SR640_Sail Power_Part II_IPF D110

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SR630_Sail Power (Part II)_D110

Construction deployment and testing of a foresail using modern sail materials and techniques on a commercial Tuna fishing vessel

Summary:

The aim of the project is to develop and test a means of integrating sail power for use on commercial fishing vessels. This report is part two of the Seafish report SR630 and describes work carried out on the construction, deployment and testing of an innovative foresail on a 21 meter commercial fishing vessel, the MFV Nova Spero (CN 187). The sail was initially tested during instrumented sea trials in Mounts Bay in Cornwall and subsequently deployed during three commercial Tuna trips to the Bay of Biscay.

This report includes details of the:

- Construction and fitting of the Forestay and Foresail
- Initial seal trials
- Modifications made to the foresail and rigging
- Results of instrumented sail performance trials
- Commercial trials results
- Future developments

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1. Introduction

Part One of this report described the history of sail power during fishing operations. The aim of the project was to design a foresail, based on historical designs, though using modern sail cloths and deck handling technologies, which could be used in conjunction with engine power to reduce fuel usage and emissions. A review of modern sail materials and sail-making techniques was carried out and initial design modifications to our test vessel, the Nova Spero, were outlined.

This report looks at the construction/fitting of the forestay and rigging/fitting of the foresail, reporting on the initial and instrumented trials and the deployment of the foresail during three commercial trips.

2. Construction and fitting of the forestay

The Nova Spero arrived in Newlyn overnight on the 30th November 2009 after the completion of a week long commercial fishing trip. A close eye had been kept on the weather forecast, as the boat's foremast is of aluminium construction and welding to this structure requires relatively windless conditions. The design and modifications required to the Nova Spero are outlined in Part 1 of this report.

Unfortunately the weather all week was forecast to be very wet and windy. It was therefore decided that the forestay fittings should be initially bolted to the Nova Spero's foredeck and mast section. This would allow for measuring and manufacture of the forestay and construction of the sail. The forestay fittings would be welded to deck and mast when weather conditions were suitable and prior to the fitting of the foresail and associated rigging.

Figure 1: The fabricated fitting being bolted to the tripod mast

The forestay was made of 6mm 7*19 strand stainless steel wires and finished with solid thimbles and copper ferrules. The ropes breaking load of 3850 kg was more than sufficient to take any load the foresail would put on it.

Before fitting the deck forestay bracket, the area of deck adjacent to and underneath the bracket was ground free of paint. The stay was attached to the forward lug of our paired head and foot attachment brackets (Figure 2) by means of stainless shackles with a 4100kg breaking load and tensioned by means of a hi-mod rigging screw.

Similarly, the base of the top forestay bracket was prepared prior to welding. Both deck and mast brackets were then bolted in their final positions. Measurements were then taken for manufacture of the forestay.

Figure 2: The mounting for the base of the forestay

3. Making Foresail Prototype

The intention was to design and construct a sail which was durable enough to withstand the rigours of use on a working fishing boat, whilst making it as light as practicable to ensure the manual handling of the sail was made as easy as possible.

A sail plan was drawn up and we decided to use challenger 6.53 ounce high modulus sail cloth. The sail would be designed with a lot of luff and foot curve and have a sewn in bolt rope all round (Figure 3 & 4).

Figures 3 & 4 ‘Jossie’ stitching in the bolt rope

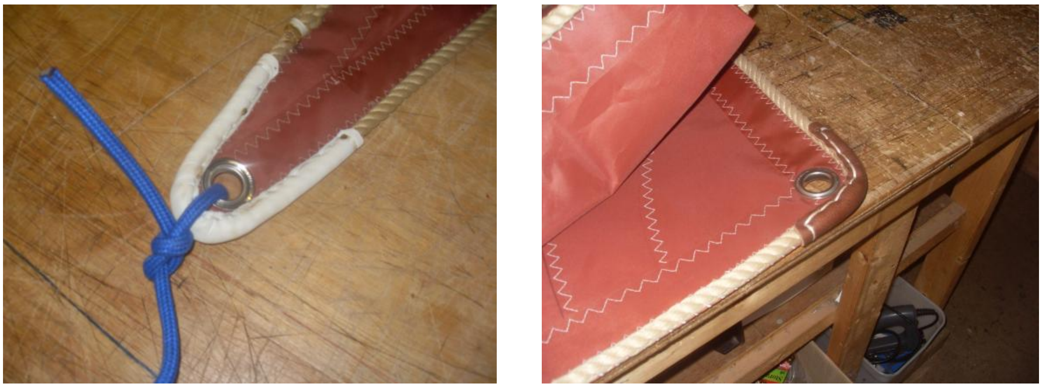
Hand stitching a bolt rope onto a sail has the effect of ‘pinching in’ the sail edges (figure 5).

Figure 5 Bolt rope

Along with pronounced foot and luff curves, the bolt rope will help to give the sail a full and powerful shape in order to optimise the sails performance. The bolt rope is also important in terms of chafe resistance as the sail will be required to be manually positioned on either side of the tripod mast dependent on wind and vessel direction. In use the sail may also rub against the sides of the forward tripod mast: the bolt rope will protect the sail edges and along with heavily reinforced sail corners will give the sail good strength and durability (figure 6).

Figure 6: Reinforced sail corner

Sail corner durability was further enhanced by hand stitched leather work which would prevent wear from shackles and rigging gear (figures 7 & 8).



Figures 7/8: Hand stitched leather work on the sails corners

The luff of the foresail will attach directly to our forestay by jib hanks (Figures 9/10).

Figures 9/10 Sail Hanks

This direct hank connection will provide the luff support required, giving a powerful luff profile and facilitate easy rigging and stowing when the sail is in use.

4. Fitting the Prototype Foresail (21/12/09)

Initial fitting of the sail was carried out over a spring tide, whilst the Nova Spero was in harbour at Newlyn. A relatively windless day was required for the sail fitting; the sail was rigged on the forestay and fixed at the head and tack (Figures 11-13)

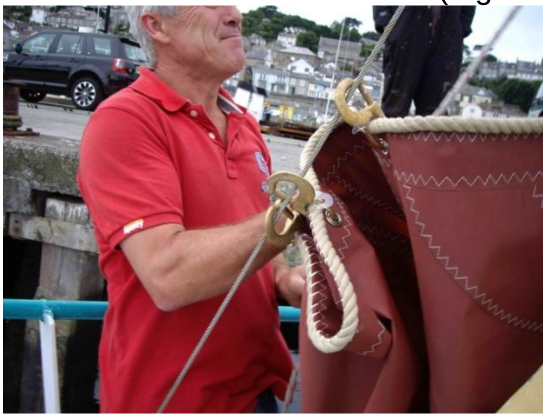


Figure 11/12: Fitting the tack of the sail

Figure 13: The head of the sail attached to the fabricated mast fitting

The clew rope was attached to one of the aft mooring cleats and checked for sail clearance above the starboard deck railings. The sail cleared the starboard side rail and set cleanly around the forward tripod mast when deployed (Figures 14/15).


Figure 14/15 Fitting of the Foresail

Satisfied that the sail fitted the rig perfectly the vessel was ready to commence the initial sea trials.

5. Initial Sea Trials

Tuesday 2nd February - Wind – South Westerly 20 knots

Ideal weather conditions allowed the initial testing of the foresail to commence in February. The MFV Nova Spero was manned with a crew of five and accompanied by a film crew of six students from University College Falmouth. The students had been commissioned to produce a video diary of the project as part of their degree course. The Nova Spero was also accompanied by the Newlyn Harbour boat to allow the film crew to shoot footage of the Nova Spero whilst underway. The two vessels headed out of Mounts Bay towards Mousehole Island then set a downwind course Northeast.

The foresail was manually deployed by two of the crew and once deployed set beautifully on a range of courses with the wind aft of the beam –


Figure 16/17 Foresail being set & underway

Figure 18: Wheelhouse view underway

The vessel was then knocked into neutral and with the wind freshening to 20 – 25 knots the vessel made 3 knots over the ground under sail power alone.

The Nova Spero's weather/shelter deck caused a windage effect on the vessels speed over the ground – an estimation of the relative effects of sail and weather deck are:

Sail – 75%
Weather deck – 25%

Shaun Edwards – Skipper of the Nova Spero was very impressed with the downwind performance of the sail and the ease with which the sail had been set and later stowed.

Initial assessment, was that in a 30 knot following wind the vessel could save an estimated 150 rpm whilst still achieving its 8.5 knot top speed. This reduction in revs would equate to 2 gallons or 8 litres per hour. On a 48 hour steam a saving of 96 gallons or approximately 380 litres. At 50 pence a litre this constitutes a saving of £190 in 2 days of use of the foresail.

The Falmouth university film crew were excited by the potential of the footage acquired during the sea trial from both the deck of the Nova Spero and from filming onboard the harbour vessel. Film was shot from the harbour vessel whilst at sea and when the Nova Spero was alongside in the harbour.

As Skipper Shaun Edwards stated "in appropriate weather conditions he would, definitely use the sail" "with fuel prices increasing, it would be lunacy not to"

6. Modifications made to Rigging and Sail

Although the foresail performed admirably a number of modifications were required to maximise its performance.

- Tell tales fitted in the luff of the foresail to assist trimming of the sail and to maximise performance.
- Straps at the head and foot of the sail luff will enable us to properly tension the luff in those areas.
- Removal of part of the bolt rope on the top of the sail – this may 'fall away' in lighter winds and compromise the sails shape and performance.
- Clearly mark the head and foot of the sail to ease rigging.
- Increase the size of the pulley block for the clew and increase the diameter of the sheet rope.
- Fit a set of clipped straps to the weather deck rails for ease of storage while the foresail is in use and make a bag for storage when not in use.

Confident that the foresail performed perfectly, Seafish and European Fisheries Fund (EFF) logos were adhered to the foresail prior to further sea trials and filming.

Figures: 19/20 Foresail Logo's

7. Results - Monitored sail performance trials

Project Meeting - Thursday 8th July 2010

Prior to the commencement of the monitored sail trials Paul Johnson (Jossie) & Gus Caslake met at Lodey Sails in Longrock. The methodology & schedule for the trials was worked through and objectives clearly set out. A logsheet was produced to ensure the data collected was reliable and reproducible. Readings of speed over the ground and through the water would be recorded along engine revs, vessel course and heading, wind strength and direction.

As the tuna season was due to start in earnest within a couple of weeks the window of opportunity for the project was limited. It was decided to commence the sea trials at the earliest opportunity with favourable wind conditions.

A timetable for sea trials was discussed with Shaun Edwards and given the right wind conditions it was agreed to commence the trials during the following week.

7.1. Sea Trials - Monday 12th July 2010

The Nova Spero sailed at 09:30 onboard were Shaun Edwards (skipper) Jossie (sail maker) Gus Caslake (Seafish Project manager) and one of Shaun's crewmembers. Alterations to the sail rig had been made as outlined. During the steam out of the harbour the sail was attached to the forestay and clew block ready for deployment once the Nova Spero was clear of the harbour.

Wind Speed (knots)	Wind Direction	Weather conditions	Vessel Heading	Sail Deployed Y/N	Angle off the Wind	Engine Revs	Vessel Through water m/s	Vessel Speed GPS knots
20	SSE	Force 3-4	260 degrees	Yes	90 degrees	Knocked out		2.8
10	SSE	Force 3	230 degrees	Yes	60 degrees	Knocked out	0.593	1.8
10-15	SSE	Force 3-4	240 degrees	Yes	70-80 degrees	580 revs	2.635	5.5

Table 1: Initial Sail Results

When the sail was initially set the wind conditions were force 3-4 SSE with a wind speed of ~20 knots. A course was set of 260 degrees an angle off the wind of 90 degrees. The engine was knocked out of gear to see how the vessel performed under sail power alone. The sail performed well being easy to deploy and set. With the sail set the vessel made speed over the ground of 2.8 knots as can be seen in Table 1.

The wind speed subsequently dropped at 10 knots causing the sail to stall. The engine was put into gear and a course of 240 degrees was set. The sail would not properly set when the vessel was steaming downwind, her downwind speed effectively nullifying any wind effect.

After steering a number of different courses off the wind, an angle of 80 degrees off the wind proved to me the most effective and beneficial angle in the light 10-15 knots of breeze. A run was then commenced steering a course of 238 degrees with an engine rev setting of 570. The sail was initially raised then lowered half way through the trial run. The results of which are shown in the Table 2 below. Speed through the water was measured in m/s using a Braystoke current flow meter linked to a Valeport Display unit, speed over the ground was recorded using the vessels Furuno GP70 GPS navigator. Wind speeds were recorded using a Skywatch Xplorer 3 wind speed sensor.

Figures 21-23: GP70 GPS Navigator, Valeport Display Unit & Braystoke current meter

Wind Speed (knots)	Wind Direction	Weather conditions	Vessel Heading	Sail Deployed Y/N	Angle off the Wind	Engine Revs	Vessel Through water m/s	Vessel Speed GPS knots
10-15	SSE	Force 3-4	238	Yes	80 degrees	570	2.701	5.7
10-15	SSE	Force 3-4	238	Yes	80 degrees	570	2.719	5.6
10-15	SSE	Force 3-4	238	Yes	80 degrees	570	2.684	5.6
10-15	SSE	Force 3-4	238	Yes	80 degrees	570	2.697	5.6/7
10-15	SSE	Force 3-4	238	Yes	80 degrees	570	2.733	5.6
10-15	SSE	Force 3-4	238	No	80 degrees	570	2.688	5.6
10-15	SSE	Force 3-4	238	No	80 degrees	570	2.719	6
10-15	SSE	Force 3-4	238	No	80 degrees	570	2.666	5.8
10-15	SSE	Force 3-4	238	No	80 degrees	570	2.586	5.6
10-15	SSE	Force 3-4	238	No	80 degrees	570	2.617	5.6

Table 2: Motor sailing results

Due to the lack of wind the sail sets at its best with the vessel travelling across the wind rather than downwind. This causes the sail to try and push the bow of the vessel in a downwind direction. To maintain a the course of 80 degrees off the wind the sail is fighting against the rudder and autopilot as the vessel tries to maintain a heading of 238 degrees. More wind is required to enable the vessel to sail further downwind without the sail stalling. Due to the light wind conditions no significant benefit was seen during this stage of the trial.

It was concluded that in order for the sail to be of benefit during motor sailing operations a minimum wind speed of 15 to 20 Knots is required.

After a couple of downwind runs in similar wind conditions testing was abandoned for the day. Sail stowage requirements were discussed. During commercial operations the sail would only be used on the way to or from the tuna grounds. On deck stowage would not be required as the sail was easily handled and could be stowed in a bag below decks when not in use.

7.2. Sea Trials - Tuesday 13th July 2010

Although the 7am forecast predicted very light winds it was decided to meet up at 9am at Newlyn Harbour. In discussion with Paul Johnson and Shaun Edwards it was decided to cancel today's sailing and concentrate our efforts on the following day when wind speeds were forecasted at 20 to 25 knots.

Paul Johnson also discussed with Shaun the need to appoint a 'sail master', someone who could be trained in rigging and stowing the sail, the conditions to look for and how to make the sail set correctly.

7.3. Sea Trials - Wednesday 14th July 2010

Wind – Southerly 15-20 MPH

The Nova Spero left the harbour at 9.00 AM to maximise our time at sea, steaming South of Mousehole Island to commence a series of test runs. The test runs were set downwind, lasting 30-40 minutes each. On completion of each run the Nova Spero would steam back upwind to its original position. The sail was rigged and set in a variety of orientations off the wind, the results of which are described below.

Fig 24/25: Workstation set up in the Nova Spero Galley and the Xplorer wind sensor

7.3.1. Maximum/Minimum and Optimum sail angle

In order to establish the foresails maximum working envelope (angles off the wind at which the sail could be effectively operated) a number of runs were conducted with the engine knocked out of gear. The angle of the vessel to the wind was set and adjusted using the auto pilot. Readings were taken at each setting to calculate the maximum, minimum and optimum angle at which the sail could be set.

Angle off the wind	Average wind speed	Average m/s	Average speed knots
30 degrees **(Min)**	14.9mph	1.51	2.94
60 degrees	16.6mph	1.35	2.63
70-80 degrees	18mph	1.27	2.48
80 degrees**(max)**	18mph	1.38	2.68

Table 3

Table 3 shows a summary of the results from a series of runs using the sail alone. The maximum angle achieved can be seen as 80 degrees with a minimum angle of 30 degrees. Angles outside this envelope where effected by the super structure of the wheelhouse obstructing the wind (angles below 30 degrees). Angles above 80 degrees saw the foresail trying to pull the bow of the vessel downwind, fighting against the course being steered by the autopilot.

The minimum angle of 30 degrees also proved to be the optimum when the sail was used alone, without any engine propulsion. The results show that even at a reduced average wind speed of 14.9 mph the vessel obtained a maximum average speed through the water of 2.94 knots. Average wind speeds were recorded using a Skywatch Xplorer 3 wind speed sensor.

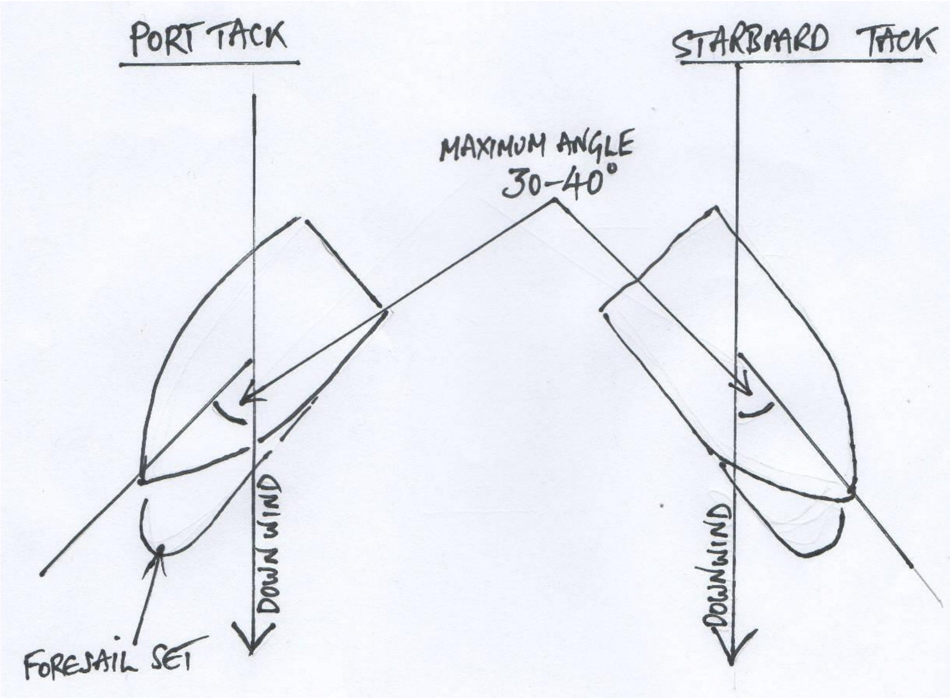


Fig: 26: Diagram of Tack angle

7.3.2. Motor sailing trials

During a commercial trip the foresail will be deployed, in appropriate wind conditions, as an addition to engine propulsion. It is anticipated that the sail will be most effective during the steam to and from the fishing grounds and whilst shifting between fishing areas. In order to test the performance of the sail during motor sailing operations and assess any associated fuel savings, a range of test runs were carried out.

In the prevailing weather conditions (Wind SSW force 4) of the motor sailing stage of the trial, the foresail set at its optimum between 40-50 degrees off the wind. This course was kept constant with readings being taken during a range of engine 'steaming' revs setting as the sail was intermittently raised and lowered. This allowed for an assessment to be made of any benefit derived from the deployment of the foresail. Wind strength was not as strong as would have been desirable, though sufficient to conduct the trials. Results are shown in the table below

Average wind speed	Sail deployed Y/N	Engine Revs	Vessel Heading	Average m/s - Through the Water	Average speed knots - Through the water	Average speed knots - Over the ground
17.5mph	YES	980	343 degrees	4.35	8.45	8.72
15.1mph	NO	980	343 degrees	4.26	8.29	8.45
15.2mph	YES	880	343 degrees	3.98	7.73	7.80
15.2mph	YES	900	343 degrees	4.06	7.90	8.27
17.0mph	YES	940	343 degrees	4.25	8.25	8.40
17.6mph	YES	880	80 degrees	4.09	7.96	6.90
16.4mph	YES	900	80 degrees	4.03	7.83	6.88
17.4mph	YES	940	80 degrees	4.19	8.14	7.13
18.6mph	YES	980	80 degrees	4.32	8.41	7.68
20.6mph	NO	980	80 degrees	4.28	8.32	7.60
19.2mph	NO	940	80 degrees	4.23	8.23	7.60
19.2mph	NO	900	80 degrees	4.03	7.84	7.62
18.2mph	NO	880	80 degrees	3.97	7.71	7.33

Table 4:

The table shows that the average wind speed over the course of this part of the trial was just less than 17.5mph; this can be seen as the minimum wind requirement to see any benefit derived from the use of the sail. The foresail requires the vessel to be travelling in a downwind direction for it to be effective. The speed of the vessel will detract from the apparent wind speed affecting the sail (apparent wind speed = wind speed minus vessel speed). For example, if the vessel is sailing down wind making 8 knots and the wind speed is 17.5 mph, then the apparent wind affecting the sail is less than 10mph.

The results show, even with very little apparent wind the foresail produced an average increase of 0.13 knots at steaming revs of 980 or a reduction of 30-40 revs to maintain the same speed whilst the foresail was deployed.

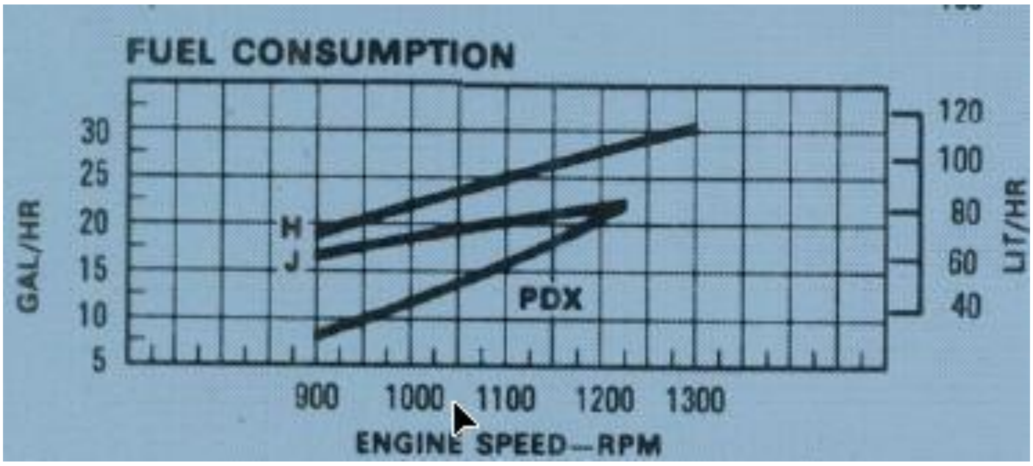


Table 5: Fuel Consumption Table for the Nova Spero Caterpillar Engine

Table 5 above shows the fuel consumption curve for the Nova Spero's Caterpillar D353 Marine Diesel engine (curve H). Using figures from the table above it can be estimated that at 980 revs average fuel used per hour is between 80-90 litres. This estimate was confirmed by Shaun Edwards as being approximately the fuel figure he would expect to use whilst steaming. Relating the increase in speed of 0.13 knots to fuel saving equates to a fuel saving of 1.38ltr/hr. Using the fuel curve a similar, if not a slightly improved, saving would be expected by reducing the revs whilst maintaining the same speed.

Although wind speeds throughout the testing never increased above 20 mph the sail set well and operated successfully within its working envelope of 30-80 degrees off the wind. In higher wind speeds the benefit derived from the sail can only increase, further improving fuel saving.

The sea state during the trial was moderate making the rigging and stowage of the sail difficult. In similar or higher wind conditions at least two crewmen would be required to deploy the sail safely and effectively. On one occasion the clew rope came loose from the aft pulley block causing the clew of the sail to flap against the deck fittings resulting in a tear in the sail. This highlighted the need for significant care and attention to be paid to working the sail to avoid damage during commercial operations.

On returning to Newlyn the day's events were discussed and Shaun Edwards was instructed on how and when best to use the foresail and how to orientate the vessel into the wind during rigging and stowing operations. Slight modifications were required to the sail and rig. The dynamic cleat system we had used for the outhaul was found to be overcomplicated and the clew rope not long enough and not of sufficient quality or weight.

It was decided to upgrade the clew rope to an 8mm braided yacht rope. The outhaul was to be replaced by a double pulley and to use a 'figure of eight' cleating system for simplicity and practicality. This simple system would make tack changes easier as the clew block aft could easily be transferred to the opposite side of the vessel when changing tack.

Thursday 15th July 2010

Jossie delivered the sail, with the modifications completed, to the Nova Spero. A meeting was held between Jossie, Shaun & Gus on the boat to discuss the deployment of the sail and data collection during the upcoming commercial Tuna trips. Shaun was issued with log sheets to record trip details, when the sail was deployed and how it performed.

Jossie discussed with Shaun's crew member, Aaron, the newly appointed 'sail master' how to get the best out of the sail and the conditions to look for when using the foresail. Aaron seemed confident that he understood what was required.

Saturday 17thth July 2010

The Nova Spero departed Newlyn for the Bay of Biscay tuna grounds.

7.4. Commercial Trials

To keep a record of the use of the foresail whilst on commercial trips Shaun kept a log on each trip. Trip information was recorded along with details of when the sail was deployed, wind and sea conditions and how the sail performed on each occasion.

Trip Number	Port of Departure	Date & Time Left Port	Date & Time arrived at Fishing Grounds	Date & Time Left Fishing Grounds	Port of Arrival	Date & Time arrived at Port of Landing
1	Newlyn	17th July 12:00	19th July 08:00	25th July 22:00	Newlyn	27th July 21:00
2	Newlyn	28th July 18:00	31st July 08:00	7th Aug 22:00	Newlyn	9th Aug 13:00
3	Newlyn	16th Aug 15:00	17th Aug 16:00	24th August	Newlyn	26th August

Table 6: Nova Spero Commercial Trip Log

Only three trips were carried out by the Nova Spero during the 2010 Albacore Tuna Season. The first two trips were successful with ~1000 fish caught on both trips. The third trip did not prove so successful and coincided with another Newlyn vessel having a particularly good trip gill netting for Hake, resulting in the Nova Spero reverting to Hake netting during the next neap tide.

Average steaming times to and from the fishing grounds were 30-40hrs with the longest steam taking over two days. Weather conditions were favourable for much of the time giving the crew plenty of opportunity to use the sail. In total, over the course of the three trips, the sail was deployed 7 times for 80 hours, in weather conditions ranging from Force 4 to 6.

Trip No.	Date/time Sail Raised	Wind Speed & Direction	Vessel Heading	Engine Revs	Vessel Speed knts(GPS)	Date/time Sail Lowered	Comments on Handling, Rev settings, Speed, Performance of Sail & Handling of Sail, fuel saving, speed change, Vessel stability etc.
1	18th July 07:00	S 5-6	272	920	8.5	22:00	Slight increase in speed from 8.2/3 to 8.5 knots. Probable fuel saving of 4 litres an Hour
1	22nd July 10:00	NNW 4-5	180	720	6.5	16:00	Shifted fishing area from North to South Used the sail to assist making way slight increase in speed fuel saving hard to say at 720 revs
1	25th July 22:00	NNW 4	60	1000	8.6		Steaming Home sail certainly helped speed a little Estimate 2-4 litres an hour fuel saving
1	26th July	Calm	60	1000	8.5	08:00	At 8am the wind dropped to a calm day so sail was dropped as it was flapping
2	30th July 08:00	NW4	240	950	8.5	30th July 22:00	Jibbed sail over the port side to catch the wind seemed to work well similar fuel saving to last trip dropped the sail when the wind dropped to calm
2	7th August 21:00	WNW 4-5	85	920	8.5	8th Aug 06:00	Dropped sail again as wind dropped to light & variable causing the sail to flap. I think a slight saving during the night but no different to last trip at 3-4 litres per hour
2	9th August 07:00	SW4-5	80	920	8.8	9th Aug 13:00	Dropped sail at 1pm as wind veered Northerly and decreased similar fuel saving as seen previously
3	16th Aug 19:00	WNW 4-5	210	1000	8.8	17th Aug 13:00	Jibbed sail port side to maximise wind direction pretty similar to last few times on fuel saving. Dropped sail and stowed when arrived in Biscay Fuel saving estimated at 2-3 litres an Hour

Table 7: Foresail deployment log sheet

Shaun, the skipper, estimates that on average that the use of the sail improves the speed of the Nova Spero resulting in a fuel saving of between 2-4 ltrs/hr, depending on the wind conditions. Over the course of the three trips, deployment of the sail over 80 hours has resulted in a fuel saving of ~240 litres and a saving of ~ £100.

Figure 27/28: Albacore Tuna being landed/ Iced Tuna Newlyn Market

8. University College Falmouth – Video Diary Project

The students from the Falmouth media college are currently compiling the video diary footage and this will be made available as an addition to this report. Some excellent footage has been taken by the students and the final cut of their work will be submitted as part of their degree course work. Working with the local University has been a very successful addition to this project, providing a novel filming experience for the students and the opportunity to enhance their portfolios. In return the project has benefited from the students providing an alternative media angle to the standard written report.

9. Future Developments

There is little doubt that as fuel costs increase, efficient motor sailing will be an important factor in the development of sustainable fisheries world wide. The performance of the foresail during the trials was limited by the constraints of having to work with a vessel not designed for sail. We could only achieve decent results in a strong following wind less than 40 degrees off the beam.

Had the Nova Spero been designed as a motor sailor and our budget allowed, we could have achieved much improved results in a wider range of conditions through the use of the foresail in conjunction with a mizzen rig for instance.

In the early 1900's the transition began from sailing luggers to a motorized fleet. This transition saw hull designs move away from sailing vessels with large hull drafts that grip the water as a means of propelling the vessel forward to smaller draught designs reducing the drag of the vessel in the water.

Future hull designs will reflect a reversal and fishing vessels will be increasingly designed for the use of sails. Sails will be easily and quickly deployed and stowed and will be designed to withstand the rigours of a working boat whilst not compromising fishing activities.

In the short term, interest in our project has been shown by Waterdance LTD as their fishing activities extend out towards the edge of the continental shelf. Undoubtedly a rig could be designed for all their vessels to save fuel as they steam to and from the fishing grounds. If future vessels were designed with motor sailing in mind, significant fuel savings could be made. There is even the prospect of photo-electric sail cloth. The sail cloth itself could charge electric motors. The figures will soon add up to enable all sustainable fisheries to use this kind of technology.

10. Conclusion

This report demonstrates how the use of a sail can be easily adapted for use within a commercial fishery and effective in reducing fuel usage and the carbon footprint of fisheries. Ease of use, durability and practicality were all important factors in the design stage of the sail and rig. Our aim was to make the deployment of the sail during commercial operations as ergonomic and fail safe as it was worthwhile. With very little instruction and limited sailing experience the crew of the Nova Spero operated the sail efficiently and effectively with minimal difficulties.

Appendices

Appendix I - Glossary of Terms

Bolt Rope – A rope fitted to edges of the sail for chafe resistance and to reduce sail stretch.

Cleat – a static or dynamic mechanism for fixing and/or tensioning sail corners.

Clew – the after corner of the foresail.

Downhaul – the rope at the tack of the sail for applying tension to the sail luff.

Foresail – a sail attached to the foredeck and foremast

Forestay – a tensioned wire attached to the foredeck and foremast to which the foresail luff is attached.

Hank – A spring loaded snap used to secure the foresail to the forestay.

High Modulus (Sail Cloth) – High tenacity sail cloth for durability and strength resistance.

Luff – The leading edge of a sail.

Pulley Block – A mechanical means of applying high loads to sail corners.

Tack – The forward lower corner of a sail.

