Development and Implementation of an Energy Audit Process for Australian Fishing Vessels

(S.E.S.S.F. Industry Development Subprogram)

Dr J. Wakeford



AUSTRALIAN MARITIME COLLEGE

UTAS

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(S.E.S.S.F. Industry Development Subprogram)

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NON TECHNICAL SUMMARY:

OUTCOMES ACHIEVED TO DATE

This project generated a number of useful outcomes that promise to deliver both private and public benefits to Australia in the future.

1) The project provided fishing company's intent on saving fuel and/or reducing energy costs with a formalised energy audit process that is both consistent with Australian Standard AUS/NZ 3598:2000 and also tailored to suit fishing vessels. Provision of this process, together with the results of six subsequent applications (presented as energy audit reports), should according to attendees at an FRDC workshop on Energy Efficiency in Fishing in 2005, instigate more audit activity in the near future. If this is the case and fishing companies start to implement fuel-saving measures presented in audit reports, then ultimately an important part of Australia's primary industry sector will become more fuel efficient, more competitive, and carry a smaller carbon footprint. Positive signs to date include: the completion of an additional energy audit on a Danish Seiner in Lakes Entrance by one of the project CI's; and the introduction of several costly (>$100K) fuel-saving measures on a MG Kailis fish-trawler as a result of an audit in 2008/9.

2) The project served to expose a deficiency not only in the number of appropriately qualified Australian's that are able to provide technical guidance on fuel-energy saving measures for fishing activities, but also in the amount of technical knowledge that is

available to such people. This situation needs to be rectified quickly to ensure fishing companies are always provided with plenty of rational fuel-saving options in the future, and to avoid stifling progress at a time when fuel-energy prices are relatively static and upgrades/alterations are more affordable.

3) The project has given proactive training institutions/providers an opportunity to include project results (*i.e.* the audit process and fuel saving measures presented in reports) in their Marine Engine Driver (level 2 and 3) syllabus that is taught to prospective fishing vessel engineers. Armed with such knowledge/skills, this new generation of marine-engine drivers will be ready to help fishing companies contend with rising fuel-energy prices and to remain viable during the challenging times ahead.

4) The project revealed that most fishing companies are not properly prepared for undertaking energy audits, simply because the 24 months of historical data required to complete the simplest energy audit (*i.e.* level 1) is either not being kept, or is kept in an inappropriate form that compromises its analytical worth.

5) The project provided a set of recognised energy-audit benchmarks that can be used for monitoring progress in this field, either at a domestic or international fishing level. Having such data on hand will benefit a range of parties interested in energy efficient fishing, namely fishing companies, fishery managers, state and federal government organisations associated with fisheries, as well as non-government organisations such as WWF and Greenpeace.

Commercial fishing vessels are reliant on fuel energy for a number of reasons; to power/propel fishing vessels to the fishing grounds, to power winches and other machinery used to deploy/haul and control the fishing gear, to provide power to support systems for crewmembers, and to keep the fish in a fresh condition with the aid of refrigeration. Rising diesel prices have the fishing industry concerned as they not only erode profits, but in some cases put excessive financial strain on the fishing business to the point where it is not viable to fish.

Energy audits are an effective way of obtaining a clearer idea of how energy is used in a business, and to subsequently identify ways of reducing the energy consumption level and associated cost. For this reason, an energy audit process for fishing vessels was developed, and then subsequently trialled on a number of different fishing vessels. The process proved satisfactory, although difficulties were encountered when it came to assembling the necessary historical data (fish landings, revenue from fish sales, quantities of fuel used and the associated expense, fishing time and/or engine running hours) for undertaking a Level 1 audit. Synchronising fuel usage with production also proved to be difficult when using fuel dockets and fish sale receipts. Of the vessels audited, those which gained the most were the ones that were more fastidious with their record/book keeping, as this permitted a more in-depth analysis to be performed.

The results from the level 1 'walkthrough' or 'opportunity' audits confirmed that passive fishing gears are less energy intensive than active forms of fishing, and furthermore that these methods are less susceptible to rising diesel prices. It was also apparent between the vessels audited that some fishing businesses need to be pro-active and become more energy efficient before the next hike in fuel prices. The audits also revealed where efforts to improve energy efficiency are best directed. For example, a West Australian prawn trawler was directed towards using more hydro-dynamically efficient otterboards; based on the data analysed, the payback period was inside one year, indicating this was a worthwhile investment.

Intuitively, as the pool of energy audit information on Australian fishing vessels grows it should be possible to identify in what areas research and development is most needed, and embark on a long term program to build up the necessary pool of technical expertise.

KEYWORDS: **energy, audit, efficiency, fishing, fuel, Australia**

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Thanks extend to:

- The owner(s)/mangers(s) and crew of the fishing vessels on which energy audits were conducted, namely the *FV Point Cloates* (David Dowding, Stephen Hood, 'Tomo' ex-skipper), *FV Ella Mae* and *C-King* (David Sterling), *FV Night Stalker* (Bruce Cockman), *FV Flying Fish 4* (Mick Manifis), *FV Torbay* (David Dowding, Stephen Hood, Glen Passmore, Paul Morton 'Bug'- skipper, Paul Henderson - Engineer, Jason Smith - Engineer), *FV Moira Elizabeth* (Tom Bibby, Ian Leck).
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BACKGROUND

Fuel is a vital but costly input to seafood production, accounting for up to 50% of the operating costs of some of the more energy intensive fishing vessels in Australia. An estimated 270 million litres of diesel fuel is currently consumed in Australian fisheries each year, as well as a substantial amount of petrol. Faced with rising fuel prices, a domestic oil deficit predicted to emerge past 2015, and a global need to reduce greenhouse gas emissions, the fishing industry is seeking to improve the energy efficiency of its operations and to find viable alternative energy sources (Anon. 2005).

In November 2005 an FRDC sponsored workshop on ‘Energy Efficiency in Fishing’ was organised to facilitate discussion on alternative energy technologies and energy-saving measures, and to develop an R&D agenda capable of supporting future activity in this field. Regarding the latter, most workshop participants agreed that the next logical step forward for the Australian Fishing industry was to introduce a form of energy audit process, similar to that described by a representative from Sustainability Victoria.

According to one source (Anon. 2002), an energy audit identifies areas of high energy consumption in a business, provides data on current energy use and equivalent greenhouse gas emissions, and also includes recommendations on how to become a more efficient energy user. For each business investigated, an audit determines a baseline on current energy usage, and presents the findings in the form of measures against defined benchmarks; for example the level of production (in this case catch quantity) per unit of expended energy. In addition to monitoring one's own performance over time, this benchmark data can also be used for analysing performance across a fishery or between fisheries, both at a domestic and international level.

NEED

The Australian fishing industry uses a considerable amount of fuel in the harvest of Australia's valuable fishery resources, and in order to remain viable as fuel prices increase, more efficient harvest strategies and gears need to be implemented. A logical step towards this goal was identified at a workshop in 2005, namely the introduction of an appropriately configured energy audit process.

A subsequent inspection of the Australian Energy Audit Standard (AUS/NZ 3598:2000) revealed that it was more suited for land based infrastructure and production processes. There was therefore a need to tailor this process to suit fishing vessels, and then demonstrate that it still provided all of the recognised outputs across a range of different fishing craft.

Energy audits are expected to provide the following outputs: a description of energy usage patterns for different operational phases and/or through a fishing season; potential energy saving measures together with an expected payback period; and measures of performance against recognised energy audit parameters, such as catch quantity per litre of diesel-fuel, and fuel expense against catch revenue. Such information is needed by fishing companies to facilitate a rational change over to energy saving practices and technologies. Government and non-government organisations concerned with the performance of this sector of primary industry, not only in terms of energy efficiency and viability, but also greenhouse gas emissions and ascertaining the industry's carbon footprint, will also find such information useful.

OBJECTIVES

1. Adapt an existing land-based-infrastructure energy-audit process to suit certain types of fishing vessel.

2. Undertake a trial energy audit (Level 1 and possibly Level 2) of up to six different

fishing vessels.

3. Present the tailored audit process, the audit findings, the energy management matrixes for each vessel type, and also provide recommendations for future work.

INTRODUCTION

In Australian waters today most of the recognised forms of commercial fishing are present, namely purse seining, beach seining, Danish/Scottish seining, dredging, longlining, trap/pot fishing, gathering, trawling, and gillnetting (FAO 1987; Kailola *et al.*1993). These fishing methods can be classified as either active or passive methods according to whether it is crucial for the gear to be manipulated during the capture process or not. Passive methods are reliant on the target species approaching and interacting with the fishing gear in a voluntary manner to have a chance of catching fish. Active methods on the other hand necessitate pursuing fish and manipulating the gear during the capture process to land them. As a general rule, this heightened level of activity with active forms of fishing necessitates using relatively more energy, primarily to drive various forms of winches and propellers (Dickson 1988; Endal 1988). In Australia, trawling is the most prevalent and widespread active fishing method.

Occasionally, active gears take such large hauls of fish that the amount of energy expended per unit of landed fish is relatively low, and may even approach or fall below that of some passive methods. From an energy efficiency perspective, this type of fishing must be supported and promoted. However, such practices usually involve targeting spawning aggregations of fish, or migrating schools of fish, and therefore understandably fish-quality, sustainability, and responsible fishing issues must be adequately addressed as well. To that end, fishing companies will have to work more co-operatively with fisheries management and relevant non-government organisations in the future (Rogers 2009).

Energy efficiency benchmarks

The importance of energy efficiency in fishing became apparent in 2008 when prices for diesel fuel in Australia approached $2/L. In some fisheries (*e.g.* Queensland East Coast Prawn Trawl) the fishing vessels did not bother going to sea as they could not adequately cover the cost of fuel with catch income/revenue to make the trip worthwhile. This index of ‘fuel cost per dollar of catch revenue’ is therefore a good indicator as to whether a fishing business is vulnerable to rising fuel prices, and additionally, whether a group of businesses all engaged in a marginal, energy intensive form of fishing should be working more collectively towards doing something about it. It is also worth noting that this latter parameter, namely 'fuel cost per dollar of catch revenue', is a derivative of the previous parameter, namely 'energy expended per kilogram of landed fish', since it includes two additional quantities, namely the cost of each unit of fuel (energy), and the income received for each unit of landed fish. Even though fishing companies can have some influence over these latter two quantities, especially the latter if more attention is paid to fish-quality/yield during the harvest/post-harvest stages of production, the price they ultimately receive for each product is largely governed by 'market forces' that are beyond their sphere of control.

Other useful parameters for ascertaining the energy efficiency profile of a fishing business include;

- catch quantity per unit of fuel energy,
- catch revenue per unit of fuel energy,
- catch quantity per unit of fishing time,
- catch revenue per unit of fishing time, and
- fuel used per unit of fishing time.

Performance monitoring

In relation to the energy audit parameters presented above, it is worth noting that catch quantity is influenced by multiple factors, and that some of these are beyond the control of the fishing vessel operator *e.g.* how many fish are available for harvest and how difficult these fish are to locate. As a consequence of the uncertainty surrounding these uncontrolled factors, it is often difficult to ascertain how much of an influence each has had on a particular result, especially when this result extends over a relatively short time. Basing the Level 1 Energy Audit on at least 24 months of historical data, and then presenting this data in average monthly amounts (*i.e.* as per the Standard), is only a partial remedy. Another option is to remove this uncontrolled influence altogether by choosing parameters that do not contain catch quantity or catch revenue (since this is a function of catch quantity), such as 'fuel used per unit of fishing time' for example; although with most fishing methods even this parameter is not strictly independent of catch quantity.

It seems therefore that assessing/monitoring production performance in fisheries is always going to be challenging because of these uncontrolled variables that have a bearing on catch quantity, and to a lesser extent other measured quantities as well.

Fishing efficiency and energy efficiency

Most fishing businesses will agree that the best solution for alleviating rising fuel prices is to explore ways of improving fishing efficiency as well as energy efficiency, as the two are often inter-related. A vessel with a higher fishing efficiency will catch the same quantity of fish with less effort days or with less/smaller units of gear, and therefore has the potential to save fuel. For example, a trawler equipped with better fish finding equipment together with trawl gear sensors for monitoring trawl shape and position in the water column, has greater potential for putting the trawl net through high fish concentrations, and can therefore afford to downsize its gear by say 10% to reduce trawl gear drag and to save fuel. Alternatively, a crayfish-boat operating in a quota managed fishery can via improvements in fishing efficiency acquire more crayfish per pot per soak hour, and therefore spend less time at sea securing its total allowable catch and save fuel in the process. Understandably for this to happen there must be a strong commitment by fisheries management to a regime that allows the fishing gear to evolve over time with fewer constraints. In other words, allow fishing businesses to fully capitalise on more fuel/fishing efficient approaches and technologies as they appear. In many of Australia's fisheries today the necessary degree of flexibility is emerging; the main hindrance seems to be the reliance on fishing gear/operational controls to alleviate concerns over irresponsible fishing (*i.e.* overfishing, unselective fishing, high-grading/dumping, and habitat disturbance).

Energy efficiency in fishing has become more important in the last decade because petroleum fuels have become much more expensive, and pollutants from engines running on petroleum fuels are receiving more attention. The short-term response is to seek improvements in energy efficiency with petroleum based fuels (Sterling 2009) and to find cheaper fuel sources/suppliers. Longer term however, the fishing industry needs to consider utilising alternative energy forms. To that end the options seem very limited at this point in time, since apart from light-fuel oil, other affordable alternatives generally undermine fishing efficiency, safety, and other key areas of performance/functionality to a level which is unsatisfactory (Sterling 2009).

Energy efficiency in fishing workshop

In 2005, a workshop on energy-efficient fishing was organised by the Fisheries Research and Development Corporation (FRDC) to stimulate progress in this field. The workshop objectives were:

- To explore opportunities for, and limitations to, improved energy use in commercial fishing operations through the use of alternative energy technologies, alternative fuels, and energy-efficient design.
- To scope R&D priorities and projects for optimising energy use in commercial fishing operations.
- To identify funding opportunities (public and private) for R&D projects.
- To identify parties interested in collaborating in R&D projects.

A copy of the workshop flyer is presented in Appendix 3a.

Attendees at the workshop included: representatives from the FRDC, State and Commonwealth fishery managers, commercial fishers, fishing vessel owners/managers, net-makers, people with technical expertise in relevant areas, plus representatives from government and non-government organisations with an interest in seeing improvements and progress in this field.

A key speaker at the workshop, namely John Osborne from Sustainability Victoria, presented an overview of how energy audits have been used to address energy efficiency and/or reduce the energy cost to a number of land-based industries in Victoria. This presentation was well received by the workshop attendees, and later when the group was directed to address objective 2, there was general consensus amongst those present that undertaking energy audits was the most logical pathway forward for the Australian Fishing industry at this point in time.

Energy audits have been completed on fishing vessels in several overseas countries, namely Canada and the United Kingdom. No documented evidence of an Australian fishing vessel being exposed to a formalised energy audit process could be found in the literature. The reason(s) is/are unclear, although it may be partly due to the Australian/New Zealand Energy Audit Standard being more suitable for building and land-based manufacturing processes rather than fishing vessels. The energy audit specification located on the Australian Greenhouse website is consistent with the Australian/New Zealand Standard AS/NZS 3598:2000 (the latter cannot be included due to copyright restrictions), and is presented in Appendix 3b.

Energy audits

The purpose of undertaking an energy audit is to obtain a clearer idea of how energy is used by a business, and to subsequently identify ways of reducing the energy consumption level and associated cost. Several tools are available to help with aspects of the auditing process, including the ‘Energy and Greenhouse Management Toolkit’ developed by EPA Victoria in partnership with the Sustainable Energy Authority Victoria.

There are three audit levels in the AUS/NZ Energy Audit Standard 3598:2000. Details on each were extracted from this standard and are presented below.

Level 1 audit

A Level 1 audit, sometimes called an overview, allows the overall energy consumption of the site to be evaluated to determine whether energy use is reasonable or excessive. It provides initial benchmarks of the site so that the effect of energy measures can be tracked and evaluated. It may be in the form of a desktop study. However the information given to, or gathered by, the auditor needs to be sufficient to enable the overall level of efficiency of the site to be determined. A Level 1 audit is expected to give an overview which provides rough orders of savings and costs. Accuracy of figures would generally be within ±40%.

Level 2 audit

A Level 2 audit identifies the sources of energy to a site, the amount of energy supplied, and what the energy is used for. It also identifies areas where savings may be made, recommends measures to be taken, and provides a statement of costs and potential savings. A Level 2 audit is an energy use survey which is expected to provide a preliminary assessment of costs and savings. Accuracy of figures would generally be within ±20%.

Level 3 audit

A Level 3 audit provides a detailed analysis of energy usage, the savings that can be made, and the cost of achieving those savings. It may cover the whole site or may concentrate on an individual item, such as a single industrial process or one of the services. The auditor may often employ a specialist to carry out specific parts of an audit or may need to install local metering and logging. The report from a Level 3 audit often forms the justification for substantial investment by the owner or an energy performance contractor. Detailed economic analysis with appropriate level of accuracy is required. A Level 3 audit is expected to provide a firm estimate of savings and costs. Accuracy of figures would be within +10% for costs and –10% for benefits.

Energy audits on fishing businesses

Applying Level 1 energy audits to fishing businesses provides an opportunity to compare standardised measures (*e.g.* catch (kg) per unit of fuel (L)) between vessels in a given fishery or between fisheries. These snapshots of performance can be quite revealing as they capture all facets of the business that impact on energy usage, including such things as cooperation between fishers in a fleet, the preparedness of skipper and crew to alter fishing practices to save fuel even though they may be paid on a percentage of the catch, the available land-based infrastructure to keep vessel and equipment reliable and well-tuned. Understandably, such information should be included in audit reports if it is on hand/available.

Project objectives

The following project objectives were formulated in response to the above need and proposed R&D direction:

- Adapt the existing energy-audit process (AUS/NZ Standard 3598:2000) so that it is more suitable for application to fishing vessels.

- Undertake a trial energy audit (Level 1 and possibly Level 2) of up to six different types of fishing vessel.

- Present the tailored audit process, the audit findings for each vessel type, and also provide recommendations for future work.

METHODOLOGY

Objective 1 - Apply the existing energy-audit process (AUS/NZ Standard 3598:2000) to several types of fishing vessel, and adapt the process accordingly.

Adapting the Energy Audit Standard (AUS/NZ Standard 3598:2000) to make it more applicable to fishing vessels presented the investigative team with a few challenges.

Firstly, the ‘standard’ was clearly configured with land-based buildings and processes in mind, since there was a strong emphasis on alternative energy forms and energy supply arrangements. In contrast, the Australian fishing industry is very limited on both fronts; diesel or light-fuel oil currently represent the only viable energy forms for powering a fishing vessel (Sterling 2009), and supply arrangements via the local wharf fuel-bunker potentially represent the only practical/feasible supply option to most fishing boats.

Secondly, the energy audit parameters in the ‘standard’ had to be adapted to suit a fishing production environment. For example, the units of production relevant to the energy audit of fishing businesses were;

- fishing duration,
- weight of saleable seafood products,
- revenue from seafood products, and
- energy content of edible protein produced.

The proposed amendments in relation to the Energy Audit Standard (AUS/NZ Standard 3598:2000) are outlined in the Results section below under *Results : Objective 1*, and captured more fully thereafter in Table 1. Note that the sections presented in this table were adhered to while preparing the report for each fishing vessel; although due to the subjectiveness associated with ascertaining the energy content of edible protein from various types of seafood, this latter parameter was only discussed and not quantified.

Objective 2 - Undertake a trial energy audit (Level 1 and possibly Level 2) of up to six different types of fishing vessel

Before trial energy audits were undertaken, a work specification was prepared for persons contracted to undertake energy audits on fishing vessels. Parts of this work specification served a number of useful purposes, including briefing/ familiarising industry personnel with what was involved in an energy audit process. The work specification was prepared by John Osborne at Sustainability Victoria with input from the principal investigator. The document in question is presented in Appendix 3c and should prove very useful once energy auditing becomes more prevalent in Australian fisheries.

A letter of invitation for fishing businesses to participate in this energy audit process was also prepared and is presented in Appendix 3d, since it may prove useful to others seeking industry support on similar projects in the future.

RESULTS

Energy Audit Process for Fishing Vessels

Objective 1 - Apply the existing energy-audit process (AUS/NZ Standard 3598:2000) to several types of fishing vessel, and adapt the process accordingly.

A number of amendments were made to the Energy Audit Standard (AUS/NZ Standard 3598:2000) to make it more suitable for fishing vessel applications. These changes are presented below in italic against specific sections in the Standard. Note that sections of the Standard found to be appropriate for auditing fishing vessels (*i.e.* not requiring any amendment(s)) have been omitted from the material presented below as strict copyright restrictions surround the AUS/NZ Standard 3598:2000.

[refer to p.12 of AS/NZS 3598:2000 Energy Audits]

13. AUDIT REQUIREMENTS

13.1 General

The energy audit may vary in its range and depth of study. As a minimum, it shall include the following elements…

13.2 Specific

Note: A summary of the typical deliverables required under each audit-level is given in Appendix C of the Standard.

13.2.1 Level 1 audit

A Level 1 audit does not necessarily require a site visit, although this can be organised if requested by either party. The requirements of this Clause shall be read in conjunction with the requirements of clause 12.1.

A Level 1 audit shall include the following:

(a) Liaison with the auditor's contact on site to ascertain the following:

(i) *Fishing method and vessel characteristics*

- *fishing gear classification (FAO) and description*
- *vessel size (length, approx. displacement)*
- *vessel construction (e.g. steel, wood, fiberglass etc.)*
- *vessel type (displacement or planning etc.)*
- *fishing location/region*

(ii) *Composition of harvested catch*

- *target species*
- *byproduct species*
- *bycatch*

(iii) *Unit of production*

- *$ of revenue*
- *Fishing day (i.e. log book fishing day)*
- *Joules (energy yield from edible protein)*

(b) Determination of total consumption of all fuels *(e.g. diesel, LPG)* for the 24-month period before the audit (ascertained from billing data provided by the energy user). If this data is unavailable, the auditor shall estimate the consumption(s) based on the installed loads, clearly stating the relevant assumptions in the report.

(c) Evaluation of load profile data, if available.

(i) *Production of a load profile over a complete fishing cycle using data supplied by the nominated energy manager for the fishing company (e.g. owner or skipper).*

ii) *Assignment of fuel usage to different phases of the operation and incorporation of this data into a pie chart.*

(d)

(i) *Preparation of monthly energy consumption profiles of all fuels for the previous two years.*

(ii) *Preparation of appropriate energy performance indicators, such as:*

- *fuel used (L) /fishing duration (day)* (N.B. an important internal performance indicator with regard to technical alterations)
- *landed catch (kg) /fuel used (L)* (N.B. obtain fuel quantity from invoices)
- *catch revenue ($) /fuel used (L)* (N.B. obtain revenue amount from accounting records)
- *catch revenue ($) /fishing duration (day)*
- *fuel costs ($) / revenue ($)*
- *fuel used (L) / revenue ($)*
- *fuel used (J) / protein energy produced (J)* (N.B. Energy Return On Inputs (EROI) – allows comparison across food production industries, if required)

(iii) *Comparison of the above indicators with available industry norms.*

(e) A tariff analysis of all forms of energy being used *on the Fishing Vessel (FV)*

- *prices and rates from alternative suppliers of the same fuel*
- *prices and rates for alternative fuels suitable for use on fishing vessels*

(f) Identification of potential for reduction of energy consumption and cost *on the FV* with regard to the above tasks, and provision of recommendations for further action, which may include staff training, capital works, maintenance, substitution of fuels, tariff changes and a higher level energy audit.

(g) Preparation of a report in accordance with section 14, which shall include any findings and recommendations arising from carrying out tasks as described above. The report should also include the sources of data and the accuracy of estimations, as well as:

(i) *A description of the fishing method, vessel characteristics and harvested catch.*

(ii) *Relevant observations concerned with the vessel's operation, process and plant.*

13.2.2 Level 2 audit

The requirements of a Level 2 audit shall be read in conjunction with the requirements of Clause 12.1.

A Level 2 audit shall include the following:

(a) The tasks specified for Level 1 audit.

(b) Meeting with the auditor's contact, *preferably on the FV to be audited, and observing during a fishing trip:*

- *Energy usage patterns during periods of fishing activity and inactivity.*
- *Plant and equipment operation and maintenance.*
- *Physical characteristics of FV and fishing gear.*
- *The business's approach to energy management (i.e. so it can be rated against Energy Management Matrix parameters).*

(c) Analysis of the *FV*'s energy use *whilst active,* identifying the sources of energy, the amount of energy supplied, and detailing what the energy is used for. The analysis should identify important factors affecting energy use, *such as environmental conditions, steaming speed, and distinct phases during fishing operations.*

(d) Preparation of energy consumption targets and indicators of energy end-use on *each FV to be audited* which compare actual, predicted, and post audit target levels. Where desegregated energy consumption data are not available to determine these indicators, an estimate of the indicators based on observed loads, including the relevant assumptions of the report.

e) Provision of an itemized list of recommendations to reduce energy consumption and cost, which shall include both capital works and general management (*i.e. operational*) options. Any capital works recommendations shall include …

13.2.3 Level 3 audit

The requirements of a Level 3 audit shall be read in conjunction with the requirements of Clause 12.1.

A Level 3 audit shall include the following:

(a) The tasks specified in Level 1 and Level 2 audits.

14. AUDIT REPORT REQUIREMENTS

The extent of information reported will reflect the level and scope of the audit undertaken. The final report shall include any specific elements, in accordance with Section 13, and as a minimum, the following:

(d) Observations on operation of *audited FV's during each phase of the fishing operation, including onboard processes and plant.*

Table 1. Energy audit guidelines from AS/NZS 3598:2000 and an audit procedure for fishing businesses.

<table>
<tr><th>The minimum requirements for a walk-through audit (AS/NZS 3598:2000)</th><th>Level 1 audit – fishing business</th></tr>
<tr><td>
• Ascertain the following information.
i) Building construction type and fabric
ii) Type and configuration of services
iii) Appropriate unit of production and its quantity (e.g. net leasable area for office space, number of students for a school, number of beds for a hospital).
• Determine total consumption of all fuels for the twenty four month period prior to the audit (ascertained from billing data provided by the energy user). If this data is unavailable the auditor shall estimate the consumption(s) based on the installed loads, clearly stating the relevant assumptions in the report.
• Evaluate load profile data, if available.
• Prepare monthly or seasonal energy consumption profiles (i.e. kWh/month, MJ/month) for fuels used over the previous two years.
• Prepare appropriate energy performance indicators (e.g. kWh/production unit, $/production unit kWh/m^2, MJ/m^2, $/m^2, kWh/student, MJ/student $/student) and compare with industry norms, if available.
• Evaluate the tariff against comparable norms to determine the possibility of savings from alternative tariffs and/or tendered supply arrangements.
• Identify potential for reduction of energy consumption and cost at the site with regard to the above indices, and provide recommendations for further action which may include staff training, capital works, maintenance, substitution of fuels, tariff changes and a higher level energy audit.
</td><td>
(a) Acquire the following data
(i) Fishing method and vessel characteristics
- fishing gear classification (FAO)
- vessel size (length, ≈ displacement)
- vessel construction (e.g. steel, wood, fiberglass etc.)
- vessel type (disp. or planning etc.)
- fishing location
(ii) Composition of harvested catch
- target species
- byproduct species
- bycatch
(iii) Unit of production
- $ of revenue
- Fishing day (i.e. log book fishing day)
- Joules (energy from edible protein)
(b) Determine total energy input from billing data and/or installed loads (≈24 months)
- diesel, LPG etc.
(c) Evaluation of load profile data, if possible
- produce load profile, at an appropriate time scale (e.g. 24 hours or trip) based on a description of the operating cycle supplied by the energy manager (e.g. owner or skipper)
- assign fuel usage to different phases of the operation and produce a pie chart.
(d) Monthly energy utilisation profiles
(i) plot monthly energy consumption profiles over two years
(ii) prepare energy performance indicators
- $ fuel costs/$ revenue (from accounting records)
- L of fuel/$ revenue (fuel (L) from invoices)
- L of fuel/fishing day (important internal performance indicator wrt technical alterations)
- J of fuel/J of protein energy (EROI allows comparison across food production industries, if required)
(iii) compare the above with available norms if possible
</td></tr>
</table>

Table 1 (cont.). Energy audit guidelines from AS/NZS 3598:2000 and an audit procedure for fishing businesses.

The minimum requirements for a walk-through audit (AS/NZS 3598:2000)	**Level 1 audit – fishing business**
• Meet with the auditors contact on site and carry out an inspection of the audit site observing energy usage patterns, plant and equipment operation and maintenance, and building fabric.	(e) Perform tariff analysis - compare prices from alternative suppliers - compare prices for alternative fuels (f) Identify opportunities for reduced fuel consumption and costs and form recommendations for further action (*e.g.* training, capital works, maintenance, alternative fuels, tariff changes, higher level energy audit).
Additional input for Level 2 audit	
• Prepare energy consumption targets and indicators (*e.g.* kWh/m^2, MJ/m^2, kWh/student, MJ/student) of energy end use throughout the audit site (*e.g.* lighting, HVAC, domestic hot water) which compare actual, predicted, and post audit target levels. Where disaggregated energy consumption data are not available to determine these indicators, estimate the indicators based on observed loads, clearly stating relevant assumptions in the report. • Provide an itemised list of recommendations to reduce energy consumption and cost. This shall include both capital works and general management options. • Identification of measures or potential measures for which additional investigation (such as a Detailed Energy Audit) is required, with an explanation as to why such investigation is required, what the benefits will be and what the expected costs are. • Recommend changes to the energy management program. • Detail a cost effective program to implement the energy audit recommendations, including a prioritised list of capital works and general management activities.	

Table 1 (cont.). Energy audit guidelines from AS/NZS 3598:2000 and an audit procedure for fishing businesses.

Deliverables	**Deliverables**
• A report detailing energy audit findings and recommendations shall be prepared in accordance with this specification and include any findings and recommendations arising from carrying out tasks as described above.	(a) Prepare a audit report in accordance with section 14 (AS/NZS 3598:2000) with the following amendments. (i) Description of fishing method, vessel characteristics and harvested catch. (ii) Observations on vessel operation, process and plant.
Additional input for Level 2 audit	**Additional input for Level 2 audit**
• A briefing to the key personnel within the site on the results.	To be added at a later date.

Vessels Selected for the Energy Audit Trial

Objective 2 - Undertake a trial energy audit of up to six different types of fishing vessel

A total of seven fishing vessels were chosen to test the adapted energy audit process (Table 2). Level 1 audit data for the SE Queensland prawn trawler *C-King* was presented with the data for the *FV Ella Mae*; since both vessels are owned by the same business and fish together.

Table 2. General details on the fishing vessels that were audited in this project.

Vessel type	Vessel name	Fishery/fishing region
Prawn trawler	Point Cloates	Exmouth Gulf Prawn Fishery/ NW Australia
Prawn trawler	Ella Mae & C-King	Queensland East Coast Otter Trawl Fishery/ SE Queensland waters
Rock-lobster pot boat	Nightstalker	Western Rock-Lobster Fishery/ Central WA
Fish trap boat	Flying Fish 4	Pilbara Fish Trap Fishery/ NW Australia
Fish trawler	Torbay	Pilbara Interim Managed Fish Trawl Fishery/ NW Australia
Fish trawler	Moira Elizabeth	Southern and Eastern Scalefish and Shark Fishery/ SE Australia

A total of four different types of fishing vessel were audited. The owner's of energy-intensive trawlers were more interested in participating in the process. Synchronising the audit periods for these vessels as well as obtaining the recommended 24-months of business activity data, proved too difficult in all but two cases (Table 3). A higher level of audit was completed on the *Point Cloates* and *Torbay*, since fuel-flow meters were installed on these vessels.

Table 3. Audit details for the seven fishing vessels involved in this project.

Vessel type	Vessel name	Fishing (audit) period(s)	Audit level
Prawn trawler	Point Cloates	Apr-Nov 2007 Apr-Nov 2008	Level 1/2
Prawn trawler	Ella Mae & C-King	Jan-Dec 2006	Level 1
Rock-lobster pot boat	Nightstalker	06/07 07/08	Level 1
Fish trap boat	Flying Fish 4	08/09	Level 1
Fish trawler	Torbay	2009	Level 1/2
Fish trawler	Moira Elizabeth	Jul 07 - Jun 08	Level 1

An energy audit for each of the seven fishing vessels participating in this project follows.

Trial Energy Audit – Prawn Trawler *Point Cloates*

Introduction

This section contains a Level 1/2 Energy Audit for the prawn trawler *Point Cloates*. This vessel is owned by a single business (MG Kailis Group – abbreviated to MGK) and operates in the Exmouth Gulf Managed Prawn Fishery (EGMPF) (Fig. 1) of Western Australia (WA).

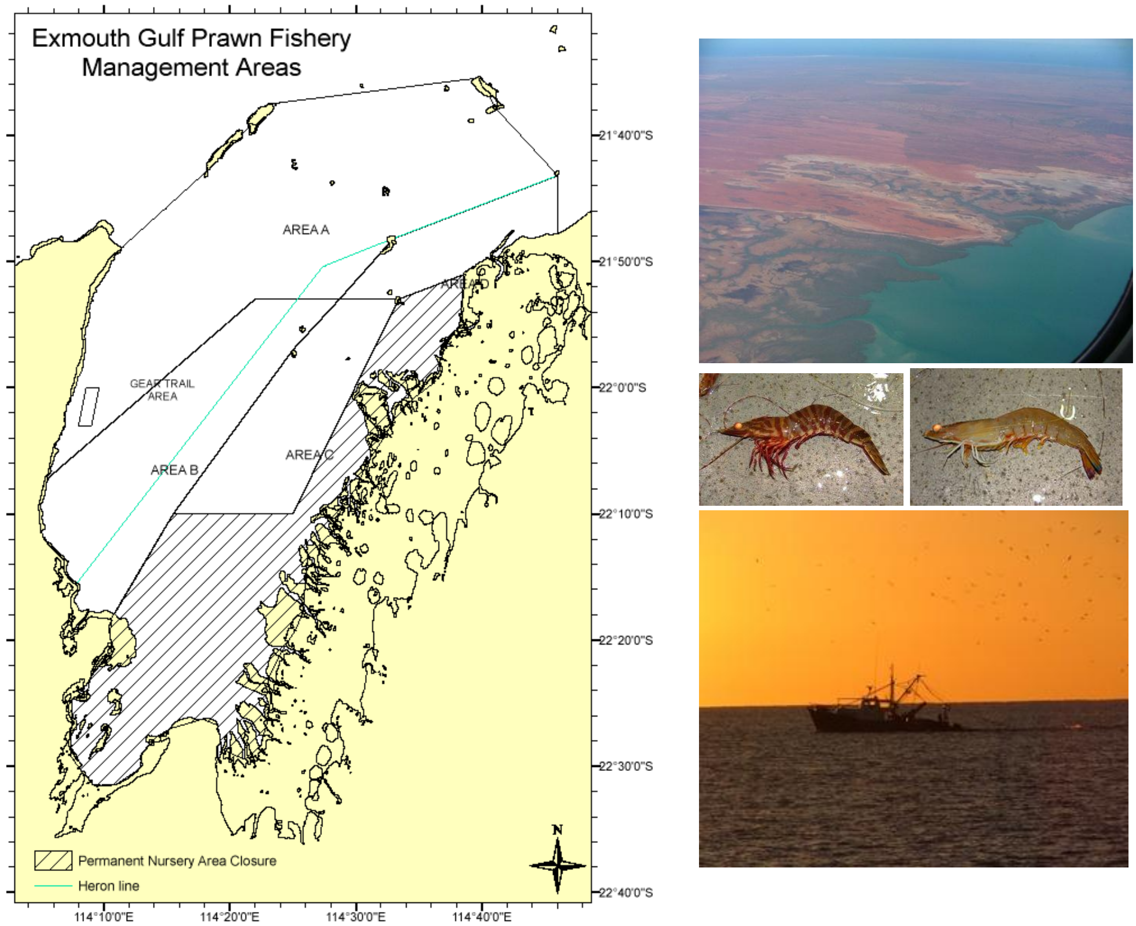


Figure 1. Geographical range of the Exmouth Gulf Managed Prawn Fishery (left pic.) and the mangrove region in the Southern part of the gulf (right top) which serves as a prawn nursery area (right middle) and supports the trawler fleet (right lower).

The *FV Point Cloates* is one of nine similar sized MGK trawlers working in this fishery (Fig. 2). Typically these trawlers return to port every morning after a night's fishing. The prawn product is normally stowed in refrigerated sea-water (refer to Fig. 3) and offloaded in an unfrozen state.

The similarity between the trawlers in this nine vessel fleet, and the cooperation promoted by vessel management ashore (*i.e.* sharing of catch statistics from the previous night's fishing), ensures that search-time/exploratory fishing approaches a minimum and harvesting potential is standardised to a degree. For example, in the 2007 season, seven of the trawlers were within 10% of the trawler with the highest catch rate (*i.e.* average catch per night/fathom of trawl headline).

Figure 2. MG Kailis prawn trawlers in Exmouth marina where they are unloaded/serviced each morning.

Figure 3. Prawn catch being sorted (left) and subsequently stowed in baskets in refrigerated sea-water (RSW) tanks (right).

Despite efforts to standardise the harvesting potential across the fleet, enough variables remain (*e.g.* trawl shot duration, usage of try winches, trawl speed adopted under different environmental conditions *e.g.* sea-state, tide, water temperature, light-level) for good-skippers to demonstrate their skill and worth.

Catch-rates do not reflect a skipper's approach to energy consumption however, and energy consumption forms a large component of the operating costs to this fishing business. All of the energy purchased by the fishing entities is diesel fuel. In the 2007 season the nine trawlers used just over 1.5ML of diesel. In the same season the average amount of fuel consumed per night per fathom of trawl-net headline ranged between 42-59L across the fleet, a difference of 40%. At 51L per night per fathom of headline, the *Point Cloates* was just above the fleet average of 49L per night per fathom of headline.

This energy audit report covers the 2007 and 2008 fishing seasons, which includes the period (*i.e.* around July 2008) when diesel prices in the Gascoyne region of WA reached \$2/L retail or \$1.62/L with the federal government fuel rebate for primary producers such as the fishing industry (Fig. 4).

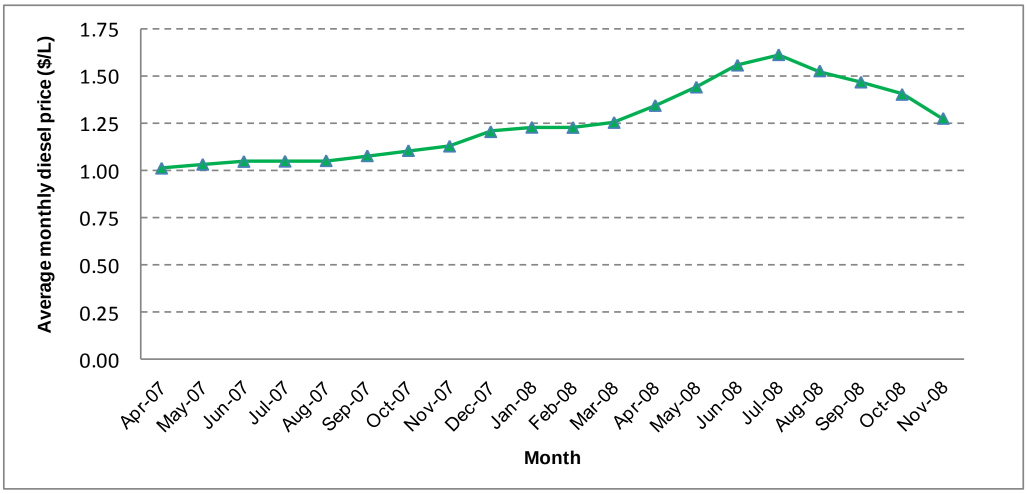


Figure 4. Average monthly prices of diesel in the Gascoyne region of WA[1] during the 2007 and 2008 Exmouth Gulf Managed Prawn Fishery fishing season.

1 Diesel prices were based on average monthly prices compiled by the WA government for the Gascoyne region, which encompasses the township of Exmouth. \$0.3814/L was also deducted from the WA 'Fuel-watch' amount as the fishing industry and other sectors of primary industry receive a Federal government fuel rebate.

The main objective of this report is to obtain a clearer idea of how energy is used by the *Point Cloates* during the course of fishing operations, and subsequently use this information to select the most appropriate ways of reducing energy consumption and cost.

Audit results

(a) Basic business data

Basic business data including vessel characteristics, fishing method, fishing location and composition of catch is provided in Table 4 for the *FV Point Cloates*.

The units of production relevant to the energy audit of this fishing business are;

- fishing duration,
- weight of saleable seafood products,
- revenue from seafood products, and
- energy content of the edible protein produced.

Table 4. Basic business data for the *FV Point Cloates.*

Vessel	Point Cloates	**Launched**	1981		
Length	22.5m	**Beam**	5.6m	**Draft**	2.4m
Construction	Steel	**Vessel type**	Displacement - fwd wheel house, raised forecastle		
Fishing gear	Low opening multi-net demersal trawling				
Fishery	Exmouth Gulf Managed Prawn Fishery				
Fishing region	Exmouth Gulf				
Base port	Exmouth marina				
Target species	prawn species - tiger, king and endeavour				
Byproduct species	sand crab, Balmain bug, squid, coral prawn				
Bycatch species	mixed finfish species plus starfish, sea cucumber, sea snake.				

Fishing duration considerations

Typically the fishing season extends from April to November, with the opening and closing dates determined by trawl survey catch results pre-season and catch rates through the season. There are also 4-5 day closures around the full-moon period to avoid catching prawns during the moulting period when catch quality can deteriorate (*i.e.* reflected by a rise in the percentage of soft and broken/soft shell prawn).

Trawling is conducted during the night-time; so the fishing duration is longest during the winter months. For the purpose of analysis the fishing duration was assigned units of trawling duration in hours, and this was equated to the average hours of darkness for each month multiplied by the number of nights fished in that month. In 2007 and 2008 the *FV Point Cloates* operated for 1971 and 2282 hours respectively.

In reality however, the trawler typically leaves port before sundown and returns after sunrise, and this period either side of the night-time trawling hours is governed by how far the trawler has to steam to the chosen trawl grounds. According to the skipper this can take anywhere between 0.25 to 3 hours, depending on distance and sea-conditions. Infrequently, the trawler may return to port before sunrise *i.e.* if the nightly maximum catch limit in the EGMPF is reached, or the vessel suffers equipment failure, or there is a medical emergency aboard.

Weight of saleable seafood products

Prawns form the primary income for trawlers in the EGMPF. The offloading and weighing system employed onshore provides very accurate data. Prawns are weighed ‘fresh’ *i.e.* wet and unfrozen. Only prawn production was considered in this analysis.

Revenue from seafood products

The revenue from the sale of prawns can fluctuate with market demand and prawn size, and is difficult to trace back to landed amounts due to the grouping of landed prawn from different periods and variable storage periods before sale. For this analysis the average prices used by MGK were adopted *i.e.* Tiger prawns $12/kg, King 11.50/kg, Endeavour $7.50/kg.

Energy content of the edible protein produced

This quantity is included to permit the ratio of production energy (in Joules) to food energy to be established. The food energy yield is not only contingent on how much of the animal is used for food (*i.e.* just the abdominal (‘tail’) section, or the entire prawn) but also the composition (*i.e.* protein, fat, carbohydrate level) of the portion eaten; and since both can vary markedly it was decided to omit this parameter from the audit.

(b) Energy inputs

All of the energy input for the *FV Point Cloates* during the 2007 and 2008 fishing seasons was in the form of diesel fuel. In 2007 a total of 178,627L of diesel was consumed, and in 2008 this amount increased by 3% to 184,061L.

(c) 24 hour energy use profile

The data to produce a detailed 24hr energy use profile has not been collected at this time. However, the trawler generally follows a similar pattern of fishing each night unless some extraordinary event occurs (elaborated on in section (a) ‘*Fishing duration considerations’*); it is possible therefore to configure a representative energy use profile from a typical night of fishing as long as the energy consumption rate associated with each fishing phase is known.

A night of prawn trawling would normally consist of steaming to the fishing grounds, deploying the trawl gear, trawling for several hours, hauling the trawl, repeating the latter three steps several more times while darkness remains, and then steaming back to port at sunrise. The goal for every night is to maximise the time the gear spends on the seabed *i.e.* trawling. Typically, very little time is spent ‘searching’ for prawns in this fishery (*i.e.* echo-sounding without trawl gear on the seabed); since the fishing grounds are well known, prawn migration patterns are closely monitored, and there is a high degree of cooperation/information sharing between the nine MG Kailis vessels in the fleet.

When the vessel has returned to port only the auxiliary engine (Hino W04D rated at 33KW, installed in Dec ’06) is left running. Lights on the trawler are deliberately left on in port to keep a small load on this auxiliary. At sea the auxiliary also provides the power for the refrigeration compressor, Fish-Quip conveyor belt motor, and deck wash motor/pump.

The main engine’s (CAT E series 3406 rated at 354KW, installed in Aug ’05) fuel consumption meter and RPM gauge yielded the following information for four operational phases identified above.

Table 5. Main engine consumption rates for each of the operational phases associated with prawn trawling. Data for *FV Point Cloates*, 22.5m LOA steel trawler powered by a 354KW main and towing 6 fathom quad-rigged low-opening prawn trawls.

Operational phase	RPM	Fuel consumption rate (L/hr)	Remark
Steaming	1400	25	≈7 knots
Deployment	1700		between 4-5 knots
Trawling	1650	61	≈3.2 knots, 77% engine-load
Hauling	1000		≈1 knot

(d) Monthly energy utilisation profiles

(i) Monthly energy consumption profile

Monthly diesel supplies to the *FV Point Cloates* during the 2007 and 2008 fishing seasons is given in Table 6 and Figure 5, together with the associated cost of this fuel.

Table 6. Energy purchases for the *FV Point Cloates* during the 2007 and 2008 fishing seasons.

Date	Diesel used (L)	Diesel price[1] ($/L)	Diesel cost ($)
Apr-07	22,482	1.02	22,821
May-07	22,283	1.04	23,072
Jun-07	20,972	1.05	22,035
Jul-07	40,299	1.05	42,391
Aug-07	18,325	1.05	19,329
Sep-07	31,210	1.08	33,732
Oct-07	16,279	1.11	18,045
Nov-07	6,777	1.13	7,672
Dec-07		1.21	
Jan-08		1.23	
Feb-08		1.23	
Mar-08		1.26	
Apr-08	20,252	1.35	27,294
May-08	18,111	1.45	26,176
Jun-08	34,478	1.56	53,844
Jul-08	18,830	1.62	30,452
Aug-08	18,990	1.53	29,077
Sep-08	37,222	1.47	54,780
Oct-08	17,656	1.41	24,835
Nov-08	18,522	1.28	23,693

1 Diesel prices were based on average monthly prices compiled by the WA government for the Gascoyne region, which encompasses the township of Exmouth. $0.3814/L was also deducted from the WA 'Fuel-watch' amount as the fishing industry and other sectors of primary industry receive a Federal government fuel rebate.

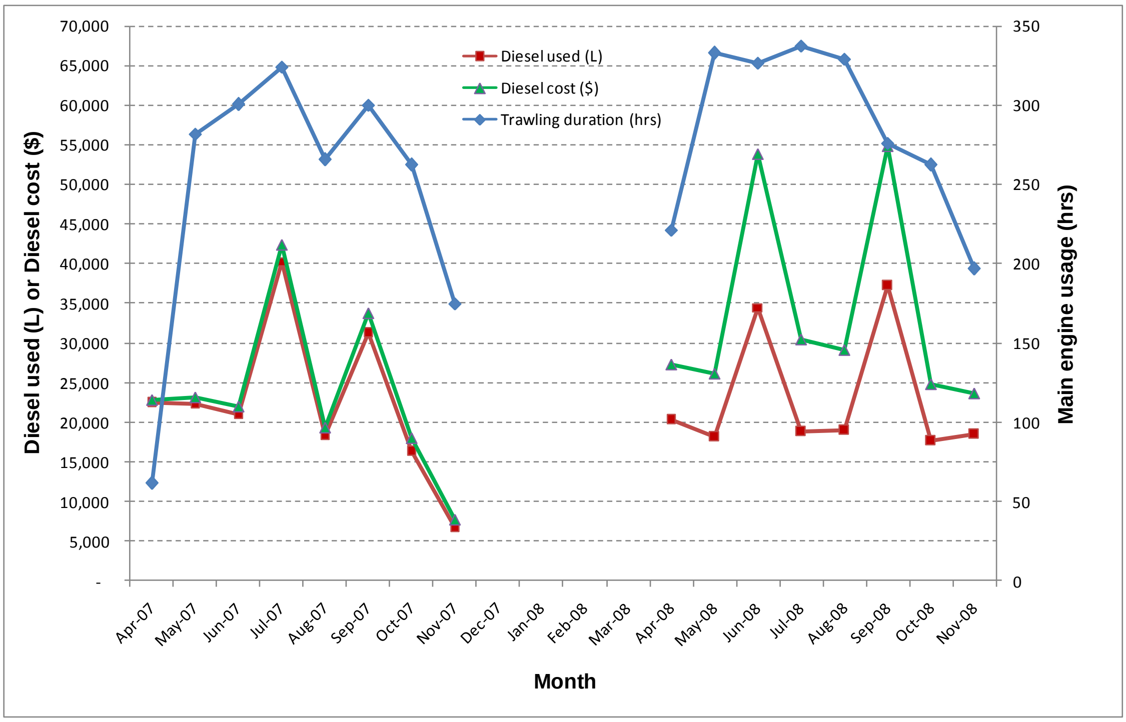


Figure 5. Monthly usage rates of diesel plus the associated cost[1] and estimated trawling duration[2] for *FV Point Cloates* during the 2007 and 2008 fishing seasons.

1 Diesel prices were based on average monthly prices compiled by the WA government for the Gascoyne region, which encompasses the township of Exmouth. $0.3814/L was also deducted from the WA 'Fuel-watch' amount as the fishing industry and other sectors of primary industry receive a Federal government fuel rebate.

2 Trawling duration was estimated by multiply the number of nights fished in a month by the average hours of darkness in that month. N.B. trawlers in the EGMPF only trawl at night.

The monthly diesel cost followed a similar trend to diesel usage; in 2008 the disparity between these quantities increased as a result of elevated diesel prices in that year.

The sharp rise in diesel usage in July '07, September '07, June '08 and September '08 (refer to Fig. 5) corresponded with periods when the vessel refuelled twice in the one month instead of only once. This data is misleading as the consumption of fuel through the year is not so erratic in reality, and in fact corresponds relatively well with the trawling duration curve. To iron out these exaggerated rises in diesel usage it would be necessary to monitor fuel consumption over a shorter time period (for example on a nightly basis with fuel meters), or apportion some of the fuel used in each double-refuel-month to the month on either side.

(ii) Monthly energy performance profiles

The revenue and diesel cost data (Fig. 6) showed a somewhat similar trend during the 2007 and 2008 season apart from the 2008 season being more lucrative (*i.e.* productive) during the first four months of the season, and diesel cost falling markedly towards the end of the 2007 season; the latter difference was caused by a relatively low refuel in November

’07 (6,777L) compared to November ’08 (18,522L) despite the vessels fishing 16 and 18 nights in those months respectively. Presumably there was some reason to run fuel down in the tanks at the end of the 2007 season, possibly in preparation for a vessel slipping.

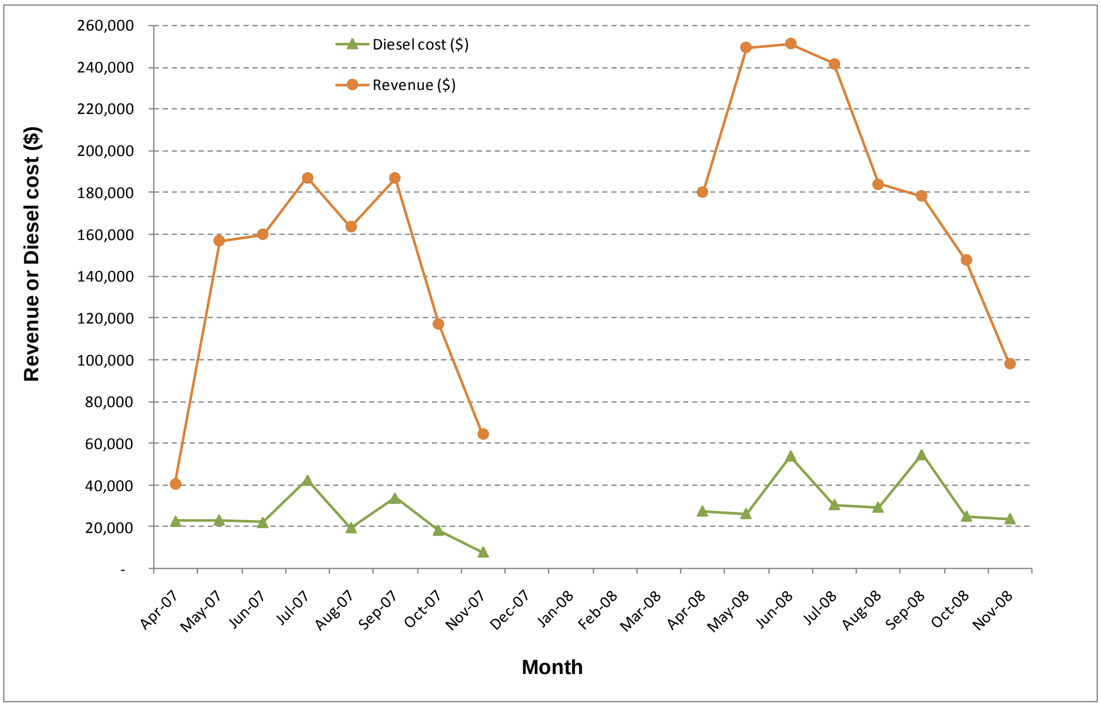


Figure 6. Monthly diesel cost[1] and revenue[2] for *FV Point Cloates* during the 2007 and 2008 fishing seasons.

1 Diesel cost was determined by using average monthly diesel prices compiled by the WA government for the Gascoyne region. $0.3814/L was also deducted from the WA ‘Fuel-watch’ amount as the fishing industry and other sectors of primary industry receive a Federal government fuel rebate.

2 The revenue derived from the prawn catch was estimated from average prices supplied by MGK.

Note that the ‘spikes’ in diesel cost for the months of July ’07, September ’07, June ’08 and September ’08 were caused by the vessel being refuelled twice in the one month instead of only once (addressed in the previous section, namely (d)(i) para. 2).

The ‘spikes’ in revenue were due to variation in catch quantity and also catch composition (since higher prices are paid for larger prawns, and prawn species such as tiger and king prawn). The vessel is usually unloaded daily.

The 2008 fishing season generated 42% more revenue than the 2007 season ($340K compared to $257K) and necessitated consuming 32% more diesel fuel (1,529KL compared to 1,076KL).

Revenue against trawling duration fell by about $300/trawling hour from the commencement to cessation of fishing in both the 2007 (*i.e.* $661/hr - $367/hr) and 2008 (*i.e.* $813/hr - $497/hr) seasons (Fig.7). The observed reduction in income per trawl hour is primarily due to the decline in prawn biomass available to trawlers in the fishing zones.

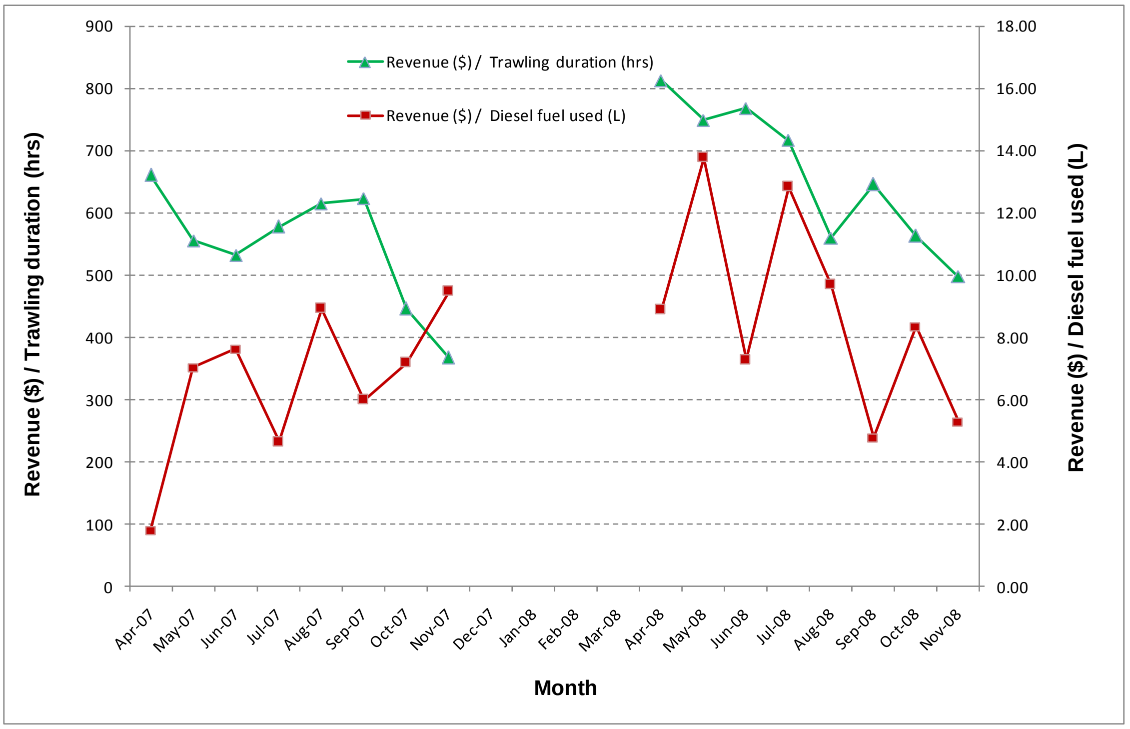


Figure 7. Monthly revenue[1] against trawling duration[2] and also monthly revenue against diesel fuel used for the *FV Point Cloates* during the 2007 and 2008 fishing season.

1 The revenue derived from the prawn catch was estimated using average prices supplied by MG Kailis.

2 Trawling duration was estimated by multiply the number of nights fished in a month by the average hours of darkness in that month. N.B. trawlers in the EGMPF only trawl at night.

Fluctuations in catch revenue through the 2007 season did however cause some notable differences between the seasons. The 2007 season was characterised by a sharp rise in revenue/trawl hour in July and August, followed by a sharper drop in October. By comparison the decline in revenue/trawl hour was steadier across the 2008 season. These observed variations across the fishing season reflect the unpredictable nature of fishing *i.e.* finding and catching prawns.

Revenue (from production output) per unit of diesel fuel varied from $1.81-9.47/L and $4.78-13.76/L in the 2007 and 2008 seasons respectively, which reflected the fluctuating nature of production associated with most capture fisheries. Note that fishing, unlike most manufacturing processes, does not necessarily share the strong correlation between inputs and outputs, because the potential of a fishing vessel and her crew to catch fish very efficiently can easily be eroded by bad luck (*i.e.* failure to locate high concentrations of vulnerable fish) and unfavourable environmental factors capable of affecting catching performance, energy consumption rate, and also available fishing time during potentially good fishing periods.

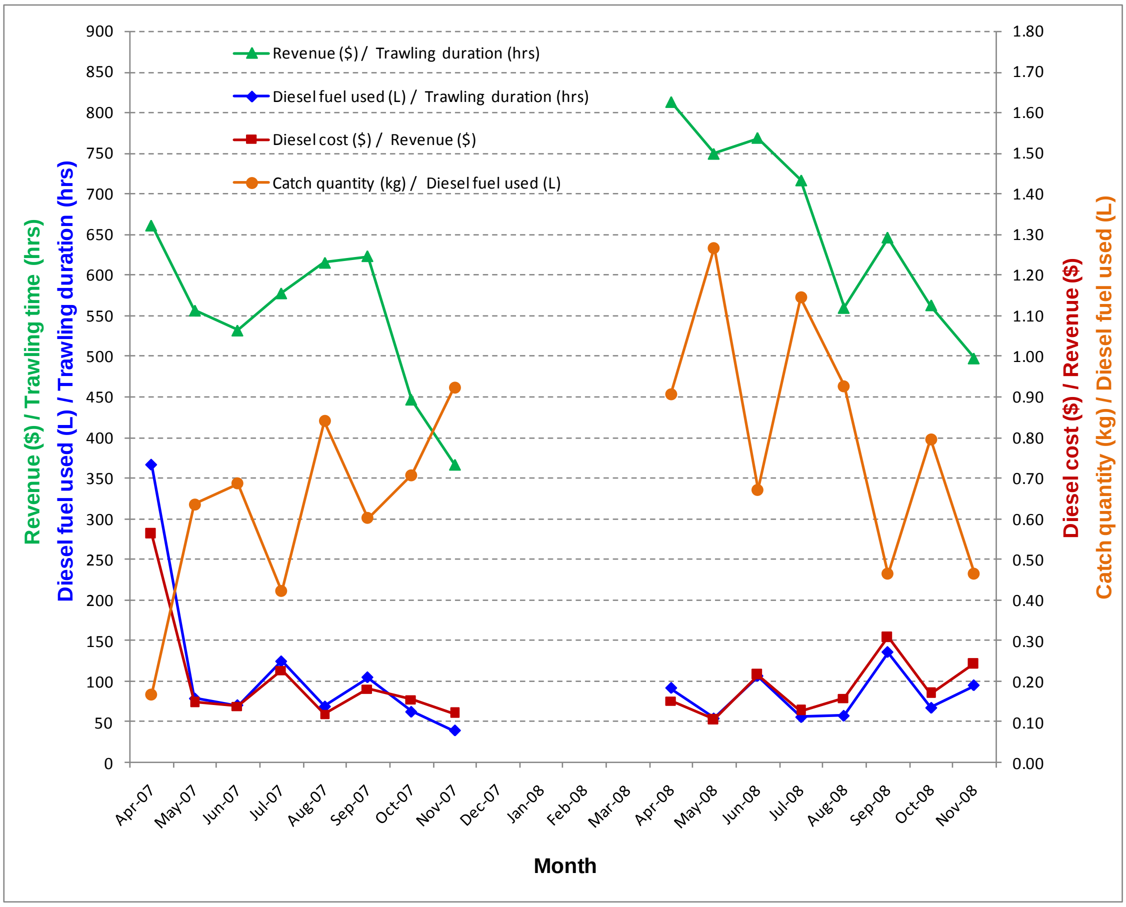


Figure 8. Energy audit performance parameters for the *FV Point Cloates* during the 2007 and 2008 fishing season. Note that diesel cost was determined by using average monthly diesel prices compiled by the WA government for the Gascoyne region. $0.3814/L was also deducted from the WA 'Fuel-watch' amount as the fishing industry and other sectors of primary industry receive a Federal government fuel rebate. The revenue derived from the prawn catch was estimated using average prices supplied by MG Kailis. Trawling duration was estimated by multiply the number of nights fished in a month by the average hours of darkness in that month. N.B. trawlers in the EGMPF only trawl at night.

The following observations relate to the energy audit data presented in Figure 8.

- In 2008 a single hour spent trawling was on average more lucrative (by 23%) for the fishing business, yielding $670/hr compared to $546/hr.
- In both seasons the revenue per trawl hour fell by about $300/hr from the start to the finish of the season *i.e.* early April to late November.
- Over the 2007 season the trawler consumed more fuel per trawl hour (12%) than in the 2008 season (*i.e.* 91L/hr compared to 81L/hr).
- In 2007 and 2008 a similar proportion (just under 18%) of the revenue *i.e.* 0.18 was needed to cover the fuel bill; note that in 2007 and 2008 the fuel cost and revenue

rose by a similar proportion, namely 42 and 43% respectively, resulting in no change in the fuel cost/revenue parameter.

- The average catch quantity in 2008 per litre of fuel was 38% higher than in 2007 *i.e.* 0.78kg/L compared to 0.57kg/L.

(e) Tariff analysis

The difficulty facing the *FV Point Cloates*, like most small to medium sized fishing vessels, is that there are currently no viable alternatives to diesel-fuel. Larger vessels can afford to run the cheaper Light Fuel Oil (LFO) and recover the expense of the required pre-heating system inside a few years. While this dependency on diesel fuel remains, the *Point Cloates* has limited options in terms of seeking out alternative fuel sources and driving prices down via competition in the market place.

MGK is also faced with an additional difficulty which does little towards creating a competitive market place for diesel fuel, and that is the remoteness of the port from which *Point Cloates* fishes. However, MGK have managed to negotiate an attractive discount on the fuel purchased from the local supplier. It is unlikely that any further discount can be obtained this way.

The susceptibility of MGK to fluctuating diesel prices is reflected in the prices paid during the audit period (refer to Fig. 4). Currently there is no mechanism/arrangement in place to insulate the company from such fluctuations, and in terms of this particular commodity, MGK would have to be classified as price-takers.

(f) Audit findings and recommendations

The *FV Point Cloates* spent 160 nights fishing in 2007 and used about 179KL of diesel fuel to harvest just over 101t of prawn. In 2008 it fished for 185 nights and used about 184KL to produce just over 143t of prawn. In terms of food production per unit of fuel, this equated to 0.57 and 0.78kg/L for these seasons respectively. This relatively low food production level per litre of fuel accounts for why prawn trawling is sometimes referred to as a fuel-intensive fishing method/food production method.

In 2007 and 2008 the cost of the diesel fuel used by this trawler accounted for 18% of the revenue from prawn sales. In 2008 the impact of elevated fuel prices on the viability of the business was offset by an increase in prawn catch per litre of fuel together with the trawler using less fuel per trawl hour. These two improvements may be interrelated. For example, the skipper may have reduced the trawl speed, which would account for the decrease in fuel usage per trawl hour, and in doing so concurrently maintained or improved the catching efficiency of the trawl nets (*i.e.* the proportion of prawn landed that reside in the path of the net) to a level that exceeded the associated loss in swept area per unit time caused by the reduction in trawl speed. Other possibilities exist as well but go beyond the scope of this audit.

The sharp rise in the price of diesel fuel in 2008 was a timely reminder to trawling businesses to direct more attention towards becoming more energy efficient food producers, and to seek out cheaper/alternative sources of fuel while diesel prices are temporarily depressed. Table 7 contains a review of the possible fuel saving options available to the *FV Point Cloates*. These options were grouped into five categories, namely

- reduce air resistance of above water structure
- reduce water resistance of the hull
- reduce resistance of underwater appendages and remove fouling
- machinery
- trawl gear

Table 7. Review of fuel saving options available to the prawn trawler *Point Cloates*.

FUEL SAVING OPTION*	**SUITABILITY (L = low, M = med., H = high) & JUSTIFICATION**
Reduce air resistance of above water structure	
• Keep frontal area of deckhouses as small as possible	L – negligible benefit at speed <15knots, plus large frontal area on deckhouses is required on this style of vessel
• Improve design of appendages (*e.g.* masts)	L – negligible benefit at speed <15knots, costly modifications yielding little benefit
• Stack nets on deck whilst steaming	L – negligible benefit at speed <15knots unless travelling longer distances; small drag reduction at no cost
Reduce water resistance of the hull	
• Increase vessel length	M – worth investigation; scale model hull tests are required to quantify the drag reduction and enable a payback period to be determined. Such modifications have been made to prawn trawlers in other fisheries *e.g.* Spencer Gulf S.A.
• Check speed/length ratio	M – operate at economical running speeds; will increase trip duration but may yield a considerable reduction in drag.
• Reduce displacement/length ratio	M – may yield a considerable drag saving and may be possible to implement by utilising lightweight materials or keeping fuel/hold spaces filled below capacity
• Check beam/draft ratio	L – negligible benefit at trawler operating speeds
• Prismatic coefficient (fine up ends of vessel)	L – difficult to take advantage of this option as trawlers do require a large underdeck volume
• Shift longitudinal centre of buoyancy (LCB) aft of amidships	L – may be possible to implement but benefit not quantified
• Check half angle of entrance of the w/line	L – may be implemented but benefit not quantified
• Fit bulbous bows	M – feasible, moderate drag saving, already utilised by prawn trawlers in other fisheries to good effect
• Use round bilge, not hard chine	L – feasible, small drag saving possible, already used by existing trawlers
• Use transom stern, not canoe stern	L – feasible, benefit not quantified, already used by existing trawlers

Table 7 (cont.). Review of fuel saving options available to prawn trawler *Point Cloates*.

FUEL SAVING OPTION*	**SUITABILITY (L = low, M = med., H = high) & JUSTIFICATION**
<u>Reduce resistance of U/W appendages & remove fouling</u>	
• Avoid bilge keels	L – boom mounted stabilisers are currently employed to good effect
• Use aerofoil stabilisers	L – feasible to use aerofoil stabilisers (or similar), however the drag saving may be small if the existing triangular design is operated at a low-moderate angle of attack.
• Use fairings on hull mounted transducers	L – worth consideration, may provide small drag reduction for minimal outlay
• Rudder modifications (asymmetric aerofoil rudder, twisted/aerofoil shaft brackets	M – suggested design modifications are feasible, drag saving not quantified but worth investigation (can always retro-fit)
• Keel cooling pipes, check alignment and design or replace with alternative system	M – feasible, moderate drag saving possible if existing arrangement is found to be poorly designed in terms of drag minimisation
• Remove/check alignment of chafing bars & sponsons	L – realignment is possible and may yield a small drag saving if found to be poorly aligned. Removing sponsons is not a viable option.
• Check position and alignment of sacrificial anodes	L – feasible; may yield a small drag reduction if poorly aligned
• Keep hull & propeller clean and smooth	M – feasible, moderate to large drag saving possible depending on the extent and level of fouling. Clean hull & propeller regularly and renew antifouling regularly, countersink bolts and use detachable lifting pads.
<u>Machinery</u>	
• Utilise waste heat from prime mover cooling water	L – feasible, small fuel saving possible if desalination system fitted and heavier fuels are used in the future
• Utilise waste heat from prime mover exhaust system	L – worthwhile investigating, especially for heating domestic water and defrosting refrigeration systems
• Avoid hydraulic winch systems driven by auxiliaries	– already addressed
• Sail propulsion	L – not feasible/practical; at the mercy of the wind, difficult to fit sails to trawlers as they have lots of overhead rigging.
• Low friction bearings in engine/gearbox/drive shaft	M – worthwhile investigating this option as advancements in this area can yield a 5-10% reduction in frictional losses

Table 7 (cont.). Review of fuel saving options available to prawn trawlers *Point Cloates*.

FUEL SAVING OPTION*	SUITABILITY (L = low, M = med., H = high) & JUSTIFICATION
Machinery (cont.)	
• Fit kort nozzle around properly designed propeller	L – already in place, although it may be worthwhile reviewing in case it is not optimised; these trawlers spend a considerable amount of the available fishing time trawling
• Fit controllable pitch propeller	M – very common on many trawlers. Debatable whether this will yield a fuel saving in the EGMPF; needs further investigation in terms of time spent steaming /trawling.
Trawl gear	
• Use high tensile warp/bridle with a smaller diameter and possibly lower drag coefficient	L – feasible but likely to only yield a small drag saving as the shallow water in this fishery means trawlers do not have to pay out much wire.
• Use more efficient o/board designs	H – feasible; rectangular flat boards on small nets at high spread ratios are relatively inefficient. Multi-foil boards are a better proposition under these circumstances and would yield moderate drag savings.
• Use lower drag nets and net appendages	M – numerous options are available; the use of stronger, braided twines has already been exploited. Other options include knotless netting, consideration of knot orientation in knotted netting panels, utilisation of more efficient body tapers and net designs that alleviate bio-fouling and reduce drag.
* main source of options: Riley & Helmore (1985)	

As a precursor to selecting the most promising fuel-saving options the energy consumption profile of the *FV Point Cloates* during a normal nights fishing (refer above to *Audit results* - section (c) *24 hour energy use profile* and Table 5) was analysed to identify the main energy pathways. This data indicated most of the fuel energy is consumed during the trawling phase, and most of this is used to generate the propulsive thrust required to overcome the drag of the vessel's hull and also the trawl gear. The trawl-gear drag is normally several times greater than the hull-drag (Sterling, 2009), and therefore intuitively this is where efforts to save energy should initially focus.

Of the options aimed at reducing trawl-gear drag, the use of more hydro-dynamically efficient otterboards was deemed the best option for MGK to explore at this point in time. A brief analysis of the respective hydrodynamic efficiency of the flat rectangular otterboard and a proven multi-foil design at a representative angle of attack (35°) revealed that otterboard drag can be reduced by 34% *i.e.* the C_L/C_D ratio of the flat rectangular to multi-foil board of 1.15:1.73 yields 1.15/1.73 = 0.66, in other words the multi-foil boards will only generate about 66% of the flat rectangular board drag for the same lift (spreading) force. Note that the worth of this analysis rests on the assigned representative angle of attack for both types of boards being accurate. To determine the operating angle of attack of the flat rectangular boards, data from tests with scale models of MGK trawl gear in a flume tank (Fig. 9) was utilised (Table 8), in particular the data relating net-spread ratio to board angle of attack. Net spread measurements at sea aboard the *FV Point Cloates* followed (Fig. 10). The Scanmar hydroacoustic sensors employed for this task revealed that the spread ratio hovered around 80%. According to the tabulated scale model data for Rig 3, at such spread ratios the boards would be operating at just under 35°.

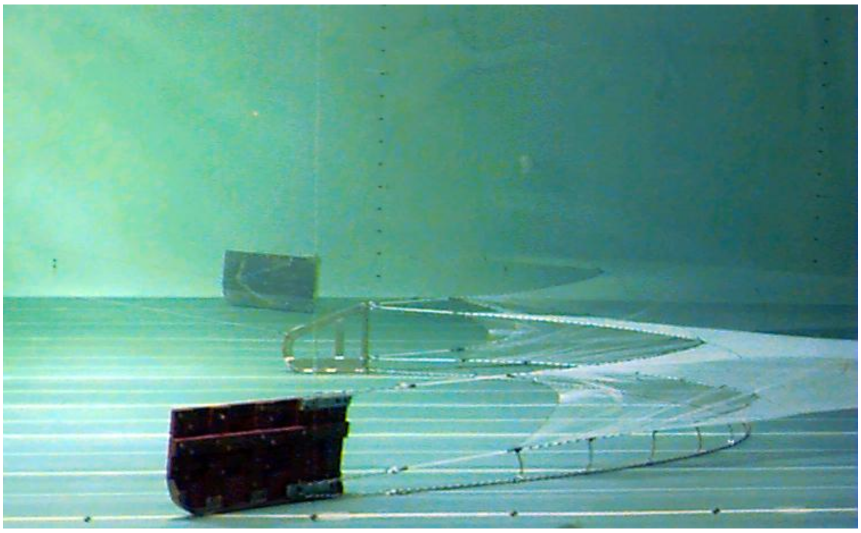


Figure 9. Scale model MGK trawl gear being streamed in a flume tank for the purpose of ascertaining net spread-ratio and the corresponding otterboard angle of attack.

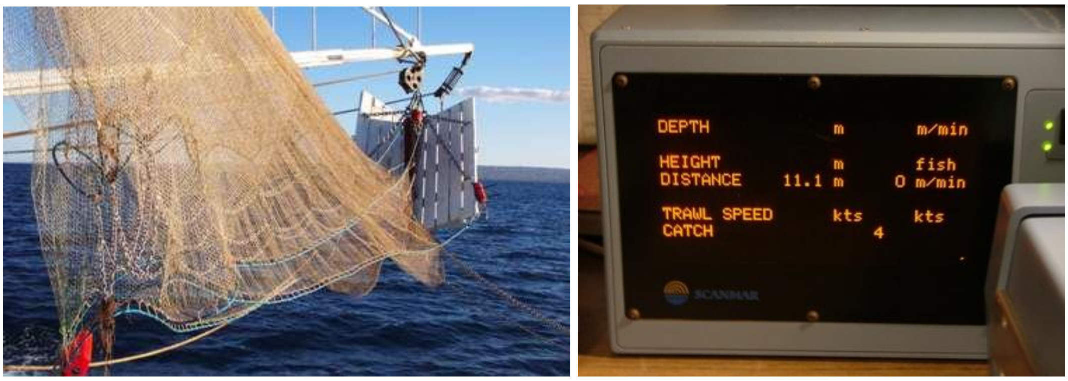


Figure 10. Scanmar spread sensors attached to full-sized MGK trawl gear (left) to determine the net spread-ratio; shown as distance on the display cabinet (right).

Table 8. Results from scale model trawl tests in a flume tank.

MG KAILIS GROUP – FLAT TRAWL FLUME TANK TEST RESULTS (1/4 scale model used- results given as full-scale in the table below)			
Rig configuration	**Trawl speed (knots)**	**Spread ratio (headline)**	**Board angle of attack**
Rig 1:- Standard rig • 6’ boards with slots • towing point just behind the quarter • set angle approx 35.5° • tow point 0.312m off the face •	3.0 3.25 3.5 3.75 4.0	76.5 76.5 76.3 76.3 76.3	30.5°
Rig 2:- Standard rig • slots filled in on boards • otherwise same as rig 1	3.0 3.25 3.5 3.75 4.0	79.3 79.5 79.5 78.3 76.3	31.5°
Rig 3:- 7’ foot boards with slots	3.0 3.5	80.3 81	33°
Rig 4:- 6’ foot boards fitted with back face bracket • net attached on aft quarter of board • towing point just behind the quarter • set angle approx 35° • tow point 0.312m off the face	3.0	75.8	34°
Rig 5:- 6’ boards towed on the third • tow point 0.312m off the face	3.5	76.3	32°
Rig 6:- Repeat of rig 4 with • set angle approx 30° • tow point 0.24m off the face			
Rig 7:- Same as Rig 6 but with one net turned inside out • port side net - knots down and up • starboard net – knots up and down* (* knot shear forces assisting to inflate the net)	3.5	76.3 (S*) & 79.3 (P)	
Rig 8:- Same as Rig 7 but lowered tow point on board by adding a single link to the upper forward leg of the spider.	3.5	76.8 (S*) & 79.6 (P)	

The fuel saving resulting from reducing the otterboard drag by 34% can be estimated using the following equation:

Fuel saving = A x B x C x D x E

Where

A	=	otterboard drag reduction factor relative to the existing flat rectangular otterboard
B	=	proportion of trawl drag attributable to the otterboards
C	=	proportion of the total drag attributable to the trawl gear
D	=	proportion of the fuel consumed while trawling
E	=	fuel consumed during the season (KL)

The calculation based on the 2008 fuel consumption level for the *FV Point Cloates*, and assigning a conservative figure of 0.5 to quantities B, C and D in the above equation, yielded

Fuel saving = 0.34 x 0.50 x 0.50 x 0.50 x 184

= 7.8KL

Based on the average diesel price for the April-Nov 2008 period of $1.46/L, a fuel cost saving of just over $11K could have been realised in that year if more hydro-dynamically efficient multi-foil boards had been deployed. Two pair of multi-foil boards of the size required on the *FV Point Cloates* would retail for less than $20K, which would put the payback period well within the expected life (possibly 5yrs) of these galvanised steel otterboards.

A number of vessel related options with moderate potential for success were also identified in the review; most of these require some form of detailed assessment/test to be performed to accurately quantify the fuel-saving and payback period prior to implementation. At the time of writing this report such information was not at hand.

In closing, it is worth noting that maintaining the prawn trawler fleet in a reliable and fuel-efficient condition, and maintaining/enhancing onshore processing facilities required to retain prawn quality and attain high prawn prices, both serve to suppress/counteract any rise in the diesel cost($) / revenue($) parameter discussed above. To that end MGK appear to have the situation well-in-hand.

Trial Energy Audit – Prawn Trawlers *Ella Mae and C-King*

Introduction

This section contains a Level 1 Energy Audit for the prawn trawlers *Ella Mae* (Fig. 11) and *C-King*. These vessels are owned by a single business (Sterling Fisheries – abbreviated to SF) and operate in the Queensland East Coast Trawl Fishery (QECTF).

Figure 11. Sterling Fisheries prawn trawler *FV Ella May*.

Each vessel has a different specification and is operated differently. For the purposes of this energy audit, each vessel has been treated as a separate entity.

Energy consumption forms a large component of the operating costs to the fishing businesses. Most of the energy purchased by the fishing entities is diesel fuel. Figure Figure 12 indicates the breakdown of operating costs for financial years between 2003/4 and 2006/7 for one of the vessels, the *Ella Mae*. The sharp rise in the proportion of costs allocated to fuel at 2005/6 corresponds to an escalation in fuel price starting at the beginning of 2005 (refer to Fig. 13).

This energy audit report follows the "audit for fishing businesses" procedure presented earlier (refer to Table 1 in the Results section).

The main objective of this report is twofold:

- Test the fishing business energy audit procedure to identify its strengths and weakness and put forward any apparent need for changes.
- Obtain a clearer idea of how energy is used by both trawlers during the course of fishing operations, and subsequently use this information to select the most appropriate ways of reducing energy consumption and cost.

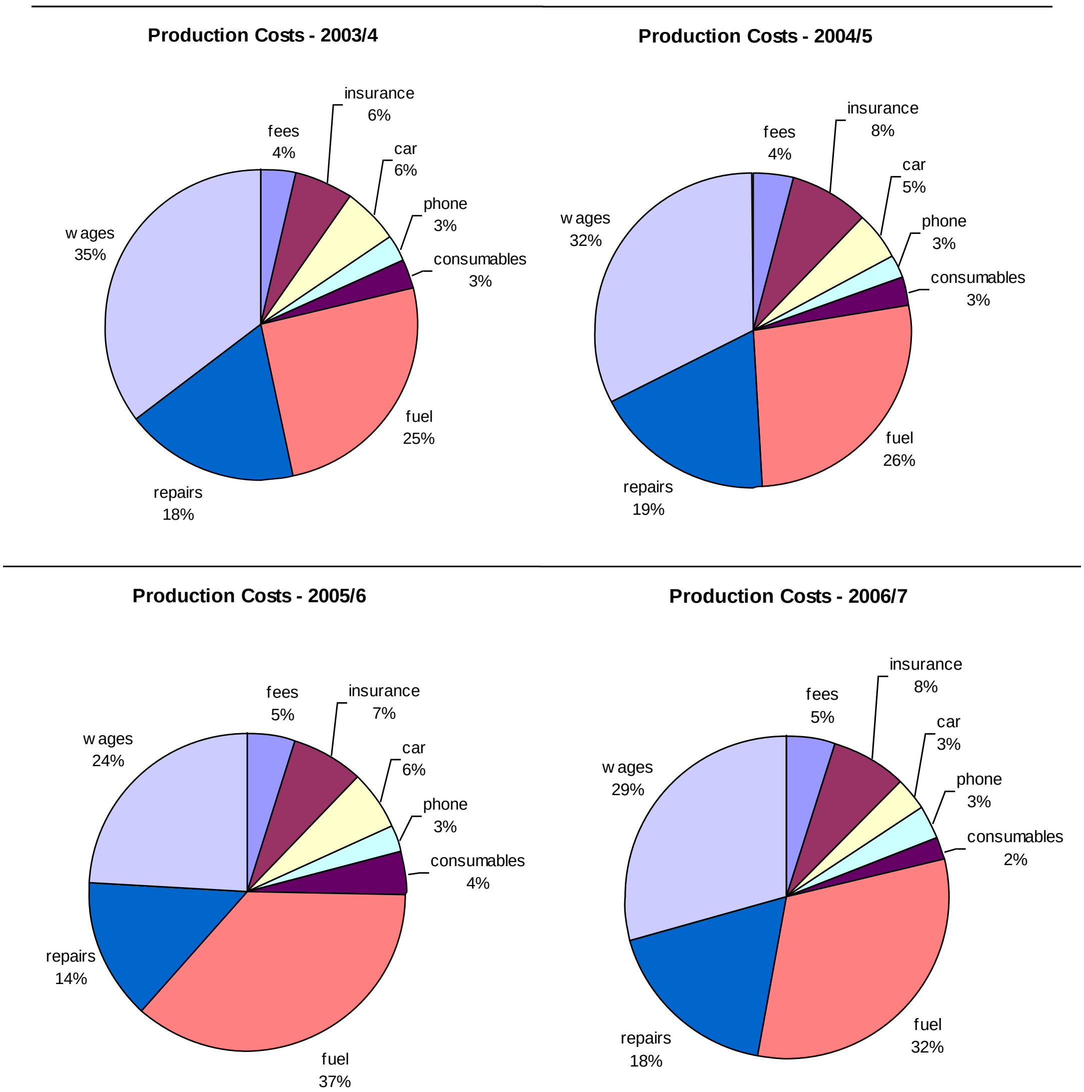


Figure 12. Breakdown of production cost for the prawn trawler *Ella Mae* for financial years from July 1 2003 to June 30 2007.

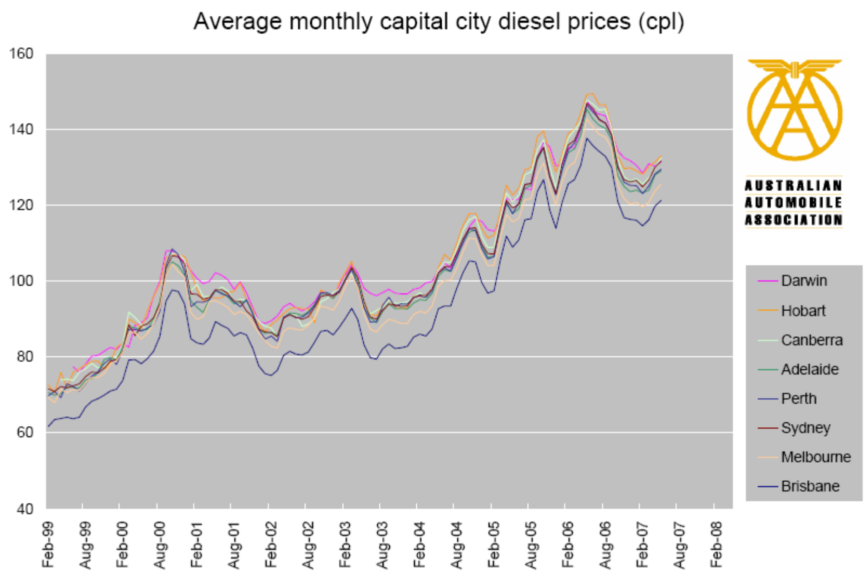


Figure 13. History of diesel prices in Australian capital cities.

Audit results

(a) Basic business data

Basic business data including vessel characteristics, fishing method, fishing location and composition of catch (target, byproduct and bycatch) is provided in **Error! Reference source not found.**Table 9 and 10 for the *Ella Mae* and the *C-King*, respectively.

Table 9. Basic business data for the *FV Ella Mae.*

Vessel	Ella Mae	**Launched**	1979		
Length	13.65m	**Beam**	4.76m	**Draft**	2m
Construction	Steel	**Vessel type**	Displacement - fwd wheel house, raised forecastle		
Fishing gear **Fishery** **Fishing region** **Base port**	Low opening multi-net demersal trawling Queensland East Coast Trawl Fishery Cape Moreton to Cape Bustard (Brisbane to Gladstone) Tin Can Bay				
Target species **Byproduct species** **Bycatch species**	king prawn, tiger prawn, scallop, Moreton bay bug sand crab, Balmain bug, squid, 3-spot crab, cuttlefish, octopus, coral prawn, pinkies. trawl whiting, grinners, flathead, flounder, starfish, catfish, sea urchin, sea cucumber, sea snake.				

Table 10. Basic business data for the *FV C-King.*

Vessel	C-King	**Launched**	1979		
Length	15m	**Beam**	5m	**Draft**	1.9m
Construction	Wood/steel	**Vessel type**	Displacement - fwd wheel house, raised forecastle		
Fishing gear **Fishery** **Fishing region** **Base port**	Low opening multi-net demersal trawling Queensland East Coast Trawl Fishery Cape Moreton to Cape Bustard (Brisbane to Gladstone) Tin Can Bay				
Target species **Byproduct species** **Bycatch species**	king prawn, tiger prawn, scallop, Moreton bay bug sand crab, Balmain bug, squid, 3-spot crab, cuttlefish, octopus, coral prawn, pinkies. trawl whiting, grinners, flathead, flounder, starfish, catfish, sea urchin, sea cucumber, sea snake.				

The units of production relevant to the energy audit of these business entities are; fishing days, weight of saleable seafood products, revenue from seafood products and the energy content of the edible protein produced.

(b) Energy inputs

The energy inputs for these two vessels during 2006 are shown in Table 11 and 12. Most of the energy input was in the form of diesel fuel. A relatively small amount of LPG was purchased in 45kg (80L) bottles; note that LPG usage was not tracked separately for each vessel, but apportioned equally and assigned to the month when it was purchased.

Table 11. Monthly diesel purchases for the prawn trawlers *Ella Mae* and *C-King* in 2006.

	Ella Mae			C-King		
Period	Diesel loaded (L)	Diesel cost ($)	Av. diesel price ($/L)	Diesel loaded (L)	Diesel cost ($)	Av. Diesel price ($/L)
Jan	7313	6524	0.89	5894	5125	0.87
Feb	none			5332	4820	0.90
March	4307	3987	0.93	10037	9430	0.94
April	9206	8975	0.97	5390	5492	1.02
May	5898	6010	1.02	5953	6066	1.02
June	5478	5306	0.97	none		
July	3334	3228	0.97	11889	11515	0.97
Aug	3797	3677	0.97	5109	4948	0.97
Sept	5145	3856	0.75	6710	5608	0.84
Oct	none			none		
Nov	9631	7227	0.75	10500	7846	0.75
Dec	2686	2055	0.77	4958	3793	0.76
Yearly total or ave.	**56795**	**50849**	**0.90**	**71772**	**64645**	**0.90**

Table 12. Monthly LPG purchases for the prawn trawlers *Ella Mae* and *C-King* in 2006.

Period	LPG loaded (45kg bottle)	LPG cost ($)	Av. LPG price ($/bottle)
Feb	3	300	100
June	3.5	289	83
Nov	3	248	83
Year total/av.	9.5	837	89

(c) 24 hour energy use profile

The data to produce a detailed 24hr energy use profile has not been collected at this time. However, the trawler generally follows a similar pattern of fishing each day or night unless some extraordinary event occurs; it is possible therefore to configure a representative energy use profile from a typical night or day (when fishing for scallop) of fishing as long as the energy consumption rate associated with each fishing phase is known. The phases in question include steaming, searching, deploying, trawling, hauling, and at anchor. At this stage such data has not been collected for either vessel.

(d) Monthly energy utilisation profiles

(i) Monthly energy consumption profile

A plot of monthly diesel supplies to the two boats is given in Figures 14 and 15. Fuel used did not always match fuel cost due to variable diesel prices ($0.75 to $1.02 /L) throughout the year. An alternative fuel supplier (that loaded boats directly from a road tanker) was used in September, November and December. This seemed to produce some competition in the supply of diesel fuel and caused the price to be subsequently lowered by the local suppliers.

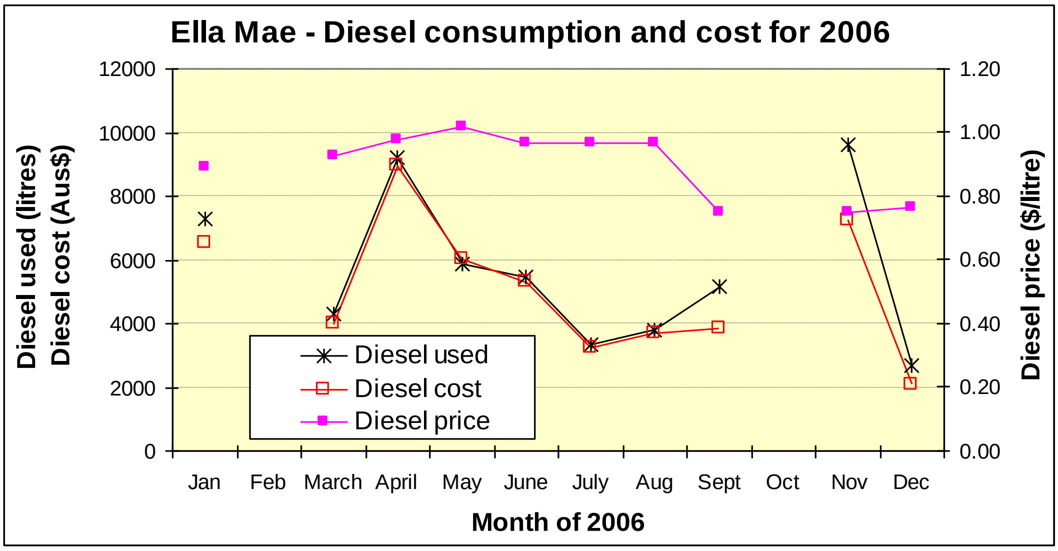


Figure 14. Monthly energy use and associated expense for the FV *Ella Mae* during 2006.

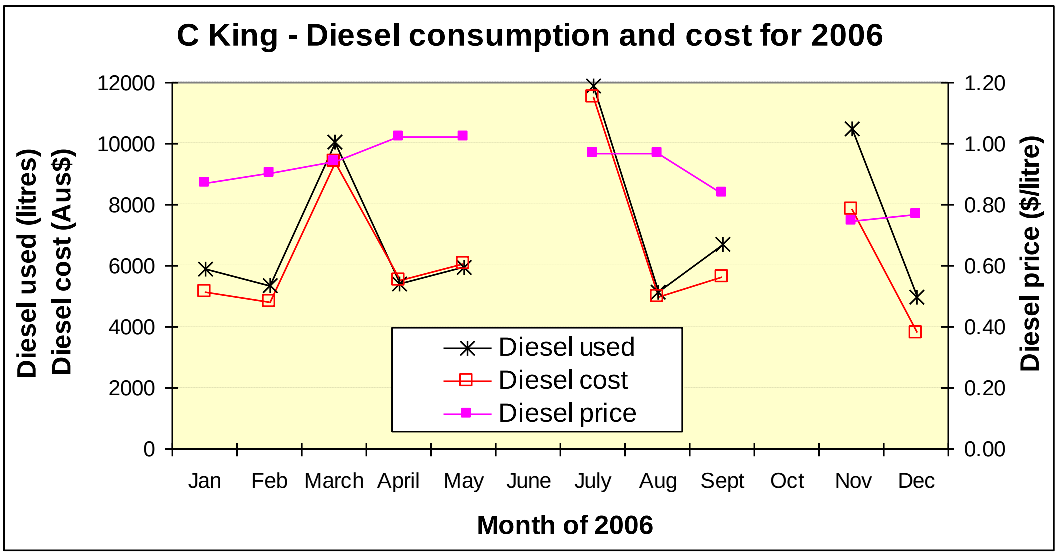


Figure 15. Monthly energy use and associated expense for the FV *C-King* during 2006.

(ii) Monthly energy performance profiles

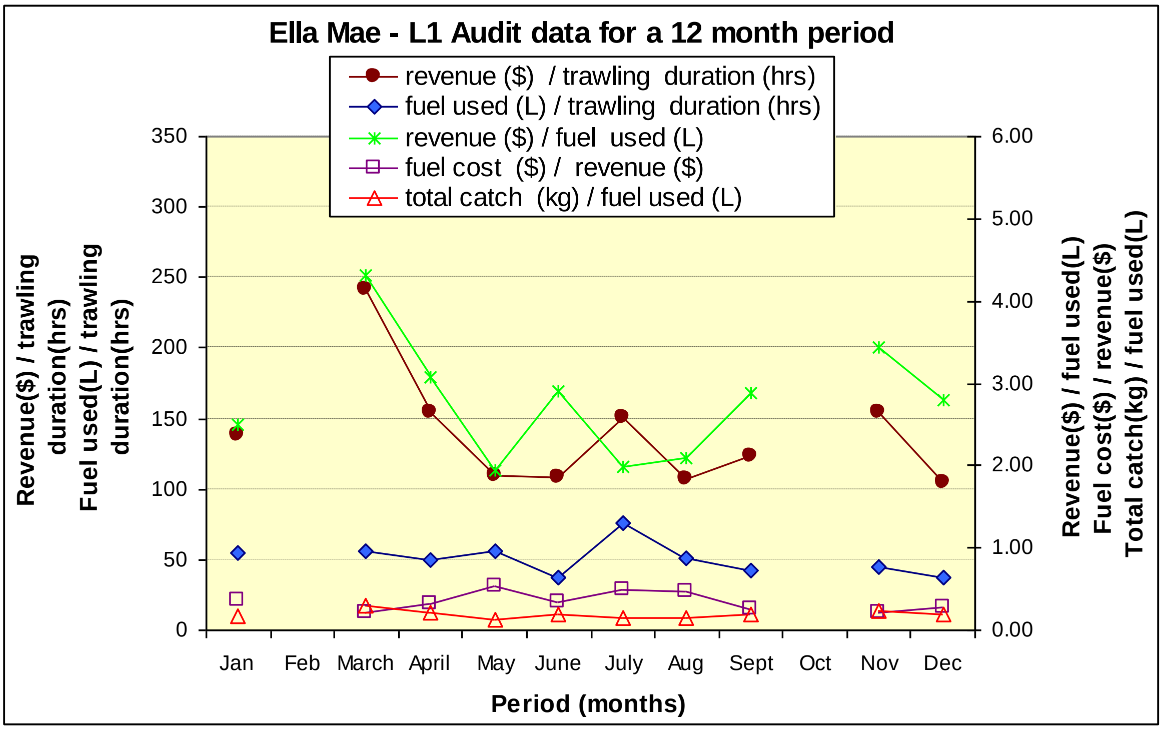


Figure 16. Monthly energy performance profiles for the FV *Ella Mae* during 2006.

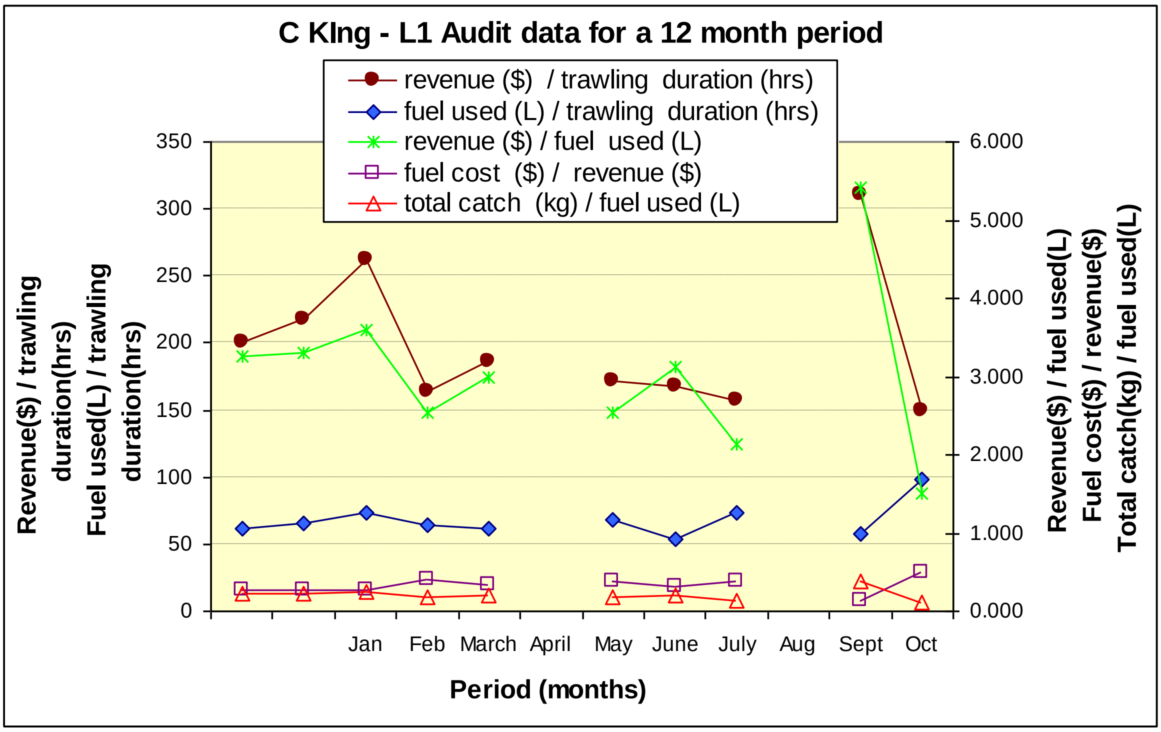


Figure 17. Monthly energy performance profiles for the FV *C-King* during 2006.

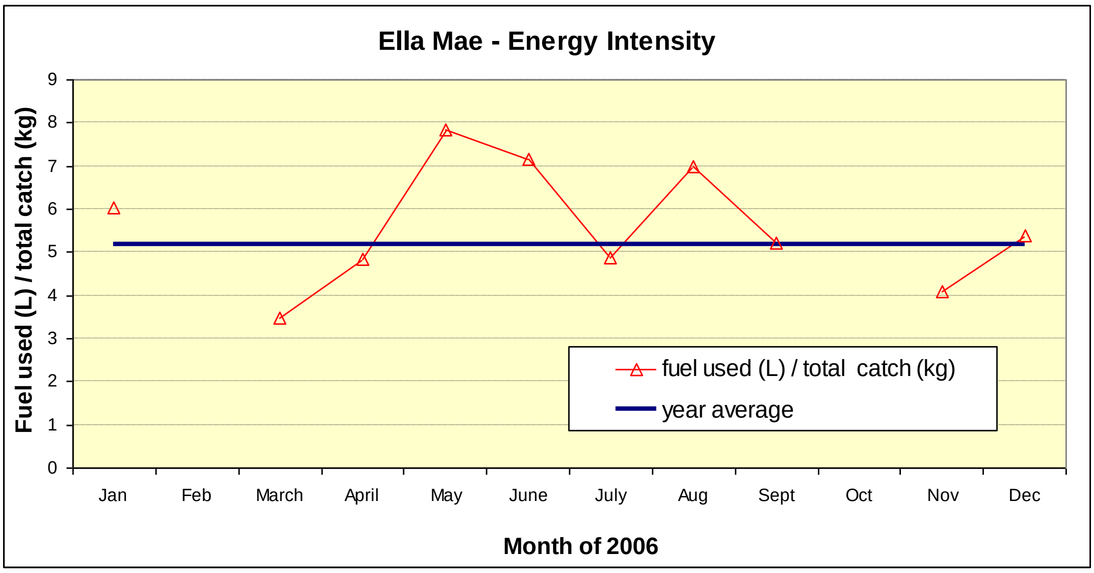


Figure 18. Monthly energy intensity profile for the FV *Ella Mae* during 2006.

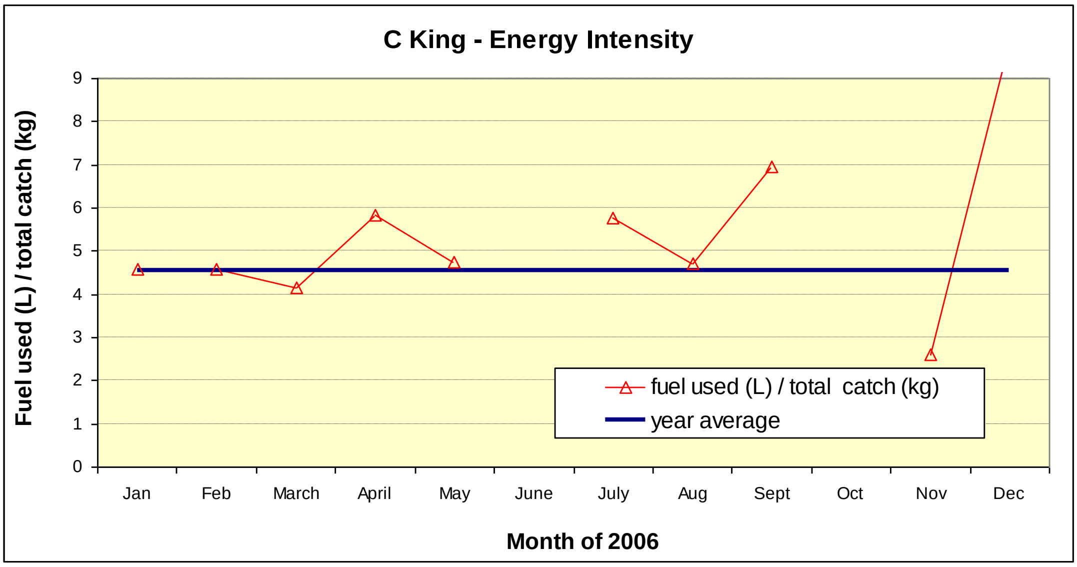


Figure 19. Monthly energy intensity profile for the FV *C-King* during 2006.

The following observations were made in relation to Figures 16 to 19.

- For both trawlers the catch revenue correlated relatively well with catch amount due to stable catch prices ($14.04 to $15.26/kg) through the year.
- There was a loose correlation between rate of income and fuel consumption due to variation in catch rate and noise in the data from incomplete fuel top ups (see June).
- Revenue (from production output) per unit of diesel fuel varied from $1.95 to $4.31/ L, which reflected the fluctuating nature of production associated with most capture fisheries. Note that fishing, unlike most manufacturing processes, does not necessarily share the strong correlation between inputs and outputs, because the potential of a fishing vessel and her crew to catch fish very efficiently, can easily be eroded by bad luck (*i.e.* failure to locate high concentrations of vulnerable fish) and unfavourable environmental factors capable of affecting catching performance, energy consumption rate, and also available fishing time during potentially good fishing periods.
- The fuel expense accounted for between 52% (May) and 22% (March and Nov.) of the revenue during 2006, and clearly put the viability of this business in jeopardy when catch rates were low.
- Food production per unit of fuel ranged from 0.13 to 0.29kg/L, which is why prawn trawling is referred to as a fuel-intensive fishing method.

(e) Tariff analysis

The difficulty facing the *FV Ella Mae* and *C-King*, like most small to medium sized fishing vessels, is that there are currently no viable alternatives to diesel-fuel. Larger vessels can afford to run the cheaper Light Fuel Oil (LFO) and recover the expense of the required pre-heating system inside a few years. While this dependency on diesel fuel remains, the owner's of these vessels have limited options in terms of seeking out alternative fuel sources and driving prices down via competition in the market place.

The introduction of direct refuelling from a road-tanker proved worthwhile. The option of bunkering fuel at the home port of Tin Can Bay is being investigated.

The susceptibility of Sterling Fisheries (SF) to fluctuating diesel prices was reflected in the production cost pie-charts (refer to Fig. 12), where diesel accounted for between 25 and 37% of the total production cost; the latter amount coincided with a sharp rise in the price of diesel in 2006 to $1.02/L (refer to Table 11). To avoid exposing the business to similar occurrences in the future, methods to dampen out price fluctuations need to identified and implemented. One possibility is to investigate whether bio-diesel can be obtained on a long-term supply contract at a fixed price.

(f) Audit findings and recommendations

A flow diagram was constructed to display the breakdown of energy flow from the fuel loaded on the boat to the final applications of energy to the various fishing processes (refer to Fig. 20). The breakdown quantities were estimated from the specifications of equipment involved in the fishing system.

The flow diagram depicting where all the energy is ultimately consumed (refer to Fig. 21) highlighted that the component of the operation related to towing the trawl gear utilses the most energy; this was therefore a priority area for reducing fuel consumption. Other aspects of the operation that consume relatively high levels of energy were; point-to-point transits of the vessel, and the refrigeration system.

The sharp rise in the price of diesel fuel in 2008 was a timely reminder to trawling businesses to direct more attention towards energy-efficient fishing, and to seek out cheaper/alternative sources of fuel while diesel prices are temporarily depressed. Table 13 contains a review of the possible fuel saving options available to the SF prawn trawlers. These options were grouped into five categories, namely:

- reduce air resistance of above water structure
- reduce water resistance of the hull

- reduce resistance of underwater appendages and remove fouling
- machinery
- trawl gear

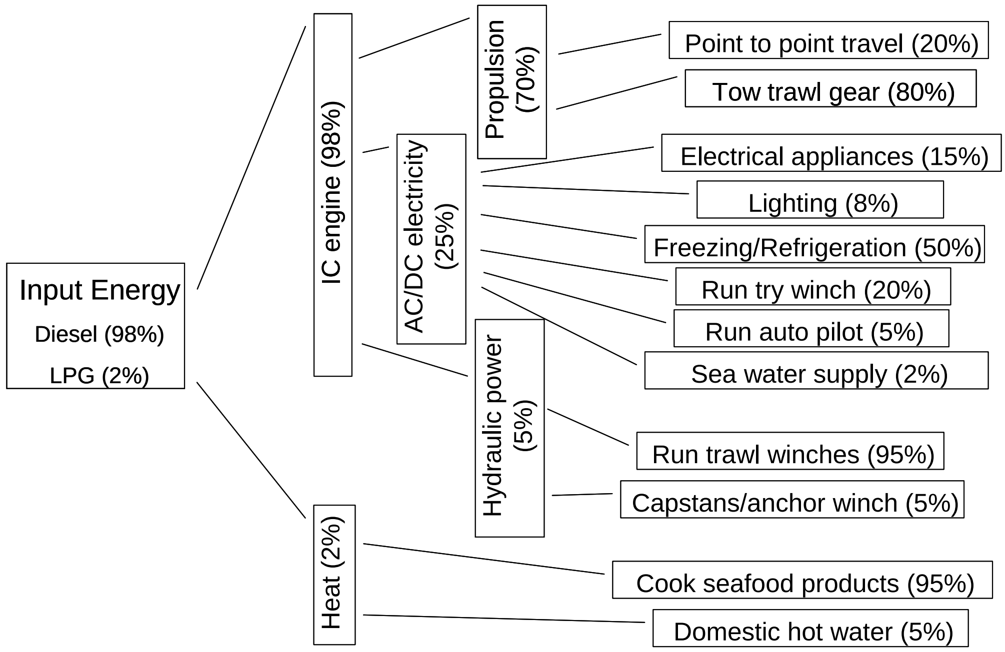


Figure 20. A depiction of where the diesel and LPG energy is potentially used on the prawn trawler *Ella Mae* whilst it is at sea. The amounts shown were estimated from machinery/equipment power specifications.

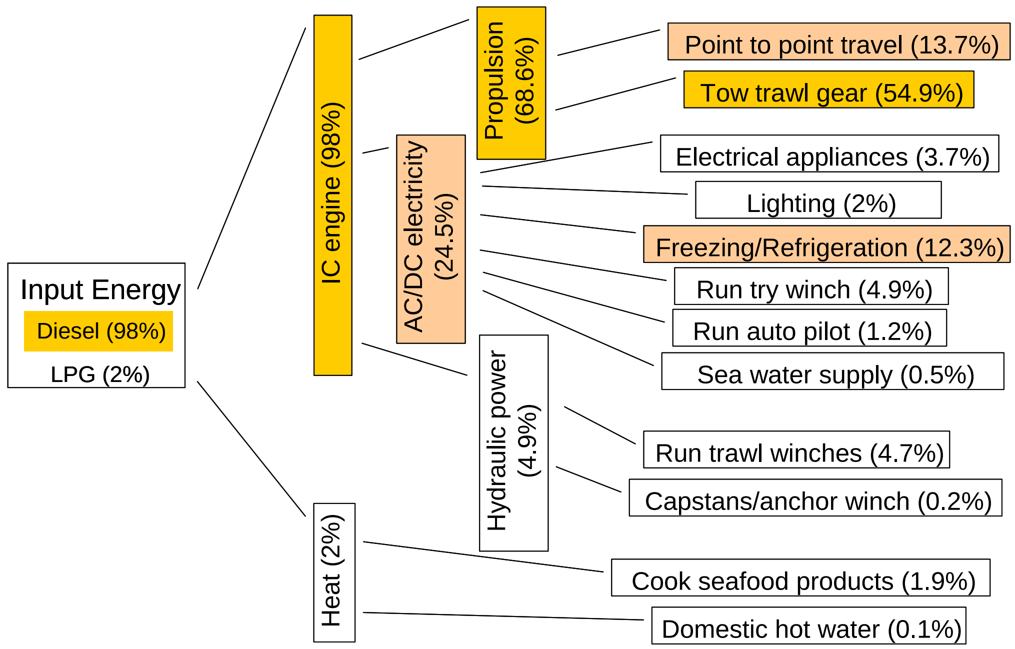


Figure 21. A depiction of where the fuel-energy is potentially used on the prawn trawler *Ella Mae* whilst it is at sea.

Table 13. Fuel saving options available to the prawn trawlers *Ella Mae and C-King*.

FUEL SAVING OPTION*	SUITABILITY (L = low, M = med., H = high) & JUSTIFICATION
<u>Reduce air resistance of above water structure</u>	
• Keep frontal area of deckhouses as small as possible	L – negligible benefit at speed <15knots, plus large frontal area on deckhouses is required on this style of vessel
• Improve design of appendages (*e.g.* masts)	L – negligible benefit at speed <15knots, costly modifications yielding little benefit
• Stack nets on deck whilst steaming	L – negligible benefit at speed <15knots unless travelling longer distances; small drag reduction at no cost
<u>Reduce water resistance of the hull</u>	
• Increase vessel length	M – worth investigation; scale model hull tests are required to quantify the drag reduction and enable a payback period to be determined. Such modifications have been made to prawn trawlers in other fisheries *e.g.* Spencer Gulf S.A.
• Check speed/length ratio	M – operate at economical running speeds; will increase trip duration but may yield a considerable reduction in drag.
• Reduce displacement/length ratio	M – may yield a considerable drag saving and may be possible to implement by utilising lightweight materials or keeping fuel/hold spaces filled below capacity
• Check beam/draft ratio	L – negligible benefit at trawler operating speeds
• Prismatic coefficient (fine up ends of vessel)	L – difficult to take advantage of this option as trawlers do require a large underdeck volume
• Shift longitudinal centre of buoyancy (LCB) aft of amidships	L – may be possible to implement but benefit not quantified
• Check half angle of entrance of the w/line	L – may be implemented but benefit not quantified
• Fit bulbous bows	L – already utilised but may not be optimised
• Use round bilge, not hard chine	L – feasible, small drag saving possible, already used by existing trawlers
• Use transom stern, not canoe stern	L – feasible, benefit not quantified, already used by existing trawlers

Table 13 (cont.). Fuel saving options available to the prawn trawlers *Ella Mae and C-King*.

FUEL SAVING OPTION*	**SUITABILITY (L = low, M = med., H = high) & JUSTIFICATION**
Reduce resistance of U/W appendages & remove fouling	
• Avoid bilge keels	L – boom mounted stabilisers are currently employed to good effect
• Use aerofoil stabilisers	L – feasible to use aerofoil stabilisers (or similar), however the drag saving may be small if the existing triangular design is operated at a low-moderate angle of attack.
• Use fairings on hull mounted transducers	L – worth consideration, may provide small drag reduction for minimal outlay
• Rudder modifications (asymmetric aerofoil rudder, twisted/aerofoil shaft brackets	M – suggested design modifications are feasible, drag saving not quantified but worth investigation (can always retro-fit)
• Keel cooling pipes, check alignment and design or replace with alternative system	M – feasible, moderate drag saving possible if existing arrangement is found to be poorly designed in terms of drag minimisation
• Remove/check alignment of chafing bars & sponsons	L – realignment is possible and may yield a small drag saving if found to be poorly aligned. Removing sponsons is not a viable option.
• Check position and alignment of sacrificial anodes	L – feasible; may yield a small drag reduction if poorly aligned
• Keep hull & propeller clean and smooth	M – feasible, moderate to large drag saving possible depending on the extent and level of fouling. Clean hull & propeller regularly and renew antifouling regularly, countersink bolts and use detachable lifting pads.
Machinery	
• Utilise waste heat from prime mover cooling water	L – feasible, small fuel saving possible if desalination system fitted and heavier fuels are used in the future
• Utilise waste heat from prime mover exhaust system	L – worthwhile investigating, especially for heating domestic water and defrosting refrigeration systems
• Avoid hydraulic winch systems driven by auxiliaries	– already addressed
• Sail propulsion	L – not feasible/practical; at the mercy of the wind, difficult to fit sails to trawlers as they have lots of overhead rigging.
• Low friction bearings in engine/gearbox/drive shaft	M – worthwhile investigating this option as advancements in this area can yield a 5-10% reduction in frictional losses

Table 13 (cont.). Fuel saving options available to the prawn trawlers *Ella Mae and C-King*.

FUEL SAVING OPTION*	**SUITABILITY (L = low, M = med., H = high) & JUSTIFICATION**
Machinery (cont.)	
• Fit kort nozzle around properly designed propeller	L – already in place, although it may be worthwhile reviewing in case it is not optimised; these trawlers spend a considerable amount of the available fishing time trawling
• Fit controllable pitch propeller	M – very common on many trawlers. Debatable whether this will yield a fuel saving in the QECTF; needs further investigation in terms of time spent steaming /trawling.
Trawl gear	
• Use high tensile warp/bridle with a smaller diameter and possibly lower drag coefficient	L – feasible but likely to only yield a small drag saving as the shallow water in this fishery means trawlers do not have to pay out much wire.
• Use more efficient o/board designs	M – multi-foil boards are already employed to good effect, although if the same boards are operated at lower angles of attack a significant reduction in drag can still be realised.
• Use lower drag nets and net appendages	M – numerous options are available; including use of stronger twines, knotless netting, net deflation via knot-orientation, utilisation of more efficient body tapers, and net designs that alleviate bio-fouling and reduce drag.
* main source of options: Riley & Helmore (1985)	

As a precursor to selecting the most promising fuel-saving options the energy consumption pathway (refer to Fig. 21) was analysed. This data indicated that a considerable amount of energy is expended overcoming the drag of the vessel's hull and trawl gear during the trawling phase. It has been established that the drag of the trawl-gear is normally several times greater than the hull-drag (Sterling, 2009). Understandably, this is where efforts to save energy should focus.

Of the options aimed at reducing trawl-gear drag, two were seen as having moderate potential to yield fuel-savings for these SF trawlers, namely the use of more hydro-dynamically efficient otterboards, and the deployment of lower drag nets. Both prospects carry considerable risk as they push the boundary of current gear design/usage. Before an investment is made therefore, scale model tests with prototypes are recommended; not only to expose the potential drag reduction, but also some to expose any inherent usage problems. Once this drag data is available it will be possible to calculate a pay-back period.

Trial Energy Audit – Rock-lobster pot boat *Night Stalker*

Introduction

This section contains a Level 1 Energy Audit for a Western Australian rock-lobster/crayfish pot boat (*FV Night Stalker*) owned by Bruce Cockman (refer to Fig. 22).

Figure 22. The *FV Night Stalker*, a 19.8m rock lobster/crayfish boat built in 1995. Source: Anon. (1995)

This vessel operates in the Western Rock Lobster Fishery (refer to Fig. 23), primarily in Zone B (refer to Fig. 24.)

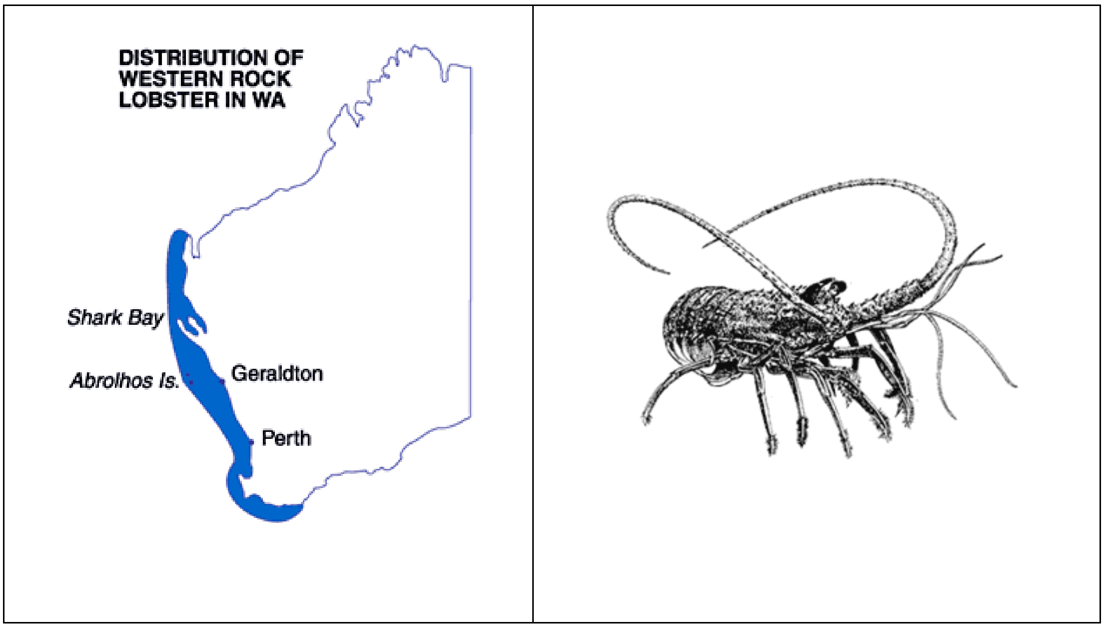


Figure 23. Distribution of Western rock lobster (*Panulirus cygnus*) along the Western Australian coastline. Source: WA Fish. Dept.

WESTERN ROCK LOBSTER FISHING ZONES

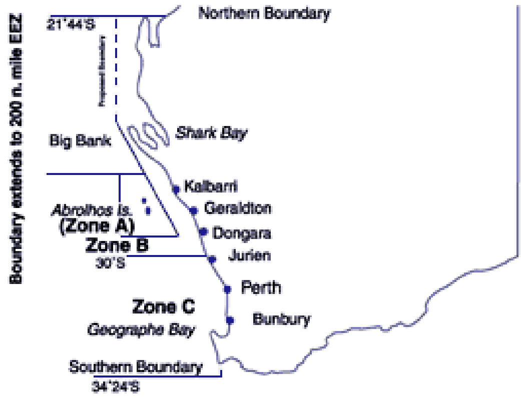


Figure 24. Fishing zones assigned to the Western rock lobster fishery in Western Australia. Source: WA Fish. Dept.

The *FV Night Stalker* is one of several hundred specialised boats fishing for Western rock lobster (*Panulirus cygnus*) as far as 60km from the coast between Augusta and Shark Bay (WA Fish. Dept.). Depending on the location and time of season, vessels may operate daily or undertake short trips. The *FV Night Stalker* with a LOA of 19.8m (65') was designed primarily for the latter. It also shares a lot of features with other planing hull vessels of similar length in this fishery; features that have been trialled and tested in this fishery over a number of years.

The level of cooperation out on the water when setting pots is contingent on fishing partnerships established amongst operators during years of fishing together. The ensuing competition and overcrowding in some areas is likely to lead to a reduction in pot productivity.

Most vessels are equipped with an array of sophisticated electronic equipment (refer to Fig. 25) (*i.e.* radar, echo-sounder, PC plus seabed mapping software, GPS plotter) to assist with the setting of pots in prime locations and the eventual recovery of pots after an appropriate length of time has elapsed.

The utilisation of such equipment coupled with increased knowledge of rock lobster distribution and migration patterns has lead to several reductions in total pot numbers in the fishery, as well as reduction in vessel numbers.

Commercial sized rock lobster are stowed in baskets and held alive in sea-water tanks. The *FV Night Stalker* has a 'live-tank' capacity to carry about 125 baskets. In past seasons the WA rock lobster fleet has landed between 8,000-14,500t. Catch-rates do not necessarily reflect a skipper's approach to energy consumption however, and energy

Figure 25. The *FV Night Stalker* is equipped with an array of electronic equipment to assist with fishing. Source: Anon. (1995)

purchases (primarily diesel fuel) form a large component of the operating cost for this business. A small quantity of LPG is used in the galley for cooking, although this energy was not considered in the following audit.

This energy audit report covers the 2006/7 and 2007/8 fishing seasons, and importantly covers the period (*i.e.* up to June 2008) when diesel prices in the Mid-West region of WA nearly reached $2/L retail, or $1.62/L with the federal government fuel rebate for primary producers such as the fishing industry (refer to Fig. 26).

The main objective of this report is to obtain a clearer idea of how energy is used by the *FV Night Stalker* while fishing, and to subsequently identify ways of reducing the energy consumption level and associated cost. Note that the report follows the "audit for fishing businesses" procedure outlined earlier (refer to Table 1 in the Results section).

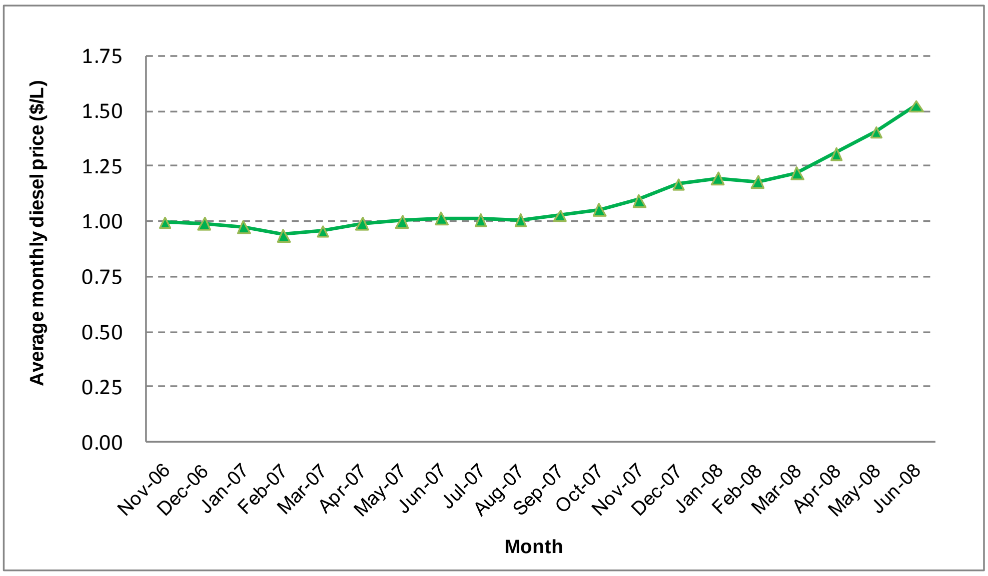


Figure 26. Average monthly prices of diesel in the Mid-West region of WA[1] during the 2006/7 and 2007/8 Western Rock Lobster Fishery seasons.

1 Diesel prices were based on average monthly prices compiled by the WA government for the Mid-West region, which encompasses the townships of Kalbarri, Geraldton and Dongara/Port Denison where the *FV Night Stalker* operates from . $0.3814/L was also deducted from the WA 'Fuel-watch' amount as the fishing industry and other sectors of primary industry receive a Federal government fuel rebate.

Audit results

(a) Basic Business data

Basic business data including vessel characteristics, fishing method, fishing location and composition of catch is provided in Table 14 for the *FV Night Stalker*.

Table 14. Basic business data for the *FV Night Stalker*

Vessel	Night Stalker	**Launched**	1995		
Length	19.8m	**Beam**	5m	**Draft**	1.55m
Vessel type	Planing - fwd wheel house and flybridge, topped with a bimini				
Construction material	Hull and deck: welded aluminium Superstructure: moulded fibreglass				
Fishing gear **Fishery** **Fishing region** **Base Port**	Pots Western Rock Lobster Fishery Mid-West – mainly Zone B Port Denison/Dongara, Kalbarri				
Target species **Byproduct species** **Bycatch species**	rock lobster *Panulirus cygnus* other species of rock lobster octopus, eel and mixed finfish species				

The units of production relevant to the energy audit of this fishing business are;

- fishing duration,
- weight of saleable seafood products
- revenue from seafood products, and
- energy content of the edible protein produced.

Fishing duration considerations

The open fishing season extends from 15 November to 30 June, with a delayed start of season in the Abrolhos Islands area of 15 March (WA Fish. Dept.). Pots can only be pulled during specific daylight hours depending on the time of the year and the depth of water being fished.

The current approach adopted with *FV Night Stalker* of staying out for about five days in zone B is a strategy aimed at minimising travel time and running expenses between port and the offshore fishing grounds. *FV Night Stalker* has the necessary capacities for such trips; *e.g.* accommodation berths x 6, fuel 6,500L, live-tanks to hold 124 baskets of crayfish (refer to Fig. 27). Occasionally, the vessel may return to port earlier than intended *i.e.* if bad weather forces them in, or the vessel suffers equipment failure, or there is a medical emergency aboard.

Figure 27. Galley/dinette area utilised on short trips (4-5 days). Source: Anon. (1995)

Weight of saleable seafood products

Rock-lobster (*Panulirus Cygnus*) forms the primary income for this fishing business. The offloading and weighing system employed onshore provides very accurate data. Rock-lobsters are weighed ‘fresh’ *i.e.* wet and unfrozen.

Revenue from seafood products

The price paid for rock-lobster can fluctuate through the year and between years depending on market conditions. For example, the average beach price for product from *FV Night Stalker* in the 2006/7 and 2007/8 seasons was $28.17/kg and $23.30/kg, a decrease of 17%. Furthermore, during these two seasons the beach price paid ranged between $26.00-$32.65 and $22.00-$27.34 respectively.

Energy content of the edible protein produced

This quantity is included to permit the ratio of production energy (in Joules) to food energy to be established. The food energy is contingent on how much of the lobster is used for food. The abdominal (‘tail’) section is used for meals, whereas the head and other remnants may be used in a different form (*e.g.* crushed into a paste) as ingredients in other food products such as sauces.

(b) Energy inputs

Almost all of the energy consumed by the *FV Night Stalker* during the 2006/7 and 2007/8 fishing seasons was in the form of diesel fuel. The balance was a small amount of LPG for cooking purposes. In 2006/7 a total of 91,203L of diesel was consumed, and in 2007/8 this amount decreased by 4% to 87,369L. The LPG was omitted from this audit because it represents an insignificant amount and cost to the business.

(c) 24 hour energy use profile

The data to produce a detailed 24hr energy use profile has not been collected at this time. However, this rock-lobster boat generally follows a similar pattern of fishing each day unless some extraordinary event occurs (elaborated on in section (a) ‘*Fishing duration considerations’*, para. 3); it is possible therefore to configure a representative energy use profile for a typical day’s fishing as long as the energy consumption rate associated with each fishing phase is known. Currently these consumption rates are not known and it will be necessary to install a fuel meter on the main engine (Detroit 12V92TA rated at 940hp) and between the pair of auxiliaries (Perkins 10419 producing 15kVA each) on this vessel to acquire such data.

A fishing trip on the *FV Night Stalker* would comprise of steaming to the fishing grounds, setting the pots through the daytime, holding station overnight in close proximity to the pots that have to be hauled first, hauling the pots through the daytime and resetting them, either in the same area or nearby depending on the catch rates, waiting overnight again and repeating the latter two steps several more times before hauling the pots in the morning and steaming back to port. The goal for every night is to maximise the pot soak-time in areas carrying relatively high numbers of commercial sized rock lobster on the outlook for food.

In port (refer to Fig. 28) only one of the auxiliary engines is needed to keep raw-water recirculating through the holding tanks until the catch is unloaded. At some stage shore power would be utilised as well.

Figure 28. *FV Night Stalker* alongside the wharf showing a fine bow. Source: Anon. (1995)

(d) Monthly energy utilisation profiles

(i) Monthly energy consumption profile

A plot of monthly diesel supplies to the *FV Night Stalker* during the 2006/7 and 2007/8 fishing seasons is given in Table 15 and Figure 29, together with the associated fuel-cost.

The monthly diesel cost followed a similar trend to diesel usage; in the latter part of the 2007/8 season the disparity between these quantities increased markedly as a result of elevated diesel prices in 2008. As a result, the fuel bill for the 2007/8 season was 24% higher than in the previous season, even though less fuel (4%) was used.

The zero quantities for engine usage in November ’06 and ’07 and February ’07, despite diesel being used in those months represents a problem with synchronising refuel amounts (recorded on fuel dockets) against engine running hours taken from a logbook. In fact an

Table 15. Energy purchases for *FV Night Stalker* during the 2006/7 and 2007/8 fishing seasons.

Date	Diesel used (L)	Diesel price[1] ($/L)	Diesel cost ($)
Nov-06	6,158	0.99	6,097
Dec-06	18,248	0.99	17,980
Jan-07	1,923	0.97	1,866
Feb-07	9,160	0.94	8,574
Mar-07	14,247	0.95	13,556
Apr-07	14,020	0.98	13,800
May-07	15,727	1.00	15,681
Jun-07	11,720	1.01	11,851
Jul-07		1.00	
Aug-07		1.00	
Sep-07		1.02	
Oct-07		1.05	
Nov-07	2,500	1.09	2,728
Dec-07	16,601	1.17	19,340
Jan-08	2,538	1.19	3,027
Feb-08	9,336	1.18	10,972
Mar-08	18,694	1.21	22,689
Apr-08	16,977	1.30	22,145
May-08	11,872	1.40	16,629
Jun-08	8,851	1.52	13,457

1 Diesel prices were based on average monthly prices compiled by the WA government for the Mid-West region, which encompasses the townships of Kalbarri, Geraldton and Dongara/Port Denison where the *FV Night Stalker* operates from. $0.3814/L was also deducted from the WA 'Fuel-watch' amount as the fishing industry and other sectors of primary industry receive a Federal government fuel rebate.

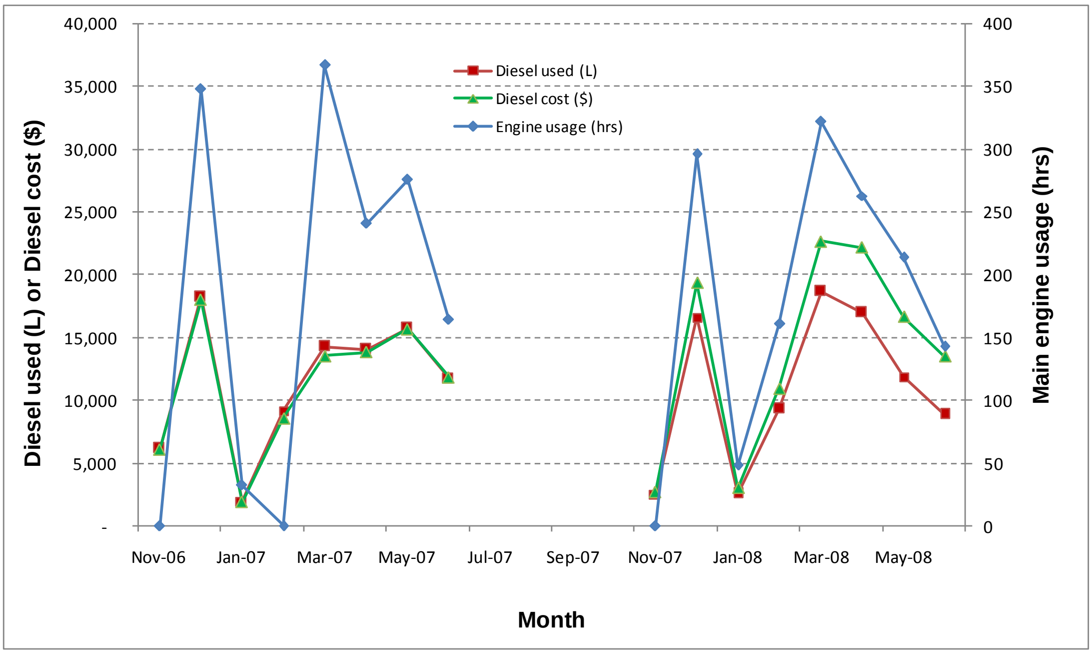


Figure 29. Monthly usage rates of diesel plus the associated cost[1] and main engine usage for the *FV Night Stalker* during the 2006/7 and 2007/8 fishing seasons.

1 Diesel prices were based on average monthly prices compiled by the WA government for the Mid-West region, which encompasses the townships of Kalbarri, Geraldton and Dongara/Port Denison where the *FV Night Stalker* is based. $0.3814/L was also deducted from the WA 'Fuel-watch' amount as the fishing industry and other sectors of primary industry receive a Federal government fuel rebate.

average for the months of Feb ’07 and Mar ’07 would probably yield a more representative view of what happened in those months. Once this adjustment was made it was evident that engine usage and diesel consumption rates followed a similar pattern through both seasons.

(ii) Monthly energy performance indicators

The monthly revenue and diesel cost data (refer to Fig. 30) showed a similar pattern during the 2006/7 and 2007/8 seasons, although the first part of the 2006/7 season was more lucrative and then fell away more sharply at the end. The impost of higher diesel prices in 2008 was also evident and because of the lower prices paid in 2008 for rock-lobster (on average 17% lower than the 06/07 season), the disparity between the diesel cost and revenue curve increased in that year. Interestingly, despite diesel prices increasing steadily through Mar-08 to Jun-08 (refer to Fig. 26), the *FV Night Stalker* was able to reduce the disparity between the revenue and cost curves by finishing the season with a run of good catch rates in those four months (*i.e.* 24, 26, 27 and 28kg/hr between Mar-08 to Jun-08), together with a sharp rise (a 17% increase on the yearly average) in product value in Jun-08. Understandably these increments in fishing efficiency and market price could not have come at a better time.

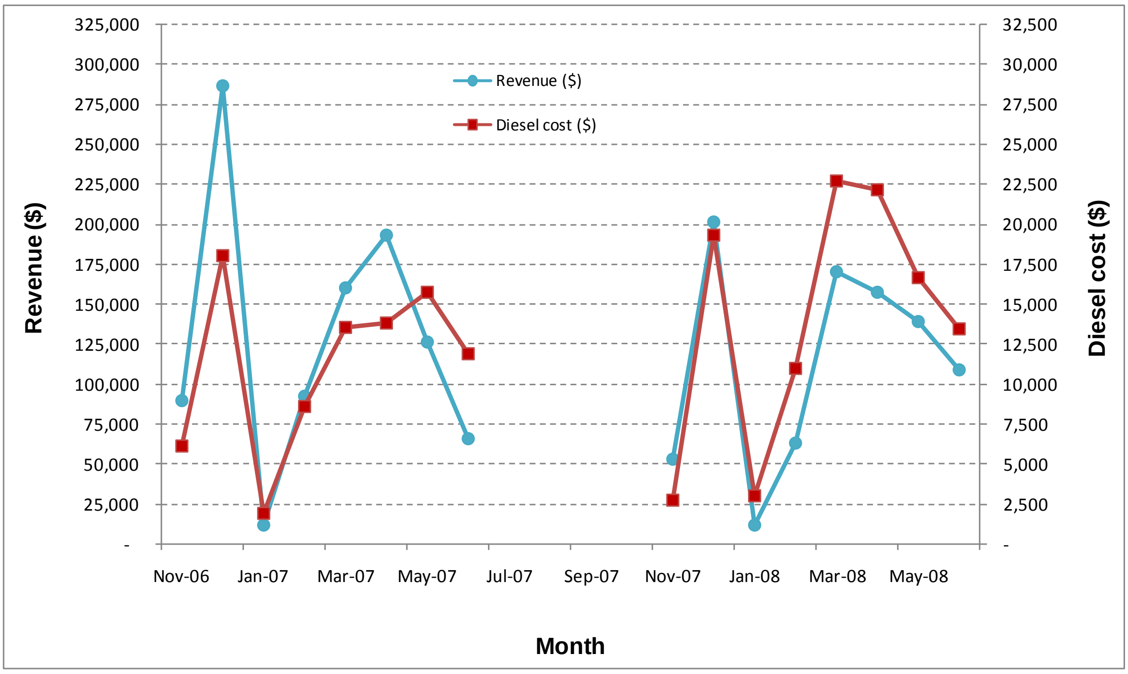


Figure 30. Monthly diesel cost[1] and revenue for *FV Night Stalker* during the 2006/7 and 2007/8 fishing seasons.

1 Diesel cost was determined by using average monthly diesel prices compiled by the WA government for the Mid-West region. $0.3814/L was also deducted from the WA ‘Fuel-watch’ amount as the fishing industry and other sectors of primary industry receive a Federal government fuel rebate.

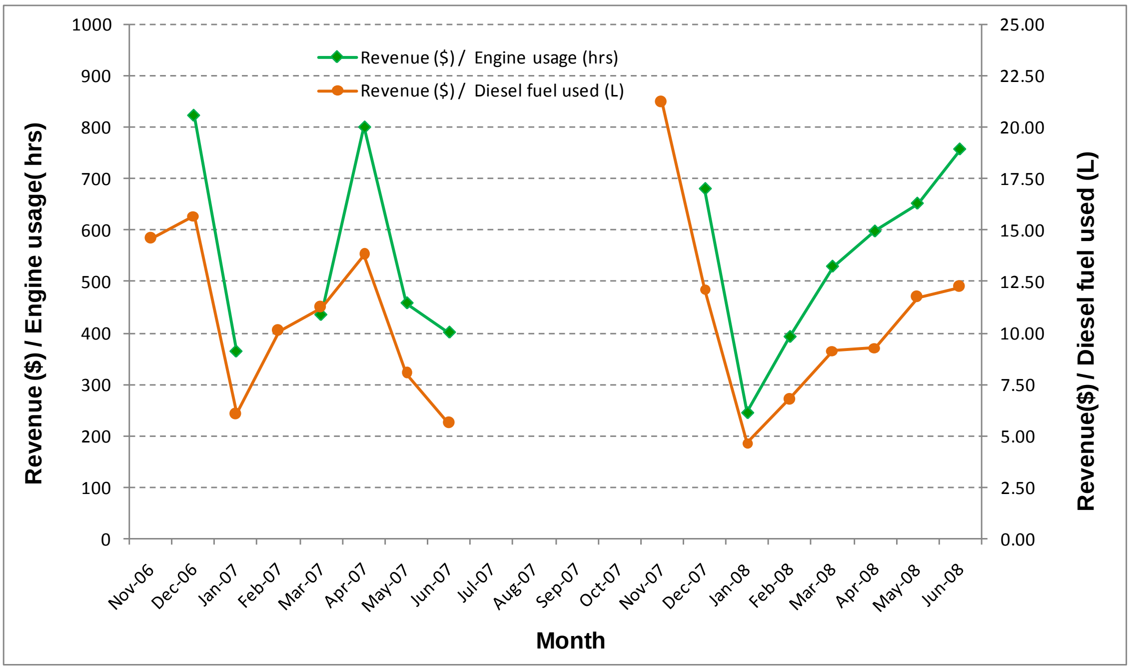


Figure 31. Monthly revenue against main engine running hours and also monthly revenue against diesel fuel used for the *FV Night Stalker* during the 2006/7 and 2007/8 fishing seasons.

Both sets of plotted data, namely monthly revenue/engine usage, and monthly revenue/diesel fuel used (refer to Fig. 31) showed a degree of correlation during both seasons. For example, revenue per engine hour fluctuated by $460/hr ($363-823/hr) and $512/hr ($245-757/hr) in the 2006/07 and 2007/08 seasons respectively. However the trend for the last three months of each season was quite different; in 2006/07 the revenue per engine hour, or revenue per litre of fuel used, fell away sharply, whereas in the 2007/08 season the steady climb in both quantities continued from Jan-08 right through to the end of the season. Differences such as this can be caused by bad luck (*i.e.* failure to locate high concentrations of vulnerable fish) and unfavourable environmental factors capable of affecting catching performance, energy consumption rate, and also available fishing time during potentially good fishing periods. They also serve to highlight that fisheries production from year to year is unpredictable and does not necessarily correlate with the level of inputs.

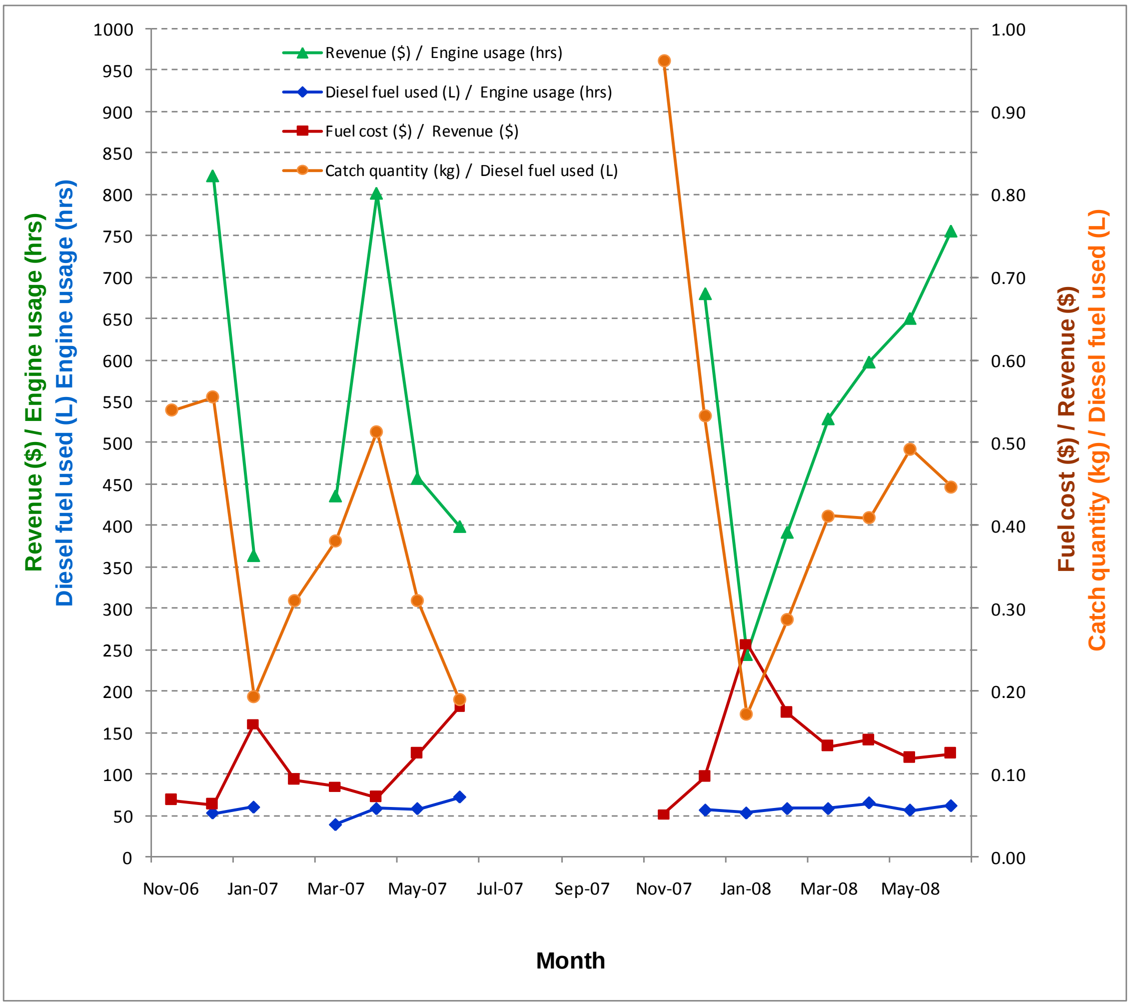


Figure 32. Energy audit performance parameters for the *FV Night Stalker* during the 2006/7 and 2007/8 fishing season. Note that diesel cost was determined by using average monthly diesel prices compiled by the WA government for the Mid-West region. $0.3814/L was also deducted from the WA 'Fuel-watch' amount as the fishing industry and other sectors of primary industry receive a Federal government fuel rebate.

The following observations relate to the energy audit data presented in Figure 32.

- In 2006/07 a single engine running hour was on average more lucrative (by 15%) for the fishing business than in 2007/08, yielding $718/hr compared to $625/hr.
- Over the 2006/07 season the rock-lobster boat consumed more fuel per engine running hour (6%) than in the 2007/08 season (*i.e.* 64L/hr compared to 60L/hr).
- In 2007/08 a larger proportion (about 41%) of the revenue *i.e.* 0.12 compared to 0.09 was needed to cover the fuel bill than in 2006/07.
- The average catch quantity in 2007/08 per litre of fuel was 11% higher than in 2006/07 *i.e.* 0.44kg/L compared to 0.40kg/L.

Audit Findings and Recommendations

The main engine on *FV Night Stalker* was used for a total of 1428 hrs in the 2006/07 season together with about 91KL of diesel fuel to harvest just over 36t of rock-lobster. In 2007/08 it used the main engine for almost the same number of hours (1447hrs), consumed 4.2% less diesel fuel (87,369 compared to 91,203L), and produced 6.7% more rock-lobster (38,825 compared to 36,392kg). Evidently the vessel was operated differently in the 2007/08 season to conserve fuel, and yet this did not a have a detrimental impact on production but instead lead to a gain in production. Such ambiguities between production inputs and output levels are common in fisheries as there are other factors affecting production that the fisherman has no control over. Farmers directing inputs into crop production share similar frustrations because they too are at the mercy of environmental conditions and uncontrolled animals consuming their crops.

In terms of food production per unit of fuel, *FV Night Stalker* produced 0.40 and 0.44kg/L for the 2006/07 and 2007/08 seasons respectively. This relatively low food production level per litre of diesel fuel accounts for why fishing is sometimes referred to as a fuel-intensive food production method.

On the financial side, the unfavourable market price of rock-lobster ($28.17/kg in 2006/07 compared to $23.30/kg in 2007/08) and also diesel ($0.98/L in 2006/07 compared to $1.26/L in 2007/08) eroded profits in the 2007/08 season; this was reflected in the diesel cost accounting for 9 and 12% of revenue in 2006/07 and 2007/08 seasons respectively. The severity of such impacts on this fishing business could be reduced if the management regime was more flexible, allowing fishers to avoid inefficient fishing times and to also capitalise or more efficient technologies and practices as they emerge.

The sharp rise in the price of diesel fuel in 2008 was a timely reminder to rock-lobster fishing businesses to direct more attention towards becoming more energy efficient food producers, and to seek out cheaper/alternative sources of fuel while diesel prices are temporarily depressed. Table 16 contains a review of the possible fuel saving options available to the *FV Night Stalker*. These options were grouped into five categories, namely

- reduce air resistance of above water structure
- reduce water resistance of the hull
- reduce resistance of underwater appendages and remove fouling
- machinery
- fishing gear

Table 16. Fuel saving options available to the rock-lobster pot vessel *Night Stalker*

FUEL SAVING OPTION*	**SUITABILITY (L = low, M = med., H = high) & JUSTIFICATION**
Reduce air resistance of above water structure	
• Keep frontal area of deckhouses as small as possible	L – in this instance the relatively large frontal area required on the deckhouse has a relatively low profile and low drag form (Fig. 22)
• Improve design of appendages (*e.g.* masts)	L – negligible opportunity here as the appendages have already been constructed with drag-minimisation in mind *i.e.* the number have been kept to a minimum, those present have been recessed or placed in positions that are shadowed from the free-stream, or constructed with a streamlined form and with a small projected area (Fig. 22)
• Stack pots on deck as low as possible whilst steaming	L – negligible benefit here as the large aft deck area already permits this condition to be met, and presumably the skipper makes sure it is addressed/followed (Fig. 22)
Reduce water resistance of the hull	
• Increase vessel length	M – worth investigation considering how much steaming time is involved in a normal trip; scale model hull tests coupled with software predictions are required to quantify the drag reduction and enable a payback period to be determined. Such modifications will need to consider other operational requirements of the vessel as well, such as coming too and hauling pots.
• Check speed/length ratio	M – operate at economical running speeds; this will increase trip duration but may yield a considerable reduction in drag. Fuel flow meters will help with the trip planning and identification of appropriate speeds etc.
• Reduce displacement/length ratio	M – may yield a considerable drag saving and may be possible to implement by utilising lightweight materials such as carbon reinforced fibres and/or keeping fuel/hold spaces filled below capacity
• Check beam/draft ratio	M – the same points made against as 'long as possible' above apply here as well. N.B. with these hull-related dimensional modifications it is unclear how much scope for improvement is available without lines drawings and undertaking the necessary analysis.
• Prismatic coefficient (fine up ends of vessel)	L – it appears that this parameter is already optimised on the bow (Fig .7). Potentially more can be done with the stern, although propulsion and steerage requirements also need to be catered for in the new design.

Table 16 (cont.). Fuel saving options available to the rock-lobster pot vessel *Night Stalker*

FUEL SAVING OPTION*	**SUITABILITY (L = low, M = med., H = high) & JUSTIFICATION**
Reduce water resistance of the hull (cont.)	
• Shift longitudinal centre of buoyancy (LCB) aft of amidships	L – this modification may be worthwhile investigating; to assess this option properly however a detailed analysis of hull-form will be needed. Currently line-plans are not available for this vessel so this analysis cannot be done. There would also be a need for scale model tests to verify the extent of the drag saving and to determine the payback period.
• Fit bulbous bows	L – not feasible on this hull-form
• Use round bilge, not hard chine	L – not feasible on this hull-form
• Use transom-stern, not canoe-stern	L – already implemented
Reduce resistance of U/W appendages & remove fouling	
• Avoid bilge keels	L – not a viable option for this type of vessel
• Use aerofoil stabilisers	L – not a viable option for this type of vessel
• Use fairings on hull mounted transducers	M – worth consideration if not optimised already, may provide small drag reduction for minimal outlay
• Rudder modifications (asymmetric aerofoil rudder, twisted/aerofoil shaft brackets	M – suggested design modifications are feasible, drag saving not quantified but worth investigation (can always retro-fit)
• Keel cooling pipes, check alignment and design or replace with alternative system	M – feasible if not already done, moderate drag saving possible if keel cooling removed and replaced with internal system/heat exchanger
• Remove/check alignment of chafing bars & sponsons	L – not a viable option for this type of vessel
• Check position and alignment of sacrificial anodes	L – feasible; may yield a small drag reduction if poorly aligned
• Keep hull & propeller clean and smooth	M – feasible, moderate to large drag saving possible depending on the extent and level of fouling. Clean hull & propeller regularly and renew antifouling regularly, countersink bolts and use detachable lifting pads.

Table 16 (cont.). Fuel saving options available to the rock-lobster pot vessel *Night Stalker*

FUEL SAVING OPTION*	SUITABILITY (L = low, M = med., H = high) & JUSTIFICATION
Machinery	
• Utilise waste heat from prime mover cooling water	L – feasible, small fuel saving possible if desalination system fitted and heavier fuels are used in the future
• Utilise waste heat from prime mover exhaust system	L – worthwhile investigating, especially for heating domestic water and defrosting any refrigeration systems aboard
• Avoid hydraulic winch systems driven by auxiliaries	L – already addressed
• Low friction bearings in engine/gearbox/drive shaft	M – worthwhile investigating this option as advancements in this area can yield a 5-10% reduction in frictional losses
• Sail propulsion	L – not feasible/practical unless the hull-form is altered and the trip duration adjusted accordingly.
• Fit a more efficient propeller	H – very worthwhile investigating this option as advances in propeller efficiency coupled with rising fuel prices and a high proportion of the time spent steaming could result in a short pay-back period.
• Fit controllable pitch propeller	L – debatable whether this will yield a fuel saving unless the CPP unit does not undermine propeller efficiency
Fishing gear	
• Use collapsible/stackable pot designs to reduce drag when steaming	L – not a viable option while fisheries regulations are so rigid on pot design
• Use pots of lightweight construction	L – this option is contingent on being able to reduce the ballast requirement (related to the two points below)
• Use thin, high tenacity hauling ropes with high abrasion resistance	L – reduce the drag of the hauling line to reduce the amount of ballast required in each pot
• Use low drag headgear	L – consider float/flag arrangements that provide the necessary buoyancy with less drag so less ballast is required in each pot
* main source of options: Riley & Helmore (1985)	

To select the most promising fuel saving options the energy consumption profile of the *FV Night Stalker* during a normal nights fishing (refer above to *Audit results* - section (c) *24 hour energy use profile*) was considered. This profile indicated that a high proportion of the fuel energy is used to propel the vessel, either between the fishing grounds and port, or while setting and hauling pots. The amount of thrust required to attain a specific speed is a function of the hull/superstructure drag. The options presented in Table 16 tended to focus on the hull-resistance more so than the superstructure resistance, primarily because the dynamic pressure associated with latter is considerable less (≈800 fold) due to the different mass densities of air and seawater.

Several 'moderate suitability' options aimed at reducing hull resistance or underwater appendage resistance were identified; a few, namely 'Long as possible' and 'Check beam/draft ratio', necessitate making significant hull alterations, and for this reason they need to be properly assessed to establish accurate pay-back periods. The remaining 'moderate suitability' options are not as costly to implement, yet still promise to yield reasonable fuel savings. Of these, three look most promising, namely 'check the speed/length ratio' (with the aid of fuel-flow sensors), 'reduce displacement/length ratio' (when vessel is laden), and 'keep hull and propel clean and smooth'. Quantitative data to indicate how much of a fuel saving is potentially possible with each of these options was not available at the time of writing this report.

The use of a more efficient propeller design was identified as machinery based option of moderate suitability. When *FV Night Stalker* was commissioned she came with a Teignbridge propeller. Details on the current design to allow a proper assessment to be undertaken were not available at the time of writing this report. Several propeller assessment software packages were investigated for such purposes, and of these Hydroprop (run by a small company based at the University of New Hampshire, U.S.A) seemed an attractive proposition at about $6K per license.

Trial Energy Audit – Fish trap boat *Flying Fish 4*

Introduction

This section contains a Level 1 Energy Audit for a fish trap boat (*FV Flying Fish 4*) (refer to Fig. 33) owned by a single business (Western Offshore Fishing & Charter Pty Ltd) based at Exmouth in Western Australia (WA). This vessel operates in the Pilbara Fish Trap Fishery (refer to Fig. 34).

Figure 33. Fresh Fish Onslow trap boat arriving in port at Exmouth marina.

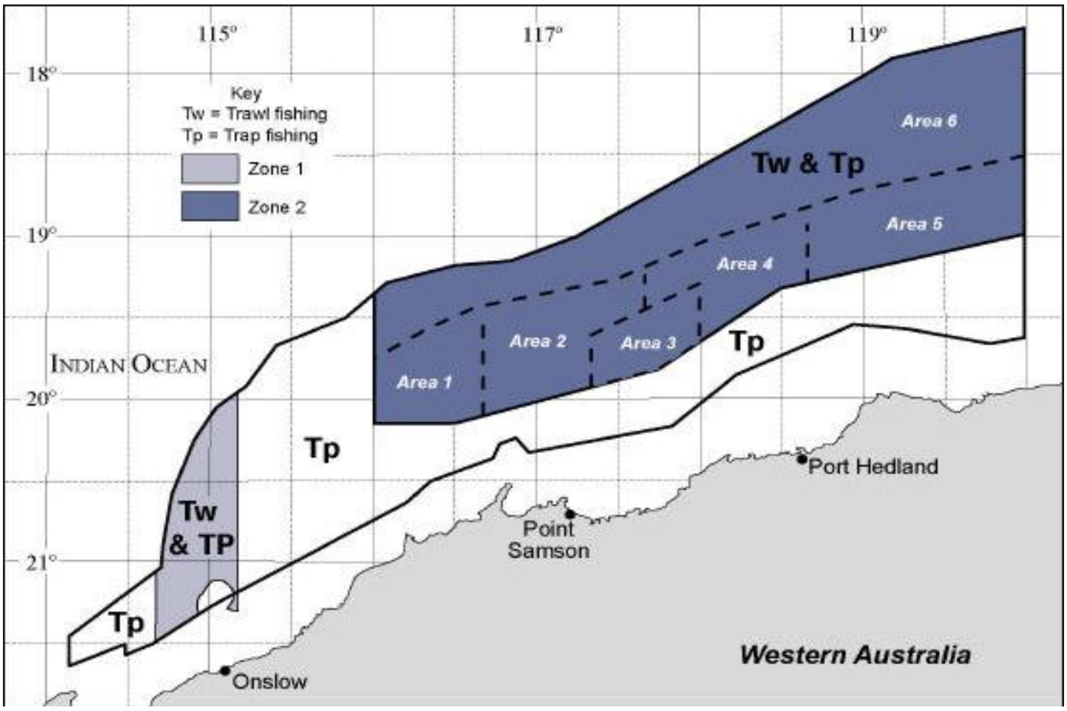


Figure 34. The trap fishing grounds for *FV Flying Fish 4* in Zones 1 and 2 of the Pilbara fishery.

The *FV Flying Fish 4* is one of two specialised trap-boats fishing for tropical finfish on grounds extending from about 100km West of Onslow to 150km East of Port Headland,

and as far as 200km off shore. It typically undertakes short trips of six days in duration, and confines most of its fishing effort to the grounds West of Point Sampson. The other trap boat spends most of its time fishing East of Point Sampson.

The *Flying Fish 4* is similar in design to most 'West-Coaster' Rock lobster boats, and has ample deck space aft of amidships for transportation of the bulky fish traps (refer to Fig. 35); 10-12 traps are used on most trips.

Figure 35. Fish traps used by *FV Flying Fish 4*.

The *Flying Fish 4* is equipped with an array of electronic equipment (*e.g.* radar, echo-sounder, GPS plotter) to assist with navigation and also for setting pots in prime locations and the eventual recovery of pots after an appropriate length of time has elapsed. Also located aboard is a sonar system, although this is no longer functional because the transducer lowering mechanism has been disabled.

Once aboard, commercial sized finfish are chilled in a refrigerated sea-water (RSW) /ice slurry tank and then transferred and stored in one of three insulated holds (total capacity ≈ 8t) at 1-3 degrees below zero for the remainder of the trip. The RSW/fish-hold compressor is powered from one auxiliary engine, while the ice-making-machine is powered from a similar second engine.

Falling catch-rates and overfishing concerns prompted adjustments to fishing effort in 1999. The current arrangement with two vessels fishing the best part of the year (40 trips @ 6 days/trip) has been in place for several years now; according to the owners catch rates have remained relatively high. Catch-rates do not reflect a skipper's approach to energy consumption however, and energy consumption forms a large component of the operating costs to this fishing business. Most of the energy purchased by the fishing business is diesel fuel. A small quantity of LPG is used in the galley for cooking, although this energy was not considered in the following audit.

This energy audit report covers the Sep-08 to Jun-09 period, which is just after fuel-prices peaked at nearly $2/L retail (or $1.62/L with the federal government fuel rebate for primary producers such as the fishing industry) in the Gascoyne region of Western Australia in July 2008 (refer to Fig. 36).

The main objective of this report is to obtain a clearer idea of how energy is used by the *FV Flying Fish 4* while fishing, and to subsequently identify ways of reducing the energy consumption level and associated cost. Note that the report follows the "audit for fishing businesses" procedure outlined earlier in Table 1 of the Results section.

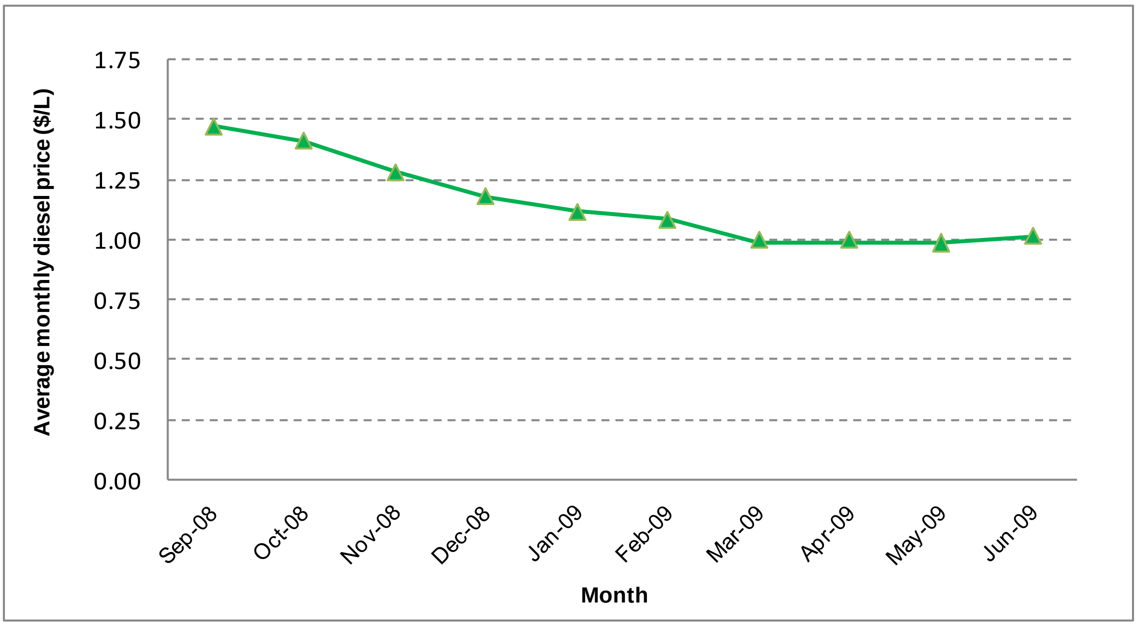


Figure 36. Average monthly prices of diesel in the Gascoyne region of WA[1] over the ten-month fishing period under review.

1 Diesel prices were based on average monthly prices compiled by the WA government for the Gascoyne region, which encompasses the township of Exmouth. $0.3814/L was also deducted from the WA 'Fuel-watch' amount as the fishing industry and other sectors of primary industry receive a Federal government fuel rebate.

Audit results

(a) Basic Business data

Basic business data including vessel characteristics, fishing method, fishing location and composition of catch is provided in Table 1 for the *FV Flying Fish 4*.

The units of production relevant to the energy audit of this fishing business are;

- fishing duration,
- weight of saleable seafood products
- revenue from seafood products, and
- energy content of the edible protein produced.

Table 17. Basic business data for the *FV Flying Fish 4*

Vessel	Flying Fish 4	**Launched**	1995		
Length	19.5m	**Beam**	6m	**Draft**	1.8m
Vessel type	Planing - fwd wheel house				
Construction material	Hull and deck: moulded fibreglass Superstructure: moulded fibreglass				
Fishing Gear **Fishery** **Fishing region** **Base Port**	Traps Pilbara Fish Trap Fishery mainly West of Point Sampson Exmouth				
Target species **Byproduct species** **Bycatch species**	tropical finfish none undersize finfish (target species), unwanted finfish, octopus, eel				

Fishing duration considerations

The *FV Flying Fish 4* is permitted to trap fish all year round. Currently it fishes in the Western region of the fishery for about six days at a time; a strategy aimed at minimising travel time and running expenses between port-fishing grounds, while meeting fish unloading/refuelling obligations at the Exmouth marina. *Flying Fish 4* has the capacity for such trips; *e.g.* accommodation berths x 5, fuel 6,000L, fish-hold 8t.

Occasionally, the vessel returns to port early due to bad weather, equipment failure, or if there is a medical emergency aboard.

Weight of saleable seafood products

Tropical finfish provide the income for this fishing business. The offloading and weighing system employed onshore provides very accurate data. Fish are weighed ‘fresh’ *i.e.* wet and unfrozen.

Revenue from seafood products

The price paid for tropical finfish can fluctuate through the year and between years depending on market conditions. Premium prices are also paid for certain species, and also for certain species of larger fish; since the latter will generally yield higher recovery rates *i.e.* yield a higher percentage of saleable flesh by weight. An astute skipper will respond to these market forces and target fish that not only meet customer orders but also maximise the revenue from the landed weight/volume of fish.

Energy content of the edible protein produced

This quantity is included to permit the ratio of production energy (in Joules) to food energy to be established. The food energy is contingent on how much of the finfish is used for food. Muscle from the body section is typically used for meals, whereas the head and other remnants may be used as ingredients in other food products.

(b) Energy inputs

Almost all of the energy consumed by the *FV Flying Fish 4* during the ten-month review was in the form of diesel fuel. The balance was a small amount of LPG for cooking purposes. The LPG was omitted from this audit because it represents an insignificant amount and cost to the business.

(c) 24 hour energy use profile

The data to produce a detailed 24hr energy use profile has not been collected at this time. However, this fish-trap boat generally follows a similar pattern of fishing each day unless some extraordinary event occurs (elaborated on in section (a) '*Fishing duration considerations'*, para. 2); it is possible therefore to configure a representative energy use profile for a typical day's fishing as long as the energy consumption rate associated with each fishing phase is known. Currently these consumption rates are not known and it will be necessary to install a fuel meter on the main engine (MTU 12V 183 TE92) and between the pair of auxiliaries (Perkins 40-48kVA each) on this vessel to acquire such data.

A fishing trip on the *FV Flying Fish 4* would comprise of steaming to the fishing grounds, setting and hauling the traps up to six-times through the daytime either in the same area or nearby depending on the catch rates, holding station overnight in close proximity to the traps that have to be hauled first, repeating the latter two steps over the next five days before hauling the traps in the afternoon of the last (sixth) day and steaming back to port. The goal for every day is to maximise the trap soak-time in areas carrying relatively high numbers of valuable commercial sized finfish on the outlook for food. Generally the skipper will steam to the most distant region to be fished on the first day (up to 18 hours away), and then work back towards Exmouth over the following six days to reduce the steaming time on the return leg (about 7 hours). Adhering to this schedule has the vessel unloading every week and fishing *i.e.* setting/hauling traps for the best part of six days in every week. The vessel typically does 40 trips per year.

In port (refer to Fig. 37) only one of the auxiliary engines is needed to power the refrigeration compressor and to supply power to the domestic appliances aboard. At some stage the vessel is transferred over to shore power and the auxiliary engine is turned off.

Figure 37. *FV Flying Fish 4* alongside the wharf with an assortment of trap gear to be loaded aboard.

(d) Monthly energy utilisation profiles

(i) Monthly energy consumption profile

The amount of diesel supplied to the *FV Flying Fish 4* during the ten-month audit period in 2008/9 is shown in Table 18 and Figure 38, together with the associated cost of this fuel and the fishing duration.

Table 18. Energy purchases for *FV Flying Fish 4* during the 2008/09 audit period.

Date	Fishing duration (days)	Diesel used (L)	Diesel price[1] ($/L)	Diesel cost ($)
Sep-08	28	15,700	1.47	23,106
Oct-08	28	17,226	1.41	24,230
Nov-08	33	20,029	1.28	25,622
Dec-08	25	11,780	1.18	13,864
Jan-09	14	5,732	1.11	6,389
Feb-09	23	15,502	1.08	16,728
Mar-09	27	13,480	1.00	13,414
Apr-09	35	16,524	0.99	16,398
May-09	28	13,271	0.99	13,109
Jun-09	28	12,114	1.01	12,257

1 Diesel prices were based on average monthly prices compiled by the WA government for the Gascoyne region, which encompasses the township of Exmouth. $0.3814/L was also deducted from the WA ‘Fuel-watch’ amount as the fishing industry and other sectors of primary industry receive a Federal government fuel rebate.

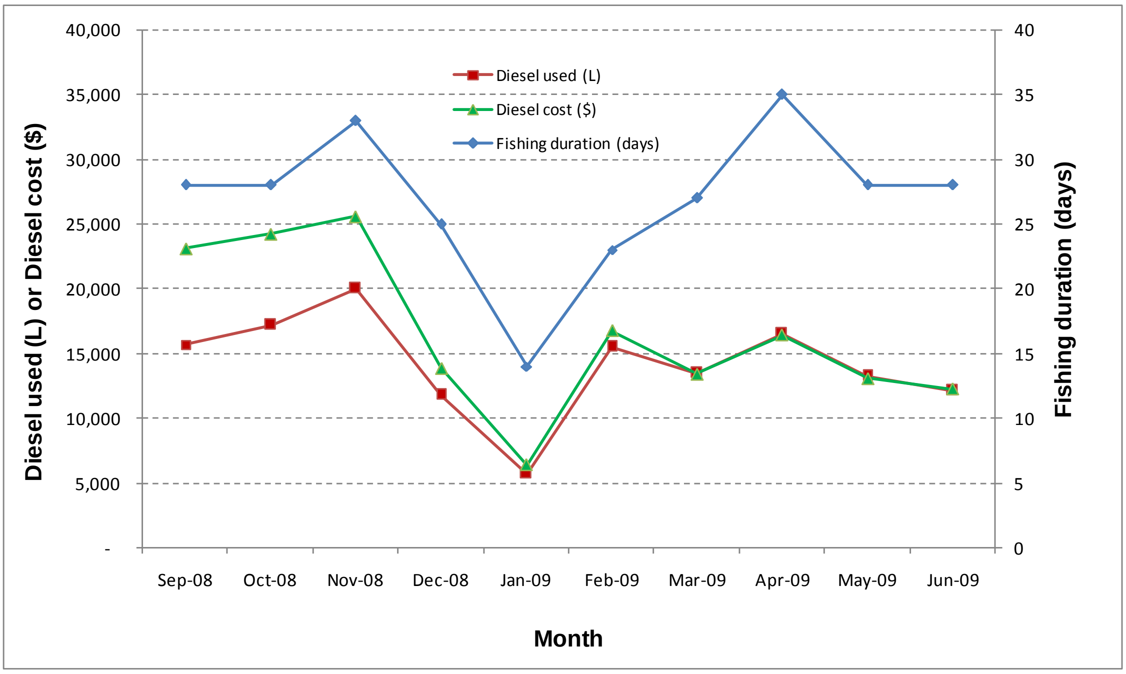


Figure 38. Monthly usage rates of diesel plus the associated cost[1] and fishing duration for the *FV Flying Fish4* during the ten-month audit period.

1 Diesel prices were based on average monthly prices compiled by the WA government for the Gascoyne region, which encompasses the township of Exmouth. $0.3814/L was also deducted from the WA 'Fuel-watch' amount as the fishing industry and other sectors of primary industry receive a Federal government fuel rebate.

The monthly diesel cost followed a similar trend to diesel usage and fishing duration over the ten-month audit period; in the latter part of the period the disparity between fuel-cost and fuel-usage diminished as the price of fuel reduced in the region. Primarily as a result of fuel prices falling, the fuel bill for the first three months (*i.e.* Sep-Nov '08) was 75% higher ($72,957 compared to $41,764) than the last three months (Apr-Jun '09) for a similar number of days spent fishing (89 compared to 91days). Also assisting with this decline in fuel-cost was a 21% reduction in fuel usage (*i.e.* ≈53KL compared to ≈42KL) for the same three-month time periods; the reason for this reduction in fuel-usage was unclear as the vessel underwent its yearly service in Aug-08. The reduction in all three quantities in Jan-09, namely fuel-cost, fuel-used and fishing duration, was due to the crew have several weeks off over the Christmas/New year period.

(ii) Monthly energy performance profiles

The monthly revenue and diesel cost data (refer to Fig. 39) showed a similar pattern during the ten-month audit period, although the first three months were 45% more lucrative than the last three months (*i.e.* $426K compared to $294K) primarily because more fish were landed (38% more by weight *i.e.* 63.0t compared to 45.5t) rather than the slightly higher (4%) average price (*i.e.* $6.77/kg compared to $6.48/kg) for this period. The impost of higher diesel prices in 2008 was also evident, although the additional income (≈$133K) from the catch during the Sep-Nov ’08 period compared to the Apr-Jun ’09 period easily covered the additional fuel expense (≈$31K). Also, from a business perspective the reduction in the price of fuel in 2009 to offset the drop in production could not have come at a better time. Note that additional data over a longer time period is required to ascertain whether this drop in productivity was due to biological factors and/or changes in the fishing gear, fishing strategy, and skipper’s skill.

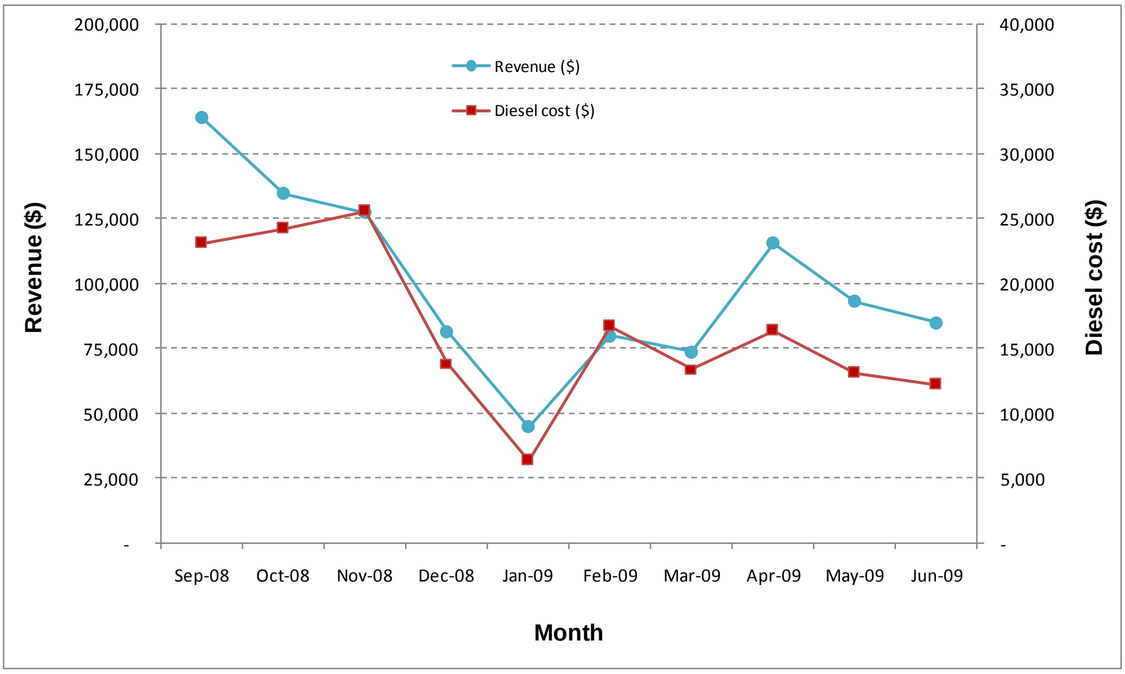


Figure 39. Monthly diesel cost[1] and revenue for the *FV Flying Fish4* during the ten-month audit period.

1 Diesel prices were based on average monthly prices compiled by the WA government for the Gascoyne region, which encompasses the township of Exmouth. $0.3814/L was also deducted from the WA ‘Fuel-watch’ amount as the fishing industry and other sectors of primary industry receive a Federal government fuel rebate.

Both sets of plotted data, namely monthly revenue/fishing duration, and monthly revenue/diesel fuel used (refer to Fig. 40) showed a degree of correlation over the ten-month audit period, apart from in the Dec-Feb period where the latter quantity rose and fell relatively sharply in comparison to the former quantity. Disturbingly, both quantities showed a downward trend for the first three months and then never really recovered. Some of this may be due to bad luck (*i.e.* failure to locate high concentrations of vulnerable fish) and unfavourable environmental factors capable of affecting catching performance, energy consumption rate, and also available fishing time during potentially good fishing periods. However for the trend to continue over five months suggests that there may be something

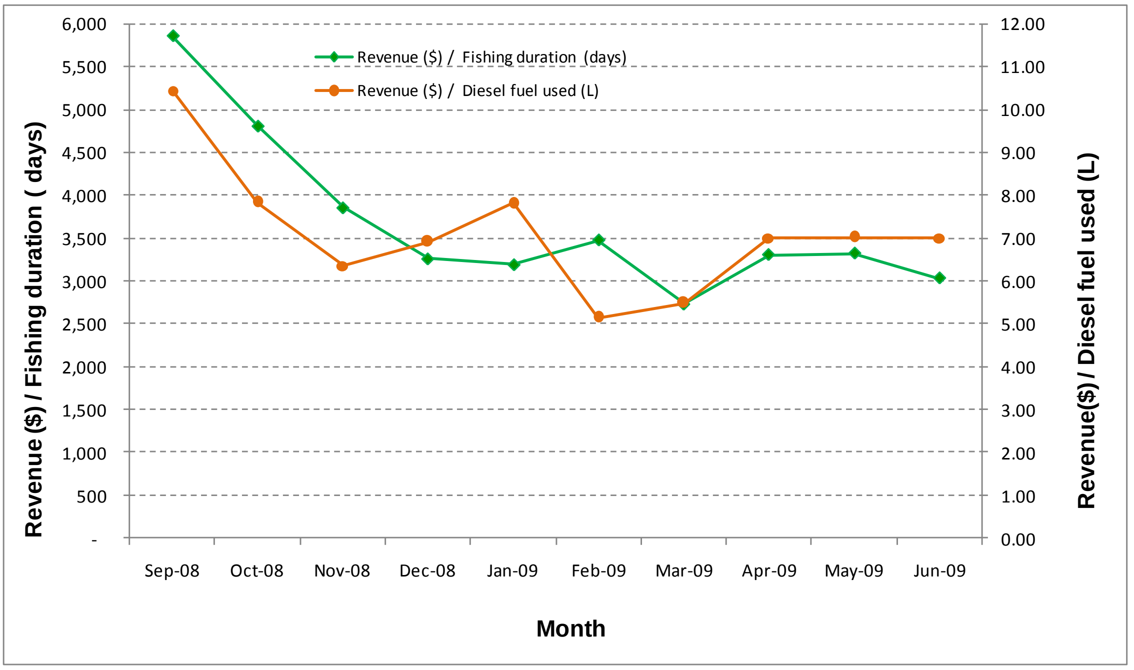


Figure 40. Monthly revenue against fishing duration and also monthly revenue against diesel fuel used for the *FV Flying Fish 4* during the ten-month audit period.

else causing the downturn in these quantities. Factors causing energy inefficiency aside, the downturn could be due to a reduction in available fish biomass and/or an inexperienced skipper struggling to find/stay on high concentrations of fish.

The following observations relate to the energy audit data presented in Figure 41.

- In Sep-08 a single fishing day was on average more lucrative (by 93%) for the fishing business than in Jun-09, yielding $5855/day compared to $3033/day.
- For the same months, the trap-fishing boat consumed on average 30% more fuel per day (*i.e.* 561L/day compared to 433L/day).
- For the same months, a similar proportion (about 14%) of the revenue was needed to cover the fuel bill.
- For the same months, the average catch quantity per litre of fuel was 52% higher *i.e.* 1.55kg/L compared with 1.02kg/L.

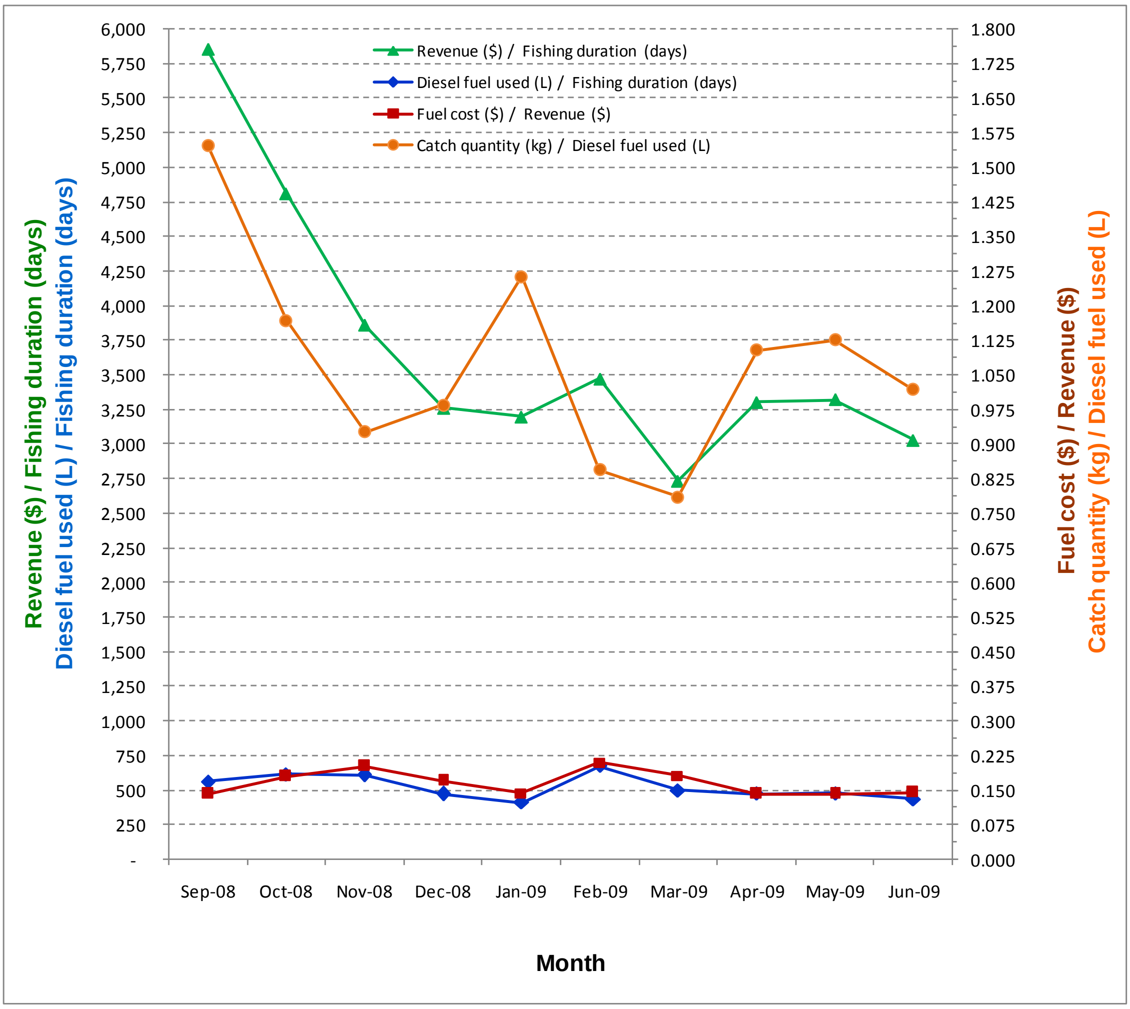


Figure 41. Energy audit performance parameters for the *FV Flying Fish 4* during the ten-month audit period. The diesel cost was based on average monthly diesel prices compiled by the WA government for the Gascoyne region. $0.3814/L was also deducted from the WA 'Fuel-watch' amount as the fishing industry and other sectors of primary industry receive a Federal government fuel rebate.

Audit Findings and Recommendations

The main engine on *FV Flying Fish 4* was used for a total of 269 fishing days in the ten-month audit period together with about 141KL of diesel fuel to harvest just over 151t of fin-fish. This relatively low food production level per unit of diesel fuel (*i.e.* 1.07kg/L) is why fishing is occasionally referred to as a fuel-intensive food-production method.

There was a noticeable decrease in both the productivity and energy consumption level towards the end of the ten-month period, which was difficult to explain without more historical data and insight into the day-to-day operations. However, the vessel and engines were serviced in August-08, and no other work has been done since, so the reduction in energy consumption level per fishing day must be due to a different fishing strategy being adopted by the skipper and/or possibly less favourable sea-conditions having a detrimental impact on fuel efficiency later in the year. If it is partly due to the former, then even though the higher fuel-consumption rate associated with the previous fishing strategy resulted in a higher fuel-cost per dollar of revenue, it was a much more productive and therefore lucrative approach, and one which must be re-established to restore business profits.

Fishing is challenging, since unlike with the mining of minerals or trees, the level of input does not guarantee a certain level of output. With fishing there is a need to locate high concentrations of vulnerable fish and stay on these concentrations as long as possible. Locating fish with the aid of an echosounder, sonar, and detailed topographical charts does make the task easier, but as experienced fleet managers will testify, even with these aids some people will still struggle to find high concentrations of fish, especially if the fish inhabit a vast area, such as the Pilbara Fish Trap Fishery. Complicating matters is the fact that some fish are migratory or disband once fishing commences, so returning to productive areas does not guarantee success.

Fishing in isolation of other boats in a fishery also places a lot of emphasis on the ability of the skipper to consistently locate high concentrations of vulnerable fish in a time (and energy) efficient manner. Sometimes it is worthwhile sharing the searching load and suffering the downside of seeing fish concentrations deplete more rapidly, especially during times when the concentrations are only available for a finite time-period. For this reason it may be worthwhile for the *Flying Fish 4* to spend some time in the sector East of Point Sampson in close proximity (*i.e.* radar range) of the other trap vessel.

On the financial side, the reduction in fuel-price towards the end of the ten-month period easily covered (by about two fold) the slight drop in average market price paid for fin-fish in the same period.

The sharp rise in the price of diesel fuel in 2008 was a timely reminder to trap-fishing businesses to direct more attention towards becoming more energy efficient food producers, and to seek out cheaper/alternative sources of fuel while diesel prices are temporarily depressed. Table 19 contains a review of the possible fuel saving options available to the *FV Flying Fish 4*. These options were grouped into five categories, namely

- reduce air resistance of above water structure
- reduce water resistance of the hull
- reduce resistance of underwater appendages and remove fouling
- machinery
- fishing gear

Table 19. Fuel saving options available to the fish-trap boat *FV Flying Fish 4*

FUEL SAVING OPTION*	SUITABILITY (L = low, M = med., H = high) & JUSTIFICATION
Reduce air resistance of above water structure	
• Keep frontal area of deckhouses as small as possible	L – in this instance the relatively large frontal area required on the deckhouse has a relatively low profile and low drag form (Fig. 33)
• Improve design of appendages (*e.g.* masts)	L – negligible opportunity here as the appendages have already been constructed with drag-minimisation in mind *i.e.* the number have been kept to a minimum, those present have been recessed or placed in positions that are shadowed from the free-stream, or constructed with a streamlined form and with a small projected area (Fig. 33)
• Stack traps on deck as low as possible whilst steaming	L – negligible benefit here as the large aft deck area already permits this condition to be met, and presumably the skipper makes sure it is addressed/followed (Fig. 33)
Reduce water resistance of the hull	
• Increase vessel length	M – worth investigation considering how much steaming time is involved in a normal trip; scale model hull tests coupled with software predictions are required to quantify the drag reduction and enable a payback period to be determined. Such modifications will need to consider other operational requirements of the vessel as well, such as manoeuvring and hauling traps.
• Check speed/length ratio	M – operate at economical running speeds; this will increase trip duration but may yield a considerable reduction in drag. Fuel flow meters will help with the trip planning and identification of appropriate speeds etc.
• Reduce displacement/length ratio	M – may yield a considerable drag saving and may be possible to implement by utilising lightweight materials such as carbon reinforced fibres and/or keeping fuel/hold spaces filled below capacity
• Check beam/draft ratio	M – the same points made against as 'long as possible' above apply here as well. N.B. with these hull-related dimensional modifications it is unclear how much scope for improvement is available without lines drawings and undertaking the necessary analysis.
• Prismatic coefficient (fine up ends of vessel)	L – it appears that this parameter is already optimised on the bow (Fig .33). Potentially more can be done with the stern, although propulsion and steerage requirements also need to be catered for in the new design.

Table 19 (cont.). Fuel saving options available to the fish-trap boat *FV Flying Fish 4*

FUEL SAVING OPTION*	SUITABILITY (L = low, M = med., H = high) & JUSTIFICATION
Reduce water resistance of the hull (cont.)	
• Shift longitudinal centre of buoyancy (LCB) aft of amidships	L – this modification may be worthwhile investigating; to assess this option properly however a detailed analysis of hull-form will be needed. Currently line-plans are not available for this vessel so this analysis cannot be done. There would also be a need for scale model tests to verify the extent of the drag saving and to determine the payback period.
• Fit bulbous bows	L – not feasible on this hull-form
• Use round bilge, not hard chine	L – not feasible on this hull-form
• Use transom-stern, not canoe-stern	L – already implemented
Reduce resistance of U/W appendages & remove fouling	
• Avoid bilge keels	L – not a viable option for this type of vessel
• Use aerofoil stabilisers	L – not a viable option for this type of vessel
• Use fairings on hull mounted transducers	M – worth consideration if not optimised already, may provide small drag reduction for minimal outlay
• Rudder modifications (asymmetric aerofoil rudder, twisted/aerofoil shaft brackets	M – suggested design modifications are feasible, drag saving not quantified but worth investigation (can always retro-fit)
• Keel cooling pipes, check alignment and design or replace with alternative system	M – feasible if not already done, moderate drag saving possible if keel cooling removed and replaced with internal system/heat exchanger
• Remove/check alignment of chafing bars & sponsons	L – not a viable option for this type of vessel
• Check position and alignment of sacrificial anodes	L – feasible; may yield a small drag reduction if poorly aligned
• Keep hull & propeller clean and smooth	M – feasible, moderate to large drag saving possible depending on the extent and level of fouling. Clean hull & propeller regularly and renew antifouling regularly, countersink bolts and use detachable lifting pads.

Table 19 (cont.). Fuel saving options available to the fish-trap boat *FV Flying Fish 4*

FUEL SAVING OPTION*	SUITABILITY (L = low, M = med., H = high) & JUSTIFICATION
Machinery	
• Utilise waste heat from prime mover cooling water	L – feasible, small fuel saving possible if desalination system fitted and heavier fuels are used in the future
• Utilise waste heat from prime mover exhaust system	L – worthwhile investigating, especially for heating domestic water and defrosting any refrigeration systems aboard
• Avoid hydraulic winch systems driven by auxiliaries	L – already addressed
• Low friction bearings in engine/gearbox/drive shaft	M – worthwhile investigating this option as advancements in this area can yield a 5-10% reduction in frictional losses
• Sail propulsion	L – not feasible/practical unless the hull-form is altered and the trip duration adjusted accordingly.
• Fit a more efficient propeller	H – very worthwhile investigating this option as advances in propeller efficiency coupled with rising fuel prices and a high proportion of the time spent steaming could result in a short pay-back period.
• Fit controllable pitch propeller	L – debatable whether this will yield a fuel saving unless the CPP unit does not undermine propeller efficiency
Fishing gear	
• Use collapsible/stackable trap designs to reduce drag when steaming	L – not a viable option while fisheries regulations are so rigid on pot design
• Use traps of lightweight construction	L – this option is contingent on being able to reduce the ballast requirement (related to the two points below)
• Use thin, high tenacity hauling ropes with high abrasion resistance	L – reduce the drag of the hauling line to reduce the amount of ballast required in each pot
• Use low drag headgear	L – consider float/flag arrangements that provide the necessary buoyancy with less drag so less ballast is required in each pot
* main source of non-fishing gear options: Riley & Helmore (1985)	

To select the most promising fuel saving options the energy consumption profile of the *FV Flying Fish 4* during a normal days fishing (refer above to *Audit results* - section (c) *24 hour energy use profile*) was considered. This profile indicated that a high proportion of the fuel energy is used to propel the vessel, either between the fishing grounds and port, or while setting and hauling traps. The amount of thrust required to attain a specific speed is a function of the hull/superstructure drag. The options presented in Table 19 tended to focus on the hull-resistance more so than the superstructure resistance, primarily because the dynamic pressure associated with latter is considerable less (≈800 fold) due to the different mass densities of air and seawater.

Several ‘moderate suitability’ options aimed at reducing hull resistance or underwater appendage resistance were identified; a few, namely ‘Long as possible’ and ‘Check beam/draft ratio’, necessitate making significant hull alterations, and for this reason they need to be properly assessed to establish accurate pay-back periods. The remaining ‘moderate suitability’ options are not as costly to implement, yet still promise to yield reasonable fuel savings. Of these, three look most promising, namely ‘check the speed/length ratio’ (with the aid of fuel-flow sensors), ‘reduce displacement/length ratio’ (when vessel is laden), and ‘keep hull and propel clean and smooth’. Unfortunately, the quantitative data to indicate how much of a fuel saving is potentially possible with each of these options was not available at the time of writing this report.

The use of a more efficient propeller design was identified as machinery based option of moderate suitability. Details on the current design to allow a proper assessment of propeller performance to be undertaken were not available at the time of writing this report. Several propeller assessment software packages were investigated for such purposes, and of these Hydroprop (a small company based at the University of New Hampshire, U.S.A) seemed an attractive proposition at ≈$6K per license.

Trial Energy Audit – Fish trawler *Torbay*

Introduction

The fish trawler *Torbay* (refer to Fig. 42) relies on energy provided by diesel fuel to:

- power/propel the fishing vessel to the fishing grounds;
- power winches and other machinery required to deploy/haul and control the fishing gear;
- provide power to electrical appliances/instruments present on the vessel, such as radar and support systems for crewmembers (*e.g.* cookers, air-conditioner); and
- retard the spoilage of landed fish with the aid of various forms of refrigeration.

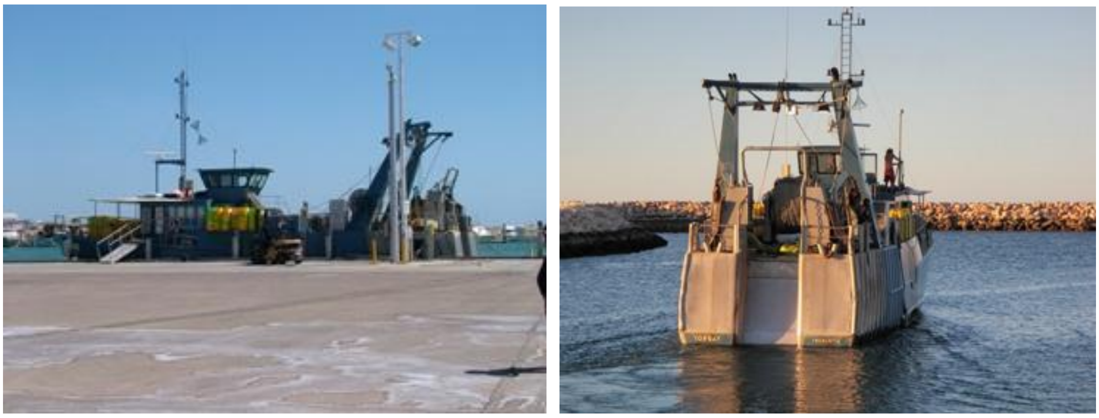


Figure 42. *Torbay* at dockside (left) and departing for another 10-12 day trip to sea (right).

In recent years rising diesel prices have put many fish-trawling businesses under excessive financial strain. Proactive businesses have responded by instigating changes that promise improvements to the energy efficiency of their harvesting operations.

An energy audit can help in this endeavour as it provides:

- a clearer idea of how energy is used by a fishing vessel,
- facilitates identification of ways of reducing energy consumption and the associated cost, and
- enables priorities to be set on energy saving measures.

In light of the points made above an energy audit (Level 1/2) was undertaken on the *FV Torbay*.

Note that this report follows the “audit for fishing businesses” procedure that was presented earlier in Table 1 of the Results section.

Audit results

(a) Basic Business Data

Basic business data including vessel characteristics, fishing method, fishing location and composition of catch is summarised in Table 20 for the *FV Torbay*.

Table 20. Basic business data for the *FV Torbay.*

Vessel	Torbay	**Launched**	198?		
Length	24m	**Beam**	5m	**Draft**	3.8m
Construction	Steel	**Vessel type**	Displacement - fwd wheel house, raised forecastle		
Fishing gear **Fishery** **Fishing region** **Base port**	Demersal fish trawl (38m Headline length) Pilbara Fish Trawl Interim Managed Fishery Indian Ocean adjacent to NW Australia Exmouth, Western Australia				
Target species **Byproduct species** **Bycatch species**	mixed tropical finfish Balmain bug, squid ray, shark, dolphin, starfish, sea cucumber, sea snake.				

i) Fishing Method and Vessel Characteristics

The *FV Torbay* (refer to Fig. 42) operates from Exmouth in Western Australia (WA) and is licensed to fish in the Pilbara Fish Trawl Interim Managed Fishery (PFTIMF) (refer to Fig. 43) which is about 160 nautical miles away at its closest point (*i.e.* SW corner of Area 1 – Zone 2). Currently the *FV Torbay* is managed by effort days, and these are assigned to Areas 1, 2, 4, and 5 of Zone 2.

Torbay is one of four similar sized ex-prawn trawlers working in this fishery. Two of these vessels (*FV Torbay* and *FV Raconteur 2*) are owned by the M G Kailis Group (abbreviated to MGK) and have been modified extensively to:

- accommodate fish trawl gear handling equipment (*e.g.* net drums (refer to Fig. 44), relocated winches),
- to facilitate fish processing (*e.g.* a hopper (refer to Fig. 44), several conveyors, and enclosed fish processing rooms (refer to Fig. 44)), and
- also unloading (*e.g.* through deck hatch to freezer room (refer to Fig. 44), articulated crane).

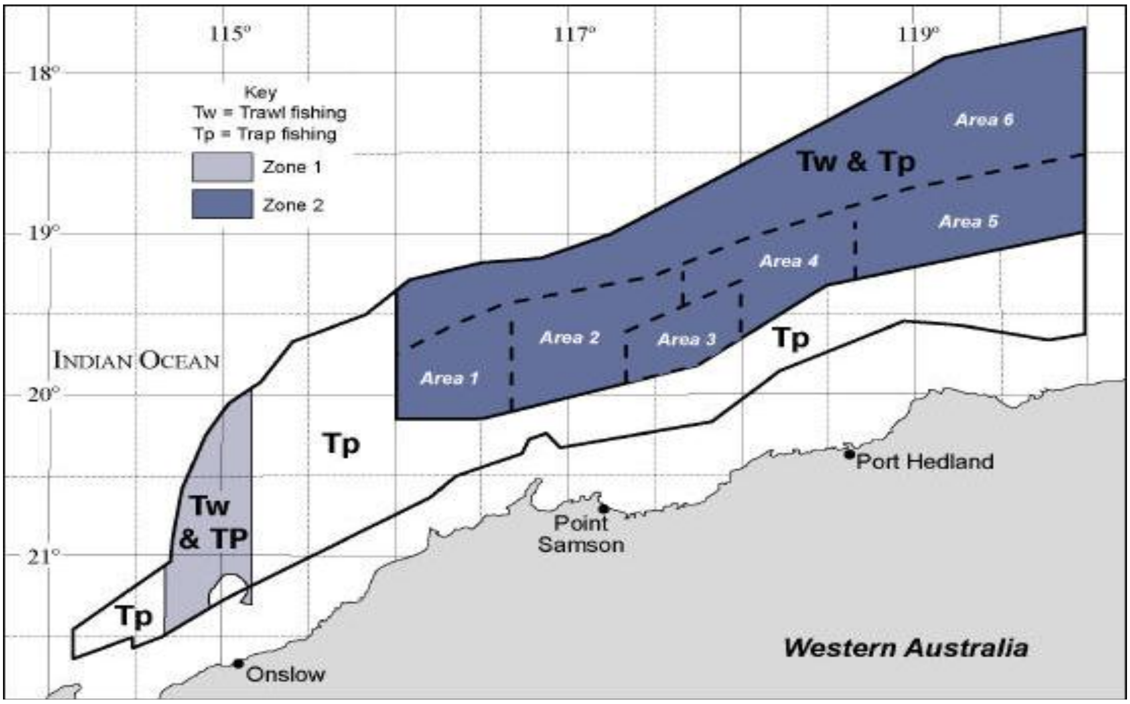


Figure 43. The current trawl grounds for the FV *Torbay* are limited to area 1, 2, 4 and 5 in Zone 2.

Figure 44. Fish trawl on net drum (upper left pic.); fish being spilled into the hopper (upper right); fish processing room equipped with hopper and conveyors (lower left); and through-deck access to the cool room (lower right).

ii) Composition of harvested catch

The *FV Torbay* is permitted to land a wide range of tropical finfish (in excess of 70 species) but tends to concentrate on the more highly valued and marketable snappers, emperors and cods (*Lutjanas sp., Lethrinus sp., Pristipomoides sp., Ephinephelus sp.*).

The fish product is initially stowed in refrigerated sea-water (RSW) (in plastic lug-baskets) for several hours until the core temperature of the fish approaches that of the RSW. These fish are then transferred into plastic fish bins and stowed in a cool room for the remainder of the trip.

iii) Units of production

The units of production relevant to the energy audit of this fishing business are;

- fishing duration,
- weight of saleable seafood products
- revenue from seafood products, and
- energy content of the edible protein or edible portion of the landed fish.

Fishing duration considerations

The duration of the fishing season is determined by how many fishing days are granted by WA Fisheries to each fishing license (these days are split between the Fishing Zone Areas shown in Fig 43.), and how quickly these days are used up through the year by the trawlers fishing these licenses. The allocation of days occurs at the beginning of the financial year. Sufficient days are held by MGK for both trawlers to fish for about 11 months in each year.

Trawling is permitted all day (*i.e.* 24hrs). For the purpose of analysis, units of trawling hours were assigned to 'fishing duration'. Trawling hours per month was determined by multiplying the total number of days spent in fishing-areas for the month x 24hrs. The total number of days spent in fishing-areas in any given month was estimated by deducting a specific number of hours (currently 44hrs) away from 'total trip hours' to allow for time spent steaming to and from the fishing grounds. The MGK trawlers currently work on a 12-day trip and return to port every Sunday to unload fresh fish on Monday morning. Note that if *Torbay* leaves the fishing area for some reason during a fishing trip then this period of non-fishing is not captured in the above 'fishing duration' calculation.

The MGK trawlers aim to maximise their trawling time once they enter a fishing area, and work to an established 24-hour routine. In reality however, the trawler is not trawling for every hour it spends in any given fishing area; since time is lost to hauling/deployment, steaming, downtime (gear failure/damage) *etc*. Typically between 50-75% of the available fishing time is spent trawling, and this was verified by undertaking several trips on *FV Torbay* during 2009 (presented at the end of this audit in *Attachment C. - Torbay Fishing Statistics*).

Occasionally, the trawler may return to port before the Sunday if it has experienced equipment failure, bad weather, or if there is a medical emergency aboard. Departures from port are sometimes delayed if the vessel or fishing gear is not in a state of readiness. Early returns and delayed departures are captured in the total trip hours and 'fishing duration' calculation.

When the trawler is returning to port, the Master takes the shortest route out of the fishing area to preserve fishing-time. As a consequence the vessel may not always take the quickest route back to port, which means there may be some departure away from the 44 hour allowance for steaming time.

Weight of saleable seafood products

A variety of tropical finfish form the primary income for trawlers in the PFTIMF. The offloading and weighing system employed onshore provides very accurate data. Fish are weighed at the time of unload, and also at the point of sale; the latter figure is used in this analysis as it is more accurate.

Revenue from seafood products

The revenue from the sale of the catch can fluctuate with market demand and species mix. Such fluctuations were captured in this analysis as the revenue from each unload was recorded and available.

Energy content of the edible protein produced

This quantity is included to permit the ratio of production energy (in Joules) to food energy to be established. The food energy is contingent on how much of the fish is used for food. In this analysis it was assumed that the entire fish was utilised.

(b) Energy inputs

During the Dec-08 to Aug-09 audit period, the *FV Torbay* acquired all of its energy at sea in the form of 433KL of diesel fuel.

Prior to Dec-08 the Torbay was owned by another fishing business (Shine Fisheries) and operated from Point Sampson instead of Exmouth. This audit therefore does not extend beyond Dec-08.

Energy provided to the vessel once it was in port and connected to shore power was not considered in this audit.

(c) 24 hour energy use profile

The data required to produce a detailed 24hr energy use profile for *Torbay* while she is fishing has not been collected at this point in time. However, each day *Torbay* generally follows a similar fishing pattern comprising of four distinct phases (namely steaming, deploying, trawling and hauling), so as long as the energy consumption rate of each phase is known a representative 24 hour energy use profile can be created. This was the approach adopted in this audit.

Diurnal fishing pattern

Once *Torbay* finishes steaming and reaches a desired location inside a fishing area, three operational phases follow, namely deploying, trawling and hauling of the trawl gear. The time spent deploying and hauling the gear is chiefly governed by how much wire has to be paid out/ retrieved, and this length is related to the depth of water being fished. The trawling duration is typically kept at around three hours, although this may vary between 1-4 hours depending on factors such as catch rate, seabed terrain and tidal strength. Once the trawl has been recovered a period of steaming may follow prior to it being redeployed. Given the goal is to maximise trawling time, this unproductive steaming time is normally kept to a minimum. According to the data collected on a trip in July 2009 (presented at the end of this audit in *Attachment C.– Fishing statistics*), about 73% of the available fishing time was spent trawling, 13% was spent hauling/deploying the gear, 5% was spent adding cameras/sensors to the trawl, and 8% was spent in motion steaming. It should be mentioned however, that one of the goals on this latter trip was to maximise trawling time, so 75% probably represents an upper limit, and 50% a conservative lower limit.

Fuel consumption rates

The Floscan fuel consumption meter (Model 86TLO-6FE-2K Fuel Log x High Flow) and RPM gauge (refer to Fig. 45) fitted to the main engine (CAT 3508 DITA (serial no. 69Z00405) down-rated from the original 705hp to 550hp by Caterpillar) yielded the following information for the four trawler operating phases identified above (refer to Table 21 and *Attachment C* at the end of this audit).

Figure 45. Floscan fuel-flow sensors (left pic.) and Floscan gauge on the lower right (right pic.)

Table 21. Main engine consumption rates for each of the operational phases associated with fish trawling. Data from *FV Torbay*, 24m LOA steel trawler powered by a 550hp main engine and towing a 38m headline demersal fish trawl at about 3.2knots.

Operational phase	RPM	Fuel consumption rate (L/hr)	Remark
Steaming	1150	97	≈9 knots
Deployment	1050	75	≈4 knots
Trawling	965	74	≈3.4 knots
Hauling	1000	100	≈1 knot

24 hour energy use profile for the FV Torbay

Combining the diurnal fishing pattern data with the fuel consumption rate data enabled a representative 24hour energy use profile for the fish trawler *FV Torbay* to be assembled (refer to Fig. 46). This profile assumed 75% of the available fishing time was spent trawling, with the remaining 25% equally split between deploying, hauling, steaming and ‘other’ activities; the latter category covered activities such as installing/removing cameras and sensors, mending holes in the net, sounding out a fish-mark, minor breakdowns *etc.* Note that with major breakdowns the trawler is directed to leave the fishing area by the quickest route possible (assuming it can make way); such activity is therefore not included in the audit.

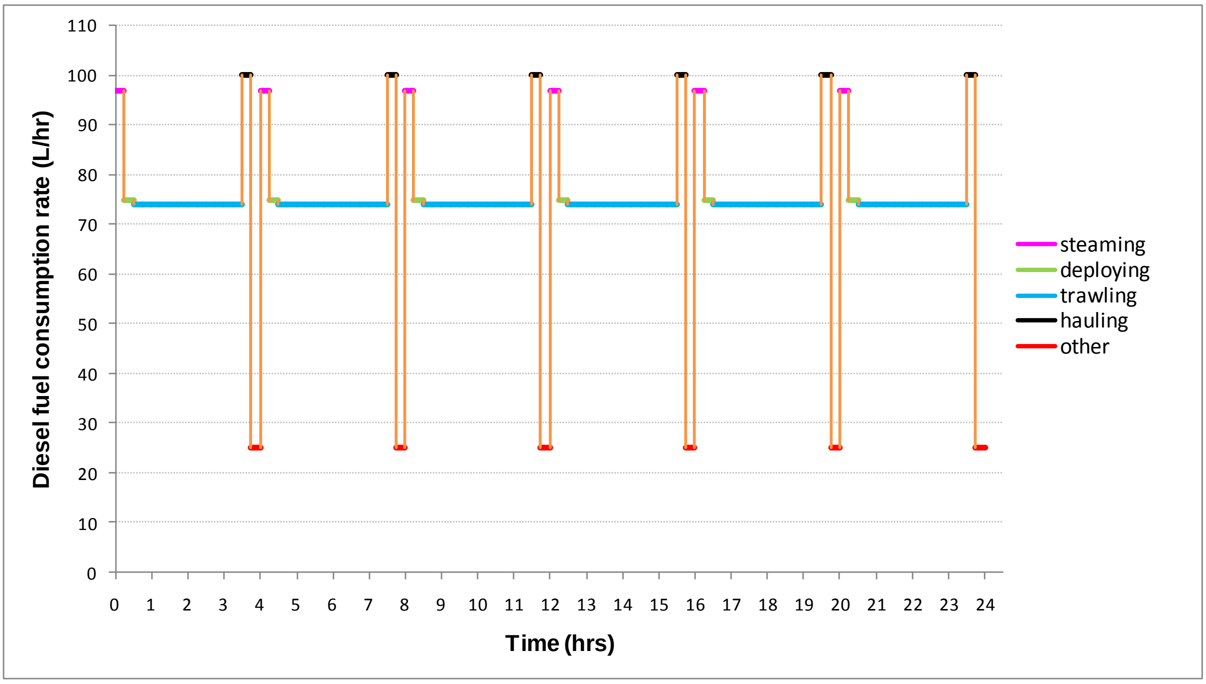


Figure 46. Representative energy use profile over 24 hours for the fish trawler *FV Torbay*. The data was collected in July 2009.

Energy usage per operational phase

The energy usage per operational phase is presented in Figure 47. This data was based on a 272 hour (*i.e.* 11.33 days) trip in July 2009 and assumes 44 hours were spent steaming to/from the fishing grounds. Even with the additional steaming time included, the trawling phase still accounted for 60% of the energy (21,154 L of diesel) consumed by the main engine on this trip.

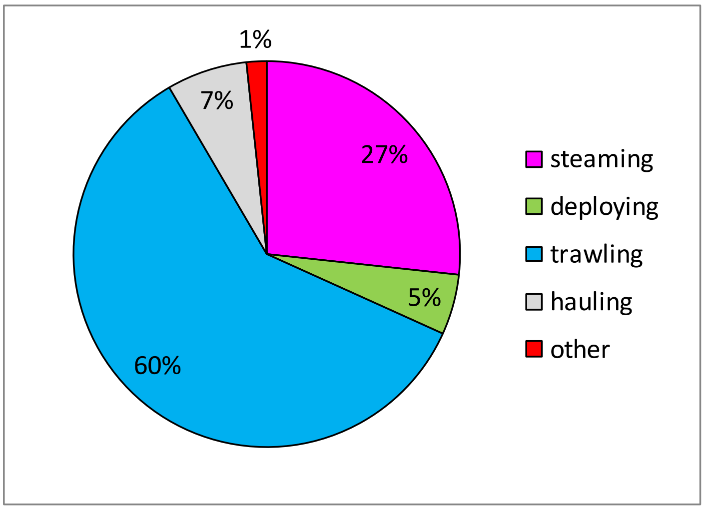


Figure 47. The proportion of energy (diesel fuel) used in each operational phase by the fish trawler *FV Torbay* during a 272 hour fishing trip in July 2009. Note that only the fuel consumed by the main engine (≈21KL) was considered.

The diesel consumed by the auxiliary engine (Cummins - rating unknown) was not considered in the above energy usage breakdown. This auxiliary provides the power to all the electrical appliances/instruments/motors onboard the *Torbay*, plus all the power packs for hydraulics, except the main hydraulics for the warp winches. The latter is driven by a power-take-off from the main engine. Based on the refuel amount of 24,702L for the 272 hour trip in July, this auxiliary consumed 3,548L of fuel during the trip, which equates to 13L/hr.

(d) Monthly energy utilisation profiles

(i) Monthly energy consumption profile

A plot of monthly diesel supplies to the *FV Torbay* during the nine-month review period Dec-08 to Aug-09 is given in Table 22 and Figure 48, together with the associated cost of this fuel. Also shown is the time spent inside the Zone 2 fishing areas; note that this time has been labelled as trawling duration, even though about 25 to 50 % of this available time may be lost to hauling, deploying, minor breakdowns, and steaming over short distances *etc* (refer to section c) for more details).

To pick up more on seasonal trends/fluctuations a longer audit period (preferably 24 months) is recommended. However prior to Dec-08 the *Torbay* was owned by another fishing business (Shine Fisheries) and operated under a different management regime from Point Sampson instead of Exmouth. There was not much point therefore in taking this audit beyond Dec-08, even if the data was available.

Table 22. Energy purchases for the *FV Torbay* from Dec-08 to Aug-09

Date	Diesel used (L)	Diesel price[1] ($/L)	Diesel cost ($)
Dec-08	38,413	1.18	45,208
Jan-09	40,703	1.11	45,363
Feb-09	36,295	1.08	39,166
Mar-09	65,317	1.00	64,997
Apr-09	48,779	0.99	48,408
May-09	43,430	0.99	42,900
Jun-09	41,247	1.01	41,734
Jul-09	49,404	1.03	51,049
Aug-09	69,667	1.03	71,757

1 Diesel prices were based on average monthly prices compiled by the WA government for the Gascoyne region, which encompasses the township of Exmouth. $0.3814/L was also deducted from the WA ‘Fuel-watch’ amount as the fishing industry and other sectors of primary industry receive a Federal government fuel rebate.

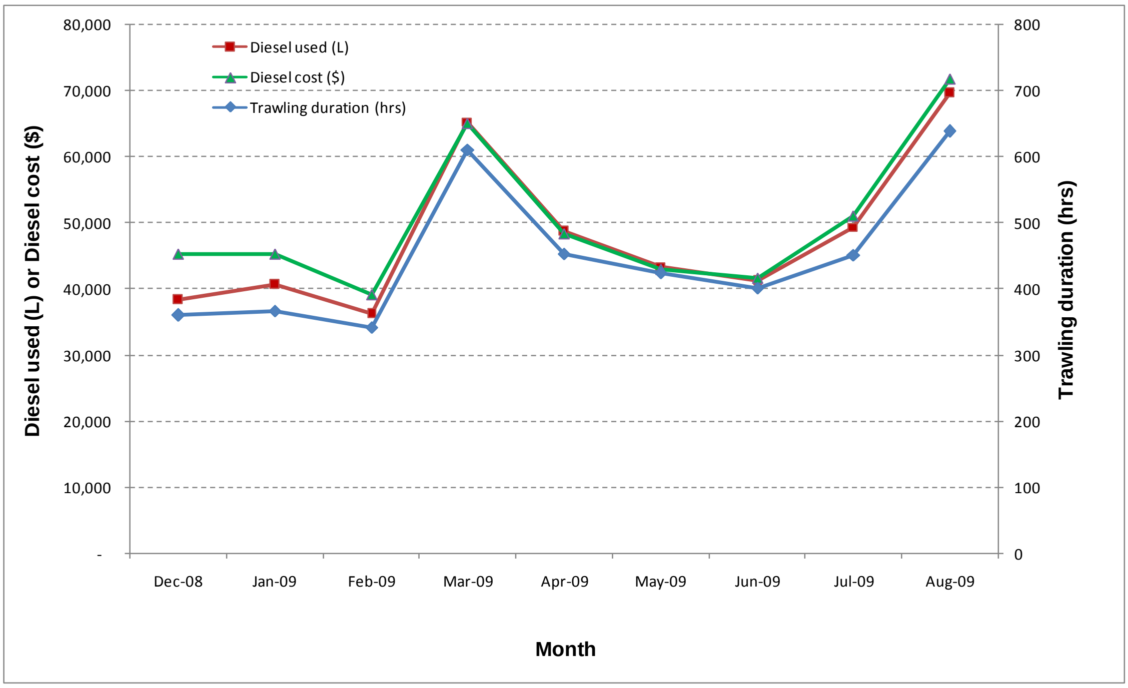


Figure 48. Monthly usage rates of diesel plus the associated cost[1] and estimated trawling duration[2] for *FV Torbay* from Dec-08 to Aug-09.

1 Diesel prices were based on average monthly prices compiled by the WA government for the Gascoyne region, which encompasses the township of Exmouth. $0.3814/L was also deducted from the WA 'Fuel-watch' amount as the fishing industry and other sectors of primary industry receive a Federal government fuel rebate.

2 Trawling duration was estimated by: [total days away from port – (no.of trips x steaming allowance to/from the fishing grounds)] x 24hrs; note these vessels are assumed to be trawling for 24 hrs.

The three parameters, namely trawling duration, diesel used, and diesel cost, showed a very similar trend across the nine month audit period. The sharp rise in March and August for all three parameters was caused by the vessel unloading a total of three times in those months instead of twice; as a consequence some of the previous month's fishing-time and fuel-consumption was assigned to the month the unload occurred in *i.e.* March and August. To address this it would be necessary to monitor fuel consumption on a daily basis, together with trawling duration. The fuel meters installed on *FV Torbay* have this daily log capability, so it is something the vessel can do from this point onwards. The daily WA Fisheries logbook contains the necessary data on trawling time, and the way this can be compiled for a single trip to facilitate future reference/analysis is shown in *Attachment C* at the end of this audit. For this report however, it is probably best to remain with the existing approach *i.e.* assign all the fuel/catch/fishing time associated with a trip to the month that the catch-unload occurred in.

It was apparent form Figure 48, despite the unrealistic increments in both trawling duration and fuel consumption in March and August, that there was an upward trend in each parameter towards the end of the nine-month period. In fact 13% more fuel was consumed by *FV Torbay* in the last four months (≈204KL) compared to the first four months (≈181KL), primarily as a result of the trawler spending about 14% more time trawling (1680hrs *compared to* 1917hrs).

(ii) Monthly energy performance profiles

The revenue and diesel cost data (refer to Fig. 49) showed a somewhat similar trend during the nine month period apart from a poor return (<$100k) in February, and a sharp rise in revenue (>$225k) in August. The drop in revenue in February was caused by a reduction in fishing time combined with some unproductive fishing. The rise in August was due to a total of three unloads occurring in that month coupled with an improvement in average production rate (*i.e.* average catch quantity per trawl hour) on those trips (the average was 67kg/hr).

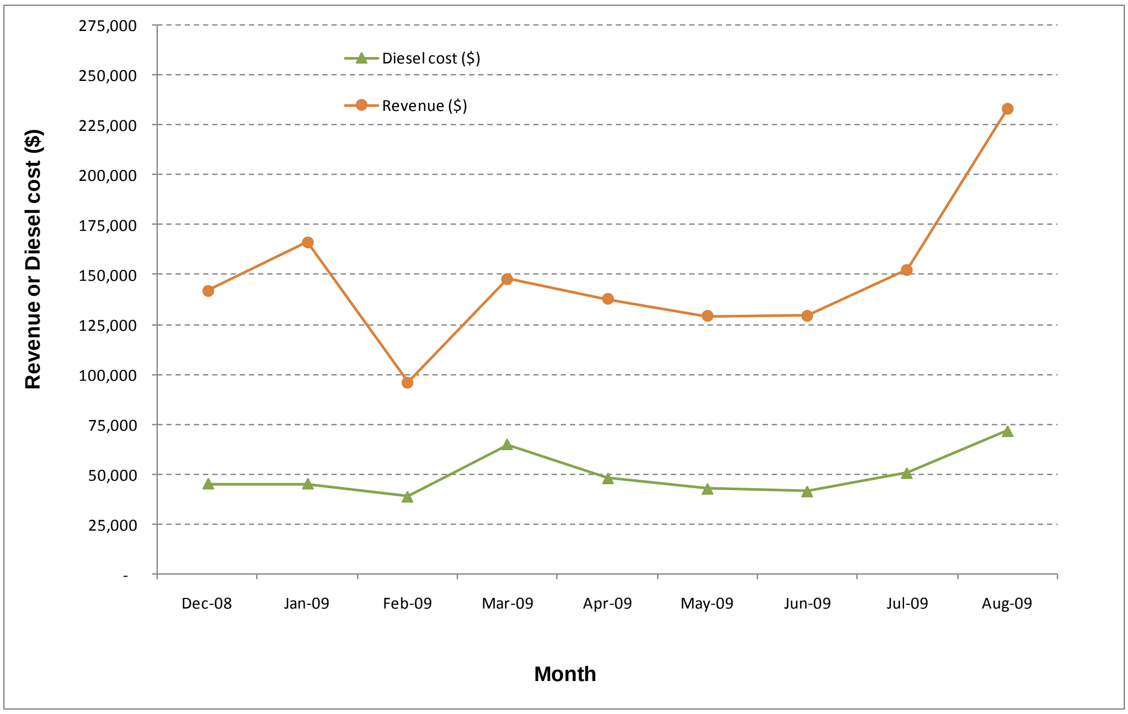


Figure 49. Monthly diesel cost[1] and revenue for *FV Torbay* during the nine-month review period.

1 Diesel cost was determined by using average monthly diesel prices compiled by the WA government for the Gascoyne region. $0.3814/L was also deducted from the WA 'Fuel-watch' amount as the fishing industry and other sectors of primary industry receive a Federal government fuel rebate.

The rise in diesel-cost towards the end of the nine-months was due primarily to the diesel cost for three trips being assigned to August instead of apportioning some of the fuel used on trip #1 in August to the month of July.

Interestingly, the last four months of fishing *i.e.* May-Aug generated 16% more revenue than the first four months ($644K compared to $553K) and required 7% more diesel fuel (207KL compared to 195KL).

It was evident in Figure 50 that both parameters, namely revenue/trawling duration and revenue/diesel used, followed a similar pattern across the nine-months examined. After a small increment in January (15% or $60/hr, 11% or $0.39/L) both parameters fell sharply over the next two months (by 47% or $212/hr, 45% or $1.82/L) to their lowest level, and then steadily recovered over the next five months to a level just below the December result ($365/hr compared to 395/hr. and $3.34/L compared to $3.70/L). The observed reduction in income per trawl hour (or litre of diesel) is difficult to explain, although it is generally accepted that summer months tend to be more productive compared to winter. Another contributing factor may be the crew changes that have occurred on this vessel together with a change in the mind-set of the skippers (crew rotations occur to give the crew time-off) towards producing a more consistent supply of fish to the processors ashore.

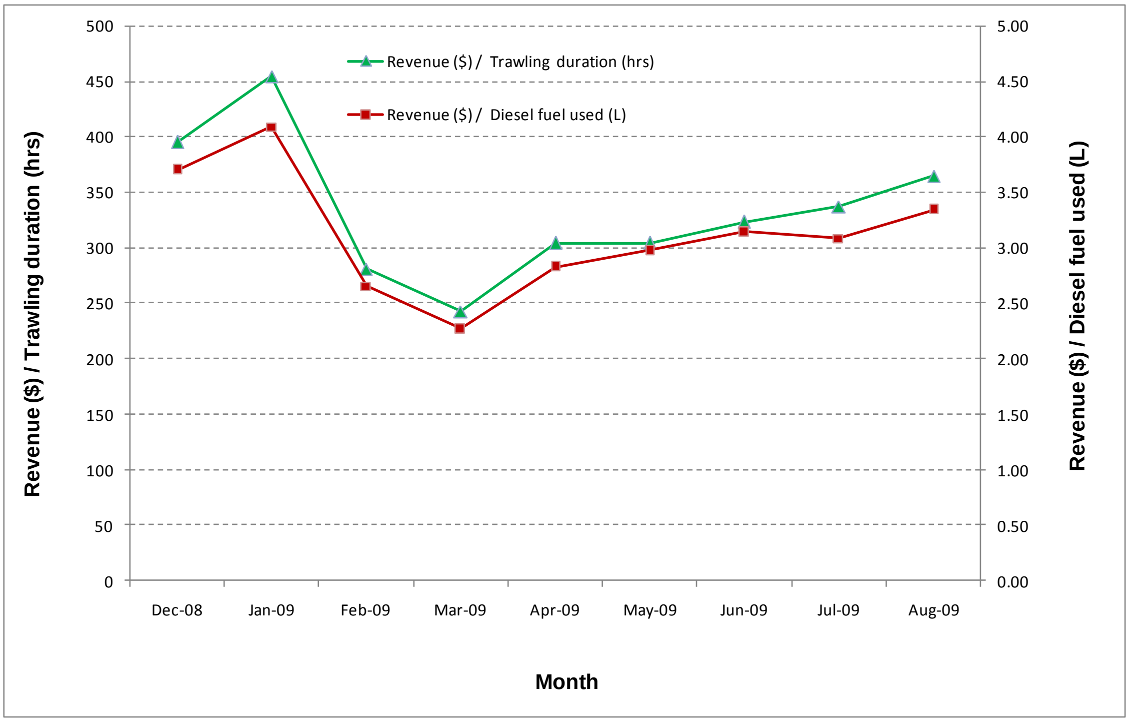


Figure 50. Monthly revenue against trawling duration[1] and also monthly revenue against diesel fuel used for the *FV Torbay* during the 2008/09 fishing period under review.

1 Trawling duration was estimated by: [total days away from port – (no. of trips x steaming allowance to/from the fishing grounds)] x 24hrs; note these vessels are assumed to be trawling for 24 hrs.

Revenue (from production output) per unit of diesel fuel increased by 3% ($3.06/L to $3.16/L) from the first four months (*i.e.* Dec-08 to Mar-09) to the last four months (May-09 to Aug-09). Revenue per trawl hour was also relatively stable between these four month blocks, only increasing by 2% ($329/L to $336/L). These figures are remarkably stable considering the monthly fluctuations observed in the earlier four-month block ($243-455/hr, and $2.27-4.09/L) compared to the latter ($304-365/hr, and $2.98-3.34/L). Note that fishing, unlike most manufacturing processes, does not necessarily share the strong correlation between inputs and outputs, because the potential of a fishing vessel and her crew to catch fish very efficiently can easily be eroded by bad luck (*i.e.* failure to locate high concentrations of vulnerable fish) and unfavourable environmental factors capable of affecting catching performance, energy consumption rate, and also available fishing time during potentially good fishing periods. Even so the skipper's approach to fishing and the way a vessel is managed can both cause fish production to become more erratic.

The following observations relate to the energy audit data presented in Figure 51, and make comparison between the first four months (*i.e.* Dec-08 to Mar-09) and the last four months (*i.e.* May-09 to Aug-09) in the nine-month time block.

- In spite of the observed variation in revenue per trawl hour across the first four months, the average for the first four months compared to the last four months only differed by 2% (*i.e.* $329/hr to $336/hr). This consistency was also present in the price paid per unit of fish production ($5.31/kg to 5.34/kg *i.e.* a 1% increase) and the production per trawl hour (62kg/hr to 63kg/hr *i.e.* a 1% increase).
- The average catch quantity per litre of fuel showed a similar trend as the revenue per trawl hour, and only increased by 3% (*i.e.* 0.58kg/L to 0.59kg/L) between the first and last four-month time blocks.
- The amount of diesel consumed per trawl hour also remained relatively constant between the first and last four month time blocks (*i.e.* it only fell by 1% from 108L/hr to 106L/hr).
- The diesel cost as a proportion of the catch revenue fell by 9% (0.35 to 0.32) between the same four-month time periods, primarily as a result of the diesel cost falling by 7%.

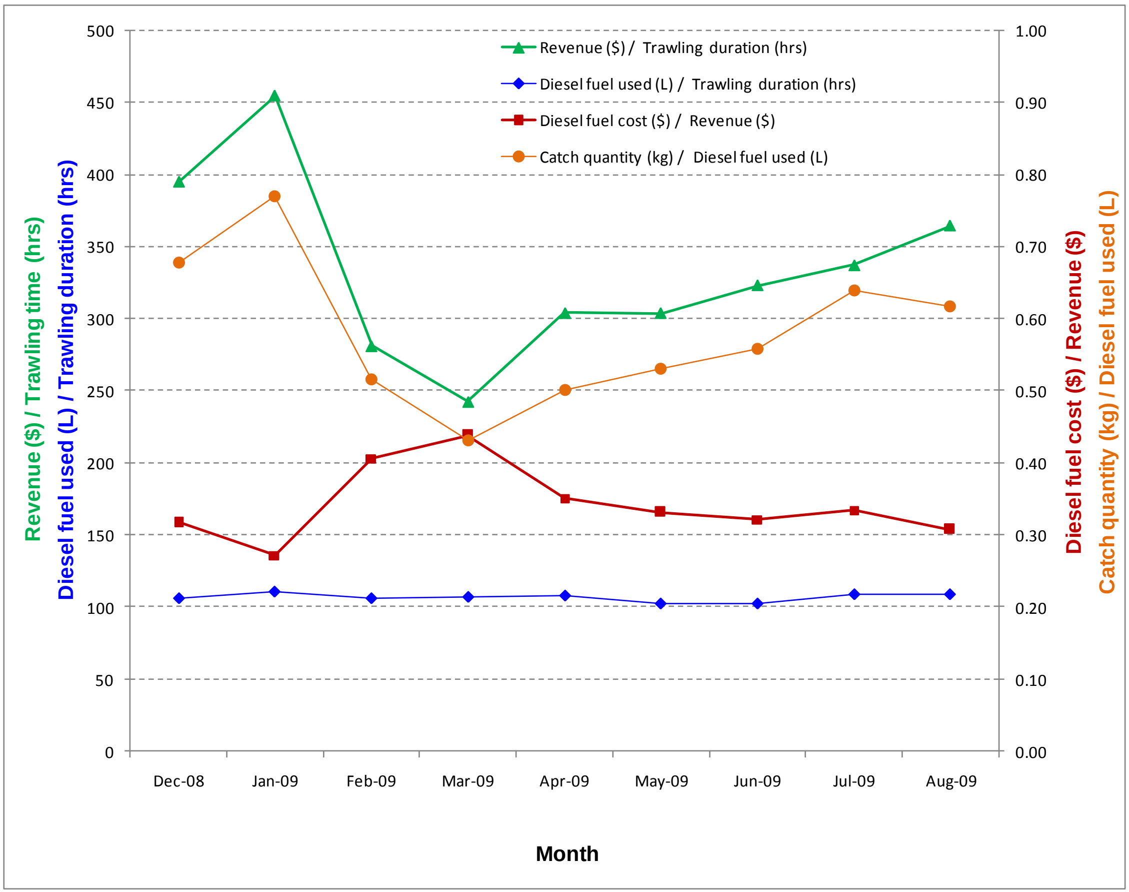


Figure 51. Energy audit performance parameters for the *FV Torbay* during the nine-month audit period. Note that diesel-cost was determined by using average monthly diesel prices compiled by the WA government for the Gascoyne region. \$0.3814/L was also deducted from the WA 'Fuel-watch' amount as the fishing industry and other sectors of primary industry receive a Federal government fuel rebate. Trawling duration was estimated by: [total days away from port – (no. of trips x steaming allowance to/from the fishing grounds)] x 24hrs; note that this vessel is assumed to be trawling for 24 hrs.

(iii) Comparison of energy performance indicators

Energy performance indicators for the fish trawlers *FV Torbay* and *FV Moira Elizabeth* are presented in Table 23. The *Moira Elizabeth* is of similar size to the *Torbay* and has less horsepower for propulsion. She operates in the Southern and Eastern Scalefish and Shark Fishery and according to the data in Table 23, outperformed the *Torbay* in the key areas. Understandably, factors such as the proximity of the fishing grounds to port, local climate, characteristics of the fishery, fuel price and average fish price differences (\$5.35/kg for *Torbay* compared to \$3.44/kg for *Moira Eliz.)* over the audit period, all have a bearing on this outcome. Nevertheless, when the price of diesel increases next, potentially the *Torbay* will feel the financial pressure first.

Table 23. Energy performance indicators for the *FV Torbay* and *FV Moira Elizabeth*

	FV Torbay	**FV Moira Elizabeth**
Vessel type	Fish trawler 24m 550hp	Fish trawler 25.5m 425hp
Audit Period	Dec-08 to Aug-09	Jul-07 to Jun-08
Fuel price range and average price	0.99 - 1.18 $/L ($1.05/L)	0.92 - 1.41 $/L ($1.09/L)
Revenue / Fishing duration	$330/fishing hour $6502/day from port	$6653/day from port
Revenue / Diesel used	$3.08/L	$4.41/L
Diesel used / Fishing duration	107L/fishing hour 2109L/day from port	1509L/day from port
Diesel cost / Revenue	0.34	0.25
Catch / Diesel used	0.58kg/L	1.28kg/L
Catch / Fishing duration	62kg/fishing hour 1215kg/day from port	1933kg/day from port
Totals - Fishing duration - Diesel used - Fuel cost - Catch quantity - Revenue	 205 days from port 433KL $451K 252t $1,336K	 185 days from port 279KL $306K 358t $1,231K

(d) Tariff analysis

The difficulty facing the *FV Torbay*, like most small to medium sized fishing vessels, is that there are currently no viable alternatives to diesel-fuel. Larger vessels can afford to run the cheaper Light Fuel Oil (LFO) and recover the expense of the required pre-heating system inside a few years. While this dependency on diesel fuel remains, the *Torbay* has limited options in terms of seeking out alternative fuel sources and driving prices down via competition in the market place.

MGK is also faced with an additional difficulty which does little towards creating a competitive market place for diesel fuel, and that is the remoteness of the port from which *Torbay* fishes. However, MGK have managed to negotiate an attractive discount on the fuel purchased from the local supplier. It is unlikely that any further discount can be obtained this way.

The susceptibility of MGK to fluctuating diesel prices is reflected in the prices paid during the audit period (refer to Fig. 52). Currently there is no mechanism/arrangement in place to insulate the company from such fluctuations, and in terms of this particular commodity, MGK would have to be classified as price-takers.

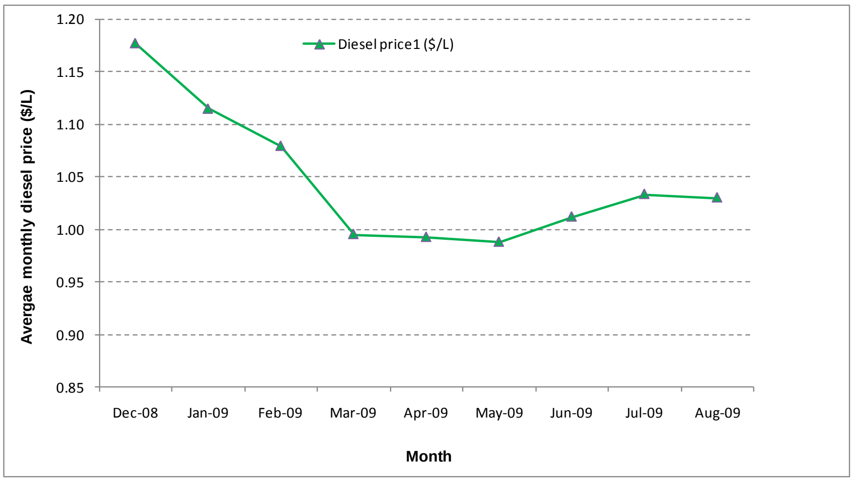


Figure 52. Average monthly prices of diesel in the Gascoyne region of WA[1] over the nine-month fishing period under review.

1 Diesel prices were based on average monthly prices compiled by the WA government for the Gascoyne region, which encompasses the township of Exmouth. $0.3814/L was also deducted from the WA ‘Fuel-watch’ amount as the fishing industry and other sectors of primary industry receive a Federal government fuel rebate.

(e) Options and Recommendations for Reduced Fuel Consumption and Costs

i) Fuel Saving Options

The sharp rise in the price of diesel fuel in 2007/08 was a timely reminder to trawling businesses to direct more attention towards becoming more energy efficient food producers, and to seek out cheaper/alternative sources of fuel while diesel prices are temporarily depressed. Table 24 contains a review of the possible fuel saving options available to the *FV Torbay*. These options were grouped into five categories, namely

- reduce air resistance of above water structure
- reduce water resistance of the hull
- reduce resistance of underwater appendages and remove fouling
- machinery
- trawl gear

Table 24. Fuel saving options available to the fish trawler *Torbay*

FUEL SAVING OPTION*	SUITABILITY (L = low, M = med., H = high) & JUSTIFICATION
Reduce air resistance of above water structure	
• Keep frontal area of deckhouses as small as possible	L – Negligible benefit at speed <15knots, plus large frontal area on deckhouses is required on this style of vessel.
• Improve design of appendages (*e.g.* masts)	L – Negligible benefit at speed <15knots, costly modifications yielding little benefit.
• Stack fish bins below deck whilst steaming	L – Negligible benefit at speed <15knots unless travelling longer distances; nevertheless, a small drag reduction is possible at no cost.
Reduce water resistance of the hull	
• Increase vessel length	M – Worth investigation; scale model hull tests are required to quantify the drag reduction and enable a payback period to be determined. Such modifications have been made to similar sized trawlers in other fisheries.
• Check speed/length ratio	M – Operate at economical running speeds; will increase trip duration but may yield a considerable reduction in drag.
• Reduce displacement/length ratio	M – May yield a considerable drag saving and may be possible to implement by utilising lightweight materials or by keeping fuel/hold spaces filled below capacity.
• Check beam/draft ratio	L – Negligible benefit at trawler operating speeds.
• Prismatic coefficient (fine up ends of vessel)	L – Difficult to take advantage of this option as trawlers do require a large underdeck volume.
• Shift longitudinal centre of buoyancy (LCB) aft of amidships	L – May be possible to implement but benefit not quantified.
• Check half angle of entrance of the w/line	L – May be implemented but benefit not quantified.
• Fit bulbous bows	M – Feasible, moderate drag saving, already utilised by trawlers in other fisheries where a considerable proportion of the trip is spent steaming.
• Use round bilge, not hard chine	L – Feasible, small drag saving possible, already used by existing trawlers.
• Use transom stern, not canoe stern	L – Feasible, benefit not quantified, already used by existing trawlers.

Table 24 (cont.). Fuel saving options available to the fish trawler *Torbay*

FUEL SAVING OPTION*	SUITABILITY (L = low, M = med., H = high) & JUSTIFICATION
Reduce resistance of U/W appendages & remove fouling	
• Avoid bilge keels	L – This vessel has a stabiliser fin (Fig. 53) secured to each side of the hull aft of amidships and near the turn of the bilge; it is impractical to remove these fins since they are needed to keep the vessel stable while fishing/steaming for several reasons; fishing efficiency, safety and comfort.
• Use aerofoil stabilisers	L – Not used and not a viable option for this fish-trawler; the existing hull-mounted roll reduction fins are a better proposition.
• Use fairings on hull mounted transducers	L – Worth consideration, may provide small drag reduction for minimal outlay if not fitted; check at next slipping.
• Rudder modifications (asymmetric aerofoil rudder, twisted/aerofoil shaft brackets	M – Suggested design modifications are feasible, drag saving not quantified but worth investigation (can always retro-fit).
• Keel cooling pipes, check alignment and design or replace with alternative system	M – Feasible, moderate drag saving possible if existing arrangement is found to be poorly designed in terms of drag minimisation.
• Remove/check alignment of chafing bars & sponsons	L – Realignment is possible and may yield a small drag saving if found to be poorly aligned. Removing sponsons is not a viable option.
• Check position and alignment of sacrificial anodes	L – Feasible; may yield a small drag reduction if poorly aligned.
• Keep hull & propeller clean and smooth	L – Feasible; although it is unlikely to yield much of a drag saving given the vessel was recently slipped. The task now is to keep the hull & propeller clean; the regular usage will help to some extent in that regard.
Machinery	
• Utilise waste heat from prime mover cooling water	L – Feasible, small fuel saving possible if desalination system fitted and heavier fuels are used in the future.
• Utilise waste heat from prime mover exhaust system	L – Worthwhile investigating, especially for heating domestic water and defrosting refrigeration systems.
• Avoid hydraulic winch systems driven by auxiliaries	L – Already addressed.
• Fit kort nozzle around properly designed propeller	L – 25% fuel saving over open propeller; very worthwhile investment in terms of cost-benefit and if vessel spends most of its time trawling. In this case the existing kort nozzle arrangement would need to be assessed to determine what improvements are possible and the associated payback period.

Table 24 (cont.). Fuel saving options available to the fish trawler *Torbay*

FUEL SAVING OPTION*	SUITABILITY (L = low, M = med., H = high) & JUSTIFICATION
Machinery (cont.)	
• Sail propulsion	L – Not feasible/practical; at the mercy of the wind, difficult to fit sails to trawlers as they have lots of overhead rigging.
• Fit controllable pitch propeller (c.p.p.)	M – Worthwhile investigating while the vessel spends several days in each trip steaming to/from the fishing grounds; c.p.p. allows the pitch of the blades to be altered to achieve the required thrust at an economical running speed for the main engine.
• Low friction bearings in engine/gearbox/drive-shaft	M – Suppliers claim that contemporary bearings provide a 5-10% reduction in frictional loss through the propulsion system compared to old style bearings; when the vessel is due for a main-engine/gearbox/shaft overhaul this option is worth investigation.
Trawl gear	
• Use high tensile warp with a smaller diameter, and possibly a lower drag coefficient	L – Feasible, but will only yield a small drag saving as the shallow water in this fishery (most of the trawling occurs in 50-90m) means not much warp wire (<400m) is towed.
• Use more efficient o/board designs	M – The current type 7GG Thyboron boards are a relatively efficient multi-foil design suitable for the type of fishing currently undertaken. While the current board rigging/fishing arrangement remains, and relatively high angles of attack (>30°) are needed, prospects appear limited in terms of drag reduction. For example, the latest Thyboron type 11 design is only capable of yielding a drag reduction of <5% at an angle of attack of 35°. However the *Torbay's* otterboards need to be replaced or refurbished, so if the former option is chosen then the Thyboron type 11 would be a satisfactory replacement.
• Modify the otterboard shoe to reduce the ground forces and to make the board more stable	M – The goal here is to reduce the magnitude of the ground forces and shift the point of contact to the halfway point along the shoe. This modification will remove some of the inefficient ground forces, and also improve the stability of the board to the point where it may be possible to operate it at lower angle of attack where it can acquire a higher hydrodynamic efficiency.
• Modify the otterboard rigging arrangement to enable the board angle of attack to be reduced	M – The goal here is to reduce the magnitude of the hydrodynamic drag by re-rigging the board so that it can operate at a lower angle of attack without compromising board stability and shooting away performance. The modification necessitates attaching the sweep wire to a point adjacent to the warp attachment point (instead of near the trailing edge of the board as is current practice).

Table 24 (cont.). Fuel saving options available to the fish trawler *Torbay*

FUEL SAVING OPTION*		SUITABILITY (L = low, M = med., H = high) & JUSTIFICATION
<u>Trawl gear (cont.)</u>		
• Use lower drag net designs	L –	By altering the trawl net design and changing the tension distribution through the net, meshes can be opened up more to improve water flow and reduce drag. Scale model trawl tests are usually required to make these refinements. The current net-design has followed such a process and therefore there may not be much room for improvement.
• Refurbish the existing otterboards to improve hydrodynamic efficiency	M –	The aim here is to restore foils to their original shape, and to restore leading edges on foils where damage is evident.
• Use lower drag netting material	M –	Numerous options are available and worth consideration; *e.g.* stronger braided twines such as dyneema yield a reduction in twine area and therefore drag, and knotless netting can be employed to good effect where knot-drag is relatively high. The payback period with such modifications understandably needs to be assessed beforehand.
• Use lower drag float configurations	M –	Replacing a greater number of smaller floats with fewer larger floats of equivalent total volume, can provide a reduction in float projected-area and therefore drag. Another possibility is to pack floats in the wings closer together so that the downstream floats do not produce as much drag; this may necessitate making up customised float packs.
* main source of options: Riley & Helmore (1985)		

Figure 53. Outer edge of the roll-reduction fin fitted located aft of amid-ships on the *FV Torbay* (left pic.). Stainless steel support strut attached to the roll-reduction fin (right pic) and nesting in a vertical groove in the hull. N.B.in these pictures the fin (coated in black plastic) is collapsed against the side of the trawler.

ii) Fuel Saving Recommendations

As a precursor to selecting the most promising fuel-saving prospects for the *FV Torbay*, the energy consumption profile for a normal days fishing (refer to section (c) *Energy usage per operational phase* and Figure 47) was analysed to identify the main energy pathways. This data indicated that most of the fuel energy (≈60%) is consumed during the trawling phase, and that most of this is used to generate the propulsive thrust required to overcome the drag of the vessel's hull and trawl gear. The trawl-gear drag is normally several times greater than the hull drag, so it stands that this is where efforts to save fuel energy should initially focus.

Of the options aimed at reducing trawl-gear drag in Table 24, the following six options were seen as the better prospects for MGK to explore at this point in time.

- Modify the otterboard shoe to reduce the ground force and to improve board stability.
- Modify the otterboard rigging arrangement to enable the board angle of attack to be reduced.
- Refurbish the existing otterboards to improve hydrodynamic efficiency (refer to Fig. 54).
- Purchase new otterboards with a higher hydrodynamic efficiency.
- Use lower drag netting material.
- Use lower drag float configurations.

The first three options are concerned with modifications to the existing otterboards, and therefore are best tackled concurrently as a single project.

Figure 54. Thyboron type 7 otterboards. Note the uneven gap between the upper sections of the foils in the left picture, and the uneven wear on the shoe in the right picture.

Otterboard option 1

The essence of the board shoe modification is to create a new shoe profile where the ground forces must act close to the mid-point along the board's length, even when the board has a distinct angle of pitch (nose up or down by up to 10°). The new shoes, especially the middle segment, must be easily replaceable as it will suffer additional wear. Currently the wear on the shoe is concentrated towards the rear inside edge. Having the ground force acting here gives it more leverage on the board in terms of angle of attack, and as a consequence the board shows greater fluctuations in said angle over undulating terrain. To compensate for this, and to prevent the ground forces acting on the outside of the shoe, operators rig the board at a higher set angle. In doing so one potential problem is resolved; the downside however is that otterboard efficiency is sacrificed in the process (refer to Fig. 55). Altering the shoe design as suggested, setting the board angle at a lower angle of attack, and trimming the operating angle of attack down by 5° from say 35° to 30° degrees improves the otterboard efficiency; in the case of the Thyboron Type 7 GG the efficiency increases from 2.09 to 2.35, and the drag reduces to 0.89 (*i.e.* 2.09/2.35) of its previous amount or by 11%. Reducing the operating angle of attack yields a gain in otterboard efficiency with most board designs. It can also cause the spread force to diminish as well, and as a consequence larger otterboards are required to generate the same amount of spread force. In the case of the Thyboron Type 7 GG, only a small loss in spread force of (C_L at 30°/ C_L at 30°/ = 1.74/1.8 = 0.97) 3% occurs, which can be tolerated as the reduction in warp tension brought about by reducing the board drag by 11% will make the warps marginally easier to spread, and therefore offset any loss in board spread due to the lift coefficient decreasing marginally.

Model specifications	
Length	0,590 m
Height	0,590 m
Projected area	0,346 m²
Aspect ratio	1,000
Area ratio	0,994
Weight in air	15,000 kg
Weight in water	12,885 kg

Angle of attack	C_L	C_d	C_L/C_d
25°			
30°	1,74	0,74	2,35
35°	1,80	0,86	2,09
40°	1,76	0,99	1,77
45°	1,67	1,07	1,56
Maximum C_l			
37°	1,81	0,90	2,02

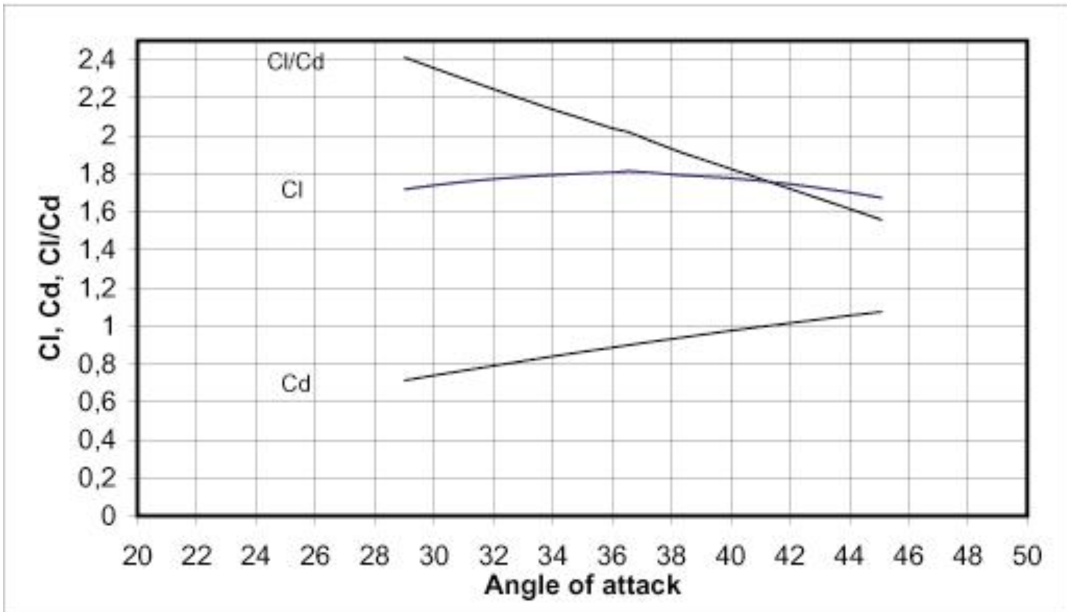


Figure 55. Thyboron type 7GG otterboard performance data. Acquired with scale model boards tested in a flume tank. Data courtesy of Thyboron.

Otterboard option 2

The second board modification also aims to create a more stable otterboard that can be operated at a lower angle of attack, and therefore attain a higher otterboard efficiency. The principle is to remove the backstrop attachments from the trailing (rear) edge of the board where they have leverage to affect the board angle of attack, and to shift them to a single point very close to where the warp wire is attached to the board. In other words connect the sweep wire directly to the board towing bracket. Understandably, such drastic rigging alterations require some thought and planning, and an appropriate implementation plan is required. Initially, experiments with scale model boards may help with exposing some of the potential difficulties and how to address them. Eventually though, sea trials will be required to prove that board stability is maintained at all phases of the trawling process, especially under demanding conditions (*i.e.* deployment in rough sea-conditions, towing in rough seas when the gear is surging and/or acted upon by a side current as well). It is advisable to undertake such trials with otterboard-sensors to enable the board depth, orientation, and spread to be monitored in real time. Compact underwater cameras should not be overlooked either, as they occasionally reveal things that sensors fail to pick up (*e.g.* board oscillations or rigging entanglements or what occurred just prior to a board falling over). Potentially though, under this new rigging arrangement the boards should be more stable under difficult conditions, hence why it is possible to operate them at a slightly lower angle of attack.

Otterboard option 3

The third recommendation is about restoring the boards and recovering the original performance level. Even robust otterboards deteriorate with usage as foils become dented, leading edges on foils become flattened, and rust takes its toll causing flaking and holes to form. In some cases the cost of refurbishment may be prohibitive and replacement is the better option. It is also critical that a pair of refurbished boards remain identical; this means they must also have a similar weight and weight distribution, and rigging points must share similar locations (an acceptable tolerance is ±2.5% on most dimensions).

Payback period- otterboards

The fuel saving that can be achieved by reducing the otterboard drag by 20% for instance can be estimated using the following equation:

$$\text{Fuel saving} = A \times B \times C \times D \times E$$

Where

A = otterboard drag reduction index relative to the existing unmodified otterboard

B = proportion of trawl drag attributable to the otterboards

C = proportion of the total drag attributable to the trawl gear

D = proportion of the fuel consumed while trawling

E = fuel consumed during the season (KL)

The calculation based on the 2008/9 average monthly fuel consumption level for the *FV Torbay*, and assigning a conservative figure of 0.25, 0.5, 0.5 to quantities B, C and D respectively in the above equation, yielded

Fuel saving = 0.20 x 0.30 x 0.50 x 0.50 x 576

= 8.6KL

Based on the average diesel price for the Dec-08 to Aug-09 period of $1.05/L, a fuel cost saving of just over $9K could have been realised in that year if more efficient boards had been deployed. A figure of $5K was quoted for the refurbishment of a pair of these Thyboron boards in the MGK Fremantle workshop. Even when this amount is doubled to account for shoe modifications and towing bracket modifications, the predicted payback period is well within the expected life (possibly 4-5 years) of these otterboards.

Otterboard replacement option

The Thyboron Type 7 GG otterboard currently used on the *FV Torbay* has been superseded in many respects by more modern designs. These new designs promise similar or better performance in key areas such as shooting away performance and rough ground capability. They are also more efficient at spreading the net; in other words they provide the necessary spreading force for less drag.

Two possible replacements were evaluated, namely the Thyboron Type 11 and Morgere SPF (refer to Fig. 56). These two designs were chosen because they are proven commercial designs with subtle design differences that provide slightly better hydrodynamic performance (refer to Table 25).

Table 25. Otterboard details. *FV Torbay* currently uses Thyboron Type 7GG boards.

Otterboard type	Description	Aspect ratio	Data source
Thyboron Type 7 GG	multifoil - 3 cascading cambered V foils	1.00	DIFTA
Thyboron Type 11	multifoil - 3 cascading cambered V foils	0.83	DIFTA
Morgere SPF	multifoil - 3 cascading cambered V foils	1.22	IFREMER

The potential drag reduction is presented in Table 26, and also portrayed in Figure 57. It was assumed that the average otterboard angle of attack for this trawl configuration is 35°. The comparison was made at three angles of attack (*i.e.* 30, 35 and 40°) to verify whether the benefit was present across a wide range of angles, since in reality the otterboard angle is not exactly known and may vary as environmental and operational conditions change. The drag ratio data showed that the Morgere SPF (Fig. 56) was clearly the best prospect at an angle of 35° (and also at 30° and 40° as well). At this angle it was able to provide the same amount of spread force as the Thyboron Type 7 GG but with only 74% of the drag (*i.e.* the drag of the SPF relative to the Thyboron Type 7 GG, given by the ratio of board efficiencies, was 2.09/2.81 or 0.74). In other words a reduction in otterboard drag of 26% could be achieved.

Figure 56. Morgere SPF otterboard viewed from the inside face (photos 1 and 2 from the left) and outside face (photos 3 and 4). The SPF is of moderate aspect ratio (A.R. = 1.22) and features three cascading cambered V-shaped foils. Convergence is present in the slots between the foils to improve the hydrodynamics of the board. [Photos courtesy of Morgere]

Table 26. Drag ratio and also Board area ratio data at three angles of attack for the existing Thyboron Type 7 GG otterboards and two alternative designs.

	Drag ratio[a] Angle of attack			**Board area ratio**[b] Angle of attack		
	30	35	40	30	35	40
Thyboron Type 7 GG	1.00	1.00	1.00	1.00	1.00	1.00
Thyboron Type 11	1.07	0.98	0.89	1.07	0.99	0.91
Morgere SPF	0.71	0.74	0.76	1.04	1.02	1.04

[a] Drag ratio = Drag of new otterboard / drag of Thyboron Type 7 GG; when both otterboard types produce the same amount of lift (*i.e.* spread force)

[b] Board area ratio = Area of new otterboard / area of Thyboron Type 7 GG; when both otterboard types produce the same amount of lift (*i.e.* spread force)

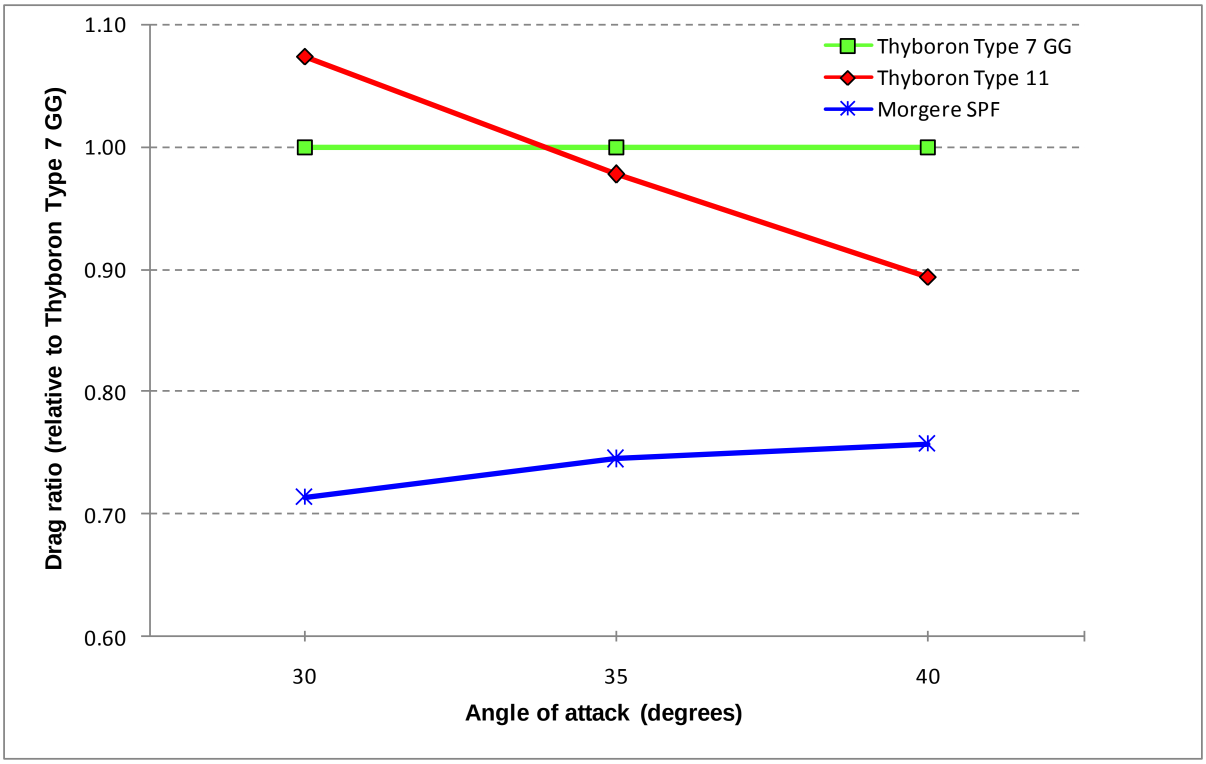


Figure 57. Drag ratio data at three angles of attack for the existing Thyboron Type 7 GG otterboards and two alternative designs.

The Morgere SPF has a higher aspect ratio compared to the other designs, and may therefore prove somewhat unstable over rough terrain. Lower aspect ratio boards generally fair better in that regard, so a possible alternative for such conditions which offers a smaller reduction in drag at an attack angle of 35 and 40° is the Thyboron Type 11. This design has an aspect ratio of 0.8, and has a drag ratio of 0.98 and 0.89 at 35 and 40° respectively.

All three designs produce a similar amount of spread force for their size at an angle of attack of 35°. The Morgere SPF and Type 11 have a board area ratio of 1.02 and 0.99 respectively (refer to Table 26 and Figure 58), which infers that a board of similar size is required to produce the same amount of spread force as the 3.73m^2 Type 7 GG's.

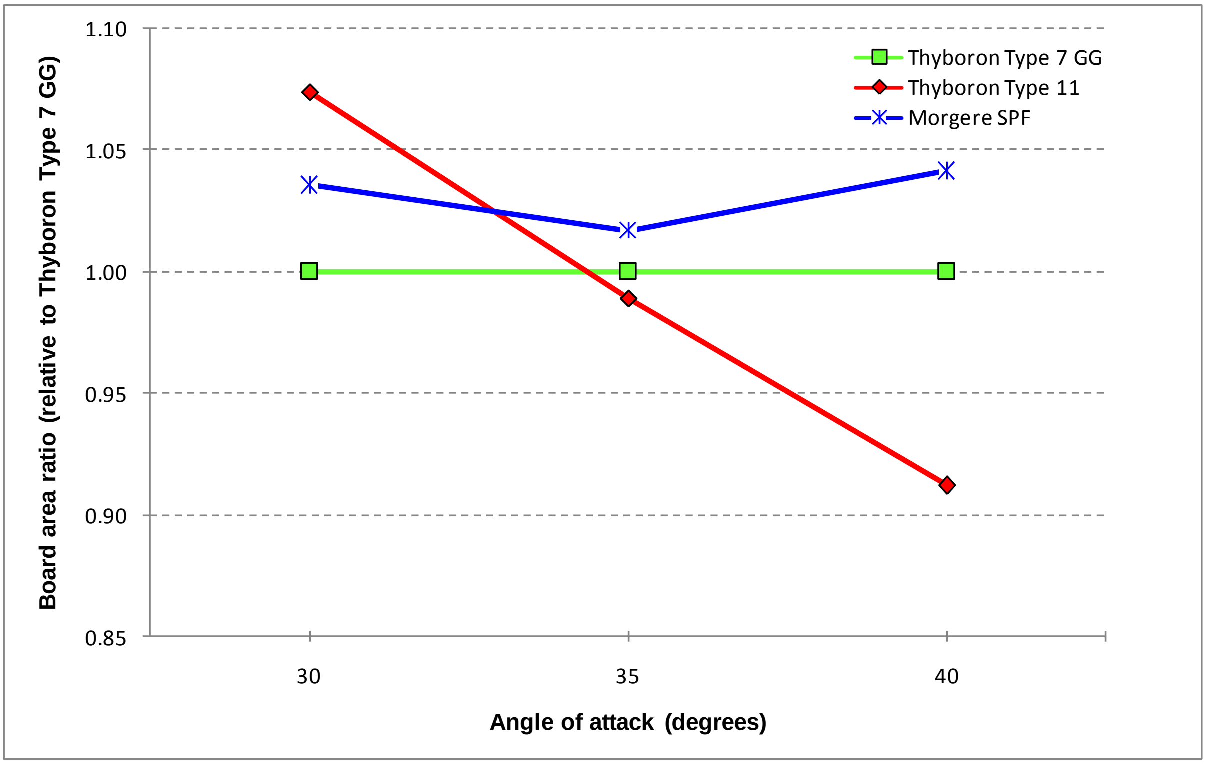


Figure 58. Board area ratio data at three angles of attack for the existing Thyboron Type 7 GG otterboards and two alternative designs.

There is also an added bonus of using more efficient otterboards that is not captured in the above analysis. The lower board drag also means that the tension in the towing warp for the same trawl speed is reduced, and as a consequence the warp inpull force is reduced as well. This means that more of an otterboard spreading force can be directed to spreading the net, and consequently a higher spread ratio is expected. This extra net-spread and board-spread may elevate the gear's drag characteristics to a level where a similar amount of thrust yields a similar trawl speed; in other words the operator is unable to detect any drag saving. To detect whether this has occurred in practice one must measure the trawl geometry and trawl speed before and after the gear change has been implemented. The trawl dimensions to monitor include board-spread, wingend-spread, and headline-height.

The fuel saving that can be achieved by using the Morgere SPF otterboard and reducing the otterboard drag by 26% (*i.e.* 1- 0.74 = 0.26 or 26%) can be estimated using the following equation:

Fuel saving = A x B x C x D x E

Where

A = otterboard drag index relative to the existing unmodified otterboard

B = proportion of trawl drag attributable to the otterboards

C = proportion of the total drag attributable to the trawl gear

D = proportion of the fuel consumed while trawling

E = fuel consumed during the season (KL)

The calculation based on the 2008/9 average monthly fuel consumption level for the *FV Torbay,* and assigning a conservative figure of 0.25, 0.5, 0.5 to quantities B, C and D respectively in the above equation, yielded

$$\text{Fuel saving} = 0.26 \times 0.25 \times 0.50 \times 0.50 \times 576$$
$$= 9.4\text{KL}$$

Based on the average diesel price for the Dec-08 to Aug-09 period of $1.05/L, a fuel cost saving of just over $9K could have been realised in that year if more efficient Morgere SPF otterboards had been deployed. A pair of these boards of the size required on the *FV Torbay* (3.73m^2 and 550kg), namely the SPF06,5 (measuring 1.75 x 2.14m and having an area of 3.45m^2 and a mass of 600kg – refer to *Attachment D* at the end of this audit), can be purchased for $14.4K (priced in Jan 2010), which would put the payback period well within the expected life (possibly 5yrs) of these steel otterboards. The boards can also be galvanised to inhibit rusting (≈$2K), and this may add a few more years to the board-life as long as impact damage is kept to a minimum.

A pair of Thyboron Type 11's of the required size (72" long) and similar weight (*i.e.* 600kg) can be imported for $14.6K. However, unless there is a need to work at higher angles of attack around 40°, these boards according to the hydrodynamic data presented above will struggle to outperform the Thyboron Type 7 GGs, whether the latter be new, restored or modified as described above.

Netting option

There is no question that the textile industry has made some significant progress in twine technology over the last few decades. On offer today are several new higher tenacity products *i.e.* they have a higher breaking load for the same tex/denier. Ultra high molecular weight polyethylene, traded as dyneema and spectra, is one such product that deservedly warrants consideration. Thought has to be put into where this product is best utilised in a trawl net however, since it is expensive and carries some attributes (*e.g.* negligible stretch/elongation under load) that make it unsuitable for certain applications. From a drag reduction perspective, to receive the most benefit from this lower diameter netting it should be placed in regions where the netting solidity is highest and where it is more exposed to the water flow. It is also worth noting here that reducing the solidity ratio of netting panels is likely to alter the water entrainment within the net, which may or may not be beneficial to the catching efficiency and traffic of animals/matter into the codend. A good place to start is the codend and codend extension, as the softness of the lower diameter netting coupled with the larger mesh-opening for an equivalent mesh-size allows more water to enter the codend and inflate it to a greater extent. Predicting the drag outcome is therefore complicated by this change in the water flow upstream and the altered codend geometry. Indeed the drag may not alter that much as a consequence, however, intuitively the increased flow-rate should see more fish entering the codend, which can go towards paying for the fuel. Like most of these new product ideas, the cost-benefit needs to be weighed up as best as one can do in the absence of definitive data. The design of this new codend will also need to factor in the optimum shape to minimise drag. For the same reason knotless netting is preferred to knotted netting. Also working in the favour of dyneema/spectra is the higher abrasion resistance compared to normal polyethylene netting. The resultant extension in netting longevity means that even initiatives promising relatively small drag reductions can prove viable in terms of reaching the payback period and yielding a dividend to the energy user in the form of a regular cost saving of fuel.

Float option

Pneumatic floats are used to provide an uplifting force to the trawl-headline in order to achieve a desired vertical mouth-opening. These floats also create drag. The amount of drag is dependent on factors such as float-quantity, float-size, float-design, float spacing/position, and trawl speed. A typical allowance for float drag is about 10% of the total trawl drag.

Float uplifting efficiency (*i.e.* buoyancy/drag) can be improved by using larger floats to provide the necessary uplift in place of a greater number of smaller floats with the same total uplift. The following example describes this principle.

1. The total uplift force required is 150kgf, and this can be achieved with either 50 x 8” floats @ 3kgf/float or alternatively 10 x 14” floats @ 15kgf/float.
2. Note that the relative projected area of the two float options is 1.63: 1 (*i.e.* no. floats x dia. x dia., yielding 50 x $(8)^2$ and 10 x $(14)^2$, resulting in 3200: 1960 or 1.63:1).

3. The projected area of these similar shaped floats relates directly to drag if we ignore secondary effects like Reynolds number on drag coefficients, or float spacing/proximity and interference drag.
4. On this basis the smaller floats with 63% more projected area also produce 63% more drag than the larger floats.

Note that reductions in float drag such as this are often masked by a commensurate rise in net drag as a result of the headline rising and the board spread increasing. These changes in trawl geometry can be monitored with hydro-acoustic sensors attached to the headline, wingends (refer to Fig. 59) and otterboards (refer to Fig. 60). Without this data the trawler operator is often left wondering why the trawler is still achieving the same trawl speed with the same amount of thrust. Data on the board spread and headline height of the current trawl gear arrangement, which includes about 50 x 8” headline floats, is presented in *Attachment B* at the end of this audit. The average headline height and board spread across this wide range of conditions was about 3.1m and 83m respectively.

Figure 59. Scanmar spread sensors attached to the upper wingends of the trawl.

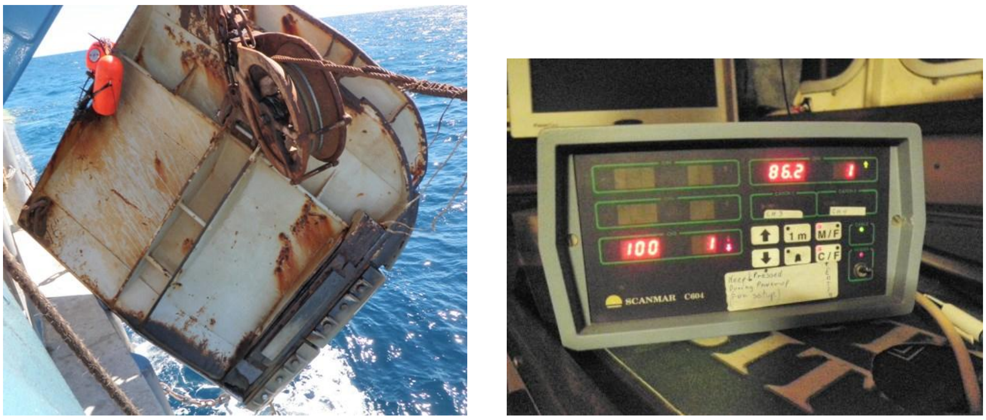


Figure 60. Scanmar spread and depth sensors attached to the port side board (left) and displaying a depth and spread of 100 and 86.2m respectively while trawling (right).

Securing a fuel-saving via a reduction in float drag is therefore complicated by the flexible and dynamic nature of trawl gear. Nevertheless, by monitoring trawl-geometry with hydro-acoustic sensors, it is possible to restore the original trawl-shape by removing some of the more efficient floats, and then a similar trawl-speed can be achieved with less thrust. In the big float versus small float example above, the potential float-drag reduction was 39%, which translates to a 4% reduction in total trawl-drag *i.e.* assuming the initial float drag was 10% of the total trawl-drag.

Using fewer larger floats is an attractive proposition despite the small potential fuel saving, simply because the larger floats work out cheaper, so the payback period is nil, and fuel cost savings can be realised immediately.

iii) Additional Considerations

Vessel related options

A number of vessel related options with moderate potential for success were also identified in the review; most of these require some form of detailed assessment/test to be performed to accurately quantify the fuel-saving and payback period prior to implementation. At the time of writing this report such information was not at hand.

iv) Closing remarks

The energy audit of the MGK trawler *Torbay* over the nine-month period from Dec-08 to Aug-09 revealed that:

- A total of 205 days were spent away from port fishing, during which time about 433KL of diesel fuel was consumed to harvest just over 252t of fish worth $1,336K. In terms of food production per unit of fuel, this equated to 0.58kg/L, and accounts for why fish trawling is sometimes referred to as a fuel-intensive fishing method/food production method.
- 34% of the revenue from fish sales was required to cover the fuel bill ($451K), which puts the business in a vulnerable position should fuel prices rise back up to the July’08 level of $2/L.
- This vessel was fishing more days towards the end of the nine-month period, and as a consequence a proportionate amount of additional fuel was being consumed as well.

- There was a level of consistency between the first half and second half of the audit period in terms of catch per unit time (1% increase) and catch per unit of fuel (3% increase) despite monthly amounts showing much more variation.
- By comparison, a similar fish trawler (7% longer, 23% less power for propulsion) working in another fishery was a more energy efficient harvesting machine (*i.e.* it landed 1.28kg of fish/L of fuel whereas the *Torbay* landed 0.58kg/L).
- These was considerable scope to improve the energy efficiency and fishing efficiency via trawl gear upgrades, vessel modifications, up-skilling and retention of key crew-members, implementing a programmed maintenance schedule, and undertaking higher level energy audits.

Attachment A. Fuel consumption rates and associated data taken aboard the *FV Torbay* in September 2009. (Data courtesy of Paul Henderson)

Shot #	Mode	Time		RPM		Depth		Wire		Tide		Heading		Trawl speed (knts)		Fuel consumption (L/hr)	
		start	finish	start	finish	start	finish	start	finish	start	finish	start	finish	start	finish	start	finish
25	trawling	0425	0755	940	996	59		275		outward	inward	N	N	3.5	3.2	64-70	72-81
31	trawling	0240	0610	940	940	64	60	270		outward		W	NW	3.5	3.8	64-70	
37	trawling	0145	0515	945	946	73				outward		E	N	3.0	3.8	68-72	
?	trawling	0300	0635	982	1028	62				outward		E (118°)	SSE (112°)	3.1	3.2	74-76	79-81
		ave.	965	952	978							ave.	3.4	3.3	3.5	69.75	78.25
31	pre-haul	0607	0610	1242	1242											130	130
31	hauling	0610	0625	1000	1000											100	100
	steaming			1245												119	
				1050												79	
				1150												97	
				1050												79	
				1245												119	
	deploying			1050	1050											74-76	74-76

Attachment B. Scanmar sensor data collected aboard the *FV Torbay* on trip #1 2009/10

Shot #	Time	Sounder depth (m)	Trawl ground speed (knots)	RPM (*digital)	Sea	Tide	Wire out	Wire:depth ratio	Board spread (m)	Board depth (m)	Headline height (m)	Wingend spread (m)	Comments
17	1439hrs	58	3.5	940			290	5.00	72	62			lower panel of net fouled
		61	3.7	960			290	4.75	78	62			extensively with fine weed
		61	4.0	1000			290	4.75	79	62			
		56	4.0	980			290	5.18	76.6	57			
18		56	3.3	990			250	4.46	67.6	58			lower panel of net fouled
		60	3.7	990			250	4.17	71.4	62			extensively with fine weed
19		61	3.2	990			275	4.51	79.7	64			lower panel of net fouled
	0018hrs	57	3.5	990			275	4.82	72	59			extensively with fine weed
20		57	2.9	1000	on bow 2m+		275	4.82	68.2				lower panel of net fouled
		57	3.5	1100	on bow 2m+		275	4.82	80				extensively with fine weed
		57	3.5 --> 3.0	1100	on bow 2m+		275	4.82	80--> 72				
21		63	3.9	940			300	4.76	83	65			nets getting cleaner
	0800hrs	66	3.5	1031*			300	4.55	83.4	66			...rougher weather?
22		65	3.5	1030			300	4.62	86.4	68			net cleaner
		68	3.2	1070	on P Qtr 2m+		300	4.41	92	70			
23		70	3.5	940			300	4.29	82	73			
24	1320hrs	66	3.1	1010	on P qtr 1m+		300	4.55	87	68			
	1620hrs	64	3.1	1040*	on P qtr 1m+		300	4.69	84	67			
	1750hrs	60	3.3	1040*	on P qtr 1m+		300	5.00	86	62			
25	1915hrs	60	3.2	970*			265	4.42	77.8	62			
	1950hrs	60	3.3	940			265	4.42	80.3	63			
26	2300hrs	68	3.2	1010			265	3.90	78	70			grid angle adjusted
27	0405hrs	64.5	3.2	980	confused 1.5-2m		275	4.26	79		3.1		
	0700hrs	65	3.3	1080	confused 1.5-2m		275	4.23	86		2.6		
28	0900hrs	65	3.2	930*	confused 1.5-2m		275	4.23	82		3.1		
29	1150hrs	65	3.2-3.5	1007*	on bow 2m+		275	4.23	74		3.5		
	1205hrs	64	3.0-3.5	1020	on bow 2m+		275	4.30	67		4.2		
	1330hrs	63	3.3	1060*	on bow 2m+		275	4.37	80		3.2		
30	1500hrs	62	3.4	937*	astern 2m+		275	4.44	84		3.1		
32	1040hrs	58	3.3	960	astern 2m+		285	4.91				18-19	
33	1433hrs	63	3.5	920*	astern 2m+		275	4.37	82	65			
	1550hrs	65	3.5	920*	astern 2m+		275	4.23	81	67			
	1700hrs	66	3.7	920*	astern 2m+		275	4.17	82	68			
34	1815hrs	64	3.4	1140*	on bow 2m+		275	4.30	95	66			
	2100hrs	59	3.5	1100	on bow 2m+		275	4.66	88	62			
35	2225hrs	58	3.4	1030	on bow 2m+		275	4.74	75	61			
	2340hrs	59	3.5	1090	on bow 2m+		275	4.66	77	63			
36	0153hrs	66	3.5	1130*	on bow 2m+		275	4.17	86	68			
	0513hrs	61	3.4	1160	on bow 2m+		275	4.51	84	62			
37	0550hrs	61	4	955*	astern 2m+		275	4.51	87	63			
	0830hrs	64	3.8	955*	astern 2m+		275	4.30	85	66			
38	1014hrs	60	3.4	950	astern 2m+		275	4.58	84	62			
	1146hrs	60	3.4	940*	astern 2m+		275	4.58	76	60			
	1300hrs	59	3.4	942*	astern 2m+		275	4.66	77	62			
39	1400hrs	59	3.5	1110	on bow 2m+		275	4.66	83	62			
	1636hrs	62	3.2	1130	on bow 2m+		275	4.44	79	65			
40	1735hrs	64	3.5	1140	on bow 2m+		275	4.30	86	66			
	1853hrs	64	3.3	1140	on bow 2m+		275	4.30	86	66			

Scanmar gear trials data (cont.)

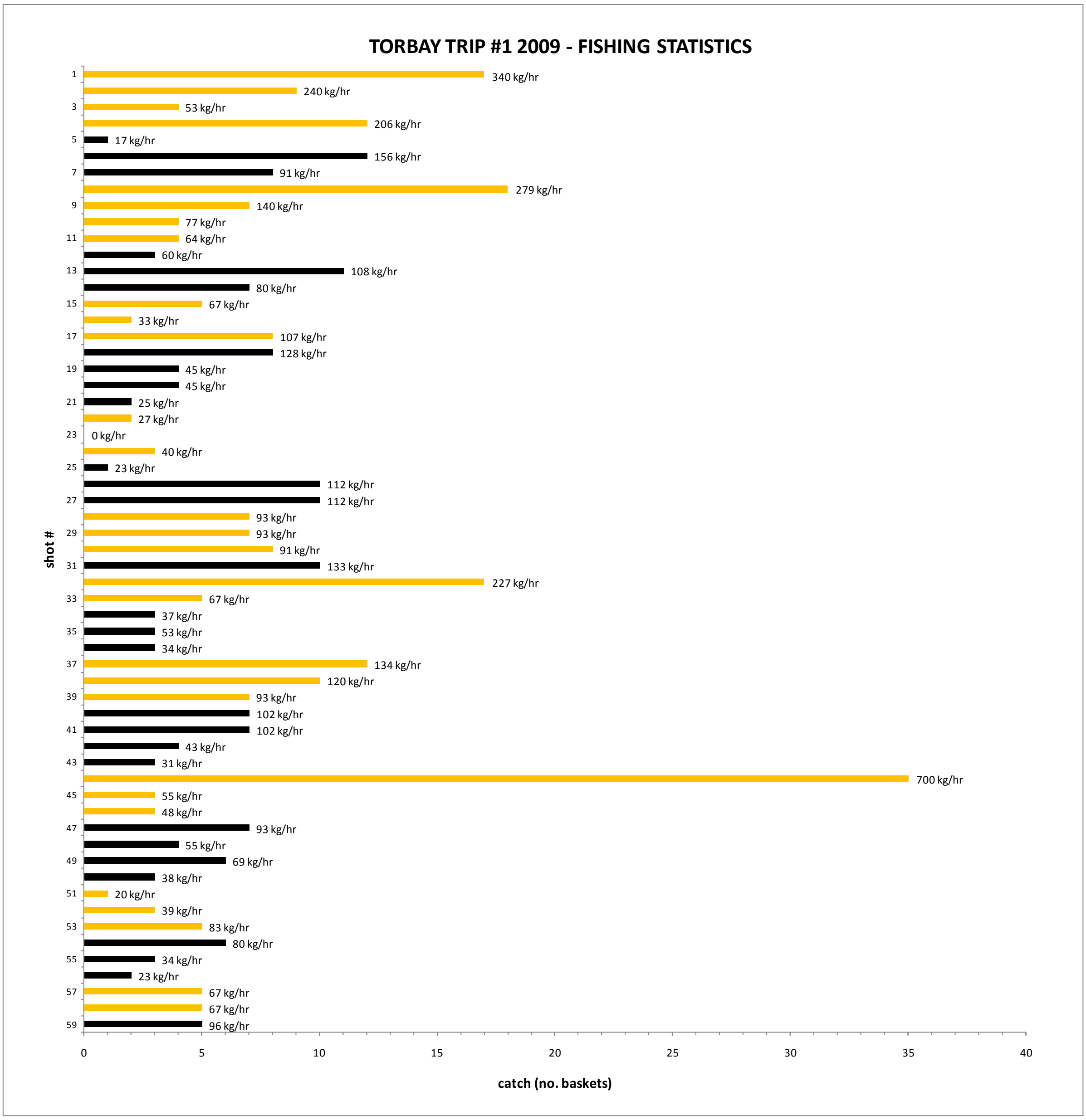
Shot #	Time	Sounder depth (m)	Trawl ground speed (knots)	RPM (*digital)	Sea	Tide	Wire out	Wire:depth ratio	Board spread (m)	Board depth (m)	Headline height (m)	Wingend spread (m)	Comments
41	2040hrs	63	3.7	980	astern 2m+		275	4.37	83	66			
	2100hrs	60	3.7	960	astern 2m+		275	4.58	82	62			
44	1012hrs	70	3.6	933*	astern 2m+		300	4.29	83	72			
	1115hrs	72	3.5	933*	astern 2m+		300	4.17	84	72			
45	1240hrs	71	3.3	1009*	on bow 1m		300	4.23	83	73			
	1320hrs	71	3.3	1030*	on bow 1m		300	4.23	87	73			
	1415hrs	71	3.5	1030*	on bow 1m		300	4.23	85	76			
46	1510hrs	75	3.2	963*	confused 1m		315	4.20	86	78			
	1552hrs	75	3.4	963*	confused 1m		315	4.20	82	74			
	1651hrs	80	3.5	963*	confused 1m		315	3.94	87	84			
	1721hrs	80	3.4	937*	confused 1m		315	3.94	84	83			
47	1837hrs	83	3.1	925*	confused 0.5m		320	3.86	81	85			
	2051hrs	81	3.5	925*	confused 0.5m		320	3.95	88	83			
	2110hrs	104	3.3	938*	confused 0.5m		320	3.08	87	105			
48		104	3.5	1040			320	3.08	92				
	2230hrs	74	3.4	970			320	4.32	85				
49	0126hrs	64	3.6	960			250	3.91	81	68			large sponge blockage
50	0533hrs	52	3.5	962		peak high	250	4.81	78	54			
51	0937hrs	56	3.3	970	relatively calm		250	4.46	76	59			large sponge blockage
	1014hrs	50	3.3	985	relatively calm		250	5.00	75	53			
	1120hrs	53	3.3	985	relatively calm		250	4.72	71	55			
52	1233hrs	55	3.2	955*	relatively calm		240	4.36	80	58			
	1307hrs	54	3.2	955*	relatively calm		240	4.44	80	57			
	1400hrs	54	3.2	955*	relatively calm		240	4.44	76	62			
58	1411hrs	72	3.2	920*	relatively calm		280	3.89	82	74			camera on starboard
	1434hrs	72	3.2	920*	relatively calm		280	3.89	81	74			board showed the
	1500hrs	72	3.4	935*	relatively calm		280	3.89	83	74			board was upright
	1545hrs	72	3.4	970*	relatively calm		280	3.89	83	73			
59	1846hrs	74	3.4	980*	confused 1m		280	3.78	90	76			
	2020hrs	72	3.2	980*	confused 1m		280	3.89	82	74			

Attachment C

TORBAY TRIP # 1 2009- FISHING DETAILS

Crew: Paul AKA 'Bugs' (skipper), Paul H (Engineer), Brody (decky), Nick (relief Decky from Ocean Raider) and John W (AMC)

Shot #	Date	Time			Catch	C.P.U.E.	Cameras	Scanmar	Fishing	Tide	Day/Night
		start	finish	duration	(no. baskets)		deployed	deployed	area		
1	9-Jul	0800	1000	2.0	17	340	2				D
2		1035	1205	1.5	9	240	4				D
3		1240	1540	3.0	4	53	4				D
4		1640	1900	2.3	12	206	4				D
5		2000	2225	2.4	1	17					N
6		2255	0200	3.1	12	156					N
7	10-Jul	0230	0600	3.5	8	91					N
8		0700	0935	2.6	18	279					D
9		1030	1230	2.0	7	140	2				D
10		1255	1500	2.1	4	77	2				D
11		1535	1805	2.5	4	64					D
12		1835	2035	2.0	3	60					N
13		2225	0250	4.1	11	108					N
14	11-Jul	0320	0650	3.5	7	80					N
15		0715	1015	3.0	5	67					D
16		1050	1315	2.4	2	33	2				D
17		1415	1715	3.0	8	107	2	y			D
18		1745	2015	2.5	8	128		y			N
19		2040	0015	3.6	4	45		y			N
20	12-Jul	0040	0415	3.6	4	45		y			N
21		0445	0800	3.3	2	25		y			N
22		0830	1130	3.0	2	27		y			D
23		1240	1410	1.5	0	0	2	y			D
24		1510	1810	3.0	3	40	2	y			D
25		1840	2025	1.8	1	23		y			N
26		2255	0230	3.6	10	112		y			N
27	13-Jul	0325	0700	3.6	10	112		y			N
28		0735	1035	3.0	7	93		y			D
29		1110	1410	3.0	7	93	2	y			D
30		1500	1830	3.5	8	91		y/n			D
31	14-Jul	0430	0730	3.0	10	133		y			N
32		0940	1240	3.0	17	227		y			D
33		1405	1705	3.0	5	67	2	y			D
34		1750	2105	3.3	3	37	2	y			N
35		2150	0005	2.3	3	53		y			N
36	15-Jul	0140	0510	3.5	3	34		y			N
37		0535	0910	3.6	12	134		y			D
38		0950	1310	3.3	10	120	2	y			D
39		1340	1640	3.0	7	93	2	y			D
40		1715	2000	2.8	7	102		y			N
41		2035	2320	2.8	7	102		y			N
42		2355	0340	3.8	4	43					N
43	16-Jul	0430	0820	3.8	3	31					N
44		0915	1115	2.0	35	700	2	y			D
45		1200	1410	2.2	3	55	2	y			D
46		1445	1715	2.5	3	48	2	y			D
47		1815	2115	3.0	7	93		y			N
48		2140	0035	2.9	4	55		y			N
49	17-Jul	0110	0440	3.5	6	69		y			N
50		0510	0820	3.2	3	38		y			N
51		0915	1115	2.0	1	20	2	y			D
52		1210	1515	3.1	3	39	3	y			D
53		1600	1825	2.4	5	83					D
54		2130	0030	3.0	6	80					N
55	18-Jul	0050	0420	3.5	3	34					N
56		0445	0815	3.5	2	23					N
57		0900	1200	3.0	5	67					D
58		1320	1620	3.0	5	67	1	y			D
59		1820	2025	2.1	5	96		y			N
			TOTALS	**169.7**	**385**						



TORBAY TRIP #1 2009 - FISHING STATISTICS

Total time available for fishing	228.4	hrs			
% spent trawling	74.3		day : night split	79.5	90.2 hrs
% spent hauling/deploying gear	12.9	(based on one half of an hour per shot)			
% spent installing/removing cameras	2.6	(based on one half an hour per installaton/removal)			
% spent installing/removing Scanmar sensors	2.2	(based on one hour per installaton/removal)			
% other	8.0				
	100.0				
Total catch	385	baskets	or	15.4	t (without bagged fish)
% taken in day shots	59				
% taken in night shots	41				
Average C.P.U.E. for the trip	91	kg/hr trawled			
Average C.P.U.E. for day shots	115	kg/hr trawled			
Average C.P.U.E. for night shots	70	kg/hr trawled			

Attachment D – Morgere SPF Otterboard details

SPF

TYPE	L	l	AREA	WEIGHT
SPF00	850	1040	0,81	100 - 120
SPF000	900	1100	0,91	100 - 120
SPF01	950	1160	1,01	120 - 140
SPF01,5	1050	1280	1,24	120 - 140
SPF02	1100	1340	1,36	150 - 170
SPF02,5	1180	1440	1,56	160 - 180
SPF03	1230	1500	1,70	180 - 320
SPF03,5	1350	1650	2,05	200 - 400
SPF04	1400	1710	2,20	250 - 450
SPF04,5	1500	1830	2,53	300 - 450
SPF05	1550	1890	2,70	350 - 550
SPF05,5	1600	1950	2,87	400 - 650
SPF06	1700	2070	3,24	500 - 700
SPF06,5	1750	2140	3,45	500 - 800
SFV07	1800	2200	3,64	600 - 900
SPF07,5	1900	2320	4,06	700 - 1000
SPF08	1950	2380	4,27	750 - 1050
SPF08,5	2000	2440	4,49	800 - 1100
SPF09	2050	2500	4,72	900 - 1200
SPF10	2100	2560	4,95	1000 - 1300
SPF11	2200	2680	5,42	1100 - 1400
SPF12	2300	2810	5,95	1200 - 1500
SPF13	2400	2930	6,47	1500 - 2200
SPF14	2500	3050	7,02	1500 - 2300
SPF15	2600	3170	7,58	1600 - 2600
SPF15,5	2700	3290	8,17	1700 - 2800
SPF16	2800	3420	8,81	1800 - 3000
SPF17	2900	3540	9,44	1900 - 3200
SPF17,5	3000	3660	10,10	2000 - 3400
SPF18	3100	3780	10,78	2200 - 3600
SPF18,5	3200	3900	11,48	2500 - 4000
SPF19	3300	4030	12,24	2700 - 4200
SPF19,5	3400	4150	12,98	2900 - 4400
SPF20	3600	4390	14,54	3100 - 4600
SPF21	3800	4640	16,22	3300 - 4800

• Poids intermédiaires sur demande • *Extra Weights on request*

MORGÈRE

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Trial Energy Audit – Fish trawler *Moira Elizabeth*

Introduction

This report contains a Level 1 Energy Audit for a fish trawler *Moira Elizabeth* (refer to Fig.61) owned by Tom Bibby. The *FV Moira Elizabeth* operates from Portland in Victoria (Vic.) and is licensed to fish in the Southern and Eastern Scalefish and Shark Fishery (SESSF). The *Moira Elizabeth* is allocated quota on a number of temperate water finfish species, and is therefore given freedom in terms of fishing times, and to a lesser extent, fishing gear configuration. Minimum mesh size restrictions and other gear controls are present to address species and size selectivity.

Figure 61. *FV Moira Elizabeth* at dockside (left) and departing for another trip to sea (right).

The *FV Moira Elizabeth* is one of many similar sized fish trawlers working in this fishery, and features:

- fish trawl gear handling equipment (*e.g.* net drum, warp winches, lazy-line winches) (refer to Fig. 62),
- unloading equipment (*e.g.* derrick/crane) (refer to Fig. 61).

The *Moira Elizabeth* undertakes short trips ranging between 1-9 days. The fish product is usually sold in a fresh state. A refrigeration system and ice-making machine provide the means to keep landed fish at low temperature in the hold and ensure product quality is preserved.

The trips undertaken by the *Moira Elizabeth* are well planned and usually entail targeting fish species that yield a good profit to the fishing business. In other words, because of the multispecies nature of the fishery, fish-tonnage is not the only key production factor, and it may prove more profitable to target less abundant higher value

Figure 62. Fish trawl on net drum (left) and warp-wire winch (right).

species. The duration of each trip, as well as the time-breakdown in terms of time spent steaming, searching/dodging and trawling, can vary greatly depending on the target species, time of the year, and area being fished.

Catch-rates do not reflect a skipper's approach to energy consumption however, and energy consumption forms a large component of the operating costs to this fishing business. Almost all of the energy consumed by the *FV Moira Elizabeth* during the 2007/8 fishing period was in the form of diesel fuel. The balance was a small amount of LPG for cooking purposes.

This energy audit report covers a twelve-month period (Jul-07 to Jun-08), during which time the price of diesel fuel escalated by almost $0.50/L and nearly reached $1.80/L retail (or $1.42/L if the $0.3814/L federal government fuel rebate for primary producers such as the fishing industry is applied) (refer to Fig. 63).

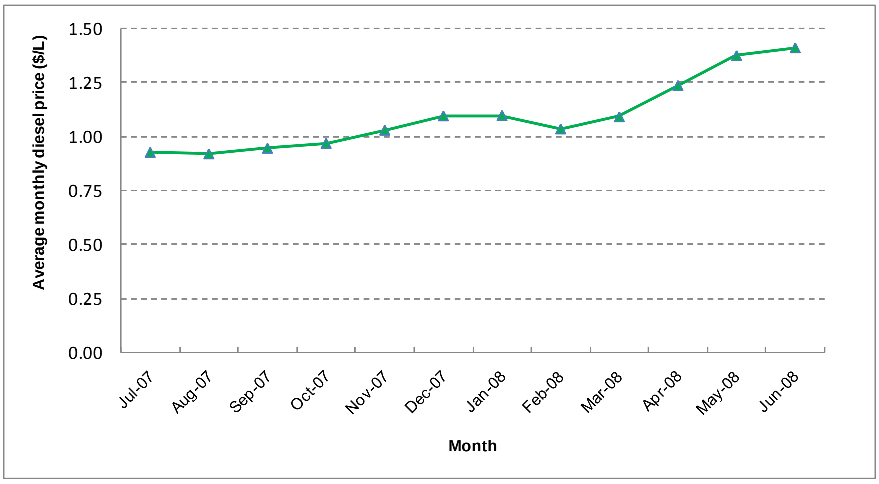

Figure 63. Average monthly prices of diesel fuel supplied to the *FV Moira Elizabeth* in Portland Victoria over the twelve-month audit period.

1 Diesel prices were based on average monthly prices paid by the vessel owner. $0.3814/L was deducted from the retail amount as the fishing industry and other sectors of primary industry receive a Federal government fuel rebate.

The main objective of this report is to obtain a clearer idea of how energy is used by this fish trawler, and to subsequently identify ways of reducing the energy consumption level and associated cost. Note that the report follows the "audit for fishing businesses" procedure presented earlier in Table 1 of the Results section.

Audit results

(a) Basic Business data

Basic business data including vessel characteristics, fishing method, fishing location and composition of catch is provided in Table 27 for the *FV Moira Elizabeth*.

Table 27. Basic business data for the *FV Moira Elizabeth*

<table>
<tr><td>Vessel</td><td>Moira Elizabeth</td><td>Launched</td><td colspan="3">198?</td></tr>
<tr><td>Length</td><td>25.45m</td><td>Beam</td><td>6.8m</td><td>Draft</td><td>3.3m</td></tr>
<tr><td>Construction</td><td>Steel</td><td>Vessel type</td><td colspan="3">Displacement - fwd wheel house, raised forecastle</td></tr>
<tr><td>Fishing Gear
Fishery
Fishing region
Base Port</td><td colspan="5">Demersal fish trawl (modified Diamond trawl from Neptune Nets)
Southern and Eastern Scalefish and Shark Trawl Fishery
South Eastern Australia
Portland</td></tr>
<tr><td>Target species
Byproduct species
Bycatch species</td><td colspan="5">mixed - temperate finfish
Balmain bug, squid
ray, shark, starfish, eel, seal, unwanted finfish</td></tr>
</table>

The units of production relevant to the energy audit of this fishing business are;

- fishing duration
- weight of saleable seafood products
- revenue from seafood products and
- energy content of the edible protein produced.

Fishing duration considerations

Trawlers licensed to fish in the SESSF are permitted to fish on any day or time of the day in the areas designated for trawling by the Australian Fisheries Management Authority (an agency based in Canberra and assigned to the management of Commonwealth Fisheries).

For the purpose of this analysis, the 'fishing duration' was assigned units of fishing-days, and the number of fishing-days in a month was equivalent to number of days that the trawler spent away from port on fishing trips; note that this measure of fishing duration includes all of the unproductive time spent away from port on a fishing trip *i.e.* the time spent steaming to and from the fishing grounds, the time spent hauling/deploying the gear, the time spent searching for fish without the trawl net in the water, and any downtime arising from gear failure/damage etc. Understandably, the goal for any fishing business is to minimise this unproductive time and maximise the productive time (*i.e.* the time spent towing the net through the water or trawling time).

Weight of saleable seafood products

A variety of temperate finfish form the primary income for trawlers in the SESSF. The offloading and weighing system employed onshore provides accurate data. Fish are weighed 'fresh' *i.e.* in an unfrozen state.

Revenue from seafood products

The revenue from the sale of the catch can fluctuate with market demand and species mix. Such fluctuations were captured in this analysis as the revenue from each unload was recorded and available.

Energy content of the edible protein produced

This quantity is included to permit the ratio of production energy (in Joules) to food energy to be established. The food energy is contingent on how much of the fish is used for food. In this analysis it was assumed that the entire fish was utilised.

(b) Energy inputs

All of the energy consumed by the *FV Moira Elizabeth* during the twelve-month review period came from the combustion of diesel fuel. Overlooked was the energy supplied to the vessel when it was idle at wharf-side and connected to shore power; the latter represents a fixed expense to the fishing business irrespective of how much shore power is used (*i.e.* an annual fee of $10k is paid irrespective of how many days the vessel is at wharf-side).

(c) 24 hour energy use profile

Like most fishing vessels, the *Moira Elizabeth* follows a set sequence of operational steps each time it leaves port (*i.e.* steaming, searching/dodging, deployment/hauling, trawling), unless some extraordinary event (gear failure, breakdown, medical emergency, adverse weather/sea-conditions) forces it to stop fishing and return to port early. This repeatability in operations from a step by step perspective is not mirrored by how much time is spent in any one step however, which makes it difficult to assemble a representative 24-hour energy use profile. Nevertheless, based on the available data and a sound knowledge of trawling operations in this fishery (and others), it is reasonable to speculate that at least 50% of the available trip-time from Jul-07 to Jun-08 was spent trawling, and of the remaining time about 30% was spent steaming and the balance was spent searching/dodging and deploying/hauling gear. For future audit work it would be useful to have such data on hand.

The *Moira Elizabeth* has several combustion engines aboard fulfilling the following roles: a main engine (34/12 CAT 425hp) for propulsion, an auxiliary (Cummins B-series 115hp) that continuously drives the 75KVA genset, and another auxiliary (Cummins NT855 300hp) that is used periodically to drive hydraulic trawl winches, derrick *etc*. (refer to Fig. 64). She also carries a third auxiliary (Perkins 4cyl 80hp) connected to a 45KVA genset which serves as a backup for the Cummins B-series. To date the fuel consumption rate of these engines during each of operational phases has not been measured with fuel-flow meters. However, a coarse estimate of 150L/hr and 125L/hr while steaming and trawling respectively was provided by the owner; these figures were based on how rapidly fuel in the smaller day tanks was consumed.

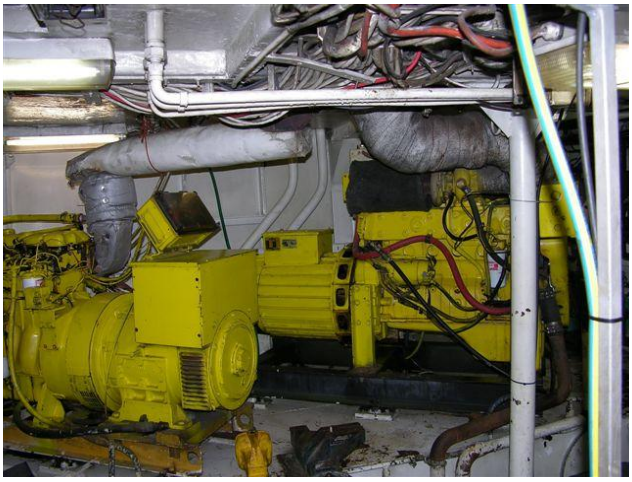

Figure 64. Two of the three auxiliary engines on the fish trawler *Moira Elizabeth*.

(d) Monthly energy utilisation profiles

(i) Monthly energy consumption profile

The *FV Moira Elizabeth* used between 10.5 to 34.2KL/month of diesel fuel during the twelve-month review period (Table 28 and Fig. 65). For the same period the average unit price per month ranged from $0.92 to 1.41/L (Table 28) and cost the business between $11.8-36.1K/month (Table 28 and Fig. 65).

Table 28. Energy purchases for the *FV Moira Elizabeth* from Jul-07 to Jun-08.

Date	Diesel used (L)	Diesel price[1] ($/L)	Diesel cost ($)
Jul-07	16832	0.93	15578
Aug-07	20714	0.92	19029
Sep-07	20683	0.94	19542
Oct-07	34151	0.97	33036
Nov-07	21265	1.01	21430
Dec-07	31392	1.09	34074
Jan-08	32213	1.10	35317
Feb-08	16890	1.03	17464
Mar-08	10501	1.12	11787
Apr-08	22247	1.21	27018
May-08	26597	1.33	35471
Jun-08	25709	1.41	36126

1 Diesel prices were based on average monthly prices paid by the vessel owner. $0.3814/L was deducted from the retail amount as the fishing industry and other sectors of primary industry receive a Federal government fuel rebate.

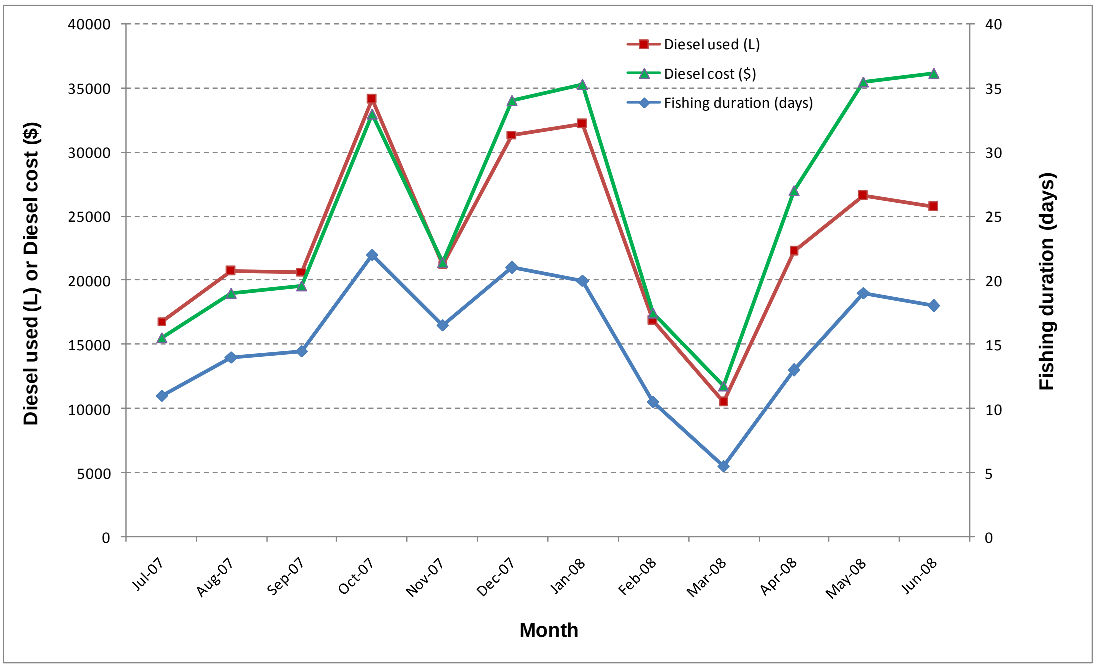

Figure 65. Monthly usage rates of diesel plus the associated cost[1] and estimated fishing duration[2] for the *FV Moira Elizabeth* from Jul-07 to Jun-08.

1 Diesel prices were based on average monthly prices paid by the vessel owner. $0.3814/L was deducted from the retail amount as the fishing industry and other sectors of primary industry receive a Federal government fuel rebate.

2 Fishing duration per month was based on the number of days the vessel spent away from port fishing.

The three parameters, namely fishing duration, diesel used, and diesel cost, showed a similar trend across the twelve month audit period (refer to Fig. 65), suggesting a degree of proportionately was maintained between these three quantities during the course of the year. However, the monthly cost of diesel did escalate in relation to the amount of diesel used (due to diesel prices rising by 52% over the twelve month audit period), and in some months it was evident that more fuel was being used per fishing day (the average was 1537L/day, and a peak and low of 1909L/day and 1289L/day occurred in March and November respectively).

There were also several noticeable fluctuations in the three quantities over the twelve month audit-period, chiefly as a result of the level of fishing activity varying by as much as 10 days from the monthly average of 15.5 days/month.

This monthly variation in fishing duration, the primary production quantity for the fishing business, was caused by several factors, including:

- The *Moira Elizabeth* undertaking 7 and 11 days of charter work (trawl survey work) in February and March respectively, which caused a noticeable fall in fishing duration.
- An inability to track the three quantities (*i.e.* diesel used, diesel cost, and fishing duration) on a daily basis, and as a consequence having to assign all of the days and fuel-used on a trip to the month that the unload and refuel occurred in, even when some of it was expended in the previous month.
- The normal/more recognised determinants such as weather/sea conditions, fish availability, mechanical failure, routine maintenance, and shore leave for the crew.

This monthly variation in fishing duration may surprise some sectors of the primary production industry where more regular patterns of work are present. However, fishing is a challenging industrial process, and something as simple as getting the harvesting machine on-site and producing units of output (in this case commercial sized fish that the business holds quota for) does represent one of the main challenges.

(ii) Monthly energy performance profiles

The revenue and diesel cost data (refer to Fig. 66) showed some resemblance over the twelve month period with revenue generally increasing as the fuel bill increased and vice versa. Peaks in revenue occurred in October and June chiefly as a result of production output increasing to about 45t/month rather than receiving a relatively high return per unit of production (the average sale price per kilogram of fish was $3.44/kg for the twelve month period, and in October and June it was $3.48/kg and $3.43/kg respectively). The fall in revenue in February and March was caused primarily by the fishing duration falling to

10.5 and 5.5 days for those months respectively (the twelve month average was 15.5 days/month). Interestingly though, the extra effort in February compared to March (almost double) did not translate to any more production (both months saw about 16t of fish landed). It did however yield more valuable fish ($4.16/kg as a monthly average for February as opposed to 2.76/kg for March), which accounts for the $23K difference in revenue between these months. This latter example of noticeably different input levels yielding similar output levels of different unit value is akin to a farmer putting twice as much effort in to produce a similar quantity of a more valuable type of crop. However, one distinct difference remains, the fishing business is never certain of what the crop is until it is landed aboard the vessel, which aligns more closely with an enterprise prospecting for gold or other precious minerals.

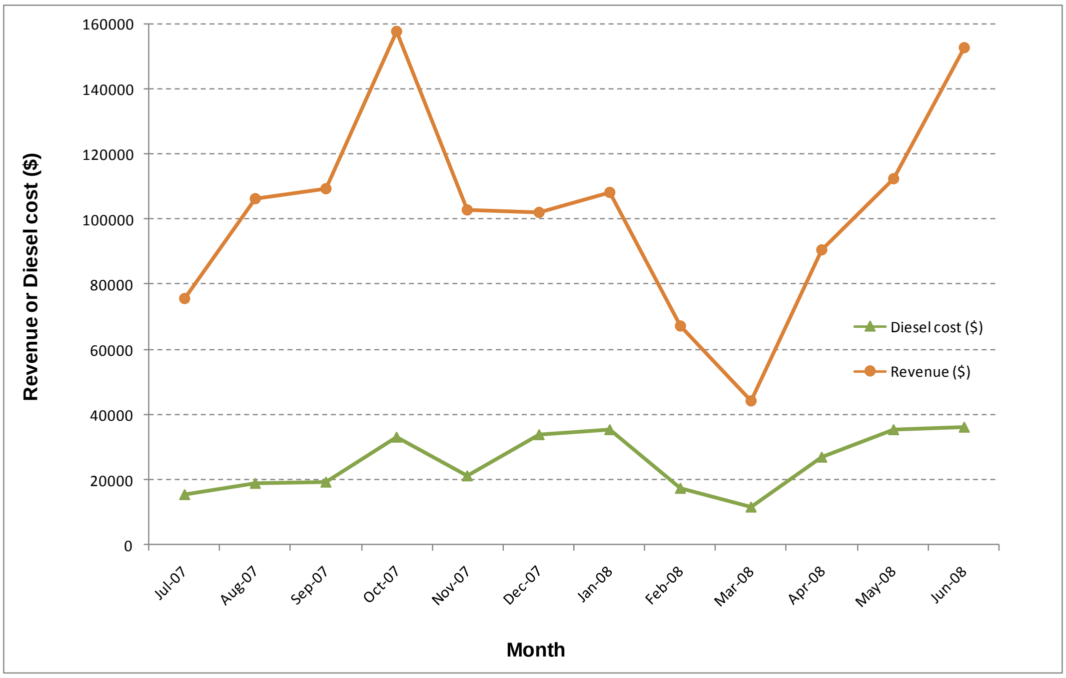

Figure 66. Monthly diesel cost[1] and revenue for *FV Moira Elizabeth* during the twelve-month audit period.

1 Diesel prices were based on average monthly prices paid by the vessel owner. $0.3814/L was deducted from the retail amount as the fishing industry and other sectors of primary industry receive a Federal government fuel rebate.

It was evident in Figure 67 that both parameters, namely revenue/fishing duration and revenue/diesel used, followed a similar pattern across the twelve-months examined. After a small increment in August (10% or $694/day, 14% or $0.62/L) both parameters fell (by 36% or $2733/day, 37% or $1.88/L) to their lowest level over the next four months. A six month recovery period followed and saw values in Jun-08 exceed the December results by 75% (*i.e.* $3636/day) and 83% ($2.70/L). The observed reduction in income per fishing day (or litre of diesel) followed by the six month recovery (which included some sharp rises and falls in the case of the Revenue/ fishing duration parameter) is difficult to explain in the absence of more historical data and background information on the fishery.

The uncertainty in securing a steady income stream from fishing was also evident from the observed monthly fluctuations in these two parameters about the twelve-month average. The revenue/fishing duration fluctuated by as much as $3600/month, which was equivalent to 55% of the twelve-month average of $6653/day. The revenue/L of diesel fuel showed even greater variation (61%) about the twelve-month mean of $4.41/L. With such variation and uncertainty present it is understandable that most fishing business and product suppliers show a reluctance to invest in new energy saving initiatives that have lengthy pay-back periods.

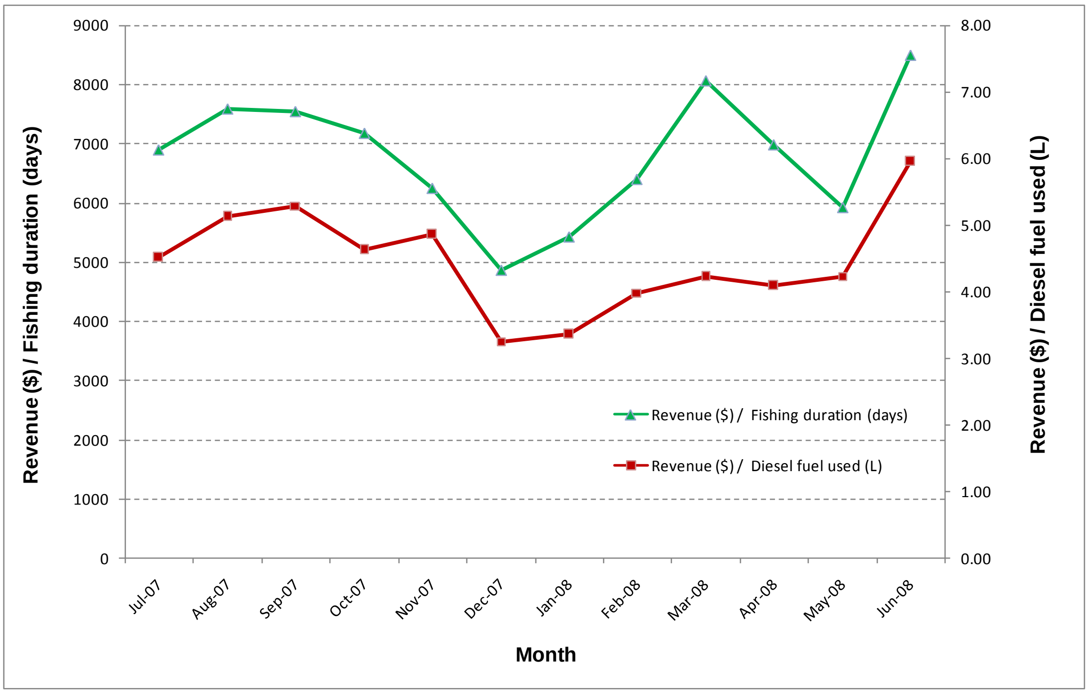

Figure 67. Monthly revenue against fishing duration[1] and also monthly revenue against diesel fuel used for the *FV Moira Elizabeth* during the twelve-month audit period.

1 Fishing duration was based on the time that the vessel spent away from port on fishing trips.

Unlike most forms of primary industry, fishing does not necessarily share the strong correlation between inputs and outputs. This transpires because the potential of a fishing vessel and her crew to catch fish very efficiently can easily be eroded by bad luck (*i.e.* failure to locate high concentrations of vulnerable fish) and unfavourable environmental factors capable of affecting catching performance, energy consumption rate, and also available fishing time during potentially good fishing periods. The skipper’s approach to fishing and the way a vessel is managed can also cause fish production to be more erratic. Such factors were evidently at work during the twelve-month audit period as there was a considerable fluctuation in each of the parameters present (refer to Fig. 68). The extent of the fluctuations is quantified below:

- Revenue / fishing duration fluctuated by as much as $3636/day across the twelve-month period. The twelve month mean value was $6653/day.
- Diesel fuel used / fishing duration fluctuated by as much as 620L/day across the twelve-month period. The twelve month mean value was 1509L/day.
- Diesel cost / revenue fluctuated by as much as 0.15 across the twelve-month period. The twelve month mean value was 0.25.
- Catch quantity / diesel fuel used fluctuated by as much as 0.97kg/L across the twelve-month period. The twelve month mean value was $1.28/L.

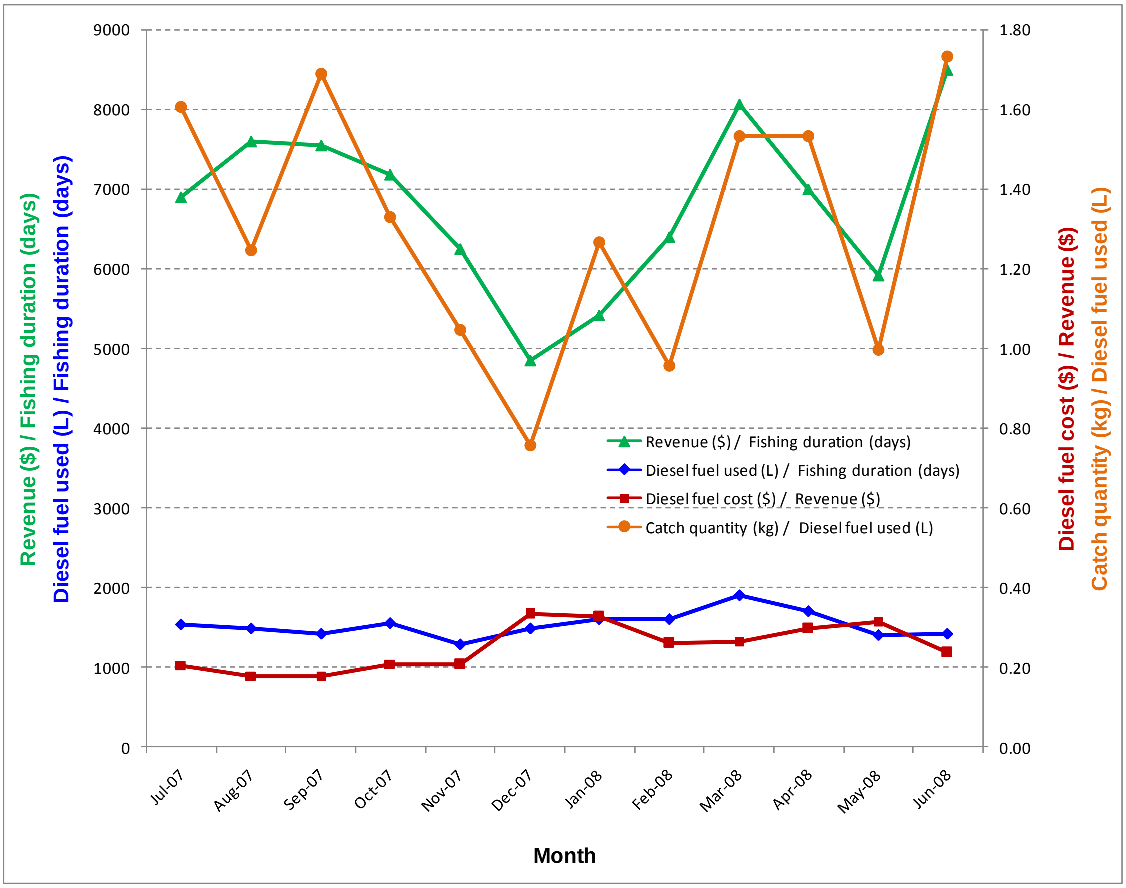

Figure 68. Energy audit performance parameters for the *FV Moira Elizabeth* during the 2007/08 fishing period under review. Note that diesel-cost was determined by using the average monthly price paid by the owner after the Federal government fuel rebate was deducted. Fishing duration was based on the time that the vessel spent away from port on fishing trips.

Audit Findings and Recommendations

The *FV Moira Elizabeth* spent 185 days fishing over the twelve-month audit period and used about 279KL of diesel fuel to harvest just under 358t of seafood (mainly finfish). In terms of food production per unit of fuel, this equated to 1.28kg/L; which helps to explain why trawling is referred to as a fuel-intensive fishing method, and why fishing is often seen as an energy-intensive food production method.

The results also showed that the production efficiency and energy efficiency of this trawler can vary considerably throughout the year (*e.g.* 1133-2926kg of fish/day, 0.76-1.73kg of fish/L of diesel, and 1289-1909L of diesel/day), primarily because of impinging factors that are largely uncontrollable or unpredictable. Decisions made by the skipper, and to a lesser extent the crew, also presumably had an impact, although with over 100 years of fishing experience residing on the vessel amongst four crew, poor decisions resulting in time and energy wastage were presumably kept to a minimum.

It was also evident from the data collected that the energy bill represents a considerable cost to this fishing business (on a monthly basis between 18 and 33% of the revenue, or annually about 25%). To learn that this business finds it difficult to pass on any additional fuel expense to the consumer by selling fish at a higher unit price was concerning. For example, when diesel-prices rose by 24% from 2007 to 2008 (based on the six-month average in each year), the average sale price of fish for the corresponding time period fell by just under 12% (*i.e.* from $3.65/kg to 3.23/kg). Clearly while this situation remains, and uncertainty surrounds future fish production rates as well as diesel prices, this fishing business will need to carefully weigh-up whether to outlay capitol on energy saving measures, particularly those which carry a long-term payback period.

The sharp rise in the price of diesel fuel in 2007/08 was a timely reminder to trawling businesses to direct more attention towards becoming more energy efficient food producers, and to seek out cheaper/alternative sources of fuel while diesel prices are temporarily depressed. Table 29 contains a review of possible fuel saving options for the *Moira Elizabeth*. These options were grouped into five categories, namely

- reduce air resistance of above water structure
- reduce water resistance of the hull
- reduce resistance of underwater appendages and remove fouling
- machinery
- trawl gear

Table 29. Fuel saving options available to the fish trawler *Moira Elizabeth*.

FUEL SAVING OPTION*	**SUITABILITY (L = low, M = med., H = high) & JUSTIFICATION**
Reduce air resistance of above water structure	
• Keep frontal area of deckhouses as small as possible	L – negligible benefit at speed <15knots, plus large frontal area on deckhouses is required on this style of vessel
• Improve design of appendages (*e.g.* masts)	L – negligible benefit at speed <15knots, costly modifications yielding little benefit
Reduce water resistance of the hull	
• Increase vessel length	M – worth investigation; scale model hull tests are required to quantify the drag reduction and enable a payback period to be determined. Such modifications have been made to similar sized trawlers in other fisheries
• Check speed/length ratio	M – operate at economical running speeds; will increase trip duration but may yield a considerable reduction in drag.
• Reduce displacement/length ratio	M – may yield a considerable drag saving and may be possible to implement by utilising lightweight materials or by keeping fuel/hold spaces filled below capacity
• Check beam/draft ratio	L – negligible benefit at trawler operating speeds
• Prismatic coefficient (fine up ends of vessel)	L – difficult to take advantage of this option as trawlers do require a large underdeck volume
• Shift longitudinal centre of buoyancy (LCB) aft of amidships	L – may be possible to implement but benefit not quantified
• Check half angle of entrance of the w/line	L – may be implemented but benefit not quantified
• Fit bulbous bows	M – feasible, moderate drag saving, already utilised by trawlers in other fisheries where a considerable proportion of the trip is spent steaming
• Use round bilge, not hard chine	L – feasible, small drag saving possible, already used by existing trawlers
• Use transom stern, not canoe stern	L – feasible, benefit not quantified, already used by existing trawlers

Table 29 (cont.). Fuel saving options available to the fish trawler *Moira Elizabeth*.

FUEL SAVING OPTION*	**SUITABILITY (L = low, M = med., H = high) & JUSTIFICATION**
Reduce resistance of U/W appendages & remove fouling	
• Avoid bilge keels	L – this vessel has a stabiliser fin secured to each side of the hull aft of amidships and near the turn of the bilge; it is impractical to remove these fins since they are needed to keep the vessel stable while fishing/steaming for several reasons; fishing efficiency, safety and comfort
• Use aerofoil stabilisers	L – not used and not a viable option for this fish-trawler; the existing hull-mounted roll reduction fins are a better proposition
• Use fairings on hull mounted transducers	L – worth consideration, may provide small drag reduction for minimal outlay if not fitted; need to check at next slipping
• Rudder modifications (asymmetric aerofoil rudder, twisted/aerofoil shaft brackets	M – suggested design modifications are feasible, drag saving not quantified but worth investigation (can always retro-fit)
• Keel cooling pipes, check alignment and design or replace with alternative system	M – feasible, moderate drag saving possible if existing arrangement is found to be poorly designed in terms of drag minimisation
• Remove/check alignment of chafing bars & sponsons	L – realignment is possible and may yield a small drag saving if found to be poorly aligned. Removing the sponsons is not a viable option.
• Check position and alignment of sacrificial anodes	L – feasible; may yield a small drag reduction if poorly aligned
• Keep hull & propeller clean and smooth	M – feasible and certainly worth investigation if the vessel sits idle for lengthy periods and heavy fouling becomes extensive; ascertaining whether it pays to slip this trawler between each survey slipping is the challenge.
Machinery	
• Utilise waste heat from prime mover cooling water	L – feasible, small fuel saving possible if desalination system fitted and heavier fuels are used in the future
• Utilise waste heat from prime mover exhaust system	L – worthwhile investigating, especially for heating domestic water and defrosting refrigeration systems
• Avoid hydraulic winch systems driven by auxiliaries	M – worthwhile investigating if an appropriate power-take-off arrangement can be fitted to the main engine
• Sail propulsion	L – not feasible/practical; at the mercy of the wind, difficult to fit sails to trawlers as they have lots of overhead rigging.

Table 29 (cont.). Fuel saving options available to the fish trawler *Moira Elizabeth*.

FUEL SAVING OPTION*	SUITABILITY (L = low, M = med., H = high) & JUSTIFICATION
Machinery (cont.)	
• Fit kort nozzle around properly designed propeller	L – 25% fuel saving over open propeller; very worthwhile investment in terms of cost-benefit and if vessel spends most of its time trawling. In this case the existing kort nozzle arrangement would need to be evaluated to determine what improvements are possible and the associated payback period.
• Fit controllable pitch propeller	M – worthwhile investigating while the vessel spends several days in each trip steaming to/from the fishing grounds; c.p.p. allows the pitch of the blades to be altered to achieve the required thrust at an economical running speed for the main engine
• Low friction bearings in engine/gearbox/drive shaft	M – suppliers claim that contemporary bearings provide a 5-10% reduction in frictional loss through the propulsion system compared to old style bearings; when the vessel is due for a main-engine/gearbox/shaft overhaul this option warrants consideration
• Replace main engine with a more fuel efficient engine	M – modern diesel engines are much more fuel efficient than older engines, especially if the latter are well used and nearing the end of their serviceable life. Replacing the 20yr old CAT main engine with a modern equivalent may therefore be a worthwhile proposition as long as the associated expense and payback period are not too great.
Trawl gear	
• Use high tensile warp with a smaller diameter, and possibly a lower drag coefficient	L – feasible, but likely to only yield a small drag saving and unclear whether the payback period can be met before the wire has to be replaced.
• Use more efficient o/board designs	M – the Thyboron Type 2 otterboard has been super-seeded by several multi-foil designs that offer higher efficiency at the angles of attack corresponding to this type of trawling configuration. Of the designs considered, the Morgere SPF was the best option (see below), followed by the Thyboron type 11. The payback period was under two years which is well within the working life of such boards, unless one is lost by chance whilst trawling.
• Refurbish the existing otterboards to improve hydrodynamic efficiency	M – the aim here is to restore foils to their original shape, and to restore leading edges on foils where damage is evident. Considering the poor condition of the existing Thyboron Type 2 boards, a drag saving of 5-10% is a reasonable expectation.

Table 29 (cont.). Fuel saving options available to the fish trawler *Moira Elizabeth*.

FUEL SAVING OPTION*	**SUITABILITY (L = low, M = med., H = high) & JUSTIFICATION**
Trawl gear (cont.)	
• Use lower drag net designs	L – by altering the trawl net design and changing the tension distribution through the net, meshes can be opened up more to improve water flow and reduce drag. Scale model trawl tests are usually required to make these refinements. The current net-design has followed such a process and therefore there may not be much room for improvement.
• Use lower drag netting material	M – numerous options are available and worth consideration; *e.g.* stronger braided twines such as dyneema yield a reduction in twine area and therefore drag, and knotless netting can be employed to good effect where knot-drag is relatively high. The payback period with such modifications understandably needs to be assessed beforehand.
• Use lower drag float configurations	M – replacing a greater number of smaller floats with fewer larger floats of equivalent total volume, can provide a reduction in float projected-area and therefore drag. Another possibility is to pack floats in the wings closer together so that the downstream floats do not produce as much drag; this may necessitate making up customised float packs.
* main source of options: Riley & Helmore (1985)	

As a precursor to selecting the most promising fuel-saving prospects for the *FV Moira Elizabeth*, the energy consumption profile for a normal days fishing (refer above to *Audit results* - section (c) *24 hour energy use profile* was considered to identify the main energy pathways. This data indicated that most (50%) of the fuel energy is consumed during the trawling phase *i.e.* 0.6 (proportion of available trip time spent trawling during the season) x 125/150 (the relative fuel consumption rates for trawling and steaming), and most of this is used to generate the propulsive thrust required to overcome the drag of the vessel's hull and also the trawl gear. The trawl-gear drag is normally several times greater than the hull drag, and therefore intuitively this is where efforts to save energy should initially focus.

Of the options aimed at reducing trawl-gear drag, the following five options were seen as the better prospects for this business to explore at this point in time.

- Refurbish the existing otterboards to improve hydrodynamic efficiency
- Replace the existing Thyboron Type 2 design with a one more efficient design

- Use lower drag netting material
- Use lower drag float configurations

Otterboard refurbishment option

The first recommendation is about restoring the boards and recovering the original performance level. Even robust otterboards deteriorate with usage as foils become dented, leading edges on foils become flattened, and rust takes its toll causing flaking and holes. The Thyboron boards used on the *Moira Elizabeth* were in relatively poor condition, so the refurbishment option may turn out to be too expensive.

It is also critical that a pair of boards remain identical. This means they must also have a similar weight and weight-distribution, rigging points must share similar locations (an acceptable tolerance is ±2.5% on most dimensions), and cambered foils must retain a similar amount of curvature. Refurbishment costs can therefore be expensive.

If the refurbished boards end up as a poor match (*i.e.* pair) then shooting away and trawling difficulties surface and compromise fishing efficiency and/or fuel efficiency.

It was difficult to quantify how much of a reduction in drag could be realised if the *Moira Elizabeth's* otterboards were fully refurbished. However, based on their appearance a 5-10% drag reduction is not an unreasonable expectation.

Otterboard replacement option

The Thyboron Type 2 otterboard has been superseded in many respects by more modern designs. These new designs promise similar or better performance in key areas such as shooting away performance and rough ground capability. They are also more efficient at spreading the net; in other words they provide the necessary spreading force for less drag.

Six possible replacements were evaluated , namely the Thyboron Type 7, Thyboron Type 7 GG, Thyborn Type 11, Morgere SPF, Bison 1-slot, and Bison 3-slot (refer to Table 30). These six designs were chosen because they are all proven commercial designs with certain key design differences that essentially cover most of the suitable boards on the market today.

The potential drag reduction is presented in Table 31, and also portrayed in Figure 70. It was assumed that the average otterboard angle of attack for this trawl configuration is 35°. The comparison was made at three angles of attack (*i.e.* 30, 35 and 40°) to verify whether the benefit was present across a wide range of angles, since in reality the otterboard angle is not exactly known and may vary as environmental and operational conditions change.

Table 30. Otterboard details. The *Moira Elizabeth* currently uses Thyboron Type 2 boards.

Otterboard type	Description	Aspect ratio	Data source
Thyboron Type 2	multifoil - 2 cascading cambered V foils	0.57	Seafish, IFREMER, DIFTA 1993
Thyboron Type 7	multifoil - 2 cascading cambered V foils	1.10	DIFTA
Thyboron Type 7 GG	multifoil - 3 cascading cambered V foils	1.00	DIFTA
Thyboron Type 11	multifoil - 3 cascading cambered V foils	0.83	DIFTA
Morgere SPF	multifoil - 3 cascading cambered V foils	1.22	IFREMER
Bison 1-slot	multifoil - 2 cascading cambered foils	0.63	Seafish, IFREMER, DIFTA 1993
Bison 3-slot	multifoil - 4 cascading cambered foils	0.63	Seafish, IFREMER, DIFTA 1993

The drag ratio data showed that the Morgere SPF was clearly the best prospect at an angle of 35° (and also at 30° and 40° as well). At this angle it was able to provide the same amount of spread force as the Thyboron Type 2 but with only 53% of the drag (*i.e.* the drag of the SPF relative to the Thyboron Type 2, given by the ratio of board efficiencies, was 1.48/2.81 or 0.53). In other words a reduction in otterboard drag of 47% was available.

Figure 69. Morgere SPF otterboard viewed from the inside face (photos 1 and 2 from the left) and outside face (photos 3 and 4). The SPF is of moderate aspect ratio (A.R. = 1.22) and features three cascading cambered V-shaped foils. Convergence is present in the slots between the foils to improve the hydrodynamics of the board. Photos: - courtesy of Morgere.

Table 31. Drag ratio and also Board area ratio data at three angles of attack for the existing Thyboron Type 2 otterboards and six possible replacement designs.

	Drag ratio[a]			Board area ratio[b]		
	Angle of attack			Angle of attack		
	30°	35°	40°	30°	35°	40°
Thyboron Type 2	1.00	1.00	1.00	1.00	1.00	1.00
Thyboron Type 7	0.78	0.79	0.77	0.90	0.90	0.80
Thyboron Type 7 GG	0.71	0.71	0.66	0.81	0.82	0.74
Thyboron Type 11	0.77	0.69	0.59	0.87	0.81	0.68
Morgere SPF	0.51	0.53	0.50	0.84	0.84	0.78
Bison 1-slot	0.86	0.84	0.77	1.15	1.10	0.95
Bison 3-slot	0.93	0.87	0.76	1.42	1.30	1.03

[a] Drag ratio = Drag of new otterboard / drag of Thyboron Type 2; when both otterboard types produce the same amount of lift (*i.e.* spread force)

[b] Board area ratio = Area of new otterboard / area of Thyboron Type 2; when both otterboard types produce the same amount of lift (*i.e.* spread force)

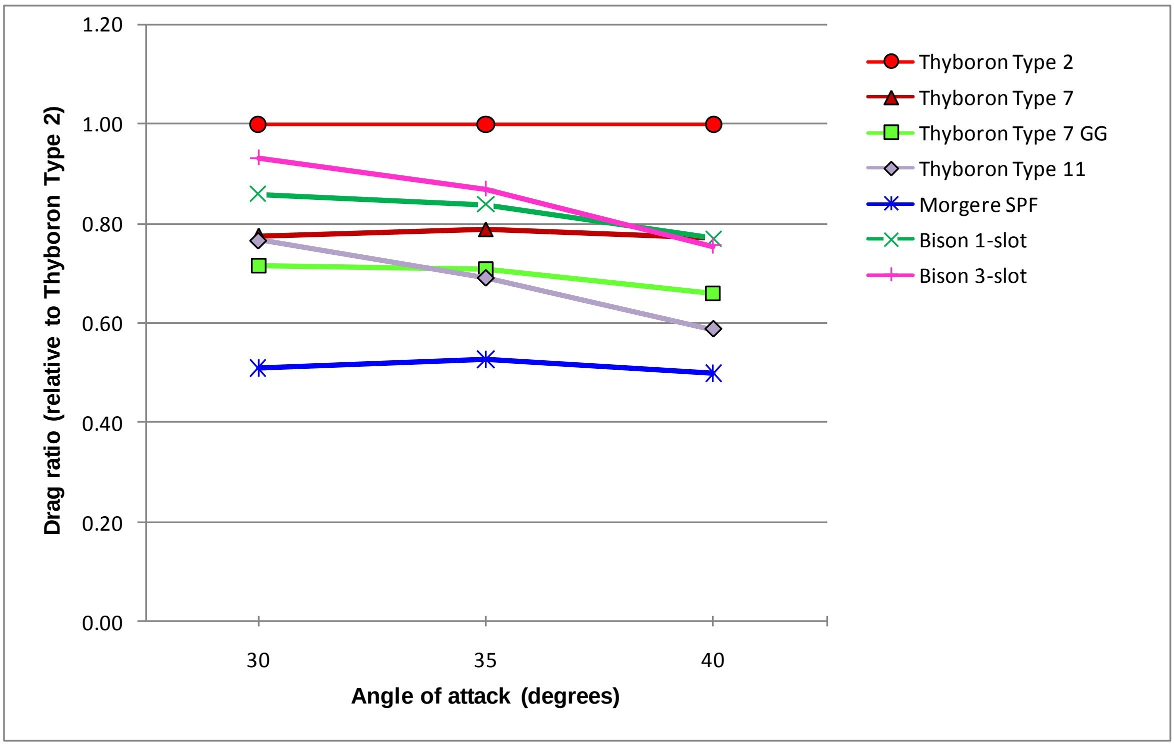

Figure 70. Drag ratio data at three angles of attack for the existing Thyboron Type 2 otterboards and six possible replacement designs.

The Morgere SPF has a higher aspect ratio compared to the other designs, and may therefore prove somewhat unstable over rough terrain. Lower aspect ratio boards generally fair better in that regard, so a possible alternative for such conditions which still offers a reasonable reduction in drag is the Thyboron Type 11. This design has a drag ratio of 0.69 at 35°, and an aspect ratio of 0.83.

Both the Morgere SPF and Thyboron Type 11 also produce a relatively high amount of spread force for their size. The former design has a board area ratio of 0.84 (refer to Table 31 and Figure 71), which infers that it only has to be 84% of the size (*i.e.* board area) of the existing Thyboron Type 2 otterboard to produce the same amount of spread force. The Thyboron Type 11 has a board area ratio of 0.81, so it is smaller again.

There is also an extra advantage of using more efficient otterboards that is not evident in the above analysis; namely that an increase in board spread may transpire as a result of the board drag decreasing together with the warp tension. To detect whether this has occurred in practice one must measure the trawl geometry and trawl speed before and after the gear change has been implemented. The trawl dimensions to monitor include board-spread, wingend-spread, and headline-height.

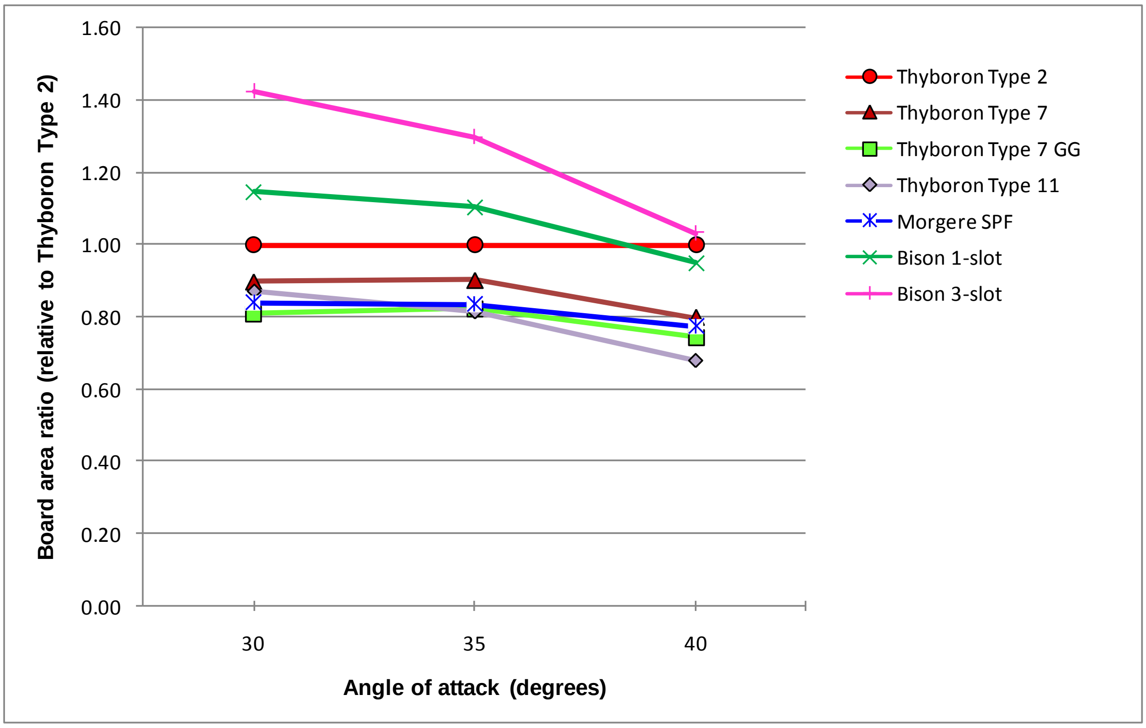

Figure 71. Board area ratio data at three angles of attack for the existing Thyboron Type 2 otterboards and six possible replacement designs.

The fuel saving that can be achieved by using the Morgere SPF otterboard and reducing the otterboard drag by 47% (*i.e.* 1- 0.53 = 0.47 or 47%) can be estimated using the following equation:

Fuel saving = A x B x C x D x E

Where

A = otterboard drag index relative to the existing unmodified otterboard

B = proportion of trawl drag attributable to the otterboards

C = proportion of the total drag attributable to the trawl gear

D = proportion of the fuel consumed while trawling

E = fuel consumed during the season (KL)

The calculation based on the 2007/8 fuel consumption level for the *FV Moira Elizabeth*, and assigning a conservative figure of 0.3, 0.5, 0.5 to quantities B, C and D respectively in the above equation, yielded

Fuel saving = 0.47 x 0.30 x 0.50 x 0.50 x 279

= 9.8KL

Based on the average diesel price for the Jul-07 to Jun-08 period of $1.09/L, a fuel cost saving of just under $11K could have been realised for the same twelve-month period if more efficient Morgere SPF otterboards had been deployed. A pair of these boards of the size required on the *FV Moira Elizabeth* (2.85m^2 and 680kg), namely the SPF04.5 (measuring 1.5x1.83m and having an area of 2.53m^2 and a mass range of 300-450kg – refer to *Attachment D* at the end of the previous fish trawler audit) would retail for less than $20K, which would put the payback period well within the expected life (possibly 5yrs) of these steel otterboards; unless they meet with misadventure before they wear out. Note that the Morgere SPF04.5 boards are marginally smaller because they have a slightly higher lift coefficient than the Thyboron Type 2. The Morgere boards will also require about 200kg of extra ballast; preferably in the form of extra shoe thickness since clip-on ballast-bars can disrupt the water flow around the board and potentially undermine the hydrodynamic performance.

Netting option

The *Moira Elizabeth* uses a modified Diamond Trawl from Neptune Nets (Hugh McKenna) in Hobart. This net is used for most of the trawling undertaken and has a headline length of around 32m. It is a four-panel trawl comprising of 9-inch knotted braided polyethylene (PE) netting in the wings and first two body panels (top panel only), followed by a panel of 6-inch netting and then two panels of 4.5-inch netting in the throat, all in knotted PE braid. The codend is made from knotted double twine PE braid.

Samples of 9-inch and 6-inch netting were taken and analysed to ascertain the twine diameter (refer to Fig. 72).

Figure 72. 9-inch and 6-inch netting samples used in the trawl net *on Moira Elizabeth*.

The diametric results showed some variation across the netting used, and indicated that the dark-blue 9-inch twine had a marginally smaller diameter (about 7%) compared to the orange material (refer to Table 32). From a drag reduction perspective, the former material should be used in preference to the latter, since first principles (*i.e.* projected twine area is proportional to hydrodynamic drag) suggest a similar magnitude reduction in drag could be realised with the dark blue netting.

Table 32. Diametric results for netting used in the trawl net on *Moira Elizabeth*. Two measurements were taken with veinier callipers on each twine element to contend with the out-of-round shape of the braided twine.

Netting description	Diameter measured (mm)		Mean dia. (mm)
6-inch Polyethylene braid, single knot, green	3.9	2.7	3.3
9-inch Polyethylene braid, single knot, dark blue/ yellow fleck	4.2	3.6	3.9
9-inch Polyethylene braid, single knot, orange	4.6	3.8	4.2

The option to use thinner twine made from new higher tenacity products (*i.e.* they have a higher breaking load for the same tex/denier) also exists. Ultra high molecular weight polyethylene, traded as dyneema and spectra, is one such product that deservedly warrants consideration. Thought has to be put into where this product is best utilised in a trawl net however, since it is expensive and carries some attributes (*e.g.* negligible stretch/elongation under load) that make it unsuitable for certain applications. From a drag reduction perspective, to receive the most benefit from this lower diameter netting it should be placed in regions where the netting solidity is highest and where it is more exposed to the water flow. It is also worth noting here that reducing the solidity ratio of netting panels is likely to alter the water entrainment within the net, which may or may not be beneficial to the catching efficiency and traffic of animals/matter into the codend. A good place to start is the codend and codend extension, as the softness of the lower diameter netting coupled with the larger mesh-opening for an equivalent mesh-size allows more water to enter the codend and inflate it to a greater extent. Predicting the drag outcome is therefore complicated by this change in the water flow upstream and the altered codend geometry. Indeed the drag may not alter that much as a consequence, however, intuitively the increased flow-rate should see more fish entering the codend, which can go towards paying for the fuel. Like most of these new product ideas, the cost-benefit needs to be weighed up as best as one can do in the absence of definitive data. Based on equivalent breaking strength, a diametric reduction of at least 50% is possible if dyneema is used in place of standard PE. Again, according to first principles this should yield a similar magnitude drag reduction. Also working in the favour of dyneema/spectra is the higher abrasion resistance compared to normal polyethylene netting. The resultant extension in netting longevity means that even initiatives promising relatively small drag reductions can prove viable in terms of reaching the payback period, and then yielding a dividend to the energy user in the form of a regular cost saving on fuel.

Float option

Pneumatic floats are used to provide an uplifting force to the trawl-headline in order to achieve a desired vertical mouth-opening, in this case between 4-4.5m according to the vessel owner. These floats also create drag. The amount of drag is dependent on factors such as float-quantity, float-size, float-design, float spacing/position, and trawl speed. A typical allowance for float drag is about 10% of the total trawl drag.

Float uplifting efficiency (*i.e.* buoyancy/drag) can be improved by using larger floats to provide the necessary uplift in place of a greater number of smaller floats with the same total uplift. Note that an example was provided in the previous audit on the fish trawler *Torbay.*

Note that reductions in float drag such as this are often masked by a commensurate rise in net drag as a result of the headline rising and the board spread increasing. These changes in trawl geometry can be monitored with hydroacoustic sensors attached to the headline, wingends (refer to Fig. 59) and otterboards (refer to Fig. 60). Without this data the trawler operator is often left wondering why the trawler is still achieving the same trawl speed with the same amount of thrust.

Vessel related options

A number of vessel related options with moderate potential for success were also identified in the review; most of these require some form of detailed assessment/test to be performed to accurately quantify the fuel-saving and payback period prior to implementation. At the time of writing this report such information was not at hand.

Other possibilities

It is worth noting that maintaining the *FV Moira Elizabeth* in a reliable and fuel-efficient condition, and maintaining/enhancing fish handling/processing facilities aboard to retain fish quality and attain high fish prices, both serve to suppress/counteract any rise in the key parameter *i.e.* diesel cost($) / revenue($) discussed above.

Discussion

Comparison of energy audit performance parameters

Energy audits were completed on a total of seven fishing vessels. Energy audit performance parameters (indicators) for each of these vessels are presented in Table 33. The following observations were made in relation to this assembled data:

- The vessels using passive fishing gears (*i.e.* fish-traps and rock-lobster pots) registered relatively low *diesel cost/revenue* figures (ranging from 0.09 - 0.17), whereas the vessels using active fishing gears (*i.e.* fish trawls and prawn trawls) registered relatively high values (ranging from 0.18-0.34). These results supported the notion that passive gears are generally less energy intensive, and furthermore, that fishing businesses based on passive fishing methods are generally less vulnerable to rising diesel prices.
- The amount of seafood landed per litre of fuel ranged from 0.19 to 1.28kg/L, which at first glance seemed low, and presumably accounts for why fishing is often referred to as an energy intensive food-production method. Interestingly, the production level of the passive gears, in particular the fish-trap, was relatively high compared to the active gears, with only the Victorian fish-trawler (1.28kg/L) surpassing the WA trap-boat (1.07kg/L).
- The catch-revenue obtained per litre of fuel varied considerably across the seven vessels audited ($2.78-11.24/L), and was clearly a function of productivity per unit of fuel, and how much the market was prepared to pay for that type of seafood. The relatively high price paid for rock-lobster ($24-28/kg), over say finfish from SE Australia (about $3.45/kg), clearly influenced this result. To boost business profits in these low-value seafood fisheries, vessels typically have to land a greater quantity of fish. This was particularly evident with the SE Australian fish-trawler as it landed about three times as much seafood per unit of fuel compared to the rock-lobster pot vessel; a similar trend was also present across the remaining five vessels.
- The amount of catch landed per unit time was difficult to standardise across the seven vessels due to a difference in the reported fishing-time in each case:

  WA prawn trawler – hours of darkness

  SE Qld prawn trawlers – logbook trawl hours

WA Fish trawler	–	trip hours with a deduction for steaming-time to/from the fishing grounds
SE Fish trawler	–	days from port
Rock-lobster boat	–	engine running hours
Fish trap boat	–	days from port

Based on these differences it was unwise to make comparison between these catch per unit time figures.

Table 33. Energy audit performance parameters for seven Australian fishing vessels.

Vessel type	Fishery/ fishing region	Fishing period(s)	Diesel cost ($)[1] / Revenue ($)	Catch (kg) / Fuel used (L)	Revenue ($) / Fuel used (L)	Catch (kg) / time (hrs or days*)[2]
Prawn trawler	Exmouth Gulf Prawn Fishery/ NW Australia	Apr-Nov 2007 Apr-Nov 2008	0.18 0.18	0.57 0.78	6.02 8.31	51.3 62.9
Prawn trawler (Ella Mae)	Queensland East Coast Otter Trawl Fishery/ SE Qld	Jan-Dec 2006	0.32	0.19	2.78	9.5
Prawn trawler (C-King)	Queensland East Coast Otter Trawl Fishery/ SE Qld	Jan-Dec 2006	0.28	0.22	3.19	14.4
Fish trawler	Southern and Eastern Scalefish and Shark Fishery/ SE Australia	Jul 07 - Jun 08	0.25	1.28	4.41	1933*
Fish trawler	Pilbara Fish Trawl Interim Managed Fishery/ NW Australia	2009	0.34	0.58	3.08	61.6
Rock-lobster pot boat	Western Rock-Lobster Fishery/ Central WA	06/07 07/08	0.09 0.12	0.40 0.44	11.24 10.35	25.5 26.8
Fish trap boat	Pilbara Fish Trap Fishery/ NW Australia	08/09	0.17	1.07	7.07	562*

1 Diesel prices with the Federal government fuel rebate of AUD$0.3814/L deducted.
2 Note that the unit of time varied between vessels and therefore only tentative comparisons can be made. Refer to the accompanying text in the FRDC report 2006/229 for more information.

Undertaking energy audits on fishing vessels – lessons learnt and potential refinements

During the course of this project a number of observations were made that may serve to improve the energy auditing process for fishing vessels in the future. These observations and potential refinements are presented below.

The energy audit performance parameters (indicators) presented in Table 1 were devised to provide a means of monitoring performance within a fishing business over time, as well as permit comparison to be made between businesses. To that end these parameters worked relatively well in this project, although the following modifications were made to facilitate the assemblage or analysis of audit data:

- The '*fuel used/ catch revenue*' parameter was altered to '*catch revenue /fuel used*' as the latter was more meaningful and easier for industry *etc.* to interpret.
- '*Catch revenue / fishing day*' and '*catch revenue / fuel used*' were presented together (refer to Fig. 67) to ascertain whether efforts to reduce fuel consumption were having a negative or positive impact on catch income.
- The '*Joules of fuel/Joules of protein energy'* parameter was omitted from the audits to avoid including a quantity, namely '*Joules of protein energy'* that proved to be very difficult to calculate; the difficulty was due primarily to ascertaining what the edible protein portion of a whole fish was, especially once recovery rates and different eating habits were considered.
- A new parameter was introduced, namely '*catch quantity / fuel used*' (as per Figure 68), since this new parameter was useful for not only monitoring the impact of fuel saving measures on catch level, but also for making comparison between fishing methods where the same species was targeted, possibly in the same region (*e.g.* refer to Table 33 –Fish trap boat against Fish trawler in the NW of Australia).
- Two of the quantities in the performance parameters, namely '*catch-revenue*' and '*fuel-energy cost*', were a function of two other quantities, namely '*unit price*' and the '*quantity used*', and consequently when the former quantities were combined it was difficult to track what was going on, since a fluctuation in any one of the four quantities could have been responsible for the observed change; further thought needs to be directed towards this matter as the parameter in question was possibly one of the more informative of the current set presented in Table 1 and elsewhere in these audit reports.

Monitoring fuel-energy consumption on fishing vessels was problematic and expensive for the following reasons:

- fuel-flow meters from Floscan were expensive, costing about AUD$5000 per unit (imported from USA);
- each combustion engine required a specific Floscan unit, and most of the fishing vessels had multiple combustion engines (single or dual main-engine plus one or more auxiliaries);
- fuel-flow meters had to be installed by a qualified fitter;
- alterations made to fuel systems had to be reported to the State survey authority and the fishing company's insurer;
- keeping track of where energy was used onboard the vessel proved to be difficult, especially when the engine being monitored had multiple power-take-offs or functions, and these additional loads were engaged manually and intermittently recorded.

Higher level energy audits (*i.e.* Level 2 and above) necessitate monitoring how much energy is consumed by the fishing vessel for different operational phases, and potentially tracking where this energy is used onboard during each operational phase. Due to the difficulties and expense associated with tracking energy consumption on fishing vessels (explained above), completing higher level audits on this project proved to be a real challenge, and from a project management perspective, both time-consuming and demanding on resources. Future investigators are therefore advised to plan and budget accordingly.

Presenting energy audit data in a monthly format was difficult to adhere to because fishing trips often extended from one month into the next, making it difficult to apportion the fuel, catch *etc.* between each month. The solution, if the intention is to analyse trends, is to assemble the data on a scale independent of time, maybe on a trip by trip basis over the two-year audit period. However, even this approach struggles to deal with multiple fish unloads/trips against a single refuel, or worse still, a partial refuel, since then it is very difficult to ascertain how much fuel was actually used on the previous trip. For the above reasons, it is highly recommended that fishing companies install fuel consumption meters on at least the main engine (refer to Fig. 45), and ensure accurate records (fuel consumption/hr for each fishing phase, total fuel consumption per trip) are entered by the skipper/engineer in the vessel's logbook for future reference.

BENEFITS AND ADOPTION

The project provided fishing company's intent on saving fuel and/or reducing energy costs with a formalised energy audit process that is both consistent with Australian Standard AUS/NZ 3598:2000 and also tailored to suit fishing vessels. Provision of this process, together with the results of seven subsequent applications (presented as energy audit reports), should according to attendees at an FRDC workshop on Energy Efficiency in Fishing in 2005, instigate more audit activity in the near future. If this is the case, and fishing companies start to implement fuel-saving measures presented in audit reports, then ultimately an important part of Australia's primary industry sector will become more fuel efficient, more competitive, and carry a smaller carbon footprint. Positive signs to date include: the completion of an additional energy audit on a Danish Seiner in Lakes Entrance by one of the project CI's; and the introduction of several costly fuel-saving measures (>$100K) on a MG Kailis fish-trawler as a result of an audit in 2008/9.

The project via the audit reports on seven fishing vessels also provided a glimpse of where the Australian fishing industry currently stands in a number of important areas related to energy use, including:

- How energy intensive and energy efficient certain active fishing methods are relative to passive methods, and how vulnerable the businesses using these methods are to a rise in the price of diesel fuel.
- How much scope there is for improving the energy efficiency of some of Australia's more common commercial fishing methods, and importantly where future efforts need to be directed.

Once disseminated, this information will prove insightful/useful to a full-spectrum of people, ranging from proactive fishing vessel owners/crew preparing contingencies for when diesel prices escalate and erode profits, through to government/industry advisers and decision-makers committed to securing a future for an industry that is very reliant on diesel fuel to harvest Australia's valuable fish resources.

Project activity was also instrumental in drawing relevant technical expertise together in a number of related projects (*e.g.* FRDC projects 2005/239, 2007/200, and 2008/206), publications (Thomas *et al* 2010 - *Energy Audit of Fishing Vessels*), and activities (E-Fishing conference 2010, NZ Seafood week in 2007), and pleasingly this seems to be continuing and gathering more momentum. For example, in 2010, five well-qualified engineers at the Australian Maritime College will submit a very relevant (according to audit findings) funding application to the FRDC titled ‘Optimising a novel prawn trawl design for maximum energy efficiency’.

FURTHER DEVELOPMENT

The project was successful in developing an energy audit process for fishing vessels, which was then applied to seven vessels at a Level 1 audit level, and subsequently taken a step further with two of these vessels to include features of a Level 2 audit.

Logical steps forward to further develop and bolster this R&D include:

1. Completion of a greater number of Level 1 audits on fishing vessels to allow a full investigation of where the Australian fishing industry currently stands in a number of important areas related to energy use. The goal should be to increase the coverage across all fisheries where a significant amount of energy is used by fishing vessels, and additionally, within these fisheries obtain a full picture of how much variation exists across the fleet.

2. Preparation of an energy audit template/work specification for future auditors of fishing vessels to follow. Logically this task should be tackled after more audits have been completed, and will require input from appropriately qualified/experienced technical/audit personnel. The final product should preferably carry an endorsement by the peak body for the Australian Fishing Industry and other groups like Energy Australia. Note that some sound progress was made in this area with the input of Jon Osborne from Sustainability Victoria (refer to Appendix 3c).

3. Creation of a site for presenting the results of energy saving initiatives trialed on Australian and overseas fishing vessels. The results and accompanying descriptor would need to be kept brief to facilitate dissemination of the information to industry. For example, ‘new otterboards (Thyboron type 11) provide a MG Kailis fish trawler with a 10% fuel saving against equivalent sized Thyboron type 7 GG boards - Contact J.Public on…for more information’.

4. Extension of the energy audit process for fishing vessels to a higher level, and show how the energy audit process is integrated in to an energy management plan. Understandably, given the resources required to undertake such a task, this project

is best tackled by a medium-large sized fishing company, possibly with multiple fishing vessels.

5. Extension of the energy audit process to onshore facilities and down through the food supply chain. Once again, best undertaken by a sizeable fishing company. Sealord in New Zealand received an award from their Energy Conservation Authority for shore-based achievement several years ago.

6. Integration of eco-efficiency principles and outputs into the energy audit process and energy management plan.

7. Assemblage of a team of appropriately qualified technical people that can commit/engage on energy audit activities in a timely fashion. These people need to be contactable and listed in an energy audit work specification (refer point 2 above).

8. Further develop the network of people committed to energy efficient fishing, and seek greater collaboration with overseas personnel where significant advancements have already been made.

9. The project delivered several informative energy audit reports containing; energy usage profiles, measures against energy audit parameters, and potential energy saving options with a payback period attached to the most promising prospects. This was not strictly in accordance with the Aus/NZ Energy Audit Standard, since a payback period for all fuel-saving options should have been given. However, for most of the options listed the necessary cost and fuel-saving information was not readily available, and to undertake the calculations from scratch would have been to taxing on projects resources. With more audit activity and input from technical personnel, this situation can be rectified.

PLANNED OUTCOMES

The main outcome for this project was to improve the fuel-efficiency of Australian fishing vessels, and in doing so reduce the industries carbon footprint and level of greenhouse gas emissions, as well as secure important economical benefits. The provision of a formalised energy audit process that is both consistent with Australian Standard

AUS/NZ 3598:2000 and also tailored to suit fishing vessels, together with the results of seven subsequent applications (presented as energy audit reports), should assist greatly in that regard.

There was some deviation away from the intended output content, namely the omission of:

- energy management matrixes in the audit reports,
- measures of Energy Return On Inputs (EROI) in audit reports, and
- pay-back periods for the less attractive energy saving measures listed in audit reports.

Provision of more pay-back period information would certainly help the industry with the uptake of fuel-saving measures (albeit for the less-attractive options), and preparing energy management matrixes for fishing companies would certainly be useful in terms of establishing how the company and workforce are orientated towards saving fuel-energy. The EROI information is also useful for establishing how the fishing industry compares against other food producing industries, including the aquaculture industry. The decision to omit these outputs from the project was therefore based primarily on achieving the project objectives in a timely fashion and on budget, not because of redundancy. As for gauging the impact of these omissions on the main planned outcome, yes an impact may indeed transpire, although in light of what was achieved in this project (two of the objectives were met, and the best part of the third objective was met) and what can be covered in the near future in projects of a similar nature, a reasonable assessment would class the impact as minor.

CONCLUSIONS

All three project objectives of FRDC project 2006/229 were met.

- A formalised energy audit process that was both consistent with Australian Standard AUS/NZ 3598:2000 and also tailored to suit fishing vessels was produced (objective 1).
- A total of seven energy audits (5 x Level 1 and 2 x Level 2) were completed on Australian fishing vessels (objective 2).
- An overarching final report containing audit reports, a summary of audit findings, plus recommendations for future work *etc.* was produced (objective 3).

Disappointingly, the project was not completed in a timely fashion; primarily because of unforeseen circumstances impinging on the PI's ability to commit sufficient time when it was needed. This project served as a reminder that acquiring access to commercial fishing vessels and crew for moderate amounts of time, whether it be to inspect the gear/equipment onboard, install fuel meters, or interview crewmembers, necessitates having a very flexible and persistent approach; especially when unload schedules and departure times change at a moment's notice, and key crew-members quickly disperse to other locations after arriving in port.

A number of more general conclusions were drawn from the project results/outputs and activity, and these are presented below.

The audit results confirmed that passive fishing gears (in this case trap/pot fishing) are less energy intensive than active forms of fishing (in this case trawling), and furthermore that passive methods are typically less susceptible to rising diesel prices. Fishing businesses reliant on active fishing methods therefore need to be pro-active in the uptake of more energy-efficient technology/practices before the next hike in fuel prices. A logical step in this process is to undertake energy audits, yet many fishing business were found to be in a poor position to assemble the required historical data.

Fishing companies attempting to become more energy-efficient harvesters should not overlook the link between energy-efficient fishing and fishing efficiency, since an improvement in the latter typically translate into improvement in the former.

As a general observation, the Australian fishing industry seems to be bound up in fishery regulations that prevent fishing gear/practices from evolving into more effective and efficient forms. Clearly more attention must be focussed on this matter. There are some shining examples of where a move towards co-management is clearly helping in that regard *e.g.* Exmouth Gulf Prawn Managed Fishery (Rogers 2009).

In light of the looming prospect of future hikes in the price of diesel fuel, it is timely for more governmental/ industry support to progress energy-efficient fishing (e-fishing) to the next level. One of the areas to be found lacking in this energy-audit project was the required technical support in specialist areas. Building up this pool of technical expertise requires an investment in appropriately qualified people, which arguably is best done by supporting the e-fishing projects these people assemble.

Suppliers of energy-efficient technology, whether it be in the form of hardware, software, or new strategies, need to be more innovative when it comes to getting this technology on Australian fishing vessels. Reliable assessments showing the true benefits of such technology, together with performance based contracts between supplier and purchaser to share the financial risk, represent steps in the right direction.

In closing it is interesting to note that the shift from sail driven vessels to propeller driven vessels in the early part of last century was responsible for a significant rise in the amount of fuel energy consumed per kilogram of fish landed. Towards the middle of the last century the energy consumption rate increased even further, following the introduction of more active forms of fishing such as trawling and purse seining. Nowadays most commercial fishing vessels are entirely reliant on some form of fuel energy (usually diesel) to harvest fish. Even though it is unlikely that we will witness a large number of commercial fishing vessel revert back entirely to sails, for some (those with prolonged transit periods and high fuel costs/catch-revenue) it is now an attractive and realistic proposition.

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APPENDIX 1. INTELECTUAL PROPERTY

There is no intellectual property arising from this project.

APPENDIX 2. STAFF

Dr John Wakeford – Flume tank manager - Australian Maritime College/University of Tas. (until Feb.2010), MGK Kailis Group – Fishing manager (Feb. 2000 onwards).

Dr David Sterling - Director: Sterling Trawl Gear Services

Jon Osborne – Sustainability Victoria.

APPENDIX 3a.

Workshop flyer on energy-efficient fishing

ENERGY-EFFICIENT FISHING: ALTERNATIVE TECHNOLOGIES, FUELS & DESIGN

R&D Workshop

South East Fishery
Industry Development Subprogram

You are invited to participate in a workshop to scope R&D priorities and projects for optimising energy use in commercial fishing through alternative energy technologies and fuels, and energy-efficient design.

Fuel is a vital, but costly, input to seafood production, accounting for up to 30% of the operating costs of a fishing vessel in Australia. An estimated 270 million litres of diesel fuel is currently consumed in Australian fisheries each year, as well as a substantial amount of petrol.

Faced with rising fuel prices, a domestic oil deficit predicted to emerge past 2015, and a global need to reduce greenhouse gas emissions, the fishing industry is seeking to improve the energy efficiency of its operations and to find viable alternative energy sources.

Australia is fortunate in having access to potentially large sources of alternative fuels and new sources of conventional fuels. Australia has large reserves of natural gas and naturally occurring liquefied petroleum gas (LPG). Significant resources for the production of biofuels also exist, as does the potential to produce hydrogen from a variety of sources. Moreover, the sun, wind, waves and tidal currents all offer potential sources of renewable energy.

Whilst the development and trial of alternative energy technologies is well advanced in the road transport sector, the maritime sector has received less attention, particularly in Australia.

This workshop aims to bring together alternative energy providers, fishing vessel and gear designers, fishing operators, industry representatives, researchers and funding providers to discuss the potential for alternative energy technologies and energy-efficient design for commercial fishing operations in Australia, and to develop an R&D agenda for advancing alternative energy use and energy efficiency in Australia's fishing fleet.

FOR MORE INFORMATION:

Ian Knuckey on ph. 0408 581 599
or email fishwell@datafast.net.au

28 - 29th November 2005
Mercure Hotel - 13 Spring St Melbourne

Australian Government
Fisheries Research and Development Corporation

WORKSHOP OBJECTIVES

- To explore opportunities for and limitations to improved energy use in commercial fishing operations through the use of alternative energy technologies, alternative fuels and energy-efficient design.
- To scope R&D priorities and projects for optimising energy use in commercial fishing operations.
- To identify funding opportunities (public and private) for R&D projects.
- To identify parties interested in collaborating in R&D projects.

WORKSHOP THEMES

- **Alternative energy technologies**
  The workshop will consider the range of alternative energy technologies available and applications in Australia and overseas, and discuss their feasibility for adoption by the fishing industry.
- **Energy-efficient vessel & gear design**
  The workshop will explore the potential for improving energy efficiency through innovation in vessel & fishing gear design.
- **Energy budgets & conservation**
  Identification of energy use on a fishing vessel and what readily applied practices can help conserve fuel.
- **R&D for optimising energy use**
  The workshop will identify R&D priorities and projects for optimising energy use in fishing operations and potential funding opportunities.

The workshop is an initiative of the FRDC South East Fishery Industry Development Subprogram. Given the relevance of fuel efficiency to most fisheries, people from a wide range of fishing sectors have been invited to participate.

<u>APPENDIX 3b.</u>

Standard specification of an energy audit for a business involving buildings

Prepared by David Sterling

Note that the following information was found on the Australian Green House website and is consistent with the Energy Audit Standard AS/NZS 3598:2000. Audits have been defined at 3 levels with different levels of achievement being sought for the energy usage problem:

Level 1- Walk-through - produce a broad internal bench-mark, make comparison with external bench marks, identify "quick wins", and recommend the next step.

Level 2 - Standard - assign energy consumption to components of the enterprise, make recommendations regarding structural changes to enterprise with estimates of costs and payback periods.

Level 3 - Detailed - to produce long term strategies for gains in energy efficiency, improve the confidence associated with setting priorities.

Level One (Walk-Through) Energy Audit

The minimum requirements for a walk-through audit are:

a) Ascertain the following information:
   i) Building construction type and fabric.
   ii) Type and configuration of services.
   iii) Appropriate unit of production and its quantity (*e.g.* net leasable area for office space, number of students for a school, number of beds for a hospital).
b) Determine total consumption of all fuels for the twenty four month period prior to the audit (ascertained from billing data provided by the energy user). If this data is unavailable the auditor shall estimate the consumption(s) based on the installed loads, clearly stating the relevant assumptions in the report.
c) Evaluate load profile data, if available.
d) Prepare monthly or seasonal energy consumption profiles (*i.e.* kWh/month, MJ/month), of all fuels for the previous two years.
e) Prepare appropriate energy performance indicators (*e.g.* kWh/production unit, $/production unit kWh/m2, MJ/m2, $/m2, kWh/student, MJ/student $/student) and compare with industry norms, if available.

f) Evaluate the tariff against comparable norms to determine the possibility of savings from alternative tariffs and/or tendered supply arrangements.

g) Identify potential for reduction of energy consumption and cost at the site with regard to the above indices, and provide recommendations for further action which may include staff training, capital works, maintenance, fuel substitution options, tariff changes and a higher level energy audit.

Deliverables

A report detailing energy audit findings and recommendations shall be prepared in accordance with this specification and include any findings and recommendations arising from carrying out tasks as described above.

Level Two (Standard) Energy Audit

The minimum requirements for a Level Two energy audit are:

a) Ascertain the following information.
   i) Building construction type and fabric.
   ii) Type and configuration of services.
   iii) Appropriate unit of production and its quantity (*e.g*. net leasable area for office space, number of students for a school, number of beds for a hospital).

b) Determine total consumption of all fuels for the twenty-four month period prior to the audit (ascertained from billing data provided by the energy user). If these data are unavailable the auditor shall estimate the consumption(s) based on the installed loads, clearly stating the relevant assumptions in the report.

c) Evaluate load profile data, if available.

d) Prepare monthly or seasonal energy consumption profiles (*i.e*. kWh/month, MJ/month), of all fuels for the previous two years.

e) Prepare appropriate energy performance indicators (*e.g*. kWh/production unit, \$/production unit kWh/m^2, MJ/m^2, \$/m^2, kWh/student, MJ/student \$/student) and compare with industry norms, if available.

f) Evaluate the tariff against comparable norms to determine the possibility of savings from alternative tariffs and/or tendered supply arrangements.

g) Identify potential for reduction of energy consumption and cost at the site with regard to the above indices, and provide recommendations for further action which may include staff training, capital works, maintenance, fuel substitution options, tariff changes, and a higher level energy audit.

h) Meet with the auditors contact on site and carry out an inspection of the audit site observing energy usage patterns, plant and equipment operation and maintenance, and building fabric.
i) Prepare energy consumption targets and indicators (*e.g*. kWh/m^2, MJ/m^2, kWh/student, MJ/student) of energy end use throughout the audit site (*e.g.* lighting, HVAC, domestic hot water) which compare actual, predicted, and post audit target levels. Where disaggregated energy consumption data are not available to determine these indicators, estimate the indicators based on observed loads, clearly stating relevant assumptions in the report.
j) Provide an itemised list of recommendations to reduce energy consumption and cost. This shall include both capital works and general management options.
k) Identification of measures or potential measures for which additional investigation (such as a Detailed Energy Audit) is required, with an explanation as to why such investigation is required, what the benefits will be and what the expected costs are.
l) Recommend changes to the energy management program.
m) Detail a cost effective program to implement the energy audit recommendations, including a prioritised list of capital works and general management activities.

Level of Detail Required

Capital works recommendations shall include:

a) A clear description of the work program involved in implementing each recommendation
b) Predicted annual energy and cost savings for each recommendation
c) Predicted cost of implementing each recommendation
d) Cost-benefit analysis

General management options, which would facilitate more efficient energy use should include:

a) Provision of energy sub-meters to facilitate ongoing sub-monitoring as both a management tool and to verify savings
b) Changes to maintenance and operating practices
c) Modifications and/or additions to existing plant
d) Alternative fuels

e) Alternative tariff structures
f) Alternative staffing arrangements
g) Staff training and involvement in energy management practices

Place the recommendations in priority order using simple payback, benefit: cost ratio, or other appropriate criterion. Recommendations must be categorised as follows:

- Those easily implemented at little or no cost,
- those requiring capital expenditure with a payback period of less than 3 years, and
- those requiring capital expenditure with a payback period of 3 years or more.

Deliverables

The following deliverables shall be provided:

a) A report detailing survey audit findings and recommendations prepared in accordance with this specification and including any findings and recommendations arising from carrying out tasks as described above.
b) A briefing to the key personnel within the site on the results.

Level Three (Detailed) Energy Audit

This level of audit requires a detailed site inspection accompanied by energy metering and logging. Required items are as follows:

a) Ascertain the following information:
   i) Building construction type and fabric
   ii) Type and configuration of services
   iii) Appropriate unit of production and its quantity (*e.g.* net leasable area for office space, number of students for a school, number of beds for a hospital)
b) Determine total consumption of all fuels for the twenty-four month period prior to the audit (ascertained from billing data provided by the energy user). If this data are unavailable the auditor shall estimate the consumption(s) based on the installed loads, clearly stating the relevant assumptions in the report.
c) Evaluate load profile data, if available.
d) Prepare monthly or seasonal energy consumption profiles (*i.e.* kWh/month, MJ/month), of all fuels for the previous two years.

e) Prepare appropriate energy performance indicators (*e.g.* kWh/production unit, $/production unit kWh/m2, MJ/m2, $/m2, kWh/student, MJ/student $/student) and compare with industry norms, if available.

f) Evaluate the tariff against comparable norms to determine the possibility of savings from alternative tariffs and/or tendered supply arrangements.

g) Identify potential for reduction of energy consumption and cost at the site with regard to the above indices, and provide recommendations for further action which may include staff training, capital works, maintenance, fuel-substitution options, tariff changes and a higher level energy audit.

h) Meet with the auditors contact on site and carry out an inspection of the audit site observing energy usage patterns, plant and equipment operation and maintenance, and building fabric.

i) Prepare energy consumption targets and indicators (*e.g*. kWh/m2, MJ/m2, kWh/student, MJ/student) of energy end use throughout the audit site (*e.g.* lighting, HVAC, domestic hot water) which compare actual, predicted, and post audit target levels. Where disaggregated energy consumption data is not available to determine these indicators, estimate the indicators based on observed loads, clearly stating relevant assumptions in the report.

j) Provide an itemised list of recommendations to reduce energy consumption and cost. This shall include both capital works and general management options.

k) Identification of measures or potential measures for which additional investigation (such as a detailed energy audit) is required, with an explanation as to why such investigation is required, what the benefits will be and what the expected costs are.

l) Recommend changes to the energy management program.

m) Detail a cost effective program to implement the energy audit recommendations, including a prioritised list of capital works and general management activities.

n) Provide a detailed analysis of the site or process to determine where, when and how energy is used. This should include, but not be limited to, evaluation of the audit site's building operation and services, plant and equipment operation, control systems, maintenance schedules, hours of operation and analysis of staff working hours, including cleaners. Identify any anomalies between predicted energy use and actual energy use.

o) Obtain copies of drawings and other documentation required to fulfil the requirements of this specification. Such documentation shall be returned to the audit site upon completion of the audit.

p) Prepare hourly consumption profiles of all fuels used in association with the relevant process(es) over a period of seven days.

q) Provide all additional meters, instruments and equipment necessary to meet the intent of the audit and be responsible for their accuracy.

Level of detail required

Capital works recommendations shall include:

a) A clear description of the work program involved in implementing each recommendation

b) Predicted annual energy and cost savings for each recommendation

c) Predicted cost of implementing each recommendation

d) Cost-benefit analysis

General management options, which would facilitate more efficient energy use should include:

a) Provision of energy sub-meters to facilitate ongoing sub-monitoring as both a management tool and to verify savings.

b) Changes to maintenance and operating practices.

c) Modifications and/or additions to existing plant.

d) Alternative fuels.

e) Alternative tariff structures.

f) Alternative staffing arrangements.

g) Staff training and involvement in energy management practices.

Recommendations shall be placed in priority order using simple payback, benefit: cost ratio, or other appropriate criterion. Recommendations must be categorised as follows:

- Those easily implemented at little or no cost,
- those requiring capital expenditure with a payback period of less than 3 years, and
- those requiring capital expenditure with a payback period of 3 years or more.

Deliverables

The following deliverables shall be provided:

a) A report detailing survey audit findings and recommendations prepared in accordance with this specification and including any findings and recommendations arising from carrying out tasks as described above.
b) Recommendations shall be defined in sufficient detail to meet normal expectation of preliminary design specification.
c) A presentation to the key personnel within the site on the results.

APPENDIX 3c.

Specification for energy services – fishing trawlers

Prepared by John Osborne, Sustainability Victoria

1.0 Introduction

The Australian Maritime College (AMC) is conducting a program of energy reviews of fishing trawlers in the Australian fishing fleet to identify potential energy savings and assist trawler owners and operators to implement energy efficiency measures. The project is being funded by a grant from the Federal Australian Government.

2.0 Definitions

The following terms are used in this Specification and have the following meanings.

Trawler Manager	The person responsible for all trawler operations.
Energy Manager	The designated contact person from the review trawler. This person may have no predefined energy management responsibilities on the trawler but will be responsible for showing the energy auditor over the vessel and collecting on-board data required by the energy auditor.
Case manager	The person appointed by the AMC to liaise with the consultant and the trawler manager.

3.0 General requirements - Energy Audit Level 1 (Opportunity Review)

Contractors must:

3.1 Be willing to undertake energy review work in accordance with the contract conditions and as described in this Specification. The Opportunity reviews required are equivalent to AS/NZS 3598:2000 Level 1. This review is expected to give an overview that provides rough orders of savings and where possible costs. Accuracy of figures would generally be within +/- 40%.

3.2 Nominate an individual(s) who shall conduct all reviews undertaken. All such work shall be performed by or under the direct supervision of the nominated individual(s). Nominated individuals shall have demonstrated qualifications, experience and expertise to undertake such work.

3.3 Any proposed variation to Scope of Work that is deemed to be necessary must be agreed in writing by both parties prior to the commencement of work.

3.4 The final report is the property of the AMC.

Energy Reviews undertaken shall:

3.5 Assess all fuel sources employed on the trawlers.

3.6 Address any major specific issues raised by the Trawler Manager or Energy Manager, and which may have led to the energy review of the particular trawler.

3.7 Assess the potential application of appropriate renewable fuel sources, including, but not limited to:

- solar
- natural day lighting, by way of photo sensors or light tubes, *etc.*

4.0 Principal tasks

A walk-through opportunity review shall be conducted on each nominated trawler. The review requires a brief inspection of the trawler. The tasks comprising the energy review shall be as follows:

4.1.1 Liaise, by telephone, with the trawler energy manager to ascertain the following information:

a) The trawler's main physical parameters.

b) The trawler's operating hours, travel hours, distance travelled.

c) Activities while fishing and while travelling to and from the fishing area.

d) Type, configuration and use of services (*e.g.* refrigeration, heating and cooling, packaged air conditioning, lighting, central hot water, pumping plant, *etc.*) This information is also to be confirmed at the site visit.

4.1.2 Determine total consumption of all fuels for the twelve-month period prior to the review. These consumptions shall be ascertained from billing data provided by the trawler energy manager and shall include fuels used when the trawler is in port. If this data is unavailable the reviewer shall estimate the consumption(s) based on the installed loads, clearly stating the relevant assumptions in the report.

4.1.3 Prepare energy consumption profiles (*i.e.* L/month, kWh/month, MJ/month,) of all fuels for representative periods of the previous year.

4.1.4 Prepare appropriate energy consumption performance indices (*e.g.* kWh/hr operation, L/tonne of fish caught, *etc.*).

4.1.5 Conduct a cost analysis of all forms of energy being used on the vessel under review.

4.1.6 Identify improvement projects and clearly identify CO_{2-e} and dollar savings.

4.1.7 Advise potential for reduction of energy consumption on the vessel with regard to the above indices, and provide recommendations for further action which may include substitution of fuels, changes to fuel contracts and/or more detailed energy auditing.

4.1.8 Present the energy review findings and recommendations in a formal report as detailed below in Section 5.0

4.1.9 Meet with the trawler energy manager and conduct an inspection of the trawler, observing plant and equipment operation and maintenance, energy usage patterns and fit-out.

4.1.10 Provide a prioritised list of recommendations to reduce energy consumption and cost. This shall include both capital works and general management options.

a) Capital works recommendations shall include:
   - i) a clear description of the work program involved in implementing each recommendation;
   - ii) predicted annual energy, greenhouse gas and cost savings for each recommendation;

b) General management options that would facilitate more efficient use of energy, including:
   - i) maintenance and operating practices;
   - ii) modifications and/or additions to existing plant;
   - iii) alternative fuels;
   - iv) alternative fuel contract structures;
   - v) staff training and involvement in energy management practices.

4.1.11 Categorise the recommendations using criteria as follows:

a) those easily implemented at little or no cost;

b) those requiring moderate capital expenditure;

c) those requiring significant capital expenditure.

In each case include the simple pay-back period for the recommendation

4.1.12 Recommend an ongoing energy management program to be implemented by the trawler manager.

4.1.13 Prepare consumption profiles of electricity used over representative seven-day periods.

Meter data, if available, will be provided by the trawler energy manager, at no cost to the contractor.

Assess the power factor of the trawler's electrical system, preferably from meter data and provide a power factor profile for a representative period. (N.B. This may not be a practical task but the data will give a good indication of the efficiency of the electrical system if it can be determined)

4.1.14 Assess the trawler based on a benchmark of data from all trawlers reviewed in the project and indicate the future expected benchmark rating and total energy and cost savings if all the study findings are implemented.

5.0 Report format

The final report shall include the following. The extent of information reported will reflect the level and scope of the review undertaken.

5.1 Table of contents.

5.2 Executive Summary highlighting: major findings, predicted energy and CO_{2-e} savings, the future benchmark rating, and recommended implementation plan for both capital works and general management options.

5.3 Overview of the review trawler and its mechanical and electrical services.

5.4 Observations on operation of reviewed trawlers' and their plant.

5.5 Data on existing energy consumption, including seasonal profiles.

5.6 Analysis of energy usage data including energy benchmarking indices.

5.7 Recommendations, including a prioritised implementation plan.

5.8 Relevant energy and cost saving and CO_2 calculations.

5.9 Appendices containing Calculations, Summary Table and Load Profiles

Three bound copies and one electronic copy of the final report shall be supplied to the AMC case manager. One copy must be suitable for photocopying.

6.0 General requirements – Implementation

6.1 Contractors must:

- Be willing to undertake energy implementation work in accordance with the contract conditions and as described in this Specification.

- Nominate an individual(s) who shall conduct all reviews undertaken. All such work shall be performed by or under the direct supervision of the nominated individual(s). Nominated individuals shall have demonstrated qualifications, experience and expertise to undertake such work.

6.2 Any variation to the Scope of Work that is deemed to be necessary must be agreed in writing by both parties prior to the commencement of work.

6.3 The final report is the property of AMC.

6.4 The implementation scope covers:

- Assisting /overseeing implementation work
- Estimating and scoping of works
- Calculation of simple payback, energy savings and $CO_{2\text{-}e}$ savings
- Review completed works and verify $CO_{2\text{-}s}$ and the dollar savings.
- Provide a report that can be used as the basis for a case study. (It is intended that the consultant will write the case study at a future time.)

7.0 Project brief

A Project Brief (refer to *Document D* at the end of this Specification) shall be provided, which shall include the following information:

a) Name of the review trawler

b) Location of the review trawler

c) Name and telephone number of the trawler’s Energy Manager.

d) Date of Project Brief issue

e) Date when completed review report is required.

f) Date of agreement of Project Brief between AMC and Consultant. This is a Request for Proposal signed by the contract parties.

g) Any specific issue(s) raised by the Trawler Manager, which may have prompted the energy review, and which are required to be addressed by the report in addition to other findings. For implementation work an attachment is required outlining the proposed works.

h) Maximum payment sum for the review/implementation, in accordance with the schedule of rates tendered and subsequently negotiated during the selection process.

i) Trawler access restrictions, if any.

j) Variations to the scope of work defined in this specification

8.0 Information to be provided by the trawler energy manager

The following information, if available, shall be provided by the trawler Energy Manager at the request of the contractor.

8.1 Trawler layout plan indicating the useable floor space of the vessel and the location of all electrical and mechanical plant;

8.2 Activity levels relating to energy use for each plant item; (*i.e.* frequency and hours of operation);

8.3 A copy of all energy accounts for the last year;

8.4 Meter and sub-meter readings if meters are fitted and their locations within the vessel;

8.5 Current maintenance schedules for the main plant and equipment;

8.6 Existing energy management program;

8.7 Lighting layout plan;

Document A. - ONLY TO BE COMPLETED BY THE ENERGY AUDIT CONTRACTOR AT THE END OF THE FULL AUDIT

Summary of Annual Energy Use **Year ....**

Name of Auditor:	....	Name of Audited Trawler:	....
Nominated Individual:	....	Location of Audited Trawler:	....
Start Date of Audit:	....	Name of Trawler E/ Manager:	....
Phone No:	....	Phone No:	....

Energy Form	Units	Annual Consumption	Conversion factor (Unit to GJ)	Energy Equivalent Total		Annual Cost Total	
				GJ	%	$	%
Natural Gas	GJ		x 1				
Electricity	kWh		x 0.0036				
Petrol	litres		x 0.0342				
Automotive	litres		x 0.0384				
Diesel Oil	tonnes		x 45.7				
Industrial	litres		x 0.0386				
Diesel Oil	tonnes		x 45.5				
LPG	litres		x 0.0266				
	tonnes		x 50.3				
CNG	*		*				
Heating Oil	litres		x 0.0376				
Fuel Oil	tonnes		x 42.9				
(high sulphur)							
Fuel Oil	tonnes		x 44.5				
(low sulphur)							
Coal	tonnes		x 19.7				
Coke	tonnes		x 28.5				
Other Fuels							
(Please Specify)							
Total					100		100

* Check supplier for units supplied and conversion factor.

Document B. - **<u>ONLY TO BE COMPLETED BY THE ENERGY AUDIT CONTRACTOR AT THE END OF THE FULL AUDIT</u>**

Performance Indices

Name of Auditor:	....
Nominated Individual:	....
Start Date of Audit:	....
Phone No:	....

Name of Audited Trawler:	....
Location of Audited Trawler:	....
Name of Trawler E/ Manager:	....
Phone No:	....

Application of Energy	Energy Consumption (GJ)		Area (MJ/m^2)		No. of Building(s) Occupants (GJ/Person.)		Other Activity (*e.g.* vehicles, product *etc.*) (GJ/____)	
	Current	Target	Current	Target	Current	Target	Current	Target
Lighting								
Heating								
Ventilation								
Cooling								
Others (specify)								

Document C. - <u>**ONLY TO BE COMPLETED BY THE ENERGY AUDIT CONTRACTOR AT THE END OF THE FULL AUDIT**</u>

Energy and Cost Saving Opportunities Identified

Name of Auditor:	....
Nominated Individual:	....
Date of Audit Commencement:	....
Phone No:	....

Name of Audited Trawler:	....
Location of Audited trawler:	....
Name of Trawler Energy Manager:	....
Phone No:	....

(a) Recommendations	Report Ref.	Major Fuel Type Involved	(b) Estimated Annual Savings $	GJ	(c) Estimated Cost of Implementation $	(d) Simple Payback Period [(c)/(b)]
		Total				

Notes:

(a) All recommendations to be listed in order of priority of implementation. (Where alternative recommendations are given in the report, the energy auditor's preferred recommendation need only be stated here).

(b) (c) (d) All cost implications arising from necessary maintenance or operating changes, to be allowed for within (b) and (c) in calculating (d).

Document D. Project brief

Fishing Trawlers **Project Brief**

An energy review is required at the following trawler. Please sign and date the form as acceptance of the Brief.

1. Name of review trawler: ....
2. Address of review trawler: ....
3. Name of trawler Energy Manager: ....
4. Trawler E/manager phone number: ....
5. Energy services required: ....
6. Occupancy of the review trawler: ....
7. Date of Specific Project Brief issue: ....
8. Date proposal is required: ....
9. Date when completed energy services report is required: ....

9. Reason for the energy service: ....
10. Major specific issues raised by the trawler's Energy Manager: ....
11. Maximum payment sum for the services to the contractor: ....
12. Trawler access restrictions: ....
13. Variations to Specification: ....
14. Variations to contract conditions: ....

AMC		CONSULTANT	
Date		Date	

AMC Case Manager - ....

T ....

E ....

Document E. Example consultant facilitator matrix

AMC Consultancy	Location	Contact	Energy Smart Business	Location	Contact

Project	Output required	Input Sourced by	Due Date	Budget Hours
Replacement of existing water heating plant	Provision of written quotations	Consultant sourced	**30th March, 2007**	3 hours
	Provide/confirm feasibility analysis Report	XXXXX Consultant	**30th April, 2007**	2 hours
	Provide written information for Case Study Development	AMC Consultant	**31st July, 2007**	2 hours
Insulation	Cost Benefit Analysis Report Project Scoping	Financial information from XXXXXX	30th March, 2007	5 hours
	Implementation Progress Report(s)	AMC Consultant sourced	30th June, 2007	2 hours
	Project Completion /Verification Report	AMC Consultant sourced	30th September, 2007	2 hours
	Provide written information for Case Study Development	AMC Consultant sourced	31st October, 2007	2 hours
Lighting in activity areas	Cost benefit Analysis – Report (Project Scoping)	AMC Consultant sourced	31st March, 2007	4 hours
	Implementation Progress Report(s)	AMC Consultant sourced	30th May, 2001	2 hours
	Project Completion/Verification Report	AMC Consultant sourced	31st July, 2001	2 hours
	Provide written information for Case Study Development	AMC Consultant sourced	30th August, 2001	2 hours
Fish Storage Improvement	Cost benefit Analysis – Report (Project Scoping)	AMC Consultant sourced	31st March, 2001	4 hours
	Implementation Progress Report(s)	AMC Consultant sourced	30th April, 2001	2 hours
	Project Completion/Verification Report	AMC Consultant sourced	30th June, 2001	2 hours
	Provide written information for Case Study Development	AMC Consultant sourced	31st July, 2001	2 hours
Total Number Consultancy Hours			**38 hours**	
Consultancy Budget (Rate of $XXXX/hour inc GST)			**$XXXX**	

AMC Case Manager :

Date :

APPENDIX 3d.

Letter of invitation to fishing vessel owner(s) to participate on FRDC Project 2006/229

The Fisheries Research Development Corporation approved funding for a project in 2006 to develop and implement and energy audit process for the Australian and New Zealand fishing industry. The Australian Maritime College was contracted to undertake the project. Co-investigators include several Australian fisheries consultants, representatives from the New Zealand Seafood Industry Council, and several fishing companies. Most of the audit activity is planned for the 2007 summer and autumn periods.

The audit process will follow the Energy Audit Standard for Australia and New Zealand (AS/NZS 3598:2000). However, this standard was initially designed with buildings and land-based production businesses in mind, so it has been adapted by the project investigators to suit fishing vessels.

To facilitate application of this energy audit process, a work specification was subsequently prepared (in conjunction with Sustainability Victoria) that captures the necessary elements contained in the standard. This work specification is currently in draft form. However, the section covering the '*Data required for undertaking an energy audit on a fishing vessel'* is ready for distribution (refer to Section 4.0 in Appendix C of the attachment). The type of information sought from each fishing vessel is broadly similar, and has been separated into two sections to reflect the audit level that it relates to (*i.e*. level 1 or 2). Some relevant background information on energy auditing and the three types (levels) is presented overleaf. Please note that in order to progress to higher level audits it is necessary to complete the lower level 1 audit first. We may also consider undertaking a Level 2 audit on some of the vessels if funds and time permit. This involves a monitoring stage with fuel flow meters, GPS, and other instrumentation as required.

The intention is to undertake a trial run with the modified audit (and new work specification) on a Queensland prawn trawler in January 2007. This will be followed by eight additional energy audits on different Australian and New Zealand fishing vessels to demonstrate that this new audit process is applicable to all fishing vessel types.

The vessel types selected for this energy audit test-run are summarised in the Table below. Selection was based on a number of factors, including the number of vessels of that type in Australian fisheries, and the technical and operational peculiarities of each, in terms of applying an energy audit process and demonstrating its applicability to all fishing-vessel types.

The project team is now preparing to select specific vessels from each category. Your company was recommended for the [**planing-hull longliner]** category. If you are interested in participating, please read on.

Australian Fishing companies electing to participate in the project are exempt from the energy audit fee, as this is covered by the FRDC. New Zealand companies are not exempt however, and will need to buy into the project on a fee-for-service basis (to be negotiated with project participants and SeaFIC NZ).

By electing to participate in the project, each fishing company will receive an energy audit report, which should prove useful in identifying energy saving opportunities associated with the fishing vessel and its operations. Companies agreeing to participate in the project will be expected however to assist the auditors with their task, which in the first instance involves preparing for an audit (see relevant section overleaf), and later, making the vessel available for the necessary technical data to be gathered (refer '*Data required for undertaking an energy audit on a fishing vessel'* for an insight into what is required*)*. The audit findings will also be included in a project report, which will eventually be made available to the rest of the fishing industry.

You may wish to discuss the timing, activity or other details further before committing, in which case please respond with any questions you have to John Wakeford (email: J.Wakeford@amc.edu.au or phone: (03) 63354468).

Yours Sincerely

John Wakeford
(Principal investigator on FRDC project 2006/229).