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Proposed trawl survey design for the estimation of ling and hake abundance on the Southern Plateau

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Final Research Report for
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Objective 1

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Final Research Report

Report Title: Proposed trawl survey design for the estimation of ling and hake abundance on the Southern Plateau

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Project Title: Estimation of ling and hake abundance on the Southern Plateau using trawl surveys

Project Code: MDT1999/01

Project Leader: Dr Rosemary Hurst

Duration of Project:

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Executive Summary:

This Southern Plateau trawl survey project has two main objectives: to develop an optimised survey design for a summer survey in November-December 2000; and to review time series trends in previous autumn and summer surveys. This report is a Final Research Report for Objective 1.

The goals of the survey design are to:
(i) estimate the biomass of hake (c.v. 20%), hoki and ling (c.v. 15%)
(ii) cover any hake and ling spawning areas appropriately and determine whether the vertical distribution of spawning hake and ling presents a problem for the trawl survey
(iii) provide improved sampling of the hake age frequency.

The proposed survey area is the Southern Plateau and Puysegur Bank in 300–1000 m depth, excluding foul ground and the 800–1000 m depth range on the eastern slope of the Plateau. The inclusion of the latter area, and the reinclusion of the Bounty Platform, were considered but rejected on the grounds that the biomasses of the target species in these areas were too small to justify the time expenditure of surveying them.

Stations were allocated statistically to achieve target c.v.s, based on historical research catch rate data from the 1991–93 summer *Tangaroa* surveys. Extra sampling effort was allocated to Puysegur Bank and the north Pukaki Rise 800–1000 m stratum to improve sampling of the hake age frequency.

Commercial catch data show that hoki, hake, and ling form aggregations off the bottom to the west of the southern tip of the Stewart-Snares shelf during November-December. This presents two problems for the bottom trawl survey. Firstly, highly aggregated fish result in occasional very high catches, and hence cause high c.v.s (a single large catch of hake led to a 43.2% c.v. for hake in the summer 1991 survey). The proposed design deals with this problem by subdividing strata to increase sampling effort in the area. Secondly, fish off the bottom are not available to the bottom trawl. We recommend the use of acoustics and midwater trawling to assess the extent of this problem.

The proposed design includes 96 phase 1 and 19 phase 2 stations, totalling 115 stations, which is more than the last two surveys of the area which included 101 and 76 stations respectively, because of the extra goals (ii) and (iii) above.

Objectives:

Project objectives

1. To continue a time series of relative abundance indices primarily for ling and hake, and secondarily for hoki in the Southland and Sub-Antarctic QMAs.

Objective 2000:

1. To optimise the design of a trawl survey on the Southern Plateau for estimation of the age structure and biomass of hoki, hake and ling populations.

There were two key activities:

1. To determine appropriate survey strata from a review of previous survey data and an analysis of commercial (observer) catch-rate and gonad stage data for hake and ling.

2. To optimise the design of a November-December survey to estimate the biomass and age structure of hoki, hake and ling.

Introduction

The summer trawl survey series of the Southern Plateau, Puysegur Bank and Bounty Platform was carried out in November/December 1991, 1992, and 1993 (Chatterton & Hanchet 1994, Ingerson et al. 1995, Ingerson & Hanchet 1995). The primary objectives of the surveys were to produce a time series of relative abundance estimates for hake and ling. Surveys were carried out from RV *Tangaroa* with standardised trawl gear and procedures (Hurst *et al.*, 1992). The survey area covered the 300–800 m depth range (excepting foul ground) and the 800–1000 m depth range off Puysegur Bank. The survey reports are referenced in Table 1.

The autumn series of *Tangaroa* trawl surveys was carried out around April-May in 1992, 1993, 1996, and 1998 (Schofield & Livingston 1994a, 1994b, Colman 1996, Bagley & McMillan 1999). The 1992 and 1993 surveys were aimed at determining the proportion of hoki which were about to spawn in winter (*see* Livingston et al. 1997). Biomass estimates from these surveys were larger and more precise than for summer surveys and hence surveys to estimate hake and ling biomass in 1996 and 1998 were carried out in autumn. The survey area was extended into 800–1000 m depth off the northern and southwestern slope of the Southern Plateau, but no longer included the Bounty Platform. The survey reports are referenced in Table 2. Figure 1 shows the Southern Plateau and Puysegur Bank areas, with the stratification of the 1998 autumn survey.

The biomass estimates and c.v.s of hoki, hake, and ling in the summer and autumn survey series are given in Table 3. The estimated c.v.s have always met the Ministry's targets of 20% for hake and 15% for hoki and ling, except in November-December 1991 when a large catch of 2.5 t of ripe male hake was taken, resulting in a high c.v.

Other stratified random trawl surveys of the Southern Plateau included *Shinkai Maru* surveys in March-May 1982 (Van den Broek *et al.* 1984) and October-November 1983 (Hatanaka *et al.* 1989), *Wesermunde* surveys in 1979 (Francis 1981), and *Amaltal Explorer* surveys in October-November 1989 (Livingston & Schofield 1993), July-August 1990, and November-December 1990 (Hurst & Schofield 1995).

Hoki and Middle Depth Working and Planning Group meetings over the last year have raised two main issues relating to the autumn time series of surveys. Firstly, the Hoki Planning Group determined that a summer survey would be more useful for hoki research. Autumn is not a good time of year to estimate the western stock hoki biomass on the Southern Plateau, because some fish have already departed to spawn. The Planning Group supported the change on the basis that longer daylight hours in summer would allow more trawl stations and an improvement in sampling of hake. It was decided that the survey should be moved back to the original November-December time of the 1991–1993 summer series. One potential disadvantage of this move is that some hake and ling might still be in spawning aggregations during the survey period. If so, their spatial patchiness and height in the water column may make them more difficult to survey.

Secondly, the Working and Planning Groups raised a concern that, although target c.v.s have been regularly achieved for hake, the age structure of the hake population has not been well determined. Recent surveys have caught low numbers of hake

(Table 4). Weighted c.v.s across all ages of hake have been high (60% and 51%), indicating low precision of the age frequency.

We therefore propose a design for a trawl survey of hoki, hake and ling on the Southern Plateau in November/December 2000. The design is intended to:
(i) estimate the biomass of hake (c.v. 20%), hoki and ling (c.v. 15%)
(ii) sample any hake and ling spawning areas appropriately and determine whether the vertical distribution of spawning hake and ling presents a problem for the trawl survey
(iii) provide improved sampling of the hake age frequency.

Methods:

1. **To determine appropriate survey strata from a review of previous survey data and an analysis of commercial (observer) catch-rate and gonad stage data for hake and ling.**

Our stratification is based on that of the most recent *Tangaroa* autumn survey in April/May 1998. We used research, observer and TCEPR data to find out whether hake and ling are spawning during the survey period, in what strata, and whether they are off the bottom in substantial amounts. We investigated the distribution of hake by length class, so as to identify strata where poorly sampled age classes are common as targets for extra sampling effort. We reassessed the need to include the Bounty Platform and the 800–1000 m depth zone off the eastern Southern Plateau in the survey area, on the basis of research catch rates of the target species in or near these areas.

1.1 Hake and ling spawning locations and vertical distribution

We used observer and research gonad staging data to identify the extent and location of hake and ling spawning during the proposed survey period. Gonad stage data were extracted for hake and ling from the Ministry of Fisheries research and observer databases. Data were selected from south of 46° S from all records in the fish biological table (trawl: fish_bio) in the research database and the gonad staging table (obs_lfs: t_gonad_stage) in the observer database.

Only female fish were used in the analysis, firstly because observers only record gonad stages of female fish and secondly because ripe or running ripe status is a better indicator of spawning for females than for males, which can spend longer periods in ripe condition. Female hake below 76 cm length and ling below 68 cm – the 50% lengths at maturity given by Hurst *et al.* (2000) – were excluded as immature. Mature females were considered to be actively spawning or recently spawned if in observer stage 3–5 or research stage 4–7, i.e. from ripe to spent (*see* Table 5 *for staging systems*).

Locations of spawning fish were plotted to identify spawning areas, by fortnight from weeks 37–38 (late September) to 51–52 (late December). The proportions of spawning fish by month in research and observer data were summarised.

For hake, ling, and hoki, catch rates in midwater and bottom trawls during daylight were extracted from TCEPR data and plotted by fortnight. Midwater trawls were defined as those where the difference between groundrope depth and bottom depth was more than 10 m (the recorded gear type was not used because midwater trawl gear can be used on the bottom). All tows which caught the species were included. Catch rates were calculated as kg/km.

1.2 Distributions of hake length classes

The distributions of hake age groups were investigated, using length as a proxy for age. Hake catches by length class in the summer and autumn surveys were plotted. The length classes were: up to 66 cm, 67–77 cm, 78–90 cm, and over 90 cm. Since all hake taken were lengthened, except in a few of the largest catches, the plots simply express catch rates as the number of measured fish in the length class. Females and males were initially plotted separately, but there were no obvious differences (except that females are bigger) so the plots were combined.

1.3 Strata at Bounty Platform and eastern 800–1000 m depth Southern Plateau

The Bounty Platform was surveyed in the 1989, summer 1990, and winter 1990 *Amaltal Explorer* surveys and the autumn 1992 and 1993 *Tangaroa* surveys, but not in the *Tangaroa* summer surveys. Ling were taken at Bounty in 300–400 m bottom depth, but hake and hoki were not present in quantity. The 800–1000 m depth range on the eastern slope of the Southern Plateau has never been included in a trawl survey and is a gap in our coverage of the Southern Plateau from 300–1000 m. We reassessed the need to include these areas for the summer 2000 survey.

Biomasses of ling, hake, and hoki at Bounty, as proportions of the total survey biomasses, were tabulated for the *Amaltal Explorer* and *Tangaroa* surveys, excluding the *Amaltal Explorer* winter 1990 survey.

The historical data for the eastern Southern Plateau 800–1000 m depth stratum was minimal because it has never been surveyed and very little commercial fishing occurs in the area. As an indication of the abundance of target species in the area, we investigated relative biomasses of target species in the adjacent stratum 15 in 600–800 m depth, and compared target species biomasses between 800–1000 m strata and the adjacent 600–800 m strata in the autumn survey series.

2. To optimise the design of a November-December survey to estimate the biomass and age structure of hoki, hake and ling

As in the previous summer and autumn Southern Plateau surveys, we propose to carry out a two phase stratified random trawl survey (*after* Francis 1984) from *Tangaroa*, using the standardised procedures described by Hurst *et al.* (1992). This Activity deals with the proposed allocation of random trawl stations to the strata recommended in Activity 1.

The proposed allocation of phase 1 stations is based on:

1. the recommendations from Activity 1 with regard to improving the sampling of hake age groups, and of all target species in areas where they are densely aggregated
2. a statistical allocation procedure based on research trawl data from previous summer Southern Plateau surveys, excluding strata that were not included in the summer survey series (*see* Section 2.1)
3. a conservative allocation of 4 stations per stratum, where neither of the above applies, so as to adequately cover areas where little data are available.

Carrying out phase 2 stations on the Southern Plateau is logistically difficult because of the large distances between areas. We propose a relatively small phase 2 allocation of 20% of the number of phase 1 stations. If the weather is favourable then we will be able to carry out more phase 2 stations. The phase 2 can be used to improve target species *c.v.*s if necessary, and otherwise will be used to sample more hake to improve age frequency estimation.

2.1 Statistical phase 1 station allocation

All strata which were included in the summer survey series, apart from those which were singled out for extra sampling effort as a result of Activity 1, were allocated phase 1 stations on the basis of an iterative statistical procedure. A separate allocation was carried out for each species, to achieve a specified target *c.v.*, and the results were combined by taking the maximum number of stations in each stratum. We used conservative target *c.v.*s of 17% for hake and 10% for ling and hoki, to increase the chance that the Ministry's targets of 20% for hake and 15% for ling and hoki would be achieved, and to increase the level of hake sampling.

Each allocation was carried out using an iterative method to find the minimal phase 1 allocation predicted to achieve the specified *c.v.* for the species biomass estimate. Catch rates in each stratum were assumed to have a mean equal to the average of the mean catch rates in the stratum in the three summer surveys and a *c.v.* equal to the average of the *c.v.*s of catch rates in the stratum in the three summer surveys. It was specified that there should be at least 3 phase 1 stations in each stratum. Strata which were included in the summer surveys, but were allocated stations on the basis of Activity 1 rather than the statistical procedure, were included for the purpose of calculating *c.v.*s. New strata were not included at all.

Results and recommendations:

3. To determine appropriate survey strata from a review of previous survey data and an analysis of commercial (observer) catch-rate and gonad stage data for hake and ling.

3.1 Hake and ling spawning locations and vertical distribution

The percentages of spawning mature female hake and ling are summarised by month in Table 6. Peak spawning of hake appears to be from August to early November but late-season spawning aggregations may still be present in November/December. Ling

peak spawning is from October to December so we expect that spawning will be taking place during the proposed survey period.

The differences between research and observer results were probably caused by the differences in sample size and in area coverage. Research trawls had a good coverage of the whole region, as opposed to commercial vessels which tended to concentrate on a smaller area, particularly during the spawning period (hence the high percentages spawning for ling in the observer data).

Proportions of spawning or recently spawned hake and ling are plotted, by fortnight, in Figures 2 and 3. In November-December, spawning or spent hake were observed at Puysegur, off the southeast of the Stewart-Snares shelf, and off the northeast of the Auckland Island shelf. Spawning ling were observed almost exclusively at Puysegur.

Hake, ling and hoki catch rates in bottom and midwater commercial trawls during daylight are plotted by fortnight in Figures 4, 5, and 6. Relatively high catch rates of all three species were taken in midwater to the west of the southern tip of the Stewart-Snares shelf, in strata 3 and 5. Bottom and midwater catch rates of hake, ling, and hoki in this area in October-December are plotted on a smaller scale in Figures 7, 8 and 9. Mean catch rates of hoki, hake, and ling in this area, in midwater and in bottom trawls, by month, are given in Table 7. Each species had a higher mean catch rate in midwater than on the bottom. Hoki were the most abundant of the three species in midwater: ling and hake had approximately equal abundance. The highest concentrations of all three species were bounded by longitudes 166 and 167.25° E and latitudes 48.5 and 49.5° S.

We conclude that hake, ling, and hoki were aggregated off the bottom in the west end of stratum 3, and to a lesser extent stratum 5, in November / December. It is not clear whether this was related to hake and ling spawning activity. The observer and research coverage of the area was minimal so it does not appear as a spawning area on the plots of spawning locations (Figs. 2, 3).

3.2 Distributions of hake length classes

The distributions of hake samples are plotted by sex and length class (as a proxy for age) for the summer *Tangaroa* surveys in Figure 10 and for the autumn surveys in Figure 11. Smaller hake were found almost exclusively on Puysegur Bank in 600–1000 m depth. Middle sized hake were distributed along the eastern slope of the Stewart-Snares shelf and over the western half of the Southern Plateau. Large hake were distributed similarly, and were also caught in deep water to the north of the Pukaki Rise in the autumn surveys (this area was not sampled in the summer surveys).

3.3 Strata at Bounty Platform and eastern 800–1000 m depth Southern Plateau

The biomass estimates for hoki, hake, and ling on the Bounty Platform in the 1989 and summer 1990 *Amaltal Explorer* surveys and the summer 1992 and 1993 *Tangaroa* surveys, as percentages of the total survey biomasses, are given in Table 8. Estimated biomasses of hoki and hake were very low or nil in all four surveys. Ling biomasses were also low in three surveys. The 1989 survey reported a relatively high 12.6% of the total ling biomass at Bounty. Note that the percentages for the 1989 *Amaltal Explorer* survey were not strictly comparable to the other surveys because

they covered the 200–800 m depth range rather than the 300–800 depth range of the other surveys: however all the stations at Bounty were in fact below 300 m depth.

Relative biomass estimates of the target species in stratum 15, next to the proposed new eastern Southern Plateau stratum in 800–1000 m depth, are listed by survey in Table 9. Ling biomass estimates for stratum 15 were moderate, but ling are not abundant deeper than 800 m on the Southern Plateau, so we do not expect that the new 800–1000 m stratum would contain a substantial amount of ling. Hake biomass estimates for stratum 15 were small or nil. Hoki biomass estimates were moderate, averaging 4% of the estimated hoki biomass in the survey area. The implication is that the new 800–1000 m stratum might also contain moderate amounts of hoki. On the other hand, in the autumn surveys, the mean hoki catch rate in each 800–1000 m stratum was typically less than half as much as in the adjacent 600–800 m strata.

3.4 Conclusions and recommendations

We expect that hake and ling spawning and postspawning activity will still be occurring during the proposed November-December survey period. At this time of year, hake, ling, and hoki aggregate off the bottom in strata 3 and 5, on the western side of the southern tip of the Stewart-Snares shelf (Figs. 7–9). High concentrations of fish in this area, near the bottom and in midwater, are bounded by longitudes 166 and 167.25° E and latitudes 48.5 and 49.5° S. The mean catch rates of hake, hoki, and ling in midwater in this area in November/December are on the same order, but the estimated biomass of hake on the Southern Plateau is much lower than those of ling and hoki, which implies that these midwater aggregations represent a higher proportion of the hake population than of the other two species, and hence are most problematic for hake.

Small hake (< 60 cm) in the survey area are found almost exclusively in strata 2 and 25, at Puysegur in 600–1000 m depth. Allocating increased sampling effort to the 600–800 and 800–1000 m Puysegur strata would increase the catch of small hake, improve the estimation of numbers at age in the youngest age groups, and reduce the mean weighted c.v. of the numbers at age. Larger size groups were more widely distributed so are not so easy to individually optimise for. Large hake (> 90 cm) were relatively common in stratum 27, to the north of the Pukaki Rise in 800–1000 m depth, in the autumn survey series. Allocating increased sampling effort to this area would improve estimation of numbers at age in the oldest age groups. Otherwise, age frequency estimation can be improved by increasing the overall sampling effort targeted at hake and by collecting more otolith data.

The estimated biomasses of the target species at the Bounty Platform do not justify the time expenditure required to survey the area. We estimate that 3 days of vessel time would be required to survey Bounty, due to the long distance from the rest of the survey area. Historical data indicates that hake and hoki biomasses at Bounty are minimal, and estimated ling biomasses were also low in 3 out of 4 research surveys.

The potential new 800–1000 m depth stratum on the eastern slope of the Southern Plateau would be expected to contain some hoki but few hake or ling. Data from the autumn survey series indicates that the hoki biomass would be small, on the order of 2% of the total hoki biomass. If hoki were found to be more common in the 800–1000 m depth range in summer than they have historically been in autumn, then this

stratum should be included, but otherwise its target species biomasses do not justify its inclusion.

We recommend that the proposed November-December 2000 trawl survey of the Southern Plateau follow the stratification of the April-May 1998 survey, except that strata 3 and 5 should be subdivided into 3b and 5a, west of 167.25° E, and 3a and 5b, east of 167.25° E, to concentrate sampling effort on the western substrata where hoki, hake, and ling are aggregated. To improve sampling of hake, increased effort should be allocated to the new strata 3b and 5a and to strata 2, 25, and 27.

We further recommend that acoustic survey work and associated midwater trawling be carried out in strata 3b and 5a to assess the extent of hoki, hake, and ling aggregations which are off the bottom and unavailable to the bottom trawl.

4. To optimise the design of a November-December survey to estimate the biomass and age structure of hoki, hake and ling.

4.1 Allocation of stations on the basis of the recommendations of Activity 1

Phase 1 stations were allocated to strata 2 and 25 (Puysegur, 600–800 m and 800–1000 m depth) and 27 (north of the Pukaki Rise, 800–1000 m depth) so as to improve sampling of hake age groups. We recommend that 4 stations be carried out in each of the three Puysegur strata, 1, 2, and 25, which would require two days of surveying without interruptions, and that 6 of the phase 2 stations also be carried out in the Puysegur area, in the strata where young hake were found during phase 1. (It is convenient to carry out phase 2 stations at Puysegur due to the relatively small distances between strata.) We suggest an allocation of 6 stations to stratum 27, which would result in a relatively high sampling density of 1:2165 km^2.

We recommend that 4 stations be allocated to each of the new strata 3b and 5a, which were subdivided to improve coverage of the area where hoki, hake, and ling are expected to be aggregated. We do not recommend allocating more phase 1 stations to these strata because they consist in large part of foul bottom and finding trawl paths will be time consuming: in addition, the bottom trawl will not effectively sample aggregations in midwater so time could be more profitably spent on midwater trawling and/or acoustics.

4.2 Statistical allocation of stations

The statistical allocation was based on all strata except 3b and 5a for which there was little historical research data, and 26, 27, and 28 which were not included in the previous summer survey series. The Puysegur strata (1, 2, and 25) were included for the purpose of calculating c.v.s but fixed at 4 phase 1 stations each, since extra phase 2 effort is to be carried out there. Areas for strata 3a and 5b are approximate.

The exclusion of strata 3b and 5a, where aggregated hake, hoki, and ling might be found, means that the predicted c.v.s are probably overly optimistic, because small numbers of high catches in 3b and 5a could have a substantial effect on biomass

estimates. However the predicted phase 1 c.v.s are 3–5 points less than the Ministry's targets, allowing some margin for error, and phase 2 effort will further improve the c.v.

4.3 Combined station allocation

The recommended allocations from Activity 1 to improve sampling of hake age groups and aggregated hoki, hake, and ling, the statistical allocation for each species, the default allocation of 4 stations per stratum where neither of the above applies, and the final combined allocation are shown in Table 10.

The allocation includes 96 phase 1 stations. We recommend a phase 2 of 19 stations (20% of the phase 1), of which 6 stations should be used to sample young hake at Puysegur.

This allocation includes more stations than the last autumn survey, which included 71 phase 1 and 5 phase 2 stations. Sampling effort has increased generally, but especially in the subdivided strata 3a/3b and 5a/5b, and in strata 1, 2, 9, 10, 25, and 27 as a result of increased sampling of hake.

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Data Storage:

Raw data were sourced from Ministry of Fisheries databases. Processed data are stored on the primary author's PC.

Table 1: The summer *Tangaroa* survey series

Year	Months	Trip code	Reference
1991	November-December	TAN9105	Chatterton & Hanchet 1994
1992	November-December	TAN9211	Ingerson *et al.* 1995
1993	November-December	TAN9310	Ingerson & Hanchet 1995

Table 2: The autumn *Tangaroa* survey series

Year	Months	Trip code	Reference
1992	April-May	TAN9204	Schofield & Livingston 1994
1993	May-June	TAN9304	Schofield & Livingston 1994
1996	March-April	TAN9605	Colman 1996
1998	April-May	TAN9805	Bagley & McMillan 1999

Table 3: Biomass estimates (t, % c.v.) of hoki, hake, and ling from previous Southern Plateau surveys by *Tangaroa*. The 300–800 m survey estimate excludes the Bounties in all years

Survey (300–800m)	Biomass estimate (% c.v.)		
	Hoki	Hake	Ling
November-December			
1991	80 285 (6)	5 553 (44)	24 085 (7)
1992	87 359 (6)	1 822 (12)	24 368 (6)
1993	99 695 (9)	2 286 (12)	29 747 (12)
April-May			
1992	67 832 (8)	5 028 (15)	42 344 (6)
1993	59 814 (11)	3 221 (14)	37 553 (5)
1996	92 568 (9)	2 046 (13)	32 274 (8)
1998	68 105 (11)	2 554 (18)	30 833 (9)

Table 4: Biomass estimates (t, % c.v.) and number of hake caught on *Tangaroa* Southern Plateau surveys, by depth range. The 300–800 m survey estimate excludes the Bounties in all years

Survey	Hake biomass estimate			Number of hake caught								
	300–800 m	300–1000 m[1]	300–1000 m[2]	300–800 m			300–1000 m[1]			300–1000 m[2]		
Nov-Dec				M	F	Total	M	F	Total	M	F	Total
1991	5 553 (44)	5 686 (43)	–	271	230	501	337	332	669	–	–	–
1992	1 822 (12)	1 944 (12)	–	14	133	149	113	262	377	–	–	–
1993	2 286 (12)	2 567 (12)	–	57	181	238	169	377	546	–	–	–
Apr-May												
1992	5 028 (15)	–	–	60	113	175	–	–	–	–	–	–
1993	3 221 (14)	–	–	36	124	162	–	–	–	–	–	–
1996	2 046 (13)	2 281 (11)	2 846 (12)	32	93	125	102	242	344	127	253	380
1998	2 554 (18)	2 643 (17)	3 946 (16)	49	146	195	57	183	240	104	204	318

[1] The 1991 survey area, which excluded Bounty and included 800–1000 m at Puysegur
[2] The autumn 1996/1998 survey area, which included 800–1000 m around most of the survey area

Table 5: The 5 observer gonad stages and the 7 research gonad stages. Stages included as 'spawning' are indicated

Observer 5 stage gonad staging scale.

1). Juvenile/rest recovery	
2). Mature	
3). Ripe	included
4). Running ripe	included
5). Spent	included

Research 7 stage gonad staging scale

1). Juvenile	
2). Resting	
3). Maturing	
4). Ripe	included
5). Running ripe	included
6). Partially spent	included
7). Spent	included

Table 6: Numbers of mature females sampled and percentage in spawning condition, by month, from observer and research datasets

(a) Hake

Month	Observer			Research		
	total	spawning	% spawning	Total	Spawning	% spawning
Jan	266	25	9.4	0		
Feb	92	12	13.0	149	67	45.0
Mar	620	131	21.1	49	19	38.8
Apr	642	50	7.8	189	16	8.5
May	1107	32	2.9	146	78	53.4
Jun	175	14	8.0	9	1	11.1
Jul	359	3	0.8	78	5	6.4
Aug	230	67	29.1	81	12	14.8
Sep	2633	718	27.3	20	8	40.0
Oct	703	203	28.9	125	7	5.6
Nov	935	111	11.9	161	37	23.0
Dec	168	17	10.1	418	181	43.3

(b) Ling

Month	Observer			Research		
	total	spawning	% spawning	Total	Spawning	% spawning
Jan	442	8	1.8	0		
Feb	700	4	0.6	593	10	1.7
Mar	2040	10	0.5	167	0	0.0
Apr	3252	0	0.0	707	5	0.7
May	5550	0	0.0	662	28	4.2
Jun	2324	25	1.1	53	2	3.8
Jul	232	17	7.3	404	1	0.2
Aug	599	39	6.5	368	5	1.4
Sep	2405	167	6.9	193	1	0.5
Oct	1177	231	19.6	404	24	5.9
Nov	4332	1933	44.6	1637	106	6.5
Dec	3420	1632	47.7	1243	126	10.1

Table 7: Mean commercial catch rates (kg/km) of hake, hoki, and ling, in bottom and in midwater, in the area shown in Figures 7–9, by month

	Hake		Hoki		Ling	
	Bottom	Midwater	Bottom	Midwater	Bottom	Midwater
October	120	160	590	630	90	210
November	140	250	180	570	130	360
December	20	280	180	350	110	200

Table 8: Biomass estimates by survey for hoki, hake, and ling on the Bounty Platform, as percentages of the total survey biomasses

Vessel	Time	Hoki	Hake	Ling
Amaltal Explorer	1989	0.0%	0.0%	12.6%
Amaltal Explorer	Summer 1990	0.2%	1.1%	2.6%
Tangaroa	1992	0.0%	0.0%	2.7%
Tangaroa	1993	0.0%	0.0%	0.5%

Table 9: Relative biomass estimates (t, % *c.v*) for hoki, hake and ling in stratum 15 (*), which is next to the proposed 800–1000 m depth stratum on the eastern slope of the Southern Plateau, compared to estimated biomasses (t) for the entire survey area

		Stratum 15			Entire survey		
Survey		Hoki	Hake	Ling	Hoki	Hake	Ling
Summer	1991	5170 (23)	0 (–)	1160 (17)	80360	5690	24100
	1992	3370 (21)	0 (–)	300 (22)	87510	1940	21970
	1993	1220 (21)	0 (–)	520 (61)	99900	2570	29900
Autumn	1992	3320 (41)	40 (100)	2500 (17)	67830	5030	42330
	1993	3060 (34)	100 (61)	2650 (18)	59810	3600	37540
	1996	2890 (24)	0 (–)	1340 (40)	96320	2850	32520
	1998	2540 (35)	80 (100)	1580 (28)	71740	3950	30950

(*) = stratum 16 in the summer survey series

Table 10: Allocation of phase 1 stations to strata. Table shows the recommended allocations from Activity 1 to improve sampling of hake age groups and aggregated hoki, hake, and ling, the statistical allocation for each species, the default allocation of 4 stations per stratum where neither of the above applies, and the final combined allocation

Stratum		Depth (m)	Activity 1	Statistical allocations			Default	Combined
				Hake (c.v. = 17%)	Hoki (c.v. = 10%)	Ling (c.v. = 10%)		
1	Puysegur Bank	300–600	4[1]	4[2]	4[2]	4[2]		4
2	Puysegur Bank	600–800	4[1]	4[2]	4[2]	4[2]		4
3a	Stewart-Snares	300–600		4	3	3		4
3b	Stewart-Snares	300–600	4					4
4	Stewart-Snares	600–800		5	4	3		5
5a	Snares-Aucklands	600–800	4					4
5b	Snares-Aucklands	600–800		3	3	3		3
6	Auckland Is.	300–600		5	5	4		5
7	South Aucklands	600–800		3	3	3		3
8	NE. Aucklands	600–800		8	3	3		8
9	N. Campbell Is.	300–600		8	5	6		8
10	S. Campbell Is.	600–800		3	4	3		4
11	NE. Pukaki Rise	600–800		4	4	3		4
12	Pukaki	300–600		4	5	5		5
13	NE. Camp. Plateau	300–600		3	5	5		5
14	E. Camp. Plateau	300–600		3	5	4		5
15	E. Camp. Plateau	600–800		3	3	3		3
25	Puysegur Bank	800–1000	4[1]	4[2]	4[2]	4[2]		4
26	SW. Campbell Is.	800–1000					4	4
27	NE Pukaki	800–1000	6					6
28	E. Stewart Is.	800–1000					4	4
							Phase 1 total	**96**

[1]Plus a further 6 phase 2 stations allocated to these 3 strata
[2]Fixed at 4

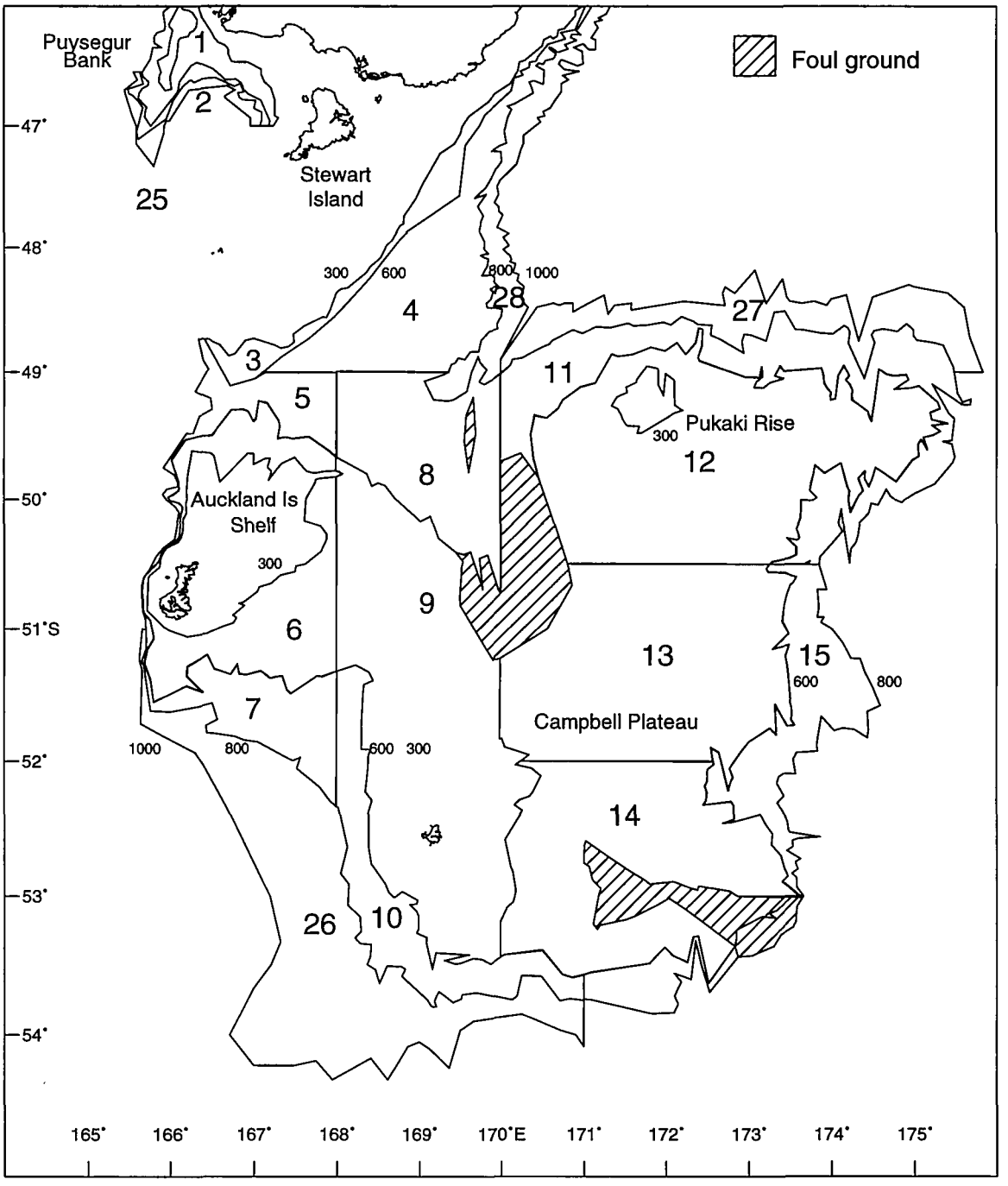

Figure 1: Stratification of the most recent Southern Plateau trawl survey in autumn 1998 (TAN9805). The proposed design for a summer 2000 survey is also based on this stratification.

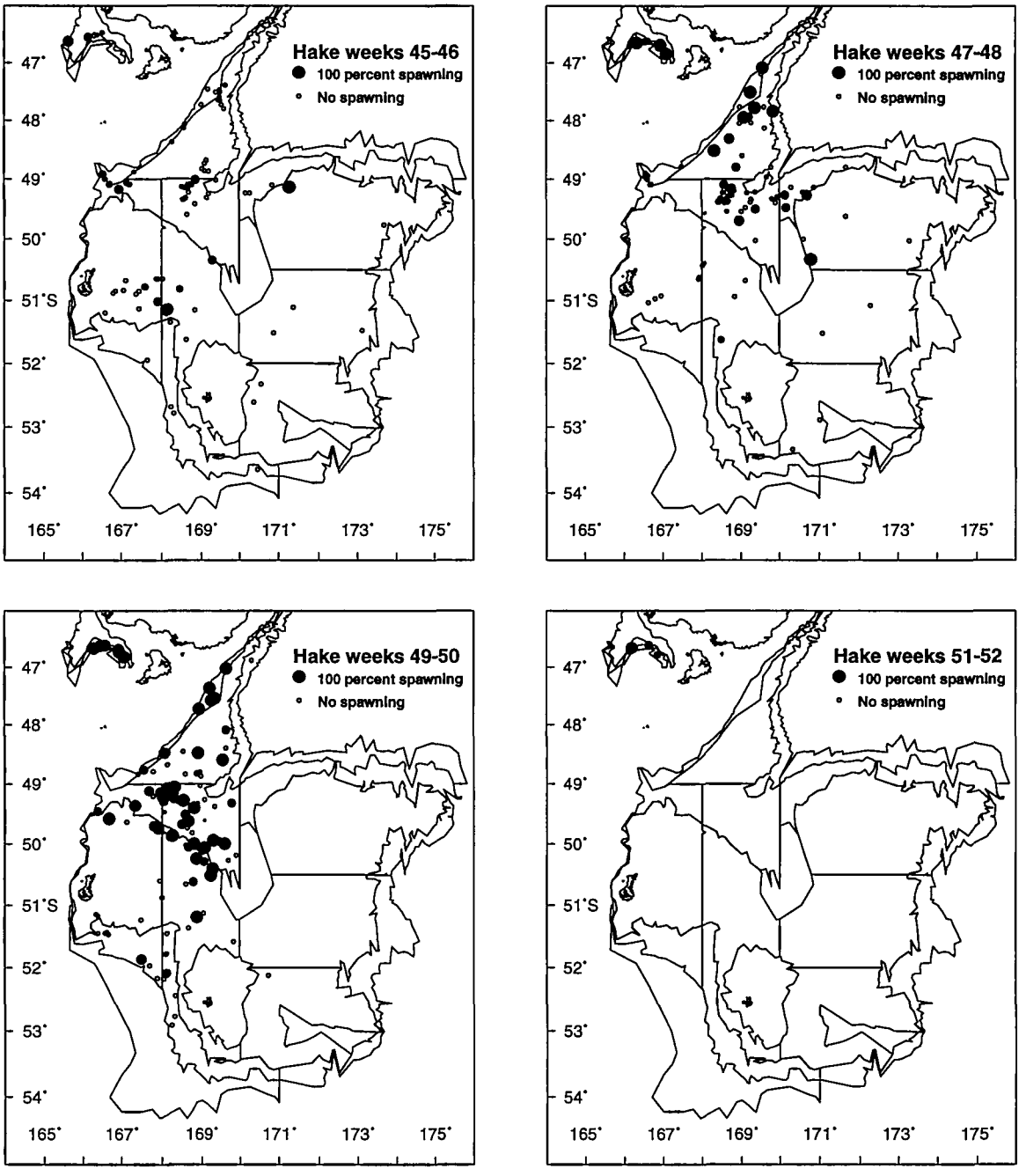

Figure 2: Percentage spawning of female hake, by fortnight, in November-December. Compiled from observer and research data. Circle size indicates percentage of spawning females.

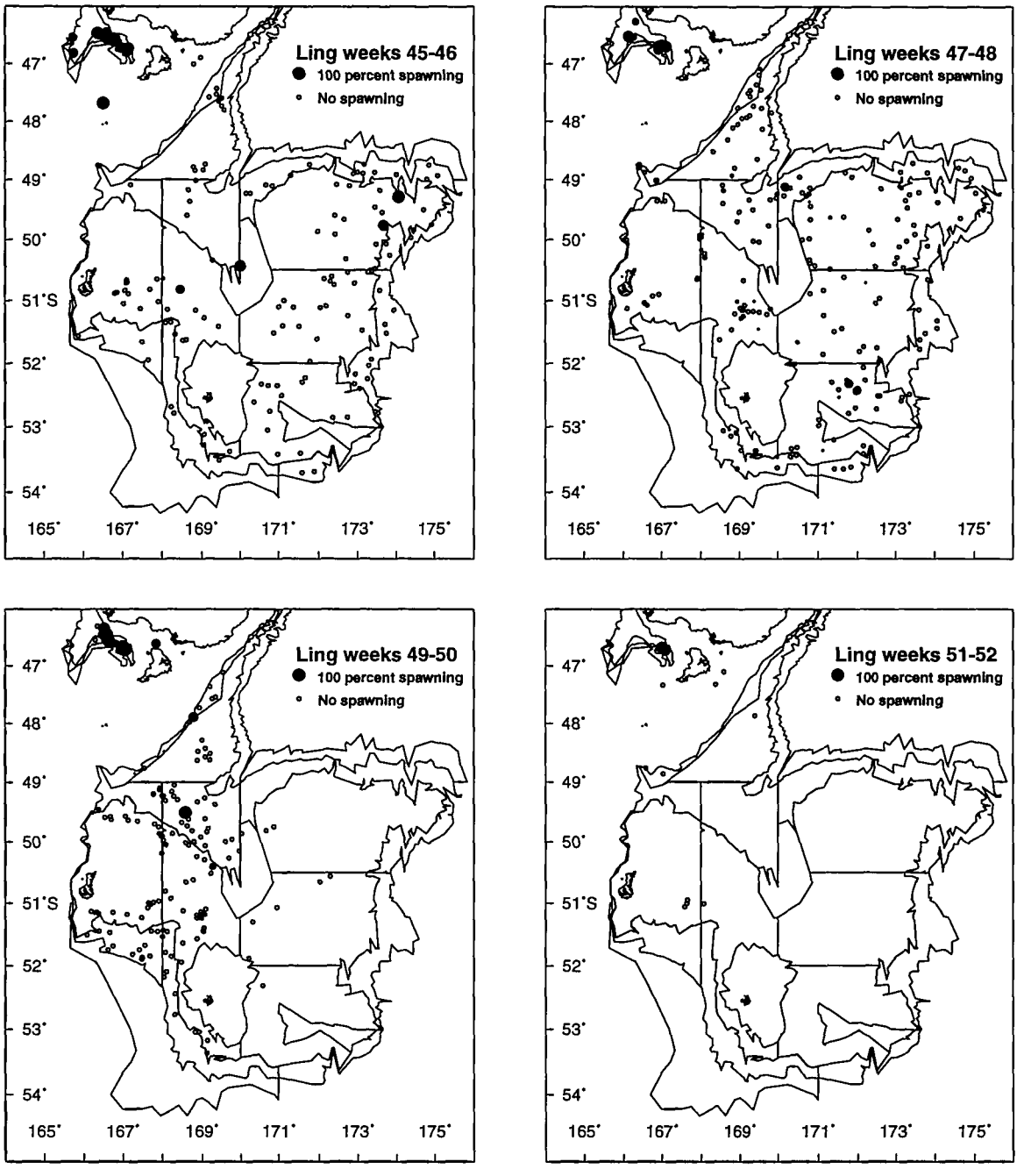

Figure 3: Percentage spawning of female ling, by fortnight, in November-December. Compiled from observer and research data. Circle size indicates percentage of spawning females.

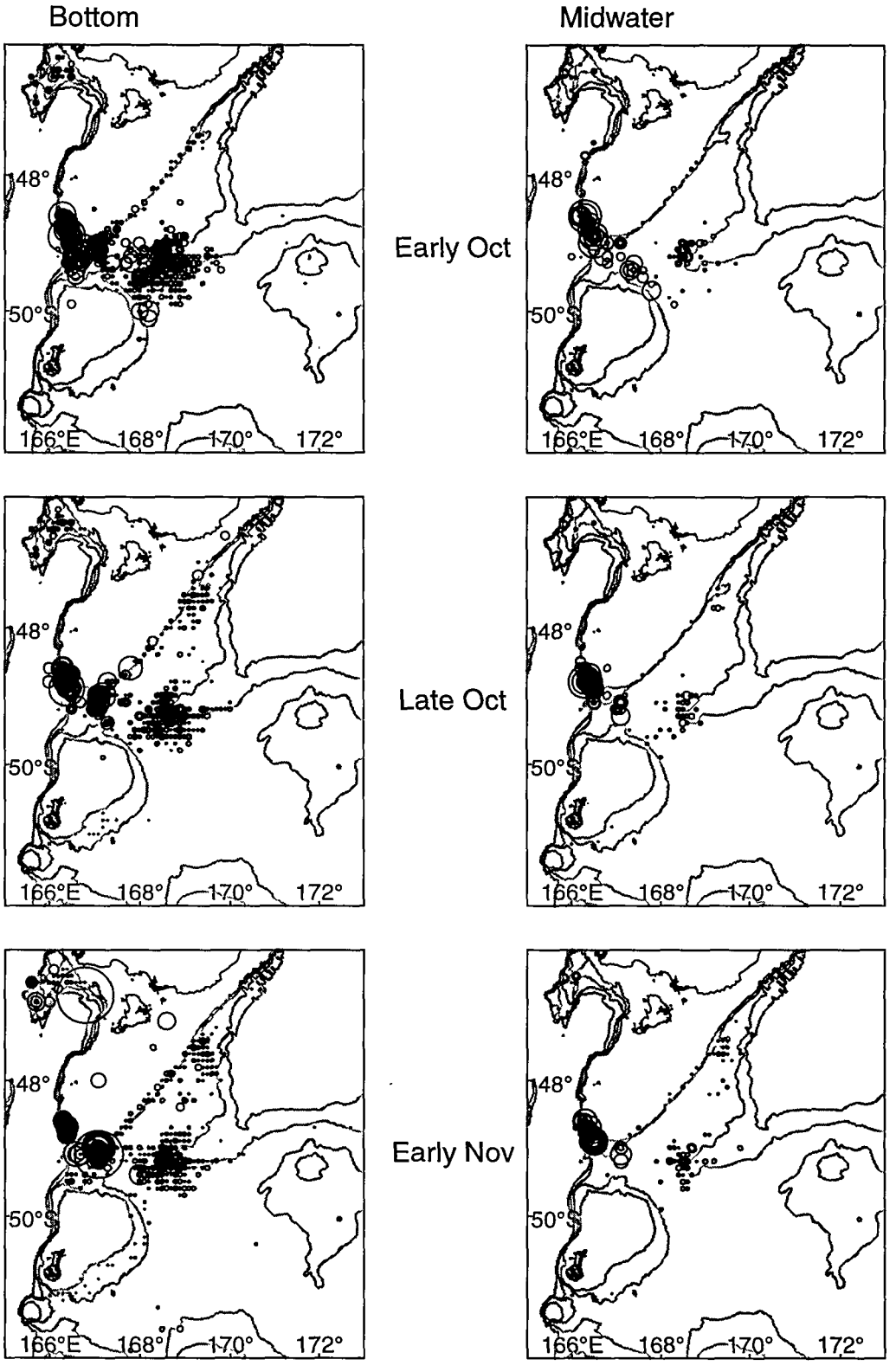

Figure 4: Hake catch rates in bottom and midwater daytime commercial tows, by fortnight, based on TCEPR data. Circle size indicates catch rate (max = 4500 kg/km). Contours represent 250 m depth intervals.

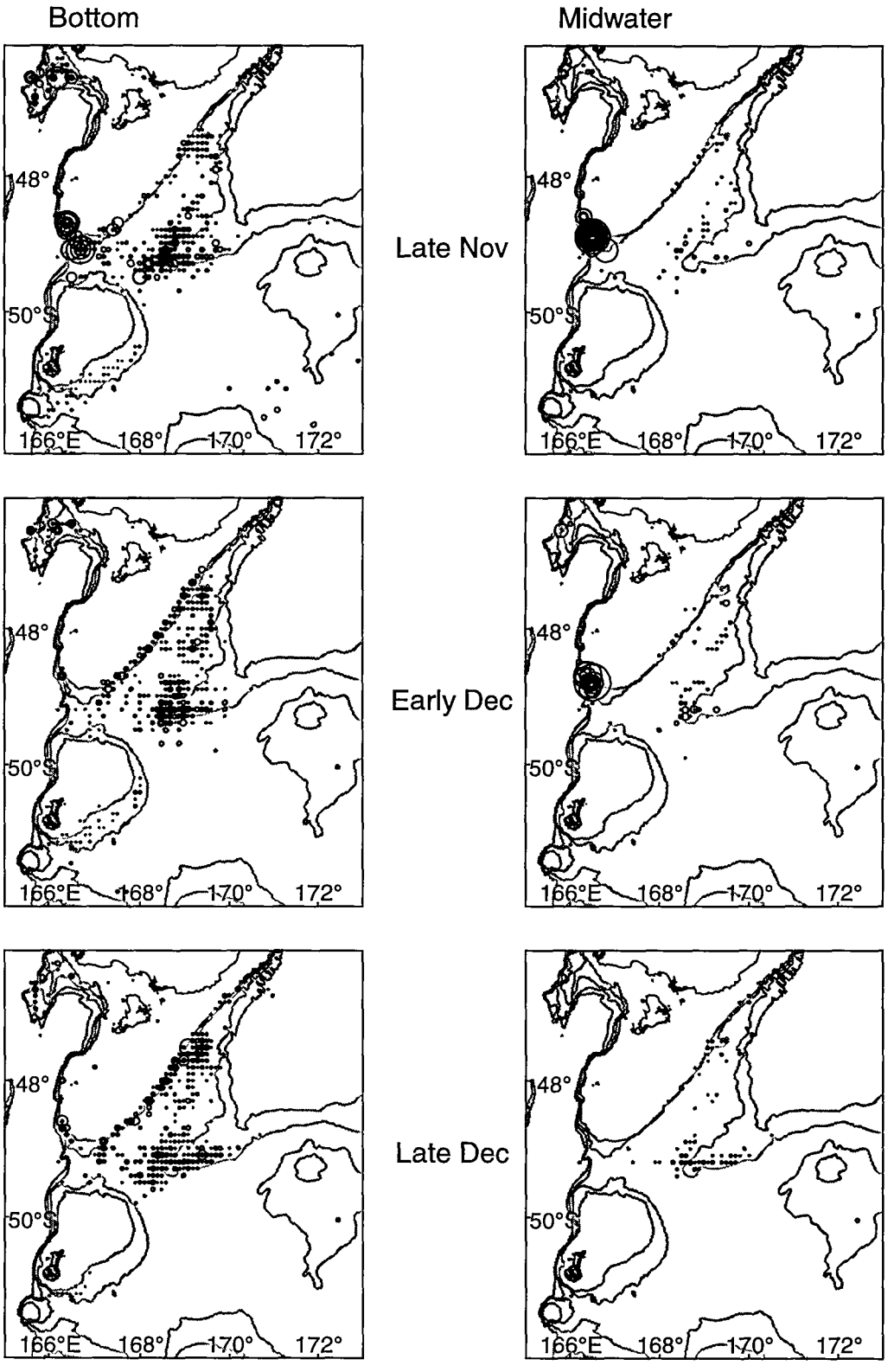

Fig. 4 *continued*

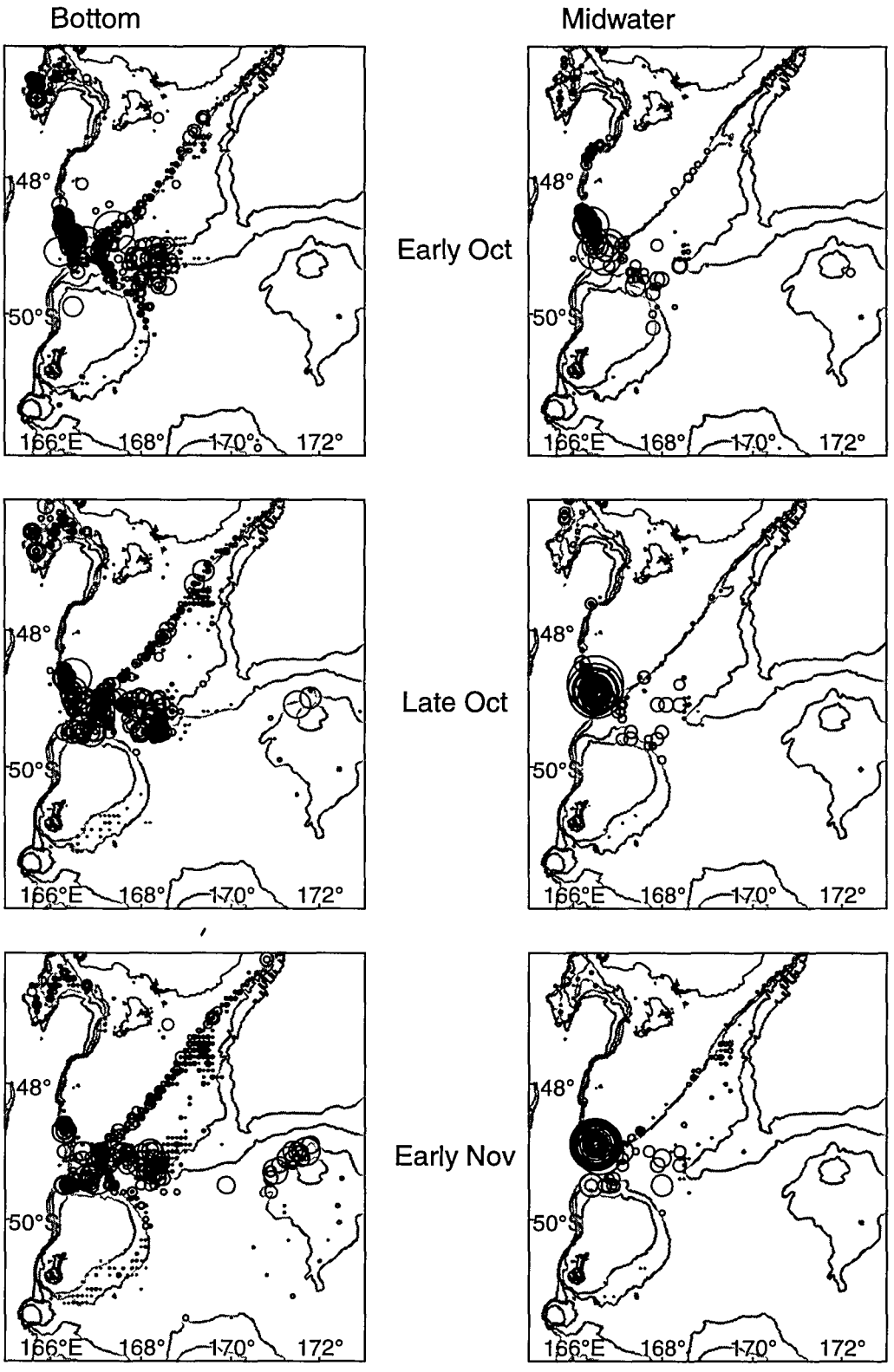

Figure 5: Ling catch rates in bottom and midwater daytime commercial tows, by fortnight, based on TCEPR data. Circle size indicates catch rate (max = 3370 kg/km). Contours represent 250 m depth intervals.

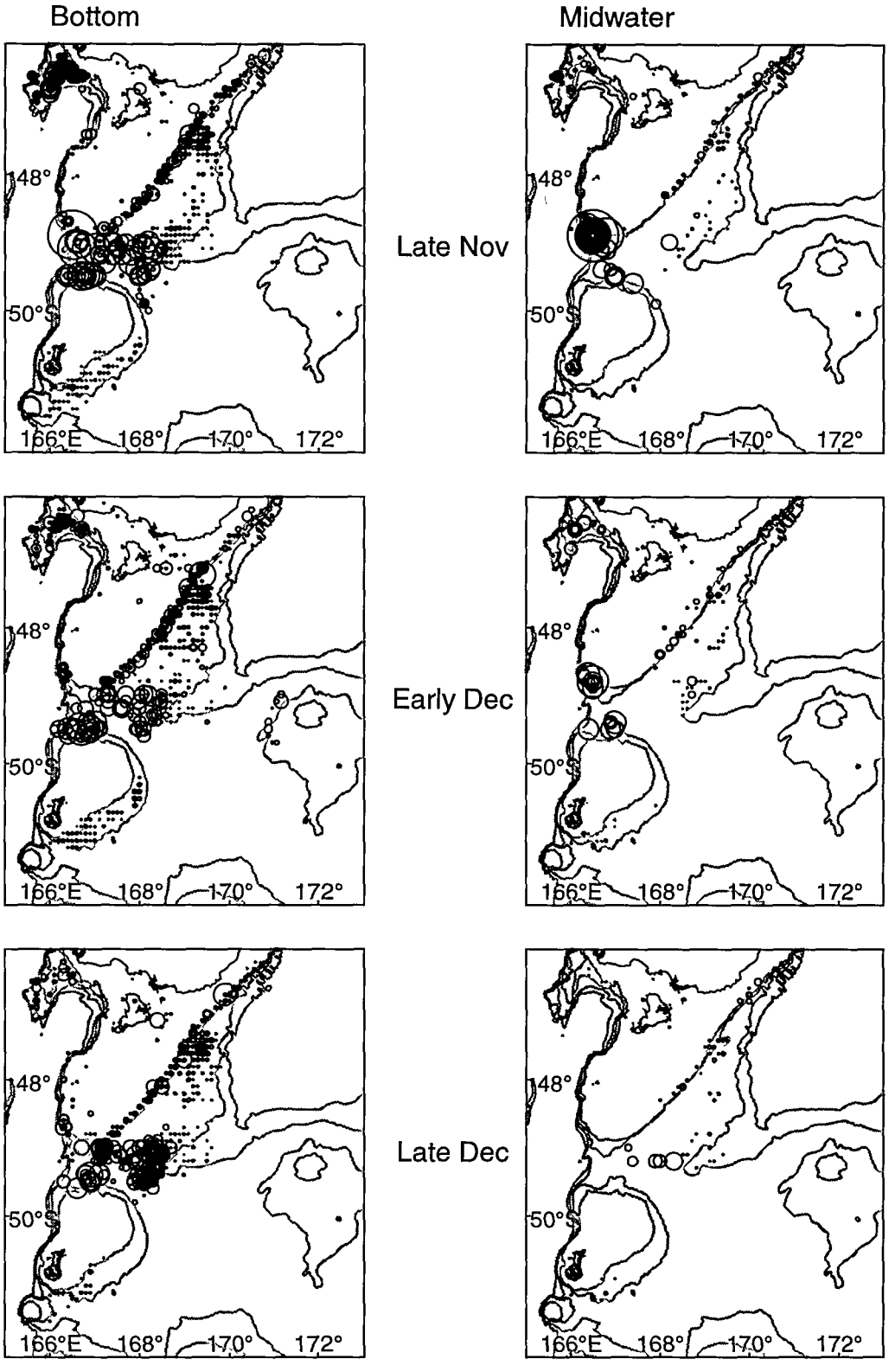

Fig. 5 *continued*

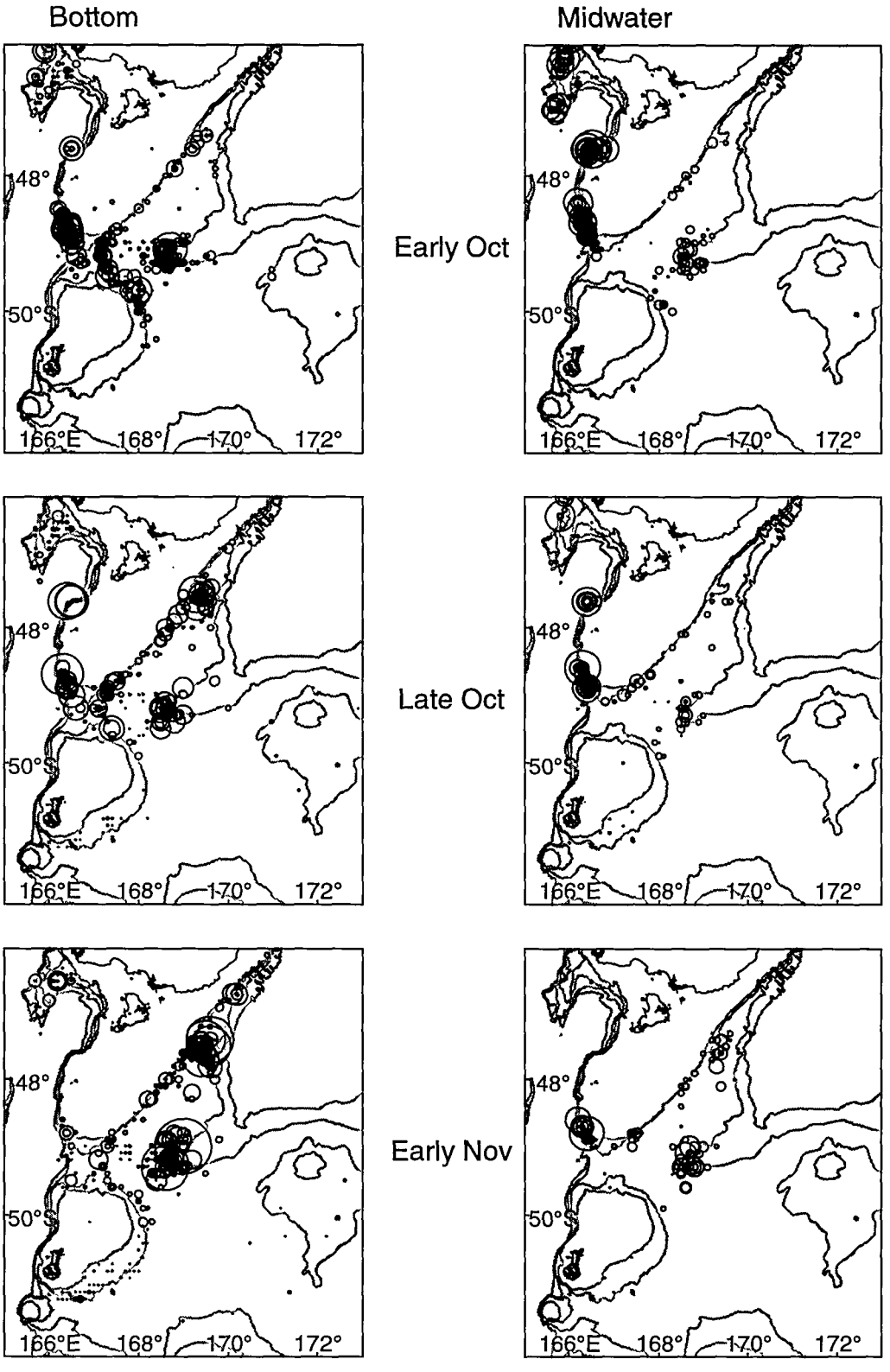

Figure 6: Hoki catch rates in bottom and midwater daytime commercial tows, by fortnight, based on TCEPR data. Circle size indicates catch rate (max = 21330 kg/km). Contours represent 250 m depth intervals.

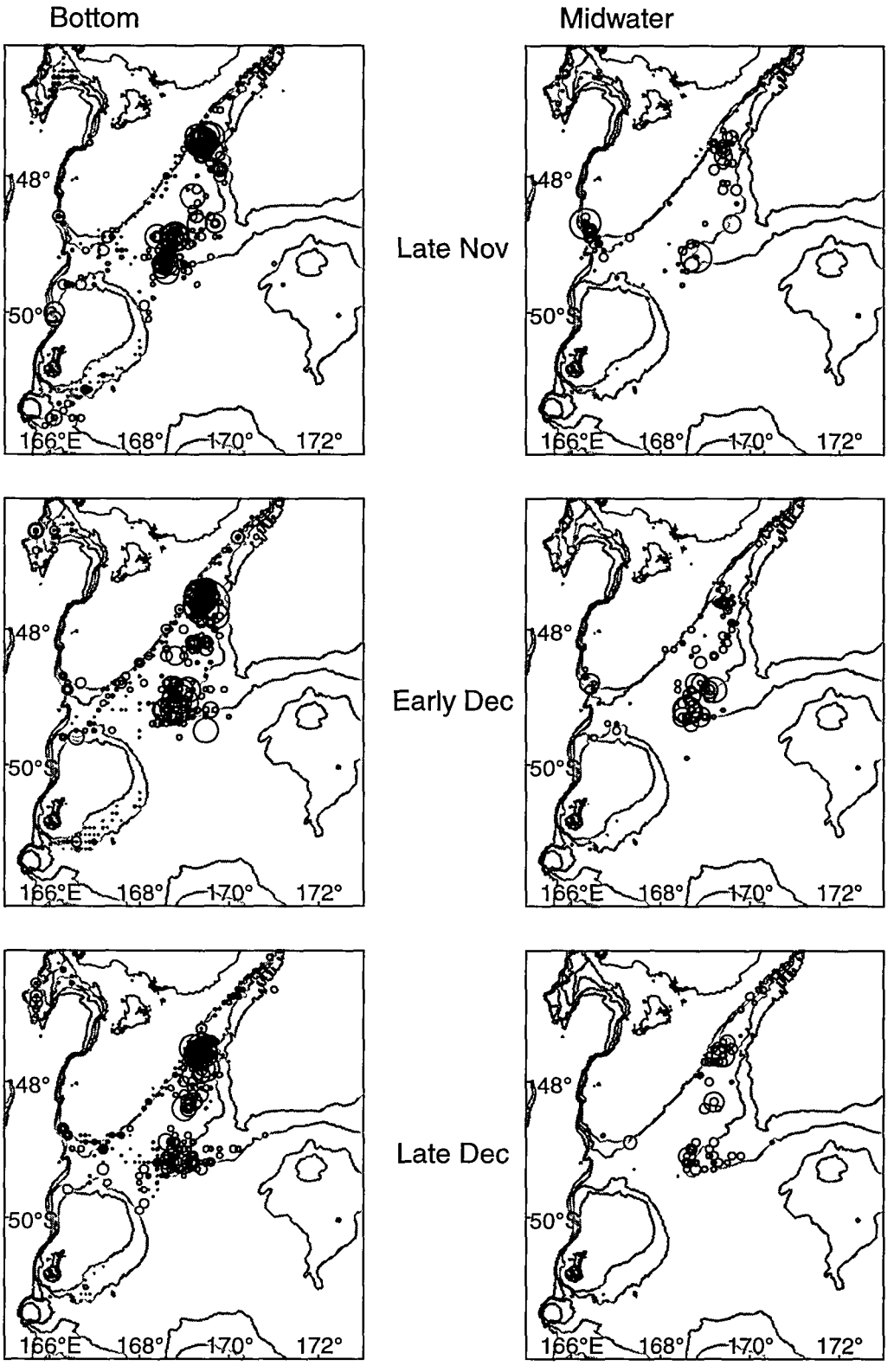

Fig. 6 *continued*

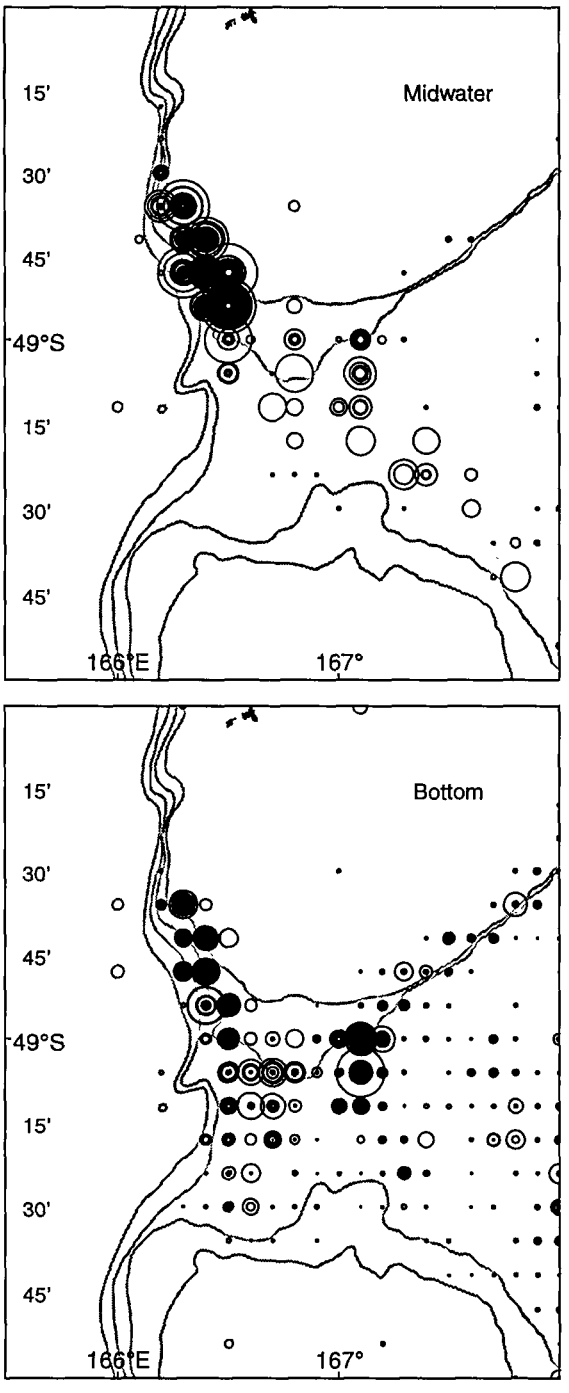

Figure 7: Hake catch rates in bottom and midwater daytime commercial tows off the southern Stewart-Snares shelf from October to December. Circle size indicates catch rate (max = 1900 kg/km). Contours represent 250 m depth intervals.

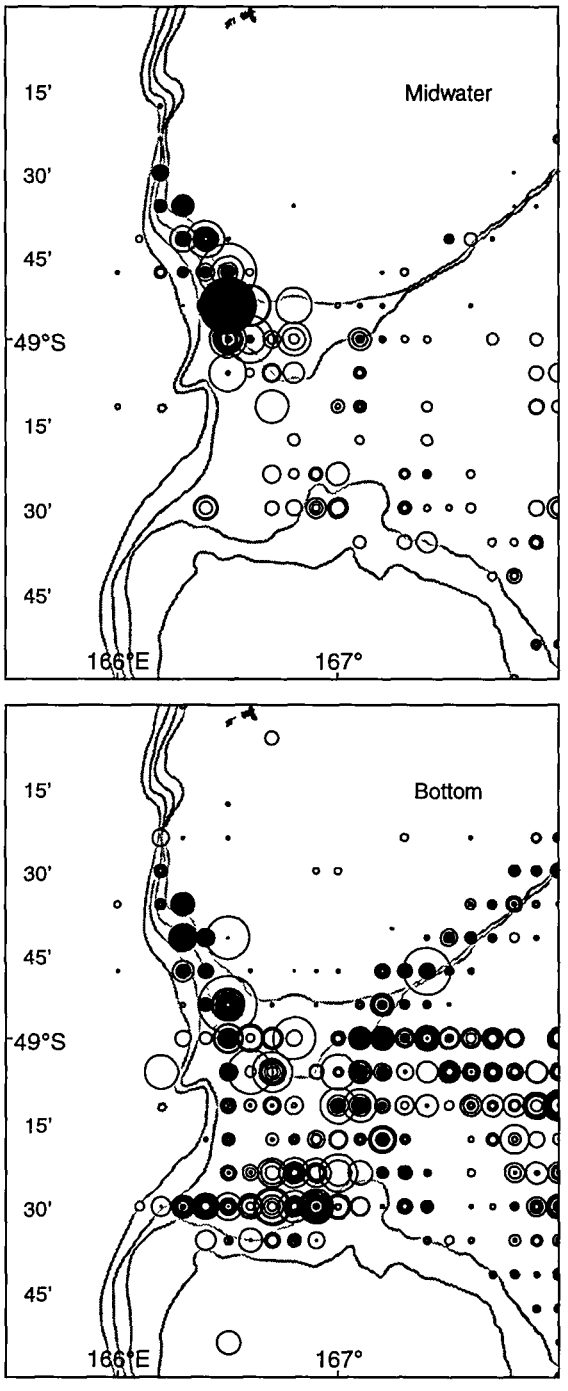

Figure 8: Ling catch rates in bottom and midwater daytime commercial tows off the southern Stewart-Snares shelf from October to December. Circle size indicates catch rate (max = 2560 kg/km). Contours represent 250 m depth intervals.

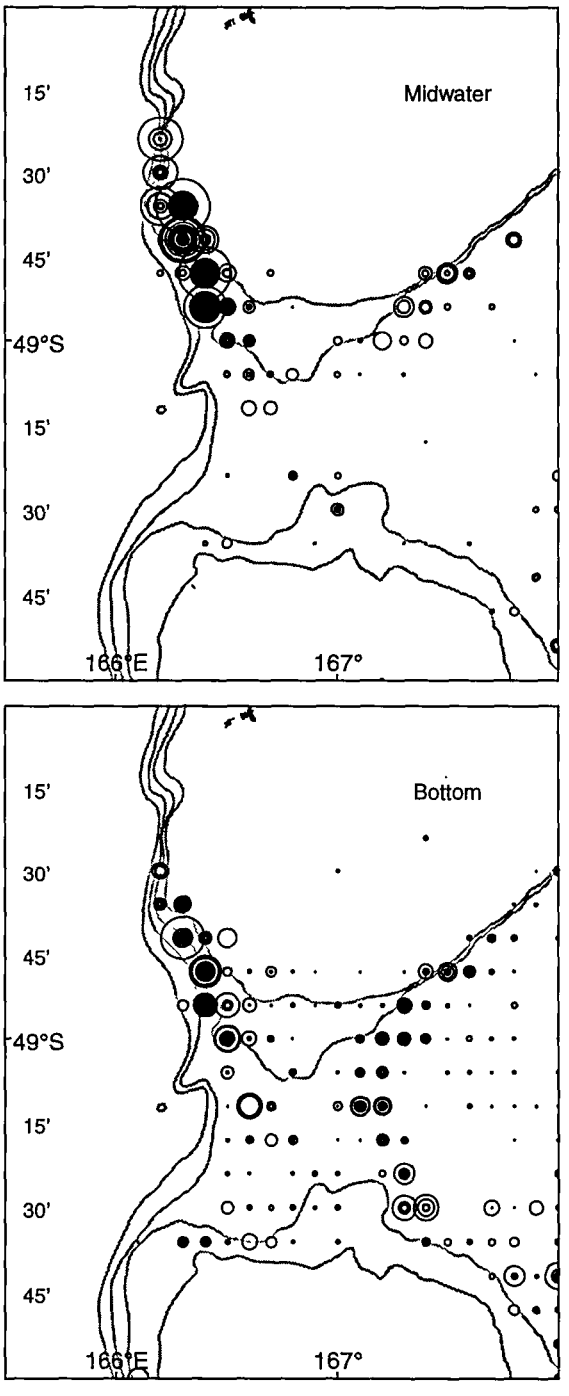

Figure 9: Hoki catch rates in bottom and midwater daytime commercial tows off the southern Stewart-Snares shelf from October to December. Circle size indicates catch rate (max = 9640 kg/km). Contours represent 250 m depth intervals.

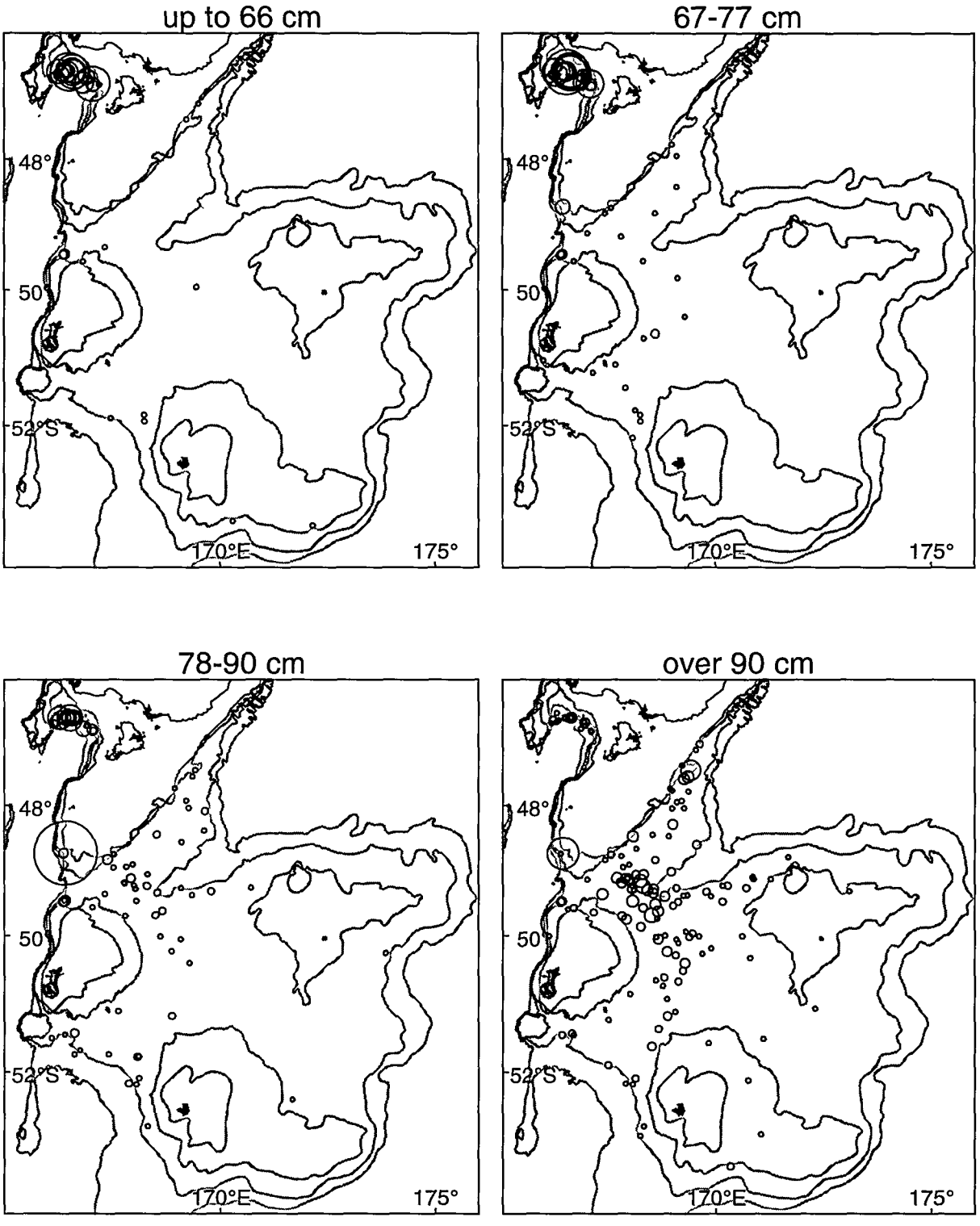

Figure 10: Distributions of hake length classes on the Southern Plateau in summer, based on research trawl data from the *Tangaroa* survey series. Circle size indicates number of measured fish at length (max = 226). Contours represent 250 m depth intervals.

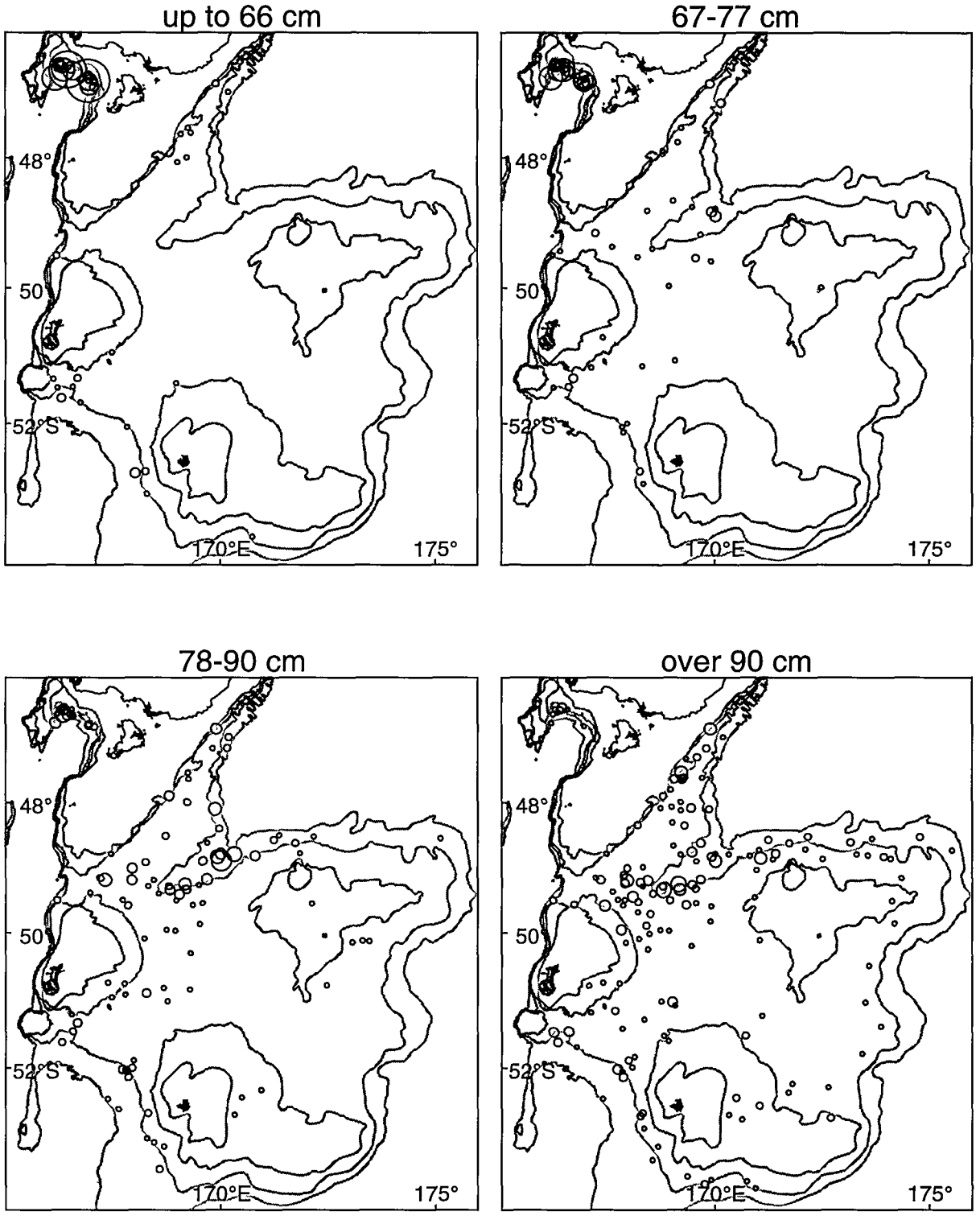

Figure 11: Distributions of hake length classes on the Southern Plateau in autumn, based on research trawl data from the *Tangaroa* survey series. Circle size indicates number of measured fish at length (scale as per Fig. 10). Contours represent 250 m depth intervals.