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Development of Canadian Research Trawl Gear Conversion Factors for Thorny Skate on the Grand Banks Based on Comparative Tows

by

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Abstract

Based on the STACFIS request for standardization of the Canadian research survey series, which utilized different trawls, for thorny skate in Divisions 3LNO, various conversion factors were investigated. Conversion of Thorny skate indices from the Canadian research surveys was based on comparative fishing trials conducted during 1995 and 1996. Absence of size-based differential catchability of the two trawls, based on assessment of the available length frequency data from comparative trawl experiments eliminated the necessity of a length based conversion factor. Comparable conversion factors were developed based upon the Mean CPUE and Robson conversion factors from comparative trawl experiments and spring survey catch ratios. STACFIS recommended adoption of a conversion factor of 1.57 and 2.42 for converting numbers per tow caught in *Gadus Atlantica* and *Templeman* Engel trawls, respectively into Campelen equivalents. Conversion factors for weight per tow was estimated as 1.14 and 2.54.

Introduction

Thorny skate (*Amblyraja radiata* Donovan, 1808, Family Rajidae) is a boreal/arctic species in the north Atlantic. In the eastern Atlantic, they are distributed from western Greenland, around Iceland to the Barents Sea, English Channel, North Sea, western Baltic, and as far south as Cape Town, off of South Africa (Froese and Pauly, 2003). In the eastern Atlantic, they are referred to as starry ray. Details of the distribution in the North Sea have been reported by Shreman and Parin (1994) and in ANON (2005).

In the western Atlantic, thorny skate are widely distributed from Greenland to South Carolina, with its centre of distribution on the Grand Banks (Kulka *et al.*, MS 1996; Kulka and Mowbray, MS 1998, 1999; Kulka and Miri, 2003). There, thorny skate comprise about 90% of the rajids caught in research survey trawls. Historically more widespread on the Grand Banks, thorny skate presently reach their greatest density on the shallower southwestern bank and shelf break, and into the Laurentian Channel in late autumn and winter, and along outer reaches of the banks in spring and summer.

Thorny skate have undergone a decline over their entire western Atlantic range. In the Gulf of Maine, thorny was one of 4 skate species regarded as overfished (Anon 2000) On the Scotian Shelf, Simon *et al*. (2003) reported a decline in the survey indices for winter (*Leucoraja ocellata*) and for thorny skate taken there in a mixed skate fishery. On the Grand Banks, Kulka and Miri (2003) indicated that thorny skate have had a low but stable abundance since the early 1990s, having undergone a substantial decline in the late 1970s to late 1980s. Thorny skate was observed to have declined to a greater degree in the northern extent of its range.

Abundance estimates for thorny skate in the Northwest Atlantic rely, in part, upon research surveys conducted by Canadian research vessels. Doubleday (1981) summarizes the stratified random design adopted by Fisheries and Oceans - Newfoundland and Labrador region after 1970 for spring surveys, and after 1976 for autumn surveys. Spring stratified-random surveys have been carried out on the Grand Bank (NAFO Div. 3LNO) by Canadian research vessels from 1971 to 2005, with the exception of 1983. As well, surveys have been conducted in NAFO Subdiv. 3Ps since 1972, and in recent years (since 1993) have taken place prior to the spring survey. Autumn surveys of

NAFO Div. 3L began in 1981, and then commenced for Div. 3NO in 1990. Subdiv. 3Ps is not surveyed in the autumn. While stratified survey design has remained constant over time, both inshore and deepwater strata have been added to the survey area in recent years (beginning in 1993), along with modifications to some of the original strata. Both surveys use the same random stratified sampling protocol and the same gear logistics. A summary of early modifications can be found in Bishop (1994). However, in 1995, the Engel 145 High lift otter trawl employed on the *Gadus Atlantica* and *Wilfred Templeman*, was replaced with the Campelen 1800 shrimp trawl for operation on the *Teleost* and *Wilfred Templeman* for research vessel surveys in the region. The details of these gears have been described by McCallum and Walsh (1996).

It has been found that the Campelen trawl, for species previously examined, is more efficient in catching smaller fish (Warren, 1996; Warren *et al*., 1997). In order to maintain continuity for the time series, two sets of comparative fishing experiments were conducted for the major commercial species to derive factors by which catches prior to 1995 carried out with the Engel's trawl could be converted to values equivalent with those obtained with Campelen trawl (Warren, 1996; Warren *et al*., 1997).

For species of lesser commercial importance, no size based conversion factors were developed, therefore the time series prior to and after 1995 had been considered as distinct indices. In this paper, we develop a conversion factor for thorny skate using data from the comparative trawling experiments conducted in 1995/1996 to permit conversion of Engel trawl data into Campelen equivalents. In addition, a conversion factor based on adjacent years from the spring survey was also calculated.

Material and Methods

Details of the comparative fishing trials have been described in detail elsewhere (Warren, 1996; Warren *et al*., 1997). In both sets of experiments (*Gadus Atlantica* with Engel's *vs Teleost* with Campelen, *Alfred Needler* with Engel's *vs Wilfred Templeman* with Campelen) paired tows were conducted at the same time along parallel courses. It should be noted that Campelen trawls were only conducted for 15 minute, 0.8nm tows (new standard) while Engel tows were conducted for 30 minute, 1.8nm tows (old standard). As well, two experiments were required due to differences in the Engels trawl used prior to 1995 by the *Gadus atlantica* and the *Wilfred Templeman*. Numbers and weights of captured fish were recorded, and in some cases length measurements were also made on Thorny skate. There were 285 successful trawls reported over three trips for the *Gadus-Teleost* experiment and an additional 180 successful trawls reported for the *Templeman-Needler* experiment. Length frequencies for Thorny skate were only collected on 45 sets during the *Gadus-Teleost* experiment. During the *Templeman-Needler* experiment, 150 sets were sampled for length frequencies. Only eight of the sets were from paired trawls in which both vessels captured Thorny skate.

To develop a conversion factor for thorny skate, the relationship between the catch per unit of effort (CPUE) for the two trawl types needs to be established. A basic comparison of the ratio of the mean CPUE of the two trawls, which is equivalent to developing a ratio of the sum of the catches of the two vessels, is the simplest solution to develop a conversion factor. However more complex methods have also be investigated.

Robson (1966) proposed a multiplicative model to establish the relationship between the CPUE for two trawls which has been used extensively to model catch relationships in the northwest Atlantic (i.e. Gonzalez Troncoso. 2004; Paz *et al*., 2002).

$$CPUE_{ij} = e^{\mu + t_i + h_j + \varepsilon_{ij}}$$

where: t_i is the effect of the ship i

h_j is the effect of the haul j

μ is the model parameter

ε is the model error

A logarithmic transformation is performed in order to obtain a linear relationship:

$$\ln(CPUE_{ij}) = \mu + t_i + h_j + \varepsilon_{ij}$$

where the conversion factor was estimated as the vessel effect (t) from the GLM.

In addition to the above conversion factors, a conversion factor was also derived from the knife-edge change in biomass and abundance over the time of the gear change, comprising an average of the 1996 and 1997 biomass and abundance estimates divided by an average of the same estimates for 1994-1995.

As well, previous efforts to develop conversion factors for trawls in the northwest Atlantic have used a multiplicative model, using the length distribution (Warren, 1996; Warren *et al*., 1997). For thorny skate, the paucity of length frequency distributions from paired comparative tows prevents the application of a full analysis using the multiplicative model. However the limited length frequencies were investigated to assess any pattern between the ratio of Campelen Catch to Engel catch by length group. As well, the historic length frequency patterns between gears were assessed.

In addition to the above analyses, conversion factors based on CPUE ratios and multiplicative models were investigated from comparative trawl experiments conducted in 1983 in NAFO Div. 3L (Gavaris and Brodie, 1984). These additional analysis were necessary to extend the thorny skate time series to 1971 since the *Wilfred Templeman* replaced the previous research vessel *A.T. Cameron*.

Results and Discussion

Average number/tow and average weight/tow for all successful sets are presented in Table1a which compares the efficiency between the Engel and Campelen trawls from the *Gadus atlantica/Teleost* and the *Alfred Needler/Wilfred Templeman* experiments. Similar comparisons between vessels in which only one vessel captured Thorny skate (Table 1b) or both vessels captured Thorny skate (Table 1c) are also presented. In all cases, the vessels equipped with the Campelen trawls (*Teleost* and *Wilfred Templeman*) captured significantly more Thorny skate than vessels equipped with Engel trawls (*Gadus atlantica* and *Alfred Needler*). This relationship between paired tows is illustrated in Fig. 1a and 1b for each experiment. The conversion factors based on simple catch ratios for each experiment are presented in Table 1a,b,c for both numbers and weights of thorny skate. Based on the average catch ratio, the conversion factor between the Campelen and Engel trawl for numbers caught would be 1.62 and 2.63 for converting *Gadus Atlantica* and *Templeman* Engel trawls respectively into Campelen equivalents (Table 1c). Similarly, the conversion factor for weight would be 1.78 and 2.77. It should be noted that the difference in conversion factors between the two experiments could reflect the differences in the original Engel trawls employed upon the *Gadus Atlantica* and *Wilfred Templeman* which had evolved into different gears (McCallum and Walsh, 1996) and as such had necessitated the two experiments. Alternatively, it may also reflect that the *Gadus atlantica – Teleost* comparison potentially reflects differences between vessels and trawls, while the *Wilfred Templeman* and *Alfred Needler* (being sister ships), comparison perhaps only reflects trawl differences.

Calculation of thorny skate conversion factors was also conducted using a multiplicative model (Robson 1966, Wilderbauer *et al*., 1998; Gonzalez Troncoso and Paz, 2003; Gonzalez Troncoso, 2004). Based on this model, the conversion factor between the Campelen and Engels trawl for numbers caught would be 1.57 and 2.42 for converting *Gadus Atlantica* and *Templeman* Engel trawls respectively into Campelen equivalents. Similarly, the conversion factor for weight per tow was estimated as 1.14 and 2.54.

In addition to the above methods, a conversion factor was derived using the ratio of the average of the first two years of Campelen biomass and abundance to the last two years of Engel biomass and abundance. This yielded a conversion factor of 2.8 for biomass and 2.4 for abundance. With the change in survey trawls to the Campelen trawl in the autumn of 1995, most teleost species captured by that gear were observed to have a smaller average size compared to those caught by Engel gear. Thus, a size based Engel to Campelen conversion is required to standardize the two series for those species. However for thorny skate, comparing the last year when Engel gear was used to the first year of Campelen usage, average weight (biomass/abundance) is very similar over all Divisions (Fig. 2). For thorny skate, it appears that there is no break across survey gears in terms of mean weight. This is expected given that Campelen gear appears to catch ~2.8 times more weight per tow than Engel, and 2.4 times more skates in numbers than the latter trawl.

In addition, comparison of the raw length frequency distributions, from the paired trawls, indicates that both gears sampled a similar length distribution of thorny skate (Fig. 3a, 3b). However, it should be noted that during the paired tows that only eight paired sets were used in the creation of the length frequency distribution. In most cases, the length frequency was derived from sets in which one vessel captured no skates, therefore the trawls potentially are sampling different distributions. A limited length frequency distribution, from only paired surveys trawls in which both species captured thorny skate is presented in Fig. 4. There is no significant difference between these length frequency distributions (*ks* = 0.07, *P*-value = 0.6519). Unlike previous comparative trial analyses (Warren, 1996; Warren *et al*., 1997), the gradual and continuous decline in the catch ratio over a wide range of lengths was not observed (Fig. 5). Furthermore, visual inspection of the historic length frequency distributions (Fig. 6) indicates that there is no apparent discontinuity between the length frequencies before and after the gear change.

A total of 70 paired trawls were available to compare the catch efficiency *A.T. Cameron* and the *Wilfred Templeman*. Comparison of the average number/tow and average weight/tow for all successful sets are presented in Table 2. Similar comparisons between vessels in which only one or both vessels captured thorny skate are presented. Only 28 paired tows were completed in which both vessels captured thorny skate during the comparative trials. Figure 7 shows the relationship between the *A.T. Cameron* and the *Wilfred Templeman* of ln transformed thorny skate catches. Based on the basic mean CPUE ratio, the *Wilfred Templeman* appears to capture slightly fewer skate (~94%) than the previous vessel the *A.T. Cameron*. As well, in the comparative tows the *Wilfred Templeman* caught only 64% of catch by weight during the paired tows than the *A.T. Cameron*. However, conversion factors based upon the multiplicative model indicated that there was no significant difference between the paired trawls in which both vessels captured skates and the conversion factor was 1.2 for numbers and 1.05 for weight of skates caught between the vessels.

Conclusions

Based on the STACFIS request for standardization of the two research survey series (Engel and Campelen) for thorny skate in Div. 3LNO, various conversion factors were investigated. Absence of size-based differential catchability of the two trawls, based on assessment of the available length frequency data from comparative trawl experiments eliminated the necessity of a length based conversion factor. Comparable conversion factors were developed based upon the Mean CPUE and Robson conversion factors from comparative trawl experiments and spring survey catch ratios. STACFIS recommended adoption of Robson's multiplicative model for conversion of thorny skate Engel trawl data from 1984 to 1995 to derive a standardized time series for thorny skate. Thorny skate converted and unconverted abundance indices for NAFO Div. 3LNO, are presented in Fig. 8a,b,c.

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Table 1a: Average catch of Thorny skate by vessel during comparative trawls. All sets.

		Average	
Vessel		**Number**	**Weight**
Gadus Atlantica(Engel)		6.539173	10.799
Teleost(Campelen)		11.12324	19.68838
n=284	Ratio	1.70	1.82
Alfred Needler(Engel)		7.661111	14.72339
Wilfred Templeman(Campelen)		21.09944	42.49168
n=180	Ratio	2.75	2.89

Table 1b. Average catch of Thorny skate by vessel during comparative trawls. All sets in which ONE vessel captured Thorny skate.

		Average	
Vessel		**Number**	**Weight**
Gadus Atlantica(Engel)		7.034564	11.6171
Teleost(Campelen)		11.96591	21.17992
n=264	Ratio	1.70	1.82
Alfred Needler(Engel)		8.512346	16.35932
Wilfred Templeman(Campelen)		23.44382	47.21297
n=162	Ratio	2.75	2.89

Table 1c. Average catch of Thorny skate by vessel during comparative trawls. All sets in which BOTH vessels captured Thorny skate.

		Average	
Vessel		**Number**	**Weight**
Gadus Atlantica(Engel)		10.17685	16.82418
Teleost(Campelen)		16.54545	29.9808
n=176	Ratio	1.62	1.78
Alfred Needler(Engel)		12.14159	23.38
Wilfred Templeman(Campelen)		31.92339	64.76639
n=113	Ratio	2.63	2.77

Table 2. Catch of Thorny skate during comparative trawl experiments between the *A.T. Cameron* and *Wilfred Templeman.*

Vessel		*A.T. Cameron*	*Wilfred Templeman*	*Ratio*
All Sets, including zeros				
	Average number	2.99	2.54	0.85
	Average weight	4.14	2.36	0.57
	n	70		
One vessel with skate captures				
	Average number	4.27	3.63	0.85
	Average weight	5.92	3.37	0.57
	n	49		
Both vessels with skate captures				
	Average number	6.29	5.89	0.94
	Average weight	8.50	5.41	0.64
	n	28		

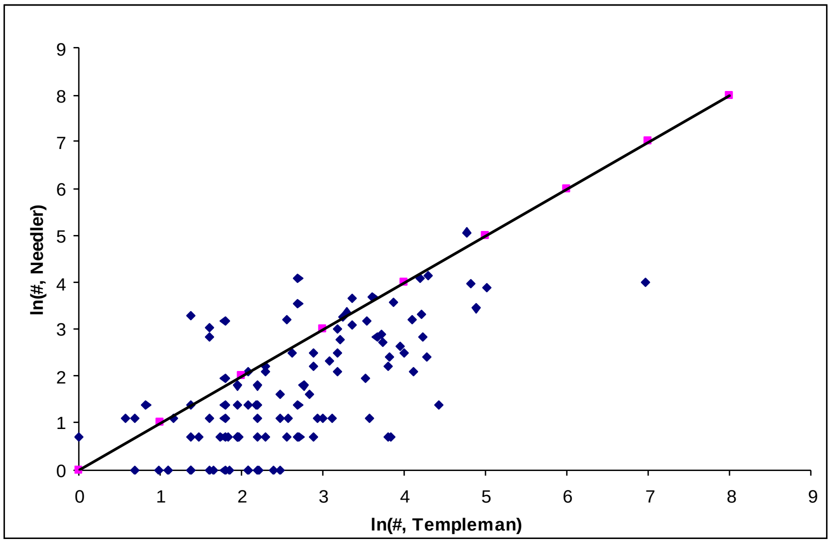

Fig. 1a. Scatterplot and linear relationship of paired comparative tows conducted by the *Alfred Needler* (Engel) and *Wilfred Templeman* (Campelen).

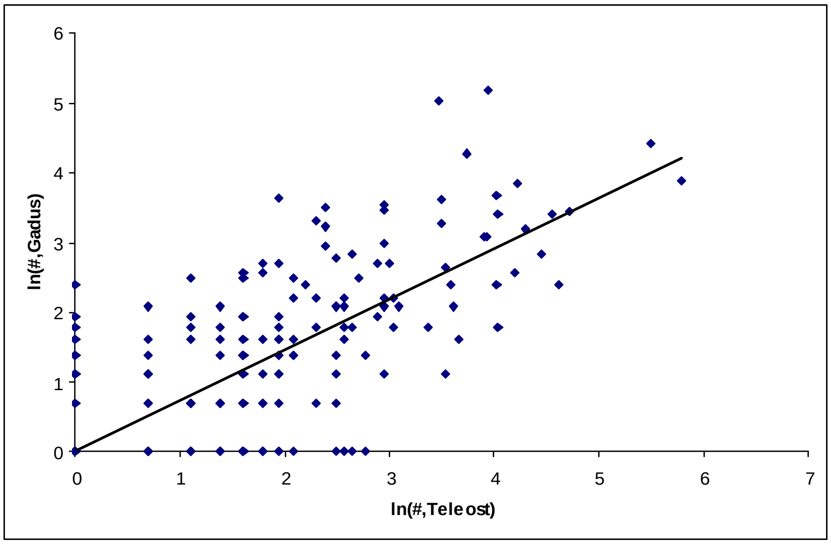

Fig. 1b. Scatterplot and linear relationship of paired comparative tows conducted by the *Gadus Atlantica* (Engel) and *Teleost*(Campelen).

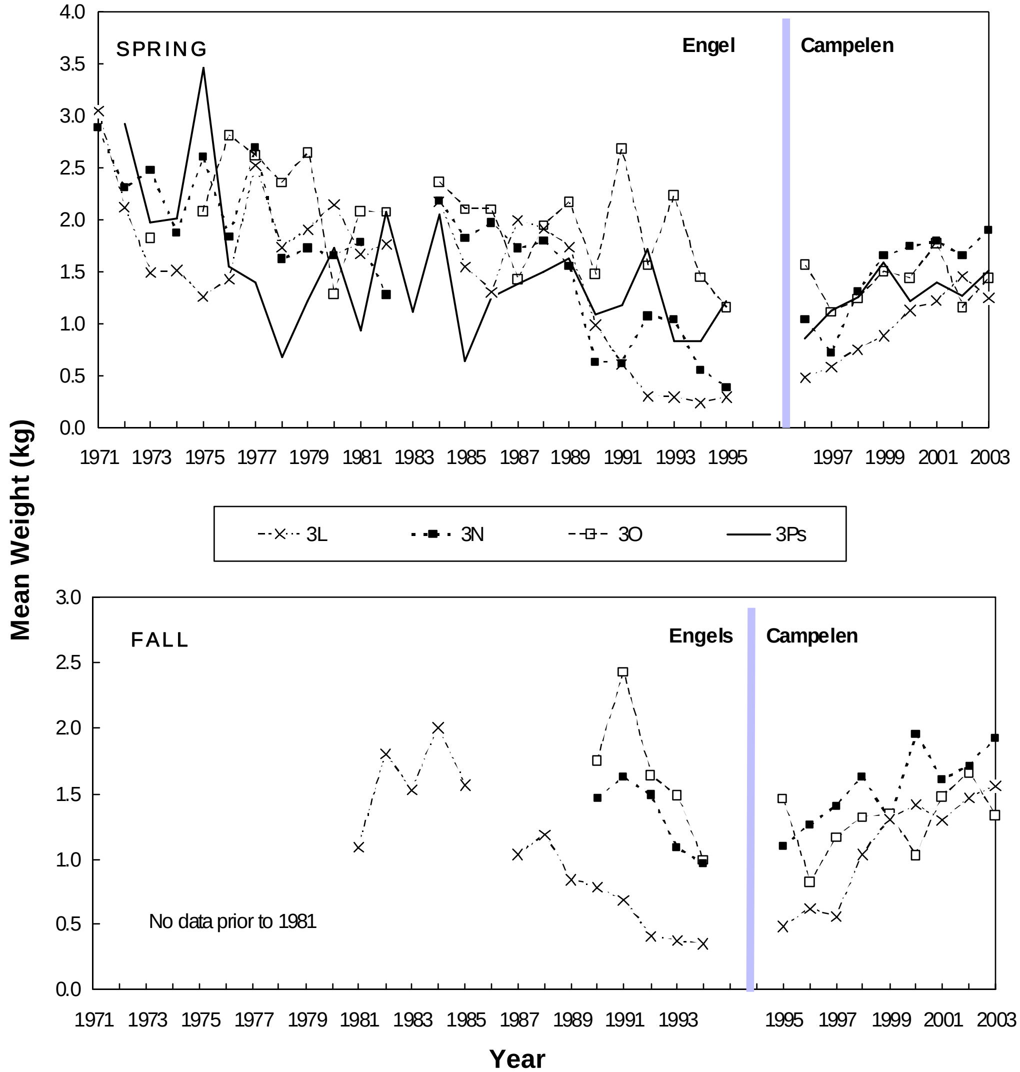

Fig. 2. Mean weight of thorny skate in spring (1971-2003) and autumn (1981-2003) surveys in NAFO Div. 3LNO and Subdiv. 3Ps.

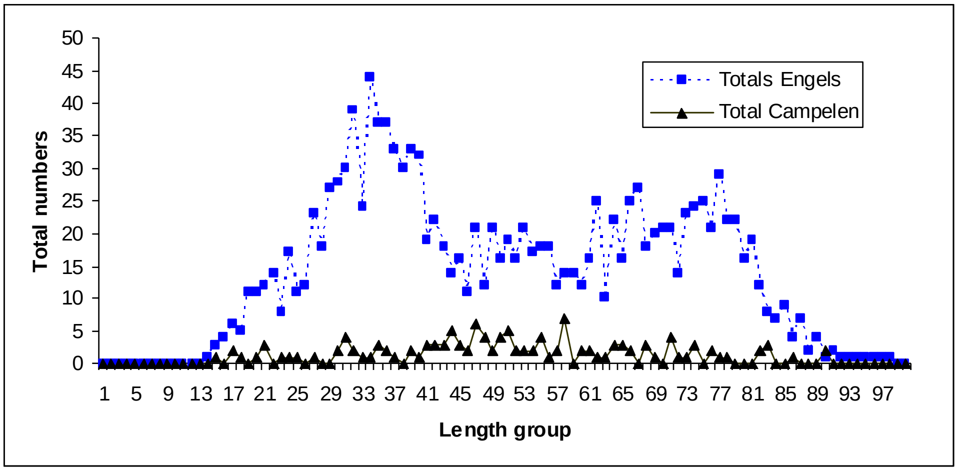

Fig. 3a. Observed length frequency of Thorny skate from comparative trawl experiments between the *Wilfred Templeman* and *Alfred Needler*.

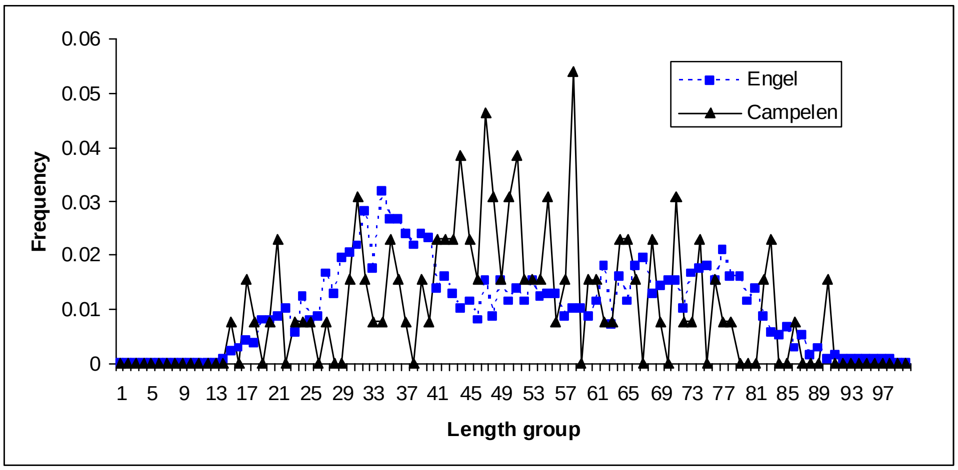

Fig. 3b. Relative length frequency distribution of thorny skate from comparative trawl experiments between the *Wilfred Templeman* and *Alfred Needler*. Observed frequencies were adjusted for sampling intensity between the two trawl types.

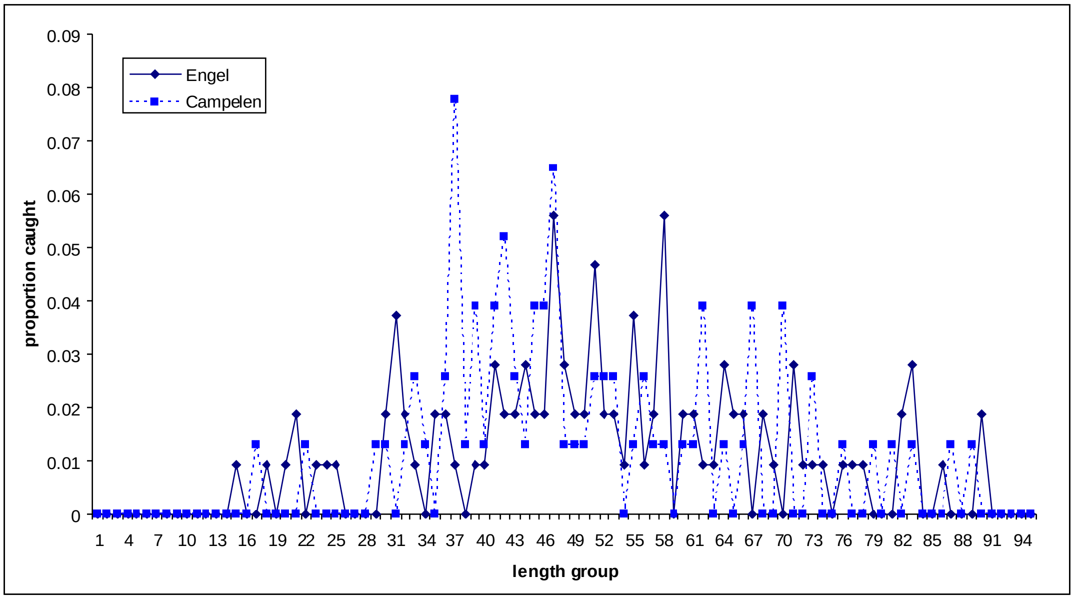

Fig. 4. Relative length frequency distribution of Thorny skate from comparative trawl experiments between the *Wilfred Templeman* and *Alfred Needler* in which BOTH vessels captured skate. Observed frequencies were adjusted for sampling intensity between the two trawl types. (*ks* = 0.07, *P*-value = 0.6519)

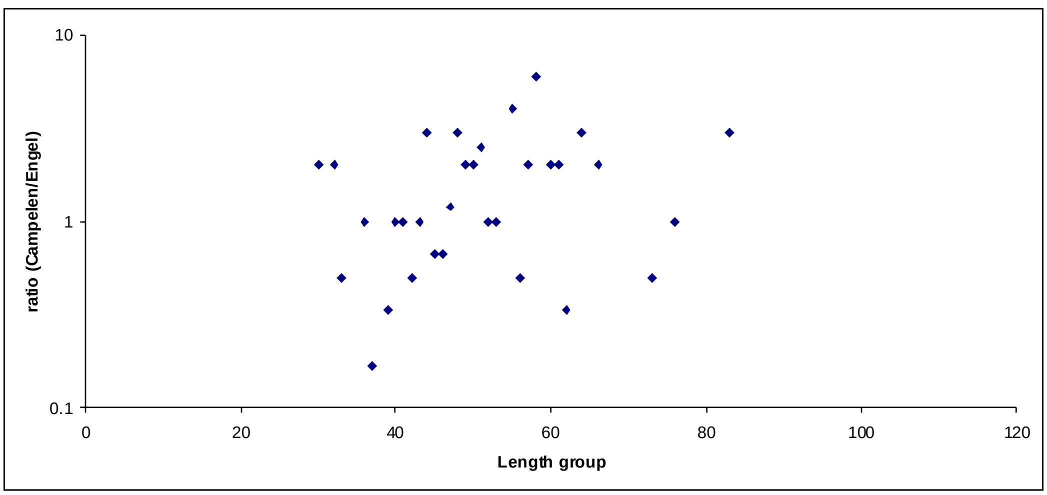

Fig. 5. Ratio of Campelen catch/Engel catch for Thorny skate by length group from paired trawls in which both vessels captured skate.

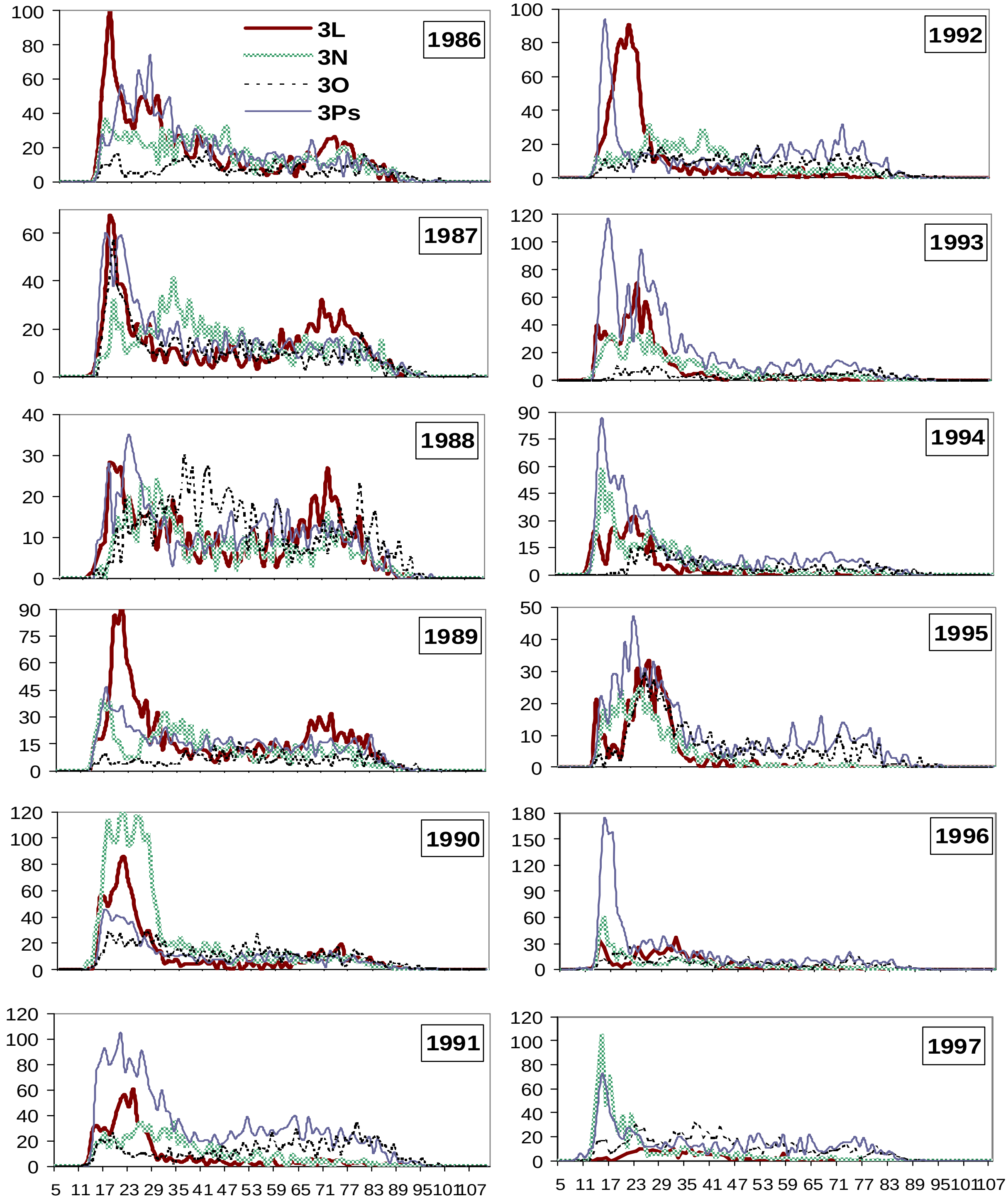

Fig. 6. Length frequencies of thorny skate caught by spring research vessel surveys in NAFO Div. 3LNOPs, 1986-2003. X-axis represents the lengths of skate in centimeters.

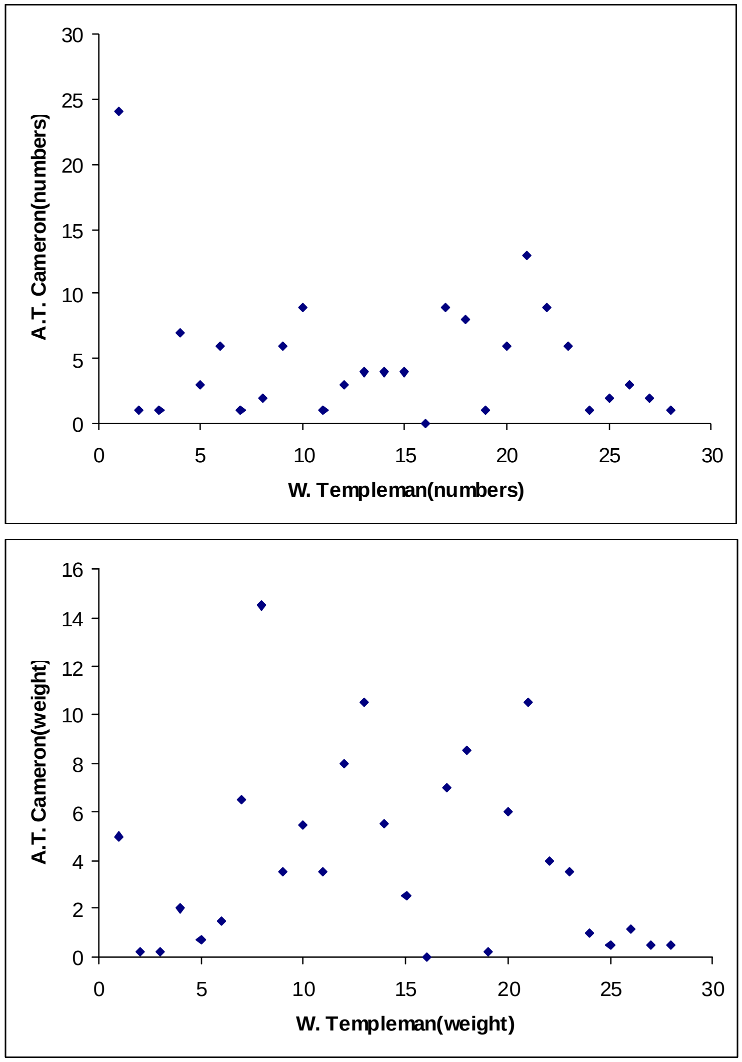

Fig. 7. Thorny skate in numbers (Top panel) and weights(Bottom panel) from paired comparative trawls between the *A.T. Cameron* and the *Wilfred Templeman*.

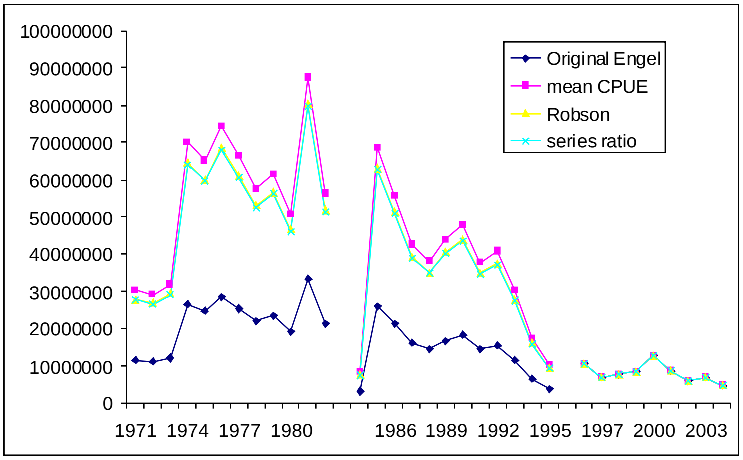

Fig. 8a. STRAP estimates of Thorny skate abundance in NAFO Div. 3L in original Engel units and converted to Campelen units by i) the ratio of mean CPUE, ii) Robsons's multiplicative model and iii) the series ratio.

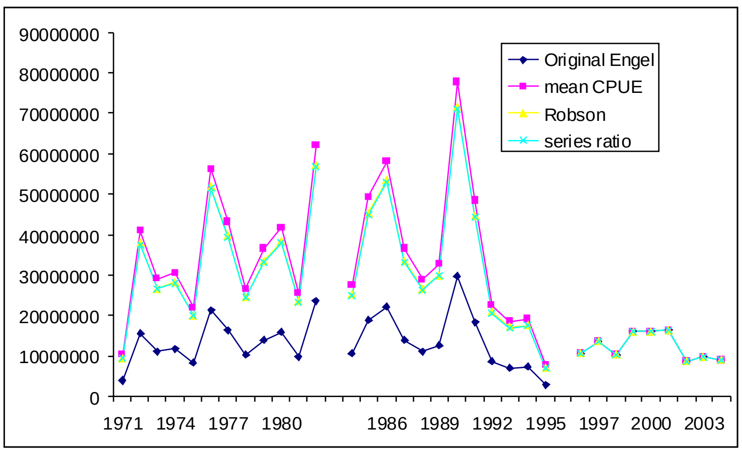

Fig. 8b. STRAP estimates of thorny skate abundance in NAFO Div. 3N in original Engel units and converted to Campelen units by i) the ratio of mean CPUE, ii) Robsons's multiplicative model and iii) the series ratio.

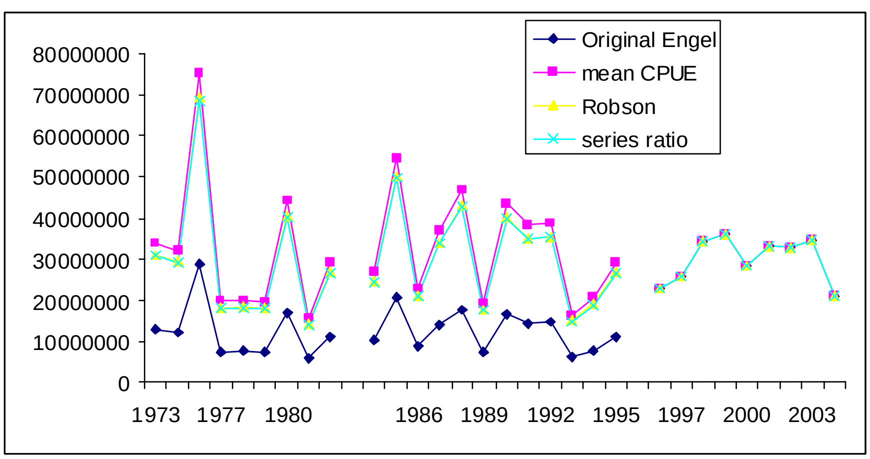

Fig. 8c. STRAP estimates of Thorny skate abundance in NAFO Div. 3O in original Engel units and converted to Campelen units by i) the ratio of mean CPUE, ii) Robsons's multiplicative model and iii) the series ratio.