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Offshore herring distribution and 1998 recruitment forecast for the west coast of Vancouver Island stock assessment region

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Abstract

A multispecies mid-water trawl survey off the southwest coast of Vancouver Island (WCVI) was conducted between August 3 - 9, 1997. Twenty-five tows were made to assess the species composition, catch-per-unit of effort, diet, condition factor, size and age compositions of the dominant pelagic fish species in the WCVI stock assessment region. The offshore distribution of herring in this area returned to a more normal state this year after the unusual 1996 summer. The apparent abundance of herring sounded this summer was much higher than last year, and the schools were found in their usual concentration centers on 40-mile and Swiftsure Banks. There was also a good showing of herring along the outer edge of the continental shelf. Seven tows targeted on herring. Analysis of the length compositions suggests that the west coast of Vancouver Island herring spawning stock will contain 33 % age 2+ recruits in March 1998. Based on stock assessment model projections of the biomass of surviving repeat spawners, we estimate that the strength of the recruiting 1995 year-class will be midway between the "poor" and "average" categories (about 8,000 t). Our long-term research program on the west coast of Vancouver indicates that herring recruitment tends to improve when ocean temperatures are cool, and the summer biomass of migratory predators (like hake and mackerel) in the region is low.

Résumé

Un relevé au chalut pélagique visant de nombreuses espèces a été effectué sur la côte sud-ouest de l'île de Vancouver du 3 au 9 août 1997. Vingt-cinq traits ont été faits pour évaluer la composition spécifique, les prises par unité d'effort, le régime alimentaire, le coefficient de condition et la distribution des âges et de la longueur des espèces dominantes de poisson pélagique dans cette région d'évaluation des populations. La distribution hauturière du hareng dans la région est revenue à un état plus normal après l'été anormal de 1996. L'abondance apparente de hareng établie cet été par sondeur à écho était beaucoup plus forte que l'an dernier, et les bancs étaient présents à leurs centres de rassemblement habituels sur les bancs Swiftsure et 40-mile. Le hareng s'est en outre manifesté en assez bon nombre le long de la limite supérieure de la plate-forme continentale. Sept traits ont visé l'espèce. L'analyse de la distribution des longueurs indique que le stock de géniteurs de la côte ouest de l'île de Vancouver se composera de 33 % de recrues d'âge 2+ en mars 1998. Selon des projections de la biomasse de géniteurs matures survivants faites d'après le modèle de l'évaluation du stock, nous estimons que l'abondance de la classe d'âge recrutée en 1995 se situera à mi-chemin entre les catégories « pauvre » et « moyenne » (environ 8 000 t). Notre programme de recherche à long terme sur la côte ouest de l'île de Vancouver indique que le recrutement du hareng a tendance à s'améliorer lorsque la température de l'océan est fraîche et que la biomasse estivale de prédateurs migrateurs (comme le merlu et le maquereau) dans la région est faible.

INTRODUCTION

A multispecies, mid-water trawl and echosounding survey of the herring, hake, dogfish, and chinook salmon stocks off the lower west coast of Vancouver Island (WCVI) was done by the R/V W.E. RICKER between August 3 to 9, 1997. The survey covered 6,000 km^2 of the continental shelf from the U.S.-Canada border, north to 49 ^{0}N. latitude, and seaward to the 300 m isobath. Mid-water trawling was conducted in the La Perouse Bank fishing subareas (Fig.1). Twenty-five tows were made to assess the species composition, catch-per-unit of effort (CPUE), diet, condition factor, size and age compositions of the dominant pelagic fish in the area. This multispecies survey has been carried out annually in August since 1985, as part of the DFO La Perouse Bank and now the Canadian GLOBEC WestSEA Project. A principal objective of this survey is to quantify how interannual variations in the physical environment, feeding conditions, and abundance of key offshore predators (like Pacific hake and mackerel), affect the recruitment and production of the WCVI herring stock. The recruitment forecasts obtained from the offshore survey have been used by the PSARC Herring Subcommittee for the last eight years to set the fishing quota for the west coast of Vancouver Island stock assessment region. A retrospective evaluation of the forecast and observed herring recruit biomass indicates that the forecasts have been reasonably accurate.

This working paper summarizes: (1) the distribution of herring on the offshore feeding grounds in the summer of 1997, and (2) a forecast of the strength of the 1995 year-class, which will recruit to the west coast of Vancouver Island herring fishery in March 1998.

RESULTS

Part I: The 1997 Offshore Trawl Survey

Sampling Data:

The standard survey was carried out by echo-sounding in the Canadian fishing subareas shown in Fig. 1A. Biological samples were collected from the largest concentrations of fish encountered in each subarea, with a large rope trawl (mouth opening 20 m [height] by 40 m [width]) with a herring liner in the codend. This liner is small enough to retain all but young-of-the-year herring. Seven tows targeted on herring. The catch was sorted by species and weighed. Standard lengths were measured to the nearest mm. The following table summarizes the location, CPUE, and sample size for each herring tow:

Area	Subarea	Tow	CPUE (kg/min)	Sample size
Swiftsure Bank	(9)	1	2	150
Swiftsure Bank	(9)	3	4	150
40-Mile Bank	(6)	5	8	150
40-Mile Bank	(6)	6	98	150
40-Mile Bank	(6)	15	189	150
South Slope	(12)	12	48	150
Central Slope	(13)	16	42	150

Herring Distribution

Pelagic fish distributions off the west coast of Vancouver Island returned to a more normal state this year, after the unusual summer of 1996. Typically, during July and August, herring tend to be concentrated in large schools on 40-mile Bank, the SW Corner, and Swiftsure Bank , and to a lesser extent in the outer shelf subareas near the 200 m edge (Fig. 1B). This year the largest herring schools were found on 40-mile Bank, Swiftsure Bank, and in the Central slope subarea.

As a point of interest, Pacific sardine were visible near the surface on the sounder and were caught in subareas 4, 7, 10, and 12. This was the largest abundance we have seen since sardines were first captured by this survey in 1992 (Hargreaves et al 1994).

Age-Length Composition

The stock age composition was estimated from the trawl length- frequency samples. The size modes of age 1+, 2+ and 3+ fish were separated by a modal analysis of the length-frequencies (Figs. 2-5) with the following results:

	Modal standard length in mm length (and range)			
Area	Age 1+	Age 2+	Age 3+	Age 4+
Swiftsure (Tow 3)	138 (122-156)	162 (157-179)	-	-
40-Mile Bank (Tow 5)	-	177 (154-192)	-	-
40-Mile Bank (Tow 6)	-	185 (168-188)	196 (192-202)	-
40-Mile Bank (Tow 15)	-	185 (174-188)	194 (189-202)	-
Swiftsure (Tow 1)	-	182 (173-186)	195 (187-201)	207
Central Slope (Tow 16)	-	185 (172-188	194 (189-198)	200-208

These estimated age-class length modes are comparable to the average lengths in age-validated samples obtained from our previous surveys (Table 1). Herring length (and age) compositions varied over the survey area, in the usual pattern. The highest occurrence of age 1+ fish was on Swiftsure Bank (subarea 9). The recruiting age 2+ fish (1995 year-class) were most abundant on Swiftsure Bank, 40-mile Bank, and in the northern portion of the Central Slope subarea. Older herring (>age 4+) dominated the South Slope sample. No young-of-the-year fish were encountered offshore, presumably because the main body was still inshore (in Barkley and Clayoquot Sounds).

To forecast recruitment to the west coast of Vancouver Island herring stock from the offshore survey data we need to: (1) estimate the percentage of age 2+ fish that will recruit to the spawning stock in March 1998, and then (2) convert this percentage into a biomass estimate. We consider each step in turn.

Proportion of age 2+ fish in the maturing stock

The frequency of maturing age 2+ herring in the August 1997 survey is a forecast of the expected frequency of this age group in the spawning stock in early March 1998. For the last 11 years, the frequency of age 2+ recruits in the offshore surveys and on the spawning grounds the following spring, has averaged 30% of the adult population (Table 2). The absolute difference between the frequency of recruits in the summer survey and their frequency six months later on the spawning grounds has averaged 9%; and has been less than 7% in seven out of ten cases (Table 2). The largest discrepancy occurred last summer, probably because of the abnormal distribution and scarcity of herring on the offshore banks at that time.

Four of the seven offshore survey samples provided independent estimates of the percentage of age 2+ fish that will recruit to the spawning stock next March (note that the spawning stock does not include age 1+ fish, which will not mature until March 1999). Hence, Tows 3 and 5 which were on schools of immature, age 1+ and age 2+ fish, were not used in the recruitment forecast. The sample from the south slope was most unusual because it only contained age 5+ (and older) herring. This sample was excluded from the analysis because the age distribution was so skewed, and because the concentration of herring in this area was relatively small (despite an average CPUE for the school that was sampled). It was felt that inclusion of this sample would introduce a downward bias on the estimated percentage of age 2+ recruits in the population. The impact of including tow 12 in the analysis is evaluated on page 6. The resulting length-frequency distributions from the remaining four samples are shown in Figs. 2-5. Although the number of samples is small, past experience has shown that they tend to be representative, because they come from the main concentration centers of the stock.

Area	Tow	CPUE	% age 2+
Swiftsure	1	2	20
40-Mile Bank	6	98	41
40-Mile Bank	15	189	30
Central Slope	16	42	29

Average % age 2+ = 33%

The raw percentage estimates were arcsin transformed, weighted by the CPUE, averaged, and then transformed back to a weighted mean value of 33% . For comparison, the unweighted mean is 30%. The weighted mean should be a more accurate estimate of the proportion of recruits in the maturing stock. The relationship between the forecast and observed percentage of recruits in the stock is shown in Fig. 6.

The potential mingling of herring from the west coast of Vancouver Island and Strait of Georgia stock assessment regions on the offshore summer feeding grounds, introduces some uncertainty into the recruitment forecast. However, there are two pieces of evidence which suggest that this is probably just a minor problem. First, not all of the Strait of Georgia herring "summer" off the lower west coast of Vancouver Island after spawning. It is suspected that a significant percentage of this stock migrates north through Johnstone Strait to summer feeding grounds in Queen Charlotte Sound. Second, Tester (1948) found that the component of the lower Strait of Georgia herring stock that historically migrated to the lower west coast of Vancouver Island to feed was distributed primarily south of subareas 9, 10 and 12. Hence, at this time, most of the herring in the La Perouse Bank survey area probably belong to the west coast of Vancouver Island stock.

1998 Recruitment Forecast

The frequency of recruit spawners (derived in the last section) can be converted to a biomass forecast by indexing the recruits to the 1997 spawning biomass estimates from the escapement and age-structured models (Schweigert et al. 1997). The average spawning biomass (ages 2+ to 9+ fish) in the southwest Vancouver Island stock assessment region in March 1997 was 33,800 tonnes (average of both stock assessment model estimates); 66% of this biomass is projected to survive, and will grow by a factor of 1.15 (the average body weight of the repeat spawners will increase from about 129 g to 148 g). Thus, the total number of repeat spawners alive in March 1998 is projected to be 26,200 t or 173.3 x 10^6 fish [0.66 x 1.15 x 33,800/.000148]. According to the offshore age distribution, repeat spawners will make up 67% (100-33) of the adult stock. Hence, the 1998 prefishery stock is projected to be 258.6 x 10^6 fish (173.3 x 10^6 / 0.67). Thirty-three percent of the mature stock, or 85.3 x 10^6 fish are forecast to be age 2+ recruits. At an average body weight of 94 g (the average weight of recruit spawners),

the biomass of the recruiting 1995 year-class is forecast to be about 8,000 tonnes. Hence the 1998 prefishery biomass is estimated to be about 33,700 t (8,000 + 25,700 t).

The recruiting biomass of age 2+ herring since 1951 was calculated by multiplying the abundance of age 2+ herring in period 1 estimated by the age structured model (Schweigert et al 1996; Appendix Table 2.5), by the average annual survival rate (0.66) and the long-term average body weight (94 g). The estimated biomass of age 2+ recruits during this period ranged from 300 to 63,000 t, with an average biomass of 17,000 t. Classifying the lowest 33% of the recruitments as "poor", the middle 33% as "average" and the highest 33% as "good" we obtain the following ranges for these three categories:

Recruitment	Biomass Range (t)
"Poor"	0 to 8,800
"Average"	8,800 to 20,700
"Good"	> 20,700

From the expected return of repeat spawners and the frequency of age 2+ recruits observed offshore this summer, the strength of the 1995 herring year-class in the west coast Vancouver Island stock assessment region is projected to be roughly midway between the "poor " and "average" categories. The accuracy of our previous forecasts compared to retrospective estimates produced by the age-structured model (Schweigert et al 1997) is shown in Table 5 and Fig. 7. Over the observed range, the correlation between the observed and forecast recruit biomass is positive and highly significant.

Uncertainty in the 1998 Forecast.

The rather large difference in the 1997 spawning stock estimates between the two assessment models (ASM = 28,200 t and Escapement model = 39,400 t) increases the uncertainty in the recruitment and prefishery biomass forecasts (Tables 3 and 4). Treating the estimates from both models independently, suggests a projected recruitment range of 6,700 to 9,300 t, and a 1998 prefishery biomass of 28,100 to 39,200 t, depending upon the weight given to each assessment model. In both cases, the forecast prefishery biomass is well above the Cutoff, however, the escapement model estimate places the 1995 year-class in the "Average" recruitment category, while the age-structured model estimate places it in the "Poor" category.

Another source of uncertainty arises from tow 12. If this tow is included, the transformed weighted frequency of offshore recruits declines to 27%, and the projected biomass of recruit spawners declines to 6,000 t. This would place the 1995 year-class in the "Poor" recruitment category.

Part II: Environmental risk factor forecast

A 56-yr year-class strength (measured as age 2+ recruits) time series for the west coast of Vancouver Island herring stock was reconstructed from a linear regression relating Taylor's (1964) estimates of the strength of the 1935 to 1959 year-classes, to the age-structured model (Schweigert et al 1996) estimates of the strength of the 1951 to 1991 year-classes. The correlation between these two time series for the 8-year period of overlap is highly significant (r^2 = 0.77; p=0.004). Consequently, the resulting linear regression was used to convert Taylor's 1935 to 1959 year-class strength estimates into age-structured model estimates (expressed as numbers of age 2+ fish alive at the beginning of the fishing season [period 1] (see Schweigert et al 1997, Appendix table 2.5).

Previous research (Ware & McFarlane 1986, Ware 1991, and Ware and McFarlane, 1995), has identified two environmental risk factors that appear to limit herring year-class size: (1) annual water temperatures in the first year of life and; (2) migratory hake biomass off southwest Vancouver Island in the first summer of life (hake is a principal predator of juvenile and adult herring). The hake biomass data were obtained from two sources: (1) proxy biomass estimates from 1935 to 1968 were compiled by Francis at al (1984) and; (2) estimates since 1968 were derived from DFO trawl survey and hydroacoustic survey data (Ware & McFarlane 1995, Kieser et al 1996). Herring year-class strength is negatively correlated with both risk factors. With respect to the mechanism, Ware (1991) speculated that the negative correlation between year-class strength and temperature may reflect: (1) poor feeding conditions for herring larvae and juveniles in their first growing season; and (2) a general increase in the mortality of larval and juvenile herring, caused by changes in the intensity of invertebrate and fish predation in the rearing area in warm years. Subsequent field studies have confirmed that the negative correlation between herring year-class strength and hake biomass could be caused largely by predation (Tanasichuk et al 1991, Ware and McFarlane 1995).

In a previous PSARC working paper (H94-4) we found that when a risk factor has a low value it has little effect on herring year-class strength. However, as the value of the factor increases it plays an increasingly stronger role in reducing year-class size. Thus, high predator (hake and mackerel) biomass, and warm water temperatures (possibly an indicator of poor feeding conditions), tend to produce year-classes of below average strength. Since each risk factor can operate independently, either a high hake biomass, or a high temperature, or a combination of both factors can determine the subsequent size of the year-class.

To identify the factors associated with "poor", "average" and "good" recruitment, the data were sorted into a contingency table which considered 9 risk combinations: the two risk factors (each of which was divided into three levels: years where the value of the factor was in the lowest third of its range (state = "-"), years where it was in the middle third (state = "0", signifying average), and years where it was in the highest third (state = "+"). The dependent variable, herring year-class strength, was divided into three categories: the 18 largest year-classes were classified as "good", the middle 21 as "average", and the bottom 17 as "poor". Ties in the factor scores caused a slight variation in the final number in each category.

Table 6 shows how herring year-class strength has varied with respect to the observed risk factor combinations for the 1935-91 year-classes. This classification scheme provides a fairly clean separation of "poor" and "good" year-classes. As expected, poor year-classes tend to be associated with above average temperatures, and above average hake abundance. Conversely, good year-classes tend to be associated with below average temperatures and below average hake abundance. Using the results in Table 6, the probability of "poor", "average", or "good" recruitment can be forecast from the observed combination of environmental and predation conditions during the formation of the year-class in the year of birth. The expected and observed strengths (determined by the age-structured stock assessment model) for the last ten year-classes are:

Year class	Chance of poor	Average	Good	Observed
1985 (--)	20	0	80	Good
1986 (+0)	57	29	14	Poor
1987 (+-)	60	40	0	Poor
1988 (+-)	60	40	0	Poor
1989 (+-)	60	40	0	Average
1990 (+-)	60	40	0	Poor
1991 (0+)	67	16	16	Poor
1992 (++)	50	50	0	Poor
1993 (+0)	57	29	14	Poor
1994 (0-)	0	50	50	(Average-good)
1995 (+-)	60	40	0	?

The 1994 year-class recruited to the fishery in 1997, so it will be another year or two before we can assess its strength. However, preliminary indications are that it is just above the borderline between average and good. This table corroborates that year-class strength forecasts from the risk factor combinations have been quite accurate for the last 10 years, and generally consistent with the forecasts from the offshore trawl survey (Table 5). Last year, the risk factor forecast produced the most accurate estimate.

SUMMARY

1. In the summer of 1997, the largest offshore herring concentrations were found where they normally are in early August.

2. The estimated age composition encountered during the offshore survey suggests that about 33% of the mature WCVI herring stock will consist of age 2+ recruits in March 1998. Indexing this frequency to the estimated number (and biomass) of surviving repeat spawners from last year suggests that the recruiting 1995 year-class will be about 6,700 to 9,300 t. This forecast places this year-class on the borderline between "Poor" and "Average" recruitment.

3. The 1995 year-class was born in a warm year, and the biomass of migratory predators (largely hake) was below average in the summer of 1995. A retrospective analysis of these two key risk factors suggests that there is a 60% chance that the 1995 year-class will be "Poor", a 40% chance that it will be "Average", and virtually no chance that it will be "Good".

4. Hence, both forecasting methods suggest that the biomass of the recruiting 1995 year-class will be near the borderline between "Poor" and "Average".

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Table 1. Average standard lengths (mm)-at age (determined by scale readings) of herring captured in the La Perouse Bank region during the August mid-water trawl surveys.

Year	Age 1+	Age 2	Age 3+	Age 4+	Age 5+
1987	150	183	204	212	220
1988	137	181	196	209	215
1989	138	182	201	210	219
1990	140	180	196	208	216
1991	139	173	194	208	212
1992	135	179	195	202	215
Average	140	180	198	208	216

Table 2. Percentage of age 2+ recruits found on the offshore feeding grounds in August and the corresponding % of the same age-class in test and roe fishery samples collected near the spawning grounds in Barkley and Clayoquot Sounds the following February/March. The error column indicates the difference between the two estimates.

Season	% August	% March	Error
1986/87	21	17	+ 4
1987/88	43	61	- 18
1988/89	40	16	+ 24
1989/90	29	27	+ 2
1990/91	15	21	- 6
1991/92	44	48	- 4
1992/93	26	28	- 2
1993/94	(.) [1]	22	*
1994/95	16	13	+ 3
1995/96	26	21	+ 5
1996/97	43	69	- 26
1997/98	33	?	?

[1] No forecast due to the unusual offshore distribution (and scarcity) of herring in the survey area during the El Niño summer of 1993. We cautioned in our 1993 PSARC working paper (H93-7) that the 1993/94 forecast was not reliable, and therefore should not be used. In retrospect, the offshore age composition estimated by the 1993 survey was biased by the extremely unusual oceanic conditions.

Table 3. 1998 Recruitment Forecast ... Age Structured Model

The estimated frequency of age 2+ recruit spawners was converted to biomass by indexing the recruits to the average 1997 biomass of spawners assessed by the age-structured model (Schweigert et al PSARC H97-1).

ASM 1997 spawning biomass estimate	=	**28,166 tonnes**
66 % of this biomass is projected to survive, and will grow by a factor of 1.15 (the average body weight of a repeat spawner will increase from 129 g to 148 g).		
Hence the number of repeat spawners alive in March 1997 [0.66 x 1.15 x 28,166/.000148].	=	**144.4 x 10^6 fish [21,400 tonnes]**
Age 3+ to 9+ repeat spawners [100-33]	=	**67% of the adult stock.**
Hence the March 1998 prefishery stock [144.4 x 10^6 / 0.67]	=	**215.5 x 10^6 fish.**

33% of the mature stock, or **71.1 x 10^6 fish** are **age 2+ recruits**

At an average body weight of 94 g, **the recruiting biomass is forecast to be**		**6,700 tonnes**
Projected March 1998 prefishery biomass [6,700 + 21,400 tonnes]	=	**28,100 tonnes**

Table 4. 1998 Recruitment Forecast .... Escapement Model

The estimated frequency of age 2+ recruit spawners was converted to biomass by indexing the recruits to the average 1997 biomass of spawners assessed by the escapement model (Schweigert et al PSARC H97-1).

Escapement model 1997 spawning biomass	=	**39,400 tonnes**
66 % of this biomass is projected to survive, and will grow by a factor of 1.15 (the average body weight of a repeat spawner will increase from 129 g to 148 g).		
Hence the number of repeat spawners alive in March 1998 [0.66 x 1.15 x 39,400/.000148].	=	**202.0 x 10^6 fish [29,900 tonnes]**
Age 3+ to 9+ repeat spawners [100-33]	=	**67% of the adult stock**
Hence the 1998 prefishery stock [202.0 x 10^6 / 0.67]	=	**301.5 x 10^6 fish**

33% % of the mature stock, or **99.5 x 10^6 fish are age 2+ recruits**

At an average body weight of 94 g **the recruiting biomass is forecast to be**		**9,300 tonnes**
Projected 1996 prefishery biomass [9,300 + 29,900 tonnes]	=	**39,200 tonnes**

Table 5. Comparison of forecast recruit herring biomass (from offshore trawl surveys) and the observed biomass (from age-structured model analysis) in the west coast of Vancouver Island stock assessment region. The year column indicates the year of the fishery. The rank is based on the "observed" biomass of recruits estimated retrospectively by the age-structured model. The 1997 recruitment estimate from the age-structured model is provisional: at least two years are required to adequately assess the strength of the 1994 year-class.

Year	Year-class	Forecast	Observed [1]	Rank
1987	1984	6,100	5,300	Poor
1988	1985	18,400	31,400	Good
1989	1986	17,900	5,400	Poor
1990	1987	9,200	6,800	Poor
1991	1988	2,900	4,000	Poor
1992	1989	13,500	13,300	Average
1993	1990	5,800	7,400	Poor
1994	1991	(*)	5,700	Poor
1995	1992	2,300	2,600	Poor
1996	1993	4,600	3,300	Poor
1997	1994	15,600	(21,900)	(Average-Good)
1998	1995	8,000	?	

1 observed biomass (tonnes) = $[N_{2+}$ (millions)$] * 0.66 * 0.7 * 94 / 10^6$

* indicates no forecast from the offshore survey due to the highly unusual distribution of herring during the El Niño conditions which prevailed during the summer of 1994.

Table 6. Contingency table showing the observed frequency of "poor", "average" and "good" herring year classes with respect to the nine possible combinations of the two environmental risk factors for the 1935 to 1991 year-classes. Note that one tie was placed in the AVERAGE category, hence there are only 17 POOR recruitment scores. [Risk factor sequence: annual SST, hake biomass]. A (+) indicates that the value of the risk factor is in the top 1/3 of its observed range, (0) means the factor score is in the middle 1/3 of its range, and (-) means the factor score is in the bottom 1/3 of its range. Thus the combination (+ -) for 1995, means that the annual SST was in the top 1/3 of its range, and the summer biomass of hake was in the bottom 1/3 of its range in the year when the 1995 year-class's was born.

Combination	"Poor"	"Average"	"Good"	Total
+ +	1	1	0	2
+ 0	4	2	1	7
+ -	6	4	0	10
0 +	4	1	1	6
0 0	1	4	3	8
0 -	0	2	2	4
- +	0	6	3	9
- 0	0	1	4	5
- -	1	0	4	5
Total	17	21	18	56

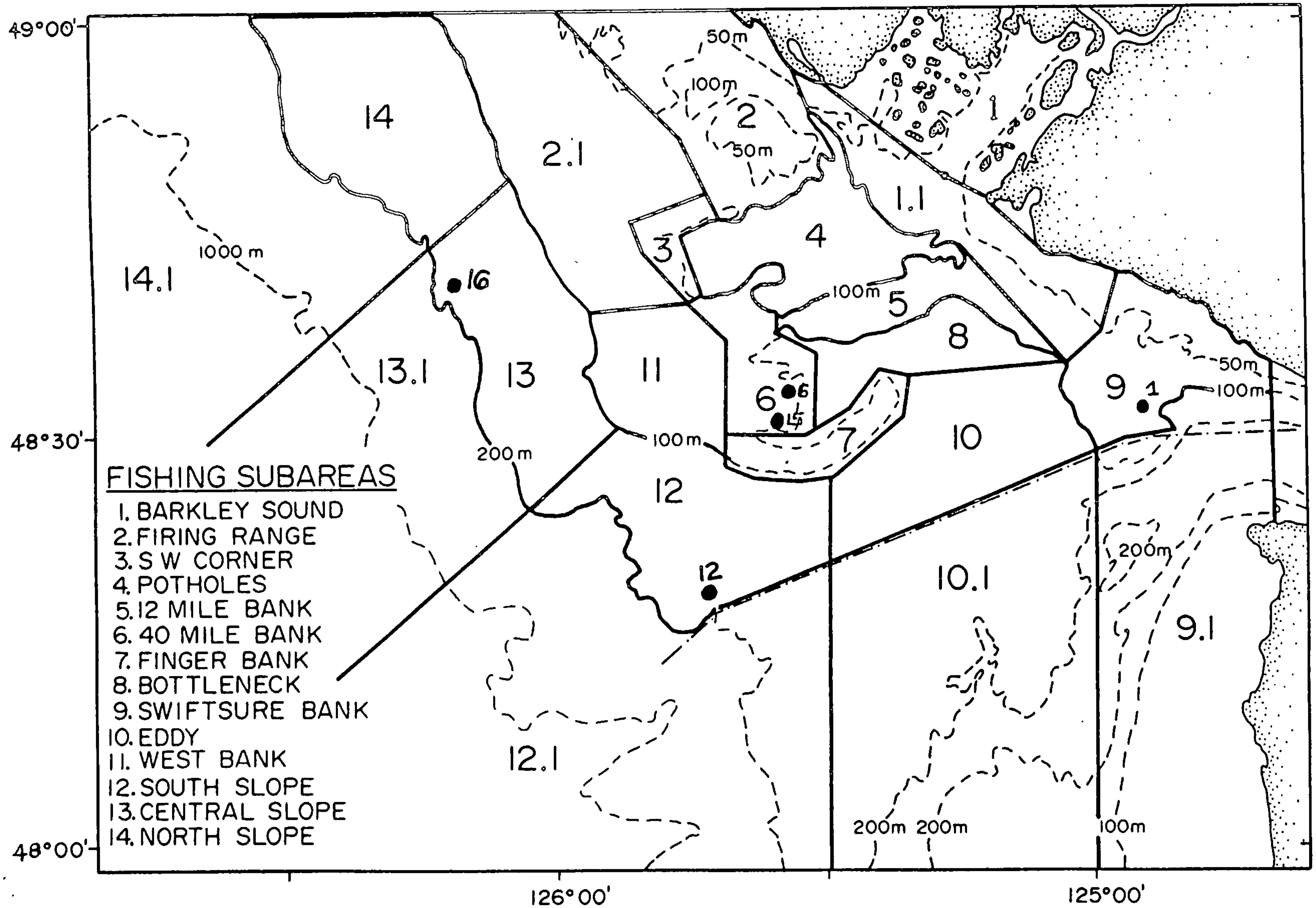


Fig. 1A Locations (solid circles with tow numbers) of mid-water trawl tows targeted on major herring concentrations during the August 1997 herring recruit survey.

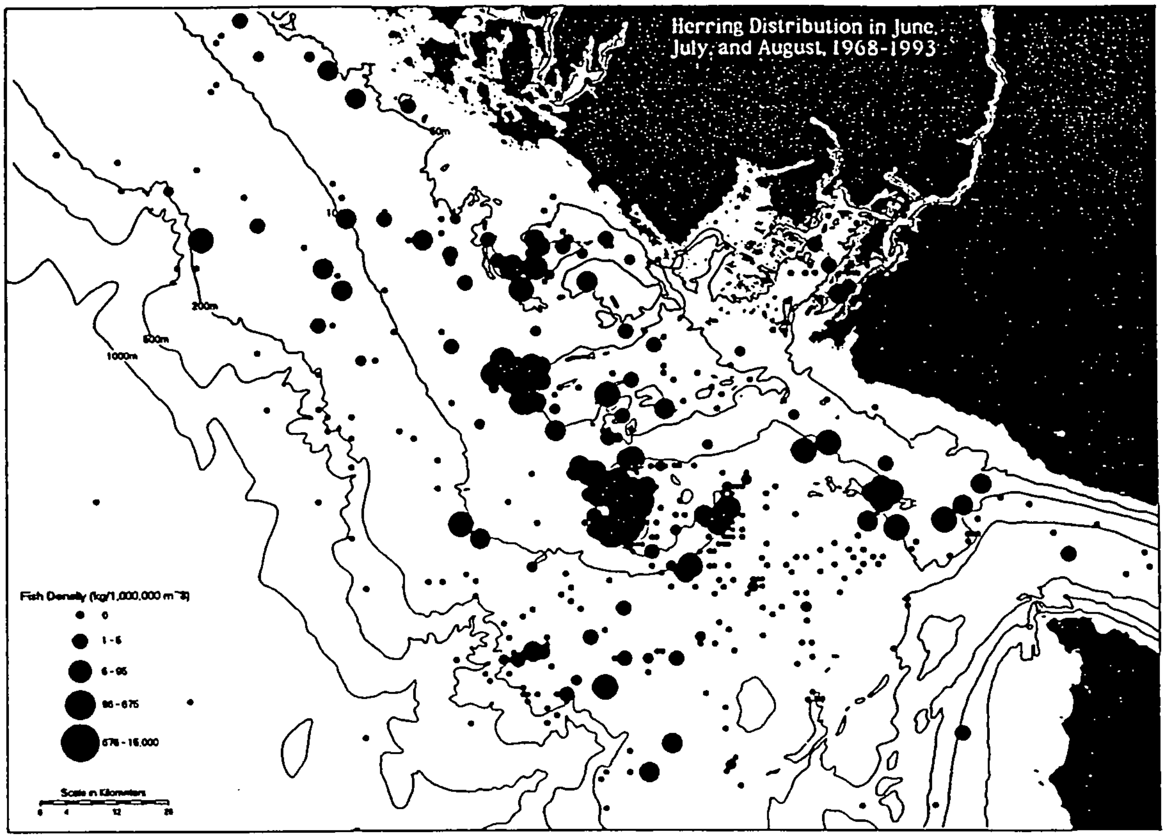


Fig. 1B Summer offshore herring distribution (and density) determined from midwater trawl sampling between 1968 to 1993. These results indicate that during this period, herring have concentrated in the summer primarily on 40-Mile Bank, and the SW Corner, and secondarily on Swiftsure Bank, and the Firing Range.

Age 2+ [30/149] = 20%

160.000	0	.00
162.000	0	.00
164.000	0	.00
166.000	0	.00
168.000	1	.66
170.000	0	.00
172.000	0	.00
174.000	1	.66
176.000	5	3.31
178.000	3	1.99
180.000	3	1.99
182.000	8	5.30
184.000	4	2.65
186.000	5	3.31
188.000	9	5.96
190.000	9	5.96
192.000	13	8.61
194.000	12	7.95
196.000	10	6.62
198.000	11	7.28
200.000	4	2.65
202.000	8	5.30
204.000	6	3.97
206.000	8	5.30
208.000	9	5.96
210.000	3	1.99
212.000	3	1.99
214.000	1	.66
216.000	2	1.32
218.000	3	1.99
220.000	0	.00
222.000	3	1.99
224.000	2	1.32
226.000	1	.66
228.000	1	.66
230.000	0	.00
232.000	0	.00
234.000	0	.00
236.000	0	.00
238.000	0	.00

Fig. 2 Length frequency distribution of herring from Tow 1. Age 2+ recruits are estimated to comprise 20% of this sample.

160.000	0	.00
162.000	0	.00
164.000	1	.67
166.000	0	.00
168.000	1	.67
170.000	2	1.33
172.000	2	1.33
174.000	5	3.33
176.000	1	.67
178.000	4	2.67
180.000	2	1.33
182.000	9	6.00
184.000	14	9.33
186.000	14	9.33
188.000	14	9.33
190.000	12	8.00
192.000	15	10.00
194.000	9	6.00
196.000	13	8.67
198.000	7	4.67
200.000	4	2.67
202.000	4	2.67
204.000	4	2.67
206.000	6	4.00
208.000	3	2.00
210.000	0	.00
212.000	2	1.33
214.000	0	.00
216.000	0	.00
218.000	1	.67
220.000	1	.67

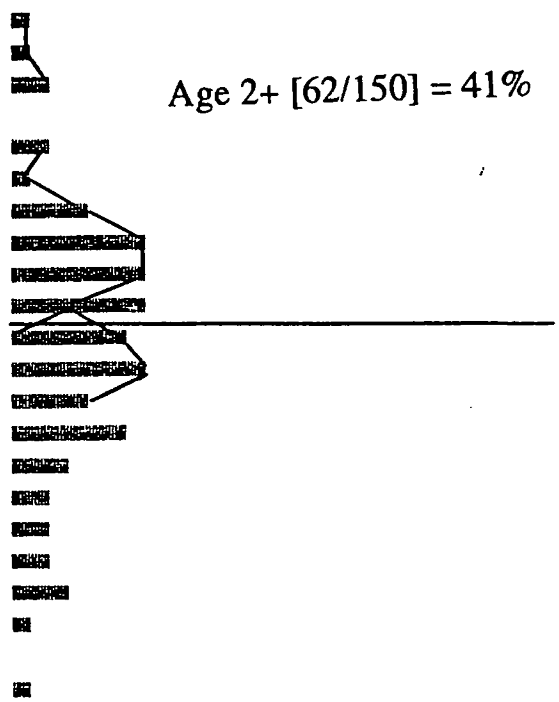


Fig. 3 Length frequency distribution of herring from Tow 6. Age 2+ recruits are estimated to comprise 41% of this sample.

160.000	0	.00
162.000	0	.00
164.000	0	.00
166.000	0	.00
168.000	0	.00
170.000	0	.00
172.000	0	.00
174.000	3	2.00
176.000	1	.67
178.000	7	4.67
180.000	5	3.33
182.000	3	2.00
184.000	9	6.00
186.000	9	6.00
188.000	17	11.33
190.000	9	6.00
192.000	15	10.00
194.000	21	14.00
196.000	13	8.67
198.000	13	8.67
200.000	6	4.00
202.000	4	2.67
204.000	1	.67
206.000	3	2.00
208.000	2	1.33
210.000	1	.67
212.000	3	2.00
214.000	3	2.00
216.000	0	.00
218.000	0	.00
220.000	0	.00
222.000	1	.67
224.000	0	.00
226.000	0	.00
228.000	0	.00
230.000	0	.00
232.000	0	.00
234.000	0	.00
236.000	0	.00
238.000	0	.00

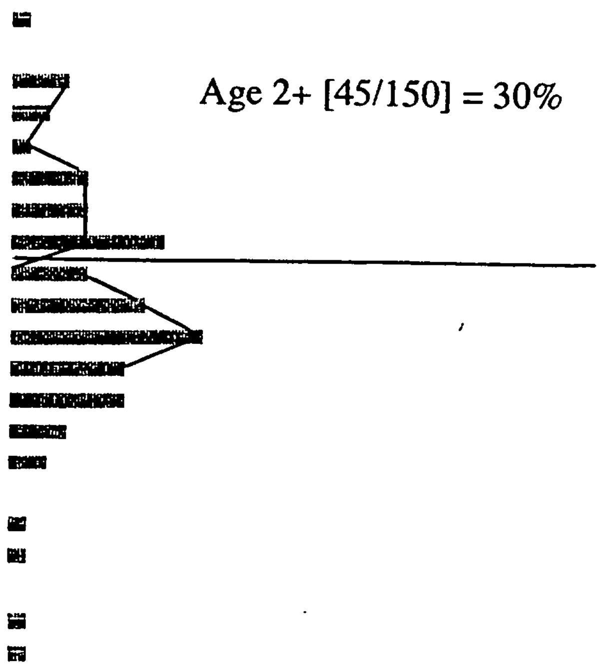
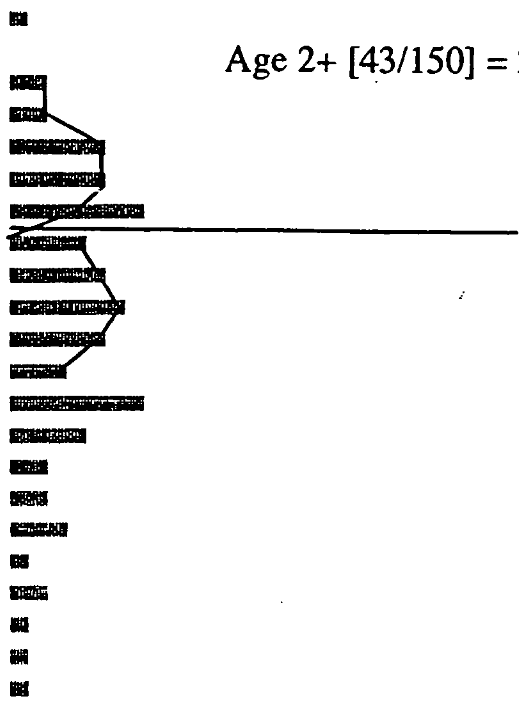


Fig. 4 Length frequency distribution of herring from Tow 15. Age 2+ recruits are estimated to comprise 30% of this sample.

160.000	0	.00
162.000	0	.00
164.000	0	.00
166.000	0	.00
168.000	0	.00
170.000	0	.00
172.000	1	.67
174.000	1	.67
176.000	2	1.33
178.000	1	.67
180.000	4	2.67
182.000	4	2.67
184.000	11	7.33
186.000	11	7.33
188.000	14	9.33
190.000	9	6.00
192.000	11	7.33
194.000	12	8.00
196.000	10	6.67
198.000	6	4.00
200.000	15	10.00
202.000	8	5.33
204.000	5	3.33
206.000	4	2.67
208.000	6	4.00
210.000	3	2.00
212.000	4	2.67
214.000	2	1.33
216.000	2	1.33
218.000	2	1.33
220.000	0	.00
222.000	0	.00
224.000	0	.00
226.000	0	.00
228.000	0	.00
230.000	0	.00
232.000	0	.00
234.000	1	.67
236.000	0	.00
238.000	1	.67



Age 2+ [43/150] = 29%

Fig. 5 Length frequency distribution of herring from Tow 16. Age 2+ recruits are estimated to comprise 29% of this sample.

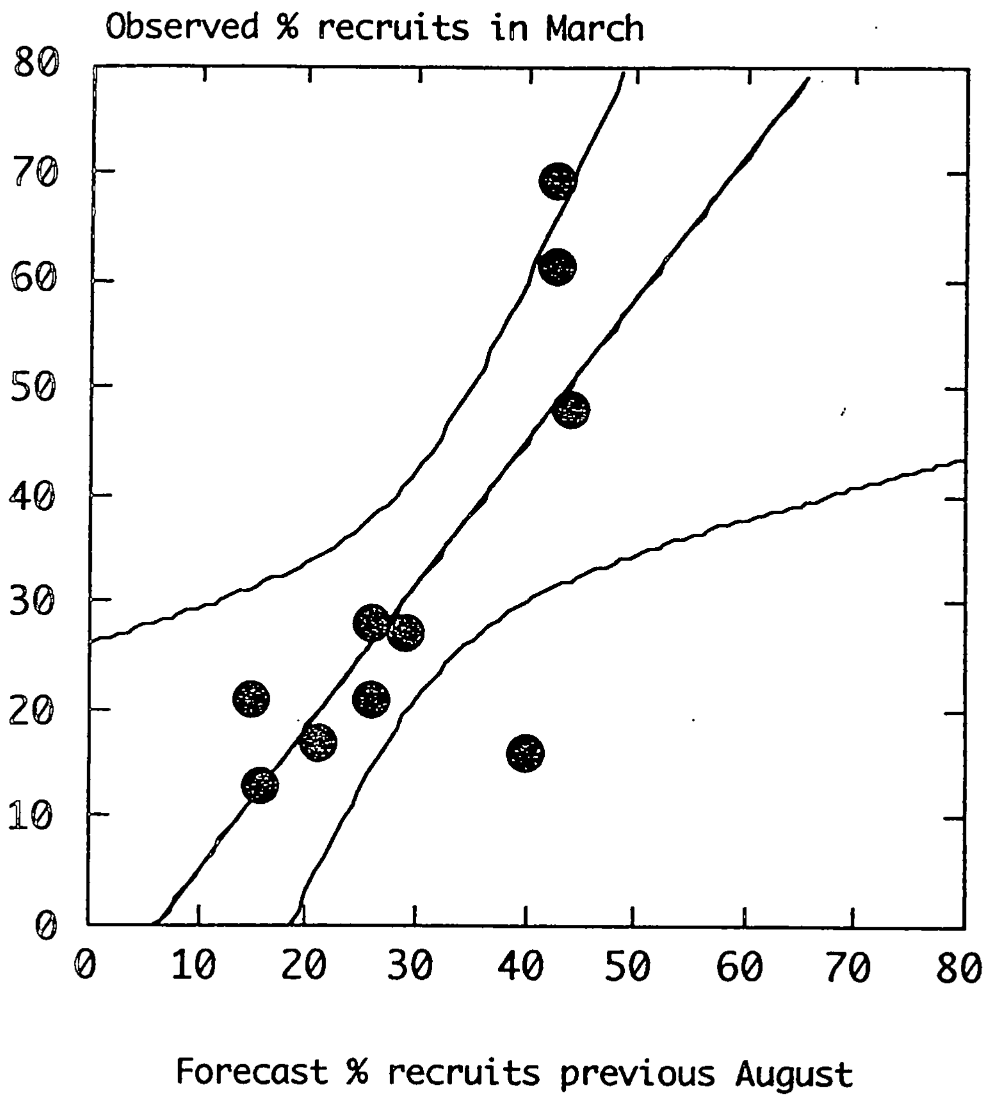


Fig. 6. Relationship between Forecast % recruits measured in the August offshore trawl survey, and the Observed % recruited on the spawning grounds the following March. The curved lines indicate the 95% confidence limits. ($n = 10$, $r = 0.76$, $p = 0.01$).

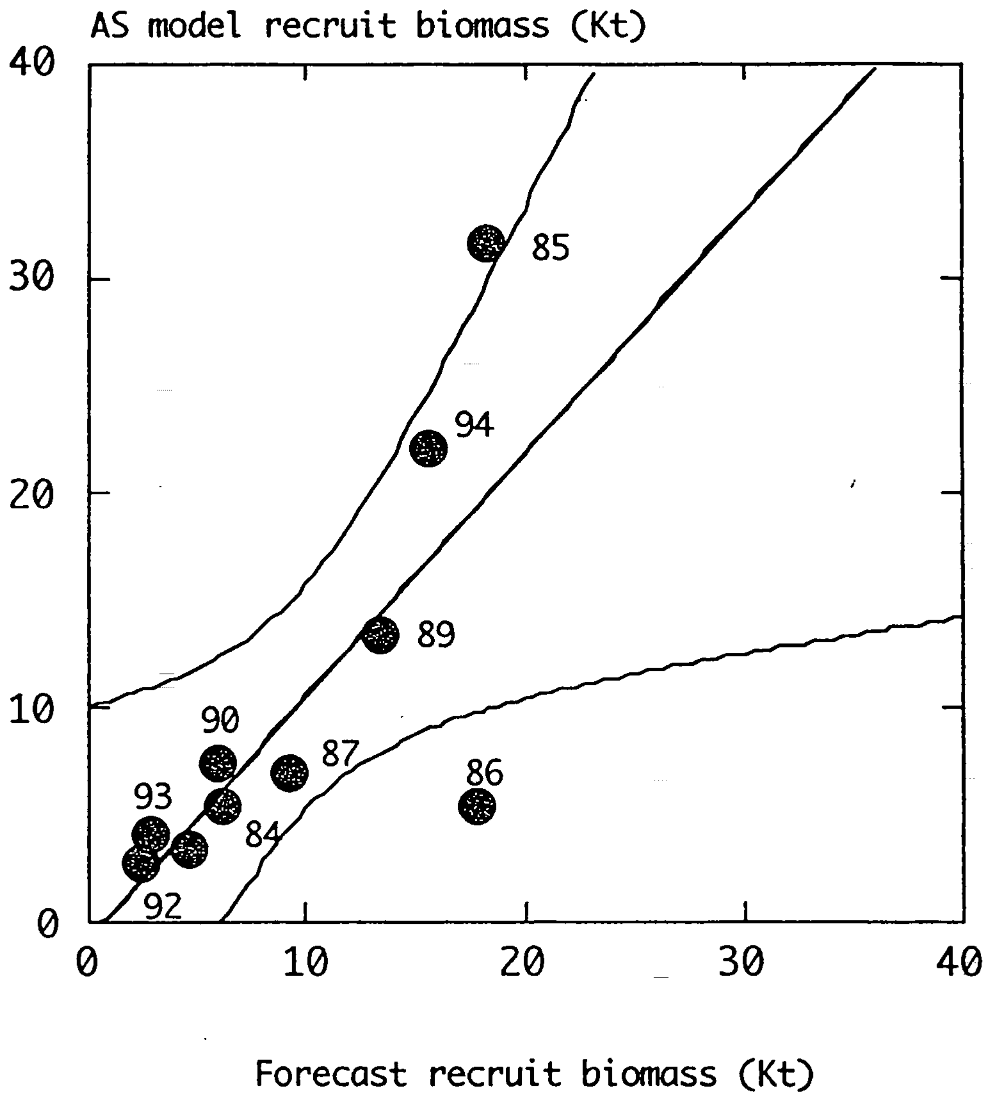


Fig. 7 Relationship between the biomass of recruits (Kt) Forecast from the offshore trawl survey (X) and the retrospective estimates (Y) from the age-structured model. The curved lines indicate the 95% confidence limits and the numbers, the year-classes. (n = 10, r = 0.74, p = 0.015).