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GROWTH AND MORTALITY OF THE MALAYSIAN COCKLE (ANADARA GRANOSA L.) UNDER COMMERCIAL CULTURE: ANALYSIS THROUGH LENGTH-FREQUENCY DATA

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This paper analyses length frequency data, by several methods, of the Malaysian cockle *(Anadara granosa* L). The data were collected monthly from five different plots under commercial culture during a period of 12-17 months. Parameters of the von Bertalanffy growth formula (VBGF) were derived for each of the five plots, along with estimates of related parameters (mortality, mean length of first capture, etc.). "Yield per recruit" analyses suggest that the present legal size for the five culture plots is well above the maximum yield per recruit. The paper discusses the limitations of the methodology and data used. Suggestions for further studies are also made.

The cockle samples were collected and measured by staff of the cockle team, headed by the author, of the Glugor Fisheries Research Station (GFRI), Penang, Malaysia. The analyses were made by the author on a fellowship visit to the International Center for Living Aquatic Resources Management (ICLARM), Manila, in October 1985.

The author wishes to thank the GFRI's Director of Research, Mr. Mohd Shaari bin Sam Abdul Latiff, and Mr. Ong Kah Sin, Head of the Aquaculture Section, for their encouragement and suggestions on the project; Dr. Daniel Pauly (ICLARM), for his help with the analyses; Dr. J. Saeger and Mr. Gayanilo (GTZ) for allowing him to use their revised version of the ELEFAN programs and their computer facilities; Ms. Faazaz bte Latiff, Mr. Kamal Zaman bin Mohamad and Ms. Devaki Nair for collecting and compiling the length frequency data at Penang and Set an gor.

The work described in this paper is one component of a programme for the Development and Management of Cockle Culture in Malaysia, supported by the small-scale fisheries project of the Bay of Bengal Programme (BOBP). The programme's first phase, undertaken during 1985, consisted primarily of biological studies. Other components were experiments with induced spawning, determination of maturity and spawning pattern by means of condition indices, monitoring of culture plots, and examination of cockle shells to determine age and growth pattern. The next phase will consist of economic and socio-economic studies.

The small-scale fisheries project of the Bay of Bengal Programme began in 1979 and covers five countries bordering the Bay of Bengal — Bangladesh, India, Malaysia, Sri Lanka and Thailand. Funded by SIDA (Swedish International Development Authority) and executed by the FAO (Food and Agriculture Organization of the United Nations), the project seeks to develop, demonstrate and promote appropriate technologies and methodologies to improve the conditions of small-scale fisherfolk in member countries.

CONTENTS

1. INTRODUCTION

Cockle culture plays a major economic role in Malaysia: it accounts for about 11% of the country's total fisheries production. In 1984 about 65,000 tonnes of cockles were produced (Anon. 1985). It is by far the most important aquaculture industry in Malaysia. Currently about 4,000 to 5,000 hectares of mudflats along the west coast of peninsular Malaysia are utilized for the culture of this important bivalve.

There have been, however, great fluctuations in the production of cockles and in prices of spats in the recent past. Production reached an all-time high of 120,000 tonnes in 1980; it was only about 40,000 tonnes in 1983. The prices of spats more than doubled from 1919 to 1980 and remained high for three years. The increase in price, an indication of shortage of spats, prompted the Government to intervene to stabilize the industry and prevent overexploitation of the cockle population. The existing legislation on minimum size of harvested cockles was strictly enforced, and a ban imposed on the export of spats (mainly to Thailand). The minimum harvesting size of 31.8 mm has met with much opposition from the cockle farmers since they consider it too large for viable culture operations.

The Government has, therefore, relaxed the enforcement of the legislation and launched a programme of biological and economic studies to obtain more information as a basis for perhaps more appropriate management measures. This programme is conducted with support from the BOBP.

The general biology and culture aspects of the Malaysian cockle *(Anadara granosa)* have been well described by Pathansali and Soong (1958), Pathansali (1963,1966), Broom (1980, 1982a, 1982b, 1982c, 1982d, 1983a, 1983b, 1983c), Ng (1982, 1984) and Wong and Lim (1985). But information on growth and mortality in general and under different culture conditions is still very scanty. The study presented in this paper addresses itself to this particular aspect of cockle biology. Five culture plots in important cockle producing areas were selected to study growth and mortality parameters by using length-frequency data.

While several methods are available to the fishery biologist for investigating growth and mortality patterns, the computer-based ELEFAN method was selected, because it obviates the need for precise and reliable production estimates and age determinations. The methodology for age determination of the cockles had not been devised at the start of this project, nor had any adaptations been made from that used for other shellfishes. Moreover, age determinations require much more trained manpower than does the establishment of length-frequency sampling.

2. LOCATION OF THE CULTURE PLOTS

Five commercial culture plots were selected for the study. Three plots were selected in the state, of Perak, and one each in the states of Penang and Selangor. Their geographic locations are shown in Figure 1.

Culture plot "A" is located outside and south of the river mouth, Kuala Juru, Penang. The surface area of the culture plot is about 20 ha and it is located between Mean High Water of Neap (M.H.W.N.) and Mean Low Water of Neap tides (M.L.W.N.).

"B" of about 40 ha, is located about one km off Pulau Sangga Besar, Perak and the culture site is between M.H.W.N. and M.L.W.N.

"C", is located in Perak just inside the mouth of the river Kuala Larut. It has an area of about 20 ha and is located between M.L.W.N. and Mean Low Water Sprint tide (M.L.W.S.).

"D", is also located in the river Kuala Larut about 0.5 km inside the river mouth between M.H.W.N. and M.L.W.N. The size is about 40 ha.

"E", is located about one kilometre outside the river Sungei Besar, Selangor, between M.H.W.N. and M.L.W.N.

Except with regard to salinity and suspended solids, the ecological characteristics of the five culture plots did not differ significantly. In the case of salinity, the culture plots at A, C and D seemed to be subjected to a wider range of fluctuation than B and E. Total suspended solids values atCand Dwere relatively high during the month of May. Details concerning ecological characteristics are given in the table below.

Ecological characteristics of culture plots A—E

Parameter	Culture Plot				
	A	B	C	D	E
Salinity (%)	16—31	22—29	14—27	12—25	22—30
Water pH	7.9—8.5	7.6—8.3	7.1—8.0	7.1—8.0	7.8—8.4
Dissolved 02 (ppm)	5.6—9.1	6.2—11.0	—	—	—
Mud organic content (%)	—	9.1—15.2	6.2—1 9.1	6.2—1 9.1	—
Suspended solid (ppm)	—	10—160	10—400	10—400	—
Soil type	sandy	sandy loam to sandy clay loam	sandy loam to clay loam	sandy loam to clay loam	sandy loam to clay loam

3. MATERIAL AND METHOD

Monthly random samples of about 500 cockles, mud and water were taken from each of the five culture plots. The sampling was conducted from May 1984 till September 1985 and the duration for each plot was as follows:

A	June 1984—September 1985
B, C	September 1 984—August 1985
D	May 1 984—September 1985
E	July 1984—September 1985

Length and weight measurements were made using a vernier caliper (to the nearest 0.1 mm) and a digital balance (0.1 g), respectively. Random samples were taken instead of taking samples from the same predetermined sites within each plot in order not to reduce the density of any one area within the culture plot. Generally, a minimum of about 3 sub samples (150 cockles) were taken from each culture plot. The length-frequency data are given in Appendix 1.

The length-frequency data were analyzed using the ELEFAN I and II programs (Pauly 1984, Pauly and David 1981, Pauly, *etal.* 1984) and the revised version of the ELEFAN I and II programs by Saeger and Gayanilo (1985).

Also, the method of Wetherall *et al.* (1 986) was used to estimate L_∞ and Z/K from the length-frequency data.

A comparison of the growth performance of *A. granosa* in the five culture plots was carried out using the parameter Ø as defined in Pauly and Munro (1984), i.e.:

$$\phi' = \log_{10} K + 2 \log L_\infty \ldots\ldots (1)$$

where K and L_∞ are parameters of the von Bertalanffy growth formula, (VBGF) stands for length and log stands for decimal logarithm.

Pending a detailed analysis of the available length-weight data, a preliminary length-weight relationship of the form

$$W = a.L^3 \qquad (2)$$

was derived, using 10 pairs of length and weight measurements from plot D, pertaining to the 10 largest specimens measured at that plot.

Equation (2) was then used to convert the available estimate of L_∞ into estimates of W_∞.

Values of the parameter t_o of the VBGF were obtained finally by solving it, for each plot, for an age of 4 months, i.e., 1/3 year at 6.4 mm, the legal size limit for seeds (see Broom I 983a).

Thus, for each plot, estimates of the 3 parameters of the VBGF for growth:

$$W_\infty = W \cdot \left(1 - e^{-k(t-t_o)}\right) \ldots\ldots (3)$$

are available, such that standard yield per recruit analyses (Beverton atjd Holt 1957, Pauly 1 984) can be performed. Since values of natural mortality (M) in *Anadara granosa* are not available, the yield per recruit analyses was performed for a range of M values (M=1/2F, M =F, M =2F), with the sum of fishing (F) and natural mortality being constrained by the total mortality (Z=F+M) observed at each site.

4. RESULTS

The growth, mortality and related parameters of the five culture plots, (L_∞, K, Z, L_{50}, L' and ϕ' obtained from the detailed analysis of the length-frequency data by ELEFAN (I and II) are tabulated below:

Estimates of growth and mortality parameters of *Anadara granosa* **from five culture plots using elefan I and II.**

	Plot				
	A	**B**	**C**	**D**	**E**
L_∞ (mm)	45.0	37.4	40.5	34.2	41.4
W_∞ (g)	27.3	15.7	19.9	12.0	21.3
K (1/yr)	0.55	0.87	0.79	0.60	0.78
t_o (yr)	0.054	0.118	0.116	—0.112	0.118
Z *(1/yr)*	3.24	2.93	4.12	4.04	3.66
L_{min} (mm)	7.0	10.5	16.5	5.5	7.0
L_{50} (mm)	25.6	21.5	26.3	19.4	27.6
L'	26.0	22.0	29.0	20.0	28.0
ϕ'	3.047	3.085	2.846	2.846	3.126
Legal age at harvest (yr)	2.28	**2.30**	**2.06**	4.42	1.99

W_∞	–	Computed by using preliminary length-weight relationship based on data from plot D i.e. $W=0.0003\ L^3$.
t_o	–	Computed by solving the VBGF for an age of 4 months at 6.4 mm.
L_{min}	–	Minimum size in samples.
L_{50}	–	Length at which probability of capture is 50 per cent (using a "Kor", i.e. the hand-held dredge used to collect samples).
Legal age at harvest	–	Converted from legal length of 31.8 mm and growth parameters L_∞, K and t_o.

The value of ϕ' showed that the cockles in culture plots A and B are similar in their growth performance; likewise for the cockles in plots C and D. These values of ϕ' imply that the cockles cultured at plots A and B grow better than cockles in plots C and D. Figure 2 shows an example (for Plot A) of the restructured length-frequency data and the optimum growth curves fitted by ELEFAN I. A good fit of the growth curve to the succession of runs of positive values (peaks) of the length-frequency data was attained for all five culture plots.

In each culture plot there is only one year class with the exception of some odd older animals remaining from previous culture cycles. The presence of two distinct year classes is thus an artifact due to the presentation of the data; the sampling lasted more than a year resulting in an overlapping of data in plots A, D and E.

The catch curve and selection pattern as calculated by ELEFAN II for data from Plot A is shown as an example in Fig. 3.

The estimates of L_∞ and Z/K using the method of Wetherall *et al.* (1986) for plots A to E are given in Fig. 4.

The L_∞ values obtained by the two methods compared favourably and appeared almost identical for culture plots A, C, and D. Details are given in the table below.

Comparison of parameter estimates using ELEFAN (I&II) and method of Wetherall *et al*, **(1986).**

Parameter	L_∞		Z/K	
Method	ELEFAN	WETHERALL	ELEFAN*	WETHERALL
A	45.0	46.4	5.891	3.444
B	37.4	34.7	3.368	2.531
C	40.5	38.4	5.215	4.128
D	34.2	34.0	6.773	4.914
E	41 .4	42.1	4.692	4.462

* From catch curve estimates (Fig. 3).

The yield per recruit analyses (Fig. 5) all suggest that yield per recruit is maximized, for each of the five culture plots, by a minimum age of harvest of about one year, well below the age corresponding to the legal harvesting size.

5, **DISCUSSION**

The growth and mortality parameters for cockles in the five culture plots clearly indicate differences between plots. It is difficult, at this stage of the study, to interpret these differences. Though they were expected because of known dissimilarities in ecological features of the five culture plots, these differences could also be due to other factors that were not recorded, such as density differences or a size distribution that is related to water depth.

The use of the parameter ϕ furthermore confirmed that the cockles in culture plots A, B and E were similar in growth pattern; a similar growth pattern was observed for culture plots C and 0. The values of ϕ' showed that the cockles cultured at plot A, B and E grew better than those in plots C and D.

Comparison of the growth parameter L_∞ estimated by ELEFAN I and by the method of Wetherall *et al.* (1 986) shows values which are similar, especially in culture plots A, C, D and E. The point to note, however, is that the estimates of Z/K obtained by both methods show marked differences. These differences are not surprising in view of the fact that in both cases, the final values obtained are largely influenced by the points included in the computations. Despite these discrepancies, the estimates of L_∞ and **Z/K** obtained by both methods are consistent as a whole.

Another observation worthy of note is that the growth curve estimated by ELEFAN I seems not to have been affected by the constant shifting of cockles from one end of the culture plot to the other. The yield per recruit analyses carried out on each of the five culture plots all suggest that the yield per recruit is maximized by a minimum age at harvest of about one year, well below the age corresponding to the present legal harvesting size of 31 .8 mm.

One could question the validity of the values of parameter W_∞ for the five culture plots, since these values were computed on the basis of length-weight relationships from culture plot D only.

However, yield per recruit estimates are directly proportional to Wa,; hence using different values of this parameter would only change the ordinate scale of the graphs in Fig. 5, but not the overall shape of the yield curves, which would still suggest that optimum harvesting size is obtained after one year.

Figure 5 shows that yield per recruit is independent of the fishing mortality, over the range of mortalities considered here. In other words, the yield per recruit analysis clearly indicates that it is indeed uneconomic to grow cockles for more than one year because of diminishing returns. The evidence from the yield per recruit analysis suggests that the present regulation on size limit on harvesting cockles should be reappraised if returns *on a yield per recruit basis* are to be *maximized.* While accepting the fact that the regulation on size limit is based on sexual maturity as well as the possibility of the cockles spawning at least once prior to their harvest, there is the need to consider the economic factor as well. Moreover, there is no evidence to support the assumption that the yearly production of seeds is directly related to the size of the *cultured* broodstock. Most culture practices today depend largely on natural seed supplies. The fluctuating pattern of seed supplies is universal and it depends largely on the environmental conditions which prevail in each country and area (Broom 1985).

The assumption that retaining a substantial broodstock in the culture areas would increase the yield per recruit could be counter-productive as well. Cockles are filter-feeders and we can therefore assume that a significant proportion of newly released gametes are filtered out by the broodstock when the cockles are kept in a crowded situation (i.e. before they reach the minimum legal size of harvest).

While a substantial amount of information has been gained by the analyses of data using the ELEFAN programmes, particularly on growth mortality and yield per recruit, further studies on possible causes of recruitment variability would go a long way in providing the answer to the question related to seed supply and production. These studies, together with other on-going studies on maturation and spawning, and possibly also a study on genetic variability, will further provide the necessary information on which future management decisions could be based.

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Figure 1

MAP OF PENINSULAR MALAYSIA
SHOWING LOCATION OF CULTURE PLOTS A TO E.

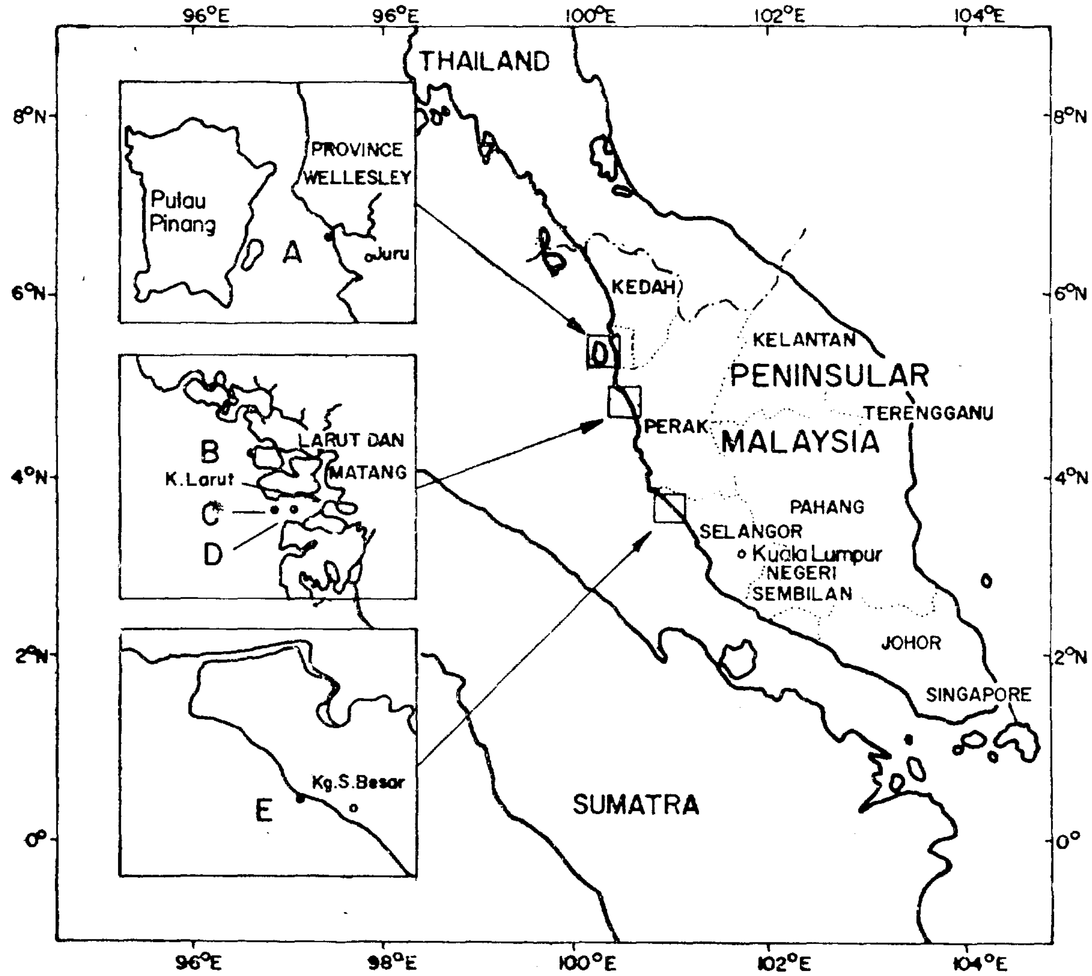


Figure 2

ESTIMATION OF La, AND K USING ELEFAN I, PLOT A

Note good fit of the growth curve to the succession of runs of positive values (i.e., peaks) of the length-frequency data in Appendix 1, as restructured by Elefan 1.

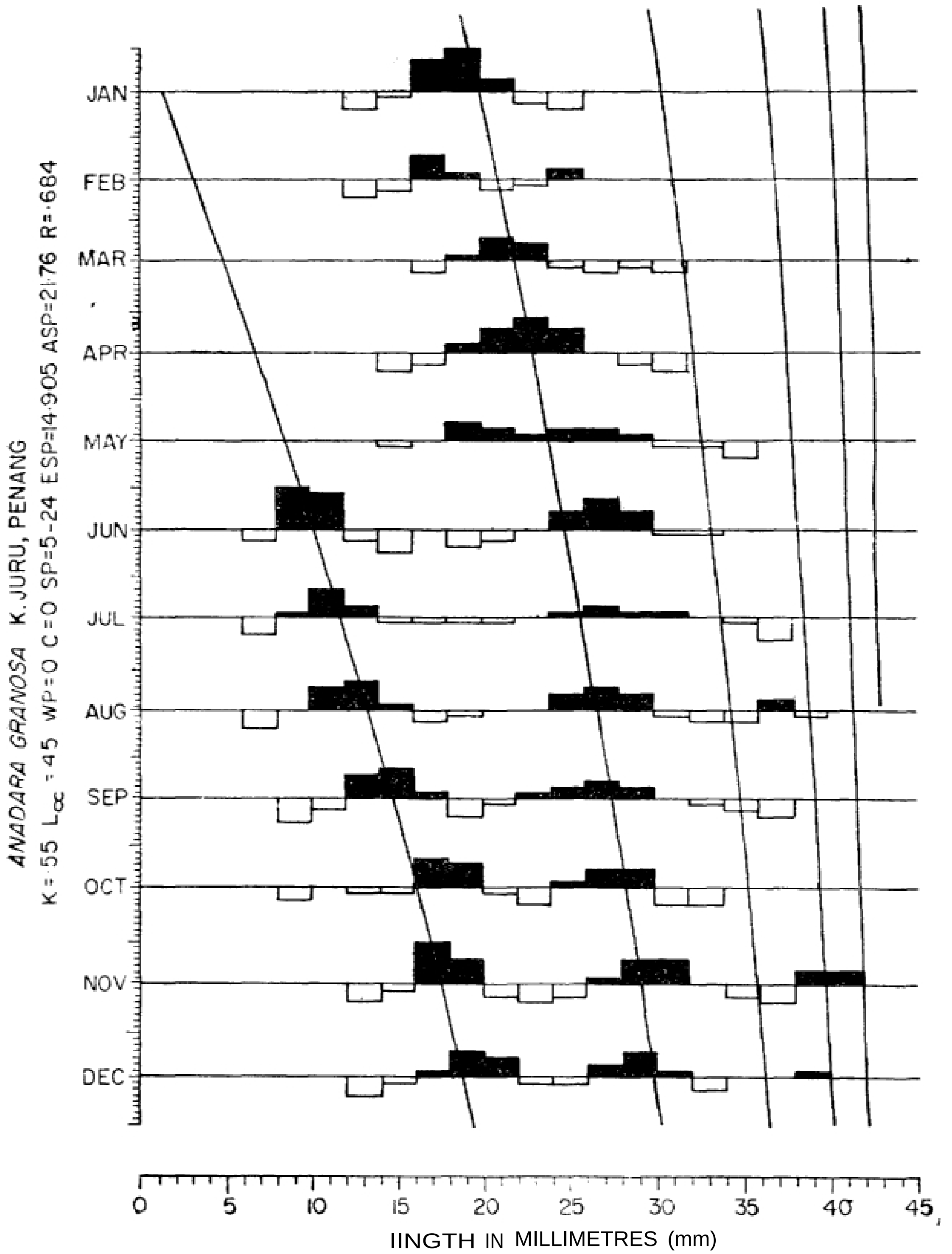


Figure 3

CATCH CURVE AND SELECTION PA1TERN FOR *A. Granosa,* **PLOT A.**

The slope of the catch provides an estimate of total mortality (z), while the ascending, left side of the curve leads to the selection pattern.

4ncdaro gronosa

K JuruPenang

L∞ = 45. K = ·55

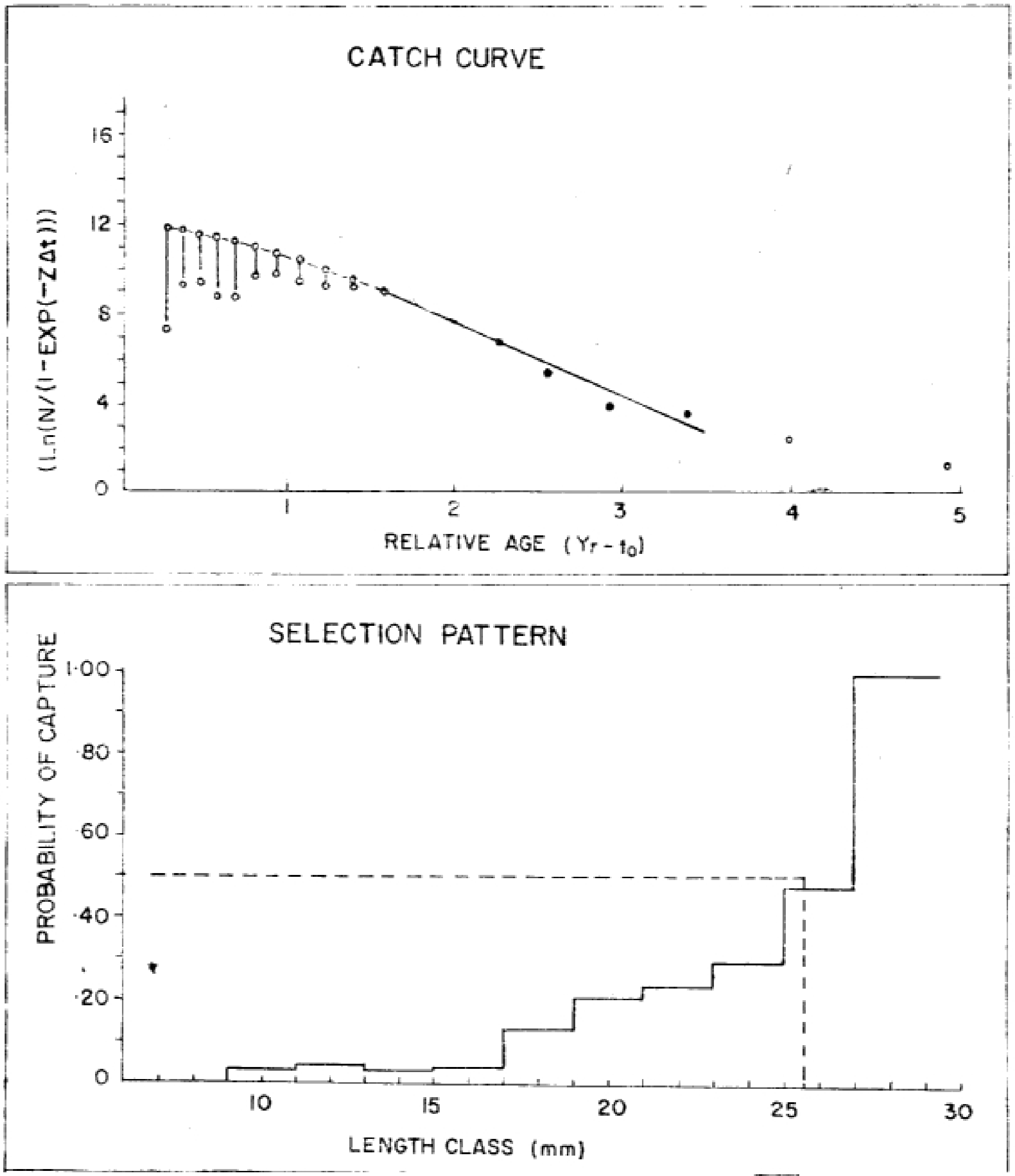


Figure 4

ESTIMATION OF L_∞ AND Z/K USING THE METHOD OF WETHERALL *EI AL.* (1986) PLOTS A TO E.

Based on length-frequency data in Appendix 1 each combined into a single, mean annual sample.

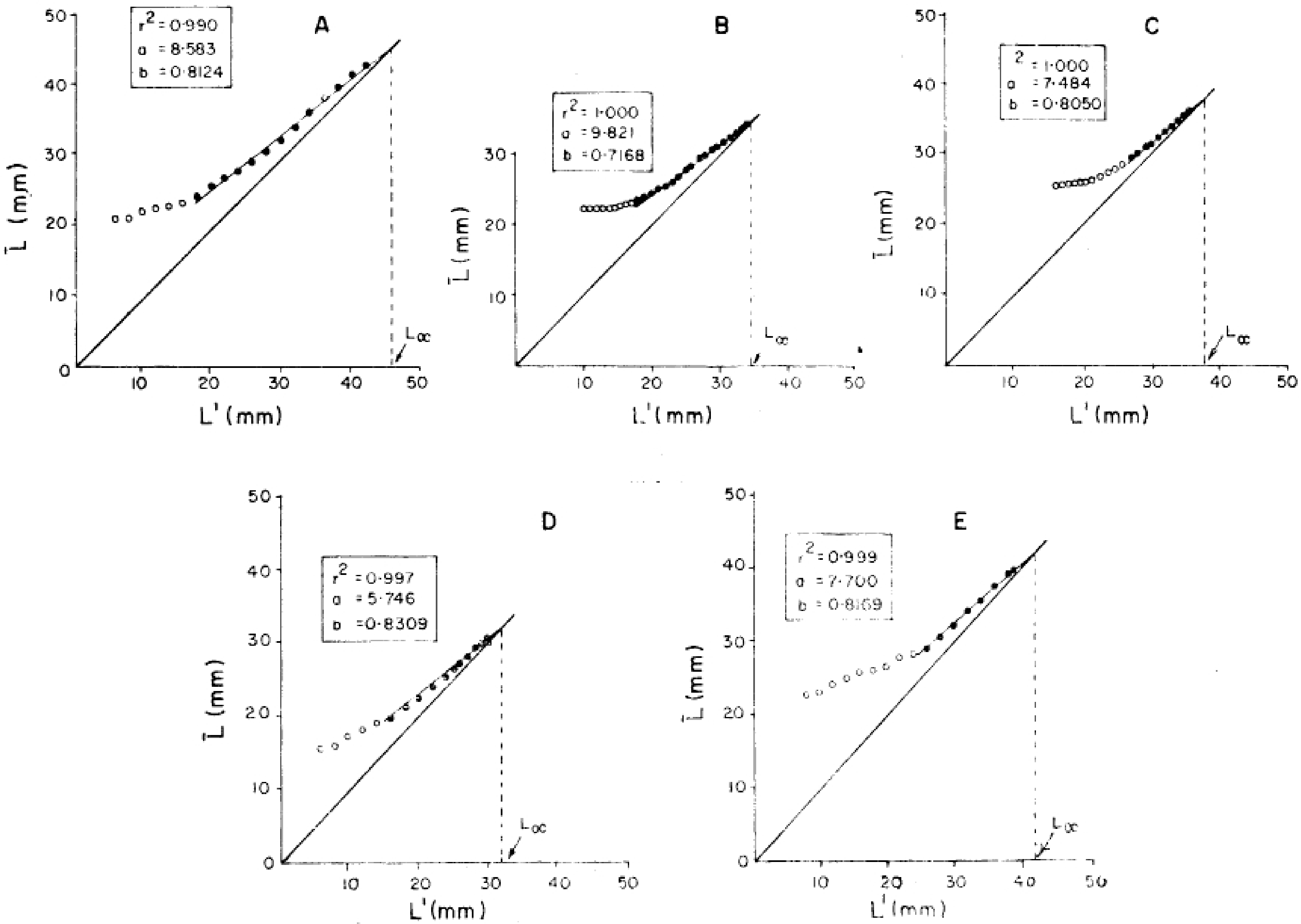
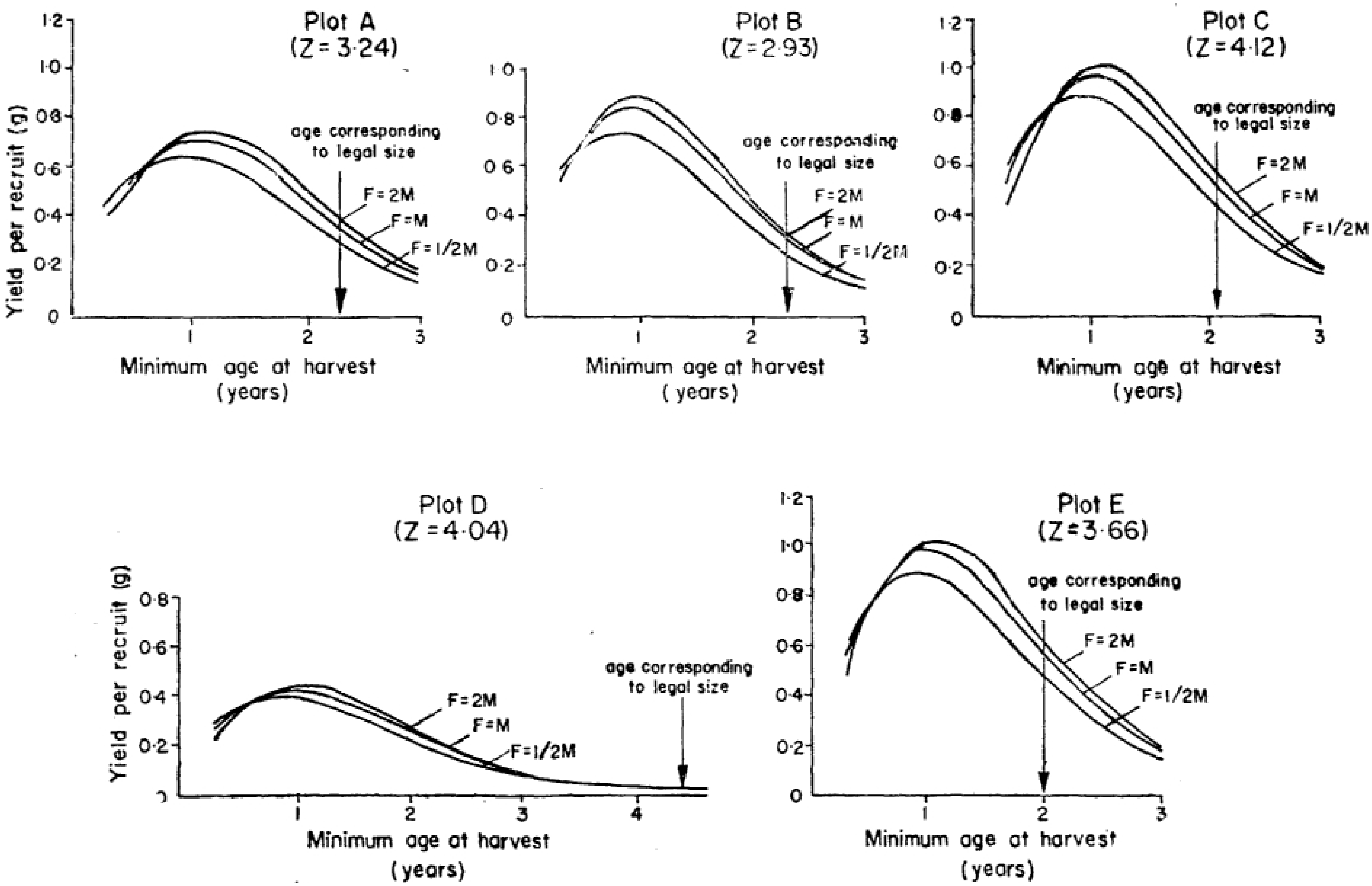


Figure 5

YIELD-PER-RECRUIT ANALYSES OF *A. Granosa,* **PLOTS A TO E**

Note that all five plots suggest that the present minimum legal size (i.e., age) at harvest is too high (particularly in cases of s/ow growth such as in Plot D), and that this result is independent of F and M over the range considered here, and of specific values of Wa,.



Appendix 1

Length-frequency data of *Anadara granasa* from five culture plots
Plot A. K. Juru, Penang.

Size (mm)	Sampling date 1/15	2/15	3/15	4/15	5/15	6/15	7/15	8/15	9/15	10/15	11/15	12/15
7.0						120	11	1				
9.0						734	116	41	1	2		
11.0						580	257	120	11	8		
13.0	8	1				70	180	135	65	18	6	1
15.0	89	25		2	14	1	78	68	73	24	44	25
17.0	348	122	26	16	38	0	53	21	45	89	200	75
19.0	449	89	140	106	98	1	37	26	9	76	138	131
21.0	219	38	237	234	100	10	36	54	34	31	28	104
23.0	34	34	203	323	107	51	66	72	68	7	1	34
25.0	2	47	84	237	111	127	124	172	108	20	5	29
27.0			30	78	96	169	158	219	127	19	27	52
29.0			16	15	63	127	128	162	102	17	57	64
31.0			4	3	22	37	99	43	55	2	58	37
33.0					9	21	56	13	23	1	23	9
35.0					1		20	3	6		5	9
37.0							1	5	1		1	4
39.0								1			3	4
41.0								1			2	
43.0											1	

Appendix 1 *(Continued)*

Length-frequency data of *Anadara granosa* **from five culture plots.**

Plot B: B1, Pulau Sangga, Perak

Size (mm)	Sampling date 1/30	2/27	3/29	4/25	5/15	6/15	7/31	8/28	9/15	10/31	11/28	12/28
10.5									2			
11.5									11	3		
12.5									43	9		
13.5									96	16		
14.5									118	50	2	
15.5	5								114	108	19	2
16.5	13	2							80	156	**33**	**10**
17.5	20	5	1	2					28	200	36	7
18.5	57	8	5	0					5	186	102	11
19.5	81	32	18	4		2			4	102	137	43
20.5	115	70	53	18	4	7	1			41	162	59
21.5	97	96	80	37	2	24	6	1		8	104	67
22.5	71	99	94	80	17	43	10	0			49	68
23.5	35	64	92	125	42	77	12	1			22	58
24.5	7	31	54	113	77	111	18	12			4	**39**
25.5		12	29	77	97	88	31	30				15
26.5		1	3	33	94	68	43	43				
27.5				15	62	26	84	57				
28.5				2	50	17	88	60				
29.5					14	9	69	61				
30.5					6	6	59	59				
31.5					1	3	20	39				
32.5						2	13	23				
33.5						1	4	8				

Appendix 1 *(Continued)*

Length-frequency data of ***Anadara granosa*** **from the five culture plots.**

Plot C: A12 K, Sepetang, Perak

Size (mm)	Sampling data											
	1/29	2/26	3/28	4/24	5/30	6/15	7/30	8/28	9/15	10/30	11/27	12/27
16.5		1										16
17.5	1	0							5			31
18.5	2	2							18	2	2	40
19.5	12	4		3					25	6	5	55
20.5	13	'11	1	7				2	42	12	9	75
21.5	49	23	10	12		3	1	2	24	36	37	96
22.5	80	38	10	21	1	0	0	0	16	60	44	65
23.5	93	64	22	42	13	1	0	3	6	81	87	40
24.4	88	85	32	77	19	1	2	6	0	77	78	10
25.5	63	96	33	106	44	19	5	4	1	44	53	8
26.5	24	76	28	91	54	28	19	15		17	19	1
27.5	14	43	12	55	53	54	35	58		4	5	1
28.5		22	6	29	82	72	50	64			1	1
29.5		3	6	22	62	66	64	50				
30.5				8	56	51	48	52				
31.5				3	28	32	40	29				
32.5				2	12	18	26	19				
33.5					14	3	14	8				
34.5						4	7	5				
35.5						1	7	2				
365							1	1				

Appendix 1 *(Continued)*

Length-frequency data of *Anadara granosa* **from five culture plots.**

Plot D: A 15 K, Sepetang, Perak

Size (mm)	Sampling date 1/29	2/26	3/28	4/24	5/30	6/15	7/28	8/28	9/28	10/30	11/27	12/27
5.5					6	5	4					
6.5					44	23	29	2				
7.5					182	68	74	13				
8.5					321	136	152	75				
9.5					363	179	211	165	10			
10.5					172	155	195	191	16			
11.5	4	2			59	75	137	162	65	2	2	
12.5	7	4			18	38	79	90	116	12	18	
13.5	17	14		1	3	11	30	59	170	29	41	2
14.5	44	47	6	8	3	3	12	24	159	48	79	14
15.5	86	69	15	22	7	2	4	10	115	103	94	63
16.6	113	114	57	28	20	7	15	2	75	103	96	95
17.5	78	80	92	75	35	19	22	4	35	113	76	137
18.5	76	64	114	95	76	55	46	22	27	77	55	91
19.5	31	43	87	102	93	80	78	37	21	37	37	60
20.5	28	29	65	76	113	102	84	62	42	10	5	27
21.5	5	10	38	49	65	65	87	100	31	4	1	13
22.5	1	2	21	25	43	71	77	102	81			5
23.5			7	19	34	44	76	66				2
24.5			4	4	10	11	17	64	62			
25.5				5	2	12	0	23	41			
26.5						5	1	8	24			
27.5							3	2	16			
28.5							1		6			
29.5									2			
30.5									3			

Appendix 1 *(Continued)*

Length-frequency data of *Anadara granosa* from five culture plots.

Plot E: S. Besar, Se/angor

Size (mm)	Sampling date 1/8	2/6	3/6	4/9	5/8	6/12	7/19	8/14	9/15	10/8	11/8	12/11
7.0							1	2	4			
9.0							39	11	19	17	1	
11.0							106	38	47	51	10	
13.0			1				129	58	89	54	26	1
15.0	15				2		75	35	50	50	42	3
17.0	96		35		1	1	17	16	43	27	42	26
19.0	136	8	47		10	2	3	20	22	10	34	52
21.0	105	33	87	2	57	1	0	5	16	1	17	22
23.0	39	150	44	22	182	12	10	34	11		6	0
25.0	4	158	45	66	152	66	46	66	33	1		0
27.0	5	41	84	62	67	202	219	123	82	1	1	1
29.0		9	36	45	11	68	203	103	134		0	0
31.0		1	12	15	7	51	55	150	124		1	2
33.0			1	3	1	11	3	95	95		1	
35.0				2	6	1	1	28	30			
37.0				0	2	0		11	9			
39.0				1	1	3		1				

Publications of the Bay of Bengal Programme (BOBP)

The BOBP brings out six *types* of publications:

Reports (BOBP/REP/....) describe and analyze completed activities such as seminars, annual meetings of BOBP"s Advisory Committee, and projects in member-countries for which BOBP inpuis have ended

Working Papers (BOBP/WP/...) are progress reports that discuss the findings of ongoing BOBP work.

Manuals and ***Guides*** (BOBP/MAG/...) are instructional documents for specific audiences.

Miscellaneous Papers (BOBP/MIS/...) concern work not originated **by BOBP** staff or consultants — but whkh is relevant to the Programme's objectives.

Infornsation Docwnents (BOBP/INF...) are bibliographies and descriptive documents on the fisheries of member-countries in the region.

Newsletters (Ba, of Bengal .Wews), issued quarterly, contain illustrated articles and features in non-terchnical style on BOBP work and related subjects.

A list ot publications follows.

Reports (BOBP/REP/...)

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