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PREDICTING NORTH SEA FLATFISH RECRUITMENT FROM YOUNG FISH SURVEYS

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ABSTRACT

Indices of recruitment of plaice and sole are available from young flatfish surveys carried out annually on the English and European continental coast of the North Sea. Most of the surveys are poorly correlated with the VPA estimate of recruitment and an attempt is being made to improve this by producing a single nursery ground index. This paper describes an alternative method of combining suitable indices using multiple regression analysis. A series of equations has been developed which explain 99% of the variance in the recruitment of one-year-old plaice and sole from the VPA. Although the reliability of these equations in forecasting is not yet clear, the technique appears promising and further work will need to be done when the improved indices being developed by the Young Flatfish Working Group are available.

RÉSUMÉ

Des index du recrutement des carrelets et des soles sont fournis par des enqêtes sur les jeunes pleuronectes menées chaque année sur les côtes european continentale et anglaises de la Mer du Nord. La plupart de ces enqêtes sont mal reliées aux predictions de recrutement donées par le VPA et la production d'un index unique des sites d'incubation pourrait améliorer cette situation. Cet article décrit une autre méthode pour constituer ces index qui utilise la méthode de l'analyse de régression multiple. Des équations sont fournies expliquant 99% des variations du VPA en ci qui concerne le recrutement des carrelets et des soles. La fiabilité de ces équations de prédiction n'est pas encore prouvée mais cette technique montre une voie où devront s'insérer des travaux ultérieurs dès que les index améliorés fournis par le Groupe de Travail sur les jeunes pleuronectes seront disponibles.

INTRODUCTION

Indices of year-class strength derived from pre-recruit surveys have been used by the North Sea Flatfish Working Group to obtain estimates of recruitment for use in VPA calculations. However, different indices have given a wide range of possible values for the size of the recruiting year classes and there has been no reliable way of selecting the best estimate of year-class size. In the 1983 Working Group Report (ICES, 1983) the mean of the predicted values was used for sole; for plaice, the mean recruitment was calculated by weighting each prediction by $1/SE^2$.

An alternative method is to use multiple regression to derive a predictive equation. This has the advantage that all the available indices can be used. Rejection of an index occurs only if it fails to add to the predictive capability of the model by reducing the residual variance significantly. One of the disadvantages is that the number of years data which can be used is determined by the index with the smallest set of data points. This paper describes one way in which multiple regression can be used to derive a series of predictive equations based on the available pre-recruit indices for plaice and sole.

METHODS

In the analysis of the pre-recruit survey indices (x) a method of forward stepwise regression was used to build up an equation of the form $y = a+b_1x_1 + b_2x_2 + b_3x_3 \dots b_mx_m$. The dependent variable Y was the VPA estimates of recruits at age one from the 1983 Flatfish Working Group Report (ICES, 1983), and the first independent variable (x_1) to enter the regression model was the one most highly correlated with the VPA. This variable was then tested together with each of the remaining X variables in turn and the pair which gave the lowest residual variance was selected. This procedure was continued until the addition of a new variable produced no significant reduction in the residual variance. To test whether the addition of a new variable had significantly improved the model, the ratio, reduction in residual sum of squares/residual mean squares, was compared with the value of the F-distribution at $P < 0.05$ with 1 and n−m−1 degrees of freedom where n = the number of data points and m = number of X variables in the model.

Pre-recruit indices

Indices of abundance were available from the TRIDENS surveys for the period 1969-79 and from the English east coast surveys for the period

1973-79. In addition indices were calculated for the Dutch Waddensea, Scheldt Estuary, Dutch coastal and Belgian coastal areas for the period 1969-79 by extending the series given in ICES (1979) Annex 1. The survey indices differed in a number of ways. The TRIDENS and English ECYFS calculated the number of fish at each age group whereas the European continental nursery surveys separated fish into length groups. The English surveys used a factor for the area sampled to derive population indices. In the TRIDENS surveys the index is based on numbers per 100 h fishing and the continental nursery survey index on the numbers caught per 1000 m^2. There is no adjustment for the area sampled. There are also differences in gear efficiency between the different surveys and all these factors will affect the precision of the indices and could influence the results of the multiple regression analysis.

The total number of indices available for each species, including different age or length groups and both spring and autumn surveys, was 25 made up from 5 TRIDENS, 4 English and 16 continental nursery surveys. In order to reduce the data set to a more manageable size most of the spring surveys and any series with missing values were omitted. The indices used are summarised in Tables 1-3. Regression analysis was carried out on the $\log_e$ transformed plaice data and $\log_e$ (1+x) sole data.

RESULTS

1. Plaice. The 1973-79 survey indices shown in Table 1 were tested against the VPA. The index showing the highest correlation with the VPA was from the TRIDENS 1-group September survey which had a correlation coefficient, $r = 0.961$. This variable was then tested with all the remaining indices and the best pair was found to be TRIDENS 1-group, September (x_1) together with TRIDENS 1-group, April (x_2). The model was successively improved by adding first the English 0-group, 0-12 m data (x_3) and then the data for the Dutch Waddensea <13 cm (x_4). The four equations are given below and summarised in Table 4:

$$\log VPA = 7.638 + .554 \log x_1$$
$$\log VPA = 7.831 + .360 \log x_1 + .198 \log x_2$$
$$\log VPA = 12.220 - .272 \log x_1 + .560 \log x_2 - .386 \log x_3$$
$$\log VPA = 11.630 - .182 \log x_1 + .526 \log x_2 - .352 \log x_3 - .040 \log x_4 .$$

The final equation was used to predict the number of recruits at age 1 in the VPA for the period 1973-79. Figure 1 shows the high correlation between the predicted and observed values over a wide range of recruitment from the low values in 1974-75 to the high recruitment in 1979.

Each equation was used to predict the recruitment of one-year-old plaice to the stocks in 1980 and 1981 and the results are given below together with the values estimated by the 1983 Working Group.

Predicted No. Recruits (millions)

Eqn. no.		1980	(95%CL x ÷)	1981	(95%CL x ÷)
	Working Group	352		1005	
1	TRID 1-gp September	496	(1.39)	1004	(1.55)
2	TRID 1-gp Sept+TRID 1-gp Apr	419	(1.21)	996	(1.21)
3	TRID 1-gp Sept+TRID 1-gp Apr+Eng.0-gp	366	(1.20)	551	(1.78)
4	TRID 1-gp Sept+TRID 1-gp Apr+Eng.0-gp +Dutch Wadd.<13 cm	370	(1.23)	-	

The 1980 estimate by the Working Group was 352 million recruits at age 1 which was close to the values calculated by equations 3 and 4. The 1981 estimate was similar to the number predicted by equations based on TRIDENS data only. However, when the English index was included in equation 3 the predicted number of recruits fell from 1005 million to 551 million. No data were available for the Dutch Waddensea <13 cm index for 1981 and it was not possible to derive a value for 1981 from equation 4.

2. Sole. There was doubt about the validity of the estimates of the 1978 year class because of the possible high mortality of 0-group sole during the winter of 1978/9 and this year class was excluded from the regressions.

When the TRIDENS data was taken together with the English and European continental nursery surveys over the period 1973-79 excluding 1978 (Table 2) the TRIDENS 2-group September index was found to explain 81% of the variation in the VPA, and the TRIDENS 1-group September 75%. The addition of other indices either to TRIDENS 2-group September or TRIDENS 1-group September gave no significant improvement to the model.

Although the English indices were restricted to the period 1973-1979, data were available from 1970 for a number of TRIDENS and continental nursery indices. These were re-run without the English data and with 1978 again excluded (Table 3).

The TRIDENS 1-group September (x_1) for the period 1970-79 excluding 1978 was best with a correlation coefficient of 0.85 and this variable was tested with all the remaining indices. The addition of TRIDENS 2-group April (x_2) increased the correlation significantly and the model was further improved by adding the Dutch coastal 13-19 cm index (x_3). The final model explained 99% of the variance in the VPA and the predictive equation was

$$\log VPA = 7.287 + .347 \log (x_1+1) + .226 \log (x_2+1) + .709 \log (x_3+1).$$

The correlation between the predicted and observed values is shown in Figure 2.

The regression equations obtained using the TRIDENS and continental nursery indices for 1970-79 excluding 1978 are shown in Table 5. The equation for the simple regression between TRIDENS 1-group September and VPA for 1969-79 inclusive which was one of the equations used by the Working Group to predict recruitment is also shown for comparison.

These four equations were used to predict the recruitment of one-year olds to the VPA in 1980 and 1981 and the predictions were compared with the estimates made by the Working Group.

Predicted No. Recruits (millions)

Eqn. no.		1980	(95%CL x ÷)	1981	(95%CL x ÷)
	Working Group	122		135	
1	TRID 1-gp September	137	(1.54)	167	(1.70)
2	TRID 1-gp Sept+TRID 2-gp Apr	140	(1.36)	-	
3	TRID 1-gp Sept+TRID 2-gp Apr +Dutch Cst.13-19 cm	-		-	
4	TRID 1-gp Sept 1969-79 incl.	127	(2.76)	155	(2.81)

No data were available for TRIDENS 2-group April from the 1982 survey or for the Dutch coastal 13-19 cm index for 1981 and 1982. As a result it was not possible to predict recruitment of one-year olds to the VPA for 1981 from equation 2 or for 1980 and 1981 from equation 3.

DISCUSSION

The use of a predictive equation depends on its ability to forecast accurately future recruitment to the fishery. For both plaice and sole in the North Sea, it has been possible to develop several equations which predict the year-class strength with little residual error for those years included in the model. However, when forecasts were made for 1980 and 1981, two years not included in the predictive models, the results were more variable. Unfortunately new English and Continental survey indices, which are being developed to replace the ones analysed in this paper, were not available and the results discussed here must therefore be regarded as preliminary.

The number of recruits derived for both plaice and sole in 1980 approached the Working Group estimate as the number of terms in the equation was increased. That is, the best estimates derived from the multiple regression equations were similar to those obtained by averaging the results of individual simple regressions, suggesting that the two methods are reasonably comparable in their predictions. The advantage of using multiple regression is that it utilises all the available indices and only selects those which add significantly to explaining the variance in the VPA estimate.

A disadvantage of the method is more evident in the forecast for the 1981 year class of plaice. The regression equation predicted a figure of 551 million recruits which was about half that estimated by the Working Group. Since all the survey indices suggest an exceptionally strong year class for 1981 it is more likely that the Working Group estimate is correct than the multiple regression equation which predicts an average year class. The equation included the English east coast index for 0-group plaice which on its own was negatively correlated with the VPA. The negative correlation suggests that the abundance of plaice on the English coast is poor when recruitment to the North Sea stocks as a whole is high. This might occur if, for instance, wind direction influences the drift of larvae from the spawning areas to the nursery grounds on the coast. Winds which cause more larvae to reach the English coast could reduce the number reaching the continental coast and vice versa. In 1981 the recruitment to both coasts was high and the negative correlation would be out of step for that year.

Another explanation for the low prediction in 1981 is the reliance of the model on only seven years data. The other comparable year class included in the analysis was 1979 and in that year there were high survey indices on the continental nursery grounds but low indices along the English east coast. In 1981, however, the indices obtained from both the continental and English nursery grounds were the highest recorded since the surveys began. Since this pattern of results was not repeated in previous years, it was poorly predicted by the equations which combined both continental and English survey indices. As further years become available and the predictions can be tested, it should be possible to improve both the reliability and predictive qualities of the model.

In addition to its use in predicting recruitment, multiple regression may in future be able to provide a means of selecting which of a range of survey indices are useful and which should be discontinued. In this preliminary analysis, the TRIDENS surveys explained the largest proportion of the variance in the VPA estimate of recruitment for both plaice and sole. The English east coast surveys improved the model significantly for plaice but not for sole and the continental nursery surveys were of only marginal value. However, both the English and continental nursery surveys are being reworked and further analysis of the new indices will need to be done before any conclusions can be reached on the value of individual surveys in determining the recruitment of plaice and sole for the fisheries in the North Sea.

REFERENCES

ICES 1979. Report of the ICES O-Group Flatfish Working Group. CM 1979/G:3, 44 pp. (mimeo).

ICES 1983. Report of the North Sea Flatfish Working Group. CM 1983/Assess:11, 126 pp. (mimeo).

Table 1 North Sea plaice pre-recruit survey data

Year class	TRIDENS No/100h fishing			Continental nursery surveys No/1000 m^2 (Sept/Oct)						English ECYFS Pop. index		VPA ('000)
				Dutch Waddensea		Scheldt Estuary		Dutch Coastal (A-F)				
	0-gp Sept/Oct	1-gp April	1-gp Sept/Oct	<13 cm	13-19 cm	<13 cm	13-19 cm	<13 cm	13-19 cm	0-20 m 0-gp Sept.	0-12 m 1-gp Sept.	
1973	5450	5835	15648	10.58	3.75	5.07	2.12	1.48	1.01	39.5	6.8	469.8
4	2193	3902	9781	8.28	2.81	1.22	0.92	0.96	0.61	68.1	8.3	342.7
5	1151	1739	12637	16.50	3.91	5.02	1.07	2.48	1.89	19.4	3.3	324.3
6	11543	8344	19119	38.37	5.01	1.25	1.45	3.74	4.13	47.2	3.6	484.1
7	4370	5054	13924	10.12	8.25	3.79	1.78	1.98	0.86	35.2	6.4	460.2
8	3349	6922	21681	60.85	17.43	6.32	1.16	6.90	10.76	26.2	6.4	519.9
9	27835	16567	59672	31.34	7.71	1.79	5.25	27.16	9.27	12.5	3.6	908.8
80	4039	2594	19611	20.43	*	3.99	*	12.53	*	18.3	3.3	*
1	31542	20251	70108	*	*	*	*	*	*	60.9	6.3	*

* Not available

Table 2 North Sea sole pre-recruit surveys

Year class	TRIDENS No/100h fishing		Continental nursery surveys No/1000 m^2 (Sept/Oct)								English ECYFS Pop. Index	
	1-gp Sept/Oct	2-gp Sept/Oct	Dutch Waddensea		Scheldt Estuary		Dutch Coastal (A-F)		Belgian Coastal		0-12 m 1-gp Sept.	VPA ('000)
			<13 cm	13-19 cm	<13 cm	13-19 cm	<13 cm	13-19 cm	<13 cm	13-19 cm		
1973	1924	887	4.08	0.16	4.39	1.49	7.31	0.25	5.79	0.04	3.5	110.2
4	597	79	3.04	0.26	0.17	0.25	0.77	0.05	0.80	0.03	2.2	40.6
5	1413	762	1.55	0.15	1.43	0.18	4.71	0.55	5.79	0.22	3.1	114.4
6	3724	1379	4.14	0.12	0.47	0.08	6.12	0.05	0.78	0.02	6.4	143.2
7	1552	388	2.57	0.00	1.75	0.16	0.69	0.01	0.77	0.03	1.0	47.2
*9	4483	1411	21.79	0.65	5.18	4.73	38.26	1.38	57.80	6.30	3.4	206.9
80	3739	1124	20.41	**	14.31	**	46.62	**	12.40	**	3.6	
1	5098	**	**	**	**	**	**	**	**	**	1.6	

* 1978 excluded
** Not available

Table 3 North Sea sole pre-recruit surveys

Year class	TRIDENS No/100h fishing				Continental nursery surveys No/1000 m^2 (Sept/Oct)						VPA ('000)
	0-gp Sept/Oct	1-gp Sept/Oct	2-gp April	2-gp Sept/Oct	Dutch Waddensea		Scheldt Estuary		Dutch Coastal (A-F)		
					<13 cm	13-19 cm	<13 cm	13-19 cm	<13 cm	13-19 cm	
1970	669	613	150	341	16.54	0.06	12.66	0.21	23.77	0.01	41.4
1	6327	1410	909	905	20.45	0.02	5.40	0.18	7.12	0.02	77.7
2	24	4686	310	397	1.69	0.07	0.17	0.68	0.42	0.11	106.1
3	847	1924	884	887	4.08	0.16	4.39	1.49	7.31	0.25	110.2
4	140	597	84	79	3.04	0.26	0.17	0.25	0.77	0.05	40.6
5	565	1413	846	762	1.55	0.15	1.43	0.18	4.71	0.55	114.4
6	475	3724	1311	1379	4.14	0.12	0.47	0.08	6.12	0.05	143.2
7	1620	1552	58	388	2.57	0.00	1.75	0.16	0.69	0.01	47.2
* 9	3908	4483	578	1411	21.79	0.65	5.18	4.73	38.26	1.38	206.9
80	5518	3739	699	1124	20.41	**	14.31	**	46.62	**	
1	3194	5098	**	**	**	**	**	**	**	**	

* 1978 excluded

** Not available

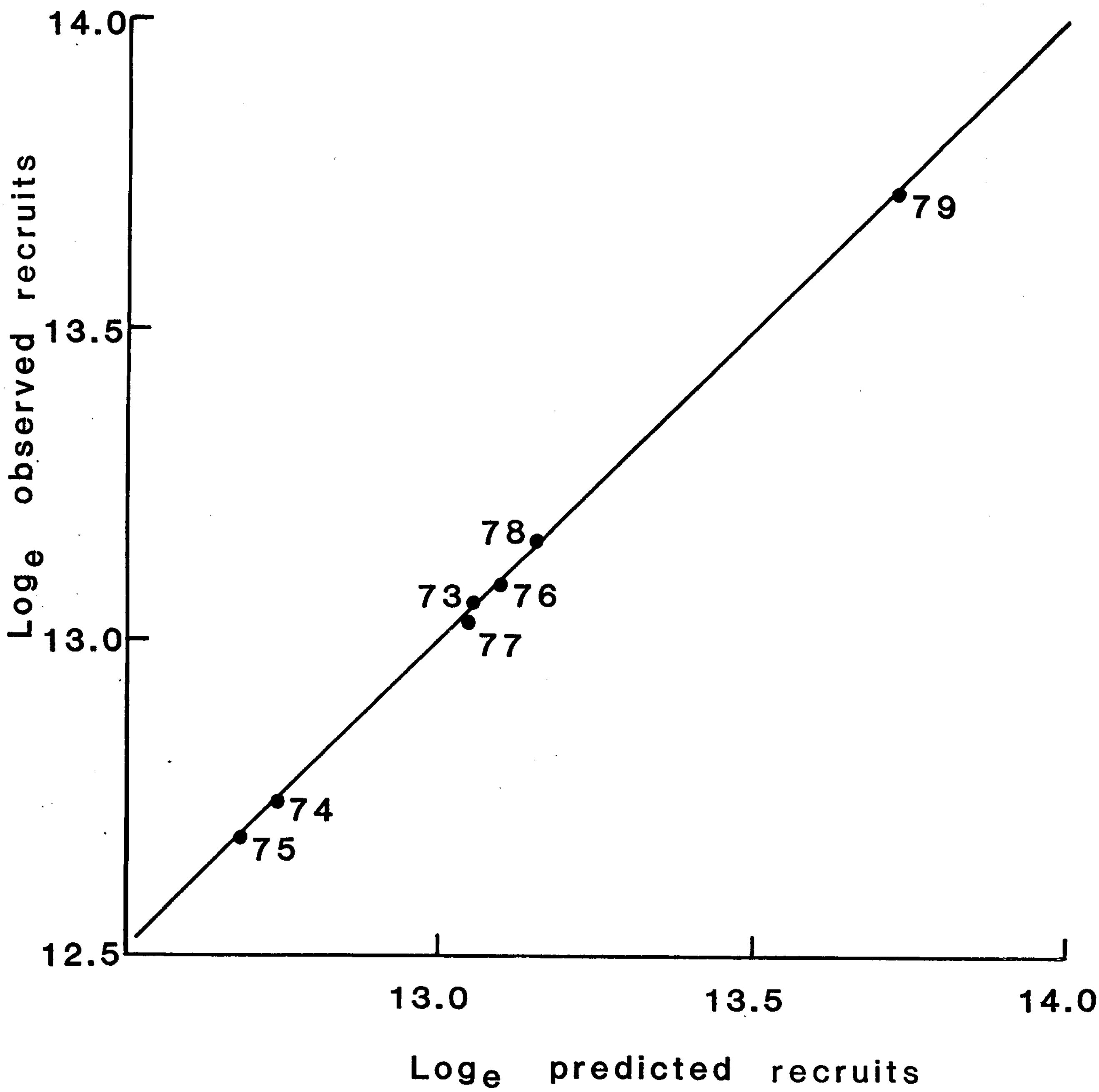

Figure 1 The correlation between the observed numbers of plaice recruits at age one from the VPA and the numbers predicted by equation 4 in Table 4.

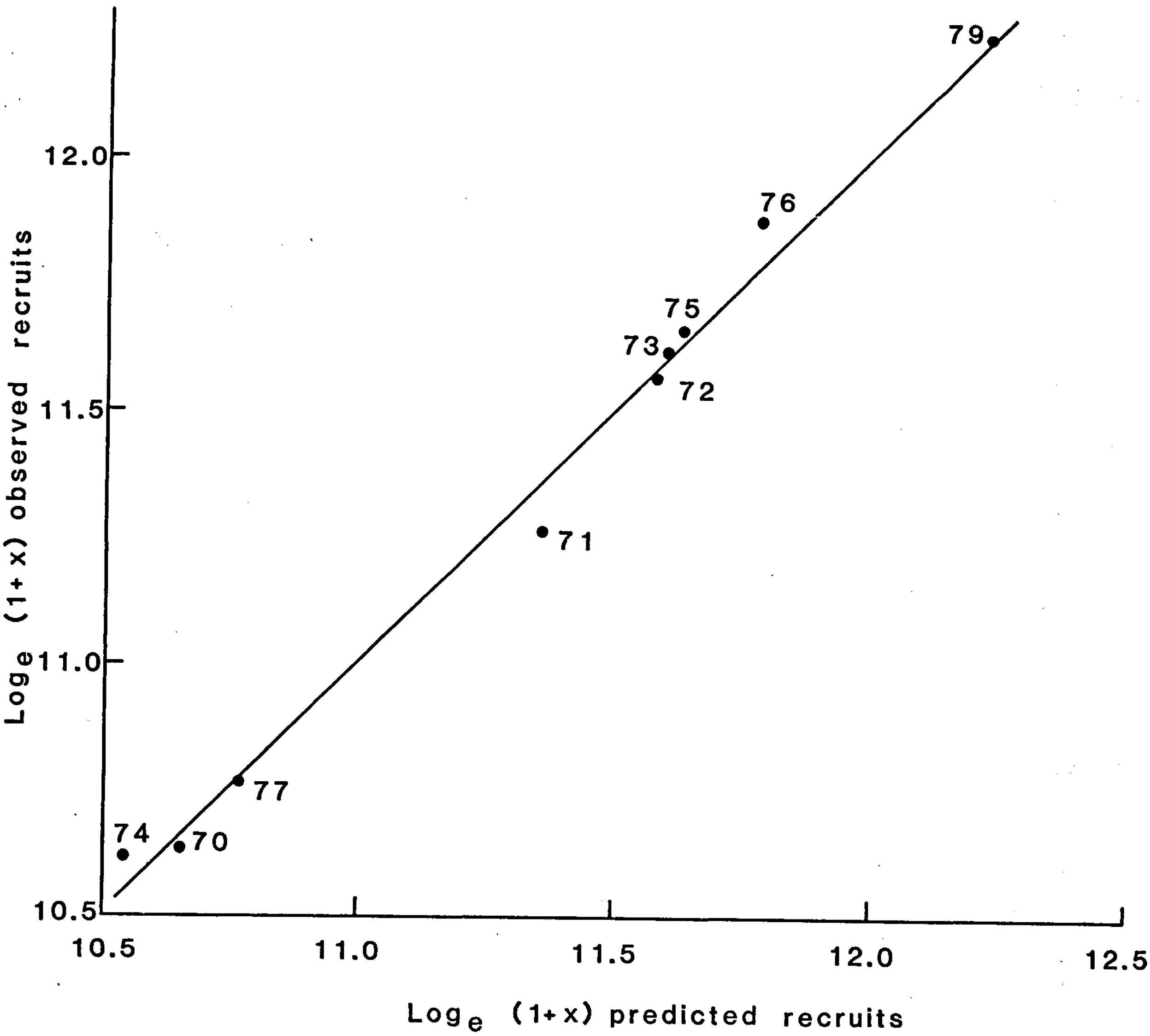

Figure 2 The correlation between the observed numbers of sole recruits at age one from the VPA and the numbers predicted by equation 3 in Table 5.

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Table 4 Results of $\log_e/\log_e$ regressions of VPA 1-year-old recruits on TRIDENS, English ECYF and continental pre-recruit survey indices for plaice

1973–1979

	TRID 1-gp Sept (x_1)	TRID 1-gp Sept (x_1) TRID 1-gp Apr (x_2)	TRID 1-gp Sept (x_1) TRID 1-gp Apr (x_2) ECYFS 0-gp 0-20m (x_3)	Trid 1-gp Sept (x_1) Trid 1-gp Apr (x_2) ECYFS 0-gp 0-20m (x_3) Dutch Wadd.<13 cm (x_4)
N	7	7	7	7
a	7.638	7.831	12.220	11.63
b_1	.554	.360	-.272	-.182
b_2		.198	.560	.526
b_3			-.386	-.352
b_4				-.040
R^2	.924	.976	.999	.999
Equation No.	1	2	3	4

Table 5 Results of $\log_e(1+x)/\log_e(1+x)$ regressions of VPA 1-year-old recruits on TRIDENS and continental pre-recruit survey indices for sole

	1970-1979 excl. 1978			1969-1979 incl. 1978
	TRID 1-gp Sept (x_1)	TRID 1-gp Sept (x_1) TRID 2-gp Apr (x_2)	TRID 1-gp Sept (x_1) TRID 2-gp Apr (x_2) Dutch coast 13-19 cm (x_3)	TRID 1-gp Sept
N	9	9	9	11
a	6.602	6.542	7.287	6.622
b_1	.636	.442	.347	.623
b_2		.254	.226	
b_3			.709	
R^2	.721	.889	.992	.850
Eqn.No.	1	2	3	4