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# Design and Construction of a 21 Tonne SWATH Fishing Vessel

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## Abstract

This paper discusses the way in which the SWATH concept was applied to a 21 tonne fishing vessel making use of various advantages over a monohull of similar size; low responses to waves, large deck area, good stability characteristics, outstanding maneuverability at low speeds, working efficiency as well as safety and lower speed loss in waves. The hydrodynamic characteristics have been rigorously examined by tank testing a one seventh scale model and comparing the results with computational results based on several computer programs. A 21 tonne SWATH boat fishery of shellfish by traps on the North West coast of Scotland was designed and constructed. The full scale measurements of resistance and powering, stability trials and rough sea trials were performed and reported in this paper.

# 1 Introduction

The application of the concept of Small Waterplane Area Twin Hull (SWATH) to the naval and commercial vessel designs has been growing rapidly over the last two decades. This is mainly due to superior seakeeping characteristics and minimum speed degradation in rough seas compared to monohulls of similar size. Various possibilities of SWATH ship roles has been put forward by the SWATH designer. Among the roles are high speed ferry, oceanic research/survey vessel, diving support vessel, survelliance ship, naval workboat, leisure/party boat and fishing vessel etc. Apart from these missions, the SWATH concept can be competitively applied to salvage ship, tug boat and a number of offshore engineering roles.

The application of the SWATH concept to fishing vessel has been made twice so far. The 24.4 m long, 175-ton SWATH fishing vessel Charwin was completed in May 1984 and successfully fished that year. But the scallop catch declined drastically in 1985 and thereafter, causing the Charwin to be layed up. In mid-1987 the Naval Coastal Systems Center decided to lease the Charwin as a support vessel to test minehunting systems. The Charwin was reactivated and modified for that purpose early in 1988 [1]. The 11.0 m long, 21 tonne SWATH fishing vessel Ali was completed in 1989 by MacGregor Bros. and

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since then, a comprehensive sea trials have been conducted. The main characteristics of Ali together with the design philosophy and the model test results are fully described in Refs.[2,3]. This paper describes the hydrodynamic performance characteristics of the full scale SWATH Ali together with a brief introduction to the design philosophy of Ali. The main dimension of Ali is given in Table 1.

## 1.1 SWATH as a Fishing Vessel

Fishing vessels are virtually the only type of ship which actually load cargo at sea. For this demanding task, a safe and steady working platform is essential. This is reflected in the design of fishing vessels.

### 1.1.1 Stability, Safety and Rolling Motion

Commercial fishing remains one of the most hazardous of industries. Fig.1 shows that the primary cause of small boat($<$12m) loss in the UK fishing fleet is flooding and foundering, with loss by capsize or unknown events also prominent in the statistics. These figures, which show no sign of decreasing, underline the dangers of wave and wind to small boats.

A very stiff vessel is difficult to capsize and may be designed to return from a capsized position. However, such stiffness or stability leads to very quick and violent rolling which makes work on deck difficult. Because of this, some fishing vessels are designed with low stiffness to provide a steady working deck. This means that the stability and ultimate safety of the vessel are compromised, and many fishing boats continue to be lost through insufficient stability.

For SWATH ships at large angles of heel, the immersion of the lee upperworks and emergence of the windward lower hull gives very large maximum GZ values. Together with low initial stability ($GM_T$) this offers an ideal combination of stability and comfortable working conditions. Compared to an equivalent monohull, work on deck may thus continue in worse weather, and efficiency will be increased in more moderate conditions.

### 1.1.2 Deck Wetness and Safety

Fishing vessels frequently operate with the working deck intermittently flooded by the sea but for even the most determined crew, there comes a time when the amount of solid water coming aboard becomes dangerous and work must cease. In this respect the dry decks of the SWATH offer a greatly increased degree of comfort, safety and hence efficiency. The 47 metre SWATH Duplus has operated for 15 years in the North Sea in all weathers and has never yet taken green seas aboard her main deck.

### 1.1.3 Fishing Performance

Apart from the danger in extreme cases to the ship and the crew working on deck, adverse weather affects fishing performance in other ways. Wave induced motions make work on deck and in the wheelhouse more difficult and less efficient. In addition, in relatively moderate conditions, small trawlers become ineffective because of their response to the waves. If the boat is moving violently and being slowed by wave impact, the trawl doors lose lift, the mouth of the net collapses, and the catching power of the net becomes negligible. In both involuntary speed loss of this nature and voluntary slowing to reduce motions, the SWATH is superior to the monohull. The Japanese SWATH ferry Seagull has reported[4] a speed loss of less than 2% (of 27 knots) in Beaufort Force 5 conditions. From the recent sea trial results of the Seagull 2 [5], her speed loss due to waves is much lower than that of the Seagull 1 and further it was revealed that the speed of the Seagull 2 in waves can be faster than that in calm water. Experiments[6-8] with several SWATH models have shown that resistance in waves is less than the calm water drag over a significant speed range. In contrast, monohull fishing boat forms show[9] increases of 2-3 times the calm water drag when operated in waves.

Smaller vessels engaged in fishing by creels or traps are subject to other problems. In conditions which are not dangerous or difficult to fish in otherwise, the ropes by which the creels are hauled may snap due to the violent motion of the vessel. During each hauling operation, fleet of up to 60 creels must be staked on deck in a manner which permits rapid and safe return to the sea (shooting) after the baiting is complete. A crewman is required to ensure that this stack does not collapse and become entangled ; even so, tangling does happen in some circumstances. Creel fishing places constant demands on the crew who must stand on deck the whole time and manipulate the creels, catch and bait, in a routine and efficient manner. Disruption, or slowing down of the hauling process reduces the amount of creels which can be fished in a day. A more comfortable fishing platform such a SWATH would alleviate these problems.

The large, square deck area provided by a SWATH is an advantage to any fishing operation but is particularly useful for a creelboat. Most small fishing boats are severely cramped on deck and inefficiencies in operation result from this.

In conclusion, the low motions and accelerations provided by the SWATH concept are ideal for certain modes of fishing. Small boat trawling and shellfish creel/trap fishing are the most suitable activities for a vessel of this type. Because of its low deadweight capacity, the SWATH is suited to high value/low bulk fisheries.

# 2 Design of the SWATH Fishing Vessel Ali

## 2.1 Background

The fishery of nephrops, lobsters and (more recently) crabs now supports the majority of the locally owned fishing fleet on Scotland's North West coast and islands. In the past, white fish and herring stocks were fished by many small boats owned locally. For a variety of reasons, the fishing industry on this coast has been overtaken by developments in ship and catching technology. Now only large modern trawlers and purse seiners seasonally exploit the pelagic stocks, while the capital investment required for such vessels has not been present locally. Creel fishing provides a significant part of the total shellfish catch in this area, which is dominated by the nephrops trawl. However, creeling is the more seasonably reliable fishery, and holds the promise of a rapidly growing crab fishery[2].

Within the UK as a whole, the fleet of small(<12m) boats is growing (Fig.2). More particularly, in NW Scotaland fishing is still part of a traditional way of life which combines the use of the sea and land, and small efficient creelboat operations are extremely popular. The novel SWATH fishing vessel described in this paper is designed to meet the demand for a cheap, safe and productive small creelboat.

## 2.2 Monohull Creelboats

The typical creelboat on the NW of Scotland is less than 12 metres registered length. This is primarily due to the length at which more stringent Department of Transport regulations become effective. The details of one such vessel are given in Table 2. These vessels operate a five/six day week and land live fish daily, with a typical day idealized in Table 3.

## 2.3 Initial Sizing

SWATH ships possess many more dimensional and form parameters than conventional ships, and there is consequently a great degree of freedom in hullform design. In an ideal situation, each dimension may be sized to give optimum hydrodynamic performance. However, in the present case, fabrication considerations were the primary driver in design.

### 2.3.1 Lower Hull Dimensions

The vessel was designed to have an overall length less than 12m. Multiples of standard plate lengths to form the midbody combined with adequate entrance and run to set the length of the lower hulls at 10.475m. A circular hull section was selected for ease of fabrication, although asymmetric sections would allow greater sectional area in the lower hulls. The aim of placing the maximum possible buoyancy in the hulls must be balanced by the need for slenderness because of resistance considerations. In this case it was not considered possible to increase the diameter of the hulls beyond 1m.

### 2.3.2 Strut Dimensions

It was decided to employ one short strut of 8.9m length on each hull in order to save weight and time in construction and also to keep LCB and LCF together. The latter point is due to the fact that, as an approximation, a vessel will pitch about its LCB, while wave excitation acts through the LCF. Wide separation of these quantities can lead to coupling of heave into pitch motions. The alternative long strut arrangement would give more slenderness, afford greater protection to the propeller and allow a spade rudder to be hung in its tailrace. Strut thickness of 0.6m was dictated purely from considerations of access during fabrication and operation. These dimensions give a rather large waterplane area for a SWATH ship, but one which is useful in proving adequate hydrostatic stiffness. In addition, the ratio(60%) of this dimension to the hull diameter is rather large for satisfactory added mass and damping qualities. Use of elliptical hulls and/or a (feasible) strut thickness of 0.5m would offer improvements in these respects.

### 2.3.3 Design Draught and Depth

The design draught was dictated by the desire to adequately submerge the lower hulls in order to provide satisfactory resistance and seakeeping. Over recent years a clear trend has emerged in SWATH design showing that the submerged depth of the lower hull centerline should be close to 68 % of the draught. This resulted in the choice of 1.6m as the design draught. The clearance of the weather deck from the still water is made of 1.0m, resulting in a depth of 3.2m.

### 2.3.4 Beam

Separation of the demihulls was dictated principally by seakeeping considerations. This dimension also affects drag through the proximity effect of two hulls, and influences loading in the cross structure. A hull centreline separation of 4m was selected to ensure that co-incidence of the natural periods of heave, pitch and roll was avoided.

### 2.3.5 Form Parameters

For ease of production, a total of 7.0m of the vessels is of uniform section. The elliptical entrances of the struts are 0.9m in length with a parabolic run of similar dimensions. This gives a waterplane area coefficient of 0.92 compared to 0.7 - 0.85 for normal SWATH designs[10]. The lower hullform consists of a 7.8m parallel section, with two conical sections of 8 and 17.5 to avoid flow separation in the run. The entrances are formed from 0.86m diameter hemispheres and a 0.42m transition section. The prismatic coefficient($C_P$) of 0.82 is higher than usual (0.7-0.8) for a SWATH design [10]. Many compromises in hydrodynamic design have clearly been accepted in the design to ease production.

## 2.4 Resistance

Fig.3 presents the measured residuary resistance coefficient together with the calculated wave-making resistance coefficient using the computer program OSWATH [11,12]. The model tests were conducted at the Hydrodynamics Laboratory of the Glasgow University with a one seventh scale model. Separate curves show the relative magnitudes of hull, strut, and hull/strut interference wave drag and the interferences between these components due to the proximity of the two hulls. It can be seen that the interference between hull and strut is a significant proportion of the total drag, and this is a area where great improvements are possible when more freedom in hullform is available to the designer. As with normal SWATH ships, major peaks occur in the residuary resistance curve at Froude numbers close to 0.32 and 0.5. These are a result of large wavemaking contributions from each strut and each hull and unfavourable interference between the two demihulls. A hollow exists at Froude numbers about 0.38 because of minimum contributions from the hulls and struts, and favorable interference between demihulls. The operating design speed of Ali is 8 knots which is within the hollow speed range.

The resistance of the conventional boat as given in Table 2 was estimated using the method described in Ref.[13]. Effective and shaft powers for both vessels are presented Fig.4. It can be seen that the SWATH has a greater resistance than the monohull at lower speeds. Above a speed of 7.8 knots, the SWATH has less resistance.

## 2.5 Motion Analysis

As seen in Table 3, more than 50 % of the time spent at sea by a nephrops creelboat is at zero speed. Other than ultimate safety, performance in this condition is therefore the most important aspect of seakeeping. An extensive motion tests with the model in head, beam and quartering seas with zero speed and also in head and following seas with forward speeds were conducted at the hydrodynamics Laboratory of the Glasgow University. Detailed results were reported in Ref.[3].

Based on the tank test results[3], the performance of the full scale fishing SWATH in seaways is predicted statistically using the ITTC'84 sea spectra formulation. Table 4 present significant responses of heave, vertical acceleration, roll and pitch in head, bow quartering and beam seas while the ship at rest as well as in head seas with forward speed near the maximum operational speed. These results are derived from model test data. The spectral analysis was based on the most common waves (around 11.6% per year) in the North Minch area where the SWATH will be operated. From the wave record it is found that the most common wave occurs with significant wave height of 0.9m and modal period of 2.8sec.

US Navy seakeeping criteria related to degraded human performance given in [14] is selected to evaluate the performance of the full scale SWATH fishing vessel as set out below.

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|---|---|
| significant single amplitude pitch | 3 deg |
| significant single amplitude roll | 8 deg |
| significant single amplitude vertical acceleration | 0.4 g's |

From Table 4 and referring to the selected criteria above the fishing SWATH operation will be in the safe side for most of its operation throughout the year. Hence, from the seakeeping viewpoint the fishing activity can be carried out safely and efficiently by the vessel. This is achieved by the SWATH without stabilising fins. The performance of the fishing SWATH with a pair of fins attached to the lower hull is expected to be much improved.

## 2.6 Structural Design

Owing to the wide beam, twin hull arrangement of the SWATH ship, the maximum design loads are encountered at zero speeds in beam seas. These give rise to large bending moments in the cross structure. At present, there exists some uncertainty about the effects of shear lag and stress concentration in the 'haunch' area between struts and cross structure. For large SWATH ships, ensuring adequate strength in these areas can be difficult. For small SWATHs, wave induced bending does not represent such a large proportion of the total loading.

In the present design, the first estimate of design side force (acting at mid draught) was estimated from Fig.5 from Ref.[15]. This was combined with large factors of safety on allowable stress to ensure adequate fatigue life. Local panels were designed to slamming loads derived from[16]. Maximum slamming loads are expected to occur in different conditions (head seas, forward speed) from the maximum wave loading (stopped, beam seas). General disposition of the all mild steel structure is illustrated in Figs.6 and 8.

The main load carrying structure is formed by 5 transverse bulkheads extending from the lower hulls through the struts to the cross structure. Plating is supported by flatbar framing carried round the inner and outer shell of the vessel with ring frames in each hull. In the cross structure the frames and bulkheads are supported by 3 longitudinal webs. All 'corners' are radiused a minimum of 100mm to mitigate stress concentration, especially in the inner haunch area between struts and deck structure. With hindsight, greater continuity of stiffening in this area could have been maintained in this small vessel by using a fully radiused haunch.

## 2.7 General Arrangement

The vessel has been arranged (Fig.7) with a forward wheelhouse containing galley and accommodation facilities for 3 men. A small hydraulic creel/trap hauler is situated on the starboard side at the aft end of the house. Approximately $26m^2$ of clear deck area is available aft of the deckhouse alone. By contrast, the total deck area of the equivalent monohull is only $35m^2$ . A much greater degree of efficiency in gear handling should thus be possible on the SWATH.

Two Perkins Diesel 4HD76 engines (continuous output 45 kW at 2250 rpm, 1/4 gear ratio) are located in outboard compartments of the cross structure/haunch. High torque vee-belt drive is employed to transmit power to the propeller shafts in the lower hulls.

Adequate space for tankage and storage is available in the various compartments, but no single large hold or fishroom has been included in the design. In this respect, the SWATH arrangement is unable to compete with modern monohull fishing boats of great carrying capacity.

# 3 SWATH Ali Construction

The vessel described above is constructed by MacGregor Bros., which was found for this vessel construction purpose, in Glasgow, Scotland, and launched in the mid of 1990. Very basic facilities are available at the building site, but the simplicity of construction has enabled 3 workers to erect the structure to a high degree of accuracy. A steel framework laid on concrete foundations provided an accurate datum plane for erection. The lower hullls were rolled from sheet steel. MIG welding with edge preparation was used throughout. To allow downhand welding of plate seams in the underdeck, full penetration welds onto glassfibre backing tape have been employed successfully. By careful sequencing of stiffener and seam welds, minimal panel distortion has been encountered.

# 4 Sea Trial Results

A considerable amount of full scale sea trials on such as inclining test (stability test), resistance test [17], self-propulsion test [18], seakeeping test [19] and manoeuvring test [20] etc were conducted. Detailed results of the sea trials are reported in the several references and some important features are briefly discussed below. The objective of the sea trials is to obtain information with regard to

(i) the negative added resistance properties of the SWATH geometry discovered by the scaled model test in the towing tank,
(ii) SWATH seakeeping and
(iii) the scale effects experienced in modelling SWATH behaviour.

## 4.1 Roughness Measurement

The roughness measurement were made using a standard roughness indicator. This normally requires a run of about 0.75m over which the average roughness is indicated. The representative roughness of the SWATH's surface as a whole was found to be 152 microns which is considered very satisfactory.

## 4.2 Incling Test

The incling experiment showed the the displacement at the time of that test was 19.4 tonnes and that the transverse and longitudinal GMs were 0.96m and 1.66m, respectively. The natural response tests gave the natural period to be 6.2, 6.0 and 3.6 seconds in roll, pitch and heave, respectively. This coincidence in roll and pitch natural periods was not anticipated from the design stage where the design had been allowed for a reasonable separation. This was because the actual load distribution was not as in the original design. The coincidence in roll and pitch natural periods as in this case means that in some quartering sea conditions a cross coupling between roll and pitch would be expected. During the sea trial period, this only occurred in practice once when returning to base in a hurry after a malfunction of the trials generator when there was a severe quartering sea. The vessel experienced appreciable corkscrewing motions, but at a period of 6 seconds or so keeping one's footing on the deck was no problem and the motion was not uncomfortable.

## 4.3 Resistance Trials

The full scale resistance of the SWATH Ali was measured by towing with a tug boat using a Y-cable towing system, as shown in Fig.8. This gave a separation of the tug's track and that of the SWATH being 30m. This kept the SWATHs out of the tug's wake and wave pattern and also put the tug in a good position to video the trials. The loads were measured using two strainstall load cells spliced into the the tow rope at the bow and stern attachment points. The trials were conducted by setting the tug's rpm to a prescribed value. The experiments were conducted over three days. On the first two days there were strong winds and high waves. On the third day the winds were less strong with the moderate waves. Useful data was collected on the first and third day. The recording from the second day exhibited considerable fluctuations and the data was discarded.

The measured resistances on the first and third day, which are corrected by the wind drag, are plotted in Fig.9 together with the predicted total resistance by the program OSWATH [11,12]. As seen in the figure, the predicted resistance gives a good correlation with the measured one in the moderate wave condition except a few points. One of the objectives of the resistance trials is to find out the scale effect between the model and full scale test results. Although the data collected is not enough to indicate the scale effect, the empirical form factor and a model-full scale correction factor of 0.0002 as described in ref [12] seem to be reasonable.

Fig.9 also shows that the rough water data is higher than that obtained in calm water but not by much. As seen in Fig.10 from the towing tank test results, the negative added resistance can not be seen from the full scale towing tests. However, from the self-propulsion test as discussed below, a possibility that the resistance of the SWATH Ali in waves could be less than that in calm water is indicated. Therefore, at the present, it is not sure whether the Y-cable towing system was not worked well, in particular, in waves or the data set is inconclusive with regard to whether the negative added resistance on a range of the SWATHs which has been found in the laboratory is attainable at seas. In the resistance experiment, the towing forces are fairly sensitive to the measurement of the angles of the tow ropes, as seen in Fig.8. In same runs, particularly in waves, slight surge motions of the SWATH meant that this angle varied during a run.

## 4.4 Self-Propulsion test

The trials were conducted by setting the SWATH's rpm to a prescribed value. The SWATH Ali began her run an appreciable distance before the mile posts to ensure that steady conditions were established to prior to entering the measured mile. The tidal current was measured. The trim was measured using a water manometer attached to a ladder which was lashed to the siderails on the starboard side. Two heights were measured and, using the distance the upright sections of tube, the trim was calculated.

As seen in Fig.11, the speed-power curve shows a discontinuity at about an engine setting of 1800 rpm, giving a step change (upwards) in speed. If the engine rpm is increased from 1700 to 1800, a speed jump occurs from 6 knots to 7.8 knots since the resistance of the vessel is decreased over this speed range, as seen in Fig.9. This kind of phenomenon which can not be anticipated for the monohull ship should be utilised in deciding the operating speed of the SWATH ship if she is designed over the hump-hollow speed range. The hump-hollow speed range for the usual SWATH design is Fn=0.3-0.4. However, this range can be varied to some extent by changing the dimensions of the SWATH component and draft.

The speed data in Fig 11 is not corrected by the tidal current measured and accordingly is not the true speed which the Ali experienced. Table 5 shows the speed achieved by mile post, corrected speed by current and wave height at 1600 engine rpm. The first 4 are data achieved for the first day rough seas, the next 2 are for the second day relatively calm water condition and the last two are the third day moderate sea condition. It was a pity not to have current data for all speeds tested. If the speeds are corrected by the current speeds available, the speeds achieved are very similar as each other for the same wave height. One of the important features in the table shows a possibility that the speed in higher waves could be faster than that in lower waves. The speed of 3.1m/s is within the speed range where the negative added resistance occurred from the tank test as seen in Fig.10. Therefore, the speed of the SWATH Ali in rough waves could be faster than that in calm or moderate waves and also the speed loss of Ali in waves observed is trivial.

This result is also observed from the sea trial results of the SWATH Seagull 2 [5]. Fig.12 shows the trim angle against speed and also indicates a marked and sudden change over the hump speed range. At higher speeds, the bow of the Ali was upwards and a severe bow down (pitch instability) was never occurred during the sea trials.

## 4.5 Seakeeping Trials

To make the best use of the seakeeping data it is necessary to have a good knowledge of the waves where the vessel is. This is never possible and a waverider was most valuable but nevertheless it is really essential to have a good knowledge of the frequency distribution of the wave energy. This can not be adequately achieved from a pen recording even by applying the recommended JONSWAP spectra. Once the waverider buoy was floating freely and seen to be working, the Ali was moved to a position downward of the buoy and driven into the predominant wave direction at a preset engine speed. Once up to speed, the log was used to monitor the running speed and the wind conditions were recorded. The recorder receiving the signals from the waverider was switched on for the duration of the runs. After the head seas, following, bow quartering, stern quartering and beam seas were completed in order.

The individual response spectra are complicated and often multi-peaked. The nature of the short crested sea was such that while the more severe pitching motions were experienced in following seas as expected (see Fig.13), the worst roll also occurred in the following and stern quartering headings because of the longer periods of encounter allowing the natural responses in both modes to be excited (see Fig.14).

Fig.15 and 16 also show that the frequencies of maximum response are relatively insensitive to heading in head to beam seas but the response to the longer wave components in following seas is important. This pitch responses in particular seems to concentrate at about 1.8 rad/s or 0.9 rad/s. Fig.18 shows that the response spectral peaks tend to be associated with the peak of the wave spectra but there are a substantial number of times when the natural period response is greater. Many responses have strong secondary and tertiary peaks associated with resonances. In summary, the SWATH Ali responses are sharply tuned and are dominated by the response at the natural frequency. Heave motions were never significant features of the motions. The overall motion characteristics were excellent and the comfort of the ride, particularly in head seas was exceptional.

## 4.6 Manoeuvring Experiments

The instrument used were the compass, two stopwatches and the trailing log. The procedure adopted was for one experimenter in the cabin to initiate the turn with the helmsman in such a way that a second researcher at the stern could simultaneously start his/her stopwatch. Every 10 seconds, the helmsman reported the compass bearing to the first experimenter who recorded both the time and the heading. Meanwhile the second experimenter recorded the speed and logged distance at the same times. In practice the speed varied very little in the turns and no systematic speed loss, as would have been expected with conventional ships, was observed and the speed was only recorded when there was a change to be noted. The logged distance travelled was only a few hundredths on a nautical mile each ten seconds and consequently each distance measurement was somewhat coarse being only ±0.001 of a nautical mile. However, the accumulated distances were reliable since the total systematic error was of a similar magnitude. Wherever possible the SWATH Ali was turned through two complete turns to get 3 half turns at a supposedly steady radius and also to allow the effects of winds and currents to be observed.

Some of the paths are shown in Figs.18 and 19. There was a persistent tendency for the second and fourth half turns to be tighter, i.e., there was frequently an obvious drift to the east during the full manoeuvre due to wind and current.

This was the case even when the initial turn was to port ( west in the case of most of these trials ). Indeed it was the turns to port that most apt to run away east particularly at the higher revolution settings.

Fig.20 shows that the yaw rate is proportional to the rudder angle and the gradient depends on the engine revolutions (and consequently speed ). The results with differential thrust indicate that it does improve turning performance by producing a higher yaw rate and a lower steady turning radius but the trial with 1900 rpm against zero was no effective than that with 1400 rpm against zero. In both cases the effectiveness may be attributed, in part, to the lower speed of the SWATH in these trials. When the data is plotted against speed it is the steady turning radius which is well behaved (see Fig.21). Over the speed range tested a linear fit is quite good with the gradient being roughly inversely proportional to the rudder angle.

# 5 Conclusions

The use of Small Waterplane Area Twin (SWATH) ships for fishing craft was discussed with the aim of producing a cheap, safe, and productive small creelboat. It has been shown that the SWATH concept has an application for high-value, low-bulk fisheries where vessel motions are a dominant factor in operation, and where deck space may be limited in a conventional craft. The application of a SWATH to the nephrops creel/trap fishery was described in detail. A 21 tonne SWATH creel boat was designed and constructed. Main factors which favour the SWATH as a creel boat are; large deck area, low motions in heave and pitch, low added resistance in waves, and regularity of shape for ease of construction. These advantages were well demonstrated by the comprehensive sea trials. During the sea trial period, it was noticed that heave motions were never significant features of the motions. The overall motion characteristics were excellent and the comfort of ride, particularly in head seas was exceptional.

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# References

[1] Jansson B.O. and Lamb G.R.,"Buoyantly Supported Multi-Hull Vessels", *Proceedings of Intersociety High Performance Marine Vehicles Conference and Exhibi, Washington D.C., USA*, June, 1992

[2] MacGregor J.R. et al.,"Design and Construction of a Small Waterplane Area Twin Hull (SWATH) Fishing Vessel", *Proc. World Symp. on Fishing Gear and Fishing Vessel Design, St John's, Newfoundland, Canada*, Nov. 1988

[3] Djatmiko E.B., Chun H.H. et al., "Hydrodynamic Behaviour of SWATH Fishing Vessel", *CSME Mechanical Engineerinf Forum, Toronto*, June 1990

[4] Narita H., et al, "Design and Full Scale Test Results of Semi-Submerged Catamaran (SSC) Vessels', *Proc. 1st Int. Marine Systems Design Conference, London*, April 1982

[5] Yaki H. and Masuyama K., "Experiences of Motion Characteristics of High-Speed SWATH", *Proc. of Korea-Japan Joint Workshop on Hydrodynamics in Ship Design, Seoul National Universiy, Seoul, Korea*, June 1991

[6] Chun H.H. et al,"On Reduced Resistance of SWATH Model in Waves", *Journal of AIAA, Vol.29, No 5*, May 1991

[7] Chun H.H. et al, "Experiments on the Added Resistance of SWATH Models in Regular Head Waves", *Proceedings of 19th ITTC, HSMV Committee, Madrid, Spain*, Sep., 1990

[8] Chun H.H. and McGregor R.C., "First and Second Order Force on SWATH Ships in Waves", *IUTAM Symposium on Dynamics of Marine Vehicles and Structures in Waves, Brunel University, London*, June 1990

[9] Judson S.R., "Added Resistance of Fishing Vessels in Head Seas", *Proc. of Int. Conference on Design, Construction and Operation of Commercial Fishing Vessel, Report No. 67, Florida Sea Grant College, University of Florida*, May 1985

[10] MacGregor J.R., "Computer Aided Design of SWATH Ship", *Ph.D Thesis, University of Glasgow*, May 1989

[11] Chun H.H. et al, "A New Computational Tool to Estimate the Resistance of SWATH Ships", *Proceedings of International High Performance Vehicles Conference, CSNAME, Shanghai*, Nov., 1988

[12] Chun H.H., et al., "Power Prediction of Full Scale SWATH Ships", *Proc. of MARIN Jubilee Meeting, MARIN, Wageningen, The Netherlands*, May 1992

[13] Ridgely-Nevitt C., "The Resistance of High Displacement Length Ratio Trawler Series", *Transanctions of SNAME*, 1967

[14] Lamb G.R., "Some Guidance for Hull Form Selection for SWATH Ships", *Marine Technology, Vol.25, No.4*, Oct. 1988

[15] Allen R.G. and Holcomb R.S.,"The Application of Small SWATH Ships to Coastal and Offshore Patrol Missions", *Symp. on Small Fast Warships and Security Vessels, RINA, London*, 1982

[16] Allen R.G. and Jones R.R., "A Simplified Method for Determining Structural Design Limit Pressure on High Performance Marine Vehicles", *AIAA Paper 78-75, AIAA/SNAME Advanced Marine Vehicles Conference, San Diego*, April 1987

[17] McGregor R.C. and Miller N.S., "Resistance Trials of Fishing SWATH ALI", *Marine Technology Centre Report MTC-92-02, Glasgow University*, U.K.

[18] McGregor R.C., et al "Self-Propulsion Trials of Fishing SWATH Ali on Skelmorlie Measure Mile", *Marine Technology Centre Report MTC-92-03, Glasgow University*, U.K.

[19] McGregor R.C., et al "Sea-Keeping Trials of Fishing SWATH Ali in Firth of Clyde", *Marine Technology Centre Report MTC-92-04, Glasgow University*, U.K.

[20] McGregor R.C. and Miller A.F., "Open Water Manoevring of a Fishing SWATH and Comparison with Predictions", *Proc. of 23rd ATTC, New Orleans, USA*, June 1992

Table 1: Main dimensions of SWATH Ali

| | |
|---|---|
| Length of Hull (m) | 10.50 |
| Hull Diameter (m) | 1.00 |
| Length of Strut (m) | 8.90 |
| Max Strut Thickness (m) | 0.60 |
| Draught (m) | 1.60 |
| Depth(m) | 3.20 |
| Centreline Separation (m) | 4.00 |
| Waterplane Coefficient | 0.92 |
| Hull prismatic Coefficient | 0.82 |
| Displacement (tonnes) | 21.00 |
| Design Speed (knots) | 8.00 |
| Installed Power (kW) | 104.00 |

Table 2: Conventional creelboat particulars

| | |
|---|---|
| Displacement(SW) | 28.50$tons$ |
| LOA | 12.90$m$ |
| LBP | 11.70$m$ |
| Beam | 3.90$m$ |
| Depth | 1.95$m$ |
| Draught | 1.56$m$ |
| Wetted Surface | 49.00$m^2$ |
| Block Coefficient | 0.40 |
| Prismatic Coefficient | 0.55 |

Table 3: Nephrops creel boat voyage profile

| Activity | Speed | Time | Time(% day) |
|---|---|---|---|
| Steam to Grounds | 8 knots | 1.50 hrs | 10.0 |
| Haul 60 creel fleet* | Stoped | 0.40 hrs | 53.3 |
| Shoot/Steam to next* | 8 knots | 0.20 hrs | 26.7 |
| Return to Port | 8 knots | 1.50 hrs | 10.0 |
| Total | | 15.0 hrs | 100.0 |

*repeated 20 times per day

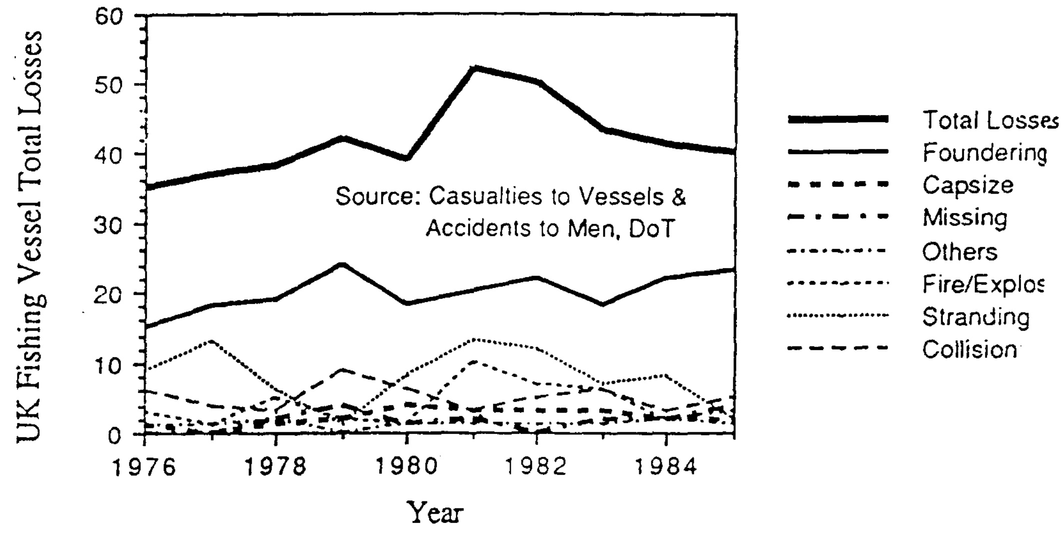
Table 4:

| Wave heading/speed | 2x$\zeta_{ay1/3}$ | 2x$\zeta_{acy1/3}$ | 2x$\zeta_{acy1/3}$ | 2x$\zeta_{a\phi1/3}$ | 2x$\zeta_{a\theta1/3}$ $(m)$ |
|---|---|---|---|---|---|
| 180 deg/V=0.0 knots | 0.6833 | 2.3762 | 0.2422 | —— | 4.5608 |
| 135 deg/V=0.0 knots | 0.6449 | 2.1201 | 0.2161 | 1.6355 | 3.2384 |
| 90 deg/V=0.0 knots | 0.6358 | 2.0277 | 0.2067 | 3.0207 | —— |
| 180 deg/V=7.8 knots | 0.0604 | 1.0744 | 0.1095 | —— | 0.7832 |

| | | |
|---|---|---|
| where | $\zeta_{ay1/3}$ | significant single amplitude heave $(m)$ |
| | $\zeta_{acy1/3}$ | significant single amplitude heave acceleration $(ms^{-2})$ |
| | $\zeta_{a\phi1/3}$ | significant single amplitude roll $(deg)$ |
| | $\zeta_{a\theta1/3}$ | significant single amplitude pitch $(deg)$ |

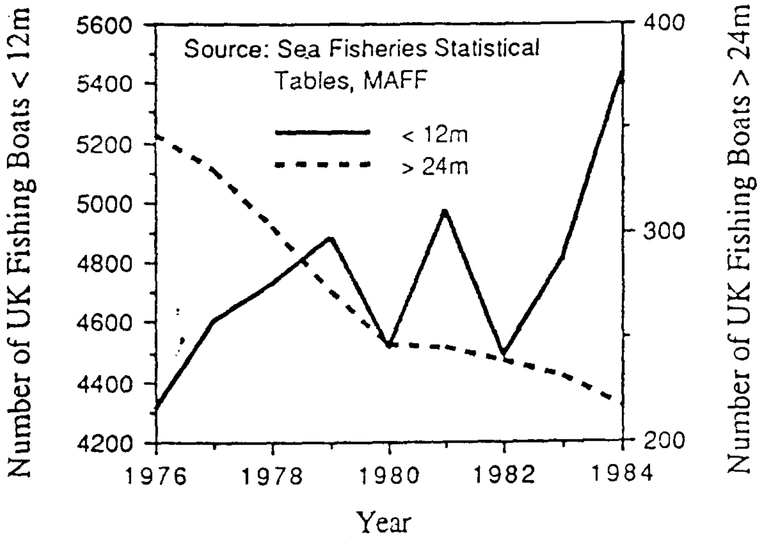
Table 5: Speed vs wave height(1600rpm)

| Speed measured(m/s) | Speed corrected by current(m/s) | Wave(m) height |
|---|---|---|
| 3.10 | 3.20 | 1.00 |
| 3.16 | 3.27 | 1.00 |
| 3.25 | 3.24 | 1.25 |
| 2.89 | 3.23 | 1.25 |
| 3.01 | | 0.10 |
| 3.11 | 3.11 | 0.10 |
| 3.02 | | 0.15 |
| 3.14 | | 0.30 |



Source: Casualties to Vessels & Accidents to Men, DoT

Figure 1: Causes of vessel loss in UK fishing fleet



Source: Sea Fisheries Statistical Tables, MAFF

Figure 2: UK fishing fleet size and composition

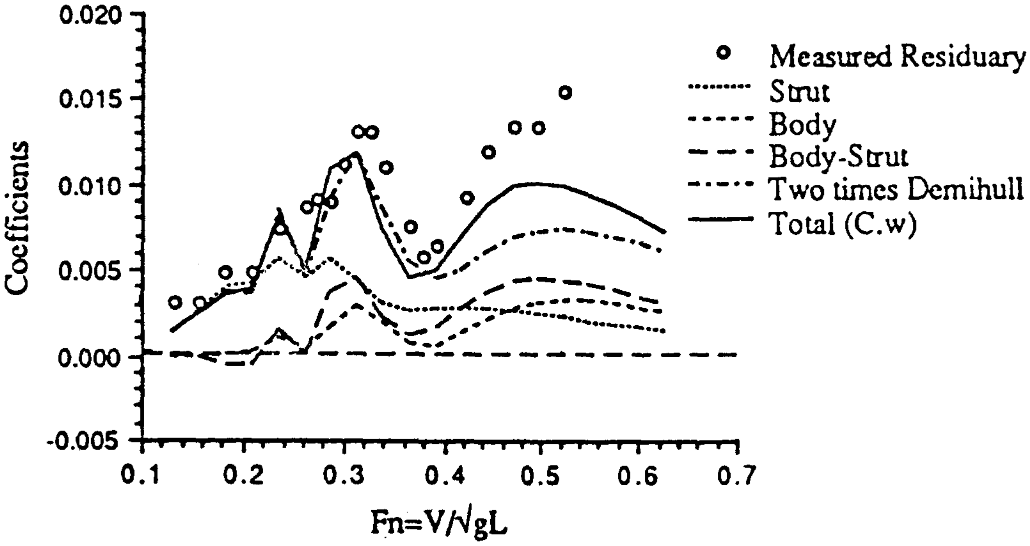


Figure 3: Measured residuary and calculated wave-making resistance coefficients and its component contribution vs Froude number

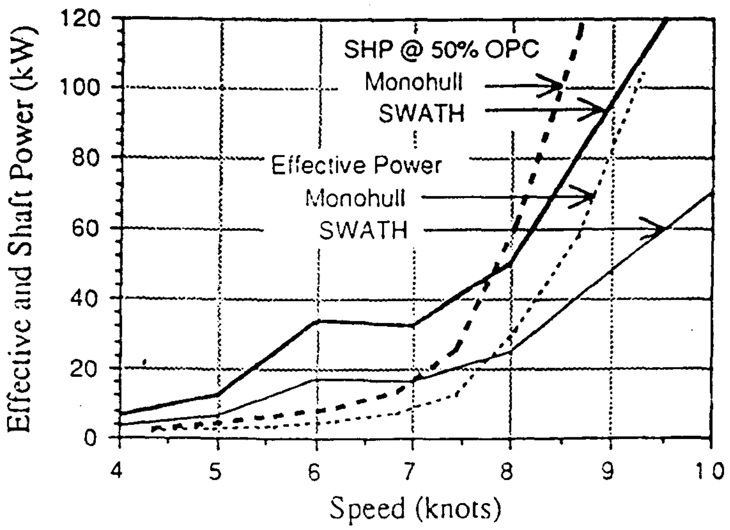


Figure 4: Speed-power curves for SWATH and monohull

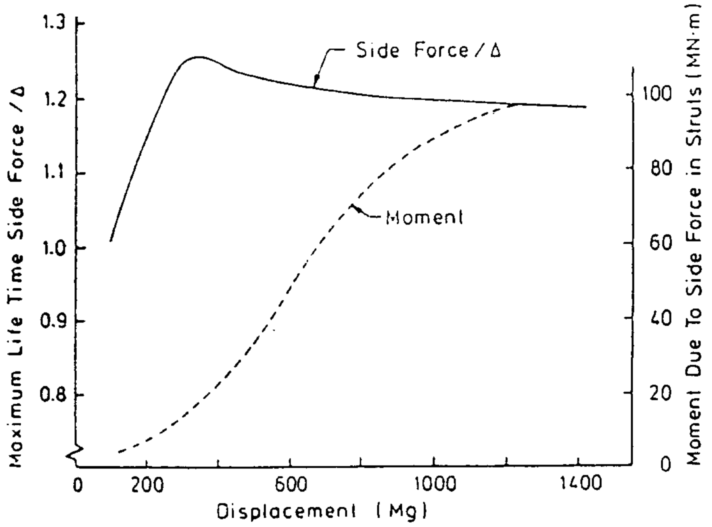


Figure 5: Design side load for small SWATHs (taken from ref.[15])

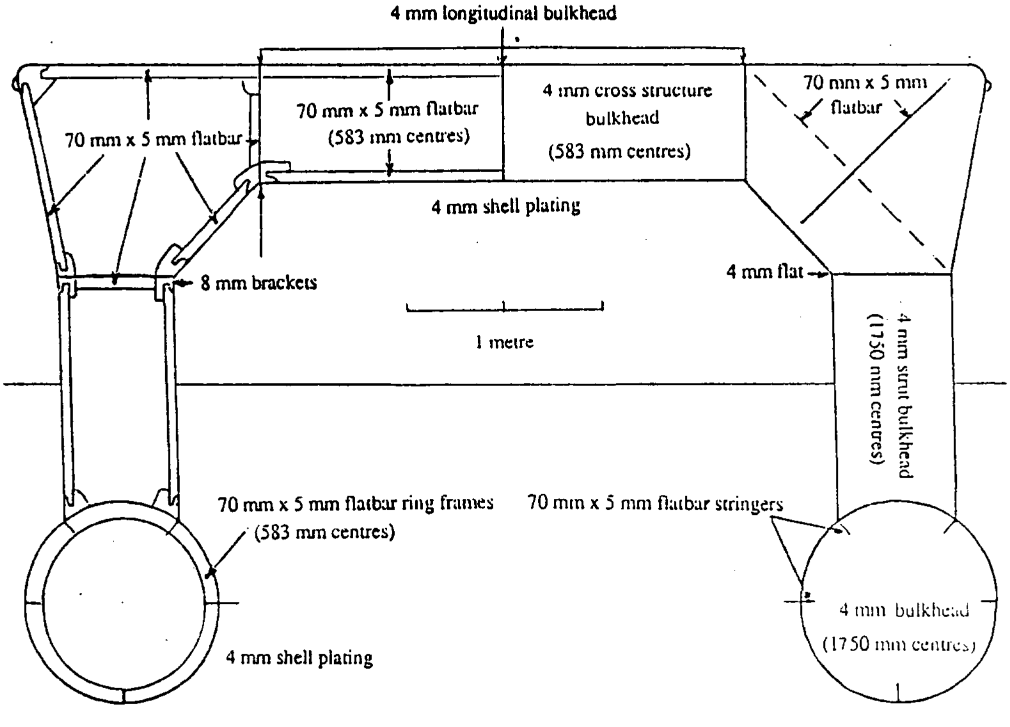


Figure 6: SWATH Ali midships section

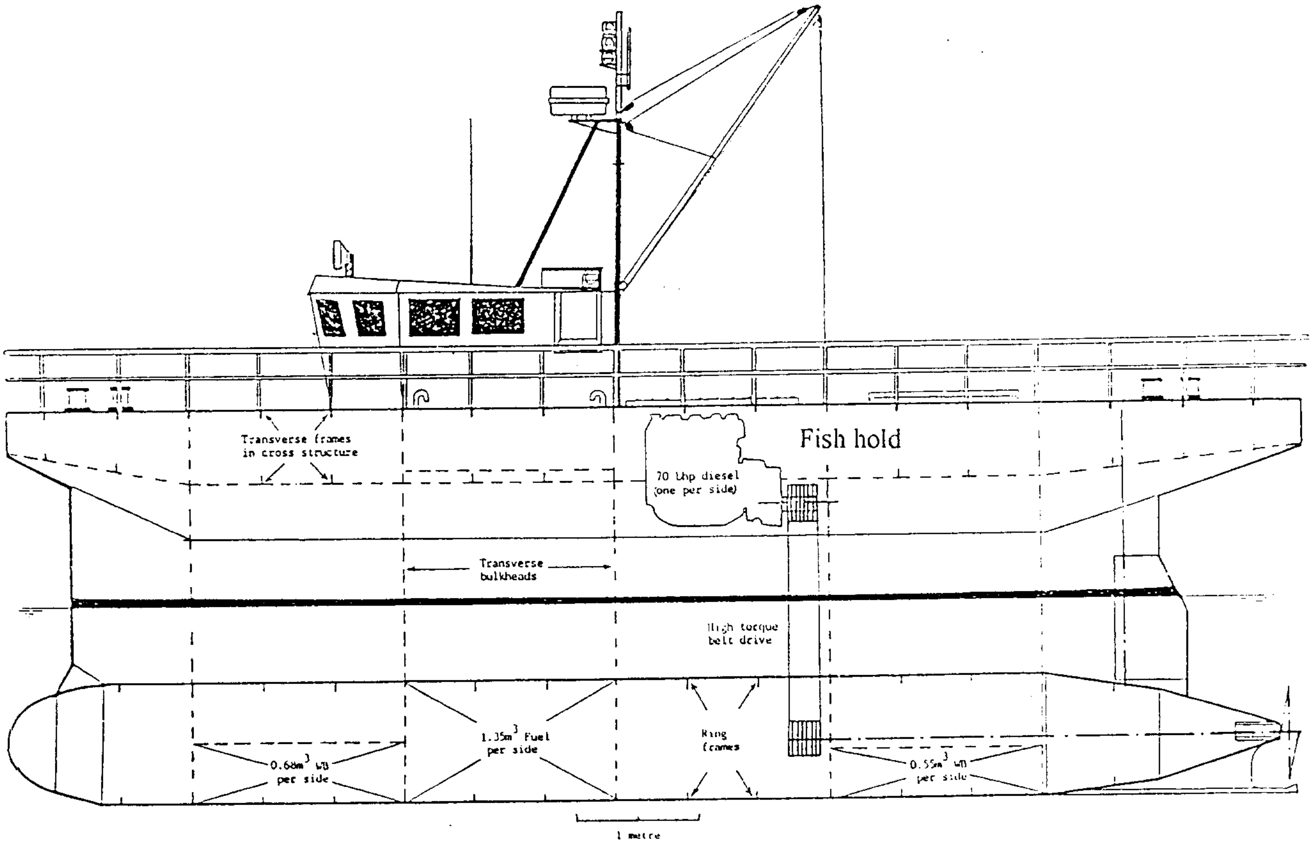


Figure 7: SWATH Ali general arrangement

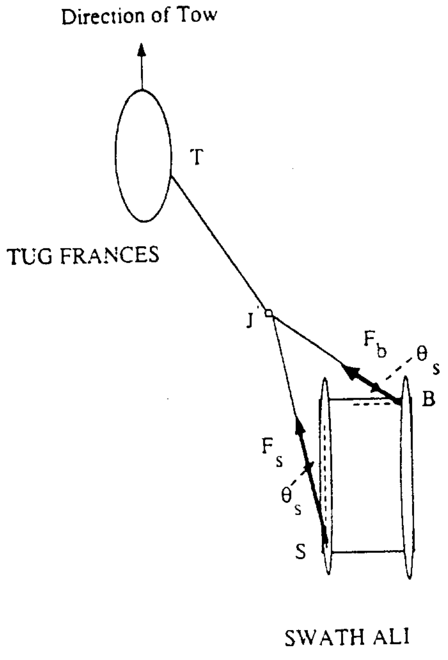


Figure 8: Diagram of towing arrangement

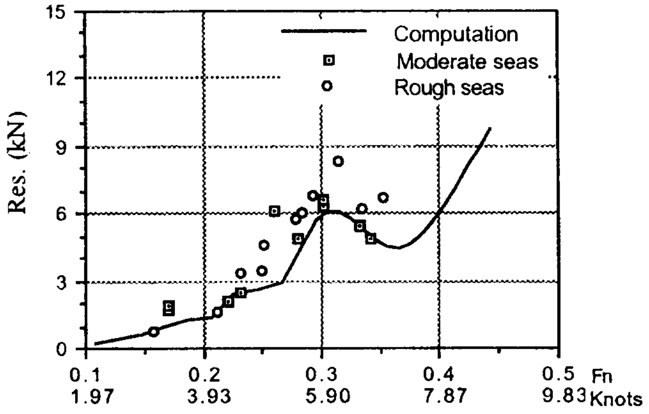


Figure 9: Resistance curve vs speed of 21 tonne SWATH fishing vessel

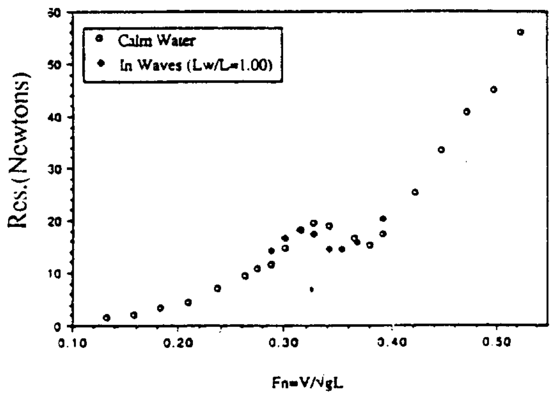


Figure 10: Total resistance of SWATH fishing model in calm water and in waves

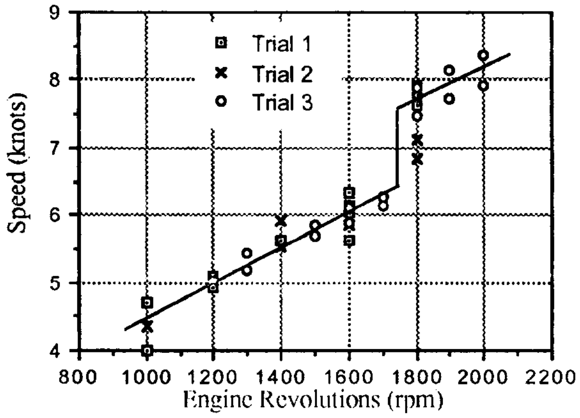


Figure 11: Speed achived against engine revolution(rpm) for the SWATH fishing vessel

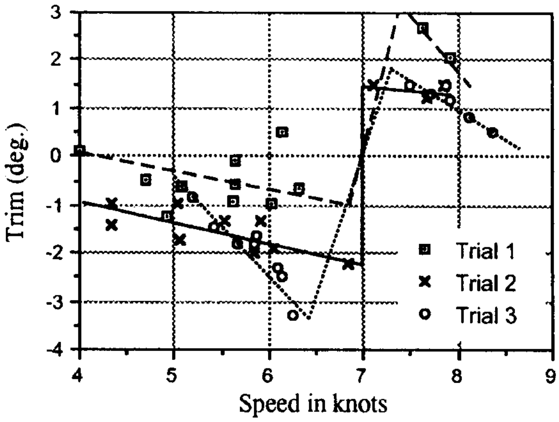


Figure 12: Trim against speed for the SWATH fishing vessel

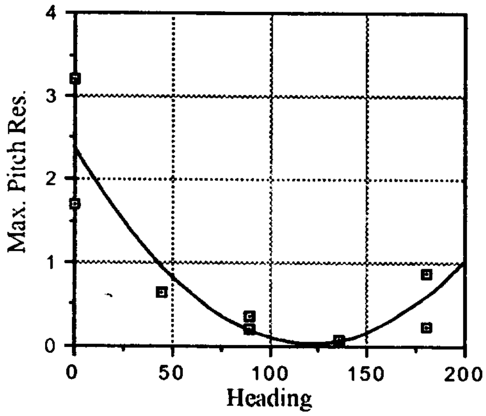


Figure 13: Maximum pitch response vs heading on 6th December 1990

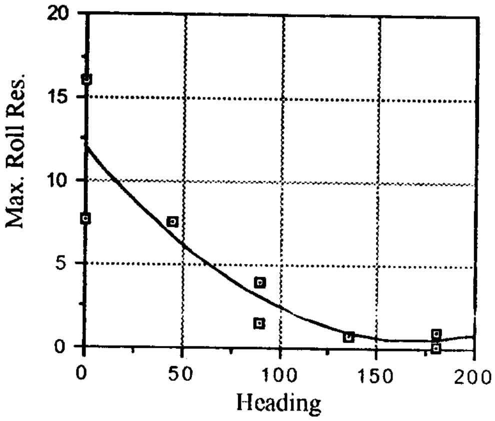


Figure 14: Maximum roll response vs heading on 6th December 1990

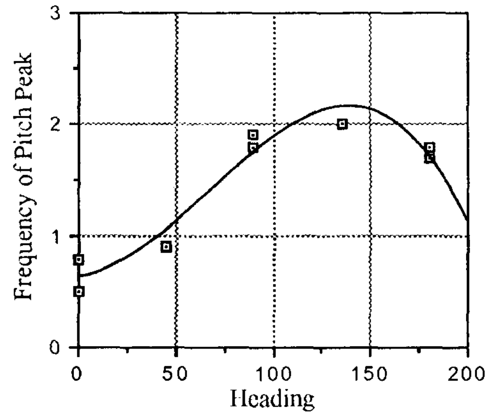


Figure 15: Maximum pitch response vs heading on 6th December 1990

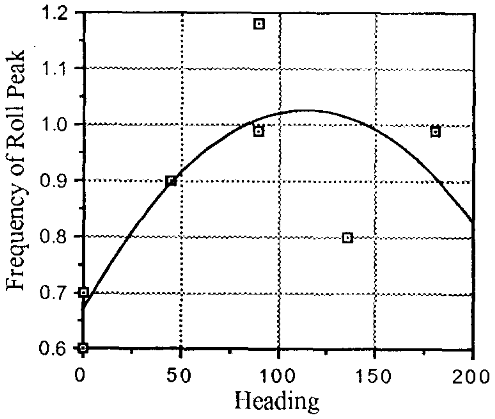


Figure 16: Maximum roll response vs heading on 6th December 1990

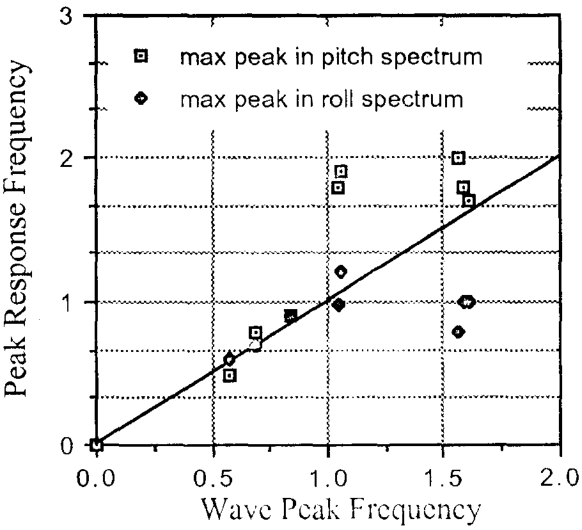


Figure 17: Correlation between peak response and peak of wave energy

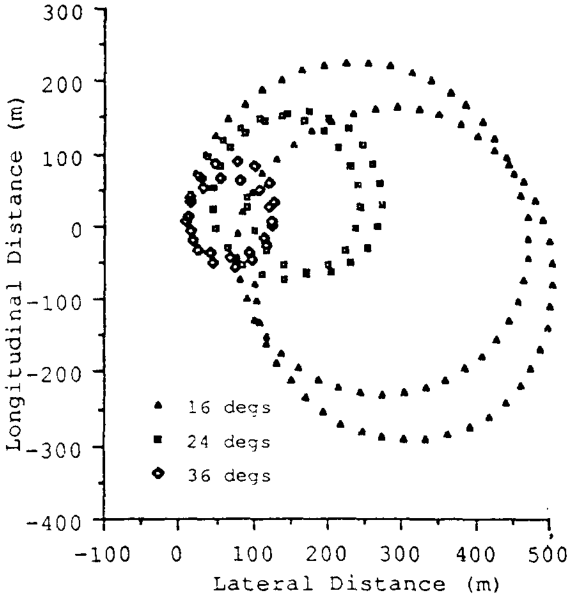


Figure 18: Effect of rudder angle on the turning path at an engine speed of 1400rpm

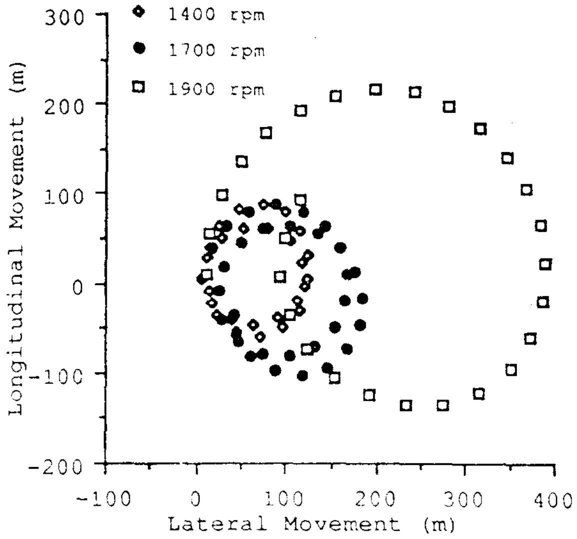


Figure 19: Effect of engine speed on the turning path with the rudder 32 degrees to staboard

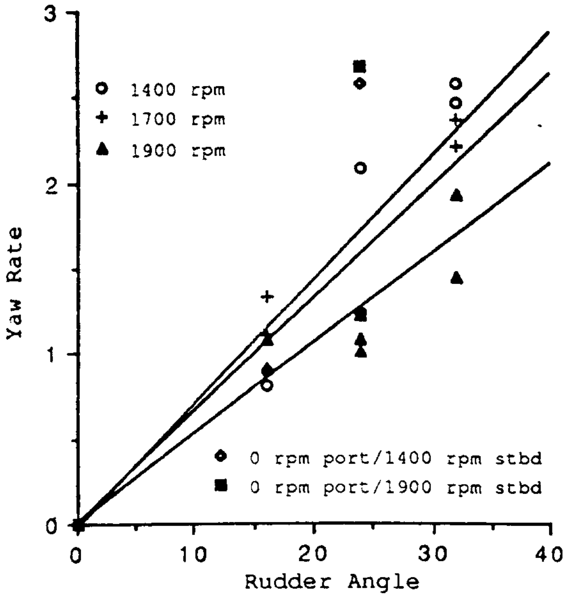


Figure 20: Linear relationship between yaw rate and helm angle

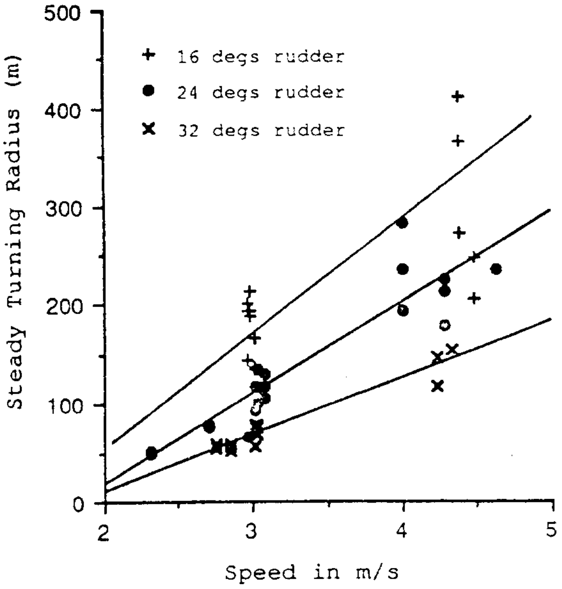


Figure 21: Turning radius against speed for different rudder angles