Fisheries and Oceans Canada / Pêches et Océans Canada
Science / Sciences

C S A S / **S C C S**

Canadian Science Advisory Secretariat / **Secrétariat canadien de consultation scientifique**

Research Document 2010/071 / **Document de recherche 2010/071**

Modelling the Cosmos 2600 shrimp trawl

Modélisation du chalut à crevettes Cosmos 2600

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ISSN 1499-3848 (Printed / Imprimé)
ISSN 1919-5044 (Online / En ligne)

Canada

Correct citation for this publication:

Siferd, T.D. 2010. Modelling the Cosmos 2600 shrimp trawl. DFO Can. Sci. Advis. Sec. Res. Doc. 2010/071. iv + 8 p.

ABSTRACT

The Cosmos 2600 shrimp trawl is used for Fisheries and Oceans Canada Central and Arctic Region's multi-species surveys conducted from the Greenland Institute of Natural Resources' research vessel Paamiut. The Centre for Sustainable Aquatic Resources, Memorial University of Newfoundland, constructed an exact model of the trawl which was tested in their flume tank facility. A mathematical model was produced to determine wing spread from door spread and tow speed. The model is used to normalize catch between stations so that standardized biomass estimates can be produced for stock assessment purposes.

RÉSUMÉ

La Région du Centre et de l'Arctique de Pêches et Océans Canada utilise le chalut à crevettes Cosmos 2600 pour effectuer des relevés plurispécifiques avec le navire scientifique Paamiut de l'Institut des ressources naturelles du Groenland. Le Centre for Sustainable Aquatic Resources de l'Université Memorial de Terre-Neuve a construit une réplique précise du chalut qui a été mise à l'essai dans leur bassin d'essais. On a produit un modèle mathématique pour déterminer l'envergure des ailes en fonction de l'ouverture des panneaux et de la vitesse de remorquage. Le modèle est utilisé pour normaliser les données sur les prises entre les stations afin que l'on puisse produire des estimations normalisées de la biomasse qui pourront être utilisées pour l'évaluation des stocks.

INTRODUCTION

In 2006, Fisheries and Oceans Canada's (DFO) Central and Arctic Region (C&A) expanded its multi-species survey program to include shrimp surveys in waters adjacent to Nunavut and Nunavik. Surveys are conducted from the Greenland Institute of Natural Resources' (GINR) research vessel Paamiut using a Cosmos 2600 shrimp trawl. The Paamiut is outfitted with a Marport MBAR used to monitor trawl geometry, with only the direct measurements of door spread and headline height available. Wing spread, however, is the most important measure in determining the swept area covered by the trawl which allows catch to be normalized between sampling stations and a standardized biomass determined for assessment purposes. Wing spread must therefore be calculated from the door spread measurement.

The GINR developed an equation based on similar-triangle trigonometry for the conversion of door spread to wing spread by assuming the trawl, from door spread to wing spread to the codend, forms a constant triangle (Bergstrøm 2007). The Cosmos trawl has a trouser-shaped codend making the determination overall length problematic. Therefore, the trapezoidal version of the equation (Fig. 1; Bergstrøm pers. comm.) based on the diameter of the codend attachment point was used to standardize DFO-C&A survey results for the 2008 assessment of shrimp stocks in the north (DFO 2008).

The consistency of the Cosmos trawl as a triangle when in the water and the accuracy of the GINR conversion formula are unknown. To examine this assumption and the formula from it under simulated *in situ* conditions, an exact model of the Cosmos 2600 shrimp trawl was produced for testing in a flume tank.

MATERIALS AND METHODS

The 2600 is a commercially produced shrimp trawl manufactured by Cosmos Trawl of Denmark. Harold DeLouche, Tara Perry and George Legge of the Centre of Sustainable Aquatic Resources (CSAR), Memorial University of Newfoundland, were contracted to construct an exact 1:10 scale model of the Cosmos trawl used on the Paamiut. The model was based on the trawl schematics and a detailed parts list supplied by Cosmos Trawl supplemented with measurements and observations of the actual trawl onboard the Paamiut. This ensured that any modifications made to the trawl between its delivery from the factory and its use on the ship were taken into account. The final configuration of the model is shown in Figure 2.

The Cosmos model was tested at CSAR's Flume Tank facility in St. John's, Newfoundland (for further information see http://www.mi.mun.ca/csar/flume_tank.htm). The Cosmos model was attached to the flume tank masts, representing the trawl doors, with a bridle and sweep line scaled to that used on the Paamiut. Tests were conducted at simulated door spreads of 40 to 70 m with 5 m steps each over towing speeds of 1.5 to 4.0 knots with 0.5 knot increments. At each combination, the upper and lower wing spread, opening from fishing line to the wing and headline and headline height from the bottom was measured using the flume tanks' optical measuring devices. Tension on the port and starboard bridles were measured with load cells connected inline between the mast and bridle.

During the 2009 DFO-C&A multi-species survey in Hudson Strait, wing spread sensors were added to the Cosmos trawl monitoring package. Marport spread sensors enclosed in protective stainless steel canisters were attached below the upper wing directly behind the bridle attachment. When installed both door and wing spread measurements were recorded by the Marport MBAR.

RESULTS AND DISCUSSION

Measurements of the Cosmos model were collected at 39 combinations of tow speed and door spread (Table 1). A multiple regression, relating the average wing spread measured from the model to door spread and tow speed set for the flume tank, was performed using SigmaStat statistical software (Jandel Corporation San Rafael, California). The regression equation produced was:

$$\text{LN wing spread} = 0.643 + (0.0299 * \text{LN tow speed}) + (0.67 * \text{LN door spread})$$

where wing and door spread are in meters and tow speed is in knots. Regression statistics are shown in Table 2.

Wing spreads were calculated using the GINR equation for all the combinations of door spread and tow speed tested with the model in the flume tank. The GINR wing spread and wing spread produced by the equation above are very similar at the narrowest door spread and slowest tow speed but diverge immediately with about a 7 m difference at the high end of the scales (Fig. 3). When using the Cosmos trawl on DFO-C&A surveys we try to target a standard tow of 15 minutes at 2.6 knots which results in a standard tow length of approximately 1.2 km. The difference between the two equations would translate into an overestimate of the swept area of up to 8400 m^2.

In flume tank testing, door spread was held constant through changes in tow speed. As the tow speed increased the pressure on the trawl increased as seen in the increasing bridle tension recorded in Table 1. In full scale, the warps, doors, bridles and the trawl are a system, each of which can move independently adjusting to the tensions acting on them. In the flume tank, the model trawl can only adjust to the increased pressure through the bridle and trawl as the doors are fixed and there are no warps. Although this may be seen as a flaw in the method, the same trawl geometry should be observed full scale under the same door spread and tow speed. The bottom of the flume tank is a large belt which moves against the model at tow speed which simulates contact friction of the footgear as a trawl moves over the sea bottom. While floor is relatively smooth, the model does experience drag as evidenced by the roll of rockhopper disks while under tow. The way in which bottom composition and/or roughness might affect full scale trawl geometry is unknown.

During the 2009 survey, 40 stations were sampled where direct simultaneous measurements of door and wing spread were recorded over water depths of 143 to 972 m. This allowed for a real world comparison of a full scale trawl to the modelling results. The modelled equation compared very well with direct measurements with 74% of the sets having less than 0.5 m difference and only one greater than 1 m at 1.39 m difference. Swept area calculated from the model equation based on the simultaneous door spread measurements versus the direct wing spread measurements had only slightly higher average absolute difference of 0.7% (Fig. 4). The same observed mean tow speed and time were used in all calculations. As one might expect from the results above, the swept area calculated with the GINR equation produced a larger average absolute difference of 17.5% higher than the direct measurements. Also, the two lines diverge as the spread increases just as observed in the modelling results.

In conclusion the modelled equation produces a more accurate estimate of wing spread for the Cosmos trawl and therefore a more accurate measure of swept area. When direct measurements of wing spread are not available the modelled equation will be used for the conversion of door spread to wing spread on DFO-C&A shrimp surveys.

REFERENCES

Bergstrøm, B. 2007. Results of the Greenland bottom trawl survey for northern shrimp (*Pandalus borealis*) off West Geenland (NAFO Sub area 1 and Division 0A), 1988-2007. NAFO SCR Doc. 07/71. Ser. No. N5457. 44 p.

DFO. 2008. Assessment of northern shrimp (*Pandalus borealis*) and striped shrimp (*Pandalus montagui*) in shrimp fishing areas 0, 2 and 3. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2008/018.

Table 1: Wing spread, opening, headline height from bottom, bridle tension mouth area and bridle angles of the Cosmos trawl measured for all combinations tow speed and door spread tested in the flume tank. All measurements have been scaled up from the model to full scale values. Note: mouth area is an approximation calculated by multiplying the headline opening by the average of the upper and lower wing spread.

Tow Speed (knots)	Spread				Opening		Headline Height From Bottom (m)	Bridle tension		Mouth Area (m^2)	Bridle Angle (deg.)
	Door (m)	Upper Wing (m)	Lower Wing (m)	Wing Ave. (m)	Wing (m)	Headline (m)		Port (t)	Starboard (t)		
1.5	40	22.2	22.7	22.5	6.3	14.4	14.8	2.7	2.8	323.7	8.7
2.0	40	22.6	22.9	22.7	6.0	13.6	14.0	4.0	4.1	309.3	8.6
2.5	40	22.9	23.0	22.9	5.8	12.9	13.3	5.6	5.9	295.8	8.5
3.0	40	23.3	23.1	23.2	5.6	12.2	12.6	7.6	8.0	282.6	8.3
3.5	40	23.2	23.1	23.2	5.3	11.4	11.8	9.6	10.1	264.0	8.3
4.0	40	23.5	23.2	23.4	5.0	10.4	10.8	12.1	12.9	242.9	8.2
1.5	45	24.2	24.9	24.5	6.2	13.9	14.3	2.8	2.9	340.8	10.2
2.0	45	24.6	25.3	24.9	5.9	13.0	13.4	4.1	4.2	323.8	10.0
2.5	45	25.0	25.4	25.2	5.7	12.1	12.5	5.8	6.0	305.0	9.8
3.0	45	25.3	25.4	25.4	5.5	11.4	11.8	7.8	8.2	289.0	9.8
3.5	45	25.5	25.2	25.4	5.1	10.5	10.9	9.9	10.5	266.2	9.8
4.0	45	25.7	25.1	25.4	4.9	9.8	10.2	12.3	13.3	248.7	9.7
1.5	50	26.0	26.8	26.4	6.2	13.4	13.8	2.9	2.9	353.4	11.8
2.0	50	26.5	27.3	26.9	5.8	12.2	12.6	4.2	4.4	328.2	11.5
2.5	50	26.8	27.2	27.0	5.6	11.5	11.9	5.9	6.2	310.2	11.4
3.0	50	27.2	27.1	27.1	5.3	10.7	11.1	7.8	8.4	290.3	11.4
3.5	50	27.1	27.0	27.1	5.0	9.9	10.3	9.9	10.7	267.6	11.4
4.0	50	27.6	27.1	27.4	4.7	9.1	9.5	12.5	13.5	248.9	11.3
1.5	55	27.6	28.7	28.2	6.2	12.8	13.2	2.9	3.0	360.4	13.4
2.0	55	28.2	29.1	28.7	5.8	11.7	12.1	4.3	4.4	335.3	13.1
2.5	55	28.5	29.1	28.8	5.5	10.8	11.2	6.0	6.3	311.3	13.0
3.0	55	29.1	29.1	29.1	5.2	9.9	10.3	7.9	8.5	288.0	12.9
3.5	55	29.0	28.9	29.0	4.8	9.1	9.5	10.1	10.9	263.5	13.0
4.0	55	29.3	28.9	29.1	4.5	8.5	8.9	12.4	13.8	247.3	12.9
1.5	60	29.3	30.4	29.9	6.1	12.3	12.7	3.0	3.0	367.2	15.1
2.0	60	30.1	30.8	30.4	5.8	11.1	11.5	4.4	4.5	337.8	14.8
2.5	60	30.2	30.7	30.5	5.4	10.1	10.5	6.2	6.3	307.8	14.7
3.0	60	30.7	30.8	30.7	5.0	9.2	9.6	8.1	8.6	282.5	14.6
3.5	60	30.6	30.5	30.5	4.7	8.5	8.9	10.0	11.1	259.4	14.7
4.0	60	30.9	30.6	30.7	4.5	7.9	8.3	12.4	13.9	242.7	14.6
1.5	65	30.9	32.1	31.5	6.1	11.8	12.2	3.1	3.1	371.5	16.8
2.0	65	31.6	32.2	31.9	5.7	10.6	11.0	4.4	4.6	338.2	16.6
2.5	65	31.7	32.2	31.9	5.3	9.5	9.9	6.2	6.4	303.3	16.6
3.0	65	32.1	32.1	32.1	4.9	8.5	8.9	8.1	8.6	273.1	16.5
3.5	65	32.0	32.0	32.0	4.6	7.9	8.3	10.1	10.9	252.7	16.5
4.0	65	32.3	32.2	32.2	4.4	7.2	7.6	12.4	13.8	232.1	16.4
1.5	70	32.2	33.7	33.0	6.2	11.4	11.8	3.1	3.1	375.9	18.6
2.5	70	33.1	33.7	33.4	5.3	8.9	9.3	6.2	6.5	297.0	18.4
3.5	70	33.6	33.5	33.5	4.5	7.2	7.6	10.1	11.0	241.4	18.3

Table 2: Statistical output from the multiple regression relating wing spread to a combination of door spread and tow speed.

Equation: LN Wing Spread = 0.643 + (0.0299 * LN Speed) + (0.670 * LN Door Spread)

N=39

R=0.998 Rsqr=0.997 Adj. Rsqr=0.997

Estimated Error of Estimate = 0.007

	Coefficient	Std. Error	t	P
Constant	0.643	0.025	25.665	<0.001
LN Speed	0.0299	0.0033	9.056	<0.001
LN Door Spread	0.67	0.00622	107.605	<0.001

Analysis of Variance:

	DF	SS	MS	F	P
Regression	2	0.556	0.278	5802.9	<0.001
Residual	36	0.00173	0.0000479		
Total	38	0.558	0.0147		

Column	SSIncr	SSMarg
LN Speed	0.00129	0.00393
LN Door Spread	0.555	0.555

The dependant variable LN Wing Spread can be predicted from a linear combination of the independent variables:

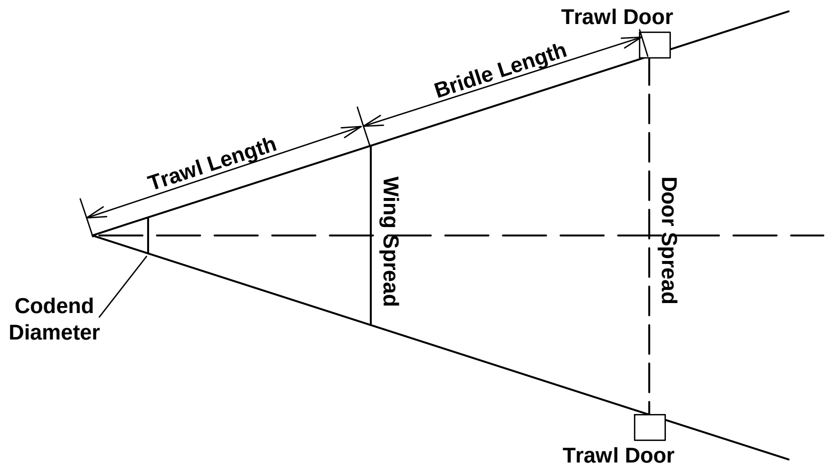
	P
LN Speed	<0.001
LN Door Spread	<0.001

All independent variables appear to contribute to predicting LN Wing Spread (P<0.05).

Normality Test: (P=0.702) Passed

Constant Variance Test (P=0.707) Passed

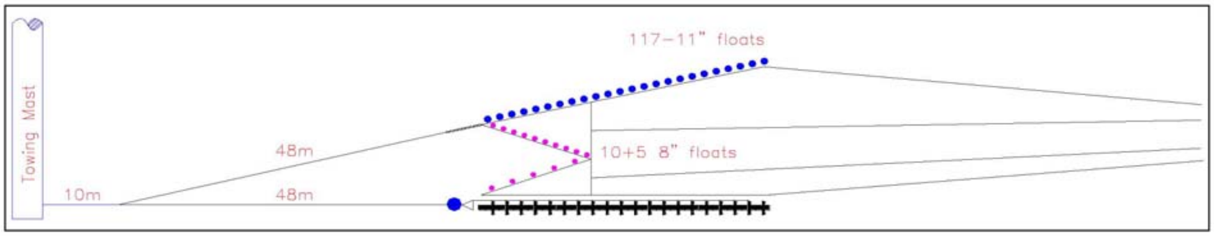
Power of performed test with alpha = 0.050:1.000



Wing Spread = Codend Diameter +

$$\frac{\textbf{Trawl Length * (Door Spread-Codend Diameter)}}{\textbf{Trawl Length + Bridle Length}}$$

Figure 1: The Greenland Institute of Natural Resources method for the estimation of wing spread from measured door spread for the Cosmos Trawl. The method was used for DFO Cosmos trawl surveys to standardize of biomass reported at the 2008 ZAP.



Upper Bridle Length (m)	Lower Bridle Length (m)	Fishing Line Floats	Lower Wing Line Floats	Upper Wing Line Floats	Sweep Length (m)	Headlin e Floats	Headline Buoyancy (kgf)
48.0	48.0	176	5	10	10.0	117	877.5

Figure 2: Configuration of the Cosmos 2600 model tested in the CSAR flume tank.

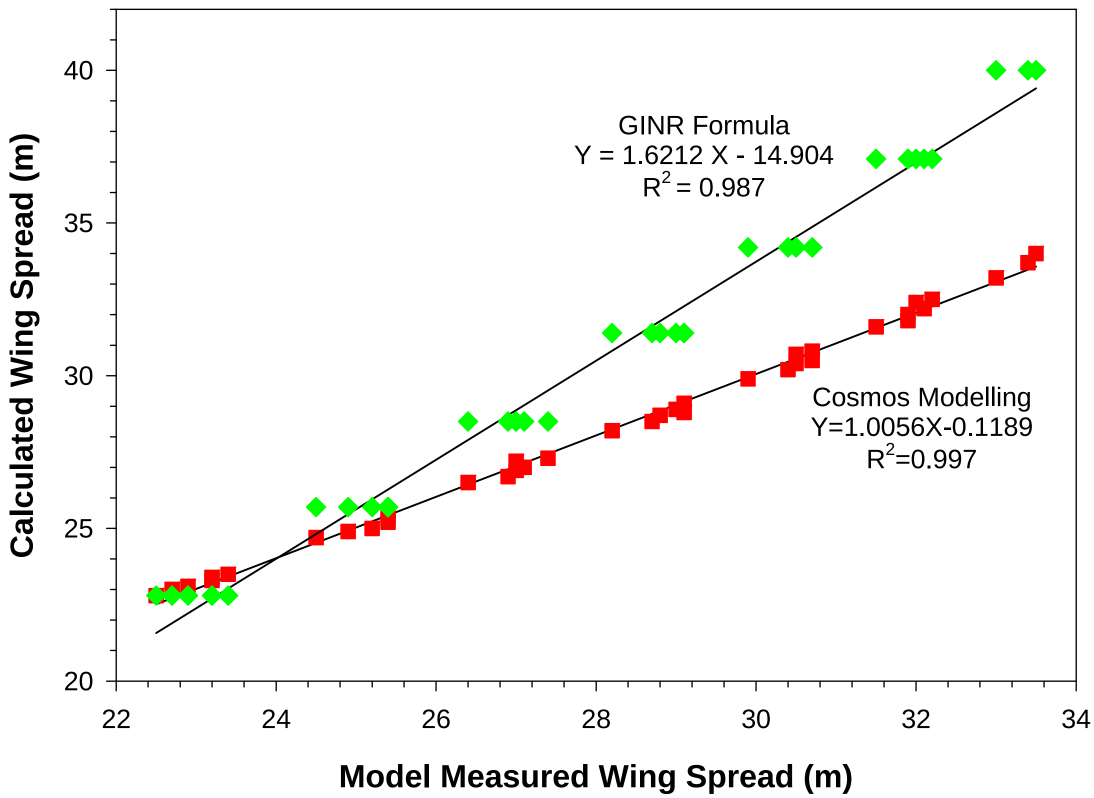


Figure 3: Comparison of the Cosmos model wing spread measured in the flume tank and that calculated by the GINR equation using door spread (green diamonds) and the Cosmos modelled equation using door spread and tow speed (red squares).

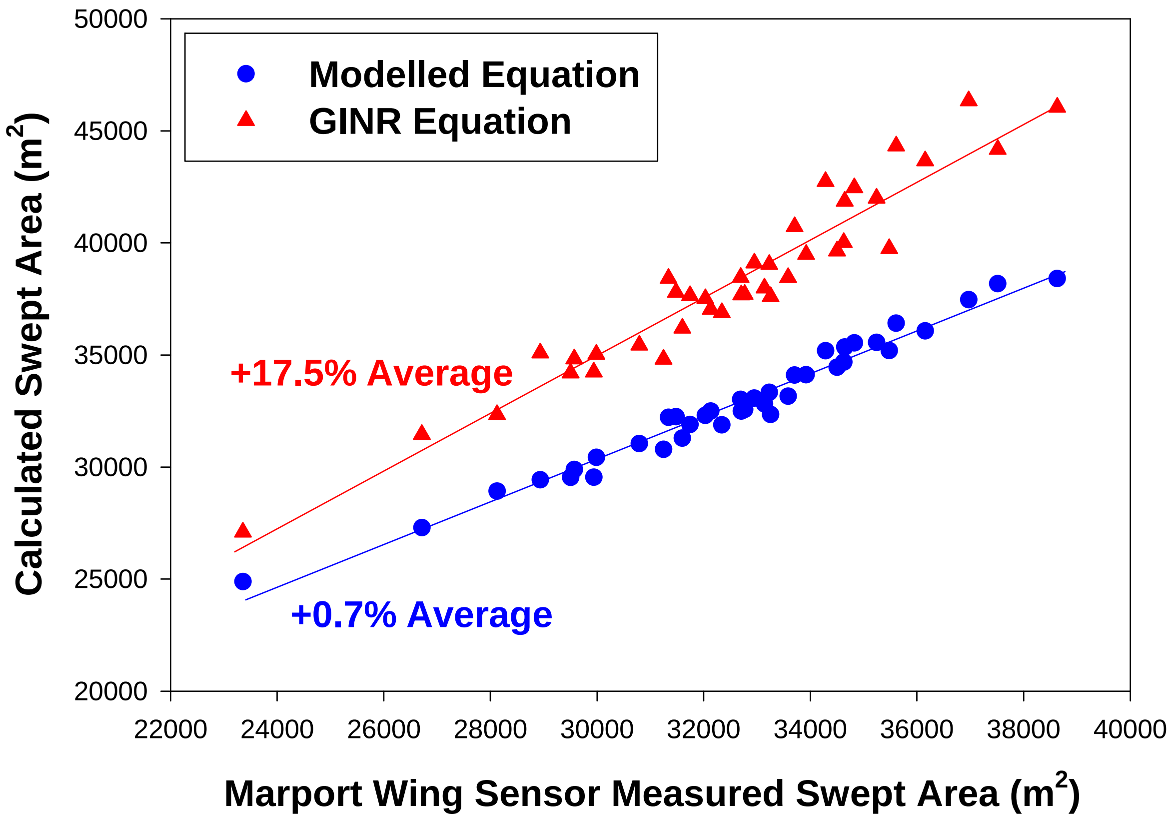


Figure 4: Comparison of Cosmos trawl swept area determined by the GINR method and the Cosmos trawl modelling versus direct in situ measurement of wing spread. Both methods are plotted against wing spreads actually measured with Marport spread sensors hung on the wings of the Cosmos trawl. Swept area is calculated using same mean speed and duration of tow determined from GPS and CTD recordings of the tow