Section 3. Examination of Possible Effects of Trawl Survey Time-Series Interventions Beginning in 2000

3.1 Description of the Warp Offset Problem

The objectives of this section are to evaluate the potential effects of mismarked trawl cables on the catches of groundfish species in NEFSC R/V trawl surveys conducted since 2000. Eight surveys were affected (Spring 2000-2002, Winter 2000-2002, and Fall 2000-2001) but the magnitude of the potential changes is unknown. First principles suggest that the likely changes should be negative (i.e., lower catches in 2000-2002). Trawls are bilaterally symmetric and offset cables will induce asymmetry in the trawl's alignment. Departures from symmetry could upset the balance of dynamic forces that govern performance of the net. Catastrophic changes are relatively infrequent and readily detected in standard surveys. More subtle features such as vibrations, variability in bottom contact, reduced net width, and decreased height of the head rope are more difficult to detect. Moreover, the effects of such changes interact with contagiously-distributed fish populations whose variations in abundance and catchability may overwhelm issues of gear performance.

While pilot studies to test the effects of offset trawl cables were conducted in fall 2002, comprehensive experiments have yet to be completed. Analysis of historical data from the NEFSC time series and comparisons with other data sets, are however, instructive for gauging the magnitude of likely effects. We have pursued three basic approaches to see if effects of the trawl warp offsets are evident in the data. The first approach is descriptive. We examined the basic properties of the catch data and performed various tests to determine if changes had occurred since 1999. These analyses rely primarily on the historical data serving as a temporal control. The second approach relies on comparisons between the NEFSC time series and contemporaneous samples from other surveys. We consider comparisons between the NEFSC trawl data and similar surveys conducted by Department of Fisheries and Ocean (DFO) Canada. In addition, vessel comparison studies (R/V *Albatross IV* versus R/V *Delaware II*) conducted before and after 2000 fortuitously allow for an estimate of the relative effect of warp offsets on catches.

Finally, we used models to evaluate the consequences of hypothesized levels of bias on the relative indices for assessment of resource status. Each potential level of bias has implications for relative efficiency of capture at depth. We used simple models to predict the reduction in capture efficiency that would have led to underestimation of abundance at the hypothesized levels.

Table 3.1.1. Measured differences in trawl warp lengths at varying fishing depths.

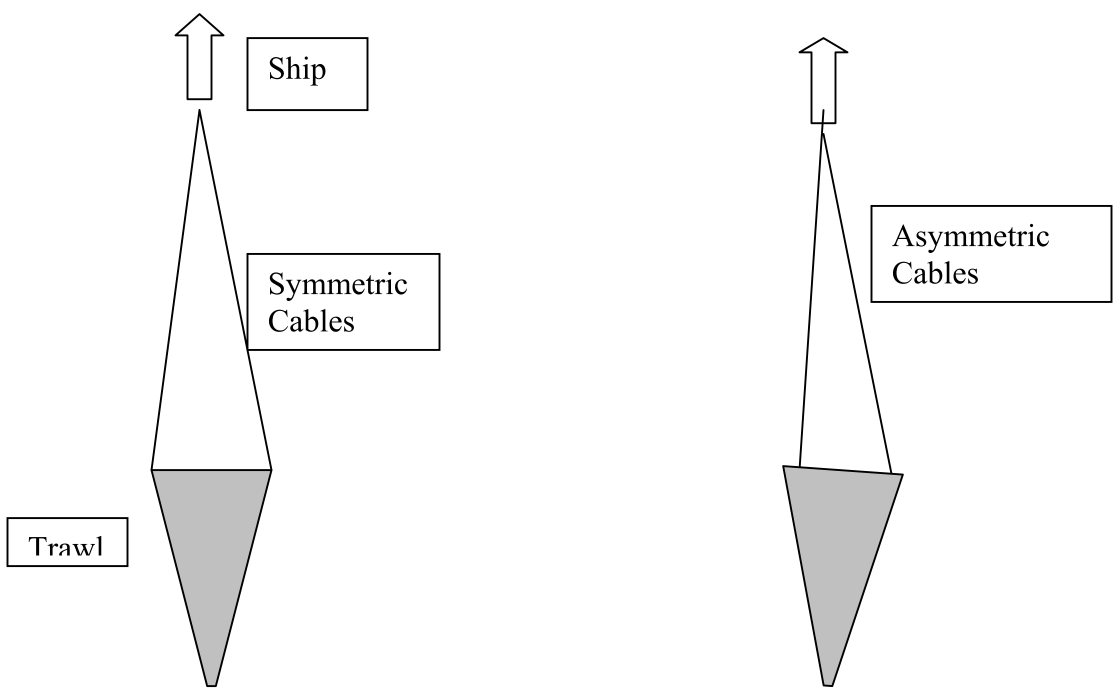
Differences in Warp length between port and starboard marks.

Warp(m)	***Depth(m)***	***Difference (inches)***	***Difference (m)***	***Difference (ft)***
0	0	0	0.00	0.0
50	17	16	0.41	1.3
100	33	1	0.03	0.1
150	50	24	0.61	2.0
200	67	39	0.99	3.3
250	83	49	1.24	4.1
300	100	67	1.70	5.6
350	117	69	1.75	5.8
400	133	81	2.06	6.8
450	150	94	2.39	7.8
500	200	107	2.72	8.9
550	220	124	3.15	10.3
600	240	131	3.33	10.9
650	260	117	2.97	9.8
700	280	150	3.81	12.5
750	300	158	4.01	13.2
800	320	164	4.17	13.7
850	340	172	4.37	14.3
900	360	188	4.78	15.7
950	380	214	5.44	17.8
1000	400	200	5.08	16.7

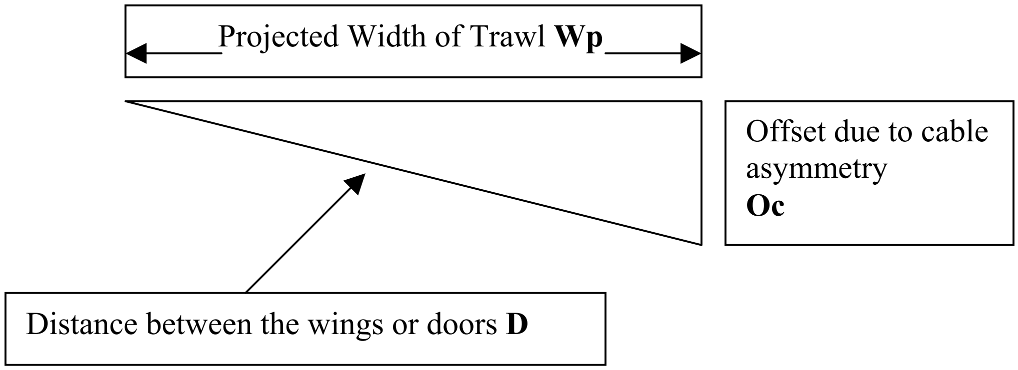
3.1.1 Trawl Geometry and Its Potential Implications for Catch Rates

The measured differences between the port and starboard cables are listed in Table 3.1.1. The ratio of the wire deployed to water depth is defined as the scope ratio. NEFSC uses a 3:1 scope for tows conducted at depths less than 150 m. At depths greater than 150 m the scope is set at 2.5:1. The difference between the cable lengths increases with the length of cable such that the differences between cables increases with fishing depth. The relationship between the warp offset and depth is linear (Fig. 3.1.1).

Basic geometric principles can be used to evaluate the potential effects of the asymmetric warp lengths on the area swept by the trawl. When the cables are of equal length, the distance between the trawl doors can be considered as the base of an isosceles triangle. A line drawn between the doors will be tangential to the direction of the ship. This distance between the wings of the net defines the measure of area swept for species which do not actively avoid the moving net. For finfish species that avoid both the net and the silt plume generated by the trawl doors, the effective area swept can be considered as the distance between the trawl doors. The minimal estimate total area swept can thus be estimated as the distance towed times the distance between the wings.



As a first approximation, the effects of asymmetric doors can be addressed with respect to the implied decrease in the distance between doors. If the Euclidean distance between the doors remains constant, then the reduction in area swept can be estimated as the base of a right-angled triangle using the Pythagorean theorem.



When the cables are symmetric then Wp=D. When the cables are asymmetric, by a distance of approximately Oc, the projected width of the trawl tangential to the axis of the ship's direction is

$$W_p = \sqrt{D^2 - Oc^2}$$

The fractional reduction in area swept per unit of towing distance can then be expressed as **$(D-W_p)/D$.** This approximation relies on the rather strong assumption that the trawl behaves like a rigid body. In reality the conformation of the trawl will depend upon the balance of forces acting on it. Detailed description of changes in net configuration and performance await the results of physical model tests, numerical model simulations, and field experiments with video observations.

The simple geometry of this example however, suggests that the consequences for changes in area swept are very small (Fig 3.1.2). At fishing depths below 300 m the difference in the area swept between the wings will less than 2%. The differences in the width swept by the doors would be about 7%. More than 90% of the NEFSC survey stations are at depths less than 200 m; at these depths, the reductions in either door width or net width would be less than 3%. Thus changes in catchability derived from considerations of simple geometry are likely to be small. Effects of the warp offset on catchability, if they exist, must manifest themselves as significant changes in net configuration or performance. Such changes could include reduced tendency to hold bottom, decreased headrope height, or excessive vibrations or pressure waves. Each of these factors should be subject to experimental confirmation through video studies and comparative fishing experiments.

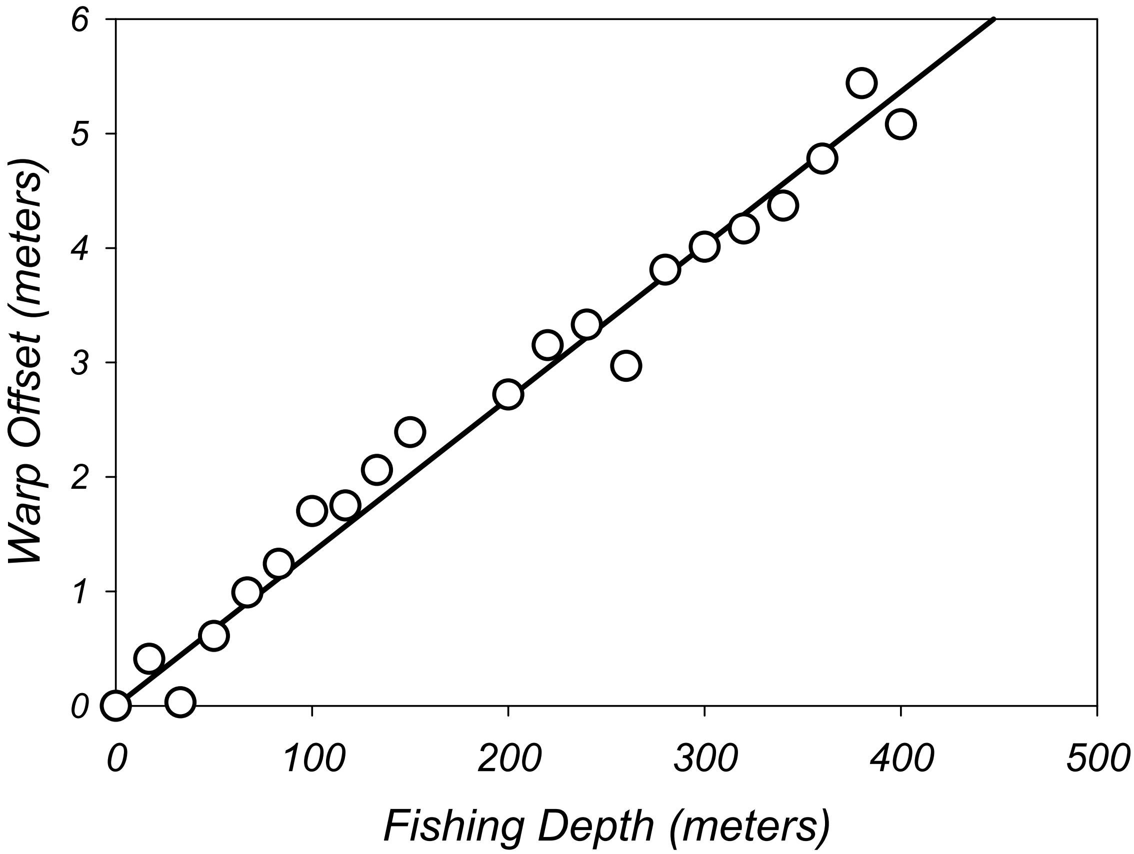
The deductive conclusions from trawl geometry provide a basis for examination of existing data. If the reductions in trawl width are greater than predicted by the static rigid-body analysis, then all species analyzed should be affected by a similar magnitude. Other modifications of trawl performance, however, are likely to have differential effects on the mix of species caught. If the warp offset causes the footrope to lose contact with the bottom, flatfish species should experience greater reductions in catches than other groundfish. Conversely, reductions in the height of the headrope should leave catch rates of flatfish unaffected but decrease catches of free-swimming species. Changes in net vibrations or increases in the net's pressure wave will tend to enhance the avoidance response of faster moving species and individuals within species. Under this hypothesis, the size composition of the catches should shift toward smaller individuals. In aggregate, these factors would be expected to increase the frequency of faulty trawl deployments, differentially reduce species-specific catch rates, and show an increasing effect with towing depth.

The following sections attempt to test these hypotheses in a variety of ways. Each section follows a general pattern of hypothesis formulation, description of the data, presentation of mathematical or statistical theory, and the results of the analyses. We attempt to inter-relate models with the observed data. In most instances, this is done in the conventional fashion of comparing statistical models with observations. In other instances, the models are used to illustrate the plausibility of hypotheses. The following table provides a guide to these hypotheses and test procedures.

Hypothesis	**Test Procedure**	**Section**
Warp offset effects should lead to an increase in frequency of gear problems during 2000-2002 compared to pre 2000 surveys. Increases between treatment and control periods should be more pronounced with increasing depth.	Examined frequency of tows with gear problems by year for the spring (1985-2002), winter (1992-2002) and fall (1985-2001) surveys for the period 1985-2002. Used generalized additive models to estimate year and depth effects.	3.2
Larger individuals should be less vulnerable to capture by an asymmetric trawl.	Compared size frequency distributions of cod, haddock, yellowtail flounder, and monkfish caught in Albatross surveys with Canadian DFO surveys, fishing power surveys on the R/V Delaware, and a special commercial survey for monkfish.	3.3
Warp offset should decrease efficiency of net leading to decreases in average abundance and higher variation in catch.	Computed variance and mean of each strata within year for fall (1963-2001), spring (1968-2002), and winter (1992-2002) surveys for 22 species-stocks. Compared 90% confidence ellipses for pre and post treatment period.	3.6
Reductions in capture efficiency at depth should shift the loci of species abundance to shallower	Computed catch (numbers/tow)-weighted and biomass (kg/tow)-weighted average depths for each year and survey type (as above) for 22 species-stocks. For selected species, compared	3.7

depths during the 2000-2002 period.	the cumulative catch distributions vs. depth by year.	
Reductions in catch rates should be more pronounced with increases in depth.	Regressed standardized pre –post treatment differences in average catch (num/tow) vs. depth (20 m intervals) and biomass (kg/tow) vs. depth (20 m intervals) for spring (1997-1999 vs. 2000-02), winter (1997-99 vs. 2000-02) and fall (1998-99 vs. 2000-01). For statistically significant changes, estimated depth dependent function to describe loss of efficiency with depth. Computed expected magnitude of underestimation for 2000-2002 indices.	3.7
Hypothesized increases in average number caught in 2000 to 2002 surveys have implication for the reductions in depth-related catch efficiency.	Estimated magnitude of depth-related decreases in efficiency for putative increases in abundance of 10%, 25% and 100% for cod, haddock, and yellowtail stocks.	3.7
Trawl surveys conducted by Canada and NEFSC scallop surveys are unaffected by warp offset. Comparisons of abundance estimates derived from these surveys with NEFSC trawl surveys should allow estimation of warp-related effects.	For annual composite abundance estimates, compared standardized log catch ratios for NEFSC trawl surveys with DFO trawl and NEFSC scallop dredge surveys for 20 species. Generalized linear model used to test for intervention effect.	3.9
Experiments to compare catch rates between the *Albatross* and *Delaware* in 1980s and 2002 provide an indirect measure of warp offset effect.	Reanalyze the vessel comparison experiments to estimate the likely magnitude of the trawl cable offset effect.	3.11
Warp offset effects may have reduced 2000-2002 indices used in assessment models. Hypothesized effect levels were 10, 25 and 100%.	Each assessment model was run with four assumed levels of warp-offset effect: 0% change, +10%, +25% and +100% for indices in 2000-02. Bootstrap estimates of biomass and full F were computed for each model run and confidence intervals were compared for terminal year estimates.	5.2

Figure 3.1.1. Difference between port and starboard warp marks vs. fishing depth



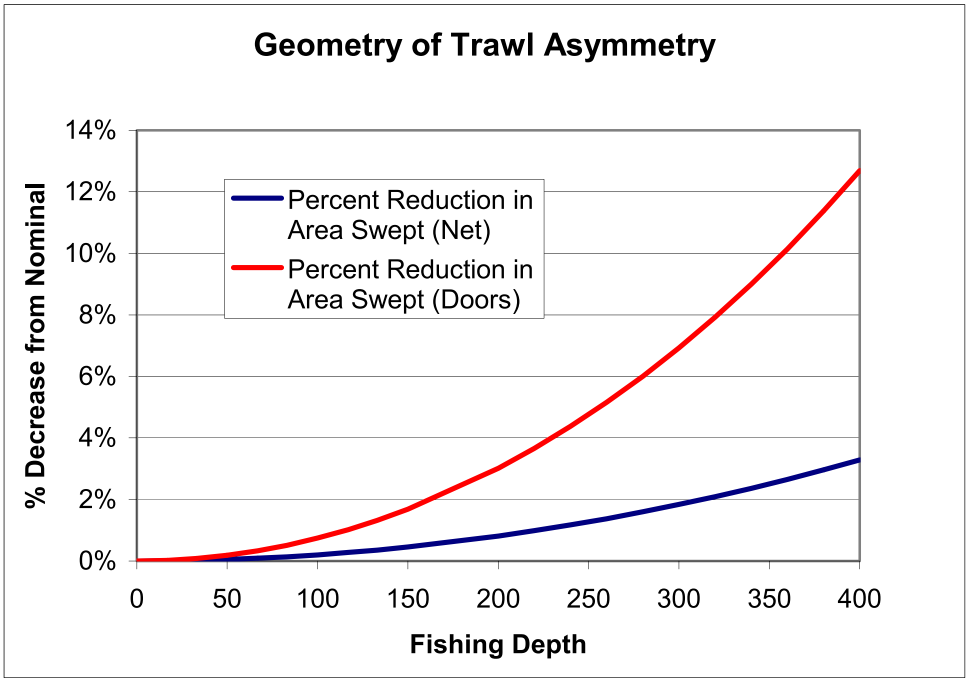


Figure 3.1.2 Predicted effect of trawl offset on reduction in area swept for fishing depths from 0 to 400 m.