (open ended in pre-test)

Shorter fishing trips (increased steam time per year) ____________________

____

Increased handling time (Dory and main vessel) ____________________

____

Costs of maintaining fish greater than costs of freezing ____________________

____

Vessel carrying capacity (ie. freezer space from installing live tanks) ____________________

____

Increased dock unloading time ____________________

____

50. How important were the following in influencing your decision <u>NOT</u> to upgrade your vessel to live fishing

	Not at all Important				Very Important
Current debt levels (your assessment)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Cost of maintaining vessel safety and competitiveness in industry	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Expected sustainability of returns from live investment	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Cost of upgrade	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Your age	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Concern over future demand for live fish	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Condition of size of primary vessel	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Credit/Borrowing limit (bank assessment)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Instability of market price for live fish	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Other	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

SECTION FOUR: INVESTMENT DECISION–MAKING

This section asks questions relating to developments and external influences on the fishery over the last 5 years that have affected your decisions to upgrade or invest. Investment is defined as annual expenditure >$5000 excluding general maintenance

51. When you first came into the reef-line fishery, how important were the following in making that decision?

	Not at all Important				Very Important
Lifestyle	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Return on Investment	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Family business	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Management of the industry	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

52. How much do each of the following influence your decision to remain in the fishery?

	Not at all Important				Very Important
Lifestyle	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Age to Retirement	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Fishermen all my life	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Return on Investment (profits)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Current Debt Levels	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

53. When making investment decisions, how important are the following in influencing that decision ?

	Not at all Important				Very Important
Current Operating income	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Maintaining the quality of the operation	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Previous years' income/profits	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Ability to secure a loan	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Improving safety on vessel	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Anticipated future income/profits	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Expected market price (live or dead)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Interest rate (cost of capital)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Potential profits in alternative fisheries	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Expected catch rates (fishery productivity)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Expected demand for product	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Necessary expenditure as required	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Expected return on that investment	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Other	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

54. Are you satisfied with the current size of your fishing operation?

☐ **Yes (go to Question 55)**
☐ **No (which of the following is an investment priority)**

a) Larger or smaller primary vessel ______________________

b) Increase the number of tender vessels ______________________

c) Install or upgrade live holding tanks ______________________

d) Increase freezer capacity or quality ______________________

55. In considering new investment, are profits made in the most recent period more important than those made two or more periods ago ?

☐ Yes... When compared with profits made in the last period, how important are profits made over the:.
☐ No

	Not at all Important				Very Important
Past two (2) years	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Past three (3) years	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Past five (5) years	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

56. On average, what percent of annual profits are invested in upgrading/maintaining your operation ?

☐ Less than 25%
☐ More than 25% but less than 50%
☐ More than 50% but less than 75%
☐ More than 75%

57. Is there a time lag between when profits accrue and when investment decisions are made ?

☐ Yes ....
☐ No

(How long?) ______________________

58. Is there usually a time lag between when investment decisions are made and when investment is carried out ? (ie. delays between decision to invest and actual commencement of investment)

☐ Yes ....
☐ No

(How long on average ?) ______________________

59. Have you incurred any down-time during the last two years when undertaking major investment work (ie from installation of live tanks to construction of vessel)

☐ Yes ....
☐ No

(What work was carried out and what were the costs?) ______________________

____

(How many fishing days were lost?) ____________ days

60. Are there a certain times of the year where you carry out major investment or upgrade work ?

☐ Yes ……… ↓

☐ No

(When?) ____________________

61. What was the source of funds for your last major investment?

☐ Long term debt (bank loan)

☐ Savings

☐ Dispose of existing assets

☐ Funds from other business(es)

☐ Other (Please specify) ____________________

62. How variable (or volatile) do you regard each of the following ?

	Not at all Variable				Extremely Variable
Market price of frozen fish	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Catch rates	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Market price of live fish	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Per day fishing costs	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Demand for frozen fish	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Costs of capital equipment	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Demand for live fish	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

63. How important are each of the factors below in stopping you from investing further in the fishery?

	Not at all Important				Very Important
Potential profits in alternative fisheries	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Current debt levels	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Market uncertainty (fish price, demand)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Availability of decent dorymen/crew	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Financial uncertainty (interest rates)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Current fishery management policies	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Catch rates (productivity of fishery)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Boat replacement policy (eg. boat length)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Size of fishing operation	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Expected changes in fishery managemnt	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Your age	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Latent effort and over-investment	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Current net returns (overhead costs/cash flows)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Other	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

SECTION FIVE: MANAGEMENT AND RESEARCH

We want to look at how changes in management policies would affect your future profits, and how you would respond to these changes to management policies

64. How much do you think each of these management policies may impact on your business profits?

	Not at all	Slightly	Moderately	Highly	Extremely
Spawning closures	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Seasonal closures over entire GBR	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Area closures within your fishing area	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Area closures outside your fishing area	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Effort restrictions (reduction of 10% in number days fished)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Catch restrictions (reduction of 10% in total allowable catch)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

65. How would you respond to ?

a) Spawning closures

☐ Increase the number of trips outside spawning closure times
☐ Increase length of trips (no. days fished)
☐ Fish in worse weather than previous outside spawning closure times
☐ Move to region not affected by spawning closure for the period of the closure
☐ Other ____________________

b) Seasonal closures over entire GBR

☐ Increase the number of trips outside seasonal closure times
☐ Increase length of trips (no. days fished)
☐ Fish in worse weather than previous outside seasonal closure times
☐ Exit fishery
☐ Other ____________________

c) Catch restrictions (total allowable catch)

☐ Reduce the number, but increase the length of trips (no. days fished)
☐ Change to another fishery
☐ Change size of fishing operation (primary vessel)
☐ Other ____________________

d) Effort restrictions (number of days fished)

- ☐ Reduce number of trips but increase length of trips (no. days fished)
- ☐ Change size of fishing operation (primary vessel)
- ☐ Exit fishery
- ☐ Other ____________________

66. Do you think the following policies would be effective ways of managing the GBR reef-line fishery?

	Not at all	Slightly	Moderately	Highly	Extremely
Spawning closures	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Comment:					
Opening and closing reefs	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Comment:					
Seasonal closures over entire GBR	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Comment:					
Effort restrictions per boat (days fished)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Comment:					
Catch restrictions per boat (catch/boat)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Comment:					
Manage the live fishery separately	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Comment:					
Other: ____________________	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

67. What is your opinion on the following ?

	Very Under Utilised				Very Over Utilised
The status of reef fish stocks in your region	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Comment:					

	Very Little Effort				Too Much Effort
The level of commercial fishing effort in the line fishery	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Comment:					

	Bad				Good
The live fish trade/industry in terms of the whole reef-line fishery	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Comment:					

68. What factors would cause you to consider exiting the industry (open ended in pre-test)?

____

____

____

69. What do you see as the greatest threat to the sustainability of the reef-line fishery (rank in order of importance)

- ☐ Overfishing
- ☐ Live fish industry
- ☐ Bad Management
- ☐ Illegal fishing activity (poor policing)
- ☐ Toursim
- ☐ Other ______________________________

70. Overall, how do you perceive the risk of investing in the:

a) **The reef-line fishery**		b) **The live fishery**	
Low risk	☐	Low risk	☐
Medium risk	☐	Medium risk	☐
High risk	☐	High risk	☐

71. Age ?

__________ Years

72. Family status ?

- ☐ Married
- ☐ Single
- ☐ Children ________

73. Would you like to receive more information about the outcomes of this research project ?

- ☐ Yes
- ☐ No

SECTION SIX: BUSINESS OPERATIONS

74. Annual Costs

What were the annual costs incurred maintaining your operation for the last three financial years (to the nearest thousand dollars). Only routine expense are included ?

Expenditure Type	**Annual Cost ($)**			
	1995 – 1996	**1996 – 1997**	**1997 – 1998**	**1998 – 1999**
Hull maintenance (incl. slippage fees)				
Major item maintenance (elec., mech.)				
Tender vessel and outboard maintenance				
Freezer/Tank Maintenance (if applicable)				
TOTAL MAINTENANCE				
Mooring fees				
Fishing gear (eg. rope, anchors, etc.)				
Insurance costs				
Long-term debt payments				
Other expenses (please specify)				

75. Replacement costs

With purchase of new, or replacement of old, equipment during the last 3 years, which if any of the following types of costs have been incurred. How many times has this occurred in past 10 years?

Expenditure Type	**Purchase Price/ Replacement or Refit Cost ($)**			
	Prior to 1995-96	**1996-97**	**1997-98**	**1998 – 1999**
Major hull repairs				
Primary vessel refit (superstructure)				
New/rebuilt engine				
Tender vessel replacement				
Outboard replacement				
Freezer or Tank refit (if applicable)				
Other				
Other				

76. Variable Costs

We would like some information about the cost of a standard trip(average costs). In addition, where possible we are seeking sufficient detail to enable us to identify how trip costs may vary depending on (i) the length of trip, (ii) the port of origin, (iii) destination reef(s) and (iv) weather conditions. Finally, we would like to be able to estimate total variable trip costs incurred per year over the last two (2) years. Costs are trip costs unless otherwise specified.

Expenditure Type	**Annual Cost ($)**			
	1995 – 1996	**1996 – 1997**	**1997 – 1998**	**1998 – 1999**
Fuel and oil for primary vessel - Litres per average trip - Cost ($) per average trip				
Outboard fuel per dory - Litres per average trip - Cost ($) per average trip				
TOTAL FUEL COSTS				
Bait costs - Annually; or - per trip				
Fishing gear - Annually; or - per trip				
Food and provisions - Annually; or - per trip				
Ice costs (per annum)				
Packaging (boxes, bags) (per annum)				
Salaries to crew				
Superannuation/Workers Compensation				
Mobile phone costs				
Onshore costs (Fishing vehicle etc.)				
Mothership costs				
Other (please specify)				

77. Catch and Revenue.

Can you indicate in the table below the gross revenues of your fishing operation, for each of the main species of fish you targeted during the last two financial years ?

Species	Revenue ($)							
	1995 – 1996		1996 – 1997		1997 – 1998		1998 – 1999	
	Catch (lbs)	Revenue (nearest $'000)	Catch (lbs)	Revenue (nearest $'000)	Catch (lbs)	Revenue (nearest $'000)	Catch (lbs)	Revenue (nearest $'000)
CCT Live								
CCT Frozen								
CCT Fresh								
OTHER								
TOTAL								

CODE: CCT – Coral Trout
OTHER – Include all other species (Red Throat, Red Emperor, Wrasse, Mixed A and B)

78. What do you need to clear each year from fishing for you to continue as a commercial fisherman ?

$ ______________________

Appendix A3 Intra and inter-year variations in monthly wholesale prices (HK$/kg) of the five most important export species

Species	Jan			Feb			Mar			Apr			May			Jun			Jul			Aug			Sept			Oct			Nov			Dec		
	Avg Price (HK $)	% Δ Month	% Δ Year	Avg Price (HK $)	% Δ Month	% Δ Year	Avg Price (HK $)	% Δ Month	% Δ Year	Avg Price (HK $)	% Δ Month	% Δ Year	Avg Price (HK $)	% Δ Month	% Δ Year	Avg Price (HK $)	% Δ Month	% Δ Year	Avg Price (HK $)	% Δ Month	% Δ Year	Avg Price (HK $)	% Δ Month	% Δ Year	Avg Price (HK $)	% Δ Month	% Δ Year	Avg Price (HK $)	% Δ Month	% Δ Year	Avg Price (HK $)	% Δ Month	% Δ Year	Avg Price (HK $)	% Δ Month	% Δ Year
1997																																				
Coral Trout	288.8			317.6	10.0		317.9	0.1		334.4	5.2		330.0	-1.3		342.4	3.8		345.1	0.8		349.3	1.2		343.8	-1.6		319.0	-7.2		305.3	-4.3		316.3	3.6	
Maori Wrasse	574.8			596.8	3.8		595.4	-0.2		598.1	0.5		605.0	1.2		629.8	4.1		629.8	0.0		638.0	1.3		643.5	0.9		643.5	0.0		558.3	-13.2		547.3	-2.0	
1998																																				
Coral Trout	327.3	3.5	13.3	316.3	-3.4	-0.4	286.0	-9.6	-10.0	283.3	-0.9	-15.3	277.8	-1.9	-15.8	270.6	-2.6	-21.0	279.3	3.2	-19.1	279.1	-0.1	-20.1	270.9	-2.9	-21.2	259.9	-4.1	-18.5	273.6	5.3	-10.4	305.3	11.6	-3.5
Maori Wrasse	437.3	-20.1	-23.9	437.3	0.0	-26.7	456.5	4.4	-23.3	420.8	-7.8	-29.6	453.8	7.8	-25.0	440.0	-3.0	-30.1	404.3	-8.1	-35.8	409.2	1.2	-35.9	415.3	1.5	-35.5	445.5	7.3	-30.8	448.3	0.6	-19.7	453.8	1.2	-17.1
Barramundi Cod	-	-	-	-	-	-	-	-	-	-	-	-	481.3	-	-	515.0	7.0	-	531.6	3.2	-	550.0	3.5	-	564.3	2.6	-	570.9	1.2	-	556.9	-2.5	-	544.5	-2.2	-
Flowery Cod	-	-	-	-	-	-	-	-	-	-	-	-	119.8	-	-	130.5	8.9	-	125.8	-3.6	-	132.0	4.9	-	162.1	22.8	-	187.7	15.8	-	176.7	-5.9	-	160.9	-8.9	-
Camouflage Cod	-	-	-	-	-	-	-	-	-	-	-	-	171.5	-	-	165.0	-3.8	-	170.0	3.0	-	163.7	-3.7	-	156.8	-4.2	-	162.3	3.5	-	167.8	3.4	-	178.8	6.6	-
1999																																				
Coral Trout	302.5	-0.9	-7.6	299.8	-0.9	-5.2	224.8	-25.0	-21.4	243.8	8.5	-13.9	233.1	-4.4	-16.1	285.7	22.6	5.6	281.7	-1.4	0.9	273.3	-3.0	-2.1	268.1	-1.9	-1.0	269.5	0.5	3.7	299.8	11.2	9.6	325.9	8.7	6.7
Maori Wrasse	514.3	11.8	17.6	530.8	3.2	21.4	436.1	-17.8	-4.5	457.9	5.0	8.8	416.6	-9.0	-8.2	459.9	10.4	4.5	468.2	1.8	15.8	488.4	4.3	19.4	456.5	-6.5	9.9	462.0	1.2	3.7	420.8	-8.9	-6.1	458.7	9.0	1.1
Barramundi Cod	541.8	-0.5	-	563.8	4.1	-	499.7	-11.4	-	495.0	-0.9	-	499.7	0.9	3.8	487.9	-2.4	-5.3	509.1	4.3	-4.2	528.0	3.7	-4.0	522.5	-1.0	-7.4	511.5	-2.1	-10.4	484.0	-5.4	-13.1	520.9	7.6	-4.3
Flowery Cod	153.5	-4.8	-	148.5	-3.3	-	141.4	-4.8	-	117.5	-16.9	-	119.6	1.8	-30.3	151.3	26.5	-8.3	154.4	2.0	-9.2	149.7	-3.0	13.4	162.3	8.4	0.1	148.5	-8.5	-20.9	152.6	2.8	-13.6	129.5	-15.1	-19.5
Camouflage Cod	174.6	-2.4	-	166.4	-4.7	-	137.4	-17.4	-	133.0	-3.2	-	137.2	3.2	-20.0	161.3	17.6	-2.2	163.8	1.5	-3.6	157.8	-3.7	-3.6	144.4	-8.5	-7.9	156.8	8.6	-3.4	165.6	5.6	-1.3	177.4	7.1	-0.8
2000																																				
Coral Trout	362.0	11.1	19.7	356.9	-1.4	19.0	296.5	-16.9	31.9	265.9	-10.3	9.1	266.6	0.3	14.4	290.0	8.8	1.5	295.5	1.9	4.9	261.0	-11.7	-4.5	254.5	-2.5	-5.1	250.5	-1.6	-7.1	251.9	0.6	-16.0	344.4	36.7	5.7
Maori Wrasse	531.2	13.6	3.3	468.7	-11.8	-11.7	420.5	-10.3	-3.6	398.8	-5.2	-12.9	402.8	1.0	-3.3	437.2	8.5	-4.9	417.9	-4.4	-10.7	397.4	-4.9	-18.6	358.5	-9.8	-21.5	413.9	15.5	-10.4	405.3	-2.1	-3.7	434.2	7.1	-5.3
Barramundi Cod	526.1	1.0	-2.9	526.4	0.1	-6.6	457.5	-13.1	-8.4	494.4	8.1	-0.1	512.2	3.6	2.5	522.3	2.0	7.1	529.3	1.3	4.0	493.8	-6.7	-6.5	522.8	5.9	0.1	538.3	3.0	5.2	547.3	1.7	13.1	558.4	2.0	7.2
Flowery Cod	213.6	39.4	39.2	180.5	-15.5	21.5	201.6	11.7	42.6	189.8	-5.9	61.5	171.4	-9.7	24.9	173.5	1.2	14.7	185.4	6.9	20.1	194.4	4.9	29.9	173.9	-10.5	7.1	175.4	0.9	18.1	180.2	2.7	18.1	212.6	18.0	64.2
Camouflage Cod	185.7	4.5		201.9	8.7	21.3	177.9	-11.9	29.5	170.9	-3.9	28.5	164.5	-3.7	19.9	167.2	1.6	3.7	178.9	7.0	9.2	169.5	-5.3	7.4	136.1	-19.7	-5.7	157.5	15.7	0.4	178.0	13.0	7.5	183.3	3.0	3.3

Intra and inter-year variations in monthly wholesale prices (HK$/kg) of the five most important export species from January 1997 to December 2000. The column (% change /month) shows consecutive changes in monthly wholesale price. The column (% change /year) compares the price in any month with the price in the respective month in the preceding year (ie. twelve months prior)

Source: Agriculture Fisheries and Conservation Department, Hong Kong, International Marinelife Alliance