Empowering Industry: Energy Audit of Prawn Trawler with Auxiliary Sail Power

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Empowering Industry: Energy Audit of Prawn Trawler with Auxiliary Sail Power

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1.0 NON TECHNICAL SUMMARY

2011/229	**Empowering Industry: Energy audit of prawn trawler with auxiliary sail power**

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OBJECTIVES:

1. Energy audit (level 2) on prawn trawler fitted with auxiliary sail system.
2. Collect data on effect of use of sail system on fuel consumption in varying environmental conditions.
3. Analyse energy audit data to determine effect of sail system on fuel consumption.
4. Disseminate information on effect of sail auxiliary power system to owners and operators of fishing vessels.

NON-TECHNICAL SUMMARY:

OUTCOMES ACHIEVED TO DATE

- Identified auxiliary sail power as a viable option for increased energy efficiency and reduce emissions.
- Undertaken energy audit of FV Sea Lion.

Commercial fishing in Australia uses approximately 205 million litres of diesel fuel per year. Active fishing techniques such as trawling consume large quantities of diesel fuel, predominantly for the propulsion power.

Russel Kilfoy is a prawn trawl fisherman based in Cairns, Queensland, targeting Leader, Endeavour, Tiger and Banana prawns. He has taken an active approach to the rising diesel fuel prices by incorporating sails as an auxiliary propulsion system onto his vessel in an attempt to reduce fuel usage.

The FV Sea Lion was found to use 69% of its energy on board for propulsion, this highlighted that the best savings stand to be made by improving the propulsive efficiency.

The effect of the sails was recorded over a five day period on board the FV Sea Lion. It was found that up to 13% fuel savings could be made under certain conditions. If this data is extrapolated out over a normal 24 hour operating period, savings of up to 7.3% could be made on the total fuel usage per day.

This demonstrates the positive impact that using auxiliary sail power can have on reducing fuel usage. However the successful application of sails as an auxiliary power source for fishing vessels will depend on each vessel's hydrodynamic characteristics and operational profile.

KEYWORDS: Prawn trawling, Sails, Energy audit, Fuel Consumption

2.0 ACKNOWLEDGEMENTS

The project was funded by the Fisheries Research and Development Corporation (FRDC project 2011/229).

Russel Kilfoy kindly provided access to his vessel, the FV Sea Lion, for the full scale measurements.

3.0 BACKGROUND

Commercial fishing in many Australian sectors is becoming increasingly marginal due to the rise of fuel costs over the last decade. The prawn trawling industry is being particularly affected by increasing fuel prices due to the energy intensive method of fishing. The biggest expenditure for most prawn vessels is fuel, with the overall cost being 30-50% of all annual expenditure.

The Australian Maritime College, in partnership with interested parties, has conducted several energy audits (Wakeford, 2010; Thomas, 2010) on vessels around Australia. The primary focus of an energy audit is to identify where energy is being used on board and allow the operator to make informed decisions about the most cost effective method of increasing efficiency of their vessel.

Through these energy audits it became clear that using sail power as an auxiliary propulsion system could result in tangible benefits with respect to reducing energy consumption. Subsequently the opportunity arose to conduct an energy audit on a prawn trawler, FV Sea Lion, fitted with an auxiliary sail system to assess its contribution to fuel savings.

4.0 NEED

Commercial fishing in Australian consumes approximately 205 million litres of diesel fuel per annum. The fishing industry needs to radically improve the energy efficiency of its operations primarily due to the rising cost of fuel and its effect on operating margins. The recent rapid increase in cost of diesel has reduced margins to such a low level that it is rapidly becoming uneconomical for operators to continue to trade.

This has significant flow-on effects down the whole production-processing-retail chain. In addition there is a global need to reduce the emissions of oxides of nitrogen (NOx) and carbon dioxide (CO_2) from fossil fuel combustion. The global fisheries industries emit annually more than 130 million tonnes of CO2 into the atmosphere. Trawling is a very energy intensive fishing method, for example Australian prawn trawlers incur fuel costs of approximately 35% of total production costs. The use of alternative auxiliary powering systems, such as sails, has the potential to radically reduce fuel consumption by a combination of providing supplementary propulsive thrust and reducing vessel motions and consequent drag.

Several fishers in Australia have installed sails onto their vessels with the aim of reducing fuel consumption, but no investigations have been conducted to ascertain the effect the auxiliary systems actually have on fuel consumption, performance and costs. The results from an energy audit on such a vessel would provide valuable information to other fishers on the benefits, or otherwise, of fitting such a system to their vessel. The need for this work was highlighted by the results from recent FRDC sponsored energy audits of fishing vessels. The 1st International Symposium on Energy Efficiency in Fishing was held in May 2010 and clearly emphasised the need for continuing RD&E in this area.

5.0 OBJECTIVES

1. Energy audit (level 2) on prawn trawler fitted with auxiliary sail system.

2. Collect data on effect of use of sail system on fuel consumption in varying environmental conditions.

3. Analyse energy audit data to determine effect of sail system on fuel consumption.

4. Disseminate information on effect of sail auxiliary power system to owners and operators of fishing vessels.

6.0 METHODS

6.1 Vessel Details

The FV Sea Lion is a prawn trawler based in Cairns, north eastern Queensland, working as far north as the Gulf of Carpentaria, see Figure 1. She is usually operated for three weeks out of four, with the down time coinciding with the darkest part of the lunar cycle. Occasionally the vessel is used for scallop fishing.

The vessel has been fitted with two furling sails attached to the forestay at the bow, with the port sail being 45 square metres and the starboard sail being 36 square metres. The sails are furled between the bowsprit and the masthead, and sheeted out to a pulley 4m out on the port and starboard trawl booms respectively. They have been used in both trawling and steaming conditions.

Figure 1: FV Sea Lion under sail

Full vessel details are provided in Table 1.

Table 1: FV Sea Lion Principal Particulars

Length	19.95m
Design draft	2.28m
Beam	5.03m
Displacement at design draft	35t
Displacement loaded	50t
C_b	0.31
Fishing gear	4.5 fathom Flyer nets in quad gear configuration attached to 6x3'6" Kilfoy boards. 2 fathom try gear
Construction	Single chine, steel
Vessel type	Displacement, forward wheel house
Base port	Cairns, Queensland
Target species	Leader, Endeavour, Tiger and Banana Prawns
By product species	Finfish
Main engine	CAT 3406 186.4kW – 5300hrs
Primary Generator	Perkins 4 cylinder
Propeller	Mikado 53" 4 Blade
Rudder	2.2x1.1m foil section
Sails	Port side: 36m^2 genoa Starboard side: 45m^2 genoa

6.2 Energy Usage

The method utilised in auditing the FV Sea Lion was based on FRDC project 2006/229. This audit method was designed to be consistent with AUS/NZ 3598:2000 and tailored to suit fishing vessels.

At either end of the fishing trip the vessel will steam to and from the fishing grounds. Once at the fishing grounds the standard daily operational profile consists of a couple of hours transiting from the night anchorage to the fishing grounds, trawling all night and then transiting at dawn to an anchorage. The load profile changes when fishing for scallops or when longer transits are made.

Transit speeds are usually between five and seven knots, with trawling between three and four knots. Sails have been used during both phases.

The prime mover on the FV Sea Lion is a 300hp Caterpillar 3406 diesel engine, driving a single screw fixed pitch propeller. It has a single 50 kW Perkins generator to supply all power on-board, with a 75kW backup alternator and a 50 kW main hydraulic pump running off a power take off on the prime mover.

LPG is used for domestic cooking as well as sometimes cooking the catch to increase sale value. Its consumption was estimated by dividing the annual usage by the total number of days fishing. The energy was determined using an energy density of 13.9kWh/kg.

The cooling pump and compressor are usually running whilst at sea, drawing approximately 10kW of power with the generator running constantly. The hydraulics, powered by a power take off from the main engine of up to 75kW (100hp), would intermittently utilise just 15kW for the trigear and trawl nets, and 10kW for other lifting equipment.

From this equipment and operational data an estimate of the power consumed by the different components was drawn up, see Figure 2.

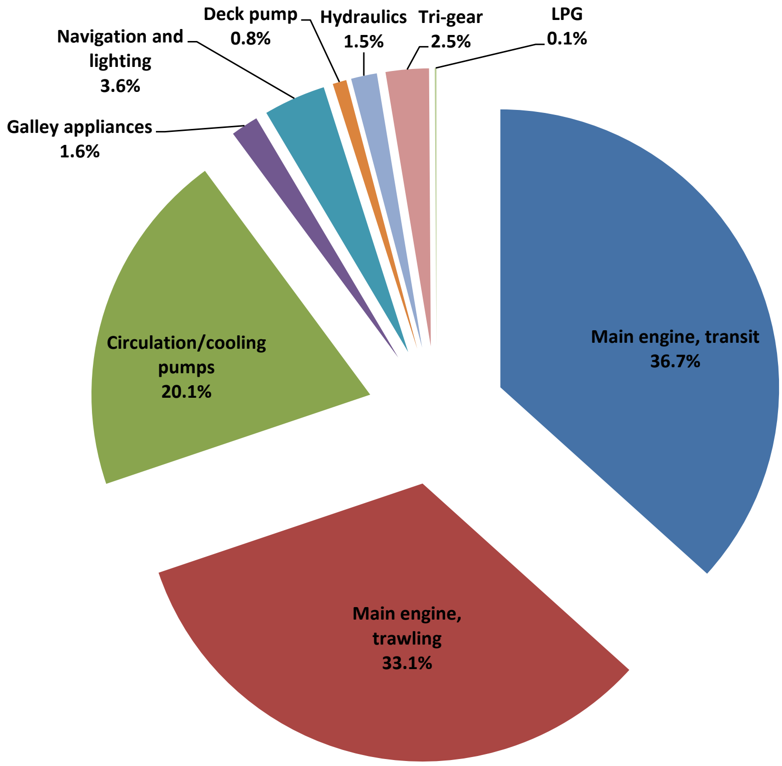


Figure 2: Energy usage breakdown for FV Sea Lion

The external lighting used during fishing operations consists of low-wattage LED floodlights; it only consumed approximately 0.55kW.

Figure 2 shows the energy usage breakdown for the FV Sea Lion. The data indicates that about 69% of the total power consumed on FV Sea Lion is used for propulsion, and that this potentially is where substantial energy savings could be made, hence the interest in improving the propulsive efficiency of the vessel.

6.3 Detailed Investigation into Effect of Sail on Energy Usage

The collection of sufficient data to determine the fuel savings due to auxiliary sail power offer up a number of complications due to the increase in variables. To undertake this energy audit a new mobile data system was developed that allowed sampling of environmental variables which will affect the vessels performance.

6.3.1 Instrumentation Package Development

To further determine the effects of the sails on the vessel’s performance an instrumentation package has been developed to measure all relevant environmental and performance characteristics. The first stage in designing the instrumentation package was to determine what variables impact the performance of a vessel which is motor sailing, and whether equipment is currently on board to measure each variable. This is shown in Table 2, which details the variable and if equipment is available to measure it.

Table 2: Motor sailing vessel important variables

Variable	Unit	Impact on performance	Sensor on board
True wind speed (TWS)	Knots	High	No
True wind angle (TWA)	Knots	High	No
Vessel Heading (True/Magnetic)	Degrees	Low	Yes
Vessel speed over ground (SOG)	Knots	High	Yes
Vessel speed through water (STW)	Knots	High	No
Latitude/Longitude	Degrees	Low	Yes
Roll angle	Degrees	Low	No
Rudder angle	Degrees	Medium	Yes
Sail settings	-	High	Operator - Visual
Operating condition (Trawling etc.)	-	High	Operator – Visual
Engine speed	RPM	High	Yes
Propeller pitch	Degrees	High	Yes
Fuel consumption	L/min	High	Yes
Sea conditions	Beufort Scale	High	Operator - Visual

Table 2 clearly shows that the primary variables requiring new equipment to log are the environmental conditions of wind speed and direction along with the vessels speed through the water. A simple mobile system was developed that will allow the logging of these variables. This system consists of a weather station and flow speed transducer, both manufactured by Airmar. The details of these are shown in Table 3.

Table 3: New sensor measured variables

Model	Variables
Airmar PB-200	Apparent wind speed and angle
	Vessel roll and pitch
	GPS longitude/latitude
	GPS speed over ground
	Heading (magnetic)
Airmar CS 4500	Vessel speed through water
Macnaught m-series ER1 flow meter	Fuel consumption

Both the PB-200 and the CS-4500 have had special mountings made to allow the deployment of both transducers on board any vessel. Figure 3 and 4 show the PB-200 and CS 4500 deployed on the FV Sea Lion. The Macnaught fuel meter is installed between the diesel supply and return line; this gives the total fuel consumed at the engine. This equipment has been designed to be rugged and mobile.

Figure 3: Airmar PB200 on-board FV Sea Lion.

Figure 4: Airmar CS4500 Deployed over the side at 1.5m water depth.

The last component of the instrumentation packages was the selection of a serial data logging software program. The program Navmon PC was selected for its simplicity and ability to vary sample frequency and create individual runs for each condition tested. Figure 5 shows the overall size of the setup on board the FV Sea Lion.

Figure 5: The instrumentation box and laptop inside the FV Sea Lion's wheelhouse.

6.4 Full Scale Measurements

After bench testing this equipment was then transported to Cairns for deployment on FV Sea Lion.

The tests were conducted during a five day period of normal fishing operations between the 25th and 29th May. The tests were conducted in the region of Bramston Beach.

The variables being measured during the trials were:

1. True & apparent wind speed
2. True and apparent wind direction
3. Vessel heading
4. Speed through water
5. Speed over ground
6. Fuel consumption
7. Engine speed

Data was also collected using visual observations of the following:

1. Sea condition
2. Sail configuration
3. Gear configuration

The equipment utilised for this testing was as shown in Table 3. On top of these sensors the vessels inbuilt tachometer was used to measure the main engine RPM.

A total of 36 runs were undertaken over the 5 day period. The runs were undertaken in a number of operating conditions, and were undertaken in a manner to try and minimise the errors induced in the data.

The process for undertaking a series of runs was as follows.

1. Confirm with operator how much time they would be holding the vessel heading constant for.
2. Select number of engine RPM settings based on time available.
3. Start at top RPM with no sails set. Record run for 10 minutes at 1Hz sample rate.
4. Reduce speed by 100-200 RPM. Record run and repeat until lower speed is reached.
5. At the lowest RPM setting, deploy sails.
6. Repeat all RPM settings with sails up, ensuring to allow 5-10minutes for vessel to settle into steady state condition before commencing recording.

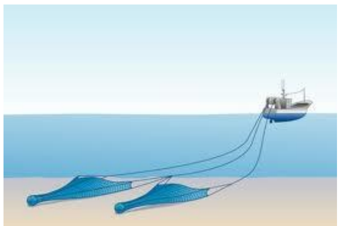
7.0 RESULTS

During the five days of data collection a total of 36 runs were recorded comparing 10 different operating conditions, these conditions are outlined in Table 4. These conditions were selected to provide a good spread of the varying operating conditions of the vessel including trawling and steaming. Three basic gear configurations were tested at a number of RPM settings. These configurations were trailing gear, double lifted nets and trawling (with or without tri gear), please see legend for further clarification. Each condition compares the vessel with and without sails for a fixed RPM setting and gear configuration.

Table 4: Conditions analysed

Condition	Run #	RPM	Sail Configuration	Gear Configuration	Sea State	Average TWS (Knots)	Average TWD (Degrees)
Condition 1							
	Run 36	580	Furled	Double lifted nets	1.5-2m SE following	17.2	181.4
	Run 35	580	Prt + Stb Set	Double lifted nets	1.5-2m SE following	15.7	178.5
Condition 2							
	Run 29	800	Furled	Double lifted nets	1.5-2m SE following	15.9	185.7
	Run 33	800	Prt + Stb Set	Double lifted nets	1.5-2m SE following	14.7	182.0
	Run 30	800	Prt + Stb Set	Double lifted nets	1.5-2m SE following	15.7	189.8
Condition 3							
	Run 28	1000	Furled	Double lifted nets	1.5-2m SE following	15.9	186.1
	Run 31	1000	Prt + Stb Set	Double lifted nets	1.5-2m SE following	15.6	186.4
Condition 4							
	Run 11	1350	Furled	Tri gear out trawl in	1-1.5m SE following	15.1	183.5
	Run 10	1350	Prt + Stb Set	Tri gear out trawling	1-1.5m SE following	13.8	168.2
Condition 5							
	Run 12	1350	Furled	Trawling with all gear inc tri	1-1.5m SE following	15.0	188.4
	Run 8	1350	Prt + Stb Set	Trawling with all gear inc tri	1-1.5m SE following	13.1	164.9
Condition 6							
	Run 6	1420	Furled	Trawling with all gear inc tri	1-1.5m SE following	15.0	168.5
	Run 13	1420	Furled	Trawling with all gear inc tri	1-1.5m SE following	14.4	182.9
	Run 7	1420	Prt + Stb Set	Trawling with all gear inc tri	1-1.5m SE following	14.4	170.9

Condition 7							
	Run 2	1100	Furled	Trailing	Following 1-1.5m	15.8	187.9
	Run 18	1100	Furled	Trailing gear, into current	1-1.5m SE following	11.7	190.0
	Run 3	1100	Port Sail set	Trailing	Following 1-1.5m	16.1	187.4
Condition 8							
	Run 1	1300	Furled	Trailing	Following 1-1.5m	14.9	188.4
	Run 19	1300	Furled	Trailing gear, into current	1-1.5m SE following	11.3	187.5
	Run 4	1300	Port Sail set	Trailing	Following 1-1.5m	16.3	185.3
Condition 9							
	Run 12	1350	Furled	Trawling with all gear inc tri	1-1.5m SE following	15.0	188.4
	Run 24	1350	Port Sail set	Trawling with all gear inc tri	1-1.5m SE Confused	14.9	162.9
Condition 10							
	Run 22	1400	Furled	Trawling with all gear inc tri	1-1.5m SE Confused	16.2	162.9
	Run 23	1400	Port Sail set	Trawling with all gear inc tri	1-1.5m SE Confused	15.9	164.7

Gear configuration legend		
Double Lifted Nets	Trailing	Trawling
		

Due to the FV Sea Lion's sail arrangement and lack of a hydrodynamically efficient hull form for sailing, the sails can only be deployed in running or broad reaching conditions. It can be seen that the true wind direction (TWD) for all conditions was between 160-180 degrees relative to the vessel's heading.

It can also be seen from Table 3 that the wind speed range analysed was between 11-18 knots. Unfortunately this is a condition that the experimental team had no control over. During the 5 days of testing no greater wind speed were encountered. However as the driving force on a sail is proportional to the square of the wind speed, it is evident further savings could be made at higher wind speeds.

Of the ten conditions analysed condition 1-6 allowed comparisons between no sails and both sails set, whereas conditions 7-10 provided comparisons between no sails and just the port sail set.

7.1 Effect of sails on fuel consumption

Figure 6 shows the comparison between the fuel consumed with and without the sails being deployed. The results show that in general (for conditions 1, 2, 3 and 4) there was a reduction in fuel consumption per hour, however in Condition 5 and 6 fuel consumption was found to increase.

The percentage reduction in fuel consumption through deploying the sails is shown in Figure 7. For conditions 1, 2, 3 and 4 there was between a 4% and 12% reduction in fuel consumption when the sails were deployed. In contrast there was a 13.5% and 1.4% increase in fuel consumption for conditions five and six respectively.

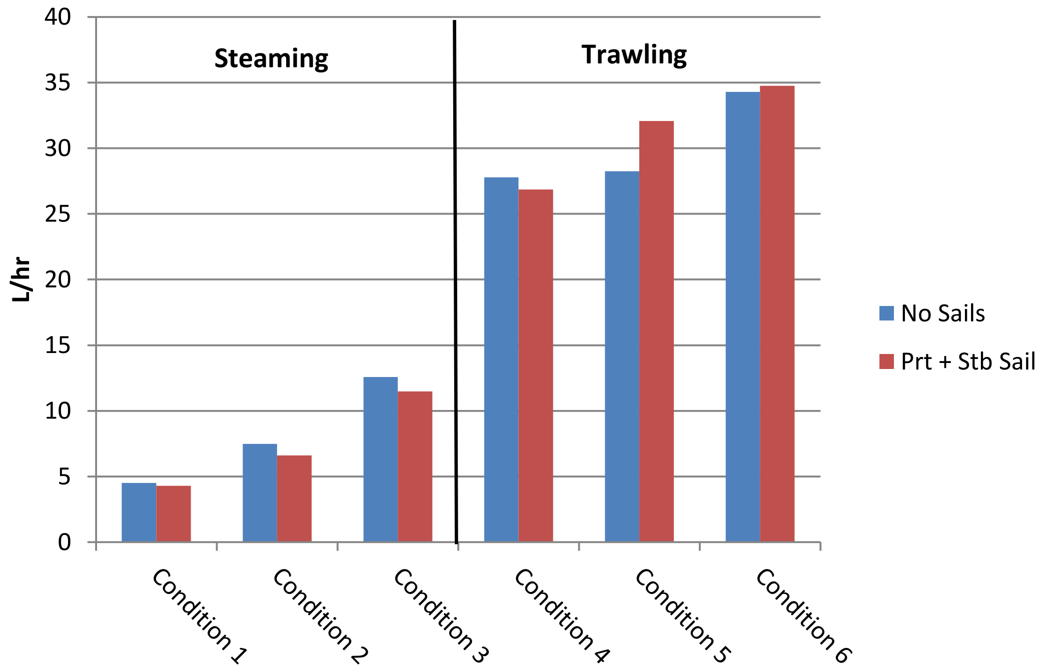


Figure 6: Fuel consumption in L/hr for conditions 1-6 comparing no sails to both sails set.

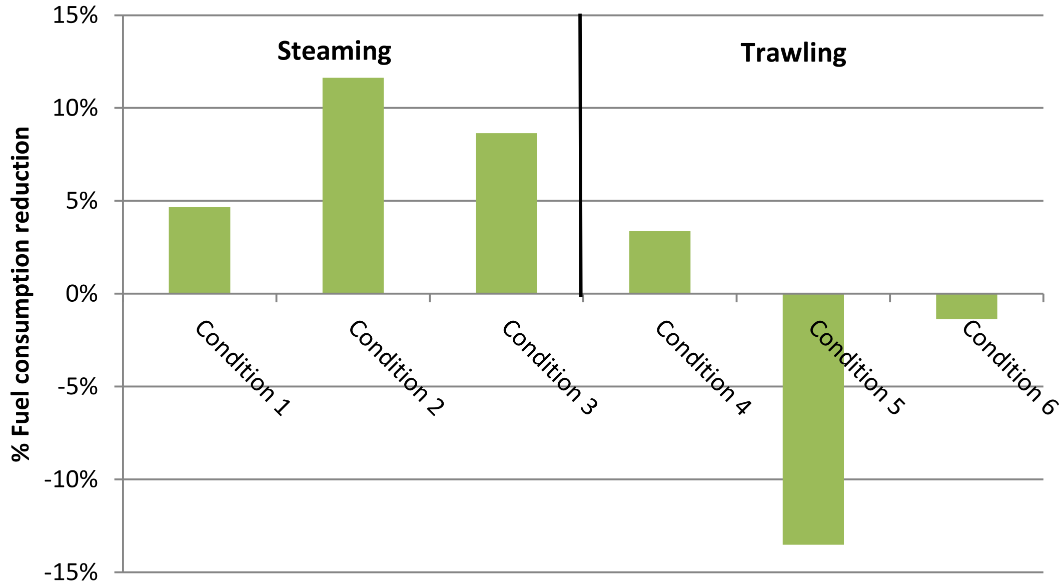


Figure 7: Percentage reduction in fuel consumption for conditions 1-6.

The reason for the increase in fuel consumption for conditions 5 and 6 is that the direct fuel consumption does not give an accurate representation of the unit of energy used to move a given distance, the true measure of propulsive efficiency. When the fuel consumption data is compared to the vessel's speed through the water (STW) and speed over ground (SOG) to determine the fuel consumption per nautical mile (L/nm) it becomes clear that significant tidal flows were affecting conditions 5 and 6. This can be clearly seen in Figure 8, 9 and 10.

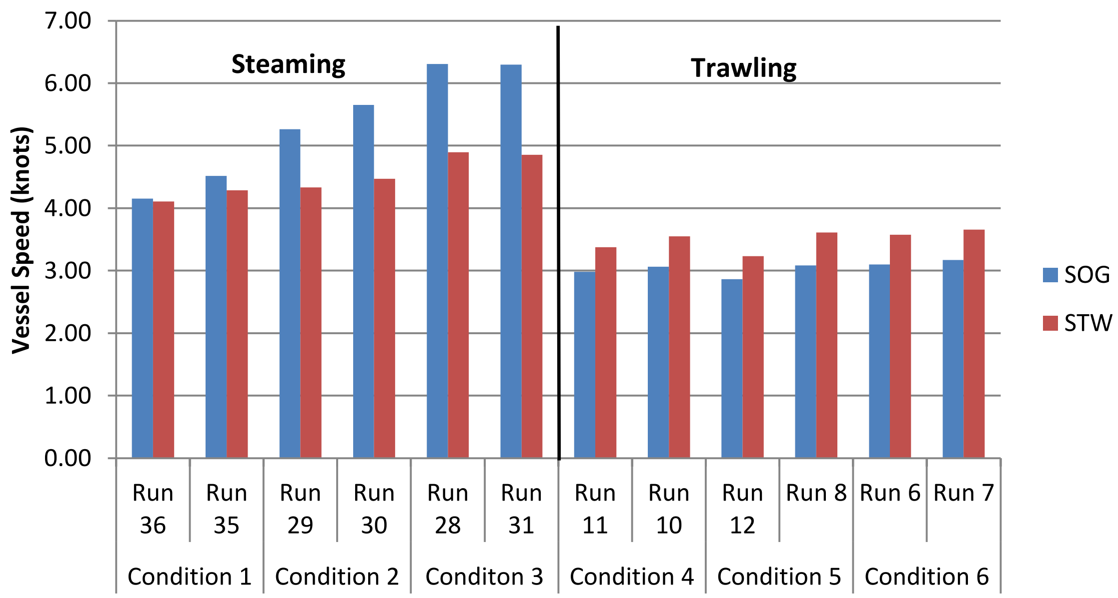


Figure 8: Comparison of vessel SOG and STW for conditions 1-6.

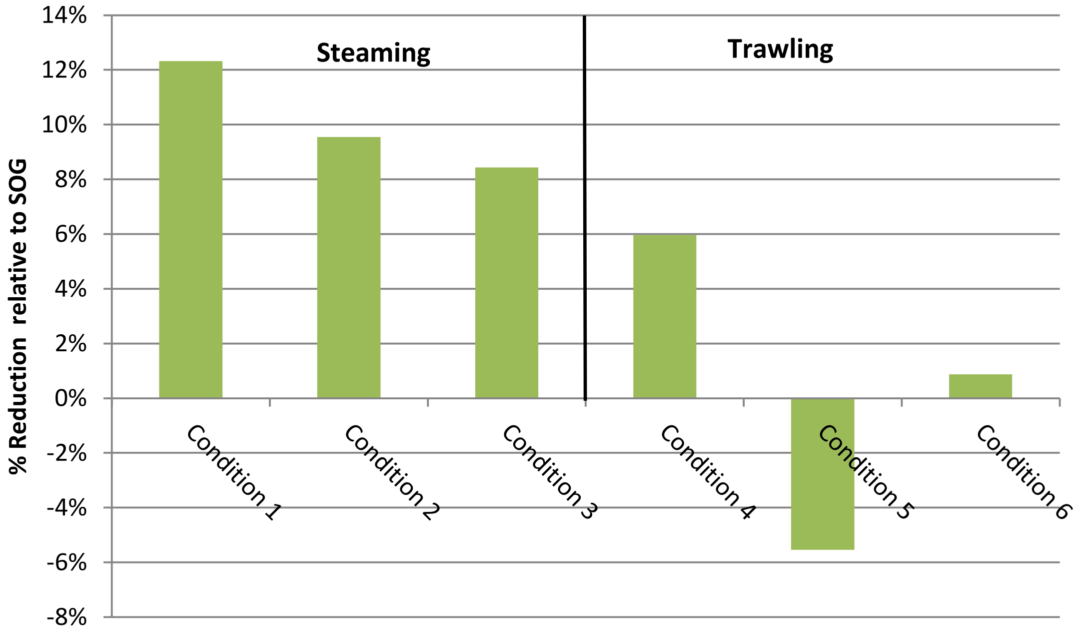


Figure 9: Percentage reduction in fuel consumption per nautical mile travelled relative to SOG.

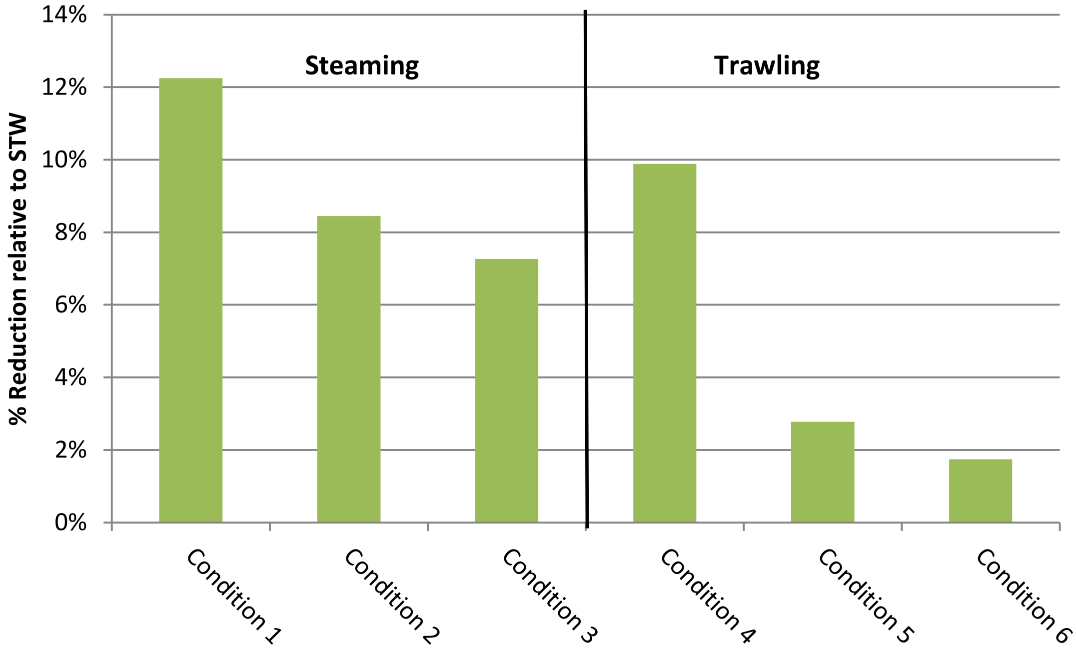


Figure 10: Percentage reduction in fuel consumption per nautical mile travelled relative to STW.

The significant effect of tide should be noted, for any further work in this area it is imperative that the vessel's speed through the water be recorded, as the SOG cannot be reliably used to determine the fuel saving potential.

Table 5: Data for Conditions 1-6.

	Condition 1 Double lifted, 580 RPM	Condition 2 Double lifted, 800 RPM	Condition 3 Double lifted, 1000 RPM	Condition 4 Trawling, 1350 RPM	Condition 5 Trawling 1350 RPM	Condition 6 Trawling 1420 RPM
Fuel use L/nm no sails	2.14	3.21	4.34	11.69	12.65	13.31
Fuel use L/nm prt + stb sail	1.88	2.94	4.03	10.54	12.29	13.08
Reduction (L/nm)	0.26	0.27	0.32	1.16	0.35	0.23
% Reduction	12.25%	8.44%	7.27%	9.88%	2.78%	1.74%

There are constraints on when the sails on the FV Sea Lion can be used. With only two crew on-board the deployment of the sail requires significant effort and is generally only done for large transits. With the addition of either a manual or hydraulic winch, and re-routing the furling lines this could be changed to allow easier deployment and recovery, and hence increased usage and thus fuel savings.

It is recommended that vessels considering the addition of sails should analyse closely their operational profile and vessel layout to ensure that employing such a system is viable as an auxiliary propulsion system. Vessels undertaking regular large transits to and from their fishing grounds with space and stability to accommodate the addition of sails would be prime candidates to utilise sails as an auxiliary propulsion source.

During the testing sails were used during trawling as well as when steaming. This is currently not a standard operation due to the difficulty in setting sails whilst trawling. However from the results obtained for Conditions 4, 5 and 6 it can be seen that fuel savings are possible through using sails while trawling. It is possible that the FV Sea Lion could trawl up to 50% of the time with a wind direction aft of athwart ships. Table 6 shows a breakdown for the propulsion systems over a typical 24 hours period, including a comparison between sails and no sails.

Table 6: 24 Hour main propulsion profile with fuel savings based on full scale measurements

	Trawling	Transiting	Anchor	Total
No sails				
	Trawling	Transiting	Anchor	Total
Main engine (hrs)	12.0	3.0	0.0	15.0
Vessel speed (knots)	3.1	5.5	0.0	
Average distance travelled (nm)	37.2	16.5	0.0	53.7
Fuel consumption rate (L/nm)	12.6	4.3	0.0	
Total fuel consumed (L)	470.4	71.6	0.0	**542.0**
Sails				
Main engine (hrs)	6.0	0.0	0.0	6.0
Main engine + sails (hrs)	6.0	3.0	0.0	9.0
Vessel speed (knots)	3.1	5.5	0.0	
Distance travelled under main engine (nm)	18.6	0.0	0.0	53.7
Distance travelled under sails & main engine (nm)	18.6	16.5	0.0	
Fuel consumption rate main engine only (L/nm)	12.6	4.3	0.0	
Fuel consumption with sails (L/nm)	12.3	4.0	0.0	
Total fuel consumed (L)	463.9	66.4	0.0	**530.3**
			Reduction	**2.2%**

It can be clearly seen that savings in fuel can be gained from the use of sails, with approximately 12 litres of fuel saved for a normal trawling day, or 2.2%. If this figure is extrapolated over an entire season for the FV Sea Lion (209 days) it would account for approximately 2400L of fuel savings. Obviously this is very dependent on the individual vessel operational profile, hydrodynamic characteristics and weather conditions.

Vessels which conduct significant transiting to and from their fishing grounds would stand to benefit the most from the application of sails. If the FV Sea Lion data is analysed for a 24 hour period of transiting, it is possible to save over 40L (7.3%) per day of transit, again depending on the wind direction and strength.

8.0 BENEFITS AND ADOPTION

The key beneficiaries of this research are the owners and operators of small to medium fishing vessels around Australia. The data collected shows that significant fuel savings can be made through the use of sails. The adoption of this technology is certainly not restricted to the Northern Prawn Fishery.

The initial application stated benefits for most fisheries around Australia. Through the correct dissemination of the data presented in this report all these fisheries stand to benefit from this research. The adoption of sails as auxiliary power will depend on the individual fisher and their vessel's operational profile. Sails will be suited to some fishing vessels and activities, but not all. However the data shown through this research will aid fishers in making an informed decision.

9.0 FURTHER DEVELOPMENT

Further work on the benefits of sails as an auxiliary fuel source could be investigated in a number of stages.

1. Initially the development of a remote data logging system to be installed on-board a number of vessels operating with sails would produce more accurate indications of true cost savings over an entire season. This system could be setup on board a vessel and log all activities and fuel usage. This would give very accurate information on a number of vessels with different operating profiles.

2. The theoretical analysis of a number of potential retrofit vessels to determine the potential fuel savings, and the corresponding development of an easy to follow assessment method for fishers to identify the savings potential based on their vessels characteristics and operational profile.

3. The investigation of the design and development of a vessel specifically built to operate with sails as a propulsion source would stand to benefit fishers looking at new build options. If designed from new a vessel would be capable of using its sails significantly more often than a retro fitted vessel. The cost benefit analysis of the production a new build vessel optimised for sail use would allow fishers to make more informed decisions about new vessels.

10.0 PLANNED OUTCOMES

The projects planned outcomes are as follows:

- Level 2 energy audit of a prawn fishing vessel fitted with auxiliary sail system.
- The clear demonstration of the effects sails have on fuel consumption.

The data produced during the time spent on-board the FV Sea Lion has allowed all outcomes to be achieved, with data presented on the potential savings from using sails as an auxiliary propulsion source.

Work on dissemination of the findings from this project is in progress.

In Appendix 3 a draft flyer is shown which could be made available from the FRDC website. Additionally an article based on this report will be developed in conjunction with FRDC publication FISH.

Chris Calogeras has provided advice on developing articles to give the fishing industry clear advice based on this work. For example publishing an article in the Queensland Fisheries Magazine. In addition the attached flyer is being provided to fishery peak bodies with a link to the full FRDC report once sited on the FRDC website.

11.0 CONCLUSIONS

This project has determined the benefits with respect to reducing fuel consumption using sails as auxiliary power for a displacement fishing vessel.

A robust and portable instrumentation package has been developed that will allow this data to be collected by an observer on-board any vessel around Australia.

Analysis of the data collected has indicated, for the conditions tested and analysed, that fuel consumption can be reduced by up to 13% by the use of sails. This reduction, over a standard fishing day, could reduce fuel consumption by up to 12L. When a vessel is transiting even greater savings could be made with reductions of up to 40L per day in 15knots of wind speed.

The results also clearly indicate that the prime mover and propulsion train are the largest energy consumer on-board the FV Sea Lion, as with most fishing trawlers. As such arguably the greatest potential gains in efficiency are to be made by improve the propulsion train efficiency or providing auxiliary propulsive system such as sails.

12.0 REFERENCES

Wakeford, J., 2010, Development and Implementation of an Energy Audit Process for Australian Fishing Vessels, Final report to the Fisheries Research & Development Corporation, Project 2006/229. Australian Maritime College, Tasmania, Launceston.

Thomas, G., O'Doherty, D., Sterling, D. and Chin, C., 2010. Energy Audit of Fishing Vessels, Proceedings of the Institution of Mechanical Engineers, Part M: Journal of Engineering for the Maritime Environment Vol 2, No. 2, pages 87-101.

13.0 APPENDIX 1: INTELLECTUAL PROPERTY

No intellectual property was developed as part of this project.

14.0 APPENDIX 2: STAFF

Name	Organisation	Funding
Thomas, Giles	Australian Maritime College	In-kind
Frost, Rowan	Australian Maritime College	FRDC & In-kind
Kilfoy, Russel	Fisherman, QLD	In kind

15.0 APPENDIX 3: PROJECT OUTCOMES FLYER

Using Sails to Reduce Fuel Consumption of Fishing Vessels

For most fishing operations fuel costs are the one of the largest components of production costs. Rising fuel prices has made some fishing operations marginally viable.

One way to reduce fuel consumption is to use auxiliary power from the wind. The easiest way to do this is to set up a sail at the bow of the vessel. Using a roller reefing system can make the sail easy to handle in a range of wind conditions.

An FRDC project, completed by researchers at the Australian Maritime College in 2012, looked into how much fuel can be saved usinga sail system on a prawn trawler.

Findings: Up to **13% fuel savings** were made.

The best savings were made in 15 knots of wind with the wind blowing from astern in the transit condition . Even bigger savings might be possible in stronger wind strengths.

More details can be found in the FRDC report 2011/229