Discarding of commercial catch

implications for Commonwealth fisheries managed with ITQs

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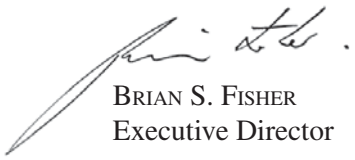
foreword

The discarding of commercial species can have important implications for the sustainability of fishery resources. While some discarding is inevitable, there is considerable concern that fisheries managed with individual transferable quotas provide an additional, and economically inefficient, incentive to discard commercial catch.

ABARE was commissioned by the Fisheries Resources Research Fund to investigate the key factors that influence the extent of discarded commercial catch and to review the policies that could be implemented in Commonwealth fisheries managed with individual transferable quotas to reduce the extent of economically inefficient discarding.

The reasons why fishers discard commercial catch are reviewed, while a range of policies developed to reduce discarding in fisheries around the world are summarised. On the basis of an econometric analysis of discarding data collected from the south east trawl fishery, some key factors contributing to discarding in the fishery as well as some options that may address this problem are identified.



BRIAN S. FISHER
Executive Director

August 2005

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contents

Summary 1

1 Introduction 4

2 Incentives to discard 5
Incentives created by the ITQ system 5
Implications for fisheries management 7

3 Evidence of discarding 9
International extent of discarding 9
Discarding in the south east trawl fishery 10
Factors influencing discarding in the south east trawl fishery 12

4 Options to reduce discarding 16
Legislative and technical measures 17
Market based measures 18
Options to reduce discarding in the south east trawl fishery 21

Appendix
A Empirical model of discarding for selected species in the SETF 23

References 26

boxes

1 Individual transferable quota as a system of fisheries management 6
2 Variable definitions 13
3 ITQ management in Iceland and New Zealand 16

figures

A Proportion of quota species discarded in the SETF 11
B Proportion of discards, selected species 11
C Length distribution of catch discarded and retained – New South Wales SETF 11

tables

1 Estimates of quota species discarded in 2003 – south east trawl fishery 10
2 Ling regression results 14
3 Silver (spotted) warehou regression results 14
4 Results of diagnostic tests 24

summary

Discarding refers to the practice of throwing unwanted catch overboard. Some level of discarding is inevitable because the cost of landing and processing some catch exceeds the price obtained from selling it. However, there is concern that fisheries managed with individual transferable quotas (ITQs) provide an additional — and economically inefficient — incentive for fishers to discard commercial catch.

ITQ management may create an incentive for fishers to discard lower valued commercial catch rather than count it toward their quota in anticipation of catching higher valued fish later in the season. This is likely to occur where a large differential exists between prices for different grades of fish. ITQ management of a multispecies fishery can create a further incentive to discard when quota for one species has been reached while quota remains unfilled for other species.

The discarding of commercial catch that is a direct result of the incentives created by ITQ or other fisheries management is inefficient from an economic perspective. Where it occurs in a fishery there may be some justification for implementing policies and measures aimed at reducing the extent of discarding.

It is estimated that 20 million tonnes of fish are discarded in fisheries around the world, representing around a fifth of the total catch. It is generally considered that discarding has decreased since the mid-1980s as a result of a decline in the level of fishing, greater use of more selective gear, greater utilisation of fish for human consumption and attempts by fisheries managers to solve the problem of discarding.

Data collected through the integrated scientific monitoring program indicate that around 7 per cent of commercial quota species in the south east trawl fishery (SETF), valued at around $3 million, were discarded in 2003. Analysis of the discarding data suggests that this involves the discarding of smaller less valuable fish — a process referred to as 'high-grading' — as fishers seek to maximise the value of their quota.

An econometric analysis of the discarding data found that variations in the prices of different grade fish explained some of the discarding

behavior in the SETF. There was some indication that discarding was also influenced by catch levels approaching TAC limits and the volume of quota traded, although these explained less of the variation than the price variables.

A range of policies or management arrangements can be implemented to reduce the extent of discarding. The regular monitoring of discarding is an important first step in managing the practice. Provided that discarding is not illegal, observers conducting surveys on vessels and at ports are likely to collect reasonably reliable estimates of the extent of discarding. Where the level of discarding is sufficiently low, these estimates of discarding can be incorporated into the assessment of fishing mortality and total allowable catch (TAC) limits can be set accordingly, without the need for additional policies or measures to reduce discarding. Regular monitoring of discard levels will also highlight the need to adopt policies to reduce discarding if it is observed to increase over time.

When the extent of discarding warrants the implementation of policies or management arrangements to reduce the problem it is important that any measures put in place are consistent with the biological and economic efficiency objectives that guide Australian fisheries management. In an ITQ fishery such as the SETF this involves ensuring that TAC limits are set appropriately and are not exceeded, and that the policies themselves do not introduce inefficiencies in fishing methods and practices. Further, any policies to reduce discarding need to be incorporated as part of any wider reforms that may be occurring in the fishery. For example, it is possible that reforms to the way in which TAC levels are set in the SETF may lead to reduced TAC limits for some species and an increase in the level of discarding in the fishery.

Particularly for multispecies fisheries such as the SETF, a well functioning quota market is likely to form an important part of the arrangements to reduce discarding. In particular, the provision and dissemination of information on the quota holdings of individual fishers, and the development of electronic quota trading systems, can facilitate trade and lead to a better functioning market. The importance of economic efficiencies generated by a well functioning quota market mean that discarding policies such as overcatch provisions and fixed quota packages, which undermine the effectiveness of the market, should be considered with caution.

Important lessons have been learned from New Zealand's experience with policies to reduce discarding in quota managed fisheries. The current system of deemed values that replaced an administratively complex system of multiple measures in 2001 as the primary measure of managing discarding bears further investigation if the level of discarding in Commonwealth fisheries increases or is considered to be unacceptably high at current levels. For a deemed value policy to work effectively in the SETF, further research needs to be undertaken to ensure deemed values are set in a manner that does not create an incentive for operators to target overquota species either because of fluctuations in the market price of fish or due to variability in the operating costs of different vessels.

introduction

All fishers discard some of their unwanted catch overboard and this occurs because some catch is simply not worth landing. While some level of discarding is inevitable, there is considerable concern that fisheries managed with individual transferable quotas (ITQs) provide an additional incentive for fishers to discard commercial catch. An ITQ system encourages fishers to maximise the profit earned from a limited volume of fish available to land. This management system may create an incentive for fishers to discard lower valued commercial catch rather than count it toward their quota in anticipation of catching higher valued fish later in the season. An ITQ system in a multispecies fishery can create a further incentive to discard that may occur when quota for one species is filled, while another is not, leading operators to continue fishing for unfilled quota, discarding quota that is filled.

Discarding of commercial catch that is a direct result of the incentives created by ITQ or other fisheries management is inefficient from an economic perspective. Where commercial catch is being discarded in a fishery there may be a need for policies or measures to be introduced to reduce the extent of discarding and the associated economic inefficiencies it generates.

This report reviews the factors that contribute to discarding, with a particular focus on the incentives created by the fisheries management system. Using data on the extent of discarding in the south east trawl fishery (SETF), an econometric analysis provides some indication of the relative importance of these different factors. This represents one of the first empirical studies of discarding ever undertaken. The report concludes with a review of the potential options available to better manage the problem of discarding. Particular consideration is given to the policy and management options that could be introduced to the ITQ managed SETF in order to reduce the current level of discarding.

incentives to discard

For the purpose of this report, discarding is taken to mean the throwing overboard of commercial species in a fishery. Unwanted, noncommercial bycatch that is thrown overboard has been excluded from this analysis.

Discarding is likely to occur, at least to some extent, in all commercial fisheries. However, it only becomes economically inefficient when the marginal social costs of discarding exceed the marginal social benefits of discarding (Arnason 1994). For example, if the value of a landed fish does not cover the cost of onboard handling and processing then it is optimal to discard the fish (Arnason 2000). There are no policies or management arrangements that can or should be used to reduce this type of discarding.

Incentives created by the ITQ system

The ITQ management system may create an unintended incentive for fishers to discard commercial catch, introducing economic inefficiencies (see box 1 for a description of ITQ fisheries management). Discarding in ITQ managed fisheries may involve the discarding of undersize or low value target species where a large differential between prices for different grades exists, referred to as quota induced highgrading. Discarding can also occur in quota managed fisheries when quota for one species has been reached while quota remain unfilled for other species. This is referred to as overquota discarding.

Quota induced highgrading

Under an ITQ based management system fishers have an incentive to maximise the value of the catch landed against their quota. All recorded landings are held against each fisher's quota for the season, creating an incentive for fishers to discard lower value catch in expectation of obtaining higher valued catch in the future. The greater the price differential between the low and high grade fish, the greater the financial incentive to highgrade. Although fishers will only highgrade in this way if the costs of continuing to fish are lower than the expected additional value of the subsequent catch.

A number of papers describe this incentive to highgrade, identifying the range of factors contributing to its occurrence (see for example, Arnason 1994, Anderson 1994, Rose 2002). Arnason (1994) developed a model of highgrading, where the decision to discard was dependent on the prices received for different grades of fish, the handling and landing costs between the different grades, and the marginal costs of harvesting and discarding.

Anderson (1994) developed a similar model, emphasising that the factors contributing to highgrading are likely to differ across the fishing fleet and for different types of trips.

The general lack of data on the extent of discarding and fishing costs disaggregated by type of boat and trip has limited the empirical analysis of highgrading in fisheries around the world. Rose (2002) illustrated the magnitude of the incentive to highgrade with a hypothetical example of yellowfin tuna (yellowfin tuna is not currently managed with quota). Estimates were derived using data on the price of small and large grade tuna, together with

Box 1: Individual transferable quota as a system of fisheries management

An open access fishery is one where an unlimited number of fishers are able to harvest an unrestricted volume of the fishery resource. Each fisher has an incentive to harvest as much of the resource in the shortest possible time in order to maximise his or her share of the total catch. This leads to overexploitation of the fishery resource and is highly inefficient from an economic perspective.

Controls that seek to limit the number of vessels in a fishery or the effort that fishers can expend in the fishery — through measures such as season closures or restrictions on the size of vessels — seek to reduce catch by lowering fishing effort. While this can address the issue of resource sustainability, it can still be economically inefficient as fishers compete against each other for fishery resources and have an incentive to increase their use of unregulated fishing inputs to increase their effective effort.

Individual transferable quota (ITQ) management provides fishers the right to harvest a share of the TAC specified by the manager of the fishery. By setting the TAC at or below the maximum sustainable yield (MSY) of the fishery each season, the long term sustainability of the resource can be assured. Further, by allocating each fisher a guaranteed share of the TAC, the economically inefficient incentive to compete against other fishers is eliminated. Fishers are able to target their fishing effort at higher valued species to maximise the value of their quota. This can result in target species being allowed to grow to an optimal size before being harvested, or being captured at a time of the year where the value of the catch is highest.

In making the individual quota allocated to fishers transferable, quota can also be bought and sold between fishers, leading to an eventual allocation of quota amongst the most efficient fishers, regardless of how the quota are allocated initially.

Since Iceland adopted an ITQ based management approach across their fisheries in the mid 1970s a number of other countries have also adopted ITQ management for some of their fisheries. In the mid 1980s New Zealand adopted a national system of ITQ based fishery management. Countries including Australia, Canada, the United States, the United Kingdom, the Netherlands, Norway and Greenland have incorporated ITQs into their system of fisheries management (Kaufmann, Geen and Sen 1999).

In 1989, ITQ management was identified as the preferred system for managing Commonwealth fishery resources in Australia, with other approaches to be considered only where ITQ arrangements are evaluated as not appropriate given the characteristics of the fishery (Commonwealth of Australia 1989). A recent review of Commonwealth fisheries policy reaffirmed this position (Commonwealth of Australia 2003). Despite this, only a few fisheries managed by the Commonwealth government are currently managed with a system of ITQs, with the majority of Commonwealth fisheries managed with input controls.

ABARE fisheries survey data on the volume of catch and fishing costs. Rose (2002) estimated that in the late 1990s large yellowfin tuna were sold to the Japanese market at around $25 a kilogram, with smaller tuna sold domestically for around $10 a kilogram. Operating costs were assumed to average $9.80 a kilogram across the fleet. Assuming that large fish made up 80 per cent of the weight of early season catch, Rose (2002) estimated that the net return of filling one kilogram of yellowfin tuna quota by fishing early in the season without highgrading was $12.20. Discarding the small tuna that make up 20 per cent of the catch and fishing again was estimated to generate a net return of $12.64 a kilogram. The financial incentive to highgrade was therefore shown to be very small and represented an increase in the net return to fishing of only a few per cent.

Further, Rose (2002) was able to show that delaying fishing until later in the season when large tuna were likely to account for a larger proportion of the total catch generated a larger increase in net returns compared with the improvement in returns from highgrading earlier in the season. Assuming that large tuna account for 90 per cent of the catch later in the season the net return to fishing later without highgrading was estimated to be $13.70 a kilogram (Rose 2002).

A similar approach was taken by Vestergaard (1996) to demonstrate the incentive to discard in the Greenland shrimp fishery. Vestergaard (1996) found that an incentive to discard is created where the price difference between discarded and nondiscarded fish is greater than the costs of replacing the discard, which included the discarding cost, effort cost and time cost. Vestergaard (1996) also showed that the price of discarded fish influenced the incentive to discard more than the price of the retained fish.

Overquota discarding

In an ITQ managed fishery where more than one species is targeted, fishers may hold separate quota for a range of different species. Under this arrangement fishers may face an incentive to discard commercial catch in addition to the incentive to highgrade within the quota allocation for each species.

If the quota for one species has been filled while quota for other species remains unfilled, fishers in a multispecies fishery may face an incentive to discard. Where the value of the retained catch exceeds the costs of fishing, fishers may continue to land catch against unfilled quota, discarding any catch of the species whose quota has already been filled. This practice is referred to as overquota discarding. The extent of overquota discarding is likely to depend on the ability of fishers to target specific species of fish as well as the ability of fishers to purchase additional quota from the quota market to cover their additional catch.

Implications for fisheries management

While there is always going to be some level of discarding in fisheries, additional discarding that results from unintended incentives created by the fisheries management system can be economically inefficient. This inefficiency is inconsistent with the objective of Commonwealth fisheries management and should be minimised where possible.

Discarding can also threaten the sustainability of fishery resources. Fisheries management requires an assessment of fishery stocks each year. For each species in the fishery this involves understanding the stock recruitment relationship, the level of natural mortality, and the level of fishing mortality. In fisheries managed with input controls an understanding of the relationship between fishing effort and fishing mortality is also required.

In a fishery where sufficient data exist, fishery managers are able to calculate the maximum sustainable yield (MSY) for the season. This represents the maximum volume of the fishery resource that can be taken from the fishery in a year, while maintaining enough stocks such that the biomass in the fishery does not decline over time. The TAC can then be set for the season at or below this MSY. If economic criteria are used to determine the optimal level of the TAC, it is set at the point where the marginal returns from fishing are equal to the marginal cost of fishing (referred to as the maximum economic yield, MEY). Assuming fishing costs increase with the level of fishing effort expended, this results in a smaller TAC than that predicted by MSY.

The appropriate setting of the TAC depends critically on the estimate of fishing mortality, typically obtained from estimates of catch reported by fishers or landings recorded against quota. If discarded fish do not survive then reported landings or catch data do not reflect the true extent of fishing mortality. If fishing mortality is underestimated then the actual level of biomass in the fishery is lower than the fishery manager believes. The MSY calculated on the basis of this overestimate of the existing biomass in the fishery, and therefore the TAC, will be too high. If this is the case, the stock will end up overexploited, contributing further to economic inefficiencies in the fishery.

The economic inefficiency of discarding induced by ITQs also has important implications for the fisheries management system more generally. If the system results in the discarding of commercial species, this represents an economic loss induced by the system. A significant economic loss and inefficiency induced by the system represents a regulatory failure and would warrant reforms to eliminate such inefficient incentives from the fishery management system.

evidence of discarding

Despite concern that discarding can undermine the economic efficiency and effectiveness of ITQ management systems, particular in multispecies fisheries, there is little data collected on the extent of discarding in fisheries around the world. Further, there has been almost no empirical analysis of the factors contributing to discarding as a precursor to making changes to fisheries management systems that can reduce the incentive to discard.

This chapter summarises the FAO (Food and Agriculture Organisation of the United Nations) research into discarding at the international level and then analyses a short time series of data on discarding in the SETF to investigate the factors contributing to discarding and the implications for fisheries management in Australia.

International extent of discarding

The discarding of commercial catch is a worldwide fisheries management problem. FAO (1997) estimates that every year 20 million tonnes of fish are discarded in fisheries around the world. With recorded landings from marine fisheries around the world of around 80 million tonnes a year (FAO 1996), discarded fish represent around a fifth of the total catch. While some data suggest that the level of discarding has increased over time, it is generally considered that discarding has decreased since the mid-1980s (Pascoe 1997). The reasons for this decline in discarding include a decline in the level of fishing, greater use of more selective gear, greater utilisation for human consumption and attempts by fisheries managers and fishers to solve the problem of discarding.

In a paper on the options for utilising bycatch and discarded commercial catch, Clucas (1997) summarised the available data on the extent of discarding in commercial fisheries around the world. He observed generally lower levels of discarding in single or few species fisheries compared with that of shrimp trawl fisheries. For example, it is estimated that less than 1 per cent of pelagic food fish (herring, pilchard, Atlantic mackerel etc) and fish for fishmeal (capelin, blue whiting etc) is discarded in the north sea and north Atlantic (Clucas 1997). Estimates of human food fish discarded were higher — around 2.7 per cent for whiting, 9.0 per cent for haddock and 9.8 per cent for redfishes.

In contrast, Alverson et al. (1994) estimate that, on average, 85 per cent of bycatch (nontarget species) in shrimp fisheries around the world are discarded. The authors estimate that close to 100 per cent of bycatch species are discarded in north west and north east Atlantic shrimp fisheries, while around 60 per cent are discarded in the eastern Indian Ocean (Alverson et al. 1994).

Discarding in the south east trawl fishery

Data collected through the Integrated Scientific Monitoring Program (ISMP — see appendix A for more detail on the program) indicate that around 7 per cent of commercial quota species in the SETF were discarded in 2003 (table 1). This average for all quota species masks a considerable degree of variability in the discarding of different species. For example, relatively high proportions of inshore ocean perch (66 per cent), eastern gemfish (39 per cent) and redfish (36 per cent) were discarded during the year. In contrast, discards of blue eye trevalla, pink ling, blue grenadier and orange roughy were all below 1 per cent.

On the basis of ISMP calculations of the estimated weight of quota species discarded, together with ABARE estimates of whole weight fish prices, the gross value of discarded quota species in 2003 is estimated to have been around $3 million. The gross value of retained quota species in the fishery is estimated at around $56.6 million in 2002-03 and $44 million 2003-04 (ABARE 2005).

The ISMP data have been collected on a consistent and comparable basis since 1999. Figure A shows that the proportion of quota species discarded between 1999 and 2003 has been between 4 and almost 8 per cent. It is difficult to observe trends in discarding over such

1 Estimates of quota species discarded in 2003
South east trawl fishery

Species	Discard rate	Estimated discarded weight	Estimated retained weight	Gross value of discarded catch
	%	tonnes	tonnes	$'000
Blue grenadier – nonspawning	0.62	2.84	406.17	4.54
Blue grenadier – spawning	0.07	5.24	8 061.57	8.38
John dory	1.29	3.19	164.55	19.30
Mirror dory	18.35	163.71	667.16	286.49
Tiger flathead	4.29	178.03	3 491.49	432.61
Eastern gemfish	38.8	115.17	74.45	357.03
Western gemfish	6.8	12.58	171.22	39.00
Pink ling	0.08	0.94	1 127.33	4.94
Jackass morwong	5.98	71.85	470.16	114.96
Orange roughy	0.92	11.39	2 949.78	41.23
Redfish	35.72	347.5	677.23	517.78
Ocean perch – inshore	66.36	61.32	25.28	156.37
Ocean perch – offshore	6.65	27.45	312.1	70.00
Royal red prawn	3.24	17.37	188.17	48.98
Blue eye trevalla	0	0	31.74	0
Silver trevally	0.63	1.51	122.39	3.22
Silver (spotted) warehou	15.08	769.76	3 023.98	800.55
Blue warehou	6.26	19.49	250.12	33.91
School whiting	6.92	46.34	564.13	94.53
Total quota species	7.19	1 855.68	23 049.02	3 033.82

The discard rate is the estimated discard rate of each species across the fishery based on ISMP data. Discard rates were combined with total landed catch to estimate the total retained and discarded catch.
Source: Talman, Koopman and Gason. (2004).

a short time period, although it appears that the proportion of orange roughy, blue grenadier and ling discarded fell over the five year period (figure B). In contrast, it appears that the proportion of silver (spot-ted) warehou discarded increased over the same period.

As part of their annual report on the ISMP, Talman et al. (2004) constructed histograms showing the distribution of catch retained and discarded, by length. Figure C shows the distribution of redfish, mirror dory and silver (spotted) warehou retained and discarded in the New South Wales zone of the SETF.

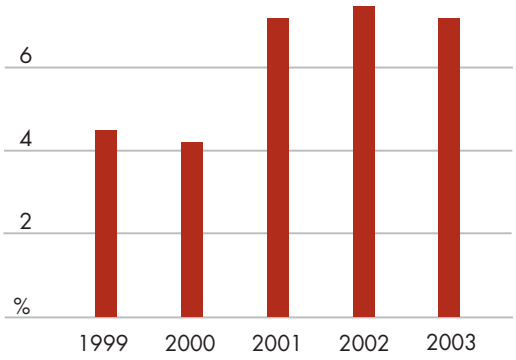
The results indicate that smaller fish tend to be discarded in preference to larger fish. For example, the majority of redfish between 10 and 15 centimetres in length caught in the New South Wales zone of the SETF were discarded in 2003. However, redfish over 20 centimetres in length were almost all retained.

Similarly, almost all mirror dory caught in the New South Wales zone of the SETF under 25 centimetres in length were discarded, while all mirror dory over 40 centimetres in length were retained.

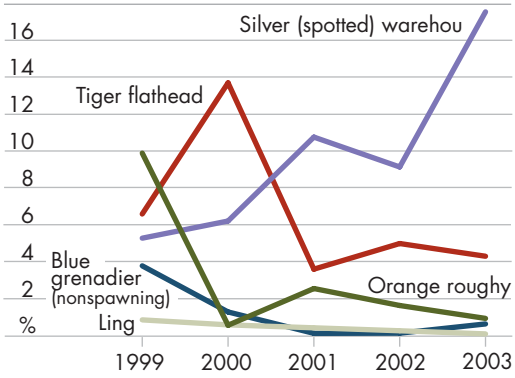
The results for silver (spotted) warehou were similar, with operators showing a preference to retain the larger fish and discard the smaller ones.

The set of histograms presented in figure C (Talman et al. 2004, pp. 60, 63, 103) suggest that fishers operating in the SETF are highgrading their catch in order to maximise the value of their quota. The lack of discarded large fish also suggests that there is little overquota discarding. If overquota discarding had occurred in 2003, the histograms would show the discarding of catch across a larger spectrum of fish sizes.

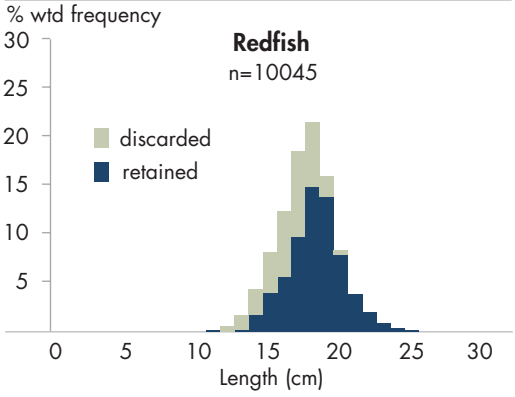
A **Proportion of quota species discarded in the SETF**



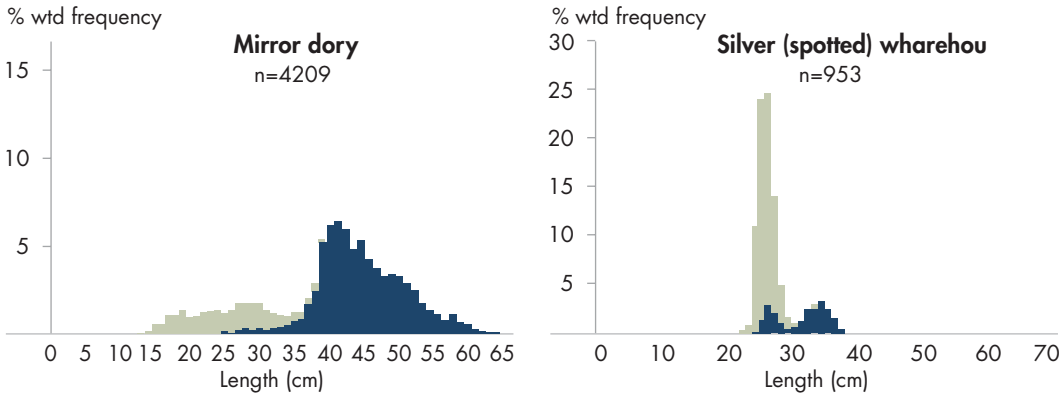
B **Proportion of discards, selected species**



C **Length distribution of catch discarded and retained** New South Wales SETF



C Length distribution of catch discarded and retained *continued*
New South Wales SETF



Factors influencing discarding in the south east trawl fishery

The use of econometric techniques enables an analysis of the factors influencing the discarding of particular species in the SETF over time, which in turn can facilitate the design of better targeted policies to reduce discarding.

Regression analysis techniques seek to estimate the influence that individual variables — the volume of quota trade, for example — have on the extent of discarding. They provide both an indication of which variables have a significant influence on the extent of discarding, as well as an indication of the nature of that relationship.

Data from the ISMP on the retention and discarding of fish in the SETF form the basis of the analysis, with additional data from the Sydney Fish Markets and AFMA's quota monitoring system. A total of 48 observations, from the March quarter 1992 to the December quarter of 2003, were used in the analysis.

The model

An ordinary least squares regression technique was used to estimate the relationship between discarding and the range of variables thought to influence discarding (see appendix A for further detail).

The following model was proposed for each of four key species to investigate the factors influencing discarding:

$$DiscardRatio = \alpha_0 + \alpha_1 pTAC + \alpha_2 qTrade + \alpha_3 priceRatio + \alpha_4 pSmall + \alpha_5 time + \varepsilon$$

where α_i is the coefficient associated with each of the factors believed to influence the proportion of catch discarded and *pTAC*, *qTRADE*, *priceRatio*, *pSmall* and *time* are the explanatory variables defined in box 2.

While the costs associated with fishing should ideally be included in this model specification, there were insufficient data on the costs of individual fishing trips and the costs associated with discarding. The incorporation of data on the costs of fishing would be expected to increase the overall explanatory power of the model.

Model results

An econometric model was used to investigate the factors influencing the discarding of four of the most valuable species in the SETF: ling, silver (spotted) warehou, tiger flathead and orange roughy. The model specified above was found to explain some of the variability in the discarding of ling and silver (spotted) warehou, but very little of the variation in tiger flathead and orange roughy discards — so results are not presented for the latter two species. The exclusion of data on the costs of fishing is likely to be contributing to the

Box 2: Variable definitions

DiscardRatio	The discard ratio is calculated as the ratio of the volume of fish discarded to the volume of fish caught on a quarterly basis.
pTAC	The proportion of the TAC filled at the beginning of each quarter. This variable is calculated as the ratio of cumulative landings each quarter to the available TAC (allowing for over and undercatch provisions) for that year and provides a measure of how close the annual TAC is to being filled. The extent of discarding is expected to increase as the catch approaches the TAC limits.
qTrade	The volume of quota traded, measured in tonnes. The variable is used as an indicator of how active the market for quota within the SETF is. The extent of discarding is expected to decline with an increase in the volume of quota traded.
priceRatio	The price ratio variables are constructed by dividing the average quarterly price per kilogram of a small grade of a species by the average quarterly price per kilogram of a larger grade of the same species. Prices have been adjusted to allow for conversion between landed and live weight. Price grade ratios express variations between unit prices for different grades. The price grade ratios are a proxy for differences in the prices for various sized fish. It is assumed that a premium is paid for larger fish and the ratio divides the average price for smaller grades by the average price for the larger grade to generate a ratio that takes a value between zero and one. The level of discarding is expected to increase when a significant premium exists for a larger grade of fish compared with a smaller grade.
pSmall	The proportion of total catch each quarter classified as small according to the Sydney Fish Market grade guidelines. This proportion is calculated based on the total catch rather than landings, and therefore includes the fish subsequently discarded by the operator. The level of discarding is expected to increase as the proportion of small fish in the catch increases.
time	Time is used as a proxy to represent the adoption of technological improvements in the fishery over time. The variable is a continuous count starting at one for the first observation in 1992 and increases by one with every quarter throughout the period. The level of discarding over time is expected to decrease as a result of technological advancements that improve targeting.

poor fit of the models for tiger flathead and orange roughy.

Ling

In 2002-03 the catch of ling was valued at around $5.5 million, representing over 8 per cent of the total gross value of production in the SETF. The overall fit of the model is judged by the variation in the discard ratio explained by the variables included in the regression. Around 38 per cent of this variation was explained by the model specified (as measured by the R^2 value).

2 Ling regression results

Variable	Coefficient	t-statistic
Intercept	–0.0102	–0.3743
Proportion of TAC filled	0.0413 **	2.4072
Price ratio		
– small / medium	0.6382 *	5.1935
– small / large	–0.7146 *	–5.0218

Note: *, ** represent significance at the 1% and 5% level.

Of the six variables included in the model, three were found to be associated with the level of discarding and included in the final specification (table 2). The price ratios were significantly correlated with the discard ratio, although the direction of this relationship varied. The negative sign on the price ratio for the small to large grades indicates that as the difference in the price between the small and large fish declines and the value of the ratio increases, the level of discarding falls.

The proportion of TAC filled was significant in explaining the discard ratio. As the catch level approaches the annual TAC limit, the proportion of ling discarded was found to increase. The volume of quota traded, the proportion of small fish that make up the catch and the time variable were not found to have a significant relationship with the discard ratio for ling.

Silver (spotted) warehou

Silver (spotted) warehou is the third most valuable species in the SETF. In 2002-03 the gross value of production for silver (spotted) warehou was approximately $4 million. This represented over 6 per cent of the total value of the SETF. Around 18 per cent of the variation in the discarding of silver (spotted) warehou was explained by the variables included in the regression.

All six of the variables were included in the final model specification, four of which were found to be significantly associated with the level of discarding (table 3). The price ratios were significantly correlated with the discard ratio, although the direction of this relationship varied. The negative sign on the price ratio for the small to large grades indicates that as the difference in price between the small and large fish declines, the level of discarding falls.

3 Silver (spotted) warehou regression results

Variable	Coefficient	t-statistic
Intercept	–0.0434	–0.4401
Proportion of small fish in catch	–0.0695	–1.0809
Proportion of TAC filled	0.0449	0.6136
Volume of quota traded	–0.1451 ***	–1.8082
Price ratio		
– small / medium	0.3441 **	2.5921
– small / large	–0.2336 **	–2.0814
Time	0.0054 **	2.4611

Note: **, *** represent significance at the 5% and 10% level.

The time variable was also found to be significantly associated with the level

of discarding, with a slight increase in the discarding of silver (spotted) warehou over time between 1992 and 2003. The volume of quota traded was also an important variable, with the level of discarding falling as the volume of quota traded increased. Although not significant, the proportion of annual TAC filled was positively correlated with the level of discarded silver (spotted) warehou.

Relative importance of different factors

The results presented indicate that the model specification explains only part of the observed variation in the level of discarding. It is possible that the inclusion of data on the costs of fishing and a longer time series of data may improve the overall performance of the regression equations. Nonetheless, the results support the notion that a combination of market and quota based factors influence the discarding of some key species in the SETF.

The market based variables included in the regression analysis were the price ratios between different grades and the proportion of catch consisting of small fish. These variables were included in the regression because significant differences in the price obtained for large fish relative to smaller fish may create an incentive for fishers to highgrade their catch. The sign and significance of the coefficient for the price ratio of small to large fish provides support for this hypothesis, with increases between the price for small and large fish found to be positively correlated with the level of discarding. The positive sign on the coefficient for the price ratio of small to medium fish is not consistent with expectations, but may be explained by smaller differences in prices between small and medium grade fish.

The quota based variables included in the regression analysis were the volume of quota traded and cumulative catch as a proportion of the annual TAC limit. An effective quota market is expected to reduce the incentive to discard, providing fishers with a mechanism to obtain quota to cover their catch. Conversely, as the level of catch approaches the fishery-wide TAC, fishers may discard either because the quota is filled, or because they wish to fill their remaining quota with higher valued fish. In general, the two quota based variables explained less of the variation in the discard ratio than the market based variables. However, increases in the volume of quota traded were associated with a decline in the discard ratio. Further, discarding was also correlated with cumulative catch approaching the annual TAC limit.

The regression results did not support the hypothesis that technological improvements to better target key species have contributed to a decline in discarding over time.

options to reduce discarding

The advantages of ITQ based fisheries management over other fisheries management systems, together with concerns about the incentives that fishers have to discard, have led to the development of a number of policy options to address the problems associated with discarding while retaining the framework of the quota system. Both Iceland and New Zealand have adopted systems of ITQ fisheries management and put in place measures to reduce discarding (see box 3 for more details).

Box 3: ITQ management in Iceland and New Zealand

Iceland was one of the first countries to implement a fisheries management system based around output controls. In the mid-1970s, individual vessel quotas were introduced to the herring fishery, which were subsequently made transferable by the late 1970s (FAO 1999). In the mid-1980s, individual transferable quotas were introduced to the demersal fisheries and by 1990 the management system was made uniform and consistent across all Iceland fisheries.

Arnarson (1993) reported that there was little evidence of increased discarding under ITQs in Iceland's multispecies demersal fisheries. It is estimated that demersal discards represent 1–6 per cent of total catch depending on the gear and vessel type. Further, there has been no detectable increase in discarding since 1984 when the vessel quota system was first introduced to Iceland's demersal fisheries.

A number of measures have been introduced to manage discarding in Iceland fisheries (Arnarson 2002). These include the development of a robust market for quota assisted by independent traders and brokers, the use of onboard observers to enforce the ban on discarding at sea, overcatch provisions that allow catch to exceed up to 5 per cent of vessel quota in one year and be recorded against the following year's quota, as well as some quota substitution arrangements in the multispecies fisheries.

New Zealand introduced a system of ITQs, referred to as a quota management system, in 1986 to cover 161 fish stocks of 28 species or species groups (Peacey 2003). Since 1986 additional species have been incorporated into the quota system.

From 1986 until 2001 a somewhat complicated system of measures was used to reduce discarding (Peacey 2003). These included the trade of quota, overcatch provisions of up to 10 per cent of a fisher's quota, a quota substitution system, and deemed values. Deemed values were payments made to the government by fishers without sufficient quota. If a fisher was subsequently able to obtain quota to cover the catch, then the deemed value was refunded by the government. The deemed value for each species was set to give an incentive to land the fish rather than discard it at sea, but to also not provide an incentive for fishers to target stocks for which they did not have sufficient quota. Since October 2001, a new regime has been introduced to replace this system, with deemed values forming the primary policy to reduce discarding, with failure to pay the appropriate value resulting in the suspension of fishing permits.

Assessing the options available to reduce discarding involves consideration of the relative net economic benefits of each option. It is only economically efficient to implement a measure to reduce discarding if the benefits in terms of reduced discarding outweigh any other costs that the measure may impose.

The management systems and policies used in quota managed fisheries around the world to reduce discarding belong to one of two broad categories: legislative and technical measures and market based measures. Market based measures seek to reduce the economic incentive that fishers have to discard, in contrast to the regulatory approach that uses legislation and technical measures to reduce the volume of discarded fish.

Legislative and technical measures

Criminalisation of discarding

A number of countries with quota managed fisheries have legislation that makes discarding at sea illegal. In Iceland, the discarding of usable fish is prohibited (Iceland Ministry of Fisheries 2004). New Zealand has also moved to criminalise the discarding of most species covered by the quota management system (Peacey 2003). The challenge of this approach is enforcing the ban, which usually involves onboard observers and the monitoring of catch composition and can be costly. With the cost associated with putting observers on all boats likely to be prohibitively high, consideration could be given to trading off the likelihood of being caught discarding with the imposition of large penalties on those who are caught. However, in practice it is difficult to identify the socially optimal level of investment — and the tradeoff between the penalty and likelihood of being caught — that should be made to enforce a ban on discarding at sea (Arnason 1994).

Closures and technical measures

Measures that prohibit the use of particular fishing methods or that involve the strategic closure of fishing grounds seek to reduce the catch of nontarget or undersize species that might be subsequently discarded. Minimum mesh sizes for nets can be used to reduce the catch of less valuable small fish. The permanent or temporary closure of nursery grounds can also reduce the catch of juvenile fish. Separator panels, square mesh cod-ends and ground gear modifications can also be used to reduce the catch of nontarget species that might otherwise be discarded (Kaufmann, Geen and Sen 1999).

While area closures and gear restrictions are relatively simple to implement, there is some danger in using them to manage discarding in quota managed fisheries. One of the reasons that ITQ management is considered an optimal system of fisheries management is because it gives fishers the flexibility to fish in an economically efficient manner. The introduction of gear restrictions and area closures for reasons other than biological sustainability — for example, to protect spawning stocks — reduce the efficiency with which fishers can operate, and create the inefficiencies symptomatic of fisheries managed with input controls.

Market based measures

Well functioning quota market

If fishers are able to easily obtain quota to cover unintended catch, the incentive to discard can be reduced. In addition to increasing economic efficiency in a fishery, a well functioning quota market is an important component of any suite of policies or management arrangements to discourage and reduce discarding.

The provision and dissemination of information on the quota holdings of individual fishers and their contact details, as well as the development of electronic quota trading systems can facilitate the trade of quota and lead to a better functioning market. Iceland has a particularly well developed quota market by world standards. A dynamic market has developed, with the bulk of trades occurring with the assistance of independent traders or brokers (Arnason 2000).

Quota substitution

Quota substitution allows fishers in a multispecies fishery who overcatch a quota species to forfeit the use of uncaught quota of another species (Kaufamann et al. 1999). In practice, this requires the development of a set of conversion ratios to prevent the creation of an incentive for fishers to target species that they have insufficient quota for. A quota substitution system operates in Iceland, with quota in the demersal fisheries able to be converted as 'cod equivalents' (Iceland Ministry of Fisheries 2004).

In addition to the challenge of setting conversion rates between the different species in a multispecies fishery, it is possible that landings of a particular species will exceed the TAC, threatening the long term sustainability of the stock. Until 2001 New Zealand fishers were able to substitute quota through a bycatch tradeoff system. There are currently no quota substitution provisions in New Zealand fisheries, in part owing to the persistent catch of some species in excess of the TAC (Peacey 2003).

Overcatch provisions

Overcatch provisions are a prominent feature in many quota managed fisheries. Permissible quota overcatch allows fishers to exceed their quota holding in a given year by a small percentage in return for a reduction in quota in the following year (Baulch and Pascoe 1992). This prevents the prosecution of fishers for small overruns of their quota and can reduce the incentive for operators to discard catch for which they have insufficient quota.

In Iceland, fishers are able to fish up to 5 per cent in excess of their vessel quota which is then withdrawn from the allocated quota in the following year (Arnarson 2002; Xinshan 2000). Similar provisions exist for some quota species in the SETF (Elliston et al. 2004). New Zealand also had overcatch provisions for a number of years that allowed for overcatch of up to 10 per cent, but these were removed when the system for managing discarding was overhauled in 2001 (Peacey 2003).

While popular in a number of quota managed fisheries and advocated as a method for reducing discarding, overcatch provisions can undermine the effectiveness of the quota market. Fishers may choose to use the overcatch provisions rather than purchase additional quota to cover any excess catch. As such, overcatch provisions can work against other measures aimed at creating a well functioning quota market which in turn can achieve economic efficiency objectives in addition to reducing the incentive to discard.

Deemed values

Deemed values are a system used in New Zealand fisheries to provide operators with an incentive to land rather than discard unwanted but commercial species. Fishers are allowed to sell landed overquota catch but are charged an administratively determined fee (Baulch and Pascoe 1992). The objective of the policy is to set the deemed value fee such that the residual price compensates the fisher for the effort involved in sorting and packing the fish, without providing an incentive to target species for which there is insufficient quota.

Since 2001, New Zealand adopted the deemed value system as the primary means for reducing discarding in its fisheries (Peacey 2003). Determining the value of the fee that provides fishers with an incentive to land incidental overquota catch without creating an incentive to target these fish is difficult. It is difficult to set a price that will induce the same behavior by all operators across the fishery. Fluctuations in market prices can further complicate the matter. If deemed values are set lower than the quota prices, then fishers have an incentive to pay the deemed value rather than lease quota to cover their overquota catch (Baulch and Pascoe 1992).

Prior to 2001, deemed values in New Zealand were based in part on the port price of different fish species. However, the balance between reducing overquota discarding and preventing the targeting of overquota speices was difficult to obtain, with some fishers able to make a profit and continue to target fish stocks while others made losses and had an incentive to discard catch of the same stock (Peacey 2003).

Under the new deemed value system in New Zealand, operating since 2001, the primary objective is to provide an incentive for fishers to cover catch with quota or their annual catch entitlement (ACE). The system separates the deemed value into two components: an annually refundable monthly interim deemed value and a nonrefundable annual deemed value (Peacey 2003). The interim deemed value is complementary to the quota buying flexibility policy, and is set to reinforce the need for fishers to cover their catch with quota before the year ends, or pay the higher annual deemed value. If a fisher can obtain sufficient ACE before the end of the fishing year, the interim deemed value is refunded.

A base rate annual deemed value is payable by fishers for levels of catch up to 20 per cent in excess of the ACE (Peacey 2003). The annual deemed value payable by fishers increases incrementally once catch exceeds quota by more than 20 per cent. The major objective of New Zealand's deemed value system is to remove the profit from catching fish stocks in excess of the ACE.

While the reformed policy simplified the administrative process of setting deemed values, it has not eliminated the potential for fishers to have an incentive to target overquota species in response to fluctuations in market prices. Incentives to target overquota species may also be created for operators with lower than average operating costs under this policy.

Value based ITQs

A value based quota system has been proposed to reduce the incentive to discard in quota managed fisheries (Turner 1996). Under a value based ITQ system, fishers hold quota expressed in dollar values rather than in weight or volume terms. Value based ITQs create an incentive for fishers to maximise the profit obtained from a given value — market value — of quota. The objective is to fill the given quota value at the lowest cost that reduces the incentive for fishers to discard lower value catch because of the costs associated with additional fishing effort to catch more valuable species.

The disadvantage of value based ITQs relates to the practicality of implementation. A value based system creates uncertainty over the volume of catch landed, which can make it difficult to achieve biologically sustainable TACs (Turner 1996). In part because of these impracticalities, value based ITQs have not been implemented as a fisheries management regime anywhere in the world.

Fixed quota packages

Fixed quota packages have been identified as an option for reducing discarding in a multi-species fishery by requiring quota holders to have minimum quota holdings for a range of different species (Baulch and Pascoe 1992). Fixed quota packages also influence the way in which the quota market operates, requiring packages of quota for a range of species to be sold together.

While fixed quota packages aim to discourage discarding by ensuring that fishers have a sufficient range of quota to cover the range of species caught in a multispecies fishery it is difficult to determine the combination and share of species that make up a fixed quota package. Further, these packages are likely to work against other measures aimed at creating a well functioning quota market that in turn can achieve economic efficiency objectives in addition to reducing the incentive to discard.

Grade based ITQs

Grade based ITQs have been suggested as a potential solution to highgrading. It involves separating the quota for a particular species into a number of grades. In a well functioning quota market the price of each grade of quota reflects the economic cost of harvesting, processing and marketing the grade, reducing the incentive to highgrade catch (Arnason 1994).

Grade based ITQs are likely to be impractical to implement, particularly in a multispecies fishery where quota for numerous species would need to be broken down into different size grades, imposing a high administrative burden (Arnason 2000). Even in a single species

fishery, grade based ITQs may be difficult to implement, with fishers facing an incentive to discard a particular grade if the quota for different grades are not allocated in proportion to the catch and quota for one grade is filled before quota for remaining grades are reached.

Iceland has implemented a less cumbersome variation of the grade based ITQ system, with quota effectively separated into two grades — small fish and larger fish, with the smaller fish not fully counting against quota (Arnason 2002). However, depending on the differences between the price obtained for small and larger fish, such a system could encourage the targeting of smaller fish, with implications for the sustainability of stocks targeted in this manner.

Options to reduce discarding in the SETF

It is important that the policies or management arrangements implemented to reduce discarding in the SETF are consistent with the biological sustainability and economic efficiency objectives that guide Australian fisheries management. This involves ensuring that TAC limits are set appropriately and are not exceeded, and that the policies do not introduce inefficiencies in fishing methods and practices.

Further, any policies to reduce discarding in the SETF need to be incorporated as part of the wider reform package for the fishery. Recent recommendations to improve economic efficiency in the SETF include reforms to the way in which management costs are recovered from operators, and measures to facilitate increased trade in quota (Elliston et al. 2004). One of the most significant reform recommendations involved improvements to the way in which TAC levels are set, which could lead to the lowering of TAC limits for some species.

If the level of discarding in the SETF has been low in part because of quota and TAC limits not being binding, then it is possible that reforms to TAC limits may lead to an increase in discarding in the future. The remainder of this section provides some recommendations for managing discarding in the SETF.

- *Continue monitoring the extent of discarding in the SETF and adjust TACs accordingly*

- *Banning discarding is likely to reduce the quality of the data collected, jeopardising the sustainability of the fishery*

The continued monitoring of discarding is an important aspect of managing the problem in the SETF. Even if data collected are not used to actively manage a reduction in discarding, they assist in the better estimation of fishing mortality and therefore contribute to the setting of sustainable TAC levels. There appears to be little reporting on actual discarding levels in New Zealand and Iceland, which may be partly because of the legislated ban on discarding at sea in both countries. As such, a ban on discarding in the SETF is likely to require the allocation of considerable resources to enforcement as well as making it virtually impossible to collect estimates on the actual level of discarding at sea that are needed to assist fisheries management.

- *Ensure that the quota market works efficiently*

Given the multispecies nature of the SETF, a well functioning quota market is likely to form an important part of any arrangements to reduce discarding. It is also consistent with other reforms proposed for the SETF (Elliston et al. 2004). The importance of economic efficiencies generated by a well functioning quota market mean that discarding policies, such as overcatch provisions and fixed quota packages, that undermine the effectiveness of the market should be considered with caution. It is possible that the implementation of these policies would impose costs in terms of economic inefficiencies that outweigh any benefits generated by a reduction in discarding. As such, a range of other policies that do not threaten the biological and economic sustainability of the fishery should be considered in preference.

- *If discarding is observed to increase from current levels, consideration should be given to a deemed value system similar to that operating in New Zealand*

Important lessons have been learned from New Zealand's experience with policies to reduce discarding in quota managed fisheries. A system of multiple measures to reduce discarding proved complicated and unwieldy in New Zealand. The deemed value approach adopted in 2001 as the primary means of managing discarding may be worth considering for the SETF if the level of discarding increases or is considered to be unacceptably high at current levels.

The reformed system in New Zealand has moved away from setting deemed values on the basis of fish prices, which represents important progress in the effectiveness of the policy by reducing the administration costs previously associated with calculating deemed values. However, fluctuations in market prices may still create an incentive to target overquota species and it remains difficult to set a deemed value that induces the same behavior by all operators within a fishery. In a multispecies fishery with considerable heterogeneity in vessel types such as the SETF, operating costs are likely to vary significantly. As a result, deemed values may discourage some operators from targeting overquota species while creating an incentive for others to continue fishing. This issue would need to be investigated further if deemed values were to be adopted in the SETF as a policy to reduce discarding.

- *If discarding principally takes the form of highgrading, temporary area closures may address the problem*

Where discarding is believed to take the form of highgrading, temporary area closures in the SETF may be able to prevent the catch of small size fish that operators wish to discard rather than land. Gear restrictions could have a similar effect but are likely to introduce inefficiencies at the vessel level that may impose costs that outweigh the benefits generated by reduced discarding.

empirical model of discarding for selected species in the SETF

Data sources

Integrated Scientific Monitoring Program Data

Data on the discarding and retention of key species in the SETF were obtained from the Integrated Scientific Monitoring Program (ISMP). The ISMP was formed by AFMA in 1996 following the amalgamation of various other data collection programs run by the Commonwealth and various states. Data collected prior to 1996 under the various other programs have been incorporated into the ISMP database. The Marine and Freshwater Resources Institute (MAFRI) within the Victorian Department of Primary Industries operate the ISMP on behalf of AFMA.

The ISMP is an observer program that currently consists of four onboard observers and three port measurers employed at various locations around the south east coastline. Participation in the program by operators is voluntary and confidential at the individual operator level. The main objective of the ISMP is to collect information on the quantity, species composition, size and age structure of retained and discarded catch from vessels in the fishery (Talman et al. 2004). At present, the majority of SETF fishers cooperate fully with the ISMP (Department of Primary Industries, Victoria 2002). As an example of the typical sample size, ISMP onboard monitors observed 940 individual shots in the SETF (approximately 101 000 fish) on 47 vessels from eight ports in 2003 (Talman et al. 2004).

The ISMP data are the only data collected on the extent of discarding in Australian fisheries. Because it is not illegal to discard, it is likely that the data collected from vessels with observers are representative of the fleet more generally. A sophisticated sampling regime is used to generate estimates within specified error bounds and MAFRI regularly review the process to ensure that the sampling regime reflects the dynamics of the fishery and generates statistically robust estimates (Talman et al. 2004).

Sydney Fish Market

Data on market prices for various grades of fish species in the SETF were sourced from the Sydney Fish Market's historical database. Prices were adjusted to allow for conversion between landed and live weight. Although it is recognised that fish caught in the SETF are sold to various domestic and international markets, the Sydney fish market data were used as a representative indicator of market conditions for various species in the fishery.

Quota monitoring system

Data on the volume of quota traded and the proportion of TAC filled were obtained from AFMA's quota monitoring system. Data recorded by the monitoring system include the volume of quota traded (both permanent and temporary), the volume of landings for particular species, and the available TAC limit for the species in the SETF covered by quota arrangements.

Methodology

An ordinary least squares (OLS) regression technique was used to investigate the factors influencing discarding in the SETF. The model was applied to data on four of the major species caught in the SETF. The OLS econometric model assumes the variance term is constant, and provides reliable estimates once a number of tests on the data have been successfully completed.

Diagnostic tests

A range of diagnostic tests were used to check the data for serial correlation and heteroscedasticity. The results of these tests supported the final choice of OLS regression technique (table 4).

Serial correlation Lagrange multiplier test

The serial correlation Lagrange multiplier tests carries out the Breusch–Godfrey Lagrange multiplier test for general higher order autoregressive moving average (ARMA) errors. The null hypothesis of the test is that there is no serial correlation in the residuals up to a specified order. If the test returns a small probability then the null hypothesis of no serial correlation is rejected and the data are known to display serial correlation.

Both the ling and silver (spotted) warehou data pass the serial correlation test (table 4).

ARCH Lagrange multiplier test

This is the Lagrange multiplier test for the autoregressive conditional heteroscedasticity (ARCH) in the residuals. ARCH does not invalidate the standard least squares inference, but ignoring ARCH effects may result in lost efficiency. The null hypothesis for this test is that there is no ARCH up to the specified order in the residuals. If the test returns a small probability then the null hypothesis of no ARCH is rejected and the data are known to display heteroscedasticity.

The ling data display no ARCH in the residuals; however, the silver (spotted) warehou

4 Results of diagnostic tests

	Ling	Silver (spotted) warehou
Serial correlation LM		
F-statistic	1.122	1.492
p-value	0.361	0.228
$T.R^2$	4.859	6.759
p-value	0.302	0.149
ARCH LM		
F-statistic	2.039	5.563
p-value	0.161	0.023
$T.R^2$	2.037	5.128
p-value	0.154	0.024

LM = Lagrange multiplier.

data do display ARCH in the residuals, implying heteroscedasticity (table 4). It is not uncommon for time series data to display signs of heteroscedasticity and fitting a general autoregressive conditional heteroscedasticity (GARCH) model can sometimes improve the fit and explanatory power of the model. However, fitting a GARCH model to the silver (spotted) warehou data did not improve the fit of the regression.

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WA Global Ocean Observing System
Woodside Energy Ltd
Woolmark Company Pty Ltd