



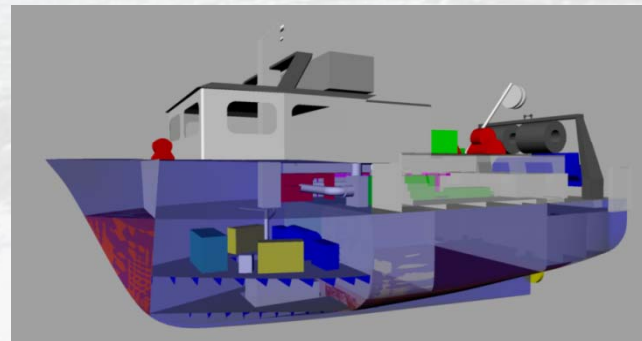
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An Overview of Fishing Vessel Energy Efficiency Work in Newfoundland and Labrador, Canada

By

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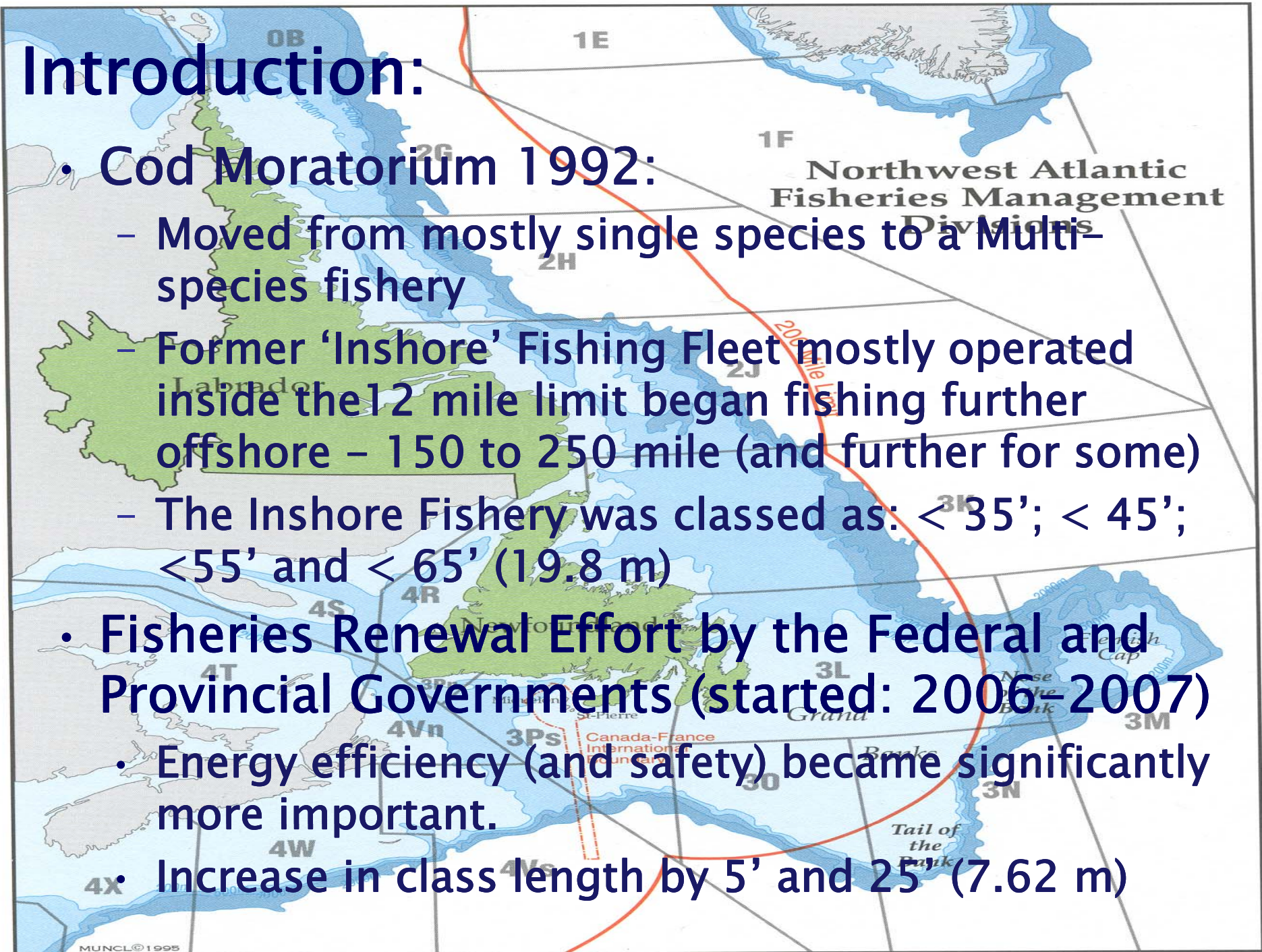
Introduction:

- **Cod Moratorium 1992:**

- Moved from mostly single species to a Multi-species fishery
- Former 'Inshore' Fishing Fleet mostly operated inside the 12 mile limit began fishing further offshore - 150 to 250 mile (and further for some)
- The Inshore Fishery was classed as: < 35'; < 45'; < 55' and < 65' (19.8 m)

- **Fisheries Renewal Effort by the Federal and Provincial Governments (started: 2006-2007)**

- Energy efficiency (and safety) became significantly more important.
- Increase in class length by 5' and 25' (7.62 m)



Tank Testing & Research Overview

- Anti-Roll Tanks for Fishing Vessels under 65' (<19.8m)
- 65' (19.8m) Wave Piercing Catamaran Fishing Vessel
- Influence of Vessel Proportions on Motions and Efficiency
- Analysis of Bulbous Bow Dimensions and Hull Fairing
- Bulbous Bows Design tested:
 - Seakeeping (Zero speed)
 - Resistance
 - Self-Propulsion
 - Added Resistance in Waves
- Vessel Lengths Tested to date:
45' ; 65' ; 110' ; 100' ; 90'
- Design Optimisation/Multi Species
- Energy Efficiency Factsheets
- Multi-year Operational Efficiency Audit

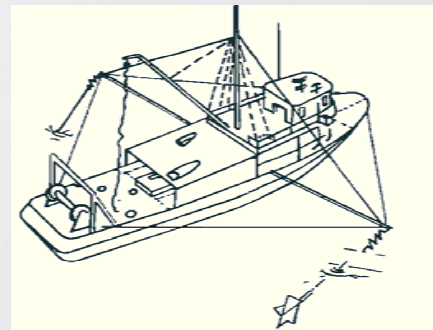


Anti-Roll-Tank (ART) Design For Fishing Vessels :

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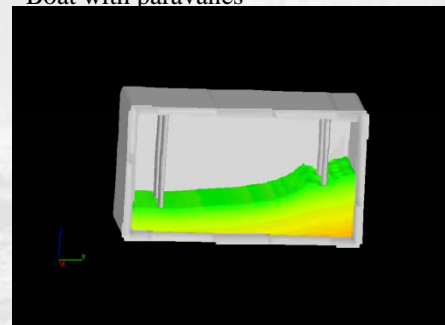
- First venture into Energy Efficiency for Fishing Vessels.
- Model Tests:
 - Computer Simulation Program Developed “Motsim” .
- The tank is designed to match vessel natural roll characteristics & period
 - water = 1.5% to 3% of vessel displacement
 - Baffles = modify flow and thereby delay the onset of tank saturation
 - The tank's righting moment due to the water flow $\sim \frac{1}{4}$ cycle out of phase with the roll motion.



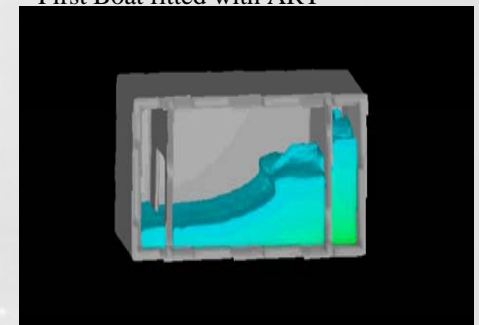
Boat with paravanes



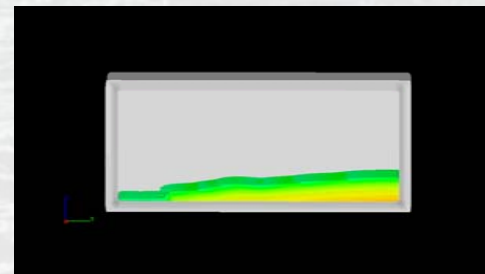
First Boat fitted with ART



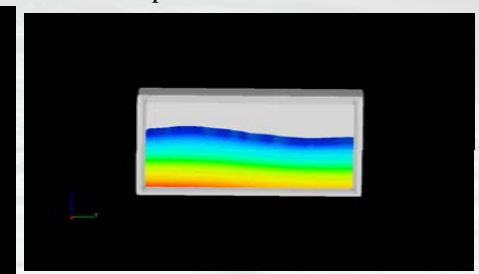
ART with rod baffles



ART with plate baffles



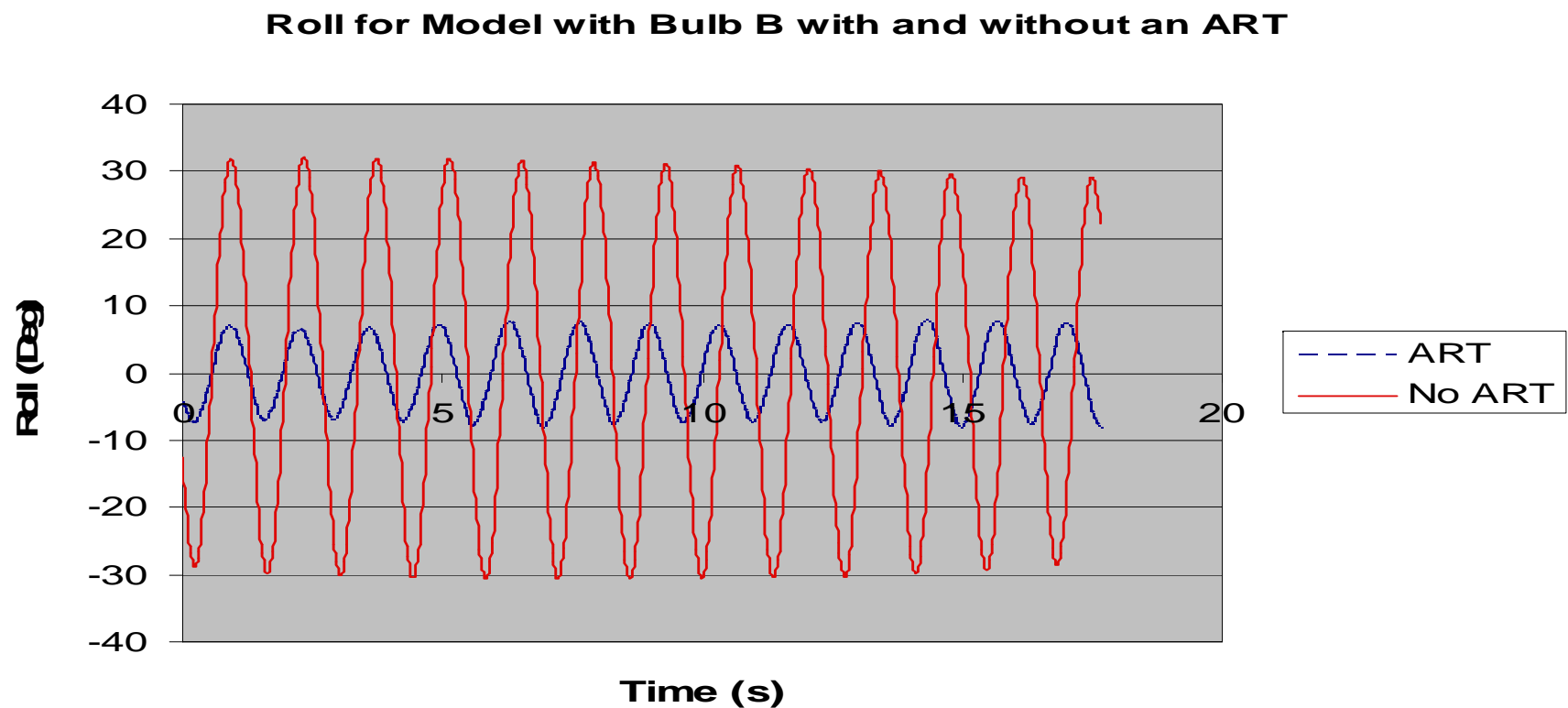
ART with long natural period



ART with short natural period

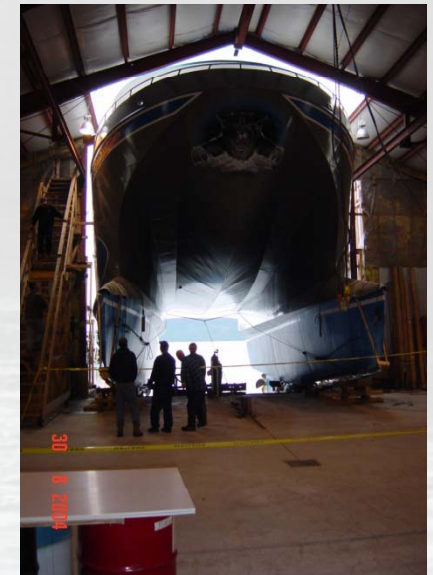
Anti-Roll-Tanks:

- Rougher Operating Conditions = more stable work platform required
- Free Surface Passive ART = safer and more energy efficient than Paravanes (~+10%)
- Looked at Cost and Benefit of Alternatives: Gyroscopes, Batwings, Stabilisers, etc



Wave-Piercing Catamaran:

- Tank tested and modifications to the hull form of a 19.8m (65ft) wave-piercing catamaran:
 - Hull Separations studied: 9.14m (30ft), 10.67m (35ft), and 12.2m (40ft)
 - Seakeeping testing to compare with similar sized mono-hulls
 - At 65' length not a significant difference in resistance so 9.14m (30ft) separation was chosen:
 - This allowed handling by local 'marine centre' Travel Lifts for winter storage and maintenance
 - Tank testing led to demi-hull modification:
 - them narrower and deeper (See Ledge in Photo)
 - sweeping the aft portion up at an angle of 5 to 6 degrees to minimize immersed transom
 - Propulsion study and recommended propeller characteristics



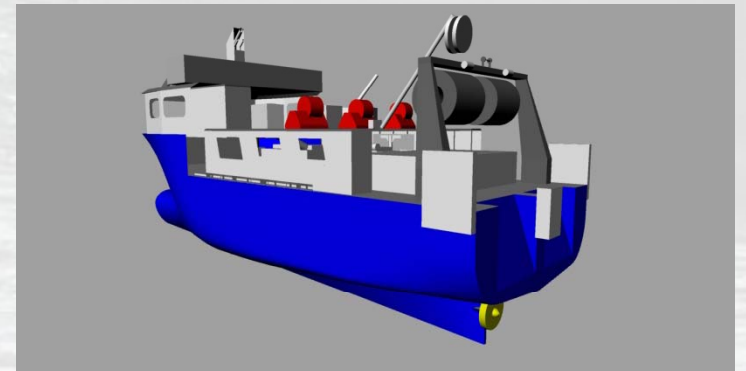
Wave-Piercing Catamaran:

- Resulting performance predictions:
 - Weight Sensitive
 - 20 knots in average loading condition and moderate seas
 - 15 knots at heaviest displacement tested with installed power of 1000HP per demi-hull, (2000HP total)
 - Fuel savings relative to equivalent capacity mono-hull was predicted ~ 30%
 - Seakeeping comparable to similar sized provided proper control of GM and vessel trim could be facilitated



The Influence of Length and Beam:

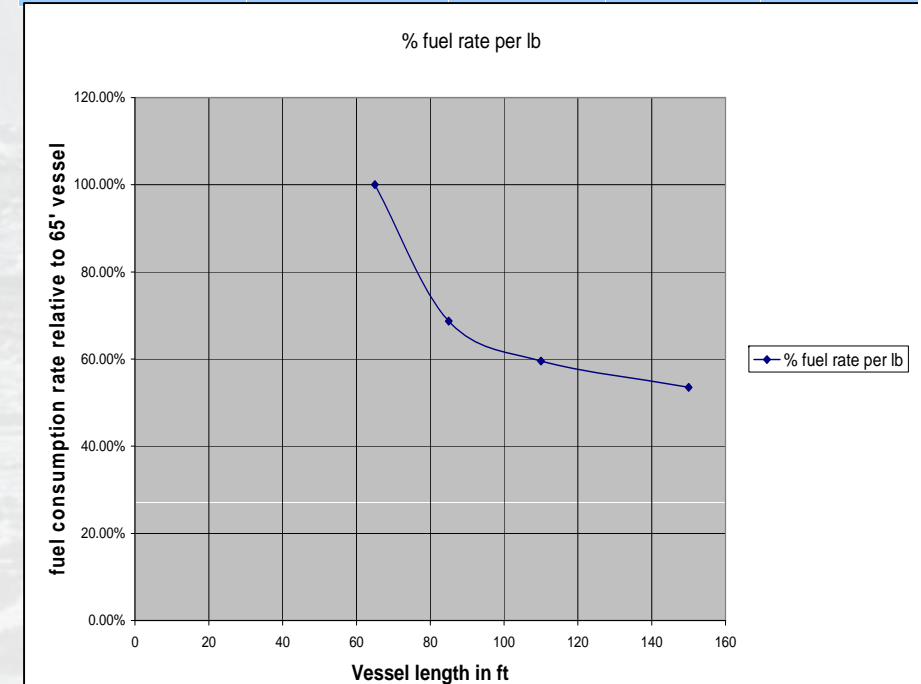
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Vessel Length and Proportions:

- Study carried out on the influence of vessel length.
- The vessels compared to date:
 - 9.8m (65ft) LOA, L/B = 2.4
 - 25.9m (85ft) LOA, L/B = 3.1
 - 27.4m (90ft) LOA, L/B = 3.3
 - 33.5m (110ft) LOA, L/B = 4.0
 - and 45.7m (150ft) LOA, L/B = 4.0
- All boats had a 8.23m (27ft) beam
- Except for the 45.7m (150ft) vessel
 - Same L/B as the 33.5m (110ft) boat. (~11.2 m Beam)

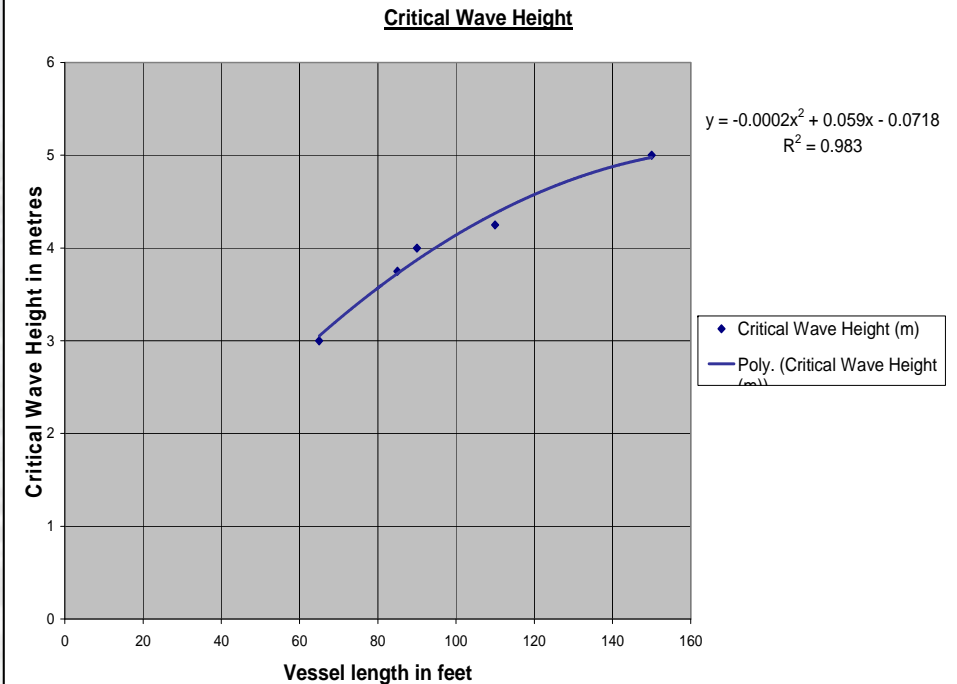
	Relative rates of fuel usage per kg of catch			
	19.8m (65')	25.9m (85')	33.5m (110')	45.7m (150')
Average	100.00%	68.72%	59.56%	53.52%
+ 2 standard deviations	100.00%	66.50%	63.93%	52.19%
- 2 standard deviations	100.00%	72.13%	52.83%	55.58%



Vessel Length and Proportions:

- Seakeeping simulations were used to assess the limiting sea conditions for fishing operations.
- The criterion used is Motion Induced Interrupts (MII).
- The limiting value is roughly 1.0 MII/minute for doing useful work

Vessel Length	Critical Wave Height	Threshold, MII/minute
19.8m (65ft)	3.0 m	0.955
25.9m (85ft)	3.75 m	1.06
27.4m (90ft)	4.0 m	0.992
33.5m (110ft)	4.25 m	0.856
45.7m (150ft)	5.0 m	1.08

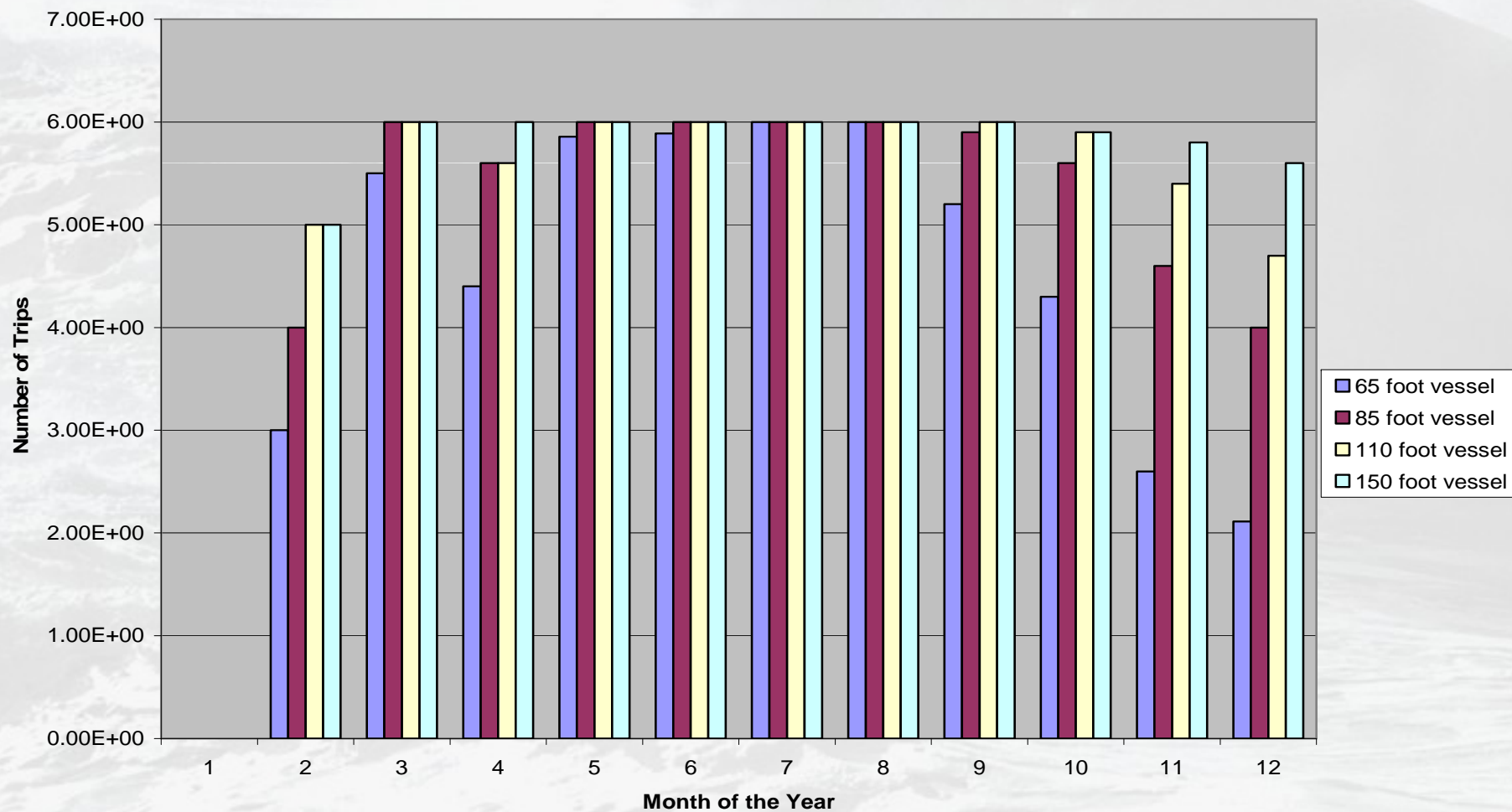


Vessel Length and Proportions:

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Number of 5 day trips for Vessels 65 feet to 150 feet



Vessel Length and Proportions:

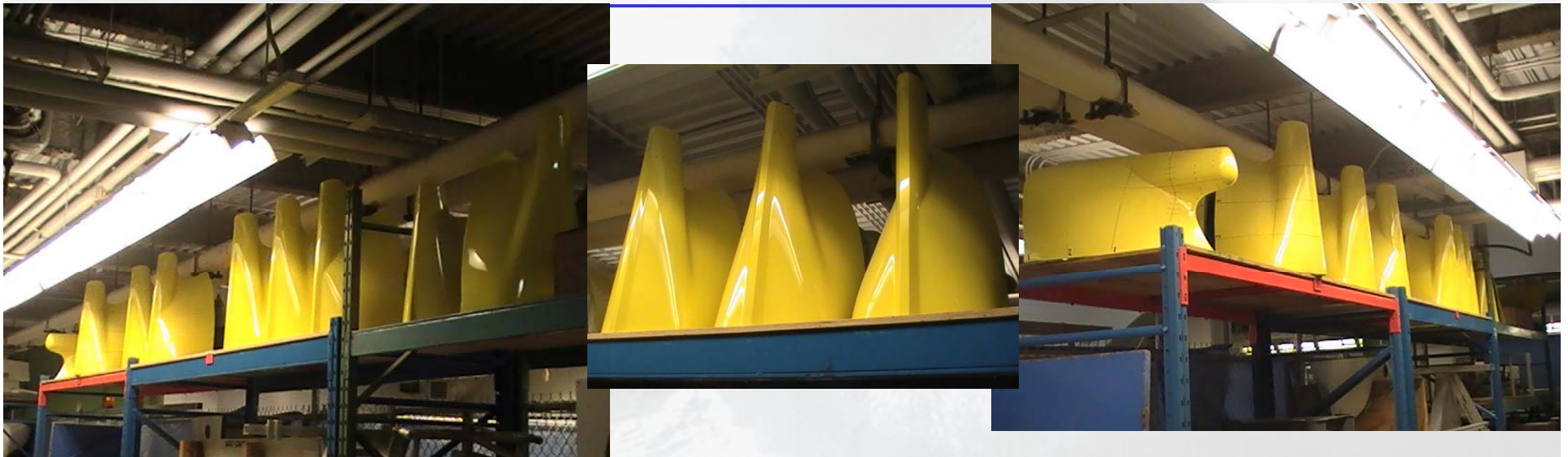
- Study of a 27.41 m (89'-11") boat design:
- Powering was estimated using the Holtrop and Mennen method.
- The hold volumes ranged from 224m³ to 358 m³.
- Steaming at 10 knots the estimated fuel consumption rates : 2,918 → 5,117 l/24hrs.
- MDO : \$0.74 /L CDN

	Difference Relative to 8.23m (27ft) beam in	Relative to 8.23m (27ft) Beam
Beam in ft	Fuel Cost \$/m ³ /24hrs	Fuel Cost/m ³
25	-\$0.96	98.30%
27	\$0.00	100.00%
28	\$0.41	100.57%
29	\$0.80	101.28%
30	\$1.18	101.99%
32	\$1.86	103.30%
34	\$2.46	104.43%
36	\$3.01	105.59%
38	\$3.50	106.66%
40	\$3.96	107.68%

If the increase in fish hold volume is factored in, the increase in fuel cost per m³ of hold space is roughly 2% greater for the 30 ft than the 27 ft beam vessel per 24 hours of steaming

Bulbous Bow Research

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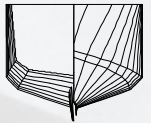


Initial Bulbous Bow Design Work:

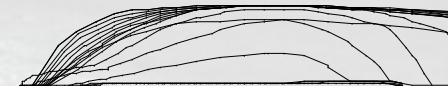
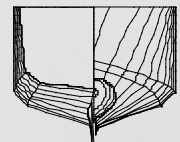
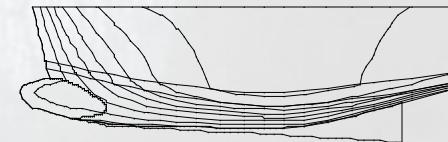
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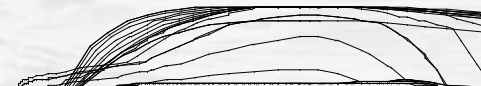
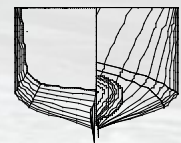
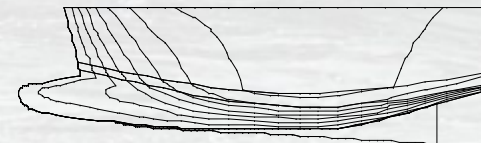
- First project looked at adding a bulb to a 19.8m (65ft) x 8.35m (24ft) boat
- Tank testing calm water
 - Shorter bulb gave about 6% reduction in resistance at around 8 knots
 - Longer bulb gave about 13% reduction
- Tank testing head seas
 - Indicated that significant reductions in Resistance and Pitch Motions in Head Seas could be achieved with the proper bulb design



Original Hull Form



Hull fitted with shorter bulb



Hull fitted with longerr bulb

Multi-Species Fishing Vessel Design and Optimisation:

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- Phase I – looked at the effect of regulations limiting the size of “inshore” fishing vessels prior to change in regulations in 2007
 - Maximum LOA 19.8m (64’-11”)
 - Cubic number maximum 600 m³
- The restricted boat :
 - 8.23m (27’) Beam to comfortably allow for twin trawl
 - Half angle of entrance ~ 51 deg
 - Design displacement 218 tonnes
- The unrestricted vessel:
 - $B = 8.23\text{m (27ft)}$ to comfortably accommodate twin trawl.
 - $\text{LOA} = 30.79\text{m (~100ft)} \rightarrow 33.73\text{m (~110ft)}$
 - Half angle of entrance 35 degrees \rightarrow 28 degs. (stretched)
 - Design displacement is about 396 metric tons.



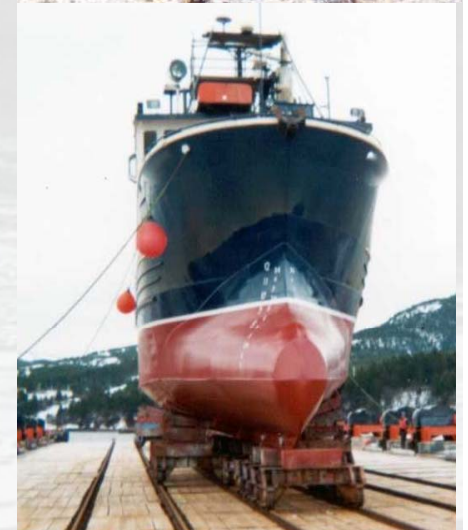
Restricted Vessel



Unrestricted Vessel

Bulbous Bow Practical Results:

- Based on Own and MIT tank test results proceeded to design bulbs for installation on existing and new vessels
- Anecdotal report on results with first 65' bulb retrofit:
 - First year of operation 15% reduction in annual fuel bill
 - Operating season shortened by 1 month due to more efficient fishing operations and steaming to and from grounds
 - Now able to steam at 9 knots +, in conditions where previously only speeds of 5 to 6 knots were possible

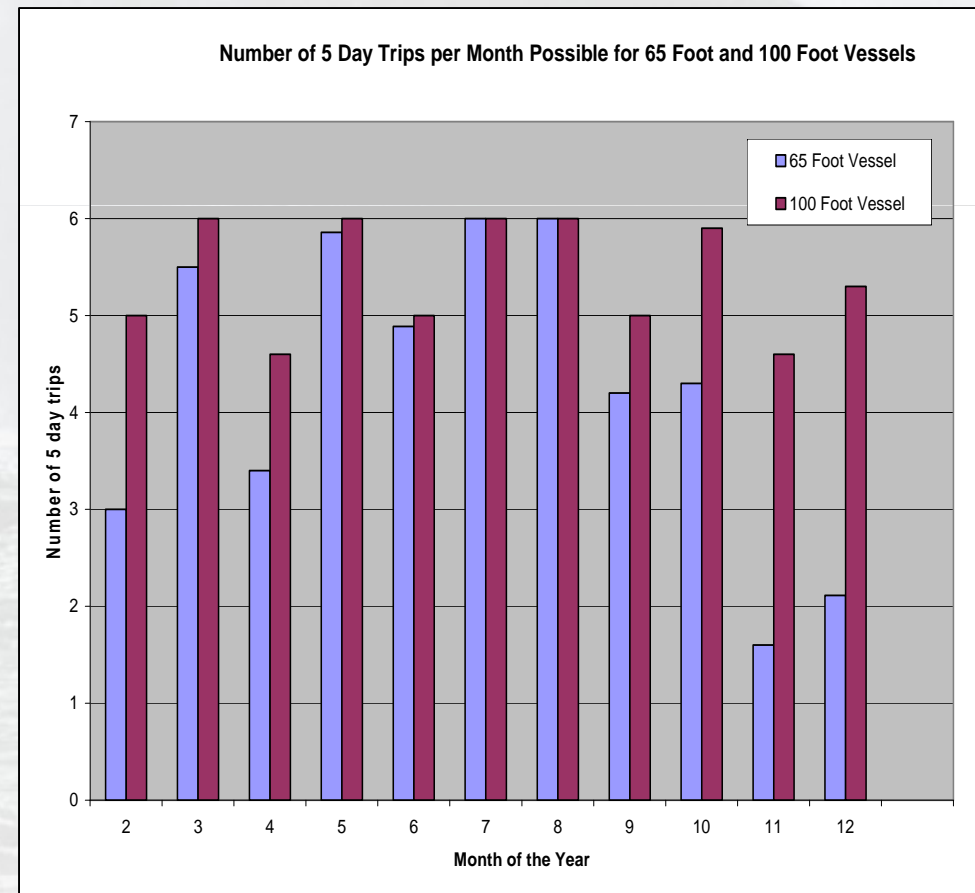


Multi-Species Fishing Vessel Design and Optimisation:

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- Seakeeping simulations were carried out for both of the initial designs:
- Limiting wave height for acceptable MIs:
 - 3 m for the restricted vessel
 - and around 4.5 m for the unrestricted vessel .
- Further tank testing and seakeeping simulations of the longer unrestricted vessel indicated that its seakeeping performance remained similar, yielding about the same limiting wave height.

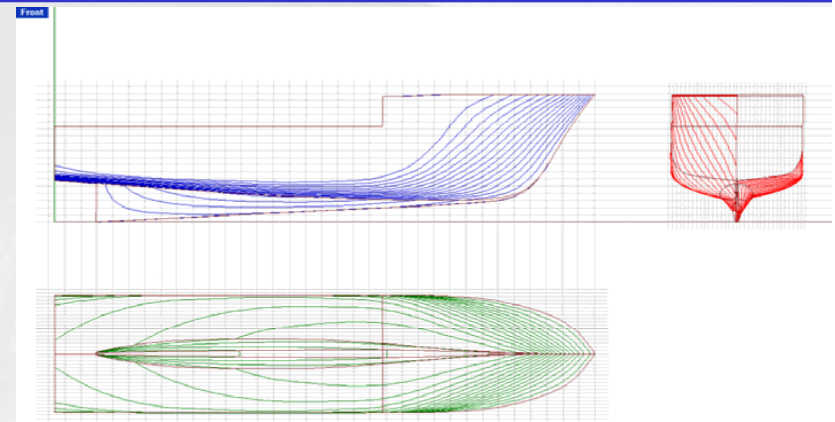


Multi-Species Fishing Vessel Design and Optimisation:

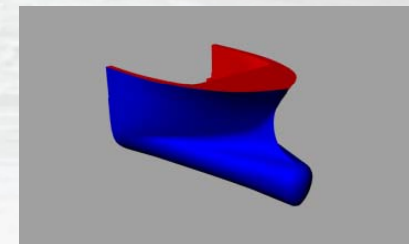
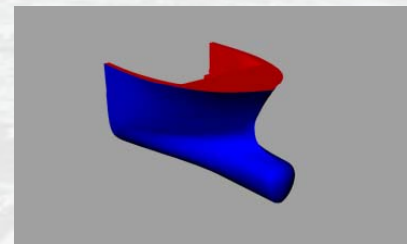
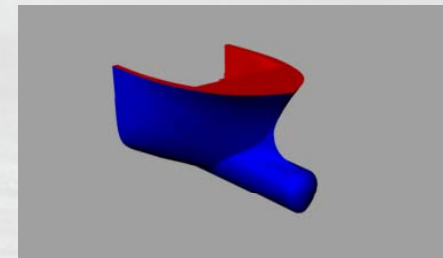
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- Phase 2 consisted of tank testing of the 33.73m (110') LOA hull with:
 - Conventional Bow
 - 4 Bulbous Bow Designs
- The Bulbs were all the same length 4.19m but were faired into the hull differently:
 - Straight Line
 - No-Fairing
 - S-curve Fairing
- The bulb profiles varied slightly
 - The slope varied from 10 to 15 degrees,
 - The fairing radius into the stem varied from 1.14m to 2.1m
- The bulb width at the front was the same for 3 bulbs at 2.0m with the 4th at 1.75m



Lines Plan with Conventional Bow



Multi-Species Fishing Vessel Design and Optimisation:

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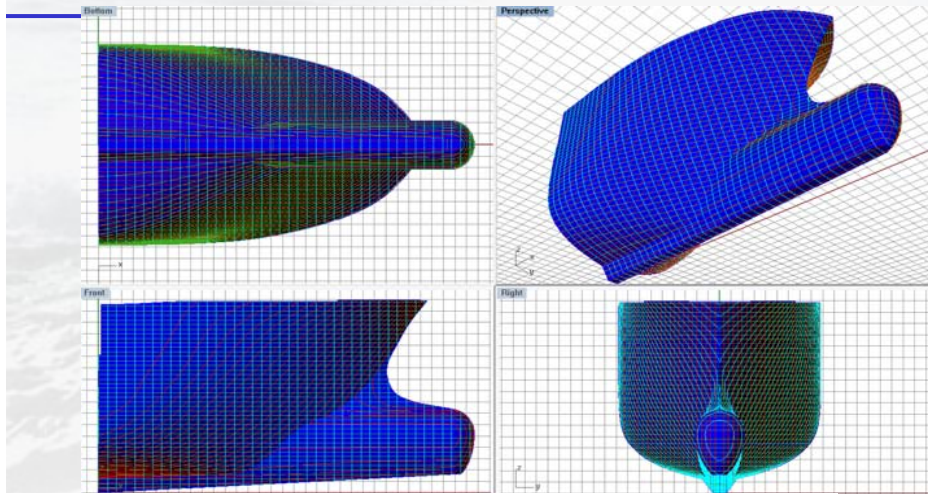


- Resistance Tests: Trim, Displacement & Speed Varied for
- Seakeeping Testing:
 - Regular and Irregular waves
 - Head Seas
 - Quartering
 - Stern Quartering
 - Beam
 - Beam with Anti-Roll -Tanks
- Self-Propulsion Tests K&R Thrust /Torque Dynamometer
- Added Resistance in Waves
- Powering Prediction Simulations
- Monte Carlo Economic Analysis
 - IRR, NPV, Payback (Fuel, Labour, Operation, Catch Price, Capital, Retrofits)

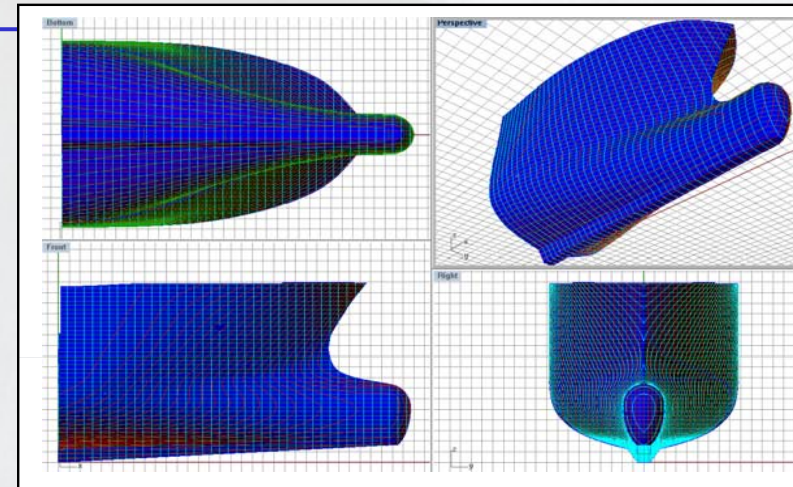


Multi-Species Fishing Vessel Design and Optimisation – 110’:

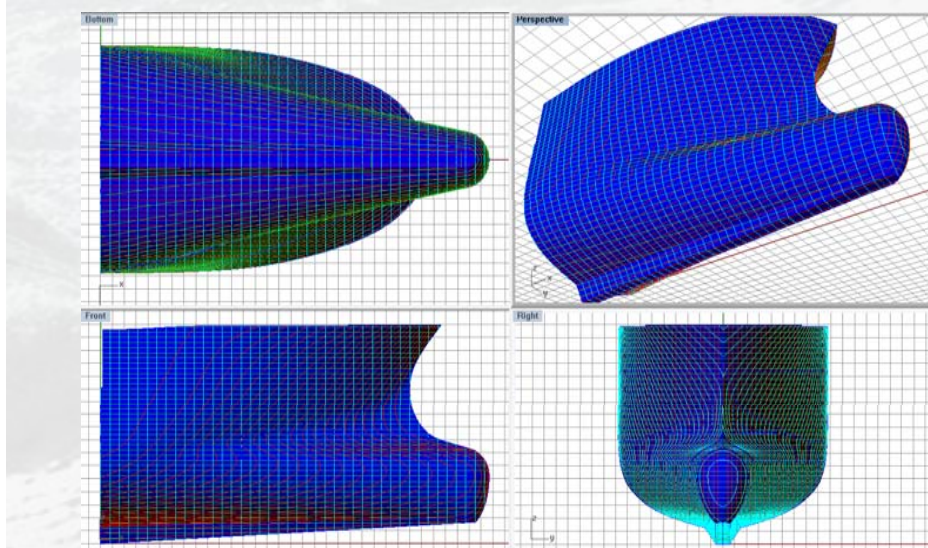
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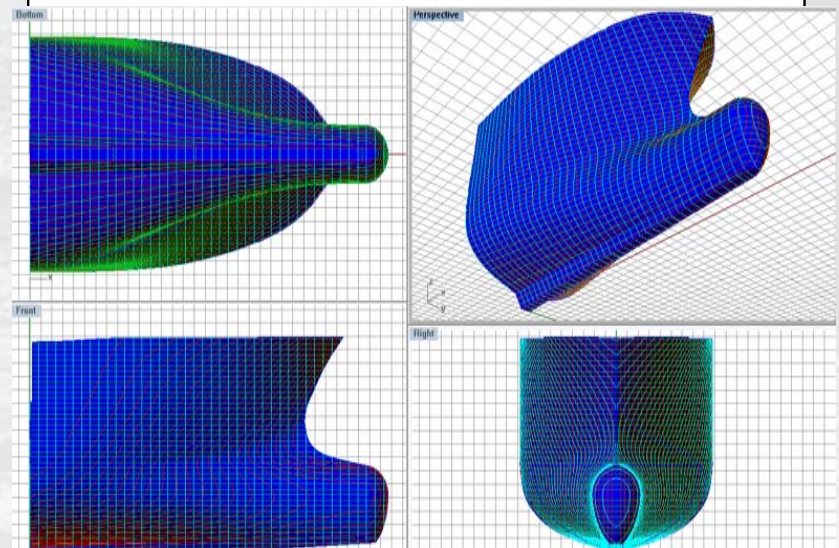
Bulb-D: No-Fairing, slope 10°, Radius 1.14m, width 2.0m



Bulb-G: S-curve fairing, slope 10°, Radius 1.21m, width 1.75m



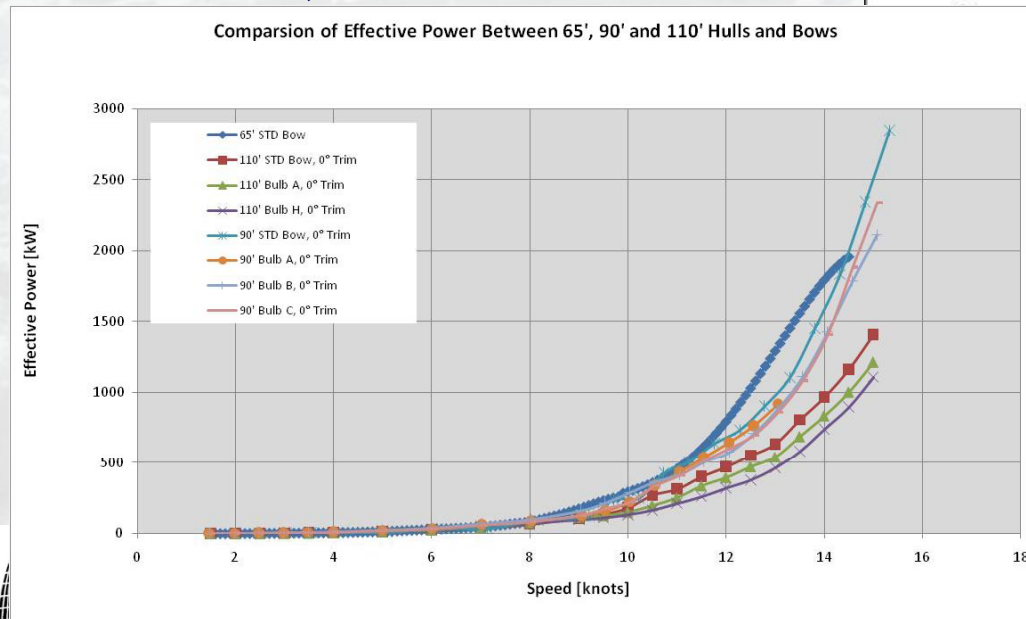
Bulb-C: Straight-line, slope 15°, Radius 2.1m, width 2.0m



Bulb-H: S-curve fairing, slope 10°, Radius 1.14m, width 2.0m

Comparison of Bulb Model Testing Results:

- Further Tank tests with refined bulbs on:
 - 27.41 x 9.14 m (89'11" x 30') – 3 bulbs (L/B = 3)
 - 14 x 4.21 m (45.9' x 13.8') Trawler Yacht – 6 bulbs (L/B ~ 3.33)



• 19+ Bulbs on different hull forms tank tested to date

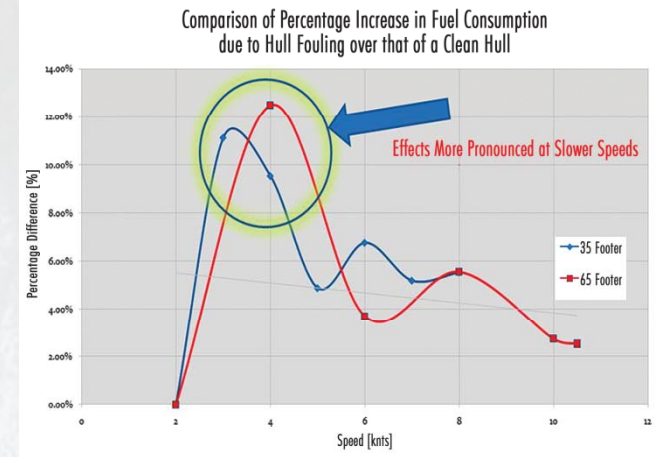
• Correlation Analysis of dimensions and parameters Influencing Bulb performance – Technical Paper (draft)

Energy Efficiency Fact Sheets:

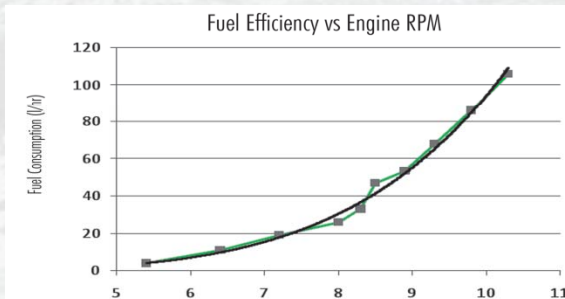
- Energy efficiency workshops around the province of Newfoundland and Labrador. Available at: www.ccfi.ca/
- The following Fact Sheets developed to address the following:
 - The effects of reducing speed
 - Hull maintenance
 - Propulsion and Shafting
 - Fishing Gear
 - Hull Modifications
 - Bulbous Bows and Ant-Roll-Devices
 - Small Vessels (Speedboat Fleet)
 - New Vessel Considerations
 - Cost /Benefit of Refurbishment options



Keel coolers and other protrusions increase drag



The Effect of Hull Fouling



Fuel Consumption per hour versus vessel speed in knots for a 19.8m (65ft) vessel



Proper Sizing of Propeller and selection of RPM; Bigger slower propeller is more efficient

Ongoing Energy Efficiency and Audit Work:

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- Instrumentation of 7 representative vessels of the “inshore fleet” to collect Data over two full fishing seasons:
 - Fuel consumption data (Flowmetres with Digital Output)
 - Environmental data (weather)
 - Vessel speed and heading data
 - Basic Vessel motion data
- Sea trials in relatively calm water plus in a suitable sea state will also be conducted (with a retrievable wave buoy) to obtain:
 - Power on the shaft and wave data
 - Detailed motion data under controlled conditions using a motion pack at the CG
 - This will allow one to benchmark the data collected by the onboard instrumentation
- Full Inspection and Energy Audits will be performed on all 7 boats
- Analysis of the first season’s data will be used to recommend hull or energy systems changes --one per boat-- to test during the second:
 - In this way we will be able to measure directly what the effect on energy consumption is of each through the second season data and new sea trials



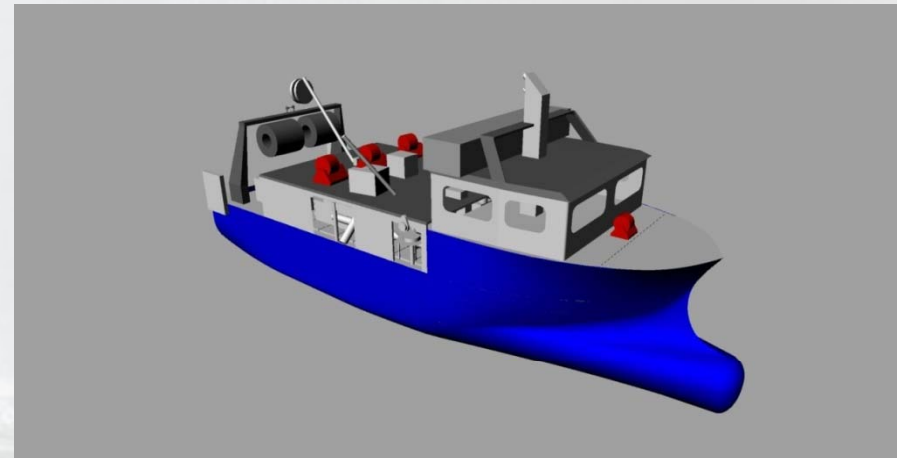
Ongoing Energy Efficiency and Audit Work:

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- Tank test two models representative of the current fleet and scale to the different length classes with two different L/B ratios:

- 10.64m (34'11")
- 13.69m (44'11")
- 16.74m (54'11")
- 19.79m (64'11")



- Seakeeping simulations will also be run to assess MII performance
- Stern extensions of 1.52m (5ft) for the first three length classes to be tested
- The stern extensions have been designed with and without extension of the skeg

Ongoing Energy Efficiency and Audit Work:

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- At least three bulbous bows will be designed and tested for each of the two models: Straight-line, Cylindrical and S-curve
 - Designs will be based on work done for the multi-species project and another project not directly related to the fishery.
 - The intention is to vary both the top bulb profile slope and the stem fairing radius to get a better understanding of the influence of these bulb parameters.
- Further work on optimising the hull characteristics and improving efficiency of the new maximum length $L/B = 3$ (89'11") inshore vessels.
- Modification to some of the existing study vessels after a first season of data collection to record changes in full season operation and sea-trials in calm water and waves

Research Facilities:

- **Memorial University of Newfoundland**
 - Ocean Engineering Research Centre (OERC)
 - 54.7m x 4.57 m x 3.04m Tow Tank with Wave board
 - Tow and Torque/Thrust Dynamometers
 - Small Flume tank and Wind tunnel
 - Deep tank
 - Technical Services: CnC Model Building and Fibreglass/Paint shop
 - Marine Institute of Memorial University
 - Large Flume Tank
 - Full Bridge and Engine Room Simulators
- **Next To NRC/CNRC – Institute of Ocean Technology in St. John’s**
 - Insulated Ice Tank Tow Tank
 - Large Ocean Wave Basin
 - Large Tow Tank with Beach
 - Cavitation Tunnel
 - CnC and Extensive Model Building Facilities



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CONCLUDING SLIDE