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An Update on the Performance of the Campelen 1800 During Bottom Trawl Surveys in NAFO Subareas 2 and 3 in 2001

by

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**Abstract**

The Northwest Atlantic Fisheries Centre conducts annual bottom trawl surveys with the *CCGS Wilfred Templeman* and the *CCGS Teleost* using the Campelen 1800 shrimp trawl. Standardization protocol have been adopted to minimize the uncertainty in estimates of abundance that could be associated with variations in trawl construction and fishing practices. Trawl performance data are recorded for all fishing sets during the surveys using SCANMAR acoustic trawl instrumentation. An analysis of the performance of the Campelen 1800 during the 2001 annual fall survey of NAFO Divisions 2J+3KLMNO and spring survey of Subdiv. 3PS and Div. 3LNO is undertaken. There is a statistical difference in survey gear performance between research vessels and between surveys conducted with the same research vessel in different years. Some of this difference may be explained by differences in mean depth fished and bottom type. Other differences in fishing power between research vessels can be explained by comparing the physical characteristics of the three research vessels i.e. displacement, horsepower and deck layout.

## Introduction

The Department of Fisheries and Oceans, Newfoundland Region, conducts annual bottom trawl surveys to provide information on the abundance, distribution, biology and ecology for many marine finfish and shellfish in waters off Canada's east coast. Bottom trawl surveys are conducted using a stratified random sampling design, an approach which assumes that survey trawl performance and catchability remains constant from tow to tow and between survey years. Should catchability change indices of abundance and size composition could be biased.

The catchability of a survey trawl is dependent on its design, application, the behavior of the individual fish in the population and the interactions of these factors within the fish capture process (Pope *et al*., 1975). Changes in the fishing power of the trawl as a result of changes to vessel power, vessel emitted noise, crew, trawl design and construction can result in a systematic error in abundance estimates (Byrne *et al*., 1981: Walsh *et al*., 1993). Trawl geometry and performance can vary from set to set and the use of SCANMAR acoustic instrumentation allows geometry to be monitored and its variability estimated.

In this paper, we present an analysis of the performance of the Campelen 1800 during the 2001 annual fall survey of NAFO Div. 2J+3KLMNO and spring survey of Subdiv. 3PS and Div. 3LNO. We also examined the performance of the survey trawl over the 7 years since its introduction in the fall of 1995.

## Materials and Methods

The Campelen 1800 is a four-panel shrimp trawl with cut-away lower wings and is rigged with a rockhopper footrope. The 1400 kg, 4.3 $m^2$ Morgere Polyvalent trawl doors are connected to the trawl with 40 m bridles and 6.1 m sweep wires, the door legs are 3.05 m long. The headline is 29.5 m long and fitted with 88 plastic trawl floats

(200 mm diameter). The 35.6 m long rockhopper footrope is constructed of 355 mm diameter rubber disks spaced at 200 mm intervals in the bosum and quarters and at 560 mm intervals in the wings. The body of the trawl is constructed of 4.0, 3.0 and 2.0 mm diameter polyethylene twine with mesh sizes (knot centre measurement) varying from 80 mm in the wings and 60 mm in the square and first bellies to 44 mm in the second and third bellies, extension and codend. A 7.0 m long knotless nylon liner of 12.7 mm mesh size was attached to the inside of the extension and codend. The extension, codend and liner are covered with a 140 mm cover bag constructed of 2.0 mm polyethylene twine (see McCallum & Walsh, 1996).

The large-scale fall survey of Div. 2J+3KLMNO is conducted by the *Canadian Coast Guard Ship (CCGS) Wilfred Templeman* and *CCGS Teleost* working together. Normally, the *Teleost* surveys depths from 100 to 1 500 m in Div. 2J+3K and >750 m in 3LMNO, whereas the *Wilfred Templeman* completes depths under 750 m in Div. 3LNO. Spring surveys of Subdiv. 3Ps and Div. 3LNO are completed by the *Wilfred Templeman*. A mechanical breakdown of the *Teleost* in 2001 and the *Wilfred Templeman* in 1996 necessitated the use of the Wilfred Templeman's "sister ship", the CCGS *Alfred Needler* in portions of the surveys in those years.

## Trawl Standardization

Prior to the beginning of each survey leg and after major damage during the survey, the trawls are measured using the NAFC Survey Trawl Checklist (McCallum and Walsh, 1985). Trawls are repaired according to specification, prior to the next fishing set.

Door spread, wingspread, headline height and trawl depth were measured using SCANMAR hydroacoustic instrumentation mounted on each trawl door, on the headline at the wing ends[1] and on the square 1.0 m behind the center of the headline. SCANMAR signals and DGPS navigational information were logged at 5-second intervals on a custom data acquisition software package (SEATRAWL). DGPS vessel speed was also logged by hand at 3-minute intervals by bridge staff. Acoustic noise was edited from the data during post mission processing with the application of range checks of: 0-1 200 m for depth, 0-100 m for door spread, 0-30 m for wingspread, 0-35 m for opening and 0-50 m for clearance. Filters are also applied to remove noise spikes and smoothing duplicates generated by SCANMAR receiver software.

Survey tow duration is 15 minutes long, starting from the moment the trawl touches bottom and ending when the trawl leaves the bottom. Touchdown and lift-off are determined using SCANMAR instrumentation. Gear performance data is collected from the time the trawl doors enter the water until they are retrieved, flags are placed in the data to indicate the start and end of the 15 minute tow. Tow duration is corrected post-mission using a more precise measure of on bottom time provided by the CTD (conductivity/temperature/depth) sensor. The trawl is towed at a vessel speed of 3.0 kts as indicated by the DGPS and the heading is in the direction of the next fishing station whenever possible. The correct warp ratio (warp length/water depth) for a given fishing depth was determined using the NAFC Warp Ratio Protocol (Walsh and McCallum, 1996).

Bridle angles (θ) were calculated using the following equation:

$$\sin \theta = \frac{1/2(ds - ws)}{bl}$$

where *ds* is the door spread, *ws* is the wingspread and *bl* is the bridle length (sum of the lengths of the sweep wire + lower bridle + door leg extensions).

## Results and Discussion

*Trawl Geometry*

Table 1 shows a comparison of design parameters for the three research vessels. There are noteworthy differences, particularly with respect to displacement and horsepower and to a lesser extent warp specification. Table 2 shows

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1 Wing end sensors are mounted in stainless steel canisters to provide protection from trawling damage. Their weight in water is offset by adding 6 x 200 mm diameter floats (15.6 kg buoyancy) to the port wing end and 4 x 200 mm diameter floats (10.4 kg buoyancy) to the starboard wing.

the summary statistics for the *Wilfred Templeman* during fall groundfish survey for the years 1995 to 2001 inclusive. There was no statistical difference in wingspread from 2000 to 2001, however there was a significant difference in doorspread (Table 8). The variability of these parameters remained similar between the two years. Over the history of the survey, average doorspreads ranged from a low of 42.5 m (2000) to a high of 48.8 m (1995) with a overall mean of 45.7 m. Average wingspreads ranged from 15.5 m (1998) to 17.1 m (1995) with a overall mean of 16.2 m. The mean depth fished from 1995 to 2001 was 232 m.

The *Teleost's* gear performance during the fall groundfish surveys is shown in Table 3. Both doorspread and wingspread were statistically different between the surveys in 2000 and 2001. Doorspread, wingspread and opening appeared to be more variable in 2001, this may be a reflection of the greater depths fished in that year. Average doorspreads ranged from a low of 52.3 m (1996/1997) to a high of 57.9 m (2001) with a overall mean of 54.1 m. Wingspreads ranged from 16.6 m (1996) to 18.6 m (2001) with a mean of 17.5 m. The mean depth fished from 1995 to 2001 was 525 m.

Table 4 shows the *Teleost* summary statistics for gear geometry at depths comparable to those fished by the *Wilfred Templeman*. A significant difference in all three-gear parameters was found when comparing between vessels in the same survey year and between survey years for 1997 and 2001. This is in contrast to 1996 where there was a significant difference in door spread and opening between the two vessels but no difference in wingspread (Walsh and McCallum, 1996). Variability in doorspread and wingspread may be the result of bottom type and/or differences in vessel displacement and sea motion and how these translate to the gear, particularly in shallow water.

*Alfred Needler* gear performance statistics for years in which that vessel was substituted into the fall survey (1996 and 2001) are shown in Table 5. Doorspread and wingspread was notably higher (20%) and variability lower in 2001 than in 1996. These differences are probably due to difference in average depth fish in both years, i.e. average depth fished in 2001, was twice that measured in the 1996 survey. During the 2001 fall surveys, there was a statistically significant difference in doorspread and wingspread between the *Alfred Needler* and the *Wilfred Templeman* and the *Alfred Needler* and the *Teleost*. Again, such differences in gear geometry could be accounted for by differences in average depth fished. Similar results were found in the analysis of the 1996 data from *Alfred Needler* and the *Wilfred Templeman* (Walsh and McCallum 1997). Although this difference could also be attributed to differences in average depths fished it is suspected that the *Alfred Needler*'s trawl was under-spread when compared to what would be expected by the *Templeman's* trawl at similar depths (Fig. 5). Inexperience of the crew in using this trawl, differences in propulsion and the use of heavier main trawl warps on the *Alfred Needler* may have contributed to the under-spreading of the trawl (Walsh and McCallum, 1997). However, in the 2001 survey, this does not appear to be the case and Fig. 5 shows good agreement with the predicted *Templeman's* data for deepwater.

Table 6 shows the summary statistics for the Wilfred Templeman during spring surveys of Subdiv. 3PS. There was no statistical difference in doorspread and wingspread between 2000 and 2001 (Table 8). Average door spreads range from a low of 44.0 m (2001) to a high of 47.9 m (1997), and the overall mean door spread over the survey years 1996 to 2000 was 45.8 m. Average wingspreads over this period ranged from 15.4 m to 16.4 m, with a mean of 16.0 m. There was no statistical difference in door spread between from one year to the next in the surveys from 1998 and 2000 (Table 8). The variability of door spread and wingspread between all survey years is relatively consistent, which may be a result of the low variation in depths fished.

Table 7 shows the summary statistics for the *Wilfred Templeman* during the spring surveys of 3LNO. Both average doorspread and wingspread were statistically higher in 2001 than in 2000. Average depth fished was comparable in both years and the reason for differences are not obvious. There was no statistical difference in either door spread or wingspread between the survey years 1998, 1999 and 2000 (McCallum and Walsh, 2001). Average door spread over the period 1996 to 2000 was 43.5 m, ranging from a low of 41.9 m (2000) to a high of 44.9 m (1996). Average wingspread ranged from a low of 14.8 m (1997) to a high of 15.9 m (1998, 2001) with a mean of 15.5 m.

Table 9 shows mean doorspread and wingspread for the three research vessels by 100 m depth intervals during the fall survey of 2001. Average doorspread and wingspread generally increase with depth and both tend to be greater on the *Teleost* for a given depth interval. The average door and wingspread for the trawl on the *Alfred Needler* and *Wilfred Templeman* are comparable, however there is less variability on the *Alfred Needler*. Figure 5 shows a semi-log scatter plot of the *Teleost* data for each depth bin in Table 9 with the *Alfred Needler* and the *Wilfred*

*Templeman's* data for each bin overlaid on top. There appears to be a trend for the *Wilfred Templeman and Alfred Needler*'s trawl parameters to be less that that of the *Teleost* at comparable depths, i.e. the Campelen trawl on the Teleost is spreading more than the other two vessels.

In Table 10 mean swept area has been calculated using a measured wingspread (SCANMAR) and tow distance, which is derived from on bottom tow duration and an assumed vessel speed of 3.0 kts. This is compared with the swept area calculation commonly used in STRAP analysis i.e. a fixed wingspread of 16.8 mand a tow distance 0.8 nm. The area of seabed swept by the trawl varies with depth (Fig. 4).

*Gear Performance*

Figure 1 demonstrates differences in mean door spread and wingspread for the *Wilfred Templeman* and *Teleost*, between survey years 1995-2001. Figure 2 shows a comparison of distances towed during the survey set between the Wilfred Templeman, Teleost and Alfred Needler for fall survey and for the Wilfred Templeman during the spring survey of 2001. DGPS tow distance is calculated from the start and end position of the tow as determined by the fishing officer and measured by the DGPS unit. In practice the fishing officer will use SCANMAR depth and height sensors to determine when the trawl has touched bottom and when it has left bottom after haul-back has commenced. A 15 minute tow at 3.0 kts will generally cover 0.75 nm under normal conditions. Average tow distances are shorter on the Wilfred Templeman (x = 0.71 nm, cv = 19.4 %) than the Teleost (x = 0.76 nm, cv = 16.6 %) or the Alfred Needler (x = 0.76 nm,12.8 %) during the fall survey. This is in contrast to 2000 when tow distances were shorter on the Teleost (x = 0.72 nm, 16.4%) than on the Wilfred Templeman (x = 0.74 nm, 32.1%) (McCallum and Walsh, 2001).

Figure 3 shows a comparison of tow duration from CTD time on bottom between the Wilfred Templeman, Teleost and Alfred Needler for the fall survey and the Wilfred Templeman during the spring survey of 2001. The trawl mounted CTD is used to determine a more precise measure of the time elapsed between trawl touch down and lift-off. Distance towed is calculated using tow duration and vessel speed. Tow durations tend to be the longer on the Alfred Needler (x = 16.3 min., 10.7%), than either the Teleost (15.9 min., 12.6%) or the Wilfred Templeman (15.5 min., cv = 6.9%). This may be due to the inexperience of the Alfred Needler's crew with NAFC touch-down and lift-off protocols.

## Conclusions

There is a statistical difference in survey gear performance between research vessels and between surveys conducted with the same research vessel in different years. However, some of this difference may be explained by differences in mean depth fished and bottom type. Other differences in fishing power between research vessels can be explained by comparing the physical characteristics of the three research vessels i.e. displacement, horsepower and deck layout. For example, the higher door spreads encountered on the Teleost when compared to the Templeman and the Alfred Needler in similar depths are most likely the result of the greater distance found between the gallows blocks. After 6 years of trawl gear data collection we have considerable information on the performance of the NAFC 's Campelen 1800 survey trawl. There is now sufficient trawl gear data to examine in more detail the differences in geometry of the Campelen aboard each vessel. The next step in the analysis is to weigh the measurements of trawl parameters by depth and re-examine some of the results summarized here. In addition, it is hope that we can incorporate bottom sediment type which affects trawl performance and which could account for some of the between years differences in surveys of similar depths.

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Table 1. Research vessel particulars.

| Particulars | Wilfred Templeman | Alfred Needler | Teleost |
|---|---|---|---|
| Vessel | | | |
| Length (m) | 50.3 | 50.3 | 63.0 |
| Breadth (m) | 11.0 | 11.0 | 14.2 |
| Draft (m) | 4.3 | 4.9 | 7.2 |
| Displacement (t) | 1125 | 958 | 2215 |
| Power (hp) | 2000 | 2600.0 | 4000 |
| Warp Spec. | | | |
| - Diameter (mm) | 25.4 | | 25.4 |
| - Weight (kg/m) | 3.0 | | 3.0 |
| *Gallows Blocks (m) | 5.3 | 5.3 | 7.9 |
| Rigging | | | |
| Doors | 4.3m/1400 kg | | |
| Sweeps (m) | 6.1 | | |
| Bridles (m) | 40 | | |
| Buoyancy (kg) | 226.5 | | |
| Headline (m) | 29.5 | | |
| Fishing line (m) | 19.5 | | |
| Footgear | | | |
| Length (m) | 35.6 | | |
| Material | 102 rubber disks (rockhopper) | | |
| Weight in air (kg) | 501.3 | | |
| Size (diameter cm) | 35 | | |
| Mesh Size (mm) | | | |
| Wings/square | 80/60 | | |
| Bellies | 60/44 | | |
| Codend | 44 | | |
| Liner | 12.7 | | |
| Material | Polyethelylene | | |

* Distance between Gallows Blocks.

Table 2. Summary statistics of Wilfred Templeman gear geometry during the fall groundfish surveys of 3KLNO.

| Survey | Variable | No. Obs. | X | Cv | Min. | Max. |
|---|---|---|---|---|---|---|
| 1995 | Depth | 169 | 285.4 | | | |
| | Doors | 169 | 48.8 | 13.0 | 16.1 | 56.4 |
| | Wings | 167 | 17.1 | 9.0 | 12.5 | 22.8 |
| | Opening | 161 | 4.4 | 13.0 | 3.5 | 7.6 |
| | Bridle Ang. | 161 | 19.2 | 15.0 | 7.4 | 22.6 |
| 1996 | Depth | 312 | 239 | | | |
| | Doors | 319 | 48.3 | 10.1 | 15.6 | 60.7 |
| | Wings | 327 | 16.9 | 10.9 | 6 | 23.6 |
| | Opening | 312 | 4.7 | 14.6 | 2.5 | 11.7 |
| | Bridle Ang. | 249 | 18.6 | 2.2 | 0.5 | 23.7 |
| 1997 | Depth | 268 | 169 | | | |
| | Doors | 278 | 45.6 | 10.7 | 26.5 | 58.3 |
| | Wings | 244 | 16.2 | 13.3 | 6.6 | 28.1 |
| | Opening | 274 | 4.8 | 10.9 | 2.5 | 7.8 |
| | Bridle Ang. | 239 | 17.2 | 15.9 | 7.5 | 29 |
| 1998 | Depth | 365 | 213.3 | | | |
| | Doors | 389 | 44.2 | 13.1 | 26.5 | 63.8 |
| | Wings | 356 | 15.5 | 9.5 | 11.6 | 20.3 |
| | Opening | 366 | 5.2 | 12.8 | 2.3 | 10.3 |
| | Bridle Ang. | 351 | 17 | 16.3 | 8.7 | 26.3 |
| 1999 | Depth | 312 | 342.6 | | | |
| | Doors | 290 | 46.2 | 16.6 | 14.9 | 69.5 |
| | Wings | 294 | 16.6 | 11.4 | 7.5 | 21.9 |
| | Opening | 273 | 4.9 | 16.4 | 2.2 | 10.9 |
| | Bridle Ang. | 274 | 17.3 | 21.3 | 7.1 | 31.3 |
| 2000 | Depth | 168 | 172.6 | | | |
| | Doors | 156 | 42.5 | 10.3 | 30.5 | 54.3 |
| | Wings | 155 | 15.6 | 6.8 | 12.5 | 18.4 |
| | Opening | 155 | 4.6 | 12.7 | 2.9 | 8.0 |
| | Bridle Ang. | 143 | 16.0 | 13.8 | 9.5 | 21.9 |
| 2001 | Depth | 361 | 202.9 | | | |
| | Doors | 358 | 44.7 | 10.1 | 29.0 | 55.3 |
| | Wings | 241 | 15.6 | 7.2 | 11.3 | 18.6 |
| | Opening | 346 | 4.5 | 11.9 | 2.7 | 8.7 |
| | Bridle Ang. | 240 | 16.5 | 12.5 | 10.4 | 22.1 |

Table 3. Summary statistics of Teleost gear geometry during the fall surveys of

| Survey | Variable | No. Obs. | X | Cv | Min. | Max. |
|---|---|---|---|---|---|---|
| 1995 | Depth | 139 | 418.6 | | | |
| | Doors | 140 | 53.0 | 13.0 | 21.7 | 72.6 |
| | Wings | 137 | 17.0 | 12.0 | 10.4 | 24.0 |
| | Opening | 142 | 4.1 | 15.0 | 2.2 | 6.4 |
| | Bridle Ang. | 126 | 21.5 | 15.0 | 6.6 | 31.8 |
| 1996 | Depth | 396 | 426.2 | | | |
| | Doors | 338 | 52.3 | 10.3 | 21.6 | 65.2 |
| | Wings | 292 | 16.6 | 8.4 | 11.6 | 24.9 |
| | Opening | 332 | 4.2 | 13.3 | 1.9 | 6.7 |
| | Bridle Ang. | 291 | 21.2 | 13.4 | 4.4 | 27.9 |
| 1997 | Depth | 371 | 465.4 | | | |
| | Doors | 394 | 52.3 | 12.4 | 21.6 | 65.8 |
| | Wings | 377 | 17.4 | 7.9 | 11.5 | 20.7 |
| | Opening | 401 | 4.5 | 15.8 | 3.3 | 10.5 |
| | Bridle Ang. | 360 | 20.8 | 15.4 | 2.7 | 27.4 |
| 1998 | Depth | 387 | 473.9 | | | |
| | Doors | 418 | 54.8 | 11.3 | 36.1 | 70.2 |
| | Wings | 402 | 17.4 | 7.0 | 12.4 | 21.4 |
| | Opening | 412 | 3.9 | 14.8 | 2.4 | 6.3 |
| | Bridle Ang. | 383 | 22.3 | 15.1 | 13.3 | 39.9 |
| 1999 | Depth | 275 | 430.3 | | | |
| | Doors | 274 | 54.0 | 10.2 | 28.1 | 69.7 |
| | Wings | 260 | 17.8 | 6.6 | 12.5 | 22.0 |
| | Opening | 268 | 4.0 | 14.0 | 3.2 | 9.6 |
| | Bridle Ang. | 259 | 22.0 | 12.9 | 9.1 | 29.5 |
| 2000 | Depth | 414 | 563.3 | | | |
| | Doors | 409 | 54.8 | 10.3 | 25.8 | 67.0 |
| | Wings | 327 | 17.8 | 7.4 | 11.0 | 22.1 |
| | Opening | 386 | 4.0 | 17.7 | 3.1 | 9.4 |
| | Bridle Ang. | 324 | 22.3 | 13.5 | 8.6 | 28.8 |
| 2001 | Depth | 168 | 900 | | | |
| | Doors | 163 | 57.9 | 16.1 | 17.4 | 81.9 |
| | Wings | 156 | 18.7 | 10.4 | 14 | 24.2 |
| | Opening | 162 | 3.7 | 31.7 | 1.7 | 14.6 |
| | Bridle Ang. | 151 | 23.6 | 18.9 | 6.9 | 36.1 |

Table 4. Summary statistics of Teleost gear performance during the fall groundfish surveys. Data has been trucanted by depth to better reflect depths fished by the Wilfred Templeman.

| Survey | Variable | No. Obs. | X | Cv | Min. | Max. |
|---|---|---|---|---|---|---|
| 1995 | Depth | 111 | 298.8 | | | |
| <615m | Doors | 103 | 51.4 | 11.0 | 21.7 | 63.1 |
| | Wings | 104 | 16.7 | 12.0 | 10.4 | 24.0 |
| | Opening | 104 | 4.1 | 14.0 | 3.3 | 6.4 |
| | Bridle Ang. | 94 | 20.5 | 12.0 | 6.0 | 26.1 |
| 1996 | Depth | 300 | 336.6 | | | |
| <855m | Doors | 295 | 51.3 | 9.5 | 21.6 | 64.0 |
| | Wings | 259 | 16.5 | 8.3 | 11.6 | 24.9 |
| | Opening | 288 | 4.6 | 13.3 | 1.9 | 6.7 |
| | Bridle Ang. | 291 | 20.7 | 12.5 | 4.4 | 27.9 |
| 1997 | Depth | 316 | 344.0 | | | |
| <788m | Doors | 303 | 49.8 | 10.3 | 12.1 | 64.4 |
| | Wings | 293 | 16.9 | 7.5 | 5.7 | 20.7 |
| | Opening | 310 | 4.6 | 15.1 | 3.4 | 10.5 |
| | Bridle Ang. | 281 | 19.6 | 12.8 | 2.7 | 27.1 |
| 1998 | Depth | 272 | 432.2 | | | |
| <1100m | Doors | 262 | 54.0 | 9.7 | 36.7 | 66.3 |
| | Wings | 254 | 17.3 | 8.2 | 3.4 | 19.8 |
| | Opening | 258 | 3.9 | 13.9 | 2.6 | 6.3 |
| | Bridle Ang. | 246 | 21.8 | 12.7 | 13.5 | 31.8 |
| 1999 | Depth | 263 | 387.6 | | | |
| <1300m | Doors | 262 | 54.1 | 9.5 | 28.1 | 68.2 |
| | Wings | 249 | 17.7 | 6.2 | 12.5 | 22.0 |
| | Opening | 256 | 4.0 | 14.0 | 3.2 | 9.6 |
| | Bridle Ang. | 248 | 21.7 | 12.0 | 9.1 | 28.1 |
| 2000 | Depth | 273 | 298.9 | | | |
| <654m | Doors | 272 | 52.2 | 7.5 | 25.8 | 59.4 |
| | Wings | 207 | 17.4 | 6.6 | 11.0 | 22.1 |
| | Opening | 255 | 4.1 | 17.5 | 3.3 | 9.4 |
| | Bridle Ang. | 207 | 20.8 | 9.8 | 8.6 | 24.4 |
| 2001 | Depth | 46 | 343.7 | | | |
| <703m | Doors | 46 | 49.3 | 20.3 | 17.4 | 59.8 |
| | Wings | 41 | 17.0 | 6.6 | 14.2 | 18.9 |
| | Opening | 44 | 3.7 | 19.1 | 3.7 | 7.5 |
| | Bridle Ang. | 41 | 19.3 | 25.8 | 6.9 | 24.7 |

Table 5. Summary statistics of the Alfred Needler gear geometry 1996 (3LNO) and 2001 (2JH3K) fall groundfish

| Survey | Variable | No. Obs. | X | Cv | Min. | Max. |
|---|---|---|---|---|---|---|
| 1996 | Depth | 84 | 113.6 | | | |
| | Doors | 90 | 40.1 | 10.8 | 26.1 | 53.5 |
| | Wings | 82 | 13.0 | 13.4 | 6.8 | 15.9 |
| | Opening | 85 | 5.5 | 10.5 | 4.6 | 9.7 |
| | Bridle | 77 | 16.2 | 14.3 | 8.9 | 25.4 |
| 2001 | Depth | 119 | 278.8 | | | |
| | Doors | 119 | 48.4 | 5.7 | 40.1 | 53.9 |
| | Wings | 116 | 16.3 | 3.8 | 13.4 | 17.7 |
| | Opening | 55 | 4.1 | 11.7 | 3.2 | 5.4 |
| | Bridle | 116 | 19.0 | 7.5 | 15.0 | 21.9 |

Table 6. Summary statistics of Wilfred Templeman gear geometry during the spring groundfish surveys of 3Ps.

| Survey | Variable | No. Obs. | X | Cv | Min. | Max. |
|---|---|---|---|---|---|---|
| 1996 | Depth | 143 | 215.2 | | | |
| | Doors | 153 | 46.6 | 11.2 | 24.5 | 53.8 |
| | Wings | 149 | 16.1 | 7.5 | 13.1 | 21.6 |
| | Opening | 153 | 4.7 | 8.5 | 4.0 | 5.9 |
| | Bridle Ang. | 144 | 18.0 | 15.4 | 5.4 | 22.0 |
| 1997 | Depth | 158 | 209.6 | | | |
| | Doors | 162 | 47.9 | 12.2 | 28.5 | 58.9 |
| | Wings | - | - | - | - | - |
| | Opening | 164 | 4.6 | 10.2 | 2.7 | 6.9 |
| | Bridle Ang. | - | - | - | - | - |
| 1998 | Depth | 118 | 238.8 | | | |
| | Doors | 126 | 46.2 | 10.0 | 33.0 | 55.1 |
| | Wings | 110 | 15.4 | 7.1 | 11.3 | 17.3 |
| | Opening | 124 | 5.0 | 8.3 | 3.5 | 6.4 |
| | Bridle Ang. | 104 | 18.4 | 12.7 | 12.2 | 23.7 |
| 1999 | Depth | 190 | 220.5 | | | |
| | Doors | 173 | 44.8 | 11.5 | 14.1 | 56.3 |
| | Wings | 184 | 15.8 | 7.2 | 12.6 | 18.6 |
| | Opening | 180 | 4.6 | 10.3 | 3.8 | 6.4 |
| | Bridle Ang. | 166 | 17.3 | 12.7 | 11.9 | 22.5 |
| 2000 | Depth | 177 | 213.3 | | | |
| | Doors | 175 | 45.4 | 12.1 | 30.8 | 62.8 |
| | Wings | 168 | 16.4 | 8.1 | 10.9 | 21.1 |
| | Opening | 158 | 4.4 | 14.4 | 2.5 | 8.1 |
| | Bridle Ang. | 166 | 17.2 | 16.3 | 10.0 | 26.1 |
| 2001 | Depth | 186 | 211.3 | | | |
| | Doors | 127 | 44.0 | 18.1 | 10.1 | 68.4 |
| | Wings | 172 | 16.4 | 7.3 | 11.1 | 19.1 |
| | Opening | 171 | 4.2 | 12.3 | 3.2 | 7.6 |
| | Bridle Ang. | 112 | 16.9 | 20.1 | 6.2 | 26.2 |

Table 7. Summary statistics of Wilfred Templeman gear during the spring groundfish surveys of 3LNO.

| Survey | Variable | No. Obs. | X | Cv | Min. | Max. |
|---|---|---|---|---|---|---|
| 1996 | Depth | 337 | 185.0 | | | |
| | Doors | 337 | 44.9 | 10.4 | 13.9 | 65.6 |
| | Wings | 305 | 15.8 | 8.6 | 11.9 | 24.3 |
| | Opening | 334 | 4.9 | 8.9 | 3.1 | 6.2 |
| | Bridle Ang. | 300 | 17.3 | 11.3 | 11.3 | 30.2 |
| 1997 | Depth | 153 | 175.4 | | | |
| | Doors | 152 | 43.4 | 13.1 | 25.5 | 56.7 |
| | Wings | 147 | 14.8 | 8.8 | 10.3 | 18.1 |
| | Opening | 149 | 5.0 | 11.0 | 4.1 | 9.2 |
| | Bridle Ang. | 146 | 16.8 | 8.9 | 8.6 | 23.4 |
| 1998 | Depth | 243 | 158.5 | | | |
| | Doors | 192 | 43.8 | 10.9 | 30.4 | 68.4 |
| | Wings | 88 | 15.9 | 16.1 | 6.2 | 25.0 |
| | Opening | 222 | 4.9 | 10.4 | 3.4 | 10.2 |
| | Bridle Ang. | 76 | 17.0 | 16.2 | 9.4 | 32.7 |
| 1999 | Depth | 368 | 179.0 | | | |
| | Doors | 358 | 42.8 | 9.6 | 30.0 | 53.7 |
| | Wings | 341 | 15.4 | 6.5 | 12.3 | 18.2 |
| | Opening | 339 | 4.6 | 13.1 | 1.8 | 10.9 |
| | Bridle Ang. | 340 | 16.3 | 13.0 | 10.4 | 29.7 |
| 2000 | Depth | 282 | 181.3 | | | |
| | Doors | 278 | 41.9 | 10.6 | 25.7 | 54.8 |
| | Wings | 266 | 15.4 | 6.6 | 12.1 | 19.4 |
| | Opening | 265 | 4.5 | 12.4 | 2.3 | 9.6 |
| | Bridle Ang. | 262 | 15.7 | 13.9 | 7.9 | 22.1 |
| 2001 | Depth | 304 | 188.5 | | | |
| | Doors | 291 | 44.1 | 9.1 | 34.1 | 55.4 |
| | Wings | 296 | 15.9 | 7.1 | 13.5 | 21.4 |
| | Opening | 295 | 4.3 | 10.5 | 3.1 | 6.6 |
| | Bridle Ang. | 283 | 16.6 | 11.1 | 11.6 | 22.7 |

Table 8. Results of the MANN-WHITNEY rank sum test on Campelen 1800 trawl geometry parameters.

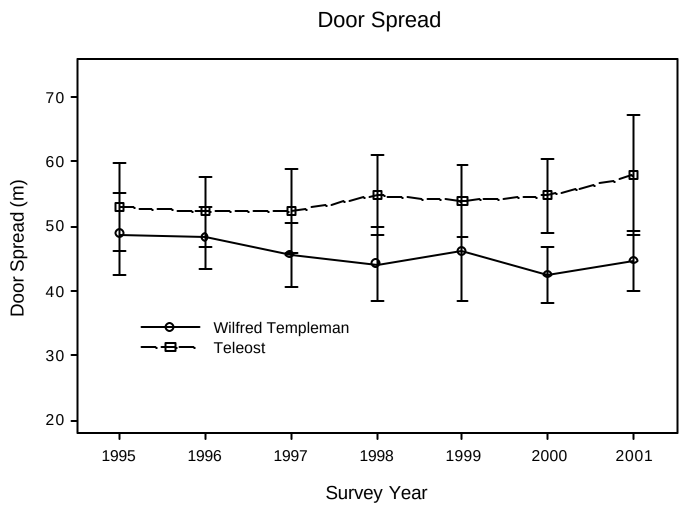
| Parameter | Comparison | T | P<0.05 |
|---|---|---|---|
| | **Teleost (Fall 98)/Teleost (Fall 99)** | **77557** | **P=0.162** |
| | **Teleost (Fall 99)/Teleost (Fall 00)** | **93318** | **P=0.878** |
| | Teleost (Fall 00)/Teleost (Fall 01) | 58189 | P<0.001 |
| | Templeman (Fall 98)/Templeman (Fall 99) | 92106 | P<0.001 |
| | Templeman (Fall 99)/Templeman (Fall 00) | 30265 | P<0.001 |
| | Templeman (Fall 00)/Templeman (Fall 01) | 75099 | P<0.001 |
| | Teleost (Fall 98)/Templeman (Fall 98) | 50755 | P<0.001 |
| | Teleost (Fall 99)/Templeman (Fall 99) | 107110 | P<0.001 |
| | Teleost (Fall 00)/Templeman (Fall 00) | 15012 | P<0.001 |
| Doorspread | Teleost (Fall 01)/Templeman (Fall 01) | 66279 | P<0.001 |
| | **Templeman (3Ps 98)/Templeman (3Ps 99)** | | **P=0.728** |
| | **Templeman (3Ps 99)/Templeman (3Ps 00)** | **29205** | **P=0.295** |
| | **Templeman (3Ps 00)/Templeman (3Ps 01)** | **17953** | **P=0.086** |
| | **Templeman (3LNO 98)/Templeman (3LNO 99)** | **55660** | **P=0.134** |
| | Templeman (3LNO 99)/Templeman (3LNO 20) | 81305 | P<0.001 |
| | Templeman (3LNO 00)/Templeman (3LNO 01) | 29698 | P<0.001 |
| | Alfred Needler (Fall 01)/Wilfred Templeman (Fall 01) | 39254 | P<0.001 |
| | Alfred Needler (Fall 01)/Teleost (Fall 01) | 9445 | P<0.001 |
| | Teleost (Fall 98)/Teleost (Fall 99) | 76739 | P=0.027 |
| | **Teleost (Fall 99)/Teleost (Fall 00)** | **75910** | **P=0.795** |
| | Teleost (Fall 00)/Teleost (Fall 01) | 45737 | P<0.001 |
| | Templeman (Fall 98)/Templeman (Fall 99) | 66213 | P<0.001 |
| | Templeman (Fall 99)/Templeman (Fall 00) | 30792 | P<0.002 |
| | **Templeman (Fall 00)/Templeman (Fall 01)** | **31063** | **P=0.791** |
| | Teleost (Fall 98)/Templeman (Fall 98) | 46947 | P<0.001 |
| | Teleost (Fall 99)/Templeman (Fall 99) | 97317 | P<0.001 |
| | Teleost (Fall 00)/Templeman (Fall 00) | 16895 | P<0.001 |
| Wingspread | Teleost (Fall 01)/Templeman (Fall 01) | 46627 | P<0.001 |
| | Templeman (3Ps 98)/Templeman (3Ps 99) | 33656 | P<0.001 |
| | Templeman (3Ps 99)/Templeman (3Ps 00) | 27154 | P<0.001 |
| | **Templeman (3Ps 00)/Templeman (3Ps 01)** | **28835** | **P=0.833** |
| | **Templeman (3LNO 98)/Templeman (3LNO 99)** | **20176** | **P=0.226** |
| | **Templeman (3LNO 99)/Templeman (3LNO 00)** | **80057** | **P=0.707** |
| | Templeman (3LNO 00)/Templeman (3LNO 01) | 31662 | P=0.010 |
| | Alfred Needler (Fall 01)/Wilfred Templeman (Fall 01) | 27312 | P<0.001 |
| | Alfred Needler (Fall 01)/Teleost (Fall 01) | 8742 | P<0.001 |

Table 9. Horizontal gear geometry increases with depth with little differences in variability between survey vessels in the year 2001 survey.

| | Doorspread | | | | | | | | | Wingspread | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TE | | | WT | | | AN | | | TE | | | WT | | | AN | | |
| Depth | n | x | Cv | n | x | Cv | n | x | Cv | n | x | Cv | n | x | Cv | n | x | Cv |
| 0-100 | - | - | - | 117 | 40.8 | 6.1 | - | - | - | - | - | - | 111 | 15.1 | 5.3 | - | - | - |
| 101-200 | 7 | 46.5 | 28.0 | 100 | 44.3 | 5.2 | 45 | 47.3 | 3.6 | 6 | 16.7 | 0.5 | 66 | 15.8 | 3.8 | 42 | 16.2 | 2.4 |
| 201-300 | 15 | 51.4 | 15.7 | 60 | 46.4 | 18.8 | 34 | 48.0 | 5.9 | 11 | 17.0 | 5.4 | 27 | 16.0 | 49.8 | 34 | 16.2 | 3.6 |
| 301-400 | 7 | 43.7 | 39.9 | 36 | 48.1 | 12.8 | 14 | 49.7 | 4.9 | 7 | 16.5 | 30.4 | 8 | 15.6 | 38.1 | 14 | 16.6 | 3.6 |
| 401-500 | 11 | 51.1 | 19.8 | 24 | 49.6 | 7.7 | 14 | 50.3 | 4.7 | 11 | 17.4 | 7.9 | 11 | 16.6 | 6.3 | 14 | 16.4 | 4.2 |
| 501-600 | 3 | 55.8 | 34.6 | 9 | 52.8 | 4.2 | 10 | 49.0 | 9.9 | 3 | 17.7 | 31.0 | 9 | 17.7 | 3.5 | 10 | 16.2 | 7.8 |
| 601-700 | 1 | 53.8 | 18.7 | 12 | 52.7 | 3.2 | 2 | 51.5 | 1.6 | 3 | 16.4 | 12.0 | 9 | 17.6 | 4.1 | 2 | 16.6 | 1.3 |
| 701-800 | 5 | 56.5 | 17.4 | - | - | - | - | - | - | 5 | 18.4 | 14.6 | - | - | - | - | - | - |
| 801-900 | 18 | 59.2 | 12.3 | - | - | - | - | - | - | 19 | 18.7 | 7.1 | - | - | - | - | - | - |
| 901-1000 | 18 | 60.6 | 9.5 | - | - | - | - | - | - | 19 | 19.3 | 10.9 | - | - | - | - | - | - |
| 1001-1100 | 12 | 61.7 | 5.0 | - | - | - | - | - | - | 11 | 19.1 | 6.0 | - | - | - | - | - | - |
| 1101-1200 | 27 | 61.5 | 11.4 | - | - | - | - | - | - | 27 | 19.6 | 9.4 | - | - | - | - | - | - |
| 1201-1300 | 7 | 62.7 | 11.5 | - | - | - | - | - | - | 7 | 20.1 | 10.7 | - | - | - | - | - | - |
| 1301-1400 | 23 | 62.0 | 10.0 | - | - | - | - | - | - | 21 | 19.3 | 9.4 | - | - | - | - | - | - |
| 1401-1500 | 7 | 66.1 | 4.0 | - | - | - | - | - | - | 6 | 20.3 | 8.3 | - | - | - | - | - | - |

Table 10. Comparison of mean swept area calculated using measured and fixed wingspread ( x 1000).

| | WT- Fall | | | | WT-Spring | | | | TE-Spring | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Measured | | | | Measured | | | | Measured | | | |
| Year | x | cv% | Fixed | Diff. | x | cv% | Fixed | Diff. | x | cv% | Fixed | Diff. |
| 1995 | 22.2 | 15.1 | 23.4 | 1.2 | - | - | 23.4 | | 24.7 | 14.8 | 23.4 | -1.3 |
| 1996 | 25.2 | 14.5 | 23.4 | -1.8 | 22.7 | 13.1 | 23.4 | 0.7 | 25.0 | 11.7 | 23.4 | -1.6 |
| 1997 | 23.1 | 14.2 | 23.4 | 0.3 | 22.7 | 14.1 | 23.4 | 0.7 | 25.4 | 10.7 | 23.4 | -2.0 |
| 1998 | 22.1 | 11.0 | 23.4 | 1.3 | 22.7 | 19.6 | 23.4 | 0.7 | 25.5 | 9.7 | 23.4 | -2.1 |
| 1999 | 23.0 | 14.3 | 23.4 | 0.4 | 23.4 | 12.1 | 23.4 | 0.0 | 25.5 | 8.4 | 23.4 | -2.1 |
| 2000 | 23.1 | 11.2 | 23.4 | 0.3 | 22.7 | 11.0 | 23.4 | 0.7 | 24.9 | 10.6 | 23.4 | -1.5 |
| 2001 | 22.8 | 11.3 | 23.4 | 0.6 | 23.3 | 11.9 | 23.4 | 0.1 | 27.5 | 15.3 | 23.4 | -4.1 |



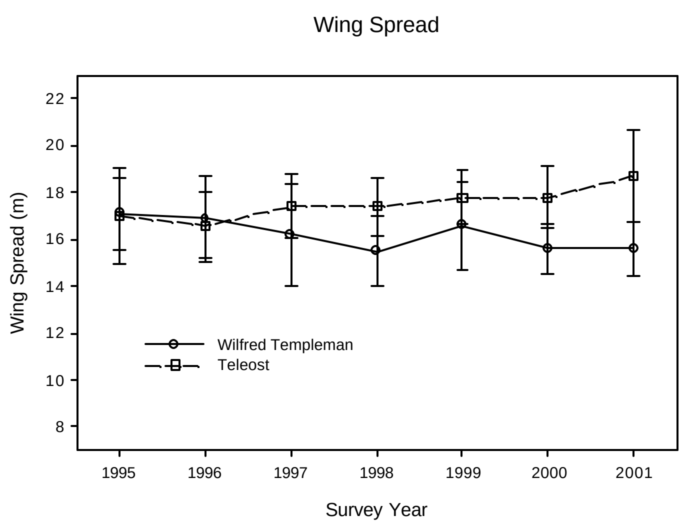
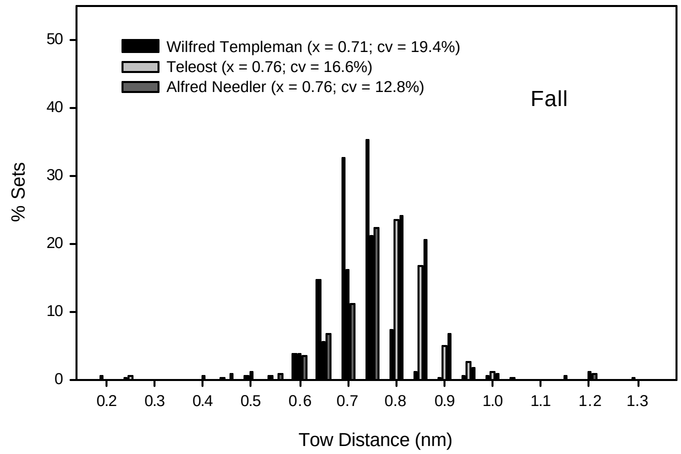




Fig. 1 Differences in mean door spread and wing spread between survey years are the result of differences in the mean depth fished between years (fall surveys).



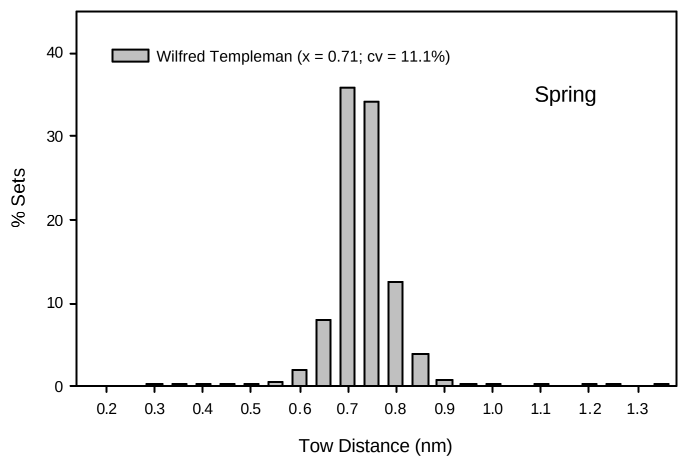
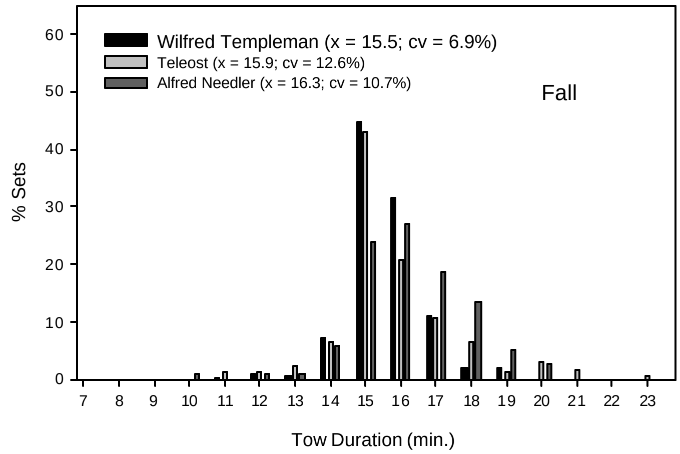




Fig. 2 Tow distance calculated from GPS vessel position for the Wilfred Templeman, Teleost and Alfred Needler during the fall survey and the Wilfred Templeman for the spring survey in 2001.



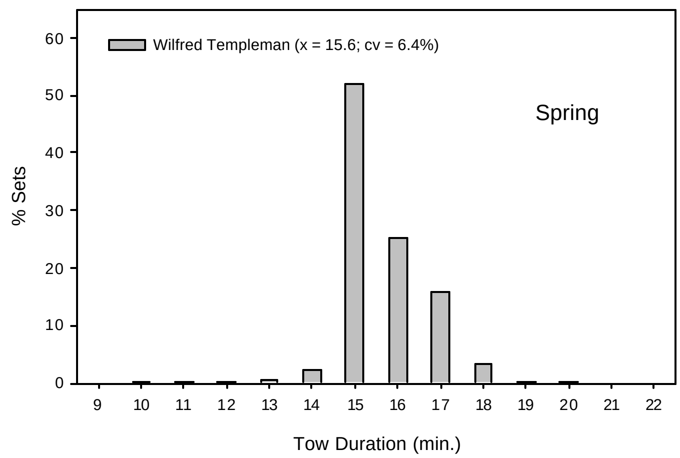




Fig. 3 Tow duration from CTD time on bottom for the Wilfred Templeman, Teleost and Alfred Needler during the fall survey (2J3KLMNO) and the Wilfred Templeman for the spring survey (3LNO) in 2001.

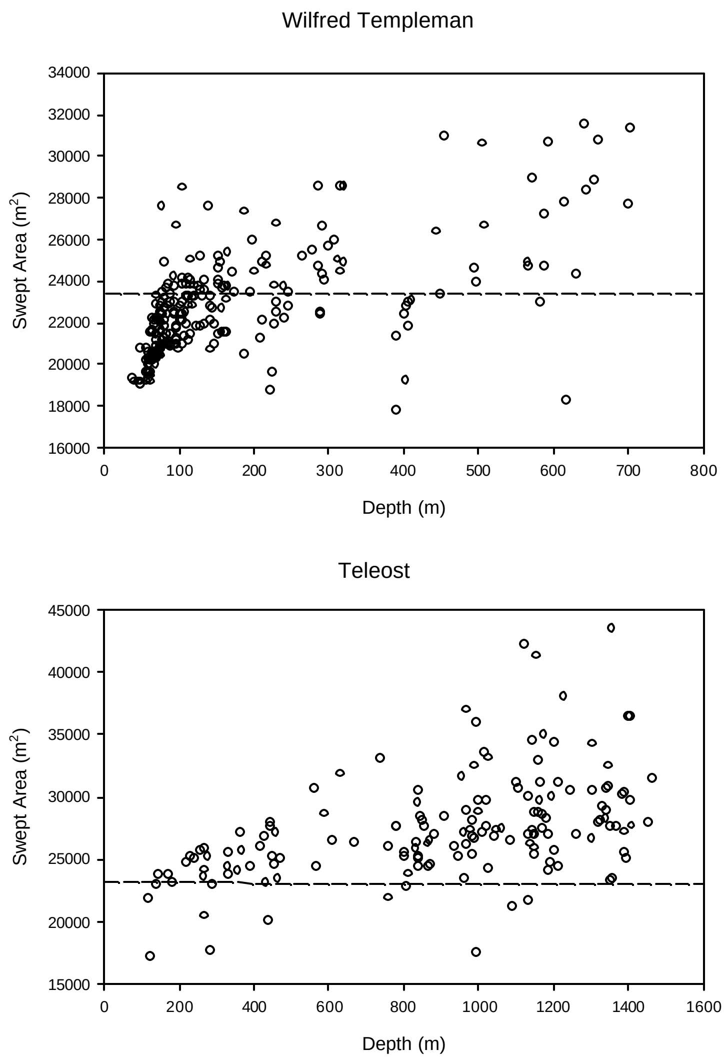



Fig. 4 Swept area calculated using measured wing spread for the Wilfred Templeman and Teleost during the fall survey of 2001. Dashed line represents swept area as calculated in STRAP.

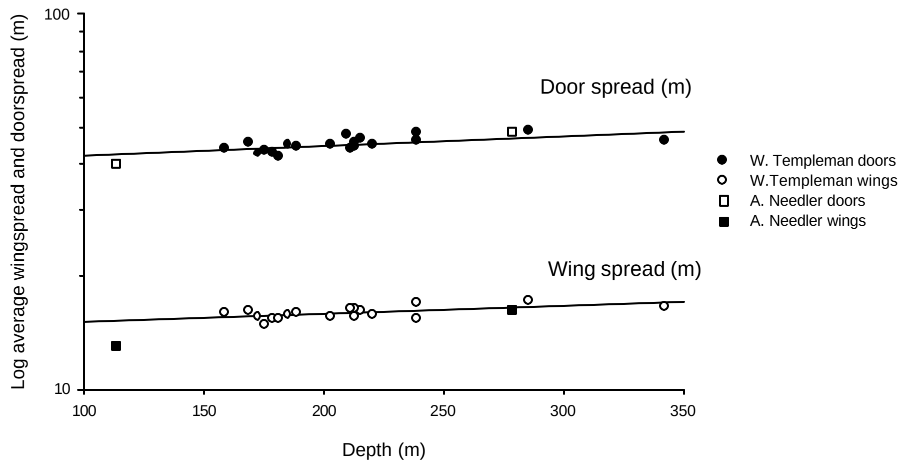



Fig.5 Semi-log scatter plot of average doorspread and wingspread against depth from the W. Templeman Fall, spring and 3PS surveys in 2001. Average doorspread and wingspread of the 1996 and 2001 A. Needler surveys overlaid for comparison.

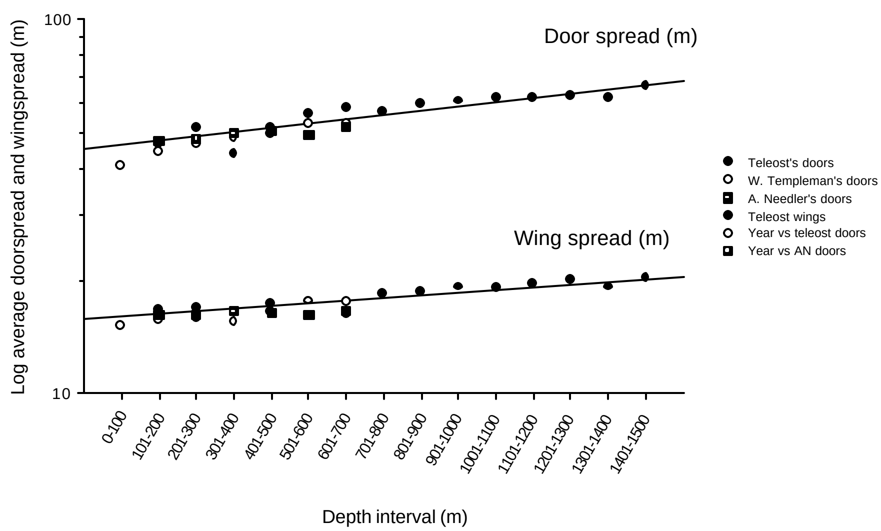



Fig. 6 Semi-log scatter plot of the Teleost's average doorspread and wingspread at 100 m depth intervals using the depth data in Table 9. The average wingspread and doospread of the A. Needler and W. Templeman is overlaid for comparison.