Jenkins, J. T. 1911 .. Report dated the 24th December 1909, on the Marine Fishery Investigations of the Bengal Government Steam Trawler 'Golden Crown', 1908–1909. Collected papers dealing with the fishery survey of the Bay of Bengal. *Bengal Govt. Publ., Calcutta*, 46–70.

Jenkins, J. T. 1912 .. Observations on the shallow-water fauna of the Bay of Bengal, made on the Bengal Fisheries Steam Trawler 'Golden Crown' 1908–1909. *Rec. Indian Mus., Calcutta*, 7, 51–64.

Knudsen, J. 1950 .. Contributions to the biology of the whiting (*Gadus merlangus* L.) in Danish waters. *Rep. Danish biol. Sta.* (52), 27–40.

Koumans, F. P. 1941 .. Gobioid fishes of India. *Mem. Indian Mus., Calcutta*, 13 (3). 205–329.

Lloyd, R. E. 1909 .. A description of the deepsea fish caught by R.I.M.S. ship INVESTIGATOR since the year 1900, with supposed evidence of mutation in *Malthopsis*. *Mem. Indian Mus. Calcutta*, 2 (3), 139–80.

MacArdle, A. E. 1901 .. An account of trawling operations during surveying season of 1900–1901. *Ann. Mag. nat. Hist.*, 7 (8), 517–26.

Nagabhushanam, A. K. 1959 .. Studies on the biology of the commoner gadoids in Manx waters. Ph.D. Thesis, University of Liverpool.

Naumov, V. M. 1961 .. Report to the Government of India on a survey of the fishery resources of the Bay of Bengal. *FAO/UN Publ. Project FAO/ETAP* 158–53: *Rep. No.* 1393, pp. 1–60.

Norman, J. R. 1927 .. The flatfishes (Heterosomata) of India, with a list of the specimens in the Indian Museum, Pt. I. *Rec. Ind. Mus., Calcutta*, 29 (1), 47.

Russell, P. 1803 .. *Description and Figure of Two Hundred Fishes Collected at Vizagapatam on the Coast of Coromandel, 2* vols., Lond.

Satyamurti, S. T. 1952 .. The Mollusca of Krusadai Island. I. Amphineura and Gastropoda. *Bull. Madras Govt. Mus., N.S.*, 1 (2), Pt. 6, 267.

Satyamurti. S. T. 1956 .. The Mollusca of Krusadai Island. II. Scaphopoda, Pelecypoda and Cephalopoda. *Bull. Madras Govt. Mus., N.S.*, 1 (2), Pt. 7, 189 pp.

Sewell, R. B. S. 1912 .. Notes on the deepsea fish obtained by the RIMS ship INVESTIGATOR during the survey season 1910–1911. *Rec. Indian Mus., Calcutta*, 7 (1), 1–15.

Shariff, A. T. 1961 .. Survey of the offshore demersal fisheries of the Andhra and Orissa coasts—1960. *Souvenir, Govt. of Gujarat, Dep. of Fisheries*, Indian Printers, Bombay, pp. 46–54.

Sverdrup, H. U. *et al.* 1942 .. *The Oceans, Their Physics, Chemistry and General Biology*. Prentice-Hall, U.S., 1905 pp.

ON THE RELATIVE FISHING POWER OF TRAWLERS OPERATED OFF COCHIN

By D. Chakraborty and S. K. Banerji

(*Central Marine Fisheries Research Institute, Cochin*)

Introduction

All vessels do not have same fishing power. The absolute fishing power of a vessel is measured in terms of the fishing mortality generated by it. But since the latter cannot be measured directly, a relative fishing power of a vessel has been defined as the ratio of the catch per unit fishing time of the vessel to that of another fishing vessel taken as standard when both are fishing on the same ground and the same density of fish. In this way, a fishing power can be allotted to each vessel. Once the relative fishing power of different vessels are known, it will be easy to compute the total intensity of fishing effort, an accurate estimate of which is so essential in the study of stock assessments of fisheries.

The definition of the relative fishing power indicates that to obtain relative power factor of a vessel, a comparison of a large number of fishing performances of different vessels in the same grounds and at the same time is necessary. This is not practicable when dealing with a large number of commercial vessels of various sizes and designs. Hence, attempts are generally made to find out some permanent characteristics of vessels (like its size, its gross tonnage, or the horse power of its engine, etc.) which is related in a simple way, preferably proportionally to the fishing power of the vessel.

A large number of mechanized vessels of varying sizes and designs has recently been introduced in Kerala waters. Naturally, the fishing power of the various vessels will differ and hence for the purpose of computation of the total effort generated by them, it is necessary to find out some simple method which will enable us to find out the relative fishing power of any mechanized vessels operating in Kerala waters. For this purpose, we have taken 12 vessels of the Indo-Norwegian Project (I.N.P.) and their records of fishing performance over a year. A mathematical model has been constructed from which by statistical methods, the relative fishing power of each of these vessels was obtained. Then these power factors were related to 2 simple characteristics of the vessels, which were readily available thereby providing a generalised procedure for obtaining the power factor of any vessel.

Extensive work along these lines have been done in other countries. Gulland (1956) has estimated the fishing effort in English demersal fisheries by working out the relative power factors of different vessels. Parrish (1953) has determined the fishing capacities of Lowestoft and Aberdeen Trawls used on the flat-fish grounds. In India, Rao and Meenakshisundaram (1967) have determined the relative fishing powers of Government of India vessels operating from Bombay by comparing the fishing performances in the identical areas and months. The power factor values thus obtained have been compared with some characteristics of the vessels in order to find out suitable indices proportional to the relative power factor of vessels. The method followed by them is, however, empirical and not based on generalized mathematical model.

Sources of Data and Method of Estimating Relative Power Factor

For the purpose of illustrating the method of determining the power factor of various vessels operating in the same waters, we have arbirtarily selected the details of catch data of 12 I.N.P. vessels operating off Cochin from the quarterly reports of the I.N.P. (1962). The relevant details regarding the 12 vessels as obtained from the quarterly reports are given in Appendix I.

Appendix II gives catch per hour in respect of 12 vessels over the four quarters of the year. Mean catch per hour over the four quarters as well as the variance are calculated. To achieve the stabilisation of variance, log transformation of the original data was resorted to and Appendix III shows the transformed variate along with mean and variance. It is seen that the stabilisation of variance has been effected well by the transformation.

For the purpose of estimating the relative fishing power of different vessels, let us set up the following model:—

$$Y_{ij} = P_i \times t_{ij} \times D_j \times a_j \times e_{ij} \qquad (1)$$

where

Y_{ij} = catch of the i-th vessel in j-th quarter.

P_i = fishing power of the i-th vessel.

t_{ij} = time spent in fishing by the i-th vessel in the j-th quarter.

D_j = density of fish in the j-th quarter.

a_j = vulnerability in the j-th quarter.

e_{ij} = random factor operating on the i-th vessel in the j-th quarter.

Taking logarithm and rearranging, (1) reduces to

$$d_{ij}' = P_i' + D_j' + e_{ij}' \quad (2)$$

where

d_{ij}' = $\log Y_{ij} - \log t_{ij}$ = log (catch/hour).

P_i' = $\log P_i$

D_{ij}' = $\log D_j a_j$ = log effective density.

e_{ij}' = $\log e_{ij}$

Let x_{ik} be the difference in log (catch/hour) between i-th and k-th vessels operating in the j-th quarter. Therefore,

$$x_{ik} = d_{ij}' - d_{kj}'$$
$$= P_i' - P_k' + e_{ij}' - e_{kj}'$$

Therefore, the Mathematical Expectation of

$$x_{ik} = P_i' - P_k'$$

Summing for all n vessels,

$$E\left(\sum_{k=1}^{n} x_{ik}\right) = \sum_{k=1}^{n} (P_i' - P_k')$$
$$= nP_i' - \Sigma P_k'$$
$$\therefore \quad E\left(\frac{1}{n}\sum_{k=1}^{n} x_{ik}\right) = P_i' - \frac{1}{n}\Sigma P_k'.$$

But $1/n \, \Sigma P_k'$ being a constant, and the fishing power is being considered only as a relative measure, $1/n \sum_{k=1}^{n} x_{ik}$ may be taken as an estimate of P_i', the log fishing power of the i-th vessel.

From Appendix III for every pair of vessels the difference in their log (catch/hour) is calculated. The arithmetic means of the differences in log (catch/hour) obtained on each occasion when the two vessels fished together are entered in Appendix IV. 1 is added to each difference to avoid negative values. The log relative fishing power of a vessel is obtained by averaging over the mean differences in respect of all the vessels. The estimated values of the log relative fishing powers of all the 12 vessels are shown in the last but one column of Appendix IV. The anti-logs of these values, furnishing the relative fishing powers of the vessels are also given in the last column of the same table. It will be seen from these estimates that relative fishing powers of the 12 vessels considered vary from 4·84 to 17·74 and the log relative fishing powers varying from 0·685 to 1·249. Obviously, the fishing powers of the vessels vary but the question is whether the variation in fishing power of the different vessels can be explained in terms of some simple permanent characteristics of the vessels.

The Relation of Fishing Power and Other Characteristics of the Vessels

The scatter diagram depicting the relationship between fishing power and length of the vessel is presented in Fig. 1. An examination reveals a linear relationship. The matrix of correlation coefficients between variates is given in Table I. Table II gives the partial correlation coefficient of the

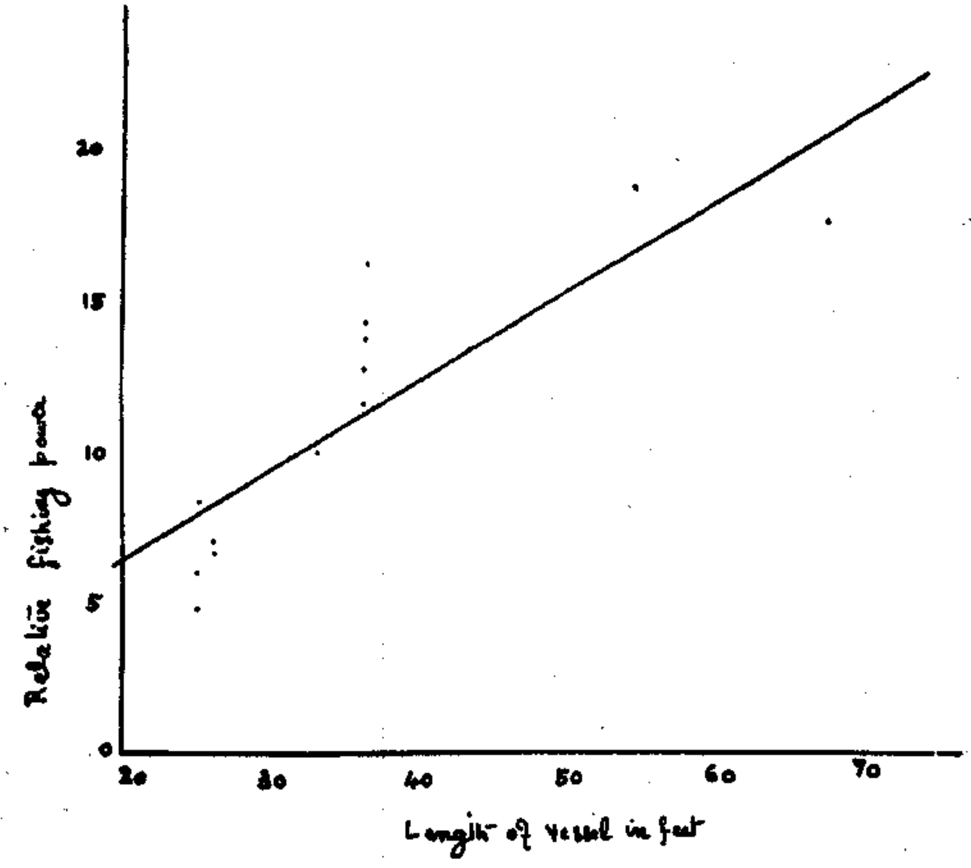

FIG. 1. Relation between fishing power and length of vessel.

1st order. The standard symbols of statistical literature have been used (Yule and Kendall, 1950). Subscript 1, 2 and 3 denote three variates, *i.e.*, fishing power, length of the vessel and horse power of engine.

TABLE I

Matrix of correlation coefficients

	Fishing power	Length	Horse power
Fishing power	1	0·8063	0·7865
Length		1	0·9758
Horse power			1

TABLE II

Partial correlation coefficient of the first order

$$r_{12\cdot3} = 0\cdot2874$$

$$r_{13\cdot2} = -0\cdot0023$$

The ordinary correlation coefficients are high. But both the partial correlation coefficients are non-significant, though the higher value of $r_{12\cdot3}$ suggests that the length of vessel exerts more influence on fishing power than the horse power of the engine does.

The linear regression for fishing power on length of the vessel obtained is

$$P = 0\cdot759 + 0\cdot2975 \text{ L} = a + b\text{L (say)}.$$

where P is the fishing power and L indicates the length of the vessel.

The significance of linear regression fit is tested in Table III.

The above table shows that the linear regression is highly significant. In fact, out of the total sum of squares of 201·783, linear regression removes 131·075, *i.e.*, nearly 65% of the variation in fishing powers is explained by linear regression on length of the vessels.

TABLE III

Significance of linear regression

Sources of variation	D.F.	Sum of squares	Mean squares	F
Linear regression	1	131·075	131·075	18·59
Deviation from regression	10	70·708	7·071	
TOTAL	11	201·783		

As remarked by Beverton and Holt (1957) a factor like length or tonnage will be most convenient as an index of fishing power, if it is proportional to the fishing power. The parameter '*a*' has a value of 0·759 with standard deviation of 0·77 with 10 d.f. Thus '*a*' does not significantly differ from zero. The relation between fishing power and length of the vessel may therefore be taken as one of proportionality.

REGRESSION FOR THE LOGARITHMIC VARIATES

The scatter diagram indicating the relationship between fishing power and length of the vessel after logarithmic transformation was examined. It is seen that this is also linearly related. Normally, when two variates are linearly related in the form, $P = a + bL$, the corresponding logarithms variates will also be linearly related if and only if the parameter '*a*' is zero. We have already pointed out that '*a*' was not significantly different from zero. The linear relation of the logarithmic variates confirms the proportionality of the original variates.

The matrix of correlation coefficients between logarithmic variates is given in Table IV and the partial correlation coefficients are indicated in Table V. The subscripts and symbols are same as in earlier tables.

The pattern of correlation coefficients obtained after logarithmic transformation of variates is more or less same as that of original variates. The correlation coefficient of fishing power with either of the vessel characteristics is slightly increased as compared to those of original variates whereas the correlation coefficient between the two vessel characteristics gets reduced. The partial correlation coefficients though still non-significant show higher values.

TABLE IV

Matrix of correlation coefficients

	Fishing power	Length	Horse power
Fishing power	1	0·8394	0·8255
Length		1	0·9007
Horse power			1

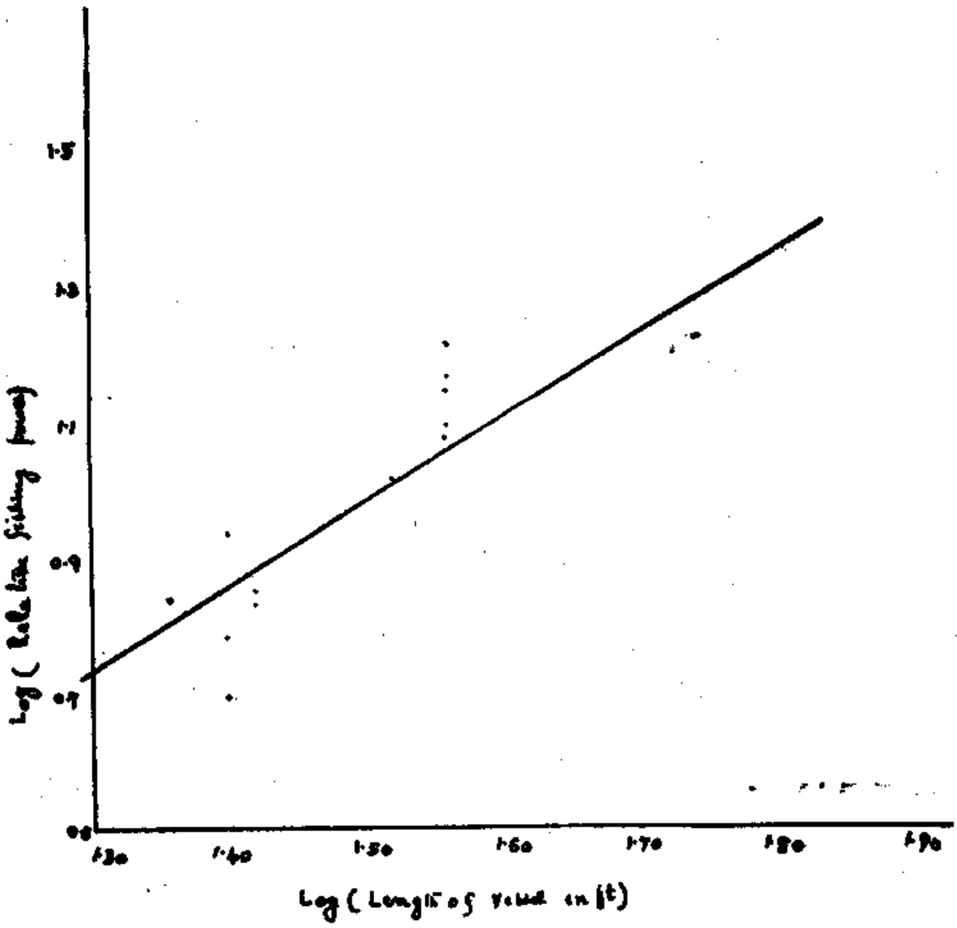

FIG. 2. Relation between logarithms of fishing power and length of vessel.

TABLE V

Partial correlation coefficients

$$r_{12\cdot 3} = 0\cdot 3913$$

$$r_{13\cdot 2} = 0\cdot 2944$$

The linear regression for the logarithmic variates come to Log P = − 0·8987 + 1·2553 Log L where P and L have their usual significance.

The significance of linear regression is tested in Table VI.

TABLE VI

Significance of linear regression

Sources of variation	D.F.	Sum of squares	Mean squares	F
Linear regression	1	0·2617	0·2617	23·90
Deviation from regression	10	0·1095	0·01095	
TOTAL	11	0·3712		

The linear regression is highly significant. In this case, the linear regression explains more than 70% of the total variation in the fishing power of the vessels.

Though the horse power of the engine is highly correlated with the length of the vessel, it was felt worthwhile to study if the introduction of horse power improves the prediction formula. The linear regression of fishing power on the length of the vessel and the horse power of the engine was obtained as

$$P = 0\cdot 7153 + 0\cdot 2997\,L - 0\cdot 0007\,H$$

where H is the horse power of the engine. The consequent improvement is tested in Table VII.

The analysis of variance shows that while the overall reduction due to use of regression equation is highly significant, the added reduction due to horse power is non-significant. It may be concluded that when length of

TABLE VII

Significance of added variate

Source of variation	D.F.	S.S.	M.S.
Regression on length and horse power	2	131·3081	65·6541
Regression on length alone	1	131·0750	
Added reduction due to horse power	1	0·2331	0·2331
Error	9	70·4749	7·8305
TOTAL ..	11	201·7830	

the vessel has been considered, the inclusion of horse power as well does not improve the prediction formula.

DISCUSSION

The study shows the linear regression of fishing power on length of vessel as

$$P = 0{\cdot}759 + 0{\cdot}2975\,L$$

The same on length and horse power of the engine comes to

$$P = 0{\cdot}7153 + 0{\cdot}2997\,L - 0{\cdot}0007\,H$$

The analysis of variance in Table VII indicates that for a prediction formula, the second equation does not register any improvement over the first. The size of the vessel alone can be used in prediction formula instead of both the length of the vessel and the horse power of the engine. This was to be expected on account of the high correlation between the length of the vessel and the horse power of the engine. Because of the high correlation existing between the latter two variates, it is only natural that any one of the two variates alone will suffice for the prediction formula of the relative fishing power of a vessel. We have already given the prediction formula in terms of the length of the vessel. Will the prediction formula based on the horse power of the engine give better results? This can be answered by examining the partial correlations coefficient $r_{12\cdot3}$ and $r_{13\cdot2}$. In case of both original variates as well as logarithmic variates, $r_{12\cdot3}$ is found to be greater than $r_{13\cdot2}$ showing that the fishing power seems to be influenced more by the length of the vessel than the horse power of the engine.

We have already shown that the fishing power will have a proportional relationship with the length of the vessel, the constant of proportionality being 0·2975. On the basis of this constant proportionality relationship, the relative fishing power of vessels of sizes 25′, 26′, 33′, 36′ and 67′ will be 7·44, 7·73, 9·82, 10·71 and 19·93 respectively. These are, of course, theoretical average values and will be useful in expressing the total effort of vessels of various size in terms of a standard unit. The fishing performances of the vessels of the same size are, however, likely to vary on account of various factors like the efficiency of the crew, the ground of fishing, the time of operation, etc. It will be seen from Appendix IV, that in the case of the 12 I.N.P. vessels considered in this study, there were three 25′ vessels whose relative fishing power varied from 4·84 to 8·43 as against the theoretical values of 7·44. The relative fishing power of two 26′ vessels varied from 6·68 to 7·06 as compared to the theoretical value of 7·73. The only 33′ vessel had the fishing power of 10·11 compared to the theoretical value of 9·82. Five 36′ fishing vessels had relative fishing powers ranging from 11·70 to 16·37 as compared to the estimated value of 10·71. The 67′ vessel '*Kalava*' had relative fishing power 17·74 as compared to the theoretical value of 19·93. Excepting in one case of 36′ vessels, the agreement between observed relative fishing powers and the corresponding theoretical estimation was good.

SUMMARY

The relative fishing power of 12 vessels has been calculated. The relation of the fishing power to the length of vessel and the horse power of the engine has been examined. The fishing power is found to be proportional to the length of the vessel.

REFERENCES

Beverton, R. J. H. and Holt, S. J. 1957 — On the Dynamics of Exploited fish populations. *Fish. Invest. Sre.* II, 19. *Her Majesty's Stationery Office*, London.

Gulland, J. A. 1956 .. On the fishing effort in English demersal fisheries. *Fish. Invest. Ser.* 2, 20 (5). *Her Majesty's Stationery Office*, London.

Indo-Norwegian Project. 1962 — Quarterly Reports.

Parrish, B. B. 1953 .. Fishing capacities of Lowestoft and Aberdeen Trawls when used on flat fish grounds. *J. du. Cons.*, **17.**

Rao, K. V. and Meenakshi Sundaram, P. T. 1967 Determination of the relative fishing powers (Power Factors) of the vessels of the Govt. of India Deep Sea Fishing Station, based at Bombay. *Adv. Abstr. Contr. Fish. Aquat. Sci. India*, **1** (4).

Yule, G. V. and Kendall, M. G. 1950 *Introduction to the Theory of Statistics*. Charles Graffin & Co. London.

APPENDIX I

Description of the vessels

Serial No.	Name of the vessel	Length of the vessel	Horse power of the engine
1	M_1	36′	48
2	M_2	36′	48
3	M_3	36′	48
4	M_4(1)	36′	48
5	M_4(2)	36′	48
6	M_5(1)	26′	36
7	M_5(2)	26′	36
8	INP-2	25′	16
9	INP-4	25′	16
10	INP-29	25′	16
11	Ashtamudi	33′	36
12	Kalava	67′	120

APPENDIX II

Quarter-wise catch in kg per hour of 12 *vessels operating off Cochin during* 1962

Serial No.	1st Qr.	2nd Qr.	3rd Qr.	4th Qr.	Mean	Variance
1	186·11	102·31	..	96·52	128·31	2,514
2	128·76	..	364·40	164·09	219·08	16,150
3	168·27	135·64	429·57	128·36	215·46	20,676
4	124·00	..	..	..	124·00	..
5	101·44	110·14	..	148·81	120·13	636
6	63·26	71·36	..	..	67·31	33
7	59·43	..	..	95·19	77·31	639
8	66·72	41·23	..	..	53·98	325
9	40·75	55·44	..	..	48·10	108
10	96·67	52·11	..	..	74·39	993
11	120·50	83·30	77·75	105·88	96·86	396
12	174·49	..	168·55	243·27	195·44	1,760

APPENDIX III

Logarithms of the catch in kg per hour of 12 *vessels operating off Cochin during* 1962

Serial No.	1st Qr.	2nd Qr.	3rd Qr.	4th Qr.	Mean	Variance
1	2·270	2·010	..	1·985	2·088	0·025
2	2·110	..	2·562	2·215	2·296	0·056
3	2·226	2·132	2·633	2·108	2·282	0·014
4	2·093	..	..	..	2·093	..
5	2·006	2·042	..	2·173	2·053	0·008
6	1·801	1·853	..	..	1·827	0·001
7	1·774	..	..	1·979	1·877	0·021
8	1·824	1·615	..	..	1·720	0·022
9	1·610	1·744	..	..	1·677	0·009
10	1·985	1·717	..	..	1·851	0·036
11	2·081	1·921	1·891	2·024	1·979	0·008
12	2·242	..	2·227	2·385	2·262	0·008

APPENDIX IV

Relative fishing powers

Vessels	1	2	3	4	5	6	7	8	9	10	11	12	Log fishing power	Fishing power
1	1·000	0·965	0·933	1·177	1·015	1·313	1·251	1·421	1·463	1·289	1·080	0·914	1·143	13·90
2	1·035	1·000	0·973	1·017	1·073	1·309	1·286	1·286	1·500	1·125	1·297	1·010	1·159	14·42
3	1·067	1·027	1·000	1·133	1·082	1·352	1·290	1·460	1·502	1·328	1·298	1·038	1·214	16·37
4	0·823	0·983	0·867	1·000	1·087	1·292	1·319	1·269	1·493	1·108	1·012	0·852	1·091	12·86
5	0·985	0·927	0·918	0·913	1·000	1·197	1·213	1·305	1·347	1·173	1·065	0·776	1·068	11·70
6	0·687	0·691	0·648	0·708	0·803	1·000	1·027	1·108	1·150	0·976	0·826	0·559	0·849	07·06
7	0·749	0·714	0·710	0·681	0·787	0·973	1·000	0·950	1·134	0·789	0·824	0·563	0·825	06·68
8	0·579	0·714	0·540	0·731	0·695	0·892	1·050	1·000	1·042	0·868	0·718	0·582	0·784	06·08
9	0·537	0·500	0·498	0·517	0·653	0·850	0·836	0·958	1·000	0·826	0·676	0·368	0·685	04·84
10	0·711	0·875	0·672	0·892	0·827	1·024	1·211	1·132	1·174	1·000	0·850	0·743	0·926	08·43
11	0·920	0·703	0·704	0·988	0·935	1·174	1·176	1·282	1·324	1·150	1·000	0·714	1·005	10·11
12	1·166	0·990	0·962	1·149	1·224	1·441	1·437	1·418	1·632	1·257	1·286	1·000	1·249	17·74