MINISTRY OF FISHERIES
Te Tautiaki i nga tini a Tangaroa

ISSN 1175-1584

Length frequency distributions of spiny dogfish from the Chatham Rise, Sub-Antarctic, and the west coast South Island fisheries

N. L. Phillips

New Zealand Fisheries Assessment Report 2004/53
November 2004

Length frequency distributions of spiny dogfish from the Chatham Rise, Sub-Antarctic, and the west coast South Island fisheries

N. L. Phillips

NIWA
Private Bag 14901
Wellington

New Zealand Fisheries Assessment Report 2004/53
November 2004

Published by Ministry of Fisheries
Wellington
2004

ISSN 1175-1584

Citation:
Phillips, N.L. (2004).
Length frequency distributions of spiny dogfish from the Chatham Rise, Sub-Antarctic, and the west coast South Island fisheries.
New Zealand Fisheries Assessment Report 2004/53. 36 p.

This series continues the informal
New Zealand Fisheries Assessment Research Document series
which ceased at the end of 1999.

EXECUTIVE SUMMARY

Phillips, N.L. (2004). Length frequency distributions of spiny dogfish from the Chatham Rise, Sub-Antarctic, and the west coast South Island fisheries.

New Zealand Fisheries Assessment Report 2004/53. 36 p.

Length frequency data form an integral part of fisheries stock assessment by providing information on the size composition of catches. Observers from the Ministry of Fisheries Scientific Observer Programme (SOP) are placed on large trawlers to collect length frequency data for certain commercially caught species.

The observer and catch effort data for spiny dogfish from TCEPR (Trawl Catch Effort Processing Returns) forms were examined to determine areas suitable for compiling scaled length frequencies, as Fisheries Management Area boundaries may not reflect biological stocks. This resulted in three fisheries being examined; Chatham Rise, Sub-Antarctic, and west coast South Island.

It was important to post-stratify length frequency samples to increase precision and avoid biases. Tree-based regression techniques were used to stratify the catch based on the mean length of spiny dogfish for each tow in each year using the observer length frequency data. Five variables (*fishing day*, *method*, *depth*, *longitude*, and *latitude*) were used by the tree regression model to determine the strata.

The resulting scaled length frequencies by sex for each area tended to have a similar length range. Males tended to be unimodal for all three fisheries. Male length frequencies ranged from 45 cm to 80 cm (mode varied between 65 and 70 cm depending on year) for the Chatham Rise, 45 to 95 cm for the Sub-Antarctic (mode varied between 65 and 70 cm depending on year), and 40 to 80 cm for the west coast South Island (mode varied between 65 and 68 cm depending on year). Females were generally larger than males and had a greater size range in all fisheries. The Chatham Rise and Sub-Antarctic length frequencies appeared bimodal. The modes from the Chatham Rise ranged between 50–60 cm, and 80–85 cm depending on year, while the modes from the Sub-Antarctic ranged between 60–65 cm and 80–85 cm. The female length frequency distribution from the west coast South Island fishery appeared unimodal, with modes between 78 and 82 cm.

In all three fisheries, certain length classes dominated the length frequencies. This was because there were few fish measured in certain tows that had a large catch, and scaling of these fish to the catch resulted in a lot of fish of the same length class. This problem would be overcome by either by removing those fish from the analysis, or, even better, to have the scaling so that it is weighted by the number of fish measured, i.e., tows where only a few fish are measured have little effect on the resulting scaled length frequencies compared with tows that have many fish measured. This was not attempted in this analysis due to time constraints.

The length frequency distributions for males and females were both similar to those from trawl surveys for all three areas. However, females from the Chatham Rise, and both sexes from the Sub-Antarctic collected by observers were smaller than fish collected from trawl surveys in those areas.

The observed tows did not appear to be representative of the commercial fishery. Most of the observed tows appeared clumped by time and depth. The distribution of observer coverage could be improved by increased and/or revised sampling of tows throughout the year.

1. INTRODUCTION

Length frequency data form an integral part of fisheries stock assessment by providing information on the size composition of catches. From this, estimates of fishing selectivity can be obtained, or when used with other information (e.g., age-length data) year class strength can be determined. Observers from the Ministry of Fisheries Scientific Observer Programme (SOP) were placed on large trawl vessels to sample hoki, ling, and hake, and commercial bycatch species such as spiny dogfish. Observers were also placed on deepwater trawlers involved in the squid fishery and inshore trawlers on the west coast of the North Island to monitor bycatch of marine mammals.

Spiny dogfish are found throughout the southern half of the New Zealand Exclusive Economic Zone (EEZ) up to East Cape and Manukau Harbour on the east and west coasts of the North Island respectively (Annala et al. 2004). They are schooling, demersal carnivores, taking a wide range of prey species.

Most spiny dogfish are taken as bycatch in the jack mackerel, barracouta, hoki, red cod, and arrow squid fisheries in depths from 100 to 500 m, but are also caught by inshore trawlers, setnetters, and longliners targeting flatfish, snapper, tarakihi, and gurnard. The highest catches have been recorded in QMAs SPD 3, 5, 6, and 7 (see Figure 1 for QMA definitions). Most of the catch in the early 1980s was taken by factory trawlers in SPD 5 and 6 (ca. 1000 to 2000 t per annum), but in recent years most of the catch has been taken in SPD 3 (ca. 3500 t per annum) and to a lesser extent SPD 7 (ca. 1400 t per annum), by factory trawlers and the inshore fleet equally (Manning et al. 2004).

Spiny dogfish are being considered for introduction to the QMS in the near future. Despite their catch history and distribution in the New Zealand EEZ and extensive study overseas, spiny dogfish in New Zealand waters have been little studied. Hanchet (1986, 1988) studied aspects of the distribution and abundance, reproductive biology, growth, and life-history characteristics of spiny dogfish off the east coast of the South Island. Regional catch histories were compiled, biological data reviewed, and biomass indices from trawl surveys tabulated by Hanchet & Ingerson (1997). A more comprehensive analysis of the New Zealand fisheries, incorporating data SOP and catch-per-unit-effort (CPUE) analyses, was attempted by Walker et al. (1999), although they were unable to relate trends in CPUE to relative abundance of spiny dogfish. Walker et al. (1999) also found that most males were between 55 and 85 cm with the mode at 70 cm, while females were between 55 and 105 cm with the mode at 80 cm. They suggested that the larger and more commercially valuable females were targeted preferentially, as in many other elasmobranch fisheries.

This paper presents the results of part of the study of spiny dogfish in New Zealand waters funded by the Ministry of Fisheries under research project SPD2002-01 Objective 1, "Characterisation of spiny dogfish fisheries". The specific objective of the project was to characterise New Zealand's spiny dogfish fisheries by analysis of existing commercial catch and effort data and data from other sources, and make recommendations on appropriate methods to monitor or assess the status of the major fishstocks. This paper describes only the calculation and the results of the scaled length frequencies of spiny dogfish from the commercial catch calculated from data collected by the SOP since 1996–97. The remainder of the study, which includes a characterisation of the spiny dogfish fisheries, an updated CPUE time series, and recommendations on appropriate methods to monitor the status of the stocks and current information needs to assess the major fisheries, was described in Manning et al. (2004).

2. METHODS

2.1 Data

2.1.1 Observer data

Observers recorded the length frequencies of spiny dogfish by sex up to a maximum of 100 fish per tow, and for a maximum of 10 tows per trip (therefore up to 1000 fish per trip) of a commercial fishing vessel.

Data to estimate length frequencies from 1996–97 to 2000–01 were extracted from the Ministry of Fisheries Scientific Observer Programme database. The observer data consists of the catch weight of spiny dogfish, length and sex of a sample of spiny dogfish, locations of tows, depth of tow gear, and method of trawling.

2.1.2 Catch effort data

As spiny dogfish is not a quota species, there is no legal requirement to either record and/or retain spiny dogfish. However, as spiny dogfish may be introduced into the Quota Management System (QMS), fishers may record their catch of spiny dogfish.

The catch and effort data were recorded by fishers on either Trawl-Catch-Effort-Processing-Returns (TCEPR) or Catch-Effort-Landing-Returns (CELR). TCEPR forms record tow-by-tow data, with positions given by latitude and longitude. The TCEPR forms also record the species and amount processed (including discards for all quota species) for a given day. The processed fish are weighed and a conversion factor (depending on processing type) allows the weight of the fish before processing (i.e., green weight) to be estimated.

CELR forms summarise daily catches (which may include several sets or tows), with position given by statistical area. Longline and setnet landings were always recorded on CELR forms, while trawl vessels less than 28 m in length can use either CELR or TCEPR forms. Trawl vessels over 28 m use TCEPR forms. Both the TCEPR and CELR recorded only the top five species caught.

For this analysis, the spiny dogfish catch recorded from the daily processed component of the TCEPR forms was used for the following reasons:

1. 98% of vessels with observers on board were over than 28 m, and therefore fill out TCEPR forms.
2. There is a correlation between size of fish and depth (i.e., smaller fish in shallower waters) (S Hanchet, NIWA, pers. comm.); CELR vessels tend to fish more inshore, therefore their catch of spiny dogfish would contain smaller fish.
3. Scaling the observer length frequencies to the CELR catch would result in biased estimates.
4. The top part of the TCEPR form has room for the recording of only the top five species caught.

The observer and catch effort data were examined to determine areas suitable for compiling scaled length frequencies based on tow locations, as Quota Management Area boundaries may not reflect biological stocks.

2.2 Stratification

It is important to post-stratify length frequency samples to increase precision and avoid biases (Bradford 2000). If possible, exogenous information should be used to help justify strata.

Tree-based regression techniques were used to find the most important stratification variables (after Francis 2002, Ballara et al. 2003). The regression tree was grown and pruned using methods described by Breiman et al. (1984).

Classification trees attempt to predict the outcome of a categorical variable by dividing the model space, *X*, defined by the predictors, into mutually exclusive regions in which the value of the response is as homogenous as possible. This is achieved by splitting *X* in a binary fashion, choosing the split so that it maximises the homogeneity in each subset. The binary split is performed upon one variable at a time, and thus the order of variables used at the splits (nodes) is an indicator of variable importance. It is possible to grow a tree that describes the data well, but is over elaborate and has little meaning. Therefore the trees were "pruned back" using a cost-complexity measure. The method used to do this was cross-validation (Breiman et al. 1984). The ability of the model to describe the data was measured using percentage of deviation in mean length (r^2).

Tree-based regression techniques were used to stratify the catch based on the mean length of spiny dogfish for each tow in each year using the observer length frequency data. The independent variables offered to the regression tree model and their description are shown in Table 1.

Table 1: Description of variables from the observer data used in the tree-based regression analysis.

Variable	Type	Description
Length	Continuous	Tow mean length of spiny dogfish (explanatory variable)
Fishing day	Continuous	Number of days since the start of the fishing year (1 October).
Depth	Continuous	Depth (m) of the groundrope at the start of a tow.
Longitude	Continuous	Longitude at the start of a tow.
Latitude	Continuous	Latitude at the start of a tow.
Method	Categorical	Method of fishing (i.e., bottom trawl or midwater trawl).

The catch effort data were also stratified using the observer strata so the total stratum catch could be calculated. As the daily processed catch summary from TCEPR forms was based on day, the median *longitude*, median *latitude*, and median *depth* were calculated using all tows the vessel made on that day. If a vessel used both bottom trawl and midwater trawl on the same day, the catch was divided proportionally by each method using the tow-by-tow data from the top part of the TCEPR form, and treated as two separate records (both with the same *fishing day*)

2.3 Calculation of scaled length frequencies

Once strata were determined, catch-at-length estimates were produced using the 'catch.at.age' software developed by Bull & Dunn (2001), which scales the length frequency of fish from each tow up to the catch weight, sums over catches in each stratum and scales up to the total stratum catch (includes discards), to yield length frequencies by stratum and overall. The precision of each length frequency was measured by the mean weighted coefficient of variation (c.v.), which was calculated as the average of the c.v.s for the individual length or age classes weighted by the proportion of fish in each class. The c.v.s were calculated by bootstrapping.

2.4 Comparison with trawl surveys

The resulting length frequencies were compared with length frequencies collected on *Tangaroa* trawl surveys on the Chatham Rise (1996–97 to 2000–01) (see Livingston & Stevens 2002, section 5.3), Sub-Antarctic (1999–2000 and 2000–01) (see O'Driscoll & Bagley 2001, section 5.5), and the west coast South Island *Tangaroa* acoustic surveys (1999–2000) (Cordue 2002). There was a west coast acoustic survey in 1997, but no spiny dogfish were measured.

As well as the *Tangaroa* surveys, *Kaharoa* carried out a number of inshore trawl surveys. The observer length frequencies were not compared, as the length frequencies from the *Kaharoa* surveys were mainly from depths of 20 to 400 m, which resulted in smaller fish (unpublished analysis).

2.5 Assessment of observer coverage

The observer coverage was also briefly assessed to determine whether the spiny dogfish catch was representatively sampled. Graphs of the empirical distribution functions (EDF) for all the commercial and observed tows were plotted against *fishing day*, *depth*, *longitude*, and *latitude*. The EDF plots show the relative distribution of commercial and observer effort in relation to one particular variable. However, lower or higher relative observer effort does not necessarily imply over or under-sampling, but indicates that the pattern of observer sampling does not reflect the pattern of effort in the commercial fishery.

3. RESULTS

3.1 Summary of data

A total of 54 444 spiny dogfish were measured by observers from 1996–97 to 2000–01 (Table 2). Eighty-four percent of all length frequencies were collected in QMAs 3, 5, and 7.

Table 2: Number of length frequency records (males and females combined) by QMA from 1996–97 to 2000–01, totals by QMA and fishing year.

	QMA										
Fishing year	1	2	3	4	5	6	7	8	9	10	Total
1996–97	-	-	471	-	1 753	42	2 681	-	-	-	4 947
1997–98	3	100	2 364	561	3 111	445	1 736	1 149	1 031	-	10 500
1998–99	-	318	3 372	533	3 468	149	2 887	-	-	-	10 727
1999–00	-	777	2 465	998	3 380	605	4 558	-	-	-	12 783
2000–01	-	800	3 574	612	6 861	697	2 943	-	-	-	15 487
Total	3	1 995	12 246	2 704	18 573	1 938	14 805	1 149	1 031		54 444

The locations of observed tows where spiny dogfish were measured are plotted in Figure 1. There appear to be four main areas where spiny dogfish were measured: the Chatham Rise, Sub-Antarctic, west coast South Island, and the west coast North Island (Table 3). Most of the length frequencies from the west coast North Island were measured in 1997–98 and are not considered in this report.

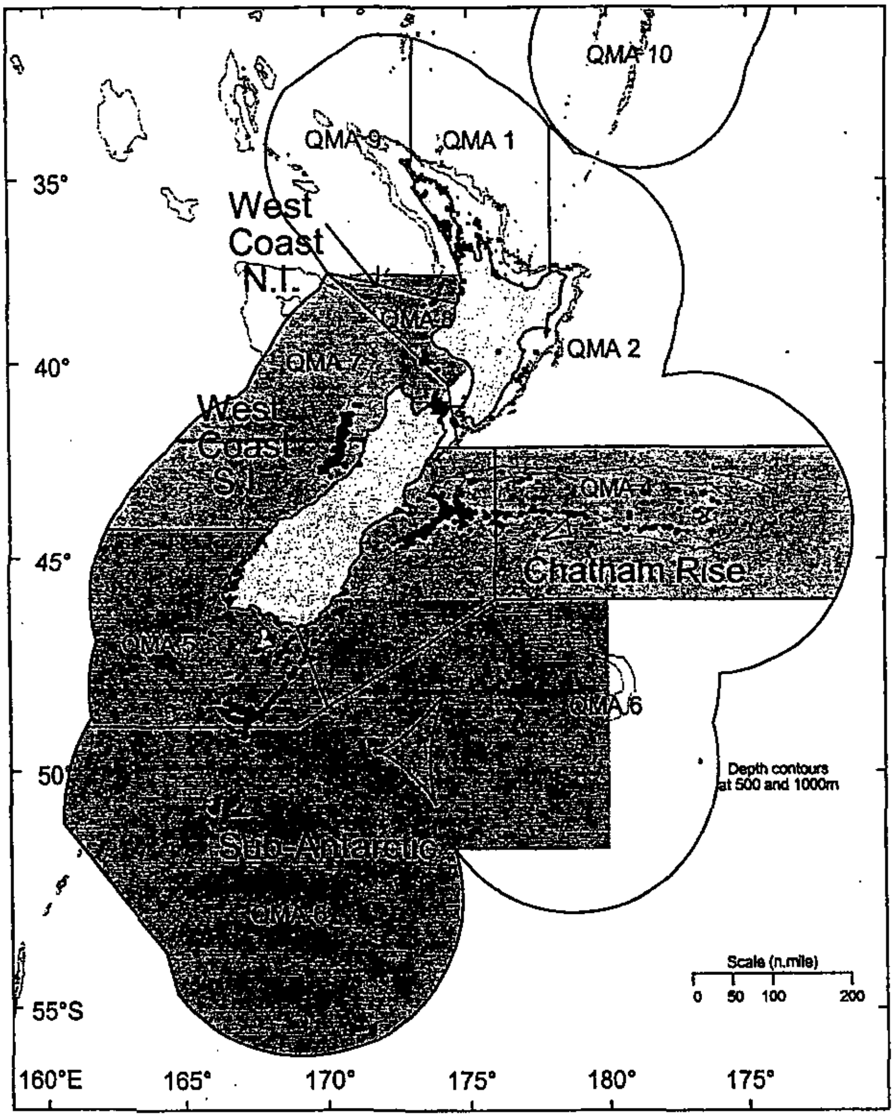

Figure 1: Location of QMAs, proposed fisheries, and location of tows where length frequency samples of spiny dogfish were collected by observers from 1996–97 to 2000–01 (shown as filled circles). Note that commercially sensitive positions are not plotted.

Table 3: Number of length frequency records (males and females combined) by fishery from 1996–97 to 2000–01 and totals by fishery and fishing year.

	Fishery					
	Chatham Rise	Sub-Antarctic	West coast N.I.	West coast S.I.	Other	Total
1996–97	471	1 795	-	2 681	-	4 947
1997–98	2 853	3 628	1 386	1 499	1 134	10 500
1998–99	3 688	3 776	-	2 832	431	10 727
1999–00	3 197	4 251	16	4 475	844	12 783
2000–01	3 715	8 029	-	2 512	1 231	15 487
Total	13 924	21 479	1 402	13 999	3 640	54 444

Spiny dogfish catches from deepwater vessels by fishing year for all fisheries combined are summarised in Table 4. About 87% of the landed catch was accounted for by the daily processed catch. The difference between these two columns was probably due to non-recording of the spiny dogfish catch or discards (as it was not a quota species). Trip records were further examined to assess the feasibility of assigning the landed spiny dogfish catch to tows from the corresponding catch effort record by some criteria. Many assumptions would have to have been made, and time constraints made this impossible.

Table 4: Summary of the catches (t) by fishing year. Catch from the catch landing returns (CLR) landing records and the daily processed catch from TCEPR records. Also presented is the daily processed catch from TCEPR records as a percentage of the CLR catch.

Fishing year	CLR catch	TCEPR	% TCEPR
1996–97	3 157	2 872	91
1997–98	2 996	2 355	79
1998–99	5 790	4 885	84
1999–00	5 056	4 452	88
2000–01	4 836	4 527	94
All years combined	21 835	19 091	87

3.2 Chatham Rise fishery

3.2.1 Stratification

The tree-based regression split the observer data into two strata in 1996–97 and 1999–2000, four strata in 1997–98, and three strata in 1998–99 and 2000–01 (Table 5). Splits by depth were at 265 and 310 m, with larger fish occurring deeper. Splits by *latitude* were at -43.6° (43.6° S), suggesting that catches on the north or south part of the Chatham Rise were being separated out, with larger fish occurring on the north side of the Rise. A split by *longitude* in 1998–99 separated the Rise at 173.7° E, with larger fish found east of the split. The stratification explained 28–69% of the variation of the mean length, depending on year.

Table 5 Percentage of deviation in mean length explained (r^2), selected strata, and mean length for spiny dogfish from the Chatham Rise fishery. Method: MW, midwater gear; BT, bottom tow gear.

			Selected variables					
Fishing year	r^2	Stratum	*Fishing day*	*Depth* (m)	*Longitude*	*Latitude*	*Method*	Mean length (cm)
1996–97	67.0	1	–	< 310.5	–	–	–	66.7
		2	–	≥ 310.5	–	–	–	72.6
1997–98	52.3	1	<59	–	–	< -43.6	–	74.6
		2	≥ 129.5	–	–	< -43.6	–	77.7
		3	59–129.0	–	–	< -43.6	–	81.5
		4	–	–	–	≥ -43.6	–	91.4
1998–99	41.4	1	–	–	< 173.7	–	–	62.5
		2	≥ 92.5	–	≥ 173.7	–	–	70.6
		3	< 92.5	–	≥ 173.7	–	–	78.2
1999–00	27.8	1	–	–	–	< -43.6	–	68.1
		2	–	–	–	≥ -43.6	–	76.5
2000–01	69.3	1	–	< 265.0	–	–	MW	58.2
		2	–	< 265.0	–	–	BT	70.0
		3	–	≥ 265.0	–	–	–	77.3

3.2.2 Scaled length frequencies

The male spiny dogfish length frequency distributions were unimodal for most years, with modes between 65 and 75 cm (Figure 2). The overall length range for male spiny dogfish was from 45 to 100 cm.

The female spiny dogfish length frequency distributions were bimodal, with the first mode between 50 and 60 cm and the second mode between 80 and 90 cm. The overall length range for females was from 45 to 105 cm.

There were some size classes (e.g., 75 cm male fish in 1997–98) that had relatively high proportions in the catch. These size classes also had corresponding high c.v.s. This was because an observer only sampled a few fish from a tow that had a high catch of spiny dogfish (i.e., a small sample size).

The mean weighted c.v.s were high for both males and females (Table 6). Males ranged from 32 to 76%, and females ranged from 32 to 79%. The combined male and female mean weighted c.v.s were lower than the individual sexes, and ranged from 27 to 65%.

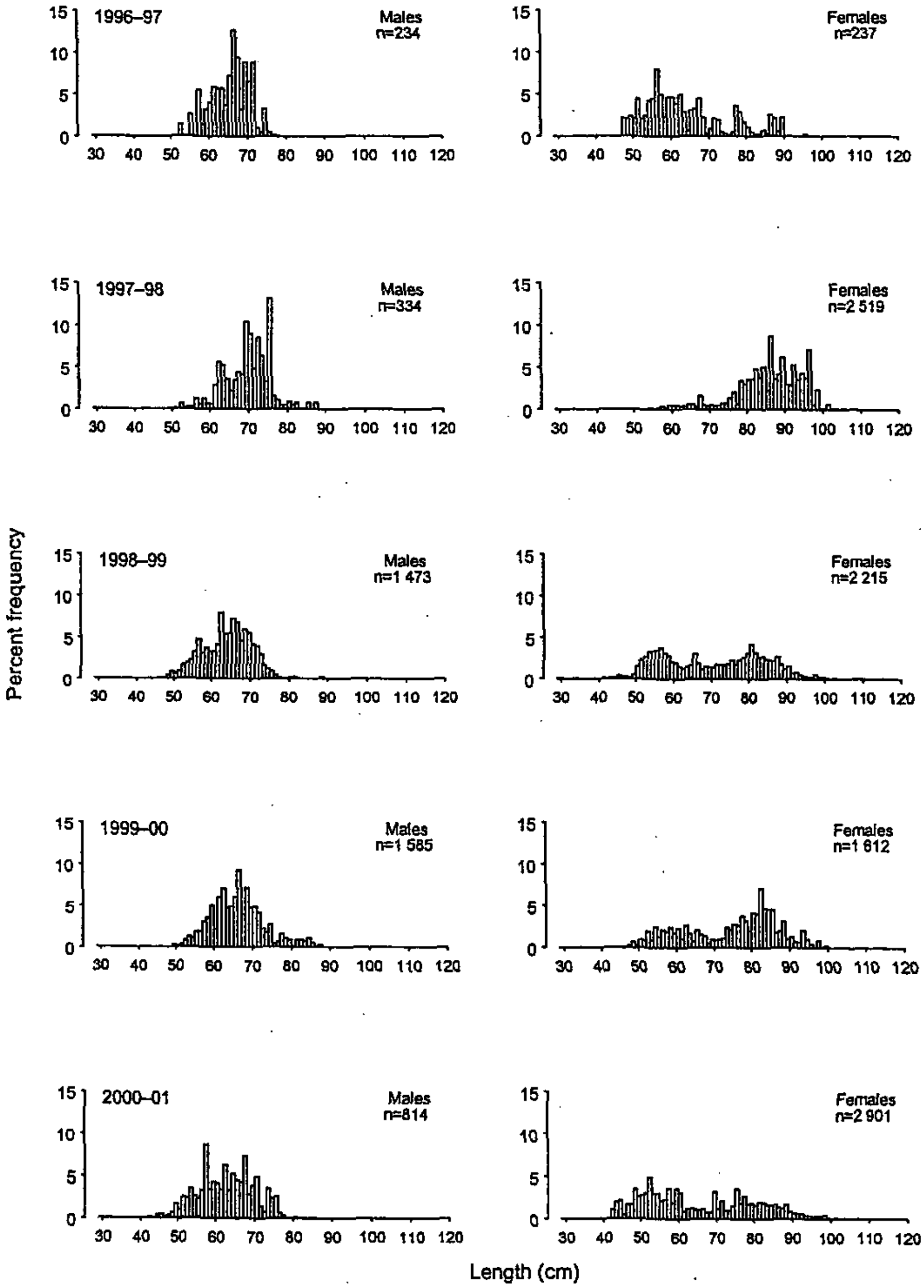

Figure 2: Scaled length frequencies for male and female spiny dogfish sampled by observers from the Chatham Rise fishery. (n, number of fish sampled.)

Table 6: Mean weighted c.v.s (%) of scaled numbers at length of spiny dogfish by sex, and both sexes combined from the Chatham Rise fishery.

Fishing year	Male	Female	Combined
1996–97	54	79	51
1997–98	76	67	65
1998–99	32	32	27
1999–00	43	48	38
2000–01	57	44	39

3.2.3 Comparison with trawl surveys

The spiny dogfish length frequencies collected by observers had similar distributions to the length frequencies collected on trawl surveys, with a unimodel distribution for males and a bimodal distribution for females (Figures 3 and 4). Both male and female spiny dogfish collected by observers were of a similar size to those collected on trawl surveys for all years, apart from larger female fish collected by observers in 1997–98 (Figure 5).

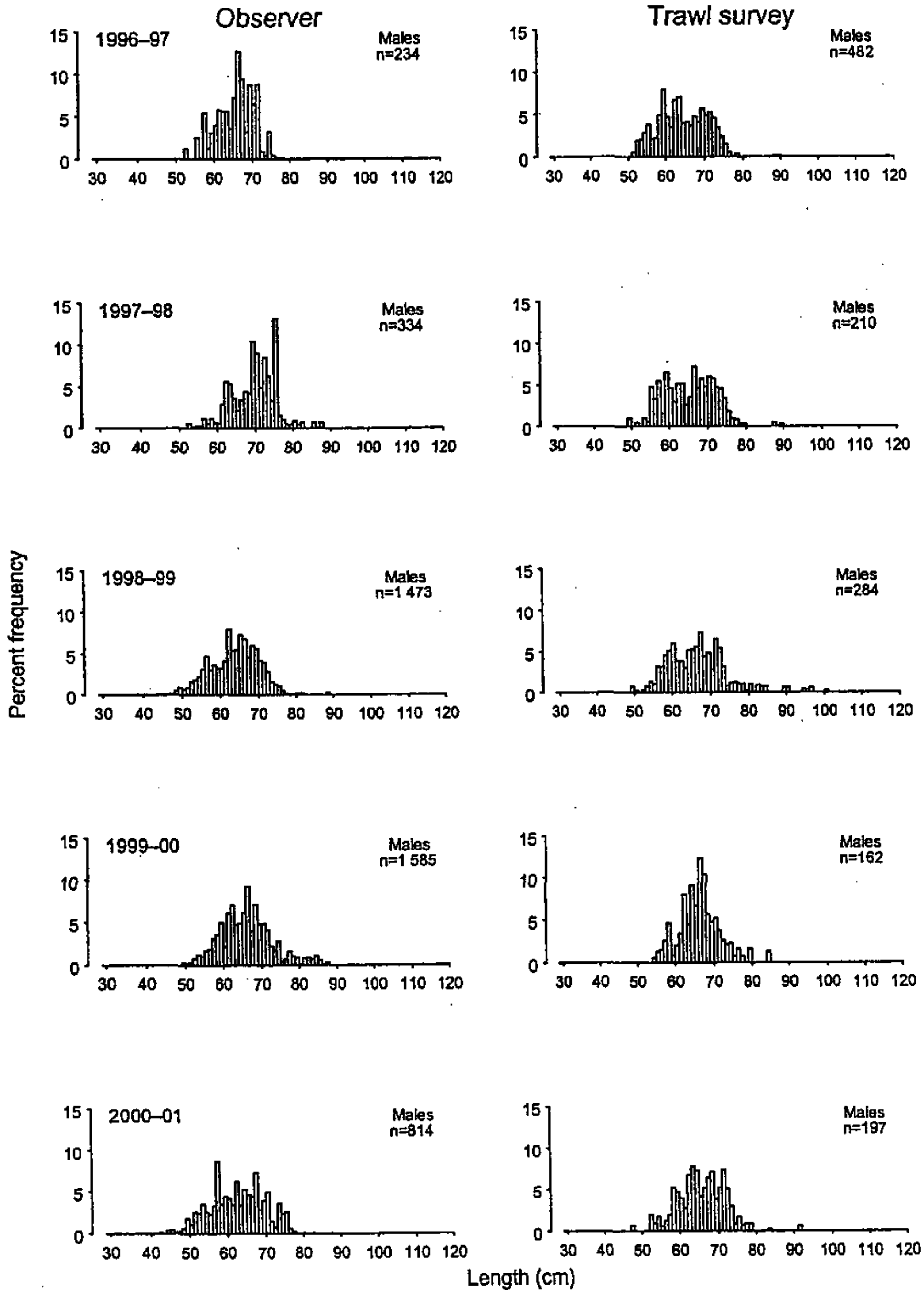

Figure 3: Comparison of male length frequencies collected by observers from the Chatham Rise to length frequencies collected on Chatham Rise trawl surveys; n is the number of fish measured.

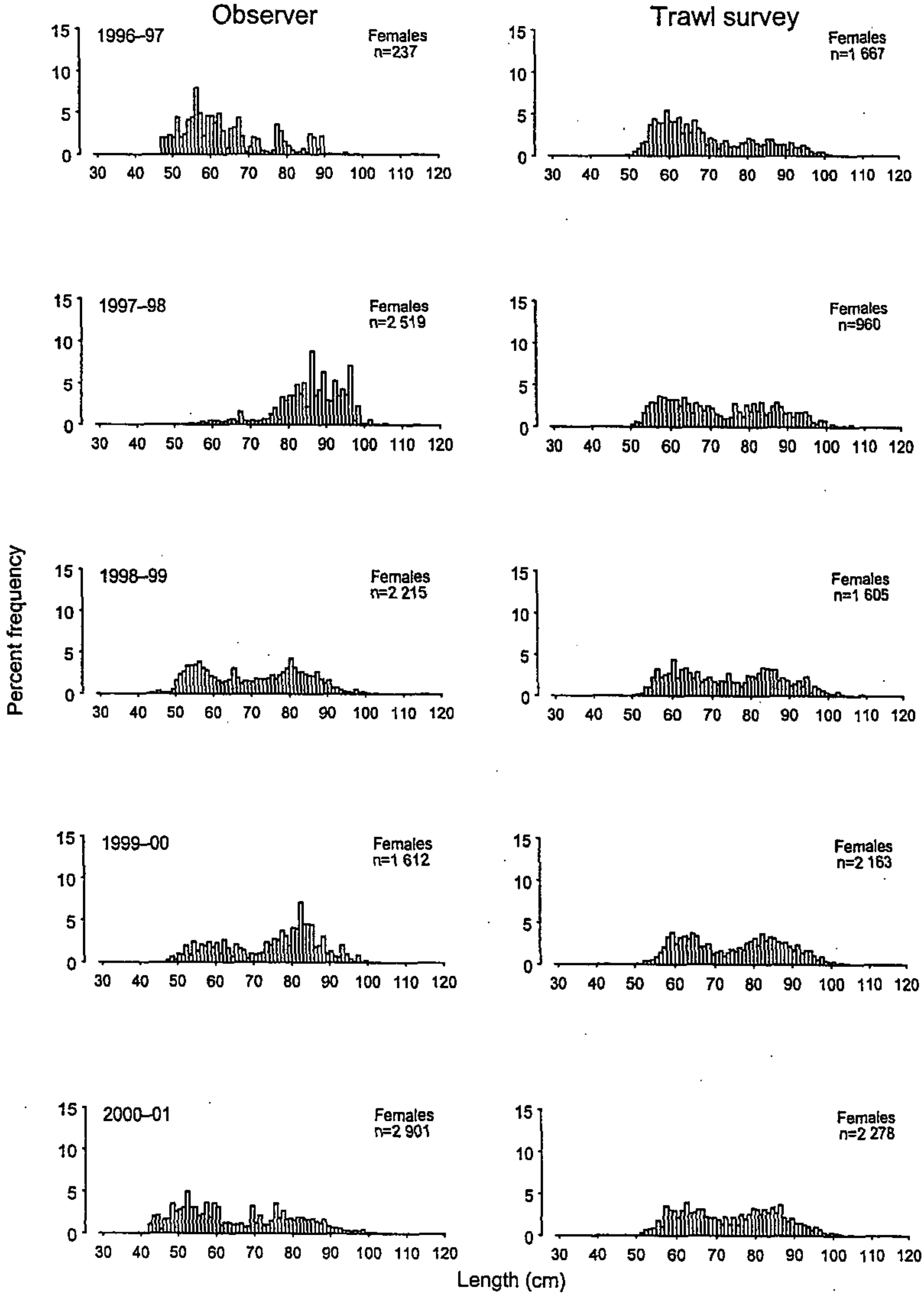

Figure 4: Comparison of female length frequencies collected by observers from the Chatham Rise to length frequencies collected on Chatham Rise trawl surveys; n is the number of fish measured.

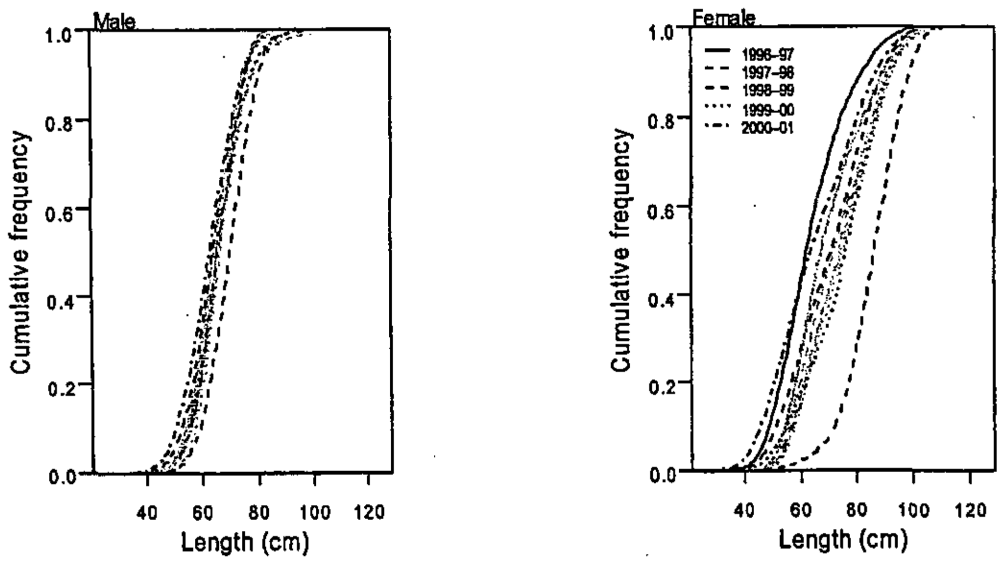

Figure 5: Cumulative length frequencies of male and female fish collected by observers (black lines) and trawl surveys (grey lines) from the Chatham Rise from 1996–97 to 2000–01

3.2.4 Assessment of observer coverage

Only 1.8% of all commercial tows from the Chatham Rise where spiny dogfish was recorded were sampled by observers (Table 7). The proportion of observed tows that recorded spiny dogfish increased from 1996–97 to 1997–98, followed by a decline to 2000–01.

Table 7: Number of commercial and observed tows that recorded spiny dogfish and the percentage of all tows that were observed from the Chatham Rise by fishing year.

	Commercial tows	Observed tows	% Observed
1996–97	1 943	6	0.3
1997–98	1 236	81	6.6
1998–99	2 344	44	1.9
1999–00	2 774	37	1.3
2000–01	3 895	49	1.3
All years	12 192	217	1.8

The commercial fishery operated throughout the year, with most tows between November to July (fishing days 30–270) (Figure 6). The observed tows all occurred between November to July for 1998–99 and 2000–01; however, no tows were observed at days 1–200 in 1996–97, days 210–365 in 1997–98, and days 65–160 in 1999–2000. Therefore there was no sampling for about 20% of tows in 1996–97, 55% of tows in 1997–98, and 30% of tows in 1999–00.

The commercial fishery that caught and recorded spiny dogfish operated at depths of about 50 to 800 m, with most tows occurring at 100–300 m and 400–600 m (Figure 7). Observed tows also occurred at similar depths to the commercial fishery in 1999–2000 and 2000–01, and the 400–600 m depth range in 1998–99. However, only a few tows (if any) were sampled for both depth ranges in 1996–97 and 1997–98, and the 100–300 depth range in 1998–99.

The commercial tows where spiny dogfish were recorded were mostly concentrated from -44.5° to 43.25° (Mernoo Bank) (Figures 8 and 9). The pattern of observed tows by longitude and latitude was similar to the pattern shown by the fishery for most years.

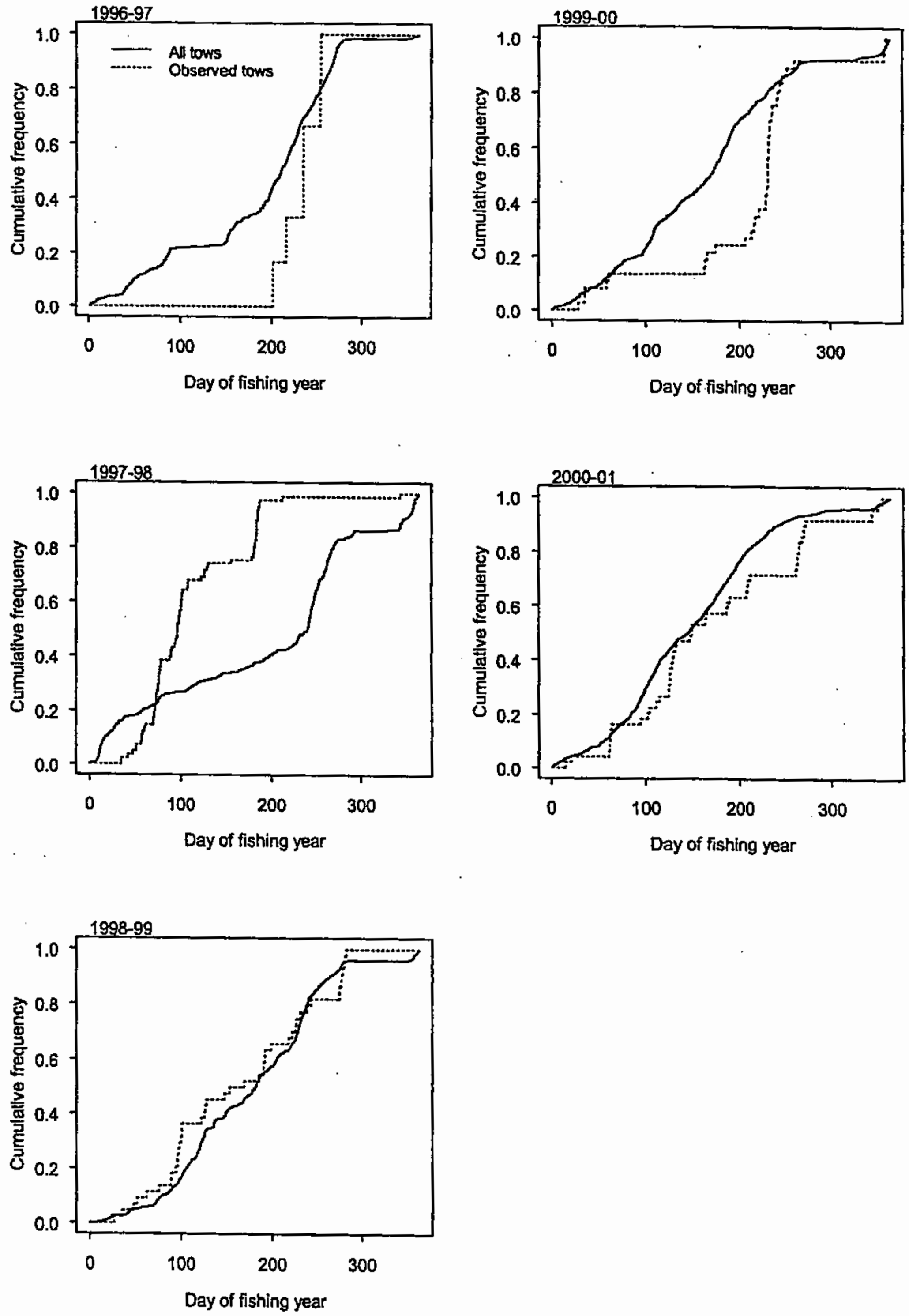

Figure 6: Comparison of the empirical distribution functions for all commercial and observed tows by *fishing day* for the Chatham Rise fishery from 1996–97 to 2000–01.

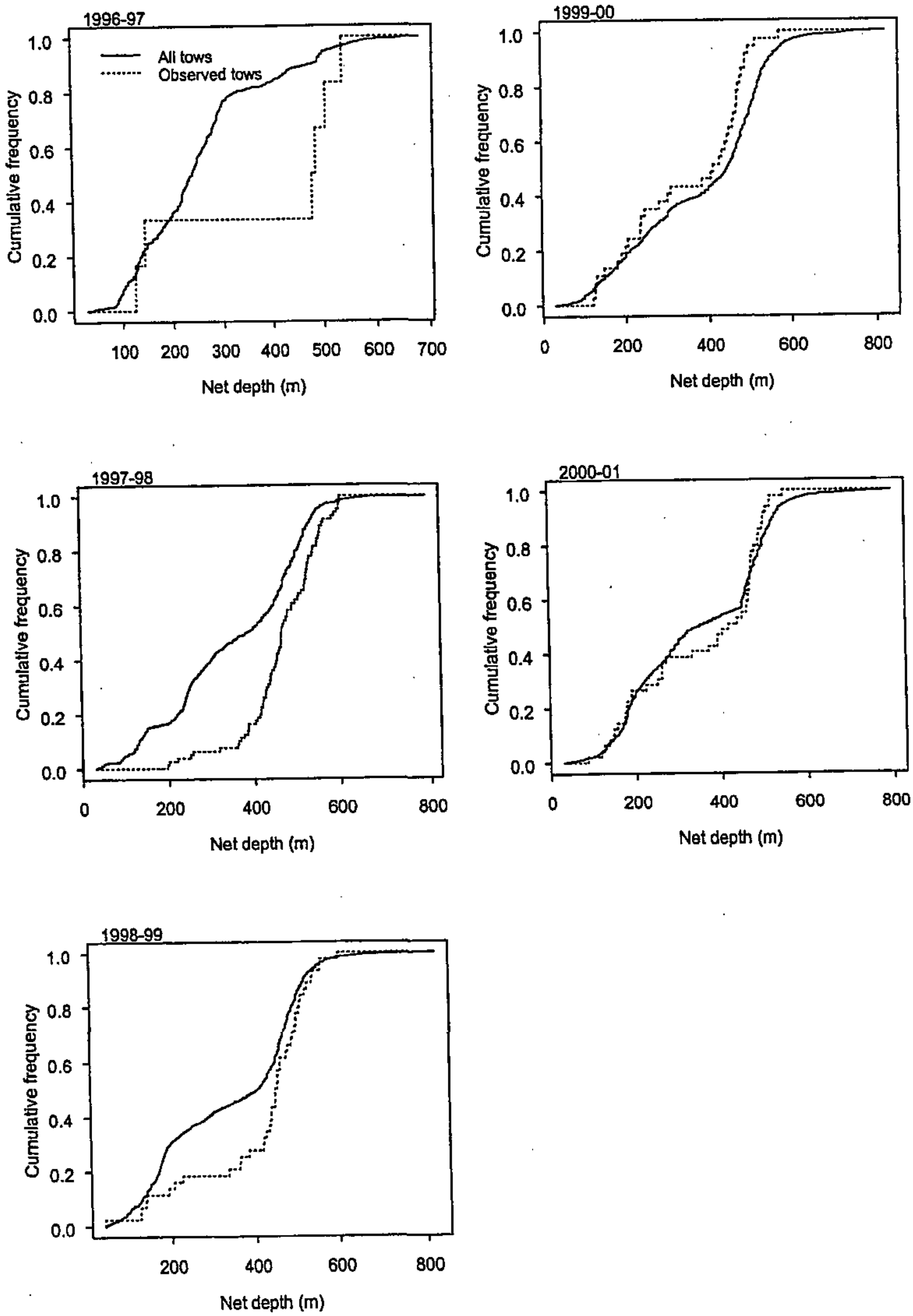

Figure 7: Comparison of the empirical distribution functions for all commercial and observed tows by *depth* for the Chatham Rise fishery from 1996–97 to 2000–01.

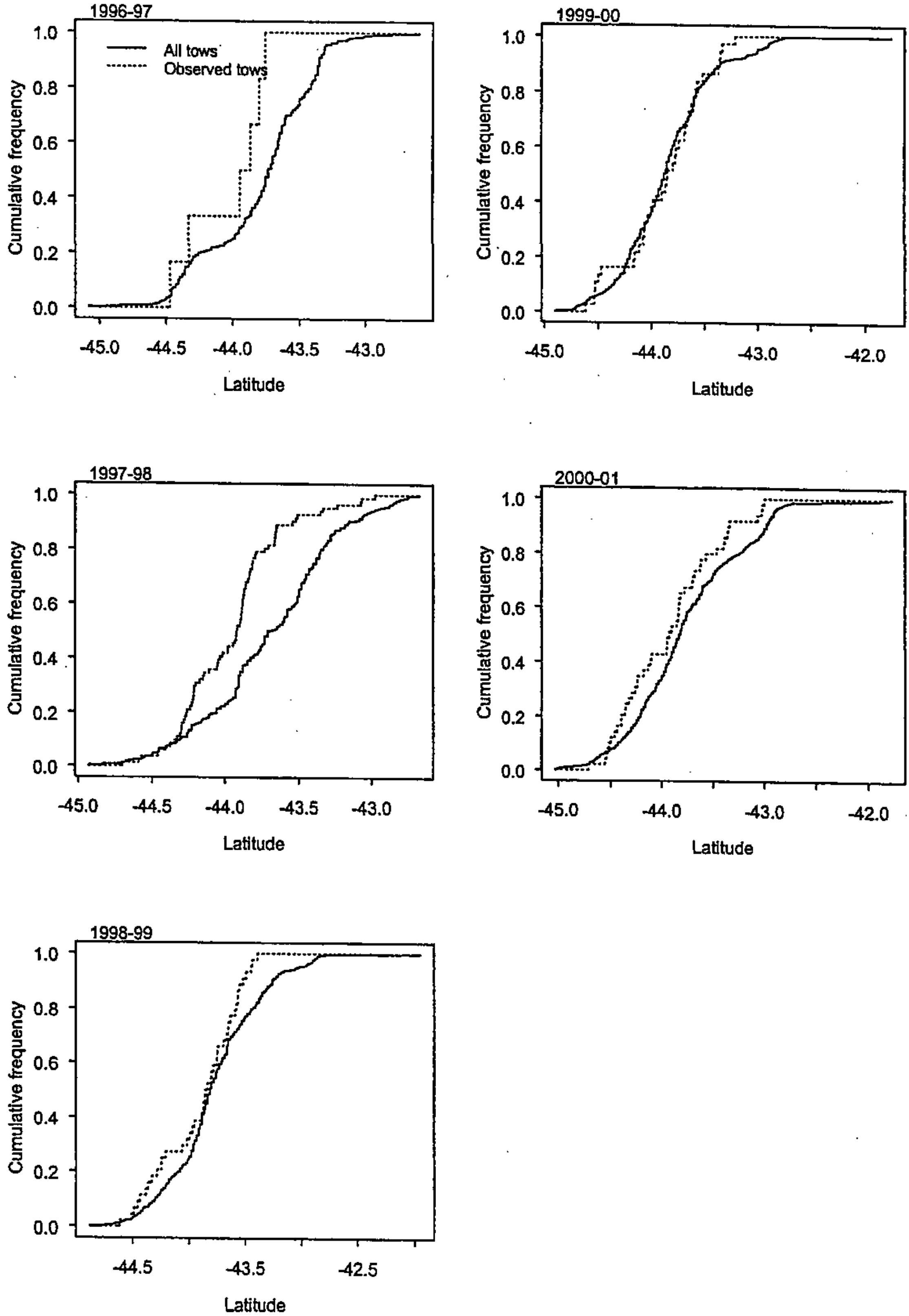

Figure 8: Comparison of the empirical distribution functions for all commercial and observed tows by *latitude* for the Chatham Rise fishery from 1996–97 to 2000–01.

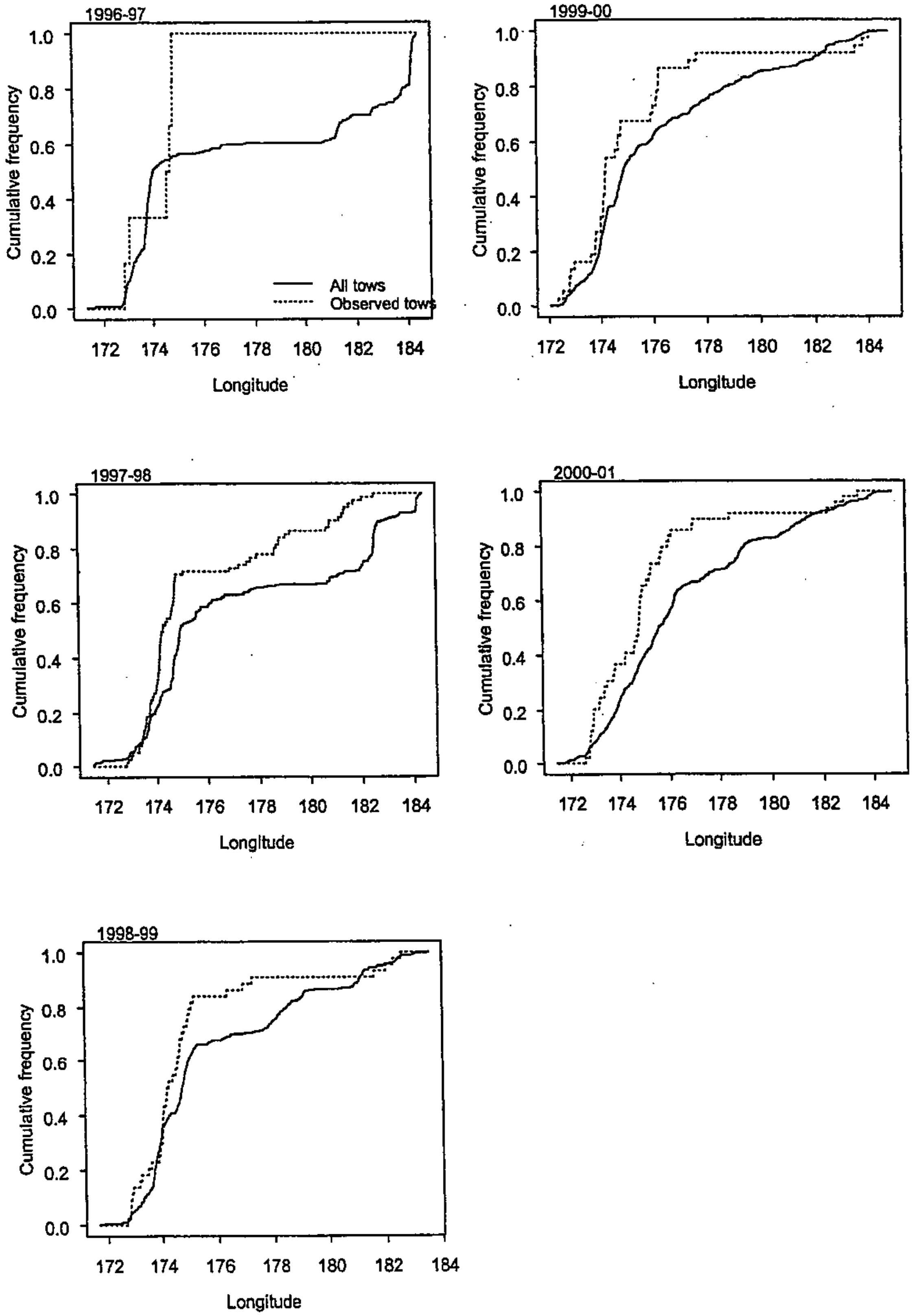

Figure 9: Comparison of the empirical distribution functions for all commercial and observed tows by *longitude* for the Chatham Rise fishery from 1996–97 to 2000–01.

3.3 Sub-Antarctic

3.3.1 Selected strata

The tree-based regression split the data into four strata in 1996–97, 1998–99, and 2000–01, and three strata in 1997–98 and 1999–2000 (Table 8). Splits by *fishing day* were towards the middle of the fishing year, and splits were made at depths of 142 and 364 m, with larger fish occurring deeper. Splits by *longitude* were at 167 to 169° E, with larger fish found between the two splits. The stratification explained 46–84% of the variation of the mean length, depending on year.

Table 8: Percentage of deviation in mean length explained (r^2), selected strata, and mean length for spiny dogfish observer length frequencies from the Sub-Antarctic fishery.

			Selected variables					
Fishing year	r^2	Stratum	*Fishing day*	*Depth* (m)	*Longitude*	*Latitude*	*Method*	Mean length (cm)
1996–97	83.9	1	–		≥ 169.4	–	–	66.9
		2	–	–	< 167.0	–	–	67.6
		3	–	–	167.0 – 167.3	–	–	74.5
		4	–	–	167.9 – 169.4	–	–	78.6
1997–98	49.2	1	≥ 166.5	–	–	–	–	69.5
		2	< 115.5	–	–	–	–	68.1
		3	115.5 – 166.5	–	–	–	–	79.1
1998–99	48.6	1	≥ 145.5	< 141.5	–	–	–	66.4
		2	≥ 145.5	≥ 141.5	–	–	–	71.5
		3	< 122.05	–	–	–	–	73.1
		4	122.0 – 145.5	–	–	–	–	80.1
1999–00	46.1	1	–	< 364.0	–	–	–	65.4
		2	≥ 180.0	≥ 364.0	–	–	–	70.1
		3	< 180.0	≥ 364.0	–	–	–	82.0
2000–01	60.5	1	–	–	< 167.0	–	MW	61.4
		2	–	–	≥ 167.0	–	MW	67.4
		3	–	–	< 168.8	–	BT	72.1
		4	–	–	≥ 166.8	–	BT	78.7

3.3.2 Scaled length frequencies

The male spiny dogfish length frequency distributions were unimodal, with mode between 65 and 70 cm depending on the year (Figure 10). The overall length range for males (45–90 cm) was narrower than for males from the Chatham Rise. As with the Chatham Rise fishery, female spiny dogfish had bimodal distributions, with the first mode between 55 and 65 cm and the second mode between 80 and 90 cm.

As with the Chatham Rise fishery, there were some length classes that contained relatively high proportions in the catch (e.g., 70 cm female fish in 1997–98). These size classes also had correspondingly high c.v.s. because there were very few fish sampled by an observer for a tow that had a high catch of spiny dogfish (i.e., a small sample size).

The mean weighted c.v.s were higher in the early years for both males and females (Table 9). Males ranged from 25 to 61%, and females from 34 to 80%. The combined male and female mean weighted c.v.s were lower than the individual sexes, and ranged from 26 to 68%.

Table 9: Mean weighted c.v.s (%) of scaled numbers at length of spiny dogfish by sex, and both sexes combined from the Sub-Antarctic fishery.

Fishing year	Male	Female	Combined
1996–97	61	80	68
1997–98	33	63	33
1998–99	38	64	43
1999–00	25	54	26
2000–01	28	34	25

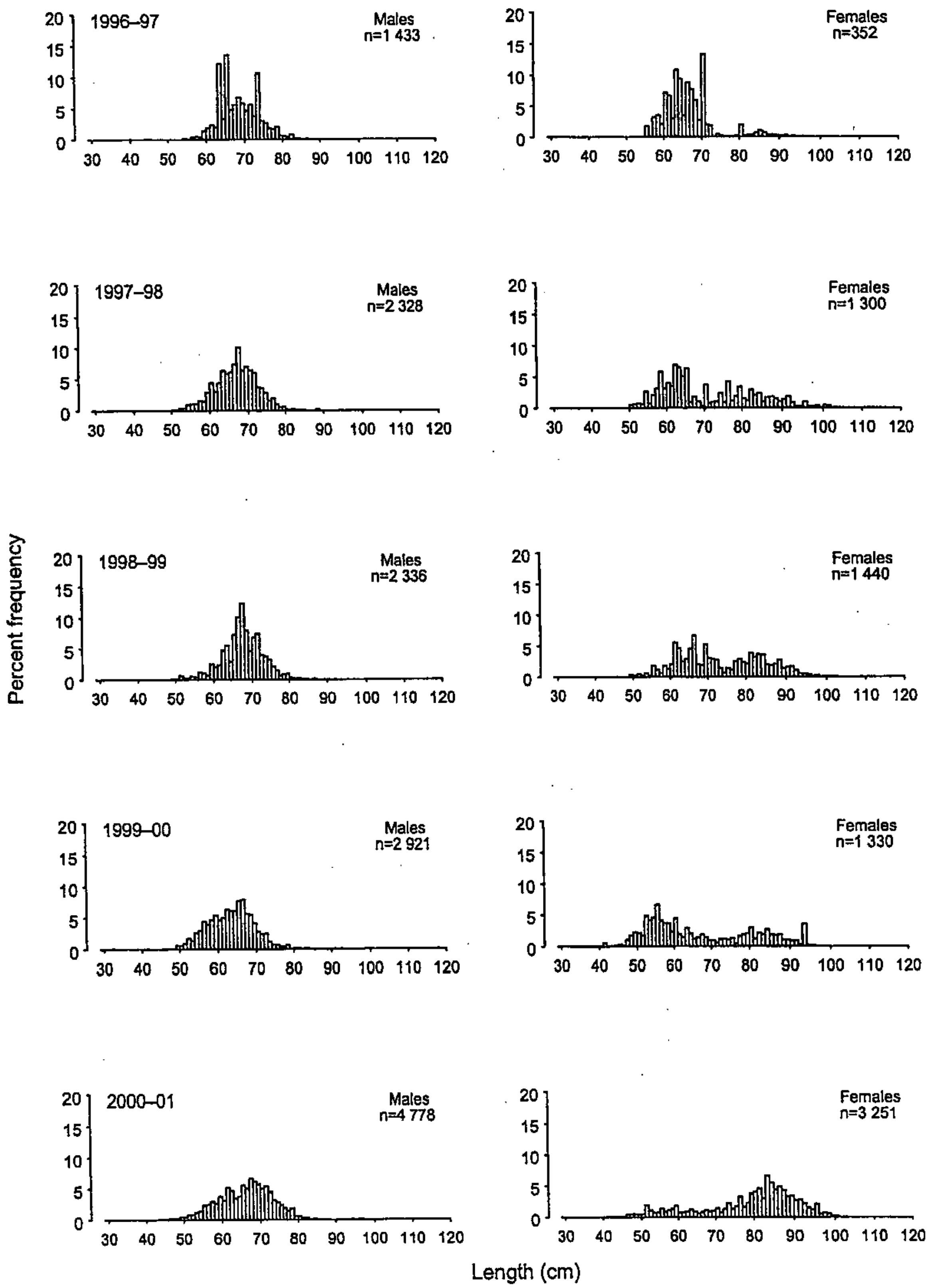

Figure 10: Scaled length frequencies for male and female spiny dogfish sampled by observers from the Sub-Antarctic fishery. (n, number of fish sampled.)

3.3.3 Comparison with trawl surveys

The spiny dogfish length frequencies collected by observers had similar distributions to the length frequencies collected on trawl surveys with a unimodel distribution for males and a bimodal distribution for females (Figure 11). However, observers collected smaller female spiny dogfish on the 1999–2000 trawl survey (Figure 12).

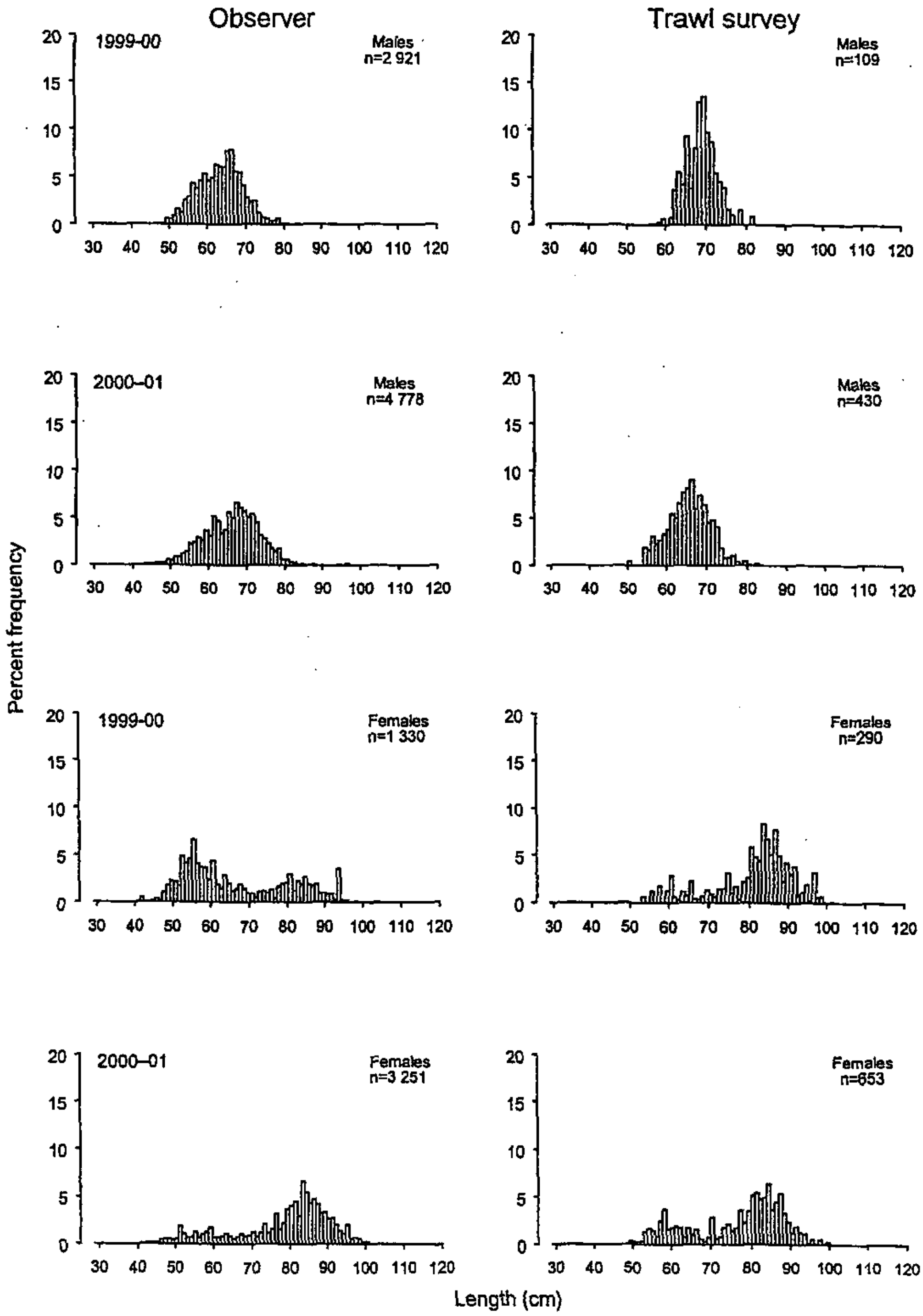

Figure 11: Comparison of male and female length frequencies collected by observers from the Sub-Antarctic with length frequencies collected on sub-Antarctic trawl surveys. n, number of fish measured.

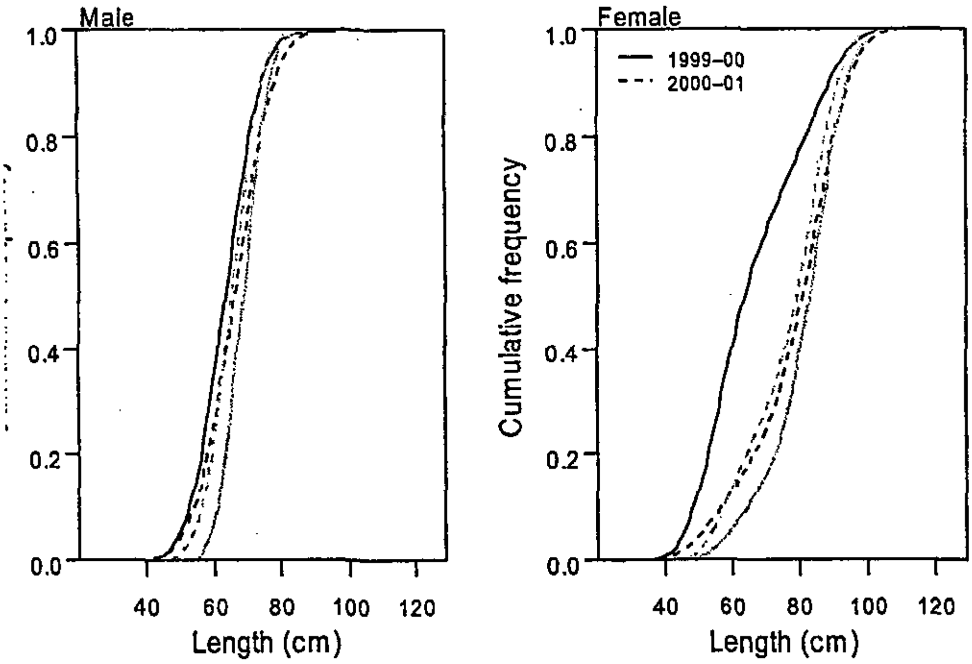

Figure 12: Cumulative length frequencies of male and female fish collected by observers (black lines) and trawl surveys (grey lines) from the Sub-Antarctic from 1996–97 and 1999–2000.

3.3.4 Assessment of observer coverage

Only 4% of all commercial tows that recorded spiny dogfish in the Sub-Antarctic were sampled by observers (Table 10). There was an increase in the number of tows sampled over the time period, but the percentages of tows sampled were still low.

Table 10: Number of commercial and observed tows that recorded spiny dogfish in the Sub-Antarctic.

	Commercial tows	Observed tows	% observed
1996–97	1 127	21	1.9
1997–98	468	74	15.8
1998–99	2 384	95	4.0
1999–00	1 896	47	2.5
2000–01	2 799	124	4.4
All years	8 674	361	4.2

The pattern of observed tows by fishing day was similar to the pattern shown by the fishery for most years apart from 1996–97, where no tows were observed at days 1–170 (Figure 13). Therefore, there was no sampling for about 60% of the commercial tows in the 1996–97 fishing year.

The commercial fishery that caught and recorded spiny dogfish operated at depths of about 50–800 m, with most tows in the 50 to 350 m range (Figure 14). The pattern of observed tows by depth was similar to the pattern shown by the fishery for most years apart from 1997–98 and 2000–01. In 1997–98, the pattern of effort was lower than on the commercial tows, and higher in 2000–01 for the 50–350 m depth range.

The commercial tows where spiny dogfish was recorded were mostly concentrated around -46–-49° and 166–170° E (Campbell Plateau) (Figures 15 and 16). The pattern of observed tows by latitude and longitude was similar to the pattern shown by the fishery for all years.

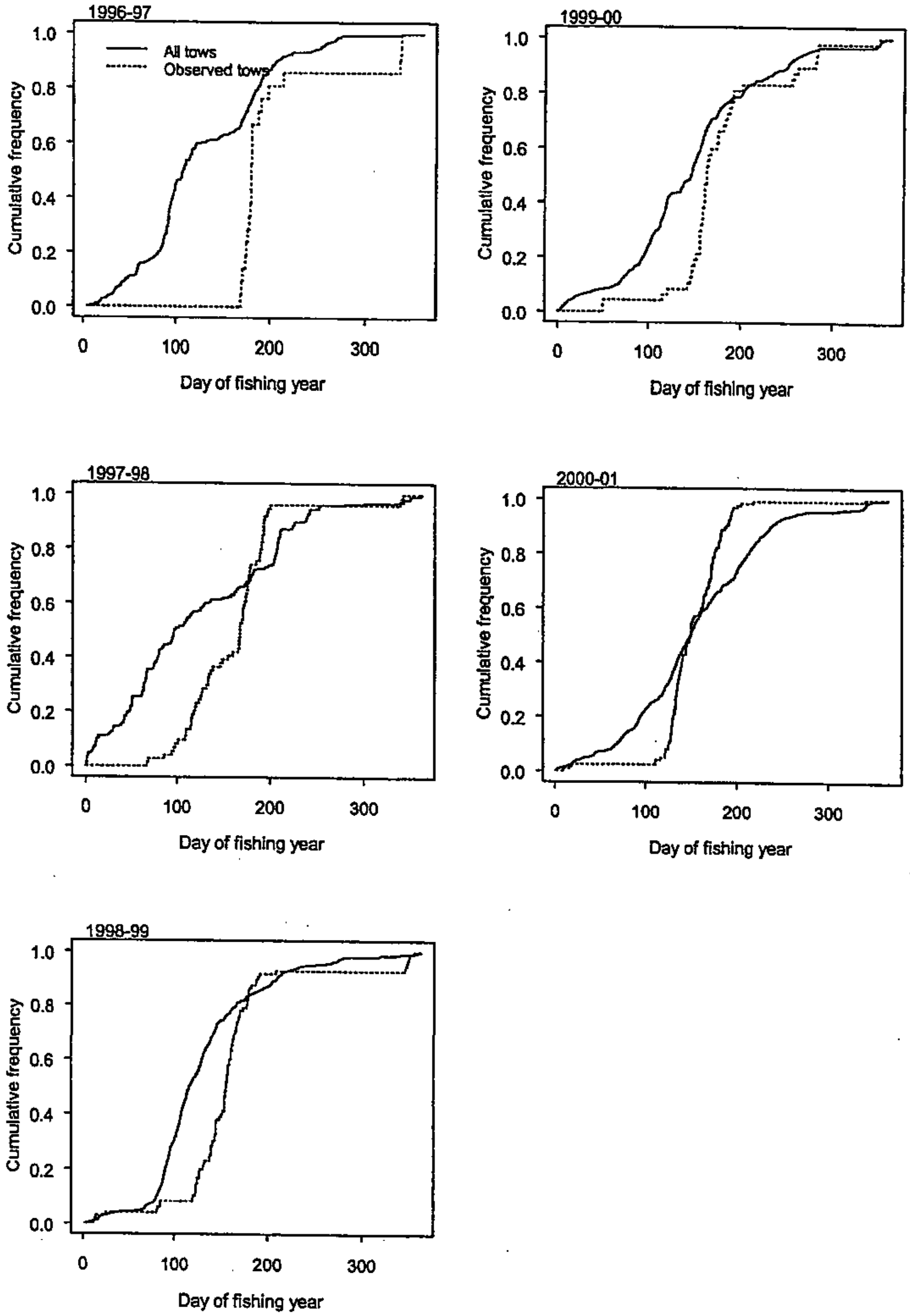

Figure 13: Comparison of the empirical distribution functions for all commercial and observed tows that recorded spiny dogfish by *fishing day* from the Sub-Antarctic fishery.

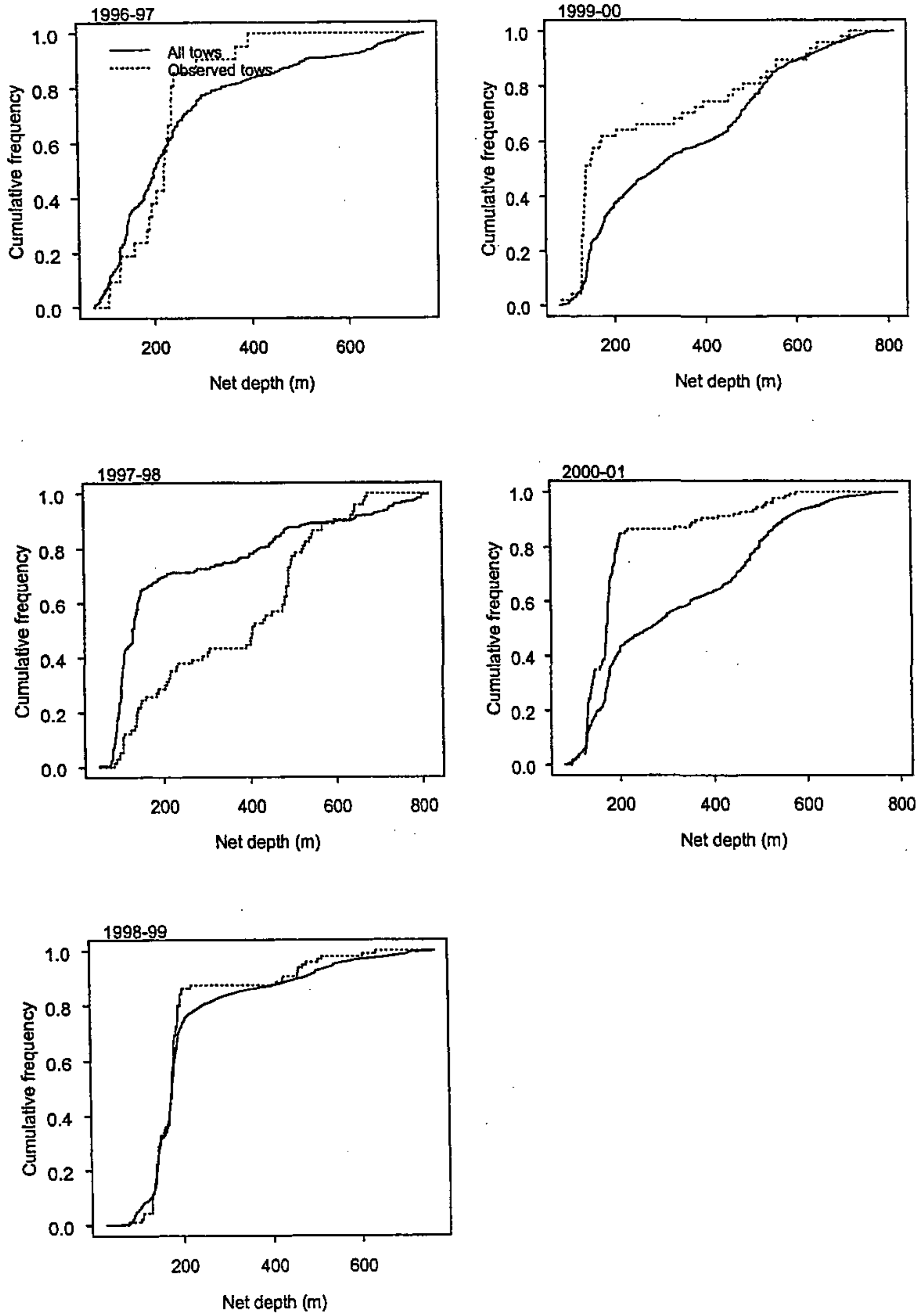

Figure 14: Comparison of the empirical distribution functions for all commercial and observed tows that recorded spiny dogfish by *depth* from the Sub-Antarctic fishery.

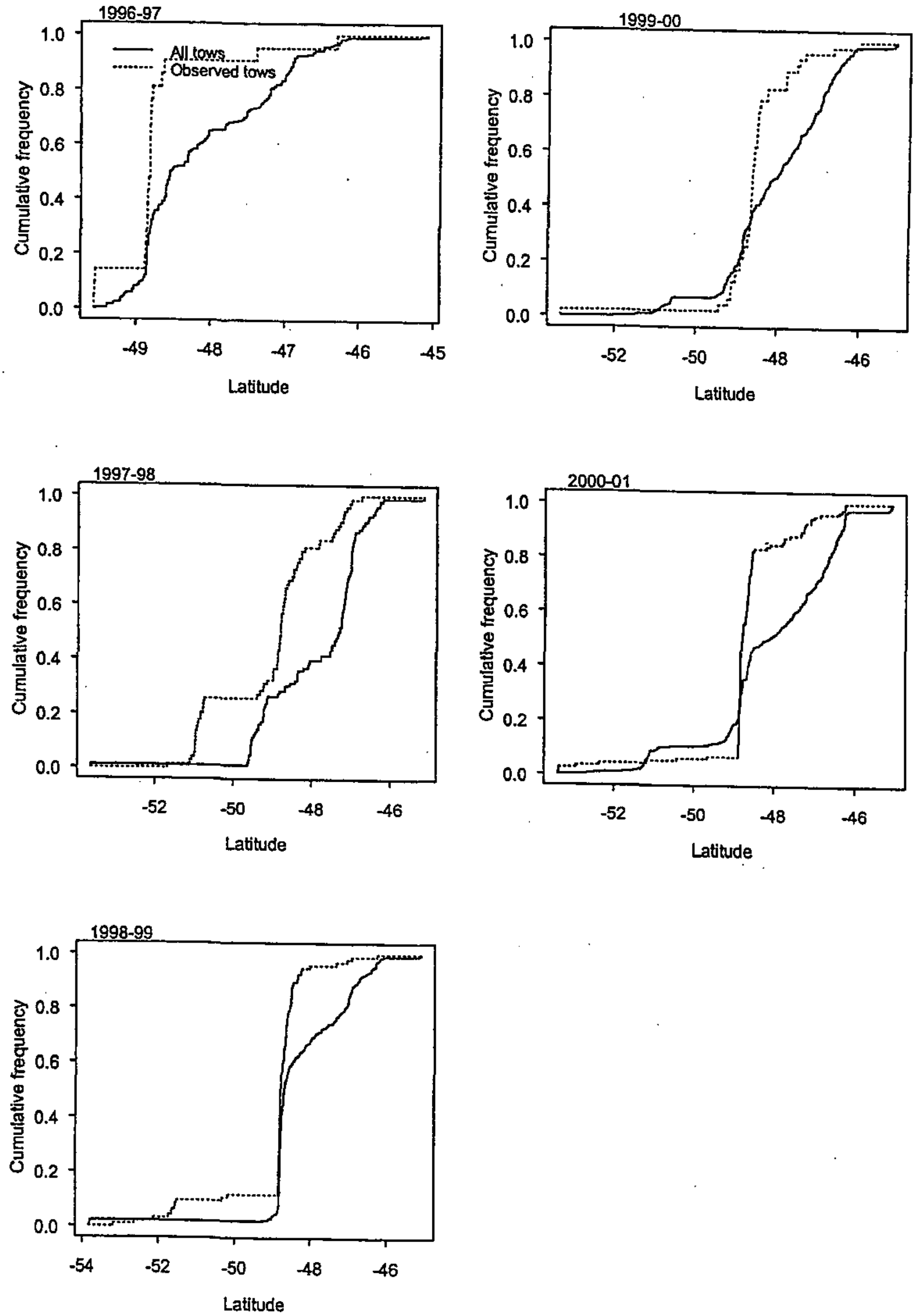

Figure 15: Comparison of the empirical distribution functions for all commercial and observed tows that recorded spiny dogfish by *latitude* from the Sub-Antarctic fishery.

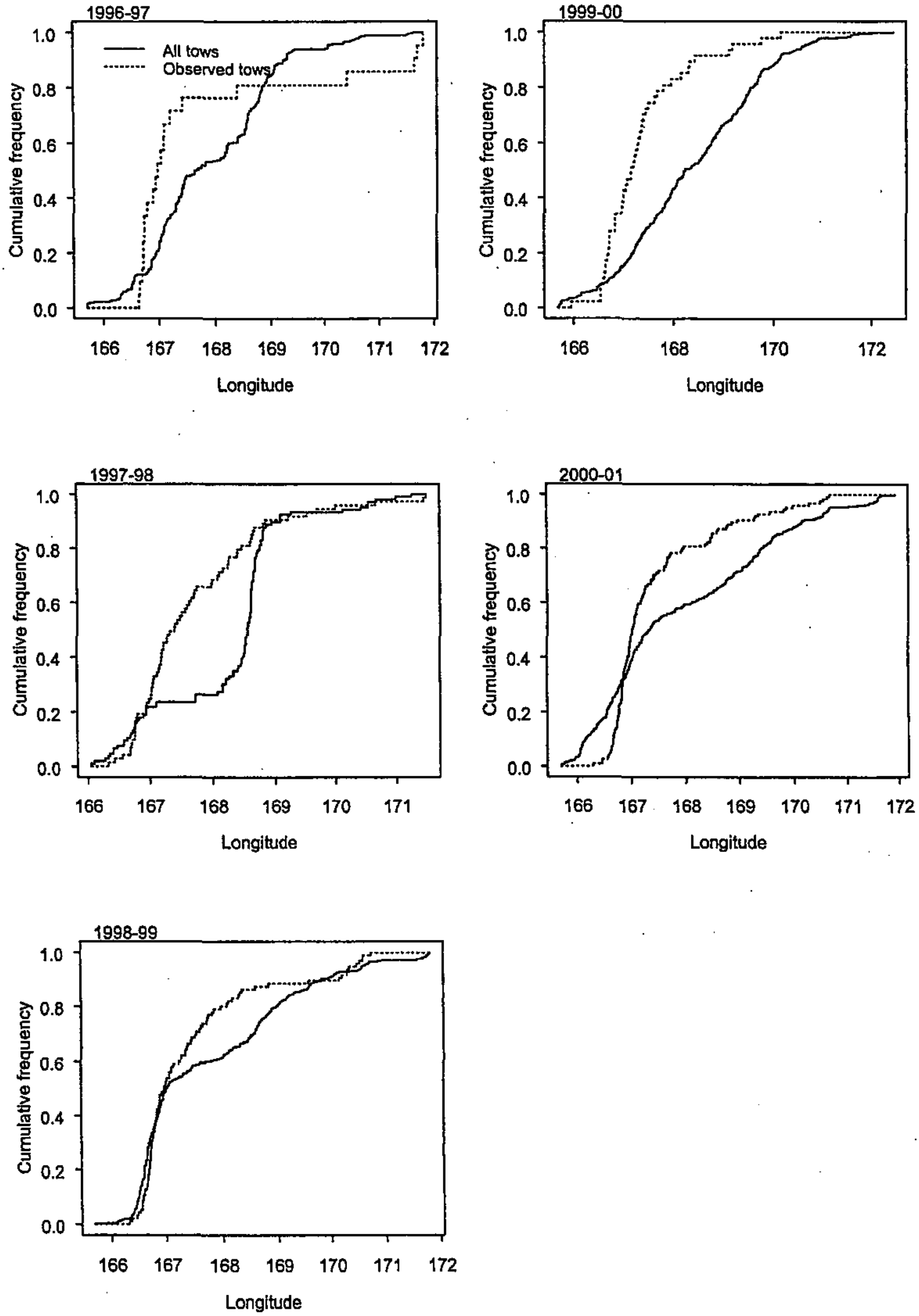

Figure 16: Comparison of the empirical distribution functions for all commercial and observed tows that recorded spiny dogfish by *longitude* from the Sub-Antarctic fishery.

3.4 West coast South Island

3.4.1 Selected strata

The tree-based regression split the data into three strata for 1996–97, 1997–98, and 2000–01, and two strata for 1998–99 and 1999–2000 (Table 11). Splits by *fishing day* were at the end of the fishing year during the peak of the hoki season. Splits by *depth* were at depths of 259 and 447 m. Splits with *longitude* occurred only in 1996–97, with splits occurring around 170° E, with larger fish found west of the split. The stratification explained 11–57% of the variation of the mean length, depending on year.

Table 11: Percentage of deviation in mean length explained (r^2), selected strata, and mean length for the west coast South Island fishery with *depth*, *latitude* and *longitude* offered as splitting variables.

			Splitting variable					
Fishing year	r^2	Stratum	*Fishing day*	*Depth* (m)	*Longitude*	*Latitude*	*Method*	Mean length (cm)
1996–97	28.3	1	< 320.0	–	≥ 170.3	–	–	73.4
		2	< 320.0	–	< 170.3	–	–	77.3
		3	≥ 320.0	–	–	–	–	77.9
1997–98	35.9	1	–	< 259.0	–	–	–	64.9
		2	<290.0	≥ 259.0	–	–	–	72.1
		3	≥ 290.0	≥ 259.0	–	–	–	77.4
1998–99	10.9	1	–	≥ 447.0	–	–	–	72.4
		2	–	< 447.0	–	–	–	74.4
1999–00	30.3	1	≥ 316.5	–	–	–	–	71.3
		2	< 316.5	–	–	–	–	76.0
2000–01	56.7	1	305.5–307.5	–	–	–	–	65.5
		2	≥ 307.5	–	–	–	–	76.3
		3	< 305.5	–	–	–	–	77.6

3.4.2 Scaled length frequencies

The male spiny dogfish length frequency distributions were unimodal for most years with modes between 65 and 68 cm (Figure 17). Male fish ranged from 50 to 80 cm apart from 1997–98, when the range was from 40 to 80 cm. The female spiny dogfish length frequency distributions were also unimodal, but with a slight skew to the left in 1996–97, and a slight skew to the right in 2000–01. The modes ranged from 75 to 85 cm, and the size from 50 to 100 cm.

As with the other two fisheries, there were some length classes that had very high proportions (e.g., 70 cm male fish in 1997–98). Again, this was due to very few fish being measured from a tow with a large catch.

The mean weighted c.v.s were high in the early years for both males and females (Table 12). Males ranged from 35 to 86%, and females ranged from 24 to 57%. The combined male and female mean weighted c.v.s tend to be lower than the individual sexes, and ranged from 24 to 53%.

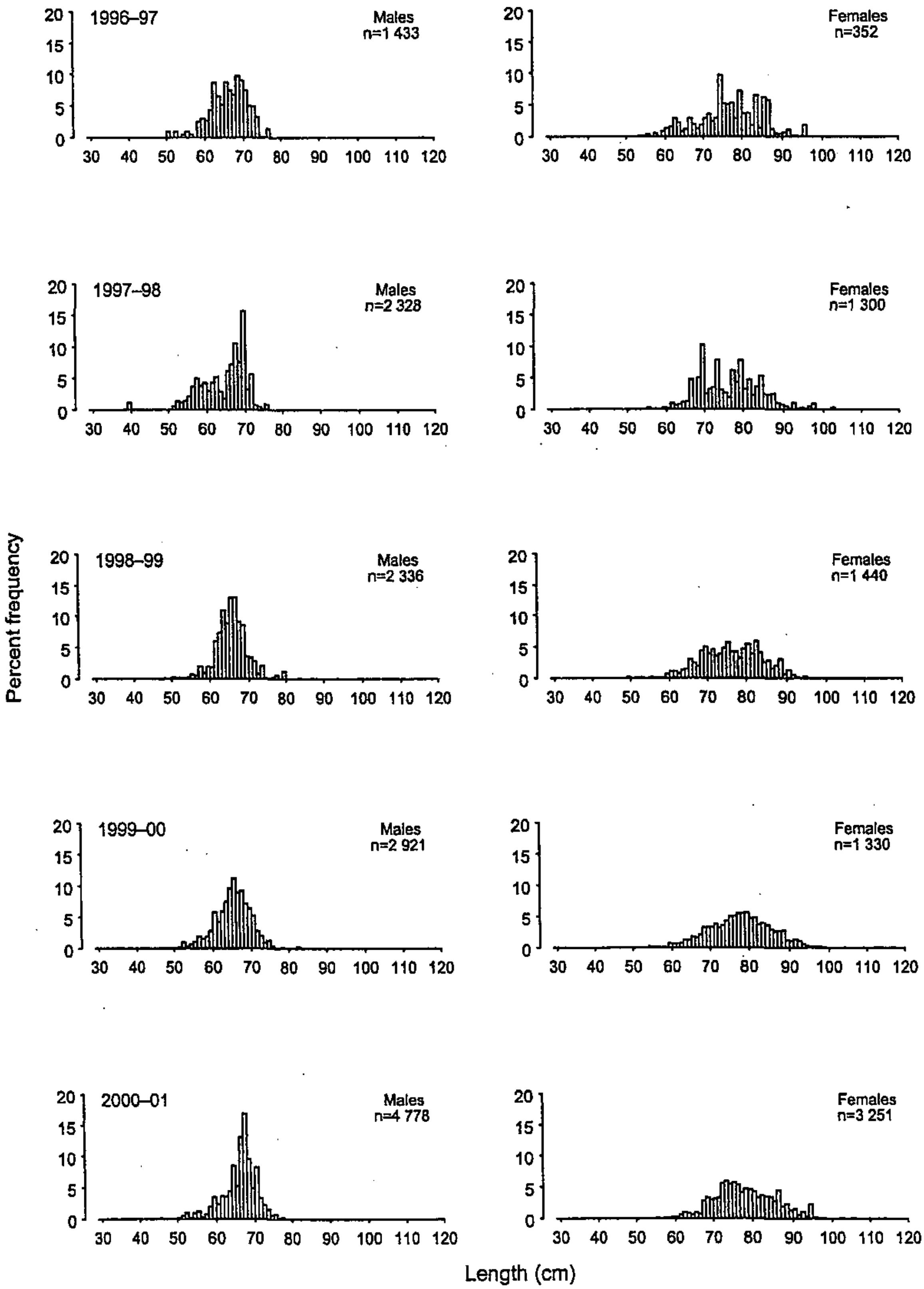

Figure 17: Scaled length frequencies for male and female spiny dogfish sampled by observers from the west coast South Island fishery. (n, the number of fish sampled.)

Table 12: Mean weighted c.v.s (%) from length frequencies for male and female spiny dogfish sampled by observers from the west coast South Island fishery.

Fishing year	Male	Female	Combined
1996–97	70	57	52
1997–98	86	52	53
1998–99	43	36	31
1999–00	35	24	24
2000–01	49	32	31

3.4.3 Comparison with trawl surveys

The spiny dogfish length frequency distribution from the trawl survey appeared bimodal for males due to fish over 78 cm present in the catch, while the observer length frequency distribution appears unimodal (Figure 18). For females, both the trawl survey and observer length frequency distributions appear similar. Similar sized females were collected by observers and on the trawl survey (Figure 19).

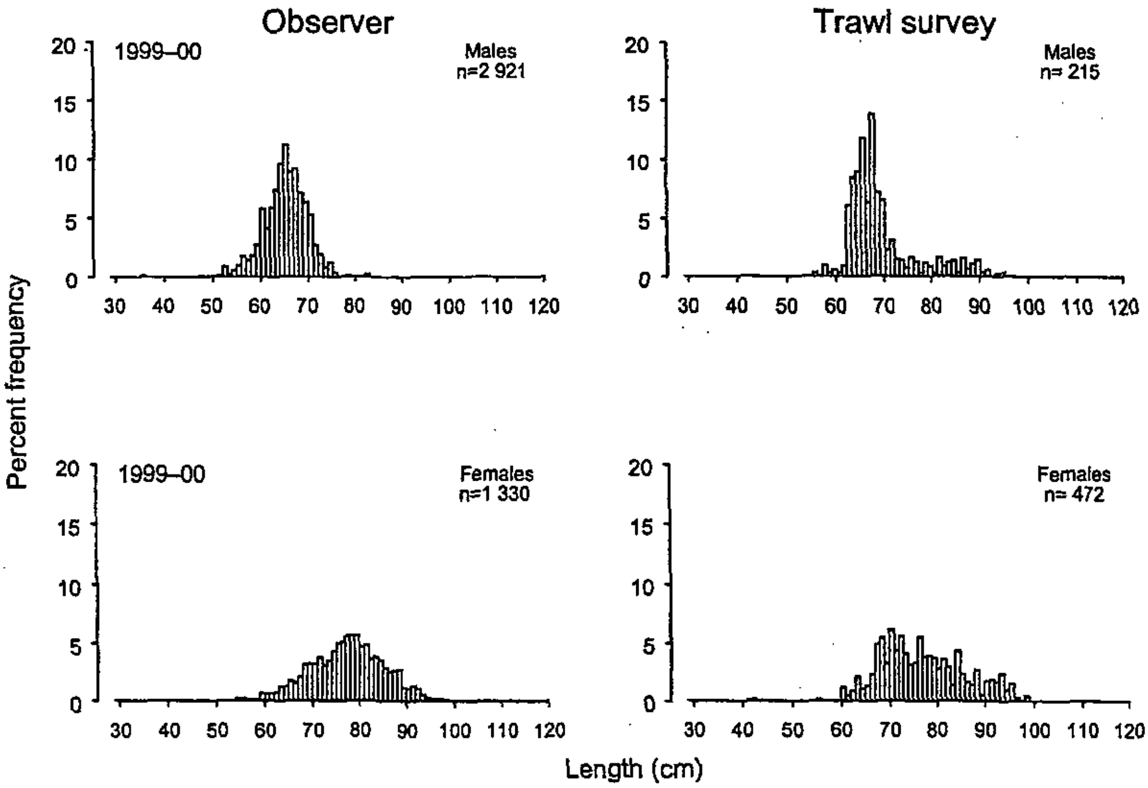

Figure 18: Comparison of female length frequencies collected by observer from the west coast South Island fishery to length frequencies collected on west coast South Island *Tangaroa* trawl survey, n, is the number of fish measured.

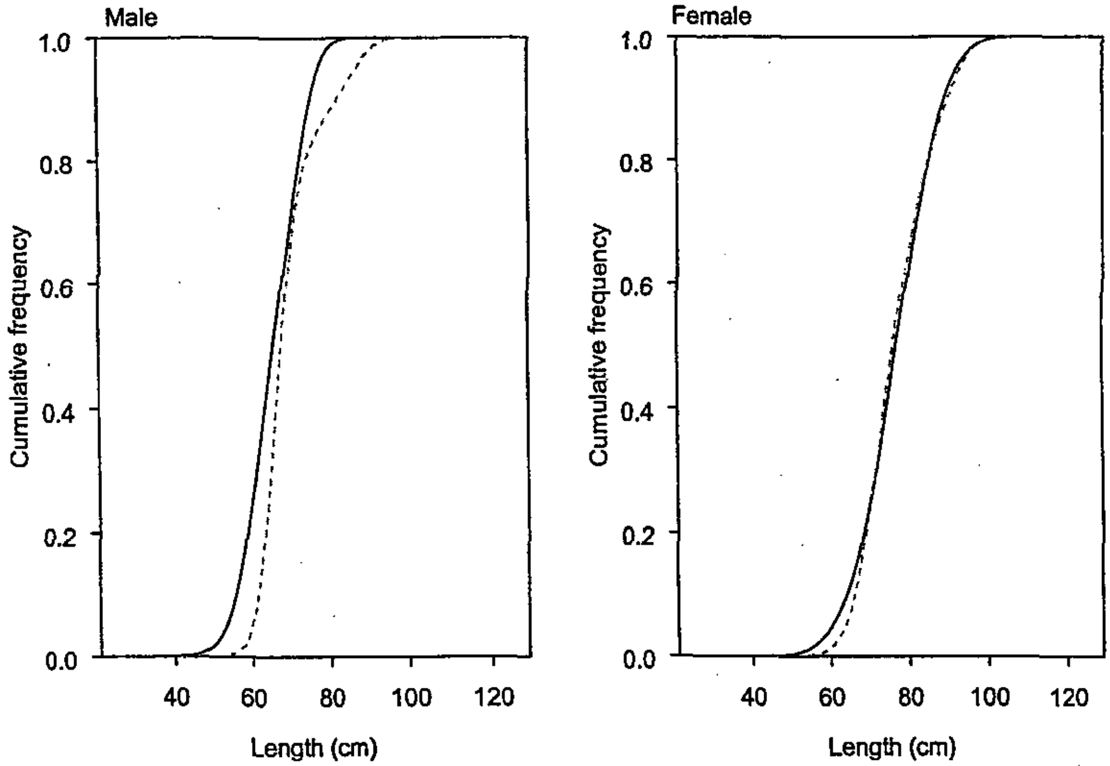

Figure 19: Cumulative length frequencies of male and female fish collected by observers (black lines) and *Tangaroa* trawl surveys (grey lines) from the WCSI from 1996–97 and 1999–2000

3.4.4 Assessment of observer coverage

There was a general increase in the percentage of commercial tows sampled by observers from 1996–97 until 2000–01, there was a slight decrease (Table 13).

Table 13: Number of commercial and observed tows that recorded spiny dogfish and the percentage of all tows that were observed from the west coast South Island fishery.

	Commercial tows	Observed tows	% Observed
1996–97	370	36	10
1997–98	418	50	12
1998–99	202	42	21
1999–00	150	45	30
2000–01	157	41	26
All years	1 297	361	16

The commercial fishery operated throughout the year, with most tows between June and October (Figure 20). The pattern of observed tows by fishing day was similar to the pattern shown by the fishery for most years, but for 1997–98 and 1998–99 no tows were observed from day 323. Therefore, there was no sampling of about 20% of the commercial tows for those years.

The commercial fishery that caught and recorded spiny dogfish operated at depths of about 50 to 600 m, with most tows at 100 to 500 m (Figure 21). For most years, it appears that the pattern of observed tows was similar to that of the commercial fishery.

Most commercial tows occurred from 169.5° E to 171.5° E. The pattern of observed tows by longitude was similar to the pattern shown by the fishery for most years, apart from 1999–2000 and

2000–01, when a higher proportion of observed tows occurred from 170.1° E to 170.5° E in 1999–2000 and 170.1° E to 170.6° E in 2000–01 (Figure 22).

Most of the commercial tows occurred from –42.7 to –42.5. The pattern of observed tows by latitude was similar to the pattern shown by the fishery for most years apart from 1998–99, when a high proportion of observed tows occurred at –42.5 (Figure 23).

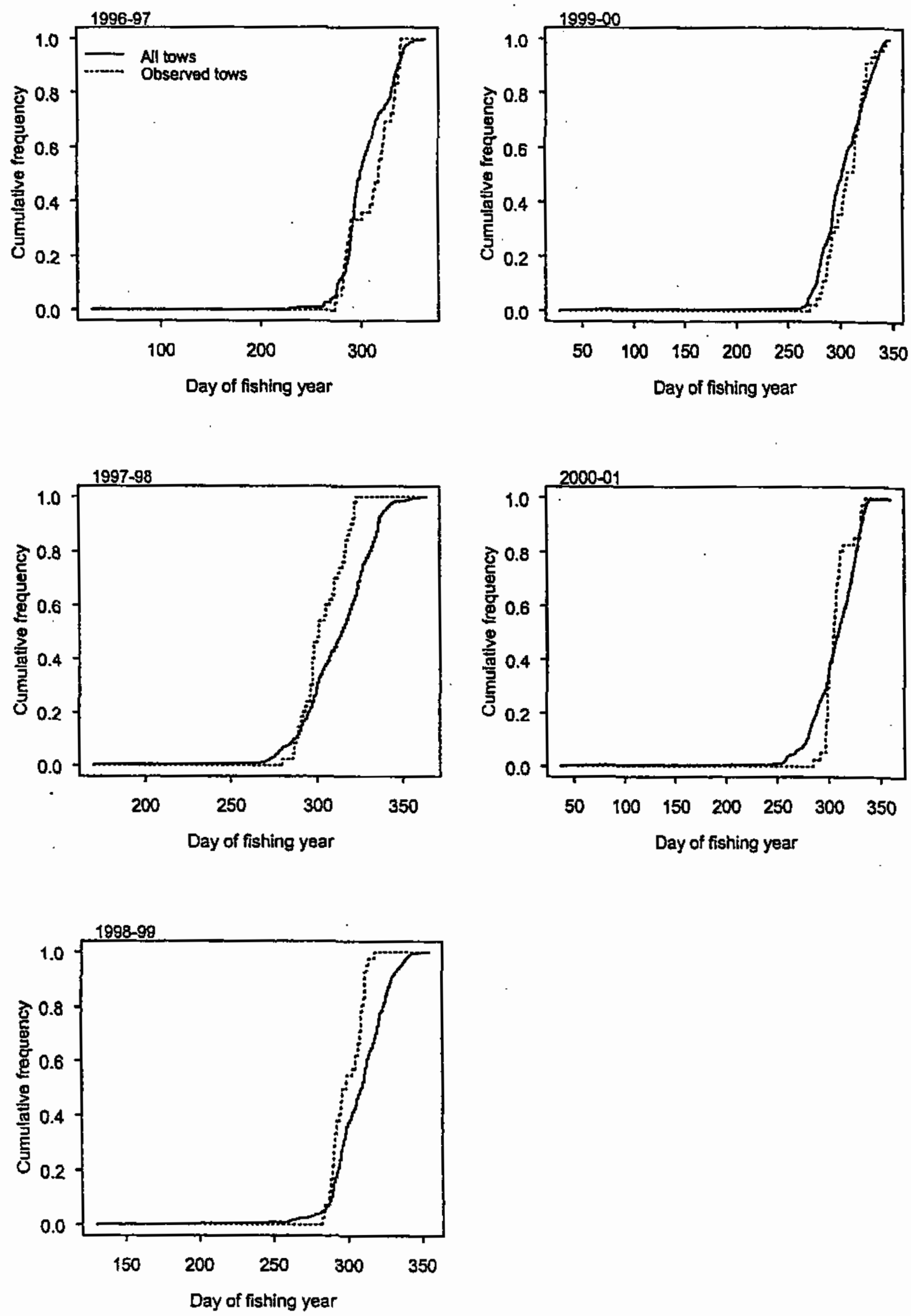

Figure 20: Comparison of the empirical distribution functions for all commercial and observed tows by *fishing day* from the west coast South Island fishery from 1996–97 to 2000–01.

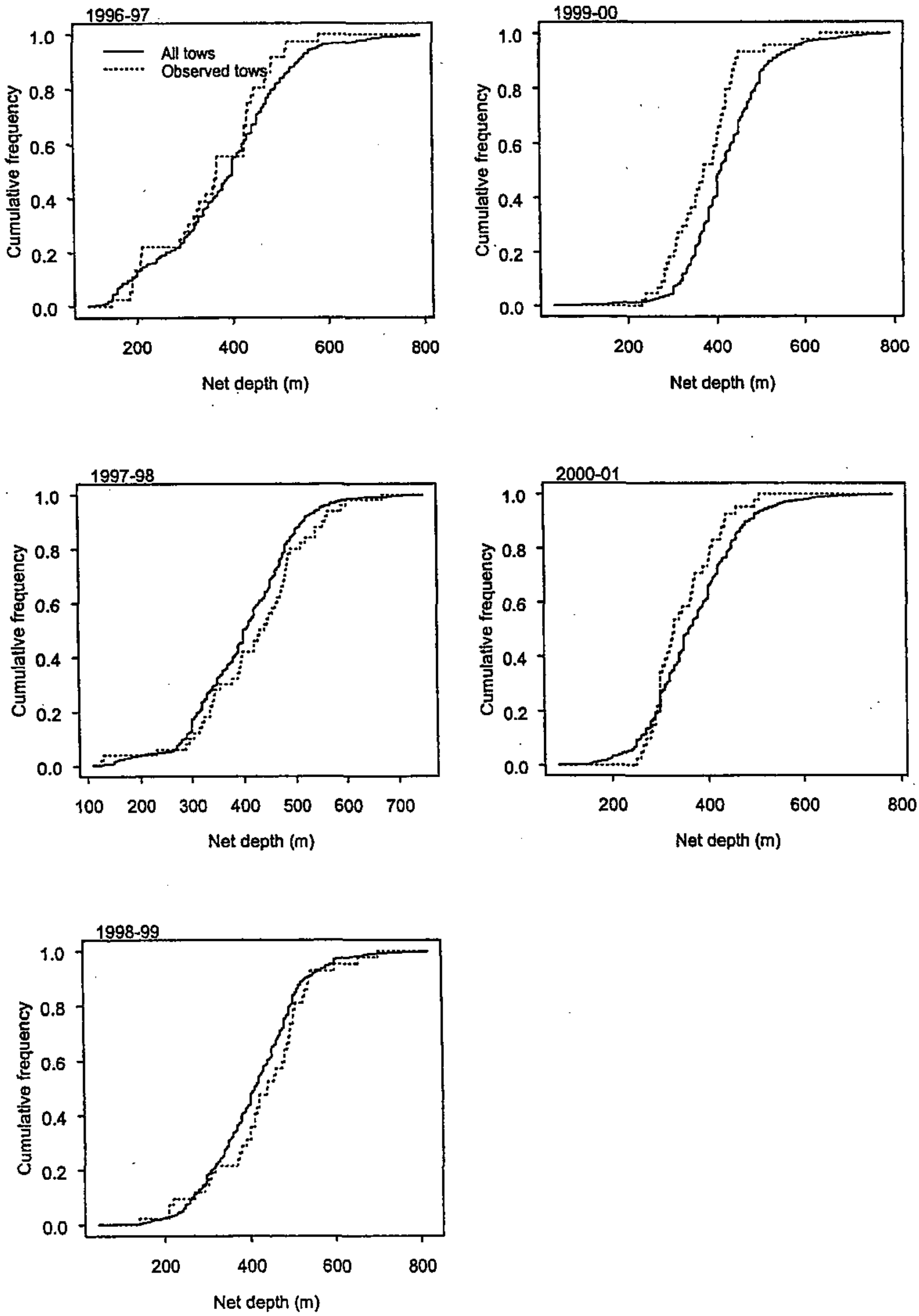

Figure 21: Comparison of the empirical distribution functions for all commercial and observed tows that recorded spiny dogfish by *depth* from the west coast South Island fishery from 1996–97 to 2000–01.

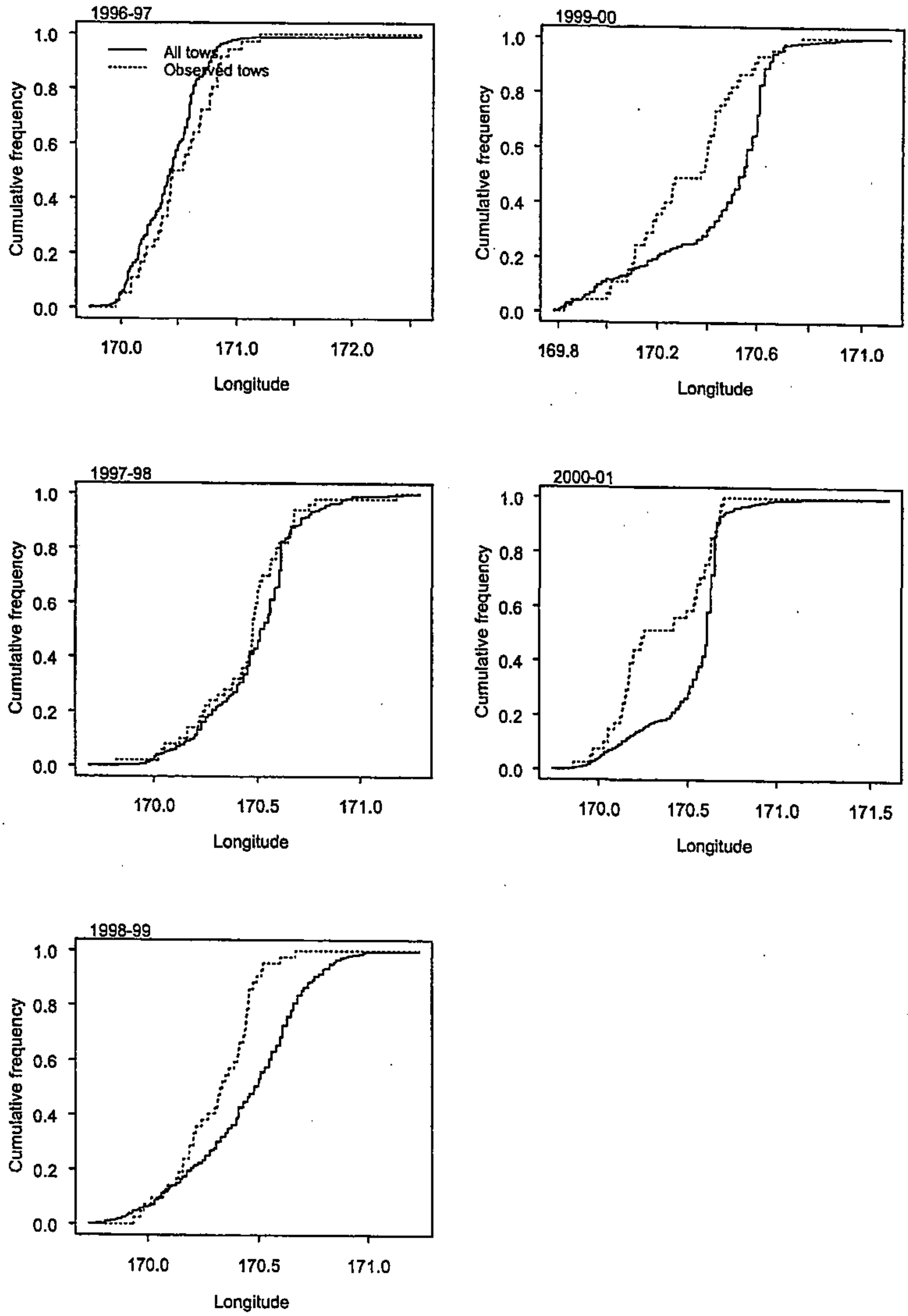

Figure 22: Comparison of the empirical distribution functions for all commercial and observed tows that recorded spiny dogfish by *longitude* from the west coast South Island fishery from 1996–97 to 2000–01.

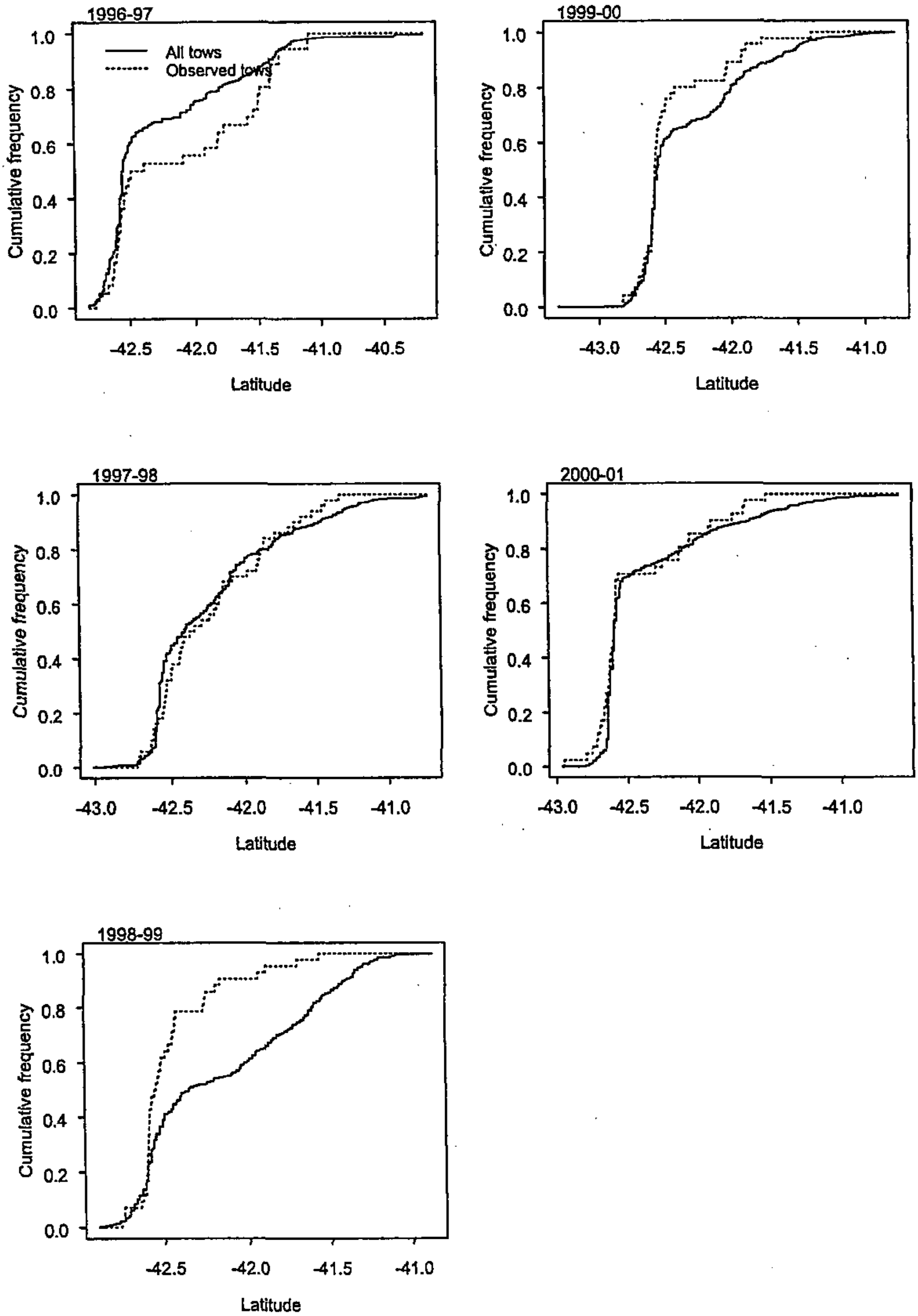

Figure 23: Comparison of the empirical distribution functions for all commercial and observed tows that recorded spiny dogfish by *latitude* from the west coast South Island fishery from 1996–97 to 2000–01.

4. DISCUSSION

The number of fish measured in the three fisheries from 1996–97 to 2000–01 varied between 4947 and 14 256 per year. There was a general increase in the number of fish measured after 1996–97 in all areas. Many of the observed tows were not proportional to the number of commercial tows by time of year, area, or depths, and appeared clumped in time, area, and depth. There has been some improvement over the last couple of years, but the distribution of observer coverage could be improved with more tows in the shallower and deeper parts of the fisheries, and in areas not adequately covered by observers.

The resulting scaled length frequencies by sex from each area had a similar distribution and length range. Males tended to be unimodal in all three fisheries. The Chatham Rise male length frequencies ranged from 45 to 80 cm (annual mode between 65 and 70 cm), 45 to 95 cm for the Sub-Antarctic (annual mode between 65 and 70 cm), and 40 to 80 cm (annual mode between 65 and 68 cm) for the west coast South Island.

Females were generally longer than males, and their length range was greater. The female length distributions appeared bimodal for the Chatham Rise and the Sub-Antarctic, but the female length distributions appeared unimodel for the west coast South Island. This could be an effect of depth because length frequencies derived from inshore *Kaharoa* trawl surveys on the west coast South Island include a large proportion of sub-adults (NIWA, unpublished analysis).

In the Chatham Rise and west coast South Island fisheries, a higher proportion of females were sampled. However, Sub-Antarctic male fish were more predominant in the observed catch. The Chatham Rise and west coast South Island vessels fished to 800 m, but vessels fishing the Sub-Antarctic mostly fished down to 400 m. This may result in a sex bias in the spiny dogfish catches. Walker et al. (1999) noted that, from trawl surveys, female fish were found in deeper waters. They also noted the males tend to out number females during autumn/winter when most of the Sub-Antarctic catch occurs. Shifts in sex ratios may also be related to fishing selectivity and fishing practices, as fishers preferred the larger more valuable females (Walker et al. 1999).

In all three fisheries, there were certain length classes that dominated the length frequencies. This was because there were few fish measured (i.e., low sample size) in a tow that had a large catch, and scaling of these fish to the catch resulted in a lot of fish of the same size class. This problem could be overcome by either removing those fish from the analysis, or by weighting the sample by the number of fish measured, i.e., tows where only a few fish are measured have little effect on the resulting scaled length frequencies compared with tows that have lots of fish measured.

The resulting mean weighted c.v.s for the length frequencies were high for all fisheries. Adequate observer coverage should result in lower uncertainty in the proportions at length and improved c.v.s.

In future, other stratification variables may worth considering, for example, Francis (2002) suggested vessel characteristics (e.g. length, processing type) may be useful as stratifying variables.

The continued estimation of proportions at length and/or age from the catch of all commercial species is fundamental for stock assessment (Taylor 2002). However, given that there much uncertainty in the proportions at length for spiny dogfish due to the lack of observer coverage and the possibility of underreporting, any inputs into a stock assessment model should reflect the uncertainty.

5. ACKNOWLEDGMENTS

Thanks to Murray Smith for the tree-based regression code and Matt Dunn for reviewing the manuscript. This project was funded by the Ministry of Fisheries as part of project SPD2002/01, Objective 1.

6. REFERENCES

Annala, J.H.; Sullivan, K.J.; Smith, N.M.W.M.; Griffiths, M.H.; Todd, P.R.; Mace, P.M.; Connell, A.M. (comps.) (2004). Report from the Fishery Assessment Plenary, May 2004: stock assessments and yield estimates. 690 p. (Unpublished report held in NIWA library, Wellington.)

Ballara, S.L.; O'Driscoll, R.L.; Phillips, N.L.; Livingston, M.E.; Smith, M.H.; Kim, S.W. (2003). Catches, size, and age structure of the 2001–02 hoki fishery, and a summary of biological research for the 2003 stock assessment. *New Zealand Fisheries Assessment Report 2003/42.* 77 p.

Bradford, E. (2000). How representative is the sampling by the observer programme of the commercial hoki catches on the Chatham Rise. Final Research Report for Ministry of Fisheries Research Project HOK 1999/04, Objective 2 (in part). 20 p. (Unpublished report held by Ministry of Fisheries, Wellington.)

Breiman, L.; Friedman, J.H.; Olshen, R.A.; Stone, C.J. (1984). Classification and regression trees. Wadsworth & Brooks/Cole. 80 p.

Bull, B.; Dunn, A. (2001). Catch-at-age user manual v1.06.2002/09/12. NIWA Internal Report 114. 23 p. (Unpublished report held in NIWA library, Wellington.)

Cordue, P.L. (2002). An analysis of an acoustic survey of spawning hoki off the west coast of the South Island during winter 2000. *New Zealand Fisheries Assessment Report.* 2002/26 51 p.

Francis, R.I.C.C. (2002). Estimating catch at age in the Chatham Rise hoki fishery. *New Zealand Fisheries Assessment Report 2002/9.* 22 p.

Hanchet, S.M. (1986). The distribution and abundance, reproduction, growth and life history characteristics of the spiny dogfish (*Squalus acanthias* Linnaeus) in New Zealand. Unpublished PhD thesis. University of Otago. 314 p.

Hanchet, S.M. (1988). Reproductive biology of *Squalus acanthias* from the east coast, South Island, New Zealand. *New Zealand Journal of Marine and Freshwater Research 22*: 537–549.

Livingston, M.E.; Stevens, D.W. (2002). Review of trawl survey data inputs to hoki stock assessment 2002. *New Zealand Fisheries Assessment Report 2002/48.* 69 p.

Manning, M.J.; Hanchet, S.M.; Stevenson, M. (2004). A description and analysis of New Zealand's spiny dogfish (*Squalus acanthias*) fisheries and recommendations on appropriate methods to monitor the status of the stocks. Final Research Report for Ministry of Fisheries Research Project SPD2002-01, Objective 1. 135 p. (Unpublished report held by Ministry of Fisheries, Wellington.)

O'Driscoll, R.L.; Bagley, N.W. (2001). Review of summer and autumn trawl survey time series from the Southland and Sub-Antarctic areas, 1991–98. *NIWA Technical Report 102.* 115 p.

Taylor, P.R. (2002). Species composition and seasonality of jack mackerel (*Trachurus declivis, T. symmetricus murphyi,* and *T. novazelandiae*) in commercial catches from JMA 1, 3, and 7 during 1998–99 and 1999–2000, with a summary of biological information from 1990–91 to 1999–2000. *New Zealand Fisheries Assessment Report 2002/51.* 72 p.

Walker, T.I.; Taylor, B.L.; Bridge, N.F.; Brown, L.P. (1999). Spiny dogfish assessment project. 120 p. (Unpublished report held by the Ministry of Fisheries, Wellington.)