Understanding the drivers of profitability in Commonwealth fisheries

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Summary

Many variables affect a fishery’s profitability over time. Without understanding these drivers and their relative movements, it is difficult to determine whether a fishery is moving closer to maximum economic yield (MEY). Furthermore, different drivers can cause profit to move in different directions and with variable magnitudes over time. The key variables that influence a fishery’s profitability include catch prices, input costs, vessel productivity and the stock biomass targeted in the fishery.

Index number profit decomposition is an approach that isolates the relative contribution of each of the variables above to changes in vessel-level profit over time. This paper presents index number profit decompositions for four key Commonwealth fishery sectors: the Commonwealth Trawl Sector (CTS) and the Shark Gillnet Sector (SGS) of the Southern and Eastern Scalefish and Shark Fishery, the Northern Prawn Fishery (NPF) and the Torres Strait Prawn Fishery (TSPF).

Recently, a number of policy actions have aimed to address stock sustainability and improve profitability in Australia’s Commonwealth fisheries. Two key policy changes are:

- implementation of the Commonwealth Fisheries Harvest Strategy Policy, which aims to prevent overfishing and move fisheries toward MEY
- government funded fishery structural adjustment assistance, particularly the Securing our Fishing Future structural adjustment package (completed in 2006).

The TSPF has not been subject to these policy changes, as it is not a fishery solely managed by the Commonwealth. It is managed under shared agreements between Australia and Papua New Guinea, through the Protected Zone Joint Authority. Nevertheless, it has been subject to its own set of policy changes including effort reductions in November 2005 and early 2006. In all cases, profit has changed following policy changes. However, variations in factors external to fishery management control (for example, prices of outputs and inputs) mean the effects of these policy changes on profit can be difficult to isolate.

The results presented in this report allow the influence of policy changes to be better understood. That is, changes in profit that have come about due to changes in variables which fishery managers have some indirect influence over (fish stocks and productivity) can be distinguished from those that fishery managers do not have control over (output prices and input prices). All results are presented using index numbers. Each index number presents information about a variable (output prices, fuel prices, labour prices, productivity, stock biomass and profitability) and its contribution to each vessel’s profit relative to the contribution that occurred for a reference vessel. Here, the reference vessel is defined as the average vessel in the most profitable year which is calculated by averaging each variable component across all sampled vessels in the most profitable year. This definition allows vessel-level performance in a fishery to be compared with an achievable level of performance for the average vessel in that fishery. Since the reference vessel is different for each fishery, results cannot be formally compared between fisheries.
Key results

The report presents results as indexes. A profit index reveals a vessel's profit relative to the profit of a reference firm (a benchmark firm that is typically the most profitable). Indexes for output prices, fuel prices, labour prices and productivity allow changes in the profit index to be attributed to contributions from these variables. The key findings from analysis of these indexes for each fishery are summarised here.

Commonwealth Trawl Sector

- Since 2004–05, the stock-adjusted profitability of the average vessel in the CTS (excluding offshore and factory trawlers) has been increasing.
- Most improvements in the stock-adjusted profit have been due to increases in output prices followed by stock-adjusted productivity.
- Increases in prices received for tiger flathead and an 'other species' group constituted most of the improvement in profit that resulted from output prices.
- Productivity improvements in recent years are consistent with regulatory and structural change in the sector, driven largely by the Securing our Fishing Future buyback (which concluded in 2006–07) and improved total allowable catch (TAC) settings. The stock biomasses of most key species in the sector have also been improving since adoption of a harvest strategy framework in 2005, which has allowed better targeting of MEY. The sector is likely to have moved towards MEY.

Shark Gillnet Sector

- The main driver of stock-adjusted profitability in the sector was stock-adjusted productivity. It was the main factor behind the improvement in the stock-adjusted profit post 2005–06.
- To a lesser extent, increases in prices received for gummy shark have also contributed to recent improvements in stock-adjusted profit.
- The productivity improvements in the SGS were influenced by factors similar to those affecting the CTS. In particular, the Securing our Fishing Future buyback, which concluded in 2006–07, was a significant driver behind the large increases in catches per vessel. Maintaining a focus on MEY for gummy shark should continue to improve the economic performance of the sector. While rebuilding of school shark stocks will improve economic performance in the long term, there will be short-term challenges.

Northern Prawn Fishery

- The NPF results are split by fishing season with each season treated as two separate sectors: the tiger prawn sector and the banana prawn sector.
- For the tiger prawn sector, stock-adjusted profit for the average vessel followed a decreasing trend from 2000–01 to 2004–05. It has gradually recovered since 2004–05 but remains well below levels in 2000–01.
The main driver of stock-adjusted profit in the tiger prawn sector has been output prices; falling prices had a strong negative influence on profit since 2000–01. However, substantial improvements in stock-adjusted productivity since 2005–06 have increased stock-adjusted profit. While fuel prices have had a negative influence on stock-adjusted profit since 2004–05, this influence is minor relative to the influence of output prices and productivity. For the banana prawn sector, profitability for the average vessel fell between 2000–01 and 2004–05. Since then, a substantial improvement occurred in 2007–08 and has been maintained. The decline in profitability in the banana prawn sector between 2000–01 and 2004–05 was primarily driven by output prices. The improvements in profitability since 2004–05 were driven by productivity, with the contribution to profit from output prices remaining low. As observed in the tiger prawn sector, fuel prices had a negative influence on profit but were of less importance relative to output prices and productivity. The ability of productivity to negate the negative influence of falling output prices and rising fuel prices in the NPF allowed profitability to improve in both sectors. These productivity improvements are likely to have been supported by the Securing our Fishing Future package and a number of changes to gear restrictions since 2006. For the tiger prawn sector, management of stocks against a MEY target has also contributed to productivity improvements. For the banana prawn sector, increased catch rates for banana prawns contributed to productivity but are a factor external to management influence given the variable nature of banana prawn stocks.

Torres Strait Prawn Fishery

The profitability of the average vessel followed a declining trend over the full period of analysis from 1998–99 to 2007–08. Between 1998–99 and 2000–01, falling vessel-level productivity was the key driver behind the fall in profitability. Favourable contributions from output prices prevented profitability from being lower. Since 2000–01, the contribution to profit from productivity remained relatively unchanged but falling output prices maintained the declining trend in profitability. The negative influence of increasing fuel prices since 2002–03 also had an influence, but to less of a degree. Historically, profitability trends in the TSPF reflected those in the NPF, but this has not been the case since 2004–05. Differences in relative productivity growth between the two fisheries have been a key driver behind the divergence in profitability trends. Unlike the NPF, the TSPF has not achieved the productivity improvements necessary to remain profitable when faced with lower output prices and higher fuel prices. This partly reflects the different types of policy changes that occurred in each fishery over recent years. For example, management restrictions on trade in fishing entitlements and ongoing restrictions on vessel size in the TSPF are likely to have constrained operators’ ability to achieve the necessary productivity gains.
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1 Introduction

Over the last two decades, effective management of Australia’s Commonwealth fishery resources has become increasingly reliant on economic information. This has been driven by the Australian Fisheries Management Authority’s (AFMA) legislated objective to manage fisheries in a way that maximises the net economic returns to the Australian community within the context of ecological sustainability. More recently, the Commonwealth Fisheries Harvest Strategy Policy (2007) put this economic objective at the forefront of fishery management decisions. It requires that harvest strategies (a set of rules that guide decisions on appropriate fishery harvest levels) be developed for Commonwealth fisheries that seek to maintain fish stocks at the target biomass associated with maximum economic yield (MEY). MEY refers to the point in a commercial fishery where fishing effort, catch and fish stock biomass are at levels that, on average, maximise the net economic return to society from the commercial use of that fishery resource (Kompas & Gooday 2005). For a commercial fishery, net economic returns are defined by the difference between total revenues earned and total economic costs incurred. This in turn reflects a fishery’s profitability.

There is an increasing need to develop informative tools to either assist fishery management decision-making against the MEY objective or to monitor management performance against it (Box 1). The index number profit decomposition is one method that can help monitor management performance. This approach allows the different drivers behind a fishery’s profit variability (such as output price, catch, fuel cost and so on) to be assessed, quantified and compared. More specifically, it allows the relative contributions of these drivers to changes in profit to be decomposed into separate elements, including the impact of a fishery’s stock abundance. It does this by quantifying changes in vessel-level profit according to the contributions from changes in key drivers, with each individual vessel’s performance being defined by an index relative to a selected reference vessel.

The profit decomposition approach was first applied by Fox et al. (2003) to the British Columbia halibut fishery, and it has since been applied to Canada’s Scotia–Fundy mobile gear fishery (Dupont et al. 2005), the Commonwealth Trawl Sector (CTS) of the Southern and Eastern Scalefish and Shark Fishery (SESSF) (Fox et al. 2006; Grafton & Kompas 2007) and the Eastern Tuna and Billfish Fishery (Kompas et al. 2009). This paper updates the previous work on the CTS and, for the first time, extends the method to the Shark Gillnet Sector (SGS) of the SESSF, the Northern Prawn Fishery (NPF) and Torres Strait Prawn Fishery (TSPF). For the CTS and SGS, preliminary versions of the results are presented in Vieira (2011a) and Vieira (2011b).

The results in this report help to assess the influence of previous management decisions on vessel-level profitability. The method used allows the contributors to profit that management has some influence over—that is, fish stocks and productivity—to be distinguished from those factors that are external of management control, such as prices for output (for example, fish) and input (for example, fuel). Two key policy changes that are likely to have influenced recent vessel level profitability are:

- The Securing our Fishing Future structural adjustment package. This government funded package included a vessel buyback and concluded in 2006–07. It reduced vessel numbers in key Commonwealth fisheries, including the CTS, the SGS and the NPF. As Vieira et al. (2010) noted, such a buyback could cause productivity improvements in a targeted fishery by having fewer vessels competing for a similar-sized resource (stock) and by removing the least efficient vessels from a fishery (a result of the voluntary tender process used in the buyback).
• The Commonwealth Fisheries Harvest Strategy Policy (2007). This policy requires that every Commonwealth fishery be managed according to a fishery-specific harvest strategy that is designed to prevent overfishing and move stocks to a biomass target consistent with MEY. For some fisheries, this meant more restrictive management settings to reduce catches and rebuild fish stocks. Stock rebuilding, if it occurs, will have a favourable impact on profitability, making catches achievable with fewer inputs. However, in a fishery where management uses market-based fishing rights (such as individual transferable quotas and individual transferrable effort units), more restrictive management settings will also encourage greater autonomous adjustment in the fishery so fishing rights move to the most profitable (and, often, more productive) operators in the fishery.

Although the TSPF has not been subject to these changes, as it is a jointly managed fishery, it has been affected by its own set of policy changes, including effort reductions in late 2005 and early 2006. Moreover, TSPF fishery management objectives have been increasingly aligned with those of Commonwealth fisheries since it adopted the TSPF Harvest Strategy policy (2010) in 2011. This policy was guided by the Commonwealth Fisheries Harvest Strategy Policy (AFMA 2010b).

In all cases, profit changes have followed such policy changes. However, variations in factors external to fishery management control (for example, prices of outputs and inputs) can make the effects of these policy changes on profit difficult to isolate.
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Box 1 Profit decomposition as a tool for assessing fishery economic performance

ABARES undertakes a range of research focused on maximising net economic returns (NER) to the Australian community from management of Commonwealth fisheries. The Commonwealth Fisheries Harvest Strategy Policy’s (2007) recommended harvest strategy target of MEY created a greater need for such research. The research can be divided into two streams:

**Informing management decisions against the economic objective**

This research is forward-looking and advises on the fishery management settings necessary to achieve MEY. Bioeconomic models serve this purpose and have been developed for the NPF (Kompas & Che 2004) and the SESSF (Kompas & Che 2006). Other management strategy evaluation based approaches that include an economic component can also do this and are a potential future research focus.

**Monitoring management performance against the economic objective**

This research is backward-looking and assesses the impact of previous management decisions on economic performance. For the fisheries analysed in this report, this includes survey-based estimation of NER (George et al. 2012; Perks & Vieira 2010), total factor productivity analysis (Hormis & Vieira 2012) and examination of economic efficiency (Elliston et al. 2004; Kompas & Che 2002; New 2012).

Profit decomposition is another tool in this stream, as it can be used to evaluate a fishery’s previous economic performance. By comparing the key drivers of a fishery’s profitability, the relative importance of drivers that are external to a fishery manager’s control, such as input and output prices, can be separated from those that a fishery manager can influence, like fish stock levels and economic productivity. While approaches such as NER estimation and productivity analysis are able to show how performance has changed, the profit decomposition approach is able to show more clearly why the observed changes have occurred. This is a key advantage of the approach.

Another advantage is that it is analytically less complex and less data intensive relative to other monitoring research tools, such as efficiency analysis. Its application here used a small number of key variables in ABARES vessel-level economic survey databases on revenue, fuel use and labour. This was combined with catch, effort and vessel characteristic data from AFMA records. Given the small amount of economic survey data used, the approach could be developed to be applied to relatively data-poor fisheries for which economic survey data do not exist. Additionally, there may be potential to provide preliminary non-survey based estimates of indexes for surveyed fisheries to provide more timely results.

While the method provides information on previous performance, it cannot inform management decisions about what future harvest levels should be to achieve MEY. Nevertheless, it can indicate whether a fishery has moved toward this objective.
2 Method

This chapter outlines the method used to decompose profitability into input prices, output prices and productivity. See Appendix A for more technical descriptions. The method follows the approach used in previous fishery analyses (for example, Dupont et al. 2005; Fox et al. 2003; Fox et al. 2006; Grafton & Kompas 2007; Kompas et al. 2009). It has also been applied to the telecommunications sector (Lawrence et al. 2006) and to decompose growth in domestic product in an open economy (Diewert & Morrison 1986; Fox & Kohli 1998). For details of the approach and its theoretical underpinnings, see Kirkley et al. (2002) and Fox et al. (2003).

The method uses index numbers to decompose and quantify the relative contribution of a variable to a firm’s profitability. It does so by examining a variable’s share of profit for one firm and compares it with the share of profit of the same variable for a reference firm. A reference firm is defined here as the average firm in the most profitable year (Kompas et al. 2009).

In the case of a fishery, a firm is represented by a vessel and the key variables that contribute to a vessel’s profit include output price \( P_o \), prices of inputs (labour \( P_l \) and fuel \( P_F \) prices), productivity \( R \) and fixed capital \( K \). For simplicity, output and inputs are together defined as ‘netputs’, where inputs are netputs with negative values and outputs are those with positive values. A vessel’s profit is then defined as the sum of netput prices (measured in real terms) multiplied by netput quantities. This profit measure is often referred to as variable profit or ‘restricted profit’ (Fox et al. 2006).

To get the profit index, the profit of each vessel in a fishery is divided by the profit of the reference vessel for that fishery. This can then be decomposed to find the relative contribution to profit from each netput price, productivity and fixed capital:

\[
\theta^{a,b} = P_o^{a,b} \cdot P_F^{a,b} \cdot P_L^{a,b} \cdot R^{a,b} \cdot K^{a,b}
\]

where \( (a, b) \) indicates relativity between an individual vessel \( (b) \) and the reference vessel \( (a) \).

Here, a vessel’s productivity \( R \) is calculated by dividing an implicit quantity index (implicit in that it represents profit over the product of netput price indexes) by the fixed capital index. This implies that productivity, as defined here, is a measure of a vessel’s ability to use its fixed capital input to produce output. More specifically:

\[
R^{a,b} = Q^{a,b} / K^{a,b}
\]

where \( K \) is measured by vessel length.

A fishery’s overall performance is estimated by geometric averages of individual sample vessel index results in each year. A profit index \( (\theta^{a,b}) \) less than one indicates a profit that is lower than that of the reference vessel. When comparing index values for output price \( (P_o^{a,b}) \), fuel price \( (P_F^{a,b}) \), labour price \( (P_L^{a,b}) \) and productivity \( (R^{a,b}) \), the following interpretation should be used:

- where an index has a value less than one, the positive contribution of that index to profit is less than that of the reference vessel
- where an index has a value greater than one, the positive contribution of that index to profit is greater than that of the reference vessel.
For example, if an input index, such as the fuel price index, has a value greater than one, it means that a vessel’s profit is receiving a greater positive contribution from fuel prices relative to the reference vessel. This would reflect either, or both, a lower price paid for fuel by that vessel or fuel accounting for a lower share of its total costs. On the other hand, if an output price index has a value greater than one, it suggests that the price received for output is higher—that is, more favourable—than the price received by the reference vessel.

In a fishery that catches multiple species, a higher output price index may reflect a catch mix that includes a greater proportion of high valued species, rather than the receiving of higher prices more generally. For this reason, the output price index can be further decomposed into output price indexes for individual species. This allows the contribution of different species to profitability over time to be evaluated.

Where fish stock biomass information is available, a stock-adjusted profit index ($\theta_{s}^{a,b}$) is also estimated and decomposed. Adjusting for stock biomass variation effects allows for more consistent comparisons of underlying average vessel performance over time. The effect of stock biomass on profit is captured in the productivity index or more specifically:

\[
\theta_{s}^{a,b} = P_{o}^{a,b} \times P_{p}^{a,b} \times P_{l}^{a,b} \times R_{s}^{a,b} \times K_{a,b}
\]

where $R_{s}^{a,b} = R_{a,b} / S_{a,b}$.

In years of high stocks, the unadjusted productivity index ($R^{a,b}$) will increase as vessels can increase their catch without using more capital. The stock-adjusted productivity index ($R_{s}^{a,b}$) will exclude the influence of stock biomass variability and provide a more accurate assessment of vessel level productivity. Stock effects can be isolated by taking the difference of the profit index ($\theta^{a,b}$) and the stock-adjusted profit index ($\theta_{s}^{a,b}$).

All results that are presented have been averaged across vessels. As a result, while the multiplicative relationship of the indexes in equation m1 and m3 holds for individual vessels, the relationship does not always hold mathematically once indexes have been averaged. This is just an artefact of the way the results have been presented and has no implications for the reliability of the results. It should also be noted that the results for each fishery use different reference vessels. This means indexes cannot be compared across fisheries, but index trends over time can be compared.

Construction of indexes for each fishery uses a combination of ABARES economic survey data and fishery statistics data, together with AFMA catch and effort data. Further details are provided in each chapter for each fishery.
3 Commonwealth Trawl Sector

3.1 Background

The Commonwealth Trawl Sector (CTS) is a sector of the Southern and Eastern Scalefish and Shark Fishery (SESSF) (Figure 1). It is one of Australia’s oldest commercial fishing sectors, having commenced operation off Sydney in the early 1900s. The primary harvesting method used in the sector is otter trawling, although a number of Danish seine vessels operate out of Lakes Entrance, in Victoria.

More than 100 species are routinely caught in the sector. However, five species constitute more than 60 per cent of the landed trawl tonnage, on average, in any given year: blue grenadier, tiger flathead, orange roughy, silver warehou and pink ling. The sector’s gross value of production in real terms has been in steady decline over the last decade, falling from $98.4 million in 1999–2000 to $57.2 million in 2008–09 (in 2009–10 dollars). A key driver of this decline has been falls in catches, driven by reductions in the total allowable catches (TACs) in response to concerns about the sustainability of key stocks. However, larger reductions in costs meant net economic returns in the sector have risen since 2004–05.
Management of the sector is predominantly based on output controls in the form of TACs allocated as individual transferable quotas (ITQs). These were first introduced for gemfish and orange roughy in 1988 and 1990, respectively. Currently, 34 species are managed under global TACs that apply to all sectors in the SESSF (AFMA 2010a).

In 2005, the fishery adopted a harvest strategy framework to provide a more strategic approach for determining TACs. This predated the 2007 Commonwealth Fisheries Harvest Strategy Policy. The framework provides rules around how TACs should be altered under different stock scenarios subject to a target of maximum economic yield (MEY). Since being implemented, TAC settings have reduced the number of species classified as subject to overfishing and have promoted greater autonomous adjustment in the fishery (Stobutzki et al. 2011).

Vessel numbers in the CTS reduced over the last decade, with the recent government funded Securing our Fishing Future vessel buyback further driving this trend. The buyback concluded in November 2006 and resulted in a 46 per cent reduction in the number of fishing permits in the SESSF. At the same time, the number of trawl vessel in the CTS declined by 39 per cent to 38 in 2007–08. Vieira et al. (2010) assessed the overall economic impact of the buyback on the CTS as positive.

3.2 Data and application

Revenue and cost data were sourced from ABARES survey data for 1998–99 to 2008–09 for sampled vessels (Perks & Vieira 2010). Key variables include vessel fish sales receipts, labour costs and fuel costs. These data were combined with logbook catch, effort and catch disposal record data on vessel departure and arrival time, both supplied by AFMA.

The CTS is typically divided into three operation types: otter trawlers, Danish seiners and factory trawlers. Only four factory trawlers operated in the sector between 1998–99 and 2008–09 and no survey data exist for these vessels. Therefore, the factory trawlers were not included in the analysis. Otter trawlers can be further categorised according to whether their operations focus on inshore or offshore waters. Historically, offshore trawlers targeted orange roughy. However, reductions in orange roughy TACs over the last decade to address sustainability concerns resulted in a substantial decline in the number of offshore trawlers. Consequently, offshore trawlers were also excluded from the analysis.

The analysis focused on inshore trawl vessels (referred to from here as trawl vessels) and Danish seine vessels. A total of 43 trawl and six Danish seine vessel observations were removed from the analysis due to data inconsistencies—particularly in relation to the price adjustment that was undertaken to allow for the multi-output analysis. This left 189 trawl and 69 Danish seine vessels in the sample data set. See tables C1 and C2 in Appendix C for the sample and population of the trawl sector and Danish seine sector, respectively, along with key summary statistics. The four main species caught by vessels in the trawl sample were blue grenadier, tiger flathead, pink ling and silver warehou. On average, these species accounted for 49 per cent of the average catch per vessel. The average Danish seine vessel caught mainly tiger flathead and eastern school whiting, which on average accounted for 90 per cent of total catch.

The aggregated stock index was calculated using biomass estimates for blue grenadier, tiger flathead, pink ling, silver warehou and eastern school whiting—as well as orange roughy, blue warehou, jackass morwong and gemfish. Together, these species have usually accounted for around 80 per cent of the sector’s total catch and value. The stock biomass estimates for these individual species were calculated by CSIRO and were sourced from Jemery Day (pers. comm., 2010).
3.3 Empirical results

Average vessel profit for the CTS was at its highest in 2008–09. Therefore, the average vessel in that year was selected as the reference vessel. A profit index \((\theta^{ab})\) of less than one indicates an average profit that is lower than that of the reference vessel. When comparing index values against the reference vessel for output price \((P_O)\), fuel price \((P_F)\), labour price \((P_L)\) and stock-adjusted productivity \((R_S)\), the following interpretation should be used:

- where an index has a value less than one, the positive contribution of that index to profit is less than that of the reference vessel
- where an index has a value greater than one, the positive contribution of that index to profit is greater than that of the reference vessel.

The stock adjusted profit index \((\theta_S)\) for the average vessel has been increasing toward that of the reference vessel since 2004–05 (Table 1, Figure 2). This is consistent with ABARES survey-based estimates of net economic returns to the sector, which suggest a positive trend in profitability (Perks & Vieira 2010).

The two main drivers of profitability are the price of output \((P_O)\) and the stock-adjusted productivity index \((R_S)\). Between 2004–05 and 2008–09, the stock-adjusted productivity index increased from 0.63 to 0.88. Although highly variable, it was at its highest point in 2007–08, the year after the Securing our Fishing Future buyback concluded, and remained high in 2008–09. Similarly, the output price index rose by 89 per cent between 2004–05 and 2008–09, from a value of 0.49 to 0.92. As all price data are in real terms, this change reflects real growth in the average price received for catch. With these changes, the stock-adjusted profit index more than doubled between 2004–05 and 2008–09 from a value of 0.30 to 0.79.

Table 1 Index number profit decomposition results for the Commonwealth Trawl Sector, average by financial year

<table>
<thead>
<tr>
<th>Financial year</th>
<th>No.</th>
<th>(\theta)</th>
<th>(\theta_S)</th>
<th>(P_O)</th>
<th>(P_L)</th>
<th>(P_F)</th>
<th>(K)</th>
<th>(R)</th>
<th>(S)</th>
<th>(R_S)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998–99</td>
<td>30</td>
<td>0.59</td>
<td>0.51</td>
<td>0.61</td>
<td>0.99</td>
<td>1.07</td>
<td>0.96</td>
<td>0.95</td>
<td>1.17</td>
<td>0.81</td>
</tr>
<tr>
<td>1999–2000</td>
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<td>2008–09</td>
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<td>0.97</td>
<td>0.88</td>
<td>1.00</td>
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</tbody>
</table>

Note: No. represents the number of sample vessels, \(\theta\) is the profit index, \(\theta_S\) is the stock adjusted profit index, \(P_O\) is the price of output index, \(P_L\) is the price of labour index, \(P_F\) is the price of fuel index, \(K\) is the capital index, \(R\) is the productivity index, \(S\) is the stock index and \(R_S\) is the stock adjusted productivity index.
The contribution of labour price to relative profit has remained more or less constant over time, as indicated by the labour price index \( (P_L) \) staying close to one. Labour costs are typically a substantial cost in the CTS, and made up around 31 per cent of the average boat’s total costs in 2008–09 (Perks & Vieira 2010). The results presented here simply suggest that the contribution of labour price to profit remains similar to that of the reference vessel over the full time series. The labour price used here was an assumed wage rate. The alternative approach would have involved using revenue shares paid to crew which vary with revenue. However, there are a number of issues associated with taking this approach which are explained in Appendix A.

Similarly, although fuel cost constitutes a large proportion of total cost, the contribution of fuel price to relative profit has remained stable, as indicated by a fuel price index \( (P_F) \) of close to one. The fuel price index switched from being above one to below one in 2005–06. This suggests that, relative to the fuel prices paid by the average vessel in the reference year, 2008–09, lower fuel prices made some positive contribution to vessel profitability before 2005–06.

For trawl vessels, the output price index was further decomposed to evaluate the contribution to profitability from prices of individual species. The species prices considered were tiger flathead \( (P_{TF}) \), blue grenadier \( (P_{BG}) \), pink ling \( (P_{PL}) \), silver warehou \( (P_{SW}) \) and the aggregate of all other species \( (P_{OT}) \). Given the low sample number for Danish seiners, multi-output results for this method are not presented here. See Vieira (2011a) for preliminary multi-output results for this method.

The stock-adjusted profit index for the average trawl vessel was at its lowest in 2004–05 (Figure 3). In the same year, the price indexes for tiger flathead and other species were also relatively low, at 0.71 and 0.75 respectively. Since 2004–05, increases in the price indexes for tiger flathead and other species were the most significant price contributors behind the increases in stock-adjusted profit. The price indexes for pink ling and blue grenadier also increased over the same period. However, the prices received for these two species, on average, made relatively less important contributions to profitability. This is indicated by these indexes having values of close to one.
3.4 Discussion and conclusions

In summary, the stock-adjusted profit index ($\theta_3$) for the average vessel in the CTS has been improving significantly since 2004–05. This was driven mostly by higher output prices and higher levels of stock-adjusted productivity. Prices for two species groups, tiger flathead and other species, were the major contributors to changes in the profit index for output prices.

Improvements in stock-adjusted productivity since 2006–07 are consistent with regulatory and structural change in the sector, including the government funded buyback that concluded in 2006–07. More specifically, the productivity improvements are likely to be attributable to positive effects of reduced crowding, which occur with fewer vessels operating in the sector (Pascoe et al. 2001; Smith 1969). The design of the buyback process also encouraged less efficient vessels to exit the sector, which is consistent with the findings of Vieira et al. (2010). The authors showed that the number of vessels in the sector decreased by 40 per cent, from 81 vessels to 49 vessels, between 2005–06 and 2007–08. Over the same period, average catch per vessel increased from 246 tonnes to 310 tonnes (Vieira et al. 2010).

Because of differences in data and assumptions, detailed comparisons of the results with previous profit decompositions for the CTS would not be reliable (Fox et al. 2006; Grafton & Kompas 2007). Nevertheless, general comparisons of key findings and conclusions can provide useful insights. Fox et al. (2006) drew similar conclusions on improved productivity following a vessel buyback, focusing on a buyback in 1997. Moreover, the authors also identified output prices to be the most important driver of profitability for the reference vessel.

Given the recent improvements in vessel-level profitability and productivity shown here, it is likely that the CTS has moved towards MEY. This is supported by the substantial increase in the fishery’s net economic returns, from $1.6 million in 2005–06 to $7.1 million in 2007–08 (Vieira et al. 2010). Continued management of the CTS according to the Commonwealth Harvest Strategy Policy objectives will help maintain this performance.
4 Shark Gillnet Sector

4.1 Background

The Shark Gillnet Sector (SGS) of the SESSF was originally part of the Southern Shark Fishery (Figure 4), which has operated since 1927 (AFMA 2004). The main gear type currently used in the sector is gillnetting and the key species caught are gummy shark, which accounts for around 60 per cent of landings, and school shark. However, due to the school shark's population status, management arrangements require that there be no targeted fishing for this species.

Figure 4 Location of the Shark Gillnet Sector

Note: Relative fishing intensity in the SGS
Source: Woodhams et al. 2011a

Production value in real terms for the Gillnet, Hook and Trap Sector (GHTS), which encompasses the SGS, has followed an increasing trend in recent years, peaking at $18.1 million in 2008–09. Gummy shark accounted for 59 per cent of this value. As in the CTS, management in the SGS is predominantly based on output controls in the form of TACs allocated as ITQs. These were first introduced into the sector for school and gummy sharks in 2001 and then for saw shark and elephant fish in 2002 (Vieira et al. 2008). The use of quota Statutory Fishing Rights (SFRs) to manage these species was introduced in May 2010, following resolution of legal challenges to the quota allocation formula (Woodhams et al. 2011a).

The aim of the SESSF harvest strategy framework, which came into effect in 2005, is to provide a more strategic approach for determining allowable catches. The framework provides guidelines for the appropriate setting of TACs such that stock levels associated with MEY can be achieved.

Vessel numbers in the SGS have declined over the last decade. The Securing our Fishing Future vessel buyback further reduced the number of active vessels in the sector. Gillnet vessel
numbers decreased by 27 per cent between 2005–06 and 2007–08. The buyback also resulted in a 44 per cent reduction in the number of boat SFRs in the sector.

4.2 Data and application

Data for the SGS decomposition draw on ABARES economic survey data for 1998–99 to 2008–09, which included revenue and cost data for sampled vessels (Perks & Vieira 2010). These data were combined with logbook catch and effort data and catch-disposal record data on vessel departure and arrival time, both supplied by AFMA.

Table C3 in Appendix C presents the sample, population and key characteristics of sampled gillnet vessels. Gummy shark and school shark accounted for 80 per cent of the average sampled vessel’s catch over the period analysed. Therefore, the aggregated stock abundance was calculated using stock abundances and harvests of these two key species. The stock biomass estimates for these individual species were calculated by and sourced from CSIRO (J Day, pers. comm., 2010).

4.3 Empirical results

The most profitable year for the SGS was 2007–08, so the average vessel in that year was selected as the reference vessel. A profit index ($\theta^{a,b}$) less than one indicates an average profit that is lower than that of the reference vessel. When comparing index values against the reference vessel for output price ($P_o$), fuel price ($P_f$), labour price ($P_l$) and stock-adjusted productivity ($R_S$), the following interpretation should be used:

- where an index has a value less than one, the positive contribution of that index to profit is less than that of the reference vessel
- where an index has a value greater than one, the positive contribution of that index to profit is greater than that of the reference vessel.

Relative to the reference vessel, stock-adjusted profitability for the average vessel declined substantially between 1999–2000 and 2005–06 (Table 2, Figure 5). It then recovered somewhat in the three years that followed. The profit index increased from 0.32 in 2005–06 to 0.71 in 2007–08. It then declined slightly in 2008–09 to 0.66.

The main factor driving profitability in the SGS was productivity. Movements in the average profit index appear to have closely followed the productivity index over the entire period. Specifically, improvements in the profit index between 2005–06 and 2007–08 corresponded with a 124 per cent increase in the stock-adjusted productivity index over the same period, from 0.33 to 0.74. The stock-adjusted productivity index began to improve significantly in 2006–07, the year of the buyback, and has remained relatively high since. It is likely that the productivity improvements were partly a consequence of the removal of less efficient vessels from the sector through the Securing our Fishing Future buyback (Vieira et al. 2010).
Table 2 Index number profit decomposition results for the Shark Gillnet Sector, average by financial year

<table>
<thead>
<tr>
<th>Financial year</th>
<th>No.</th>
<th>$\theta$</th>
<th>$\theta_S$</th>
<th>$P_O$</th>
<th>$P_L$</th>
<th>$P_F$</th>
<th>$K$</th>
<th>$R$</th>
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<td>1.01</td>
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<td>0.71</td>
</tr>
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<td>1.00</td>
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<tr>
<td>2008–09</td>
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<td>0.99</td>
<td>0.60</td>
<td>0.97</td>
<td>0.62</td>
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Note: No. represents the number of sampled vessels, $\theta$ is the profit index, $\theta_S$ is the stock adjusted profit index, $P_O$ is the price of output index, $P_L$ is the price of labour index, $P_F$ is the price of fuel index, $K$ is the capital index, $R$ is the productivity index, $S$ is the stock index and $R_S$ is the stock adjusted productivity index. Although 2007–08 was the most profitable year, the profit index suggests that profitability was relatively higher for vessels in 1999–2000; this is a result of using the geometric mean for the reporting of index averages and the arithmetic mean for the selection of the reference year.

Figure 5 Key indexes for vessels in the Shark Gillnet Sector, average by financial year

Of the netputs, price indexes for fuel ($P_F$) and labour ($P_L$) remained close or equal to one, which suggests a smaller influence on relative profitability compared to output prices and productivity. Both labour and fuel costs are significant cost items in the SGS, constituting 40 per cent and 11 per cent, respectively, of the average gillnet vessel’s total cost in 2008-09 (Perks & Vieira 2010). For labour, the results presented here simply suggest that the contribution of labour price to profit remains similar to that of the reference vessel over the full time series. The labour price used here was an assumed wage rate. The alternative approach would have involved using revenue shares paid to crew which vary with revenue. However, a number of issues are associated with taking this latter approach; Appendix A provides an explanation.

The output price index ($P_O$), on the other hand, was slightly more volatile and distant from one, contributing relatively more to profitability movements over the period analysed. The positive contribution to profit from output prices has increased since 2006–07. This is indicated by the output price index ($P_O$), which increased from 0.84 in 2006–07 to 1.08 in 2008–09.
A decomposition of the output price index identified gummy shark prices \( (P_g) \) as the most important price determinant of profitability (Figure 6). This was expected, given the dominance of gummy shark in the sector’s total catch. Price index fluctuations of school shark \( (P_s) \) and other species \( (P_{ot}) \) had a relatively minor influence.

**Figure 6 Decomposed output price indexes for vessels in the Shark Gillnet Sector, average by financial year**

![Graph showing decomposed output price indexes for vessels in the Shark Gillnet Sector, average by financial year.](image)

*Note: \( \theta_g \) is the stock adjusted profit index, \( P_g \) is the gummy shark price index, \( P_s \) is the school shark price index and \( P_{ot} \) is the price index of other species.

### 4.4 Discussion and conclusions

The improvements in profitability in the SGS over the past few years were driven primarily by improvements in productivity and, to a lesser extent, favourable gummy shark prices. This is consistent with trends observed in net economic returns for the SGS (Perks & Vieira 2010) and suggests that the sector has moved closer to MEY.

The observed productivity improvements are consistent with Vieira et al. (2010) who observed that average catch per vessel increased from 56 tonnes to 71 tonnes over the period from 2005–06 to 2007–08 with the decline in vessel numbers in the GHTS. The Securing our Fishing Future buyback (which is likely to have led to removal of less efficient vessels from the fishery) and the targeting of MEY (through TAC settings for key species) are expected to be the key drivers behind these improvements.

Although school shark prices made a relatively minor contribution to profitability in this sector over the period analysed, school shark stocks are considered heavily depleted and overfished (Woodhams et al. 2011a). Therefore, vessel-level profits and fishery-level net economic returns may have been higher had school shark not been heavily overfished in the early 1990s. While rebuilding of school shark stocks will improve economic performance in the long term, there will be challenges in the short term. If the fishery can rebuild stocks while maintaining a focus on MEY for other key stocks, improved economic performance is likely to result.
5 Northern Prawn Fishery

5.1 Background

The Northern Prawn Fishery (NPF) is located off Australia's northern coast, between Cape Londonderry in Western Australia and Cape York in north Queensland (Figure 7). This multi-species prawn fishery stretches along approximately 6000 kilometres of coastline.

With a gross value of production (GVP) of $88.8 million in 2010, the NPF is Australia’s most valuable single method Commonwealth fishery (Woodhams et al. 2011b). The vast majority of its catch and GVP comes from tiger and banana prawns, caught primarily in their respective fishing seasons, although small amounts of each species are still caught in the other’s season. The tiger prawn season is usually from August to November and the banana prawn season is from March to June. In 2009–10, these species made up 80 per cent of total landed catch and 96 per cent of GVP.

Tiger prawn catches in the NPF are primarily export oriented. Main export markets include Japan and Hong Kong. As a result, prices for these species are highly dependent on external factors such as the exchange rate and international competition. This makes tiger prawn prices vulnerable to external shocks. While tiger prawns command higher prices than banana prawns, prices received for tiger prawns are much more volatile. Historically, tiger prawns have made up the majority of GVP in the NPF.
Favourable environmental conditions in recent years have led to a significant increase in banana prawn catches, and this species now dominates the fishery’s GVP. Banana prawn catches more than doubled between 2006–07 and 2007–08 and contribute, on average, over 60 per cent of GVP since 2007–08. This is expected to have improved profitability in the fishery because catch per unit of effort is significantly higher for banana prawns than tiger prawns, owing to the aggregating nature of banana prawns.

The fishery is managed primarily through input controls in the form of seasonal closures and tradable effort units (based on the length of trawl net headrope a vessel can tow). Recently, the fishery has undergone a number of adjustments to gear types: the definition of gear unit was changed in 2006; the restriction on towing more than two nets was removed, also in 2006; and the headrope length allowance was increased by 33 per cent in 2008. In addition, the Australian Government’s Securing our Fishing Future buyback, which concluded in December 2006, decreased vessel numbers in the NPF from 86 in 2005–06 to 54 in 2007–08.

The NPF was the first Commonwealth fishery to explicitly adopt MEY as its overall management target, in 2004. A harvest strategy informed by a bioeconomic model of tiger prawn stocks was then introduced in 2007, and this has assisted it in targeting the MEY objective. It is more difficult to measure the economic status of the banana prawn fishery because of the natural variability (influenced by environmental conditions) and short life span of banana prawns. To date, no bioeconomic model for banana prawns exists.

In August 2009, the AFMA Commission agreed to move to output controls in the NPF and processes are currently underway for their implementation. This will constitute an ITQ system, with TACs calculated using a bioeconomic model of the tiger prawn stock and other key species in the fishery (Woodhams et al. 2011b). The move to output controls is likely to further enhance the fishery’s ability in meeting its MEY objective.

5.2 Data and application

Separate analyses were undertaken for the tiger and banana prawn fishing seasons because of the differences in the composition of catch between the seasons, the availability of stock information, the aggregating behaviour of banana prawns and the difference in prices received for tiger and banana prawns.

Tables C4 and C5 in Appendix C give the population and sample characteristics of sampled vessels for the two fishing seasons. Banana prawns constituted almost 100 per cent of the total catch in the banana prawn season, while tiger and endeavour prawns made up an average of 78 per cent of the total catch in the tiger prawn season in the period from 1998–99 to 2007–08. The contributions from tiger and endeavour prawns to total catch in the tiger prawn season reduced substantially, to below 60 per cent, in 2008–09 and 2009–10 as a result of favourable environmental conditions for banana prawn recruitment.

The unbalanced panel dataset for the tiger prawn season decomposition contained 476 observations in total, over the 10 years, while the dataset for the banana prawn season decomposition had 483 observations. Catch, effort and cost data were sourced from AFMA log book data, ABARES economic survey and fishery statistics data, and AFMA effort data (ABARES 2011; George et al. 2012). These data were split across the two fishing seasons, as each season was treated as an individual fishery for the analysis, while fuel prices for each season were approximated using world trade weighted average for crude oil (EIA 2011). Outlier vessels arising from reporting issues and recent changes in output mix were also identified and removed. See Appendix B for details of the data splitting and outlier identification process.
Stock information for both species of tiger prawn and the endeavour prawn species was available, so profit decomposition results for the tiger prawn season were stock adjusted. The stock estimates used to estimate the aggregated stock biomass were sourced from CSIRO (S Pascoe, pers. comm., 2011). Stock estimates for white-legged banana prawns, the main species caught in the banana prawn season, are not available. Therefore, the profit decomposition results for the banana prawn season were not stock adjusted.

### 5.3 Empirical results

#### 5.3.1 Tiger prawn season

The reference vessel for the NPF tiger prawn season was the average vessel in 2000–01, which was the most profitable year. A profit index ($\theta^{a,b}$) less than one indicates an average profit that is lower than that of the reference vessel. When comparing index values against the reference vessel for output price ($P_O$), fuel price ($P_F$), labour price ($P_L$) and productivity, both stock-adjusted ($R_S$) and unadjusted ($R$), the following interpretation should be used:

- where an index has a value less than one, the positive contribution of that index to profit is less than that of the reference vessel

- where an index has a value greater than one, the positive contribution of that index to profit is greater than that of the reference vessel.

#### Table 3 Index number profit decomposition results for the Northern Prawn Fishery tiger prawn season

<table>
<thead>
<tr>
<th>Financial year</th>
<th>No.</th>
<th>$\theta$</th>
<th>$\theta_S$</th>
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<th>$P_L$</th>
<th>$P_F$</th>
<th>$K$</th>
<th>$R$</th>
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<th>$R_S$</th>
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<td>1998–99</td>
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<td>0.94</td>
<td>0.81</td>
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<td>1.22</td>
<td>0.69</td>
</tr>
<tr>
<td>2003–04</td>
<td>41</td>
<td>0.52</td>
<td>0.50</td>
<td>0.44</td>
<td>1.00</td>
<td>1.12</td>
<td>1.03</td>
<td>1.01</td>
<td>0.89</td>
<td>0.97</td>
</tr>
<tr>
<td>2004–05</td>
<td>27</td>
<td>0.24</td>
<td>0.21</td>
<td>0.36</td>
<td>1.00</td>
<td>1.07</td>
<td>1.01</td>
<td>0.61</td>
<td>0.98</td>
<td>0.54</td>
</tr>
<tr>
<td>2005–06</td>
<td>28</td>
<td>0.37</td>
<td>0.26</td>
<td>0.43</td>
<td>1.01</td>
<td>0.88</td>
<td>1.02</td>
<td>0.96</td>
<td>1.22</td>
<td>0.68</td>
</tr>
<tr>
<td>2006–07</td>
<td>30</td>
<td>0.41</td>
<td>0.28</td>
<td>0.33</td>
<td>1.00</td>
<td>0.84</td>
<td>1.01</td>
<td>1.48</td>
<td>1.27</td>
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<tr>
<td>2007–08</td>
<td>26</td>
<td>0.35</td>
<td>0.30</td>
<td>0.27</td>
<td>1.00</td>
<td>0.78</td>
<td>1.02</td>
<td>1.61</td>
<td>1.00</td>
<td>1.37</td>
</tr>
<tr>
<td>2008–09</td>
<td>26</td>
<td>0.44</td>
<td>0.38</td>
<td>0.34</td>
<td>1.00</td>
<td>0.74</td>
<td>1.05</td>
<td>1.57</td>
<td>0.98</td>
<td>1.37</td>
</tr>
<tr>
<td>2009–10</td>
<td>30</td>
<td>0.58</td>
<td>0.55</td>
<td>0.24</td>
<td>1.00</td>
<td>0.92</td>
<td>1.05</td>
<td>2.46</td>
<td>0.90</td>
<td>2.34</td>
</tr>
</tbody>
</table>

Note: No. represents the number of sampled vessels, $\theta$ is the profit index, $\theta_S$ is the stock adjusted profit index, $P_O$ is the price of output index, $P_L$ is the price of labour index, $P_F$ is the price of fuel index, $K$ is the capital index, $R$ is the productivity index and $R_S$ is the stock adjusted productivity index.

From 2000–01 to 2004–05, the stock-adjusted profit index ($\theta_S$) followed a decreasing trend. Although the index remained well below 2000–01 levels, it has gradually recovered since 2004–05 to reach 0.58 in 2009–10.

The two main drivers of profitability were output prices and productivity. Throughout the entire series, the stock-adjusted profit index closely followed the output price index ($P_O$). Since 2000–01, the output price index has been declining steadily. Falling tiger prawn prices have primarily been a result of the high Australian dollar and increased supplies of prawns from aquaculture and international competitors in recent years (ABARES 2011)

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Since 2005–06, increases in productivity rather than output prices have been driving profitability improvements. The stock-adjusted productivity index has followed a strong positive trend since 2005–06, more than tripling from 0.68 in 2005–06 to 2.34 in 2009–10 (Table 3). This significant increase can be linked to structural changes in the fishery, both autonomous and management initiated. The vessel buyback of 2005–06 removed less efficient vessels from the fishery, which in turn reduced fishing costs at the vessel level, with stocks being shared among fewer vessels. Recent improvements in productivity have been important for vessel profitability, with tiger prawn prices at historical lows.

Figure 8 Key indexes for vessels in the tiger prawn season, average by financial year

![Key indexes for vessels in the tiger prawn season, average by financial year](image)

Note: $\theta_2$ is the stock adjusted profit index, $P_r$ is the output price index, $P_l$ is the labour price index, $P_f$ is the fuel price index and $R_2$ is the stock adjusted productivity index.

The labour price index ($P_L$) was stable at around one for all years of the analysis, suggesting that the contribution of labour price to relative profit has remained constant. Labour cost are a substantial component of costs and made up 32 per cent of the average NPF vessel’s costs in 2009–10 (George et al. 2012). The results presented here simply suggest that the contribution of labour price to profit remains similar to that of the reference vessel over the full time series. The labour price used here was an assumed wage rate. The alternative approach would have involved using revenue shares paid to crew which vary with revenue. However, a number of issues are associated with taking this approach, which are explained in Appendix A.

The price index for fuel ($P_f$), on the other hand, revealed comparatively stronger fluctuations over the entire time series (Table 3, Figure 8). Since 2003–04, the fuel price index has followed a downward trend. This indicates that fuel prices have progressively become more of a negative influence on profitability, although a slight improvement occurred in 2009–10 due to a decrease in fuel prices relative to 2008–09. The multi-output analysis shows that the decline in output price indexes comes from all three key species for the NPF tiger prawn season (Figure 9). However, as would be expected, the tiger prawn price index was the major driver of the decline in the output price index. The price indexes for other prawns ($P_{OP}$) and other species ($P_{OT}$) did not vary much over the period of the analysis, remaining close to one.
Figure 9 Decomposed output price indexes for vessels in the tiger prawn season, average by financial year

5.3.2 Banana prawn season

As noted previously, the results for the banana prawn season are not stock adjusted because stock biomass estimates for the white-legged banana prawn, which makes up the majority of catch and revenue in the banana prawn season, are not available. The reference vessel for the banana prawn season decomposition is the average banana prawn vessel in 2000–01.

Table 4 Index number profit decomposition results for the Northern Prawn Fishery banana prawn season

<table>
<thead>
<tr>
<th>Financial year</th>
<th>No.</th>
<th>$\theta$</th>
<th>$P_0$</th>
<th>$P_L$</th>
<th>$P_T$</th>
<th>$K$</th>
<th>$R$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998–99</td>
<td>57</td>
<td>0.49</td>
<td>1.12</td>
<td>1.00</td>
<td>1.10</td>
<td>0.98</td>
<td>0.41</td>
</tr>
<tr>
<td>1999–2000</td>
<td>59</td>
<td>0.29</td>
<td>1.26</td>
<td>1.00</td>
<td>1.01</td>
<td>0.97</td>
<td>0.23</td>
</tr>
<tr>
<td>2000–01</td>
<td>56</td>
<td>0.94</td>
<td>1.01</td>
<td>1.00</td>
<td>1.00</td>
<td>0.99</td>
<td>0.94</td>
</tr>
<tr>
<td>2001–02</td>
<td>57</td>
<td>0.53</td>
<td>0.86</td>
<td>1.00</td>
<td>1.03</td>
<td>0.98</td>
<td>0.61</td>
</tr>
<tr>
<td>2002–03</td>
<td>41</td>
<td>0.49</td>
<td>1.09</td>
<td>1.00</td>
<td>1.02</td>
<td>1.02</td>
<td>0.43</td>
</tr>
<tr>
<td>2003–04</td>
<td>41</td>
<td>0.37</td>
<td>0.72</td>
<td>1.00</td>
<td>1.04</td>
<td>1.03</td>
<td>0.47</td>
</tr>
<tr>
<td>2004–05</td>
<td>29</td>
<td>0.23</td>
<td>0.56</td>
<td>1.00</td>
<td>0.94</td>
<td>1.02</td>
<td>0.42</td>
</tr>
<tr>
<td>2005–06</td>
<td>27</td>
<td>0.23</td>
<td>0.27</td>
<td>1.01</td>
<td>0.64</td>
<td>1.02</td>
<td>1.32</td>
</tr>
<tr>
<td>2006–07</td>
<td>27</td>
<td>0.30</td>
<td>0.40</td>
<td>1.00</td>
<td>0.89</td>
<td>1.02</td>
<td>0.80</td>
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<tr>
<td>2007–08</td>
<td>28</td>
<td>0.67</td>
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<td>0.85</td>
<td>1.02</td>
<td>1.92</td>
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<td>2008–09</td>
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<td>0.41</td>
<td>1.00</td>
<td>0.96</td>
<td>1.05</td>
<td>1.59</td>
</tr>
<tr>
<td>2009–10</td>
<td>31</td>
<td>0.70</td>
<td>0.42</td>
<td>1.00</td>
<td>0.94</td>
<td>1.05</td>
<td>1.70</td>
</tr>
</tbody>
</table>

Note: No. represents the number of sample vessels, $\theta$ is the profit index, $P_0$ is the price of output index, $P_L$ is the price of labour index, $P_T$ is the price of fuel index, $K$ is the capital index and $R$ is the productivity index.
Between 2000–01 and 2004–05, the decline in the profit index ($\theta$) was driven primarily by falls in output price and, to a lesser extent, productivity. Over this period, the output price index ($P_o$) fell from 1.01 to 0.56 while the productivity index varied from 0.94 to 0.42. Since 2005–06, the profit index has improved despite low contributions from the output price index. This has been chiefly the result of improvements in the productivity index ($R$), which reflect the large increases in banana prawn catch. This is consistent with favourable environmental conditions in recent years (Woodhams et al. 2011b). As a result of their aggregating nature, banana prawns are relatively easy to locate such that a high proportion of the biomass is caught in each season (Venables et al. 2011; Zhou et al. 2008). Therefore, as productivity and stock effects cannot be separated, it is very likely that the high productivity index in recent years has been heavily influenced by high catch rates and implicitly high stock levels.

Increases in productivity since 2004–05 are likely to be a consequence of a range of concurring factors, including the vessel buyback that removed 43 Class B Statutory Fishing Rights (SFRs) and 18 365 gear SFRs from the fishery in 2006. Removal of excess capital achieved by these management changes, along with autonomous structural adjustment, are likely to have contributed to vessel level productivity and profitability improvements in the banana prawn season since 2005–06 (Figure 10).

As occurred for the tiger prawn season analysis, the labour price index ($P_l$) stayed relatively constant and close to one over the period of the analysis. As was explained for the tiger prawn analysis, this simply suggests that the contribution of the labour price to profit has not varied relative to the reference vessel. On the other hand, there were some slight variations in the fuel price index ($P_f$) from 2003–04 onwards (Table 4, Figure 10). Fuel price is shown to make a more negative contribution to profitability post 2004–05 relative to the preceding period. This is consistent with increases in fuel prices post 2004–05.

It is evident from the multi-output decomposition in Figure 11 that most of the fluctuations in the output price index are attributable to the price of banana prawns rather than all three species in the tiger prawn decomposition. Banana prawns constitute on average 95 per cent of total revenue, so it is not surprising that tiger and endeavour prawn price indexes ($P_T$ and $P_E$) were close to one over the period of the analysis—that is, tiger and endeavour prawn prices do not have substantial influence over vessel profitability in any given year because they contribute so little to revenue.
5.4 Discussion and conclusions

The NPF has achieved considerable improvements in profitability in recent years across both the tiger prawn and banana prawn seasons. For the tiger prawn season, this has been a result of improvements in stock-adjusted productivity, which have offset high fuel prices and low output prices. For the banana prawn season, the combined effects of productivity and increased catch rates are the major contributing factors.

Productivity improvements are likely to have been supported by recent structural changes in the fishery. In particular, the Securing our Fishing Future structural adjustment package, the lifting of the limit on towing more than two nets in 2006, and a 33 per cent increase in headrope length allowance in 2008. Increases in productivity and efficiency directly through these management changes are likely to have occurred together with market driven autonomous adjustment. These impacts (particularly through the Securing our Fishing Future package) are supported by evidence provided by Vieira et al. (2010), who showed a 56 tonne (89 per cent) increase in the average catch per vessel in the post-buyback period, between 2005-06 and 2008-09.

Targeting of MEY was another key factor behind profitability and productivity improvements in the tiger prawn season. Recent stock assessment results for both species of tiger prawn show that the species are approaching the targeted biomass levels associated with MEY. While the importance of this relative to the Securing our Fishing Future buyback is difficult to determine, it is still likely to have been a contributing factor. The increase in the fishery’s net economic returns following the buyback, from −$9.4 million in 2005-06 to $11 million in 2008-09, together with the observations presented here suggest that the fishery has moved towards MEY (Vieira et al. 2010).

The buyback was important in the recent profit increases in the NPF. However, management should focus on preventing the need for government funded buybacks in the future. Implementing output controls in the form of ITQs is generally accepted as the best way to achieve this goal, because it can eliminate ‘effort creep’ and promote more efficient use of resources (Rose 2002). Kompas et al. (2003) showed that effort creep was a key issue affecting efficiency levels in this fishery and that it can also be linked to capacity issues—that is, excess capital being accumulated in the fishery—which the buyback aimed to address. In addition, Kompas and Grafton (2009) indicated that efficiency gains are possible in the NPF under ITQs,
particularly for banana prawns, but noted that benefits from ITQs depend on the appropriateness of the TAC set. This is a key issue for the NPF, particularly for banana prawns given the variability in banana prawn biomass.
6 Torres Strait Prawn Fishery

6.1 Background

The Torres Strait Prawn Fishery (TSPF) is one of 10 fisheries jointly managed by AFMA and the Protected Zone Joint Authority (PZJA). This multi-species fishery is located north of Queensland, in an area of water shared by Australia and Papua New Guinea referred to as the Torres Strait Protected Zone (TSPZ). It operates in both Queensland and Commonwealth waters (Figure 12).

Valued at $11 million in 2007–08 (2009–10 dollars), the TSPF was the most valuable commercial fishery in the Torres Strait. However, continued declines in production since 2007–08 led to reductions in the fishery’s gross value of production (GVP) so it is now the second most valuable fishery in the Torres Strait ($3.9 million in 2009–10); the Torres Strait Rock Lobster Fishery was valued at $6.7 million in the same year. The TSPF generates most of its GVP from tiger and endeavour prawns. Vessels use otter trawl nets and do all fishing at night.

Figure 12 Location of the Torres Strait Prawn Fishery

Note: Relative fishing intensity in the TSPF
Source: Flood et al. 2011

The TSPF is an input controlled fishery, where the main input control is the number of nights fishing is permitted. The management plan allows for nights in the fishery to be permanently traded and seasonally leased, although this was only permitted since 2009 (DAFF 2009). Other key input controls include restrictions on vessel size (to 20 metres), trawl net dimensions (combined headrope and footrope length and mesh size) and fishing area.
Recent management changes included a reduction in the total fishery effort cap in November 2005 to better align with maximum sustainable yield objectives (Woodhams & Perks 2009). Fishing nights were reduced by 32 per cent to 9197 days. The objectives of this jointly managed fishery focus on sustainability rather than MEY targeting.

Despite the reduction in total effort cap, large amounts of unused (or latent) effort remained in the fishery. The latent effort is due to unfavourable economic conditions—that is, historically low prawn prices and high costs. High latency coupled with vessel reduction and reallocation (vessels redirecting effort to operate in other fisheries, like the NPF) indicates low net economic returns (NERs) in the fishery. This is supported by the most recent survey results for the fishery: the fishery achieved a negative NER of −$2.7 million in 2007–08 (Vieira & Perks 2009).

6.2 Data and application

The unbalanced panel dataset used in the TSPF analysis consists of 159 observations in total, over 10 years from 1998–99 to 2007–08. Catch, effort and cost data were sourced from AFMA catch and effort logbook data, and ABARES economic survey and fishery statistics data (ABARES 2011; Vieira & Perks 2009). See Table C6 in Appendix C for sample and population numbers for the TSPF, along with key catch summary statistics. The key prawn species caught in the TSPF are endeavour, king and tiger prawns. The catch for these species accounted for 96 per cent of total average catch per vessel in the sample.

Outlier vessels were eliminated based on comparisons between fish sales receipts and expected revenue, which was calculated by multiplying average unit prices and catch for each species, and then summing this up across the species. Vessels that had a sale-to-expected-revenue ratio outside three standard deviations from the mean ratio were excluded from the sample. As with the NPF decomposition, vessels that made negative profits due to unreasonably high fuel or labour costs relative to revenue received and catch landed were also excluded, as this is usually caused by owners of multiple vessels making errors in separating costs.

6.3 Empirical results

Results for the TSPF are not stock adjusted, as recent estimates of stock abundance were not available. Average vessel profit was highest in 1998–99. Therefore, the average vessel in that year was selected as the reference vessel. A profit index ($\theta^{a,b}$) less than one indicates an average profit that is lower than that of the reference vessel. When comparing index values against the reference vessel for output price ($P_o$), fuel price ($P_f$), labour price ($P_l$) and productivity ($R$), the following interpretation should be used:

- where an index has a value less than one, the positive contribution of that index to profit is less than that of the reference vessel
- where an index has a value greater than one, the positive contribution of that index to profit is greater than that of the reference vessel.
Understanding the drivers of profitability in Commonwealth fisheries

Table 5 Index number profit decomposition results for the Torres Strait Prawn Fishery, average by financial year

<table>
<thead>
<tr>
<th>Financial year</th>
<th>No.</th>
<th>θ</th>
<th>P₀</th>
<th>Pₗ</th>
<th>Pᵢ</th>
<th>K</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998–99</td>
<td>19</td>
<td>0.82</td>
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<td>1.00</td>
<td>1.00</td>
<td>0.99</td>
<td>0.88</td>
</tr>
<tr>
<td>1999–2000</td>
<td>21</td>
<td>0.75</td>
<td>1.21</td>
<td>1.00</td>
<td>0.98</td>
<td>0.98</td>
<td>0.64</td>
</tr>
<tr>
<td>2000–01</td>
<td>18</td>
<td>0.62</td>
<td>1.25</td>
<td>1.00</td>
<td>0.96</td>
<td>0.97</td>
<td>0.53</td>
</tr>
<tr>
<td>2001–02</td>
<td>24</td>
<td>0.59</td>
<td>1.11</td>
<td>1.01</td>
<td>0.98</td>
<td>0.99</td>
<td>0.55</td>
</tr>
<tr>
<td>2002–03</td>
<td>16</td>
<td>0.36</td>
<td>0.72</td>
<td>1.01</td>
<td>1.00</td>
<td>0.97</td>
<td>0.51</td>
</tr>
<tr>
<td>2003–04</td>
<td>16</td>
<td>0.38</td>
<td>0.54</td>
<td>1.01</td>
<td>0.95</td>
<td>0.98</td>
<td>0.75</td>
</tr>
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<td>2004–05</td>
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<td>1.01</td>
<td>0.91</td>
<td>0.97</td>
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</tr>
<tr>
<td>2005–06</td>
<td>12</td>
<td>0.18</td>
<td>0.31</td>
<td>1.02</td>
<td>0.80</td>
<td>0.99</td>
<td>0.70</td>
</tr>
<tr>
<td>2006–07</td>
<td>11</td>
<td>0.16</td>
<td>0.32</td>
<td>1.01</td>
<td>0.67</td>
<td>1.08</td>
<td>0.65</td>
</tr>
<tr>
<td>2007–08</td>
<td>11</td>
<td>0.15</td>
<td>0.32</td>
<td>1.01</td>
<td>0.67</td>
<td>1.08</td>
<td>0.65</td>
</tr>
</tbody>
</table>

Note: No. represents the number of sampled vessels, θ is the profit index, P₀ is the price of output index, Pₗ is the price of labour index, Pᵢ is the price of fuel index, K is the capital index and R is the productivity index.

The profit index (θ) followed a declining trend for the full period of analysis, although the rate of decline has slowed in more recent years (Table 5, Figure 13). It fell from a value of 0.82 in 1998–99 to a much lower value of 0.15 in 2007–08.

For the three years following 1998–99, the decline in the profit index was driven by falls in productivity. The productivity index (R) fell from 0.88 to 0.53 between 1998–99 and 2000–01. Over the same period, the output prices made favourable contributions to profit relative to the reference vessel, with the output price index (P₀) peaking at 1.25 in 2000–01. This reduced the negative impact on profitability of falling productivity during this period.

Since 2000–01, the contribution to profit from productivity fluctuated more or less around 0.60. This occurred despite evidence of increasing stock biomass levels for key species targeted in the fishery (Cocking et al. 2011) and is likely to reflect lower participation in the TSPF. The contribution from output prices declined significantly since 2000–01 and maintained the declining profitability trend. The output price index fell from a value of 1.25 in 2000–01 to a value of 0.31 in 2005–06. It remained relatively stable in the two years to 2007–08.

Further contributing to the decline in profitability is fuel prices. The fuel price index (Pᵢ) began to fall in 2002–03, from a value of 1.00, reaching a value of 0.67 by 2007–08. This growing negative influence on profit is consistent with substantial increases in fuel prices in recent years and the high share of total costs constituted by fuel for vessels in the TSPF (Perks & Vieira 2010).

The labour price index (Pₗ) was stable at around one for the entire period of analysis. This suggests that the influence of labour price on relative profit has remained more or less constant. Labour costs are generally a substantial component of costs in the TSPF, making up 27 per cent of total costs for the average vessel in 2007–08 (Vieira and Perks 2009). The results presented here suggest the contribution of labour price to profit remains similar to that of the reference vessel over the full time series. The labour price used here was an assumed wage rate. The alternative approach would have involved using revenue shares paid to crew which vary with revenue. However, a number of issues are associated with taking this approach, which are explained in Appendix A.
The output price index was decomposed into price indexes for endeavour prawns ($P_E$), tiger prawns ($P_T$) king prawns ($P_K$), other prawns ($P_{op}$) and other species ($P_{ot}$). Both the endeavour and tiger prices were relatively important drivers of profitability (Figure 14). The price for king prawns, on the other hand, was less important. This is expected, as king prawns constitute a much smaller portion of catch and revenue compared with tiger and endeavour prawns.

**6.4 Discussion and conclusions**

Historically, changes in fishery-level profitability in the TSPF and the NPF followed similar patterns (Perks & Vieira 2010). However, since 2006–07 profitability has diverged—with net economic returns improving in the NPF but remaining negative in the TSPF. For both fisheries, low output prices and increasing fuel prices have negatively contributed to profitability. While average output prices in the TSPF tend to be lower relative to the NPF, the declines in output prices across both fisheries have been relatively similar (Figure 15). However, fuel price movements may have had a greater impact on profitability in the TSPF given its remote location and removal of key infrastructure that supplied the fleet with fuel (Flood et al. 2011).
A key difference between the two fisheries is the contribution to profit from productivity. For the TSPF, the productivity index has remained relatively stable since 2002–03 and, with falling output prices, profitability has also fallen. For the NPF, the productivity index has increased substantially. These productivity improvements have allowed the negative influence of rising fuel prices and falling output prices to be mitigated, and profitability has improved as a result.

This presents an important question around why trends in productivity (and profitability) in the two fisheries have diverged. A key factor has been the improvement in catch rates for banana prawns in the NPF. However, increased productivity was also observed for the tiger prawn fishery. As productivity was stock adjusted for this component of the fishery, it suggests that differences in management may also be playing a role.

It is possible that inflexible input controls may have constrained productivity in the TSPF. Before the restriction on trade in effort entitlements was lifted in 2009, the only autonomous adjustment available to fishers was to exit the fishery (DAFF 2009). More productive vessels in the fishery may have been hampered from optimising their operations at minimum cost because they could not purchase effort from less competitive vessels. Nevertheless, it is also likely that incentives for trading in the TSPF were low. This is reflected in the high number of total fishing nights available for most of the period, meaning that fishers were not likely to have been constrained by effort to seek trading. Before the reduction in fishing rights, the total allowable effort set (in the form of nights) well exceeded actual efforts exercised.

Finally, the fishery still operates under a limit on vessel size (DAFF 2009), which may be an issue for such a geographically isolated fishery. A limit on vessel size implies greater number of fishing trips due to capacity constraints, and hence greater fuel consumption. Both of which constrain productivity. It may be possible for the TSPF to improve profitability and achieve positive economic returns if management focuses on implementing management arrangements that promote productivity.
Appendix A: Detailed methodology

The index decomposition method has several stages. First, the reference vessel is selected (A.1). Then the profit index and associated component indexes are estimated (A.2, A.3). Finally, stock abundance data are used to adjust for stocks where possible (A.4).

A.1 Selection of the reference vessel

The choice of reference vessel is normally based on the vessel that is the most profitable over the period of the analysis (Fox et al. 2006), although Kompas et al. (2009) used the average vessel in the most profitable year. Both approaches mean the performance of each vessel in the sector can be compared to a more desirable level of performance of the reference vessel. Therefore, conclusions can be drawn about what an individual vessel in the sector would need to change to reach a reference level of profit. It should be noted that the decomposition results for different sectors for which a unique reference vessel have been assumed cannot be compared. This is because the characteristics of the reference vessel in each decomposition will influence the results of that decomposition in different ways, making comparisons inconsistent.

To select the reference vessel, the variable, non-negative (and non-zero) profit of each vessel is calculated using vessel level revenue and cost data. This is done by summing the product of all ‘netputs’ and their respective prices. Netputs refer to both the outputs and variable inputs (excluding fixed inputs) that are produced and used by a vessel, where an input is a netput that has a negative value and an output is one that holds a positive value. For $N$ netputs, the variable non-zero profit ($\pi$) for a given vessel in a given period is defined as:

$$\pi = \sum_{n=1}^{N} (p_n \cdot q_n) \quad \text{for } n = 1 \ldots N \text{ netputs}$$

where $p_n$ and $q_n$ denote the price and quantity of netput $n$, respectively. As this profit measure excludes fixed inputs, it has also been referred to as ‘restricted profit’ in previous applications (Fox et al. 2006).

Following the approach of Kompas et al. (2009), the reference vessel is selected as the average vessel in the year that the average variable profit is the highest. Where stock information is available, average stock-adjusted profits ($\pi_s$) are used instead:

$$\pi_s = \frac{\pi}{S}$$

where $S$ represents a measure of the fishery’s stock biomass in the relevant period. In this way, the contribution of fish stocks to profit can be distinguished in the analysis.

A.2 Profit decomposition

Once the reference vessel (vessel $a$) has been selected, each vessel’s variable profit ($\pi^b$) is compared to the variable profit of the reference vessel ($\pi^a$) using the profit index:

$$\theta^{a,b} \equiv \frac{\pi^b}{\pi^a}$$

The index above can be rewritten using an aggregated Törnqvist price index ($P^{a,b}$), which allows the contribution to profit from prices of all netputs between vessels $a$ and $b$ to be compared. As outlined by Fox et al. (2003), the profit index can be rewritten consistent with the ‘weak factor reversal test’ of Fisher (1922):
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With the Törnqvist price index, $P^{a,b}$, defined directly as the product of netput prices after adjusting for contributions to profit (see section A.3), an aggregate quantity index, $Q^{a,b}$, can be derived implicitly as (Allen & Diewert 1981):

(Eq. 5) \[ Q^{a,b} \equiv \frac{g^{a,b}}{P^{a,b}} \]

Using the implicit quantity index above and a fixed capital input index, the productivity index can be then be derived. Productivity is usually defined as a measure of input-output conversion. Here, productivity focuses on vessel utilisation of a fixed capital input, vessel length ($K$); this differs to measures of total factor productivity which focuses on the utilisation of all inputs. More specifically, the productivity index ($R^{a,b}$) between vessels $a$ and $b$ is defined as (or rewritten as equation 7 by substituting in equation 5):

(Eq. 6) \[ R^{a,b} \equiv \frac{Q^{a,b}}{K^{a,b}} \]

(Eq. 7) \[ = \frac{g^{a,b}}{(P^{a,b} \cdot K^{a,b})} \]

which, once rearranged (using equation 4 and 6), defines the overall profit decomposition as:

(Eq. 8) \[ g^{a,b} = P^{a,b} \cdot R^{a,b} \cdot K^{a,b} \]

However, the unadjusted profit index above does not distinguish the contribution of fish stocks to profit. To obtain the stock-adjusted profit index, only the productivity index ($R^{a,b}$) in equation 8 is stock adjusted. The stock-adjusted productivity index between vessels $a$ and $b$ ($R^{a,b}_{sa}$) can be calculated by dividing the productivity index by the ratio of stocks observed for vessels $a$ and $b$:

(Eq. 9) \[ R^{a,b}_{sa} = R^{a,b} / S^{a,b} \]

where $S^{a,b} = \left( S_b / S_a \right)$ and $S_a$ and $S_b$ are the fish stocks that each firm harvests from respectively. For multi-species fisheries, the calculation of $S$ requires aggregating the stock abundances of individual species into one measure of stock abundance. The approach used to do this is outlined in detail in section A.4.

With the adjustment for stock and individual netput price indexes obtained from the expansion of the aggregated price index (see equation 14), the profit decomposition described in equation 8 can be broken down further to reflect individual netput price contribution. Assuming that there are three key netputs—a single output ($O$), a fuel input ($F$) and a labour input ($L$)—and the stock biomass ($S$) is known, the stock adjusted profit index can be decomposed as follows:

(Eq. 10) \[ \theta^{a,b} = P^{a,b}_O \cdot P^{a,b}_F \cdot P^{a,b}_L \cdot R^{a,b}_{sa} \cdot K^{a,b} \]

where $P^{a,b}_O$, $P^{a,b}_F$ and $P^{a,b}_L$ represent the relative price indexes of output, fuel and labour of vessels $a$ and $b$. With the stock-adjusted profit decomposed in this way, the trend in relative profitability to be assessed for each sector over time and contributions to relative profits from input and output prices, capital, productivity and fish stocks can be separately distinguished. It also allows profit contributions from specific netputs to be compared between vessels $a$ and $b$ in each period.
A.3 Construction of the aggregated price and capital indexes

The aggregated Törnqvist price index is based on a vector of netput prices specified for \( N \) variable netputs. For vessel \( b \), the vectors for prices and quantities of netputs related are specified below:

\[
\begin{align*}
   p^b &= (p^b_1, \ldots, p^b_N) \\
   q^b &= (q^b_1, \ldots, q^b_N)
\end{align*}
\]

where an output is represented by a positive netput \((q^b > 0)\), while a variable input is denoted by a negative netput \((q^b < 0)\). Further, the price vector in equation 11 satisfies the requirement that each element be positive (Fox et al. 2006).

As shown by Fox et al. (2003) the Törnqvist index, \( P^{a,b} \), can be expressed using netput price and quantity indexes:

\[
\ln P^{a,b} = 1/2 \sum_{n=1}^{N} \left[ s_n^b + s_n^a \right] \cdot \ln \left( \frac{p_n^b}{p_n^a} \right)
\]

where \( s_n = p_n q_n / \sum_{n=1}^{N} p_n q_n \) is the profit share of netput \( n \).

The multiplicative nature of the Törnqvist index allows the aggregate price index between vessels \( a \) and \( b \) to be decomposed into a product of individual price differences:

\[
P^{a,b} = \prod_{n=1}^{N} P_n^{a,b}
\]

where the index for each netput \( n \) is assumed to be itself a Törnqvist index.

Similarly, the fixed input or capital index \( K^{a,b} \) of firm \( b \) can be derived by substituting the fixed input prices \((k^b_1, \ldots, k^b_N)\) and the profit shares of each input into equation 13 (Fox et al. 2003). Given that only a single fixed input has been assumed in previous applications of the method to fisheries, with all profits attributed to that single input—that is, that fixed input’s profit share is unity—the calculation of the fixed input index can be reduced to (Dupont et al. 2005; Fox et al. 2003; Fox et al. 2006; Grafton & Kompas 2007; Kompas et al. 2009):

\[
K^{a,b} = k^b / k^a
\]

where \( k \) is vessel length measured in metres.

A.4 Aggregating stocks in a multi-species fishery

For a fishery that catches multiple species, the calculation of the stock index \((S^{a,b} = S_a / S_b)\) requires that stocks be aggregated into a single biomass estimate for all years being analysed. This is complicated by two things. First, the abundances of different species will move in different directions and magnitude in a given period. Second, the relationship that exists between a given species’ stock biomass and profitability will vary across species. However, the key drivers of a species’ contribution to vessel profit are likely to be the catch of that species and its price.

Accordingly, an aggregated measure of stock biomass can be computed by weighting each species’ contribution to the aggregated abundance according to the average price and quantity of catch for each species in each year. As shown by Kompas et al. (2009), aggregated stock biomass \((S_{r})\) can be defined as:
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ABARES

(Eq. 16) 

\[ S_t = \sum_{i=1}^{n} S_i \cdot \frac{p_i \cdot q_i}{\sum_{i=1}^{n} p_i \cdot q_i} \]

where \( S_i \) is the stock biomass for species \( i \) in time period \( t \), \( p_i \) is its relevant price and \( q_i \) is the amount of that species caught in that time period.

Weighting stock contribution by price and quantity of catch for each key species offers a monetary valuation of biomass for those species, which allows a more direct link between biomass changes and profit to be made. Although having an aggregated stock index that is relevant to each vessel would be ideal, such an approach is problematic as catch differences do not necessarily reflect variations in biomass abundance across locations where individual vessels fish (Fox et al. 2006).

A.5 Netputs and fixed inputs

The contribution of output to vessel profitability uses the same approach as Vieira (2011a) to examine profit contribution from multiple species (outputs). In this manner, the importance of key species to profitability can be revealed.

Revenue data for individual species are not available on a vessel level from ABARES survey data. As a result, ABARES average unit price data and catch data for key fishery species from the Australian Fisheries Management Authority (AFMA) are employed to quantify each species’ contribution to profit. First, an estimated value of production is calculated for each vessel by multiplying the average unit price and catch for each species. Then a scaling factor (\( \delta^b \)) based on the difference between total vessel revenue (from ABARES survey data) and the sum of estimated values of production for all species caught is applied to the average unit prices. Finally, the adjusted average unit prices are then multiplied by the quantity of catch for each species to work out their individual revenue contribution. Equations 17 to 19 below illustrate the procedure for vessel \( b \):

(Eq. 17) 

\[ \delta_t^b = \frac{\pi^b_t}{\sum_{i=1}^{n} p_i \cdot q_i^b} \]

(Eq. 18) 

\[ ap_t^{ib} = \delta_t^b \cdot p_t^{ib} \]

(Eq. 19) 

\[ r_t^{ib} = ap_t^{ib} \cdot q_t^{ib} \]

where \( q_t^{ib} \) is the quantity of catch for vessel \( b \) of species \( i \), and \( ap_t^{ib} \) and \( r_t^{ib} \) are the adjusted price and revenue of species \( i \) specific for vessel \( b \).

This use of average price data differs to the multi-species analysis of Dupont et al. (2005), who took a more direct approach given the availability of species level revenue and catch data by vessel, which allows a direct estimation of average prices received for species per vessel.

Fuel and labour make up the two key negative netputs (inputs) used in this paper. Fuel expenditure data were taken from ABARES survey data and the average off-road diesel price in Australia—which was adjusted to an on-road price—was taken from ABARES time series data. The on-road fuel price adjustment was necessary as total fuel costs reported by vessel operators are based on on-road prices prior to off-road diesel rebates. Fuel quantity was then derived by dividing each vessel’s fuel cost by the relevant diesel price. Labour quantity was calculated based on the product of the average crew per vessel (collected in ABARES surveys) and an indicator of labour time in each of the fisheries. Previous index number profit decompositions for the CTS (Fox et al. 2006; Grafton & Kompas 2007) have used trawl hour data—that is, time spent pulling a trawl net through the water—to indicate labour time. However, this study used
estimates of fishing days. Such an indicator reflects total time that crew spend working on the vessel more accurately and the lost opportunities for employment elsewhere. It is also a more relevant measure for the Danish seine sector in the CTS, which does not use the trawl method.

Annual wage rates based on the national Pastoral Award rates for agricultural labour were used to derive the price of labour. Although crew are generally paid a share of revenue, using a labour price based on share payments is problematic. Variability in revenue due to fluctuations in stock, productivity or output prices can cause share-based labour prices to vary significantly. This means the contribution of a share based labour price to profitability captures the contributions of other indexes to profit. Furthermore, the structure of the decomposition equation means variations in share payments (driven by changes in revenue) will lead to the productivity index being calculated in an inconsistent fashion between years.

The National Pastoral Award Rates was instead used for the price of labour as it represents an opportunity cost based price for labour. It also allows the contributions to profit from other factors to be measured consistently over time. For the fisheries assessed here, the labour price index typically takes a value close to one for the entire series. This does not reflect the size of labour costs for most vessels, which typically constitute around a third of total costs for most of the fisheries analysed. However, revenue shares paid to crew do not vary significantly across vessels and so the outcome of having a constant contribution to profit from labour relative to other drivers of profit is not necessarily inaccurate. Despite this, the issue of labour price measurement remains an area for future research to improve the current approach.

A.6 Application of averages

Summaries of decomposition results in this paper were calculated using the geometric mean of all the indexes across vessels sampled in each financial year. The reference vessel, the average vessel in the most profitable year (after stock adjustment), was selected using the arithmetic mean.

Geometric averages are preferred over arithmetic averages for the index results because arithmetic means are not correct when averaging normalised results or results that are presented as ratios to reference values. Conversely, arithmetic averages are preferred when calculating the year for the reference vessel because it is the most efficient mean for averaging sample statistics and is capable of processing zero values in the sample, unlike the geometric mean. Moreover, it is important to keep in mind that the averages of index values in each year is not the same as the index values of the average vessel in each year.
Appendix B: Calculations for the Northern Prawn Fishery

B.1 Estimating fishing costs

Catch by species and effort in the form of days fished and hours trawled are available at vessel level for each season, but cost data are not. The number of crew members, which is required to calculate labour cost, is only available as an average across the two seasons for each vessel. However, based on the responses to the most recent ABARES survey of the fishery, the number of crew employed in the tiger prawn season is generally around two less than those employed in the banana prawn season. Hence, the number of crew for the tiger prawn season was adjusted by subtracting one from the average and for the banana prawn season by adding one to the average. For vessels that only fished in one season, the number of crew was left unadjusted.

Adjusting fuel cost was more challenging. Fuel consumption is not only dependent on the season in which the vessel operated (unlike banana prawns, tiger prawns aggregate less and hence fishing for tiger prawns consumes more fuel as more travelling is required) but also varies based on individual vessel characteristics, such as vessel length and hours trawled. The splitting of fuel cost was based on results from empirical analyses.

Regression analyses were conducted to select the best model for estimating real fuel cost using data from 2004–05 to 2009–10. The independent variables considered include: catches of tiger, banana and endeavour prawns in each season; vessel length; year; number of operation days and hours trawled by vessels in each season; seasonal oil prices; and various interaction terms of the variables listed. After some initial variable selection, vessel and company variables were also included for those that consistently exhibited single directional or large residuals.

The final model was selected based on significance level of individual regressors and overall significance of the model. The model did not suffer from heteroskedasticity or misspecification according to the Breusch–Pagan and RESET tests, and the signs of the remaining regressors were all consistent with general understandings of the fishery (Table B1). The regressors remaining in the final model were: tiger prawn catch in the tiger season, banana prawn catch in the banana season, boat length, dummy for 2009–10, dummies for two companies and one vessel, the interaction term of days operated in the tiger season and oil price for the first half of financial years, the interaction term of tiger prawn catch in the tiger season and oil price for the first half of financial years, the interaction term of tiger prawn catch in the tiger season and days operated in the tiger season, the interaction term of banana prawn catch in the banana season and days operated in the banana season, and the interaction term of days operated in the banana season and oil prices for the second half of financial years.

Using the regression results (Table B1), fuel cost in each season was estimated by substituting season-specific variable values and dividing equally those values that are shared across the two seasons (that is, the constant and dummies). From this, a ratio based on estimated fuel cost in each fishing season over estimated total fuel cost (sum of estimated fuel cost in the two seasons) is created. This ratio represents the estimated portion of fuel consumption in each season. It is then applied to the actual total fuel cost to get the final estimated fuel cost for each season.
Table B1 Regression output for estimating fuel cost in the Northern Prawn Fishery

<table>
<thead>
<tr>
<th>Fuel cost</th>
<th>Coefficient</th>
<th>Robust standard error</th>
<th>t</th>
<th>P&gt;t</th>
<th>[95% conf. interval]</th>
</tr>
</thead>
<tbody>
<tr>
<td>tigercatch1</td>
<td>11.02</td>
<td>2.03</td>
<td>5.44</td>
<td>0.00</td>
<td>7.02</td>
</tr>
<tr>
<td>bancatch2</td>
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<td>6.06</td>
<td>0.00</td>
<td>1.41</td>
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<td>days*fuelpc1</td>
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<td>8.88</td>
<td>0.00</td>
<td>18.03</td>
</tr>
<tr>
<td>tig*fuelpc1</td>
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<td>0.02</td>
<td>-5.01</td>
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<td>-0.17</td>
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<td>tig*days1</td>
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<td>0.02</td>
<td>-1.50</td>
<td>0.14</td>
<td>-0.05</td>
</tr>
<tr>
<td>ban*days2</td>
<td>-0.03</td>
<td>0.01</td>
<td>-4.14</td>
<td>0.00</td>
<td>-0.05</td>
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<td>days*fuelpc2</td>
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<td>3.89</td>
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<td>0.61</td>
<td>-89126.77</td>
</tr>
</tbody>
</table>

Note: For variable numbering, 1 implies operation in the tiger prawn season and 2 for banana prawn season.

B.2 Outlier identification

Given the variation in catch composition in recent years and reporting issues associated with multiple vessel ownership, some outlier vessels were eliminated from the sample for the Northern Prawn Fishery. Outlier vessel observations were removed from the sample if:

- The observed vessel had a sale receipt (actual vessel revenue) to expected revenue (calculated using average unit prices and catch) ratio outside three standard deviations from the mean ratio. This indicates that the prices received by the observed vessel are significantly different to other sample vessels in the fishery, which may be due to an error in reporting.
- The observed vessel made negative profits due to unreasonably high fuel or labour cost relative to revenue received and catch landed. This is usually as a result of errors in separating costs by owners of multiple vessels.
- The contribution to the observed vessel’s profit from banana prawn revenues fell outside three standard deviations from the average profit contribution from banana prawns in the tiger prawn season. This indicates that there is a significant difference in catch composition between the observed vessel and the reference vessel, which is likely to distort decomposition results.

The reason for the last criteria comes from the change in catch trends for banana prawns. Historically, banana prawns made up only a small proportion of revenue and this is the case for the reference vessel, which occurs in 2000–01 (Table C6). However, vessels in recent years exhibit much higher proportions of banana prawn catch, resulting in higher contributions to profit from banana prawns. Therefore, the results in Table 3 for 2008–09 and 2009–10 may be distorted as the decomposition approach does not incorporate sudden changes in profit composition well.
Appendix C: Sample and population statistics for vessels operating in assessed fisheries

Table C1 Sample, population and characteristics of sampled trawl vessels, average by financial year

<table>
<thead>
<tr>
<th>Financial year</th>
<th>Trawl sample number</th>
<th>Trawl population number</th>
<th>Average days at sea</th>
<th>Average vessel length (m)</th>
<th>Average catch (kg): blue grenadier</th>
<th>Average catch (kg): tiger flathead</th>
<th>Average catch (kg): pink ling</th>
<th>Average catch (kg): silver warehou</th>
<th>Average catch (kg): other species</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998–99</td>
<td>20</td>
<td>69</td>
<td>183</td>
<td>20.8</td>
<td>29 488</td>
<td>21 357</td>
<td>26 243</td>
<td>29 552</td>
<td>134 201</td>
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<tr>
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<td>21</td>
<td>72</td>
<td>185</td>
<td>21.6</td>
<td>36 436</td>
<td>26 415</td>
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<td>32 380</td>
<td>98 590</td>
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<td>41 544</td>
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<td>24 766</td>
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<td>2008–09</td>
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<td>22.7</td>
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<td>47 746</td>
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<tr>
<td>Financial year</td>
<td>Danish seine sample number</td>
<td>Danish seine population number</td>
<td>Average days at sea</td>
<td>Average vessel length (m)</td>
<td>Average catch (kg): tiger flathead</td>
<td>Average catch (kg): eastern school whiting</td>
<td>Average catch (kg): other species</td>
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<td>92 931</td>
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Table C6 Sample, population and characteristics of sampled vessels in the Torres Strait Prawn Fishery, average by financial year

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