REPORT ON THE

NORFOLK ISLAND DOMESTIC FISHERY

(FIRTA 81/49)

by A.G. CHURCH

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1. INTRODUCTION

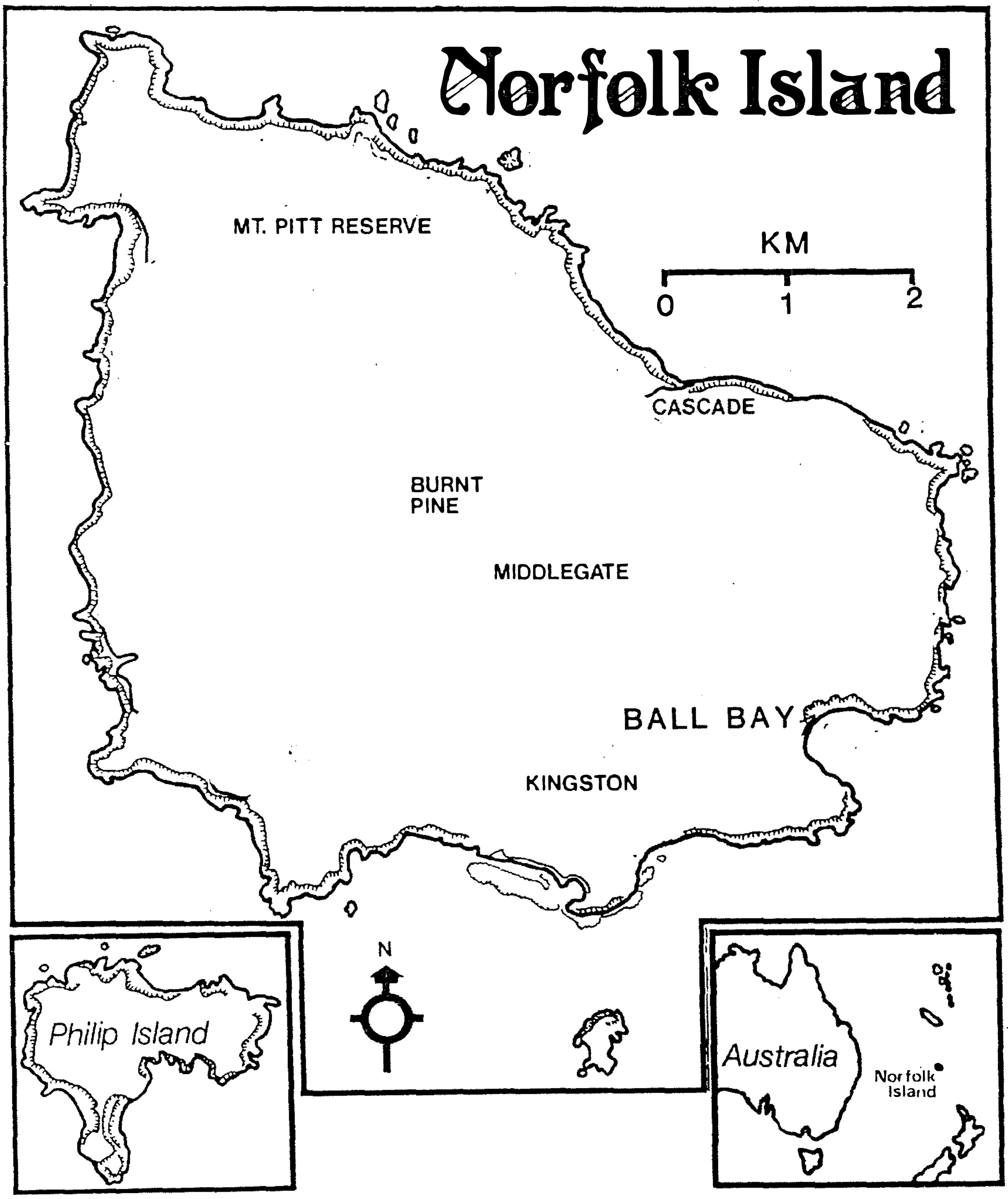
The Norfolk Island domestic fishery survey was undertaken by Department of Primary Industry (DPI),Canberra on behalf of the Norfolk Island Legislative Assembly. Research undertaken on Norfolk Island during 1981 to 1983 was funded by the Fishing Industry Research Trust Account (FIRTA 81/49) with contributions from DPI for computing and research design, and the Norfolk Island Government for subsidised accomodation, transport and laboratory facilities.

The program followed consultation between the Norfolk Island Fishing Club, the Norfolk Island Legislative Assembly, the Department of Territories and DPI, Canberra in response to complaints from local fishermen that fish stocks were declining. Local fishermen considered that foreign fishing vessels (FFV's) in Norfolk Island waters had depleted continental shelf demersal fish stocks.

Information is presented here indicating that the decline in fish abundance in Norfolk Island waters is a normal response to increased fishing pressure from the growing domestic fishery. Furthermore, it is believed that the Norfolk Island continental shelf demersal fishery is approaching full exploitation.

As reliable historical information is virtually non-existent, the current program was designed to provide a baseline for future fisheries management.

Figure 1.


Norfolk Island
KM
0
1
2
MT. PITT RESERVE
CASCADE
BURNT
PINE
MIDDLEGATE
BALL BAY
KINGSTON
N
Philip Island
Australia
Norfolk
Island

2. EARLY HISTORY AND DEMOGRAPHIC CHANGE

Captain James Cook discovered Norfolk Island on 10 October, 1774 on his second voyage around the world. Settlement was established on 6 March, 1788. At one stage, the survival of the settlement depended upon occassional hauls of fish, catching seabirds and collecting their eggs. By 1814 the first settlement was abandoned.

The second penal settlement was in operation from 1825 to 1856, when 194 people from Pitcairn Island were relocated to Norfolk Island by the British Government. Norfolk Island was duly surveyed in 1858 and 1859 and a grant of 20 hectares of land was made to the head of each family.

By 1885 the population had increased to 662, and to approximately 800 by 1896 and then remained fairly static through to the 1930's. The population increased during the 'banana boom' of the early 1930's with a peak of 1231 in 1933.

The post war years until the 1960's included a ten year period when the Norfolk Island resident population exceeded 1000, reaching a peak of 1172 in 1953 when the production of bean seed provided impetus for mainlander immigration. The rapid growth of the Norfolk Island Tourist Industry since the 1960's, however, has brought about far greater and more rapid demographic change than any experienced throughout the preceding century.

The Census of Population and Housing undertaken on Norfolk Island on 30 June, 1981 gave a total population of 2175 of whom 1849 were categorized as residents (including 532 temporary permit holders); 616 of the resident population were listed as being of Pitcairn Descent (Walker,1982).

3. THE NORFOLK ISLAND GOVERNMENT

The High Court of Australia held in the Berwick Case in relation to the Income Tax Assessment Act, (1936-1973) that Norfolk Island is a Territory of Australia and went on to state its legal position as such a Territory, viz., that the Commonwealth Parliament has plenary law making power in respect of it. Specifically, the Court stated that by virtue of S.122 of the Commonwealth Constitution, the Commonwealth can pass laws providing for the direct administration of Norfolk Island by the Commonwealth Government or endow the Island with seperate political, representative and administrative institutions. It is, therefore, open to the Commonwealth to lay down the form of government and administration for the Island that it sees fit.

In 1979, the Commonwealth Parliament passed the Norfolk Island Act, to provide new arrangements for the government of the Island. It established the Legislative Assembly of Norfolk Island and conferred on the Assembly power to make laws for the peace, order and good government of Norfolk Island.

Under this Act the Administrator is charged with the responsibility of administering the government of the Territory. The Administrator is required to act in accordance with advice given to him by the Executive Council of Norfolk Island in relation to any matter over which the Executive Members i.e., the Ministers of the Norfolk Island government, have authority. These matters are specified in Schedule 2 of the Norfolk Island Act.

Other matters of particular sensitivity or national importance over which the Executive Members also have authority, are subject to veto by the Administrator. Such matters are immigration, education, customs and fishing and are listed in Schedule 3 to the Act (Trebilco,1983).

4. FISH FAUNA OF NORFOLK ISLAND

The diverse fish fauna of Norfolk Island has attracted limited research. Offshore species including pelagic fishes, sharks and many demersal species are still poorly known. Richardson (1848) provided the type specimen and original description and figure of *Lethrinus chrysostomus* from Norfolk Island waters. *L. chrysostomus* is known locally as the 'trumpeter' due to its extended snout.

Hoese et al.(1975) undertook the most comprehensive study by collecting 105 species, 86 of which were newly recorded bringing the total number of Norfolk Island fishes to 163. Of the 163 species 147 were considered shore-fishes and 117 of these were also found to occur at Lord-Howe Island. Only four species (*Archamia leai,* *Parablennius sp., Tetraodontidae sp.,*and *Eviota sp.*) were found to be endemic to Norfolk Island. The most speciose families were Labridae (17 species), Pomacentridae (13), Chaetodontidae (11), Blennidae (8), Serranidae (7) and Gobiidae (6).

Hoese et. al.(1975) divided the distribution patterns of Norfolk Island species into two categories: widespread tropical Indo-west Pacific or western Pacific species, and the south-western Pacific endemics which are restricted to the southwestern or southern Pacific Ocean. Thus almost half of the Norfolk Island species are tropical.Few, however, of the tropical species were in abundance and many were recorded only from juveniles.

Hoese et.al.(1975) recommended that due to the distinctive character of fauna in Norfolk Island waters, reserves for the protection of fishes should be introduced. The banning or licensing of aquarium fish collectors to prevent the depletion of rare and colourful species was also recommended.

5. SEA FLOOR TOPOGRAPHY

Norfolk Island is a truly oceanic, volcanic island, in the South Pacific Ocean, lying on the narrow, steep-sided Norfolk Ridge, 675 kms south of New Caledonia, 775 kms northwest of New Zealand and 1375 kms east of Australia at 29° S latitude and 168° E longitude; Lord Howe Island is approximately 900 kms to the southwest. Two smaller outcrops, Nepean and Philip Islands lie to the south of Norfolk Island at 0.8 and 5.6 kms, respectively.

The ridge of continental material on which the island is built was below sea level at the time of the initial eruption in the late Pliocene era about three million years ago. Susequent erosion, has reduced the island to a fragment of the original land mass. Reference to the most recent bathymetric chart of the Island, published by the New Zealand Oceanographic Institute in 1981, shows clearly that the present land surface is approximately 1% ($35kms^2$) of the original area of the pedestal i.e., 35 by 105 kms = 3675 kms^2 (Carter 1979, Duvall 1983).

The continental shelf surrounding Norfolk is elongate and aligned north - south. To the east and west of the island the shelf dips almost continuously at 0.5 - 0.7° to the shelf edge at the 100 metre isobath. By contrast, the northern and southern sections have lower inclinations being almost flat between the 50 and 75 metre isobaths (Carter, 1979).

Scattered dredge samples collected by the New Zealand Oceanographic Institute in 1979, revealed that the main morphologic elements included scattered degenerated coral reefs, an abundance of sand and gravel on the shelf and upper slope consisting mainly of coral together with subordinate but locally important quantities of bivalve, bryozoan, echinoderm and crustacean debris. The presence of live, unabraded fragments of coral in dredge hauls implied a small-scale rough topography at <u>in situ</u> coral colonies surrounded by coarse calcareous sediment.

On the southern side of the island the sea floor is typified by steep-sided coral colonies (known locally as 'pinnacles') and on the northern side by less prominent 'platform' reef systems.

6. HISTORY OF THE NORFOLK ISLAND DOMESTIC FISHING INDUSTRY

Very little historical information is available on the Norfolk Island fishing industry besides the Administrator's Annual Reports, 1914-1983. Of the many attempts to establish businesses based on the catching, processing and marketing of fresh and frozen fish products, none have survived.

A number of factors have prevented the development of the fishing industry based on a central processing facility. These factors include:

(1) The lack of a permanent all-weather deep water small boat harbour.

(2) Inconsistent supplies of fresh product due to variable weather conditions.

(3) Irregular freight services and high freight costs.

Prior to 1900, Norfolk was a frequent port of call for whaling vessels. By 1914, however, this once lucrative industry was languishing - the price of whale oil had halved.

In 1915, the Pacific Fisheries and Trading Company commenced operations. Business was suspended in 1918, however, due to the curtailment of shipping and the loss of a valuable fishing launch in a cyclone. Another company erected a factory in 1925 but soon closed for lack of fish. In 1937 another freezer factory opened at Kingston (Figure 1). At the time 14 - 15 men were engaged in part - time fishing and six men were working at the factory as required. The plant was capable of handling 4 tons of whole fish or 12 tons of fillet. Due to a combination of bad weather and the lack of a suitable all-weather harbour the plant ceased operations.

In 1945, Norfolk Island Industries Ltd., was established to trade in frozen fish, shark and whale oil products. A building was erected and fitted with refrigeration and snap freezing facilities. In 1946, frozen fish valued at £2306 were exported to Australia, but their fifty ton fishing vessel was wrecked. In 1947 a second vessel was destroyed by fire , and finally, in 1948 another launch was wrecked.

In 1949, the South Seas Whaling and Sharking Co.Ltd., set up operations at Ball Bay (Figure 1). By late 1950 the company had lost one launch and had had their chaser and premises destroyed by fire. In 1957, Burnt Pine Investments Co.Ltd., erected a fish processing factory incorporating a 20 ton freezer at Cascade landing (Figure 1). Fish were supplied by local fishermen at prices ranging from 6d. to 8d. per pound of whole fish which were then filleted by the company and snap frozen for export. Besides fresh fish sold locally, the company exported 26,173 lb. of frozen fish fillets by June, 1958. Then bad weather and high freezer-freight costs to Australia, made the venture uneconomical.

During 1959, at the request of the Norfolk Island Administration, Mr.H.Van Pel of the South Pacific Commission visited the Island to examine the possibility of increasing the whale quota. He was also commissioned to investigate means of increasing returns to local fishermen for fresh fish products and thereby improve continuity of supply to the factory. As Van Pel's report is the only detailed information available on the Norfolk Island fishery it will be treated in greater detail in the next chapter.

Between 1963 and 1972, two more factories opened to trade in fish products. Neither prospered or survived.

7. THE VAN PEL REPORT

The most comprehensive document on the Norfolk Island fishing industry is the South Pacific Commission report compiled by H. Van Pel in 1959. He was commissioned to undertake the survey by the Island's Administrator during January and February, 1959 to assess:

a. the possibility of increasing the Norfolk whale quota from 120 to 150 whales per season to make the whaling company more profitable.

b. methods of stimulating the catching of fresh fish supplies by increasing monetary returns to local fishermen.

During Van Pel's visit there were nine petrol motor launches ranging in size from 3.9 to 6.7 metres LOA. They were powered by 2.5 to 7.0 hp Chapman inboard motors or 4.0 to 5.0 hp Seagull outboard motors. Each boat carried 2 to 5 fishermen.

All commercial fishing was carried out using the traditional hook and line technique. Van Pel distinguished four types of fishing gear commonly used on the Island:

1. Bottom handline (using size 6/0-8/0 hooks)
2. Floating handline.
3. Pole and line
4. Cast handline.

Due to the absence of a boat harbour, vessels were launched at either the Kingston pier using a 5 ton mobile crane or at Cascade pier using a car hauled block-and-tackle crane.

Van Pel stated that at the time the knowledge of fishing grounds was limited to a radius of approximately 12 nautical miles from the Island. Product was brought ashore in the round and then scaled, filleted and packed in cardboard boxes at the fish freezing and cold storage plant. Records from the plant show that during the twelve month period from June, 1957 to July, 1958 there were 118 fishing days resulting in a total catch of 47618 kg. of whole fish (mainly *L. chrysostomus*) sold to the factory at an average price of 6d. per lb. During the 118 fishing days there were 239 actual boat days, resulting in an average catch of 199 kg. per boat day. From the personal records of one fishermen for a five month period in 1958, there were 31 boat days resulting in a total catch of 9452 kg. with an average catch of 305 kg. per boat day.

In summarizing his findings Van Pel made the following recommendations to improve returns to fishermen and to improve the general profitability of the Island's domestic fishing industry:

1. A Goverment subsidy be paid to local fishermen at a rate of 2d. per pound for trumpeter and snapper and 1d. per pound for trevally, kingfish and grouper for a two year period for export product.

2. Two 25ft. fishing boats with 12 hp. diesel engines, sails and live-wells be built on or imported to Norfolk Island.

3. The services of a fish preservation technologist be sought for a one year period to determine the most profitable product presentation and to test potential markets overseas.

4. A harbour should be built near Kingston pier.

During 1962 to 1963 the possibility of building a boat harbour was investigated by the Commonwealth Department of Works. It was found to be too expensive. No other Van Pel recommendations were implemented.

8. THE PRESENT SITUATION

Although considerable fishing is still undertaken on Norfolk Island the central processing and freezer factories no longer exist. The industry has grown, however, with a steady increase in the number of fishing boats registered with the Norfolk Island Fishing Club between 1959 to 1983 (Figure 2). Any person resident on the island can purchase a boat and fish commercially or as an amatuer: there are no licensing restrictions.

The fishing industry has grown with the tourist industry, the mainstay of the Island's economy. In 1983, the market consisted of 5 hotels, 1 motor hotel, 2 main clubs, 7 guest lodges, 22 apartments, 18 restraunts, 2 butcher shops and 2 fish shops. Product was sold for A$3-4 per kg. of fillet and together with multiplier effects provides supplementary incomes for many Island families. The local product also helps to reduce a trade deficit caused by imports of frozen fish products. For example, in 1981 frozen fish products imported from New Zealand were valued at NZ$62,821.

Fishing on Norfolk is still undertaken in the traditional manner by lowering boats into the water for each fishing operation using a car hauled block-and-tackle crane at either the Cascade or Kingston piers. For full details of fishing operations refer to Grant (1981). Whilst fishing gear remains the same, the new era of fishing boats have much improved performance, range, durability and are equipped with depth sounders and radios.

9. AGE AND GROWTH

9.1. Introduction

The only previous study of age and growth of *L. chrysostomus* was undertaken by Walker (1975) in Queensland waters. This research yielded estimates of parameters of the von Bertalanffy growth equation for the combined sexes of L_∞ = 58.5, K = -0.175 and t_0 = -2.26.

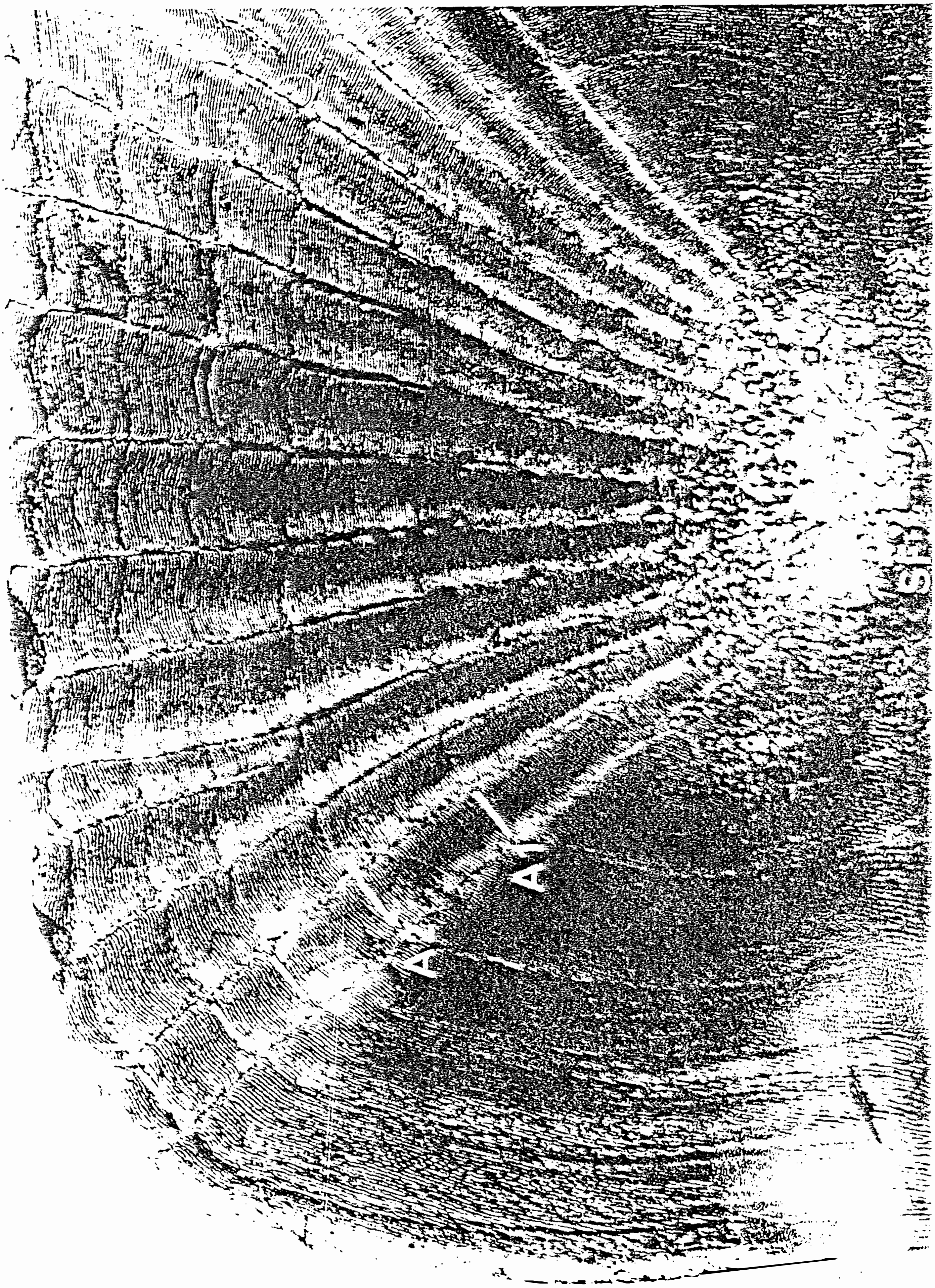
During the initial phase of research on Norfolk Island it was observed that many fish of both sexes had fork lengths well in excess of the predicted L_∞ for the Queensland population. These estimates for *L. chrysostomus* from Queensland were therefore inadequate for Norfolk Island and prompted the present study.

Due to the importance of *L. chrysostomus* in the catch this study examines its biology in Norfolk Island waters and provides estimates of growth parameters and total instantaneous mortality rates.

9.2. Methods

Regular sampling was carried out at either the Cascade or Kingston piers where whole catches were intercepted prior to processing. On several occassions it was possible to collect samples from both locations.

PLATE 1: A typical L. chrysostomus scale.



(Taken from a 40cm 5+ female. SF=Scale Focus,MI=Scale Margin,A1,A2=Annulus 1,2 etc.)

Before the collection of samples, length frequency distributions of several catches were recorded from different fishing areas. These determined the sampling strategy which involved the collection of five samples for each sex for each 5cm length class over the length range encountered per month for a period of 14 months.

Regular sampling included the collection of fork length (F.L.) to the nearest cm., weight in grams, sex and scales. The length frequency distributions (F.L. to the nearest cm.) of whole catches were recorded (where n>30) whenever time permitted.

Scales were collected from an area encompassing the third to eighth scale rows directly beneath the pectoral fin in accordance with Paul (1968) who demonstrated this to be the most suitable site for *Chrysophrys auratus*. Each scale was inspected and replacement scales were discarded.

In the laboratory scales were washed, dried and five or six were mounted between two microscope slides and viewed under an Olympus stereo microscope fitted with a graduated micrometer. The distance from the scale focus (SF) to each successive annulus (A1,A2 etc.,) was recorded for four seperate scales from each fish (Plate 1). The marginal increment (MI) or distance between the outermost annulus and the scale margin was recorded for all scales.

Only clear annuli which extended most of the way around the scale were included. Where scales were hard to read they were listed as unreadable.

Figure 3: The mean monthly scale marginal increments for 5+ and 6+ *L. chrysostomus* sampled on Norfolk Island during the period December, 1981 to January, 1983.

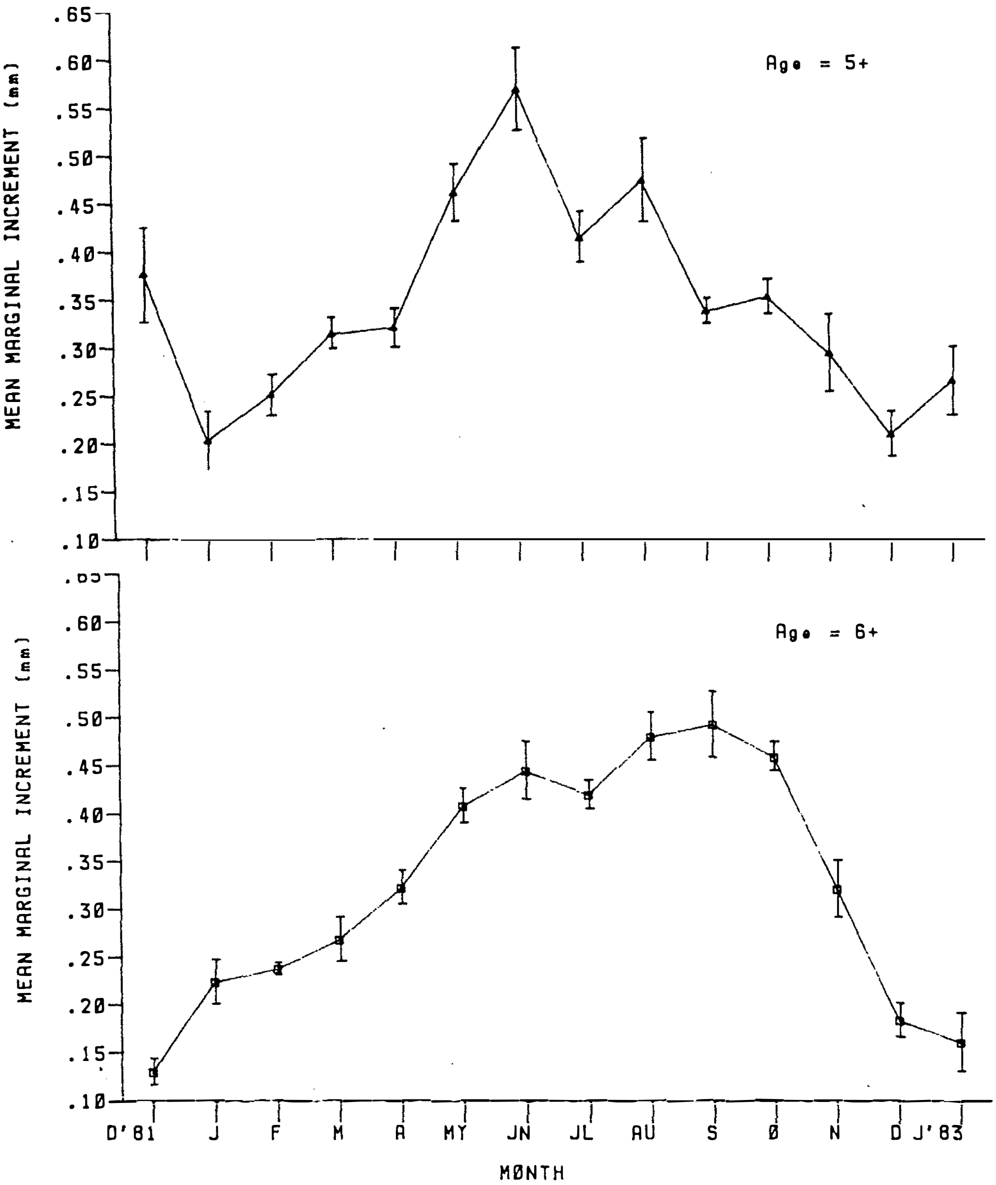
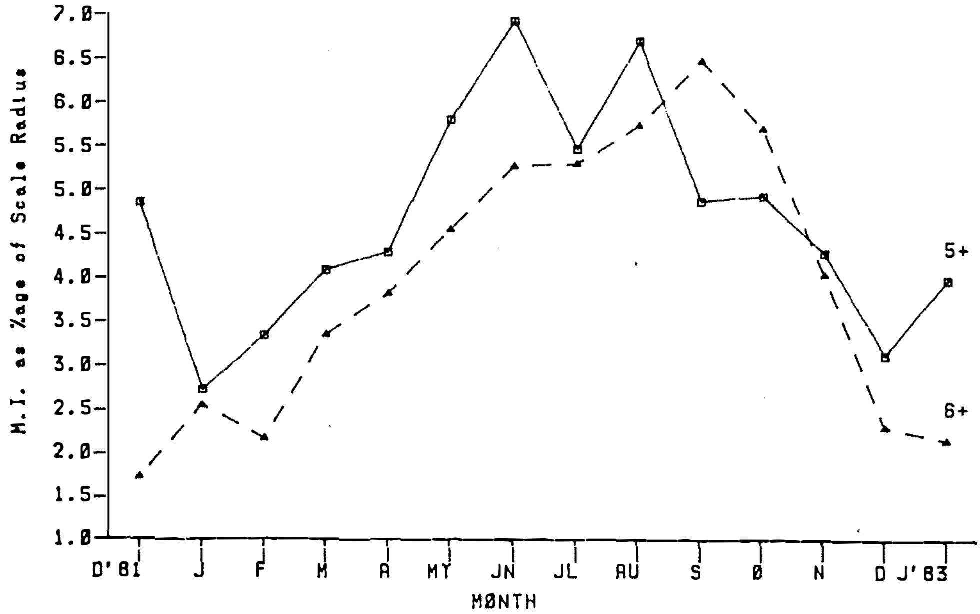


Figure 4: The mean monthly scale marginal increments expressed as a percentage of total scale radius for 5+ and 6+ *L. chrysostomus* sampled on Norfolk Island during the period December, 1981 to January, 1983.



Data Analysis

Length and age data were fitted to the von Bertalanffy growth curve and the maximum likelihood estimation of the three growth curve parameters were undertaken following Kirkwood (1983). The growth curves were compared using his likelihood ratio test.

The relationship between length and weight was established by using a least squares linear regression analysis.

Total instantaneous mortality rates (Z) by major fishing areas and for the total stock were estimated from catch curves after Pauly (1980). The null hypothesis that no significant differences exist between the total mortality estimates for each area and the total stock was tested using a Students *t*-test.

9.3. Results

Periodicity of Scale Checks

Figures 3 and 4 show plots of mean marginal increment (in micrometer units) and marginal increment as a percentage of total scale radius for the period December, 1981 to January, 1983 for 5+ and 6+ individuals.

Mean marginal increments increased during the late summer through to winter with a maximum during June and September for 5+ and 6+ individuals, respectively.

A Student-Newman-Keuls (SNK) multiple range test showed that mean marginal increments for 5+ fish during

TABLE 1: Age and Length Relationship for *L. chrysostomus* females sampled on Norfolk Island during the period December, 1981 to January, 1983.

F.L.	AGE IN YEARS 0	1	2	3	4	5	6	7	8	9	10	11
20	1											
21		1										
22	1	2										
23		3	2									
24		4	1									
25		3	1									
26		6	3									
27			7	2								
28		2	7	8								
29			5	8	4							
30			6	10	2	2						
31			5	6	5	6						
32			1	5	3	3						
33			2	2	4	9	1					
34			1	3	3	6	3					
35				4	4	5	3					
36						3	8					
37					2	1	5	2				
38						7	5	3				
39						5	5		1			
40						1	8	2				
41						2	7	2	1			
42						5	3	1				
43						2	6	6	1			
44						1	2	1	2			
45						3	6	1	3			
44							2	3	1			
47							3		1	1		
48							1					
49							2		1			
50								2	2	1		1
51							1			1	2	1
52												
53										1	2	
54											1	
55										1		
56											2	1
57												
58												
59											1	
	2	21	41	48	27	61	71	23	13	5	8	3

TABLE 2: Age and Length Relationship for *L. chrysostomus* males sampled on Norfolk Island during the period December, 1981 to January, 1983.

F.L.	AGE IN YEARS											
	2	3	4	5	6	7	8	9	10	11	12	13
25	2											
26												
27												
28	1											
29	1	1	2	1								
30	1	1		1								
31		3	3	3	1							
32	1	2	4	3								
33			1	8								
34			1	1	2							
35		1		4	5							
36			1	1	2							
37			2	6	4							
38			1	5		2						
39			1	5	13	2						
40				3	13	2						
41				1	4	7	2					
42				2	10	7	3					
43				1	5	5	1	1				
44					4	10	3		1			
45					2	8	5					
46					5	2	5	3	2			
47					5	3	5	3				
48					3	3	3	1	1			
49					1	3	2	3				
50					2	3	1	3		1		
51						2	2	3				
52						3	1	1	3	1		
53						1	2	1		2		
54						1	3		1			
55							2		1	1		
56								2	2		1	
57							1		2	3	1	1
58								2	1		1	
59										1	1	
60										2		2
61										1	1	
62												1
63										1		
64										1		1
65												
66											1	
	6	8	16	46	80	64	41	23	14	14	6	5

January and December, 1982 were not signifcantly different (p<0.05), however, both were significantly different from June, 1982. The mean marginal increment for 6+ individuals during December, 1981 was also significantly different from that during September, 1982.

Minimal scale marginal increments during December and January indicates that check formation occurred each summer.

Assignment of Ages

Approximately 12% of all scales collected, particularly those from older fish, were unreadable and therefore discarded.

Individuals were assigned ages according to the number of annuli observed on the scales. As the first annulus on scales is formed during the second summer, those individuals without an annulus were regarded as being of 0+ age and were nominally designated as females.

Despite a large marginal increment, individuals were not regarded as having completed a years growth until an annulus was clearly discernible.

The resultant age - length distributions for each sex are given in Tables 1 and 2. The lack of 0+ and 1+ males is partly attributable to the fact that all juveniles (i.e., individuals in which sex was indeterminate) were classified as females. Males may also have a later age of recruitment to the fishery.

Figure 5: Relationship between Fork length and Scale Radius for *L. chrysostomus* females, sampled on Norfolk Island during the period December, 1981 to January, 1983.

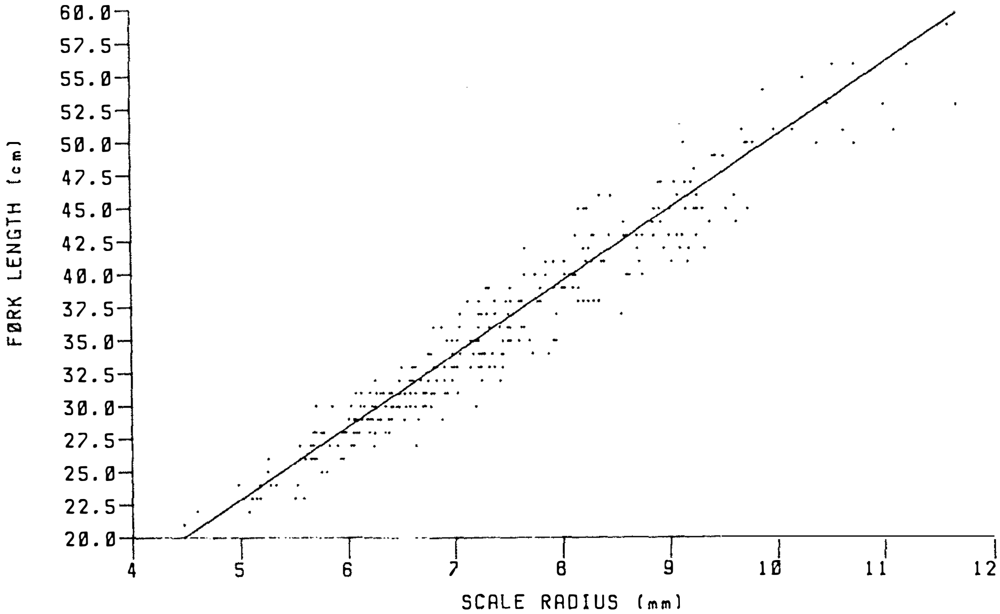
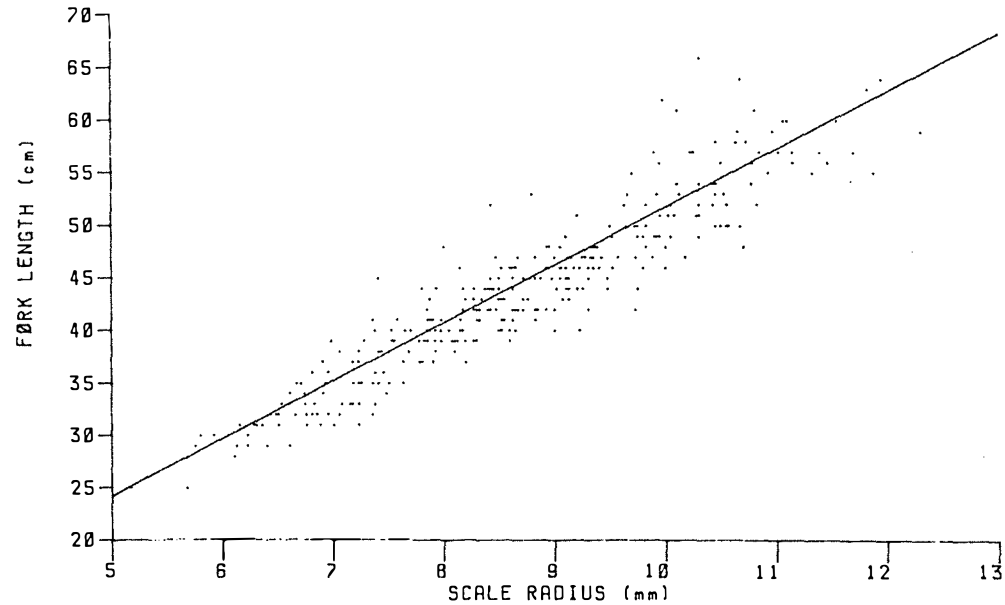


Figure 6: Relationship between Fork Length and Scale Radius for *L. chrysostomus* males, sampled on Norfolk Island during the period December, 1981 to January, 1983.



Scale Radius and Fork Length Relationship

A linear relationship between scale radius and fork length was obtained by least squares regression analysis (Figures 5 and 6). The values of parameters for 324 females and 323 males, are as follows:

	a	*b*	r^2
Females	-4.79	5.54	0.91
Males	-3.40	5.52	0.85

Growth in Length

The values of the parameters *a* and *b* from the linear relationship established between scale radius and fork length were used to estimate the fork length of individuals at successive annuli by back-calculation from the scale margin.

The back-calculated fork lengths and corresponding ages derived from one scale for each fish, were used in the growth analysis, giving the curves

$$L_t = 65.7\{1-\exp[-0.109(t+2.30)]\}$$

for females;

Table 3: Maximum likelihood ratio test for the comparison of the three von Bertalanffy growth curve parameters.

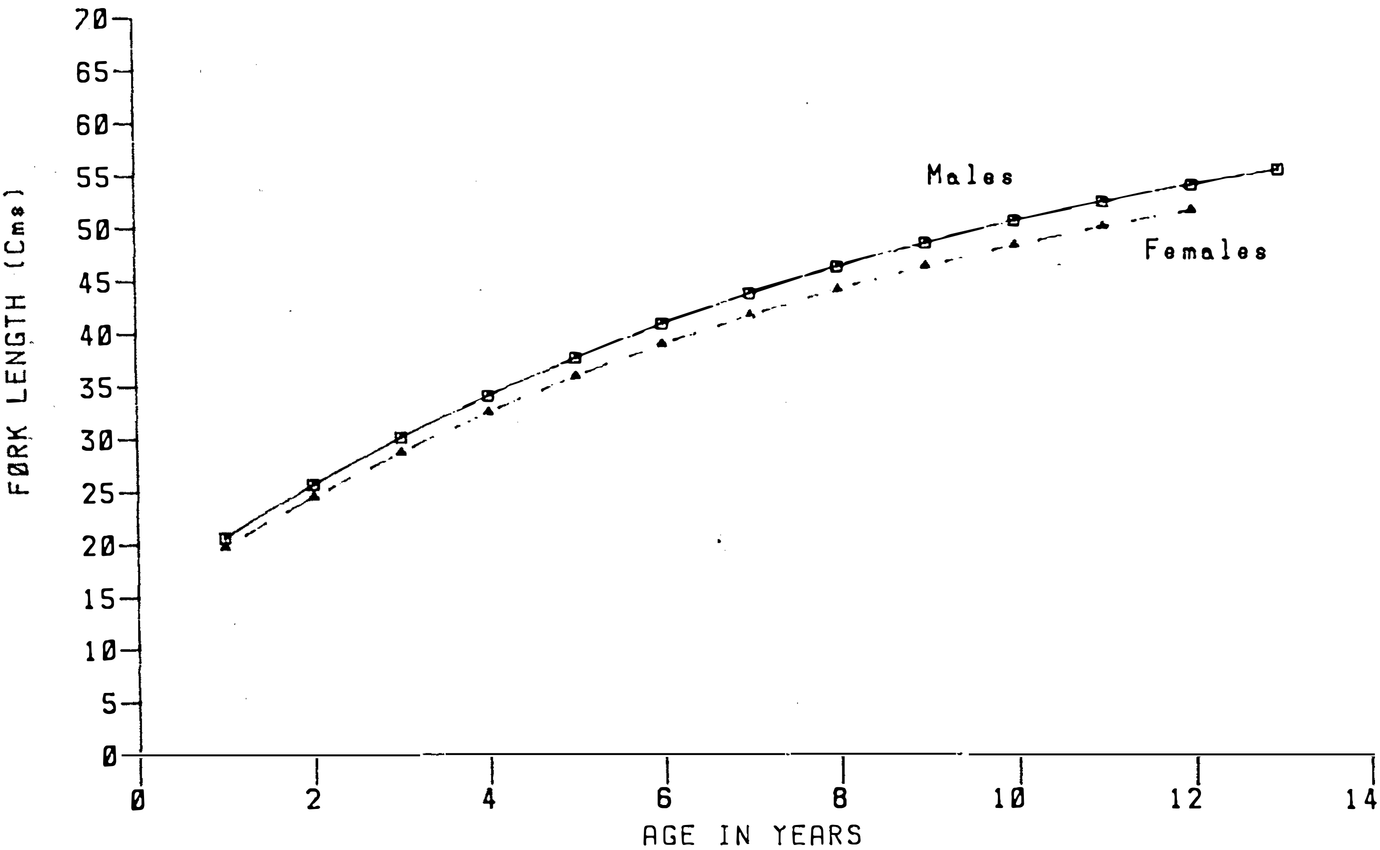
Sex	n	$\hat{L}\infty$ (s.e.)	$\hat{K}$ (s.e.)	$\hat{t}o$ (s.e.)	$\hat{\sigma}_1^2$	$\hat{\sigma}_2^2$	Ln (L/K)
Male	2223	68.33 (1.65)	0.111 (0.006)	-2.26 (0.10)	10.04	-	3675.59
Female	1523	65.70 (2.67)	0.109 (0.009)	-2.30 (0.12)	-	8.42	2383.99
Combined	2223,1523	69.90 (1.56)	0.103 (0.005)	-2.30 (0.08)	10.54	9.16	6176.55

Test for differences: $T = -2\left(\ln(L/K)_{combined} - \ln(L/K)_{male} - \ln(L/K)_{female}\right)$

$$\approx X_2^2$$

Here $\hat{T} =$ 233.9, which is very highly significant

Figure 7: The von Bertalanffy Growth Curves for *L. chrysostomus* males and females sampled on Norfolk Island during the period December, 1981 to January, 1983.



$$L_t = 68.3\{1-\exp[-0.111(t+2.26)]\}$$

for males, and

$$L_t = 69.9\{1-\exp[-0.103(t+2.30)]\}$$

for the sexes combined. The maximum likelihood ratio test of Kirkwood (1983) showed that the curves for males and females are significantly different ($P<0.001$)(Table 3).

The observed maximum lengths during the period of study were 66cm and 59cm for males and females, respectively.

The von Bertalanffy growth curves for female and male *L. chrysostomus* are shown in Figure 7.

Length - Weight Relationships

The values of parameters obtained by least squares regression analysis for the length-weight relationship $W = L^b$, where W is the whole fish weight in grams and L is the fork length in centimeters, are as follows:

	a	*b*	r^2	*n*
Females	-18.77	0.02	0.99	349
Males	-9.85	0.0196	0.98	403

Figure 8: Length frequency distributions by area of fishing operations for *L. chrysostomus* sampled on Norfolk Island during the period December, 1981 to January, 1983.

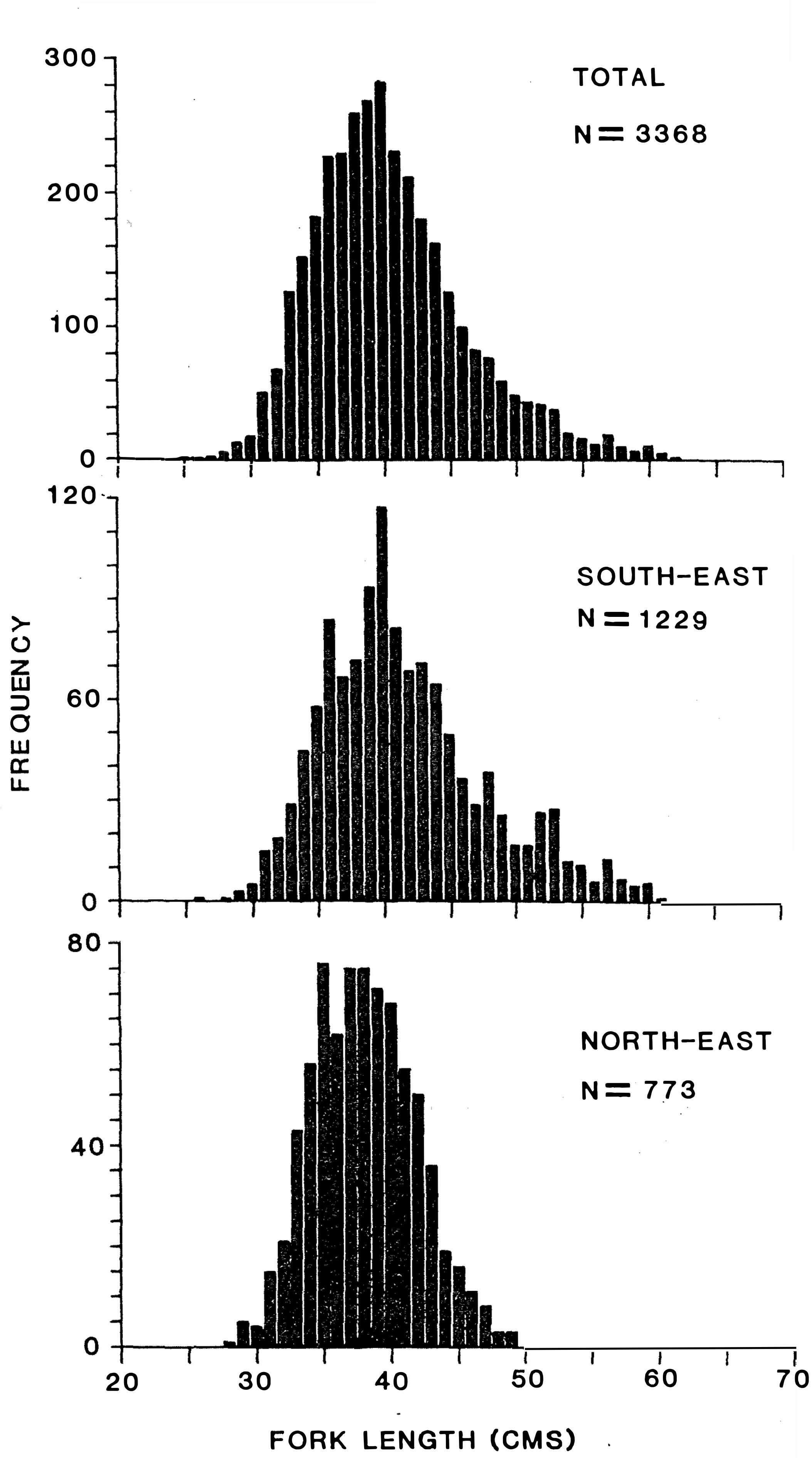
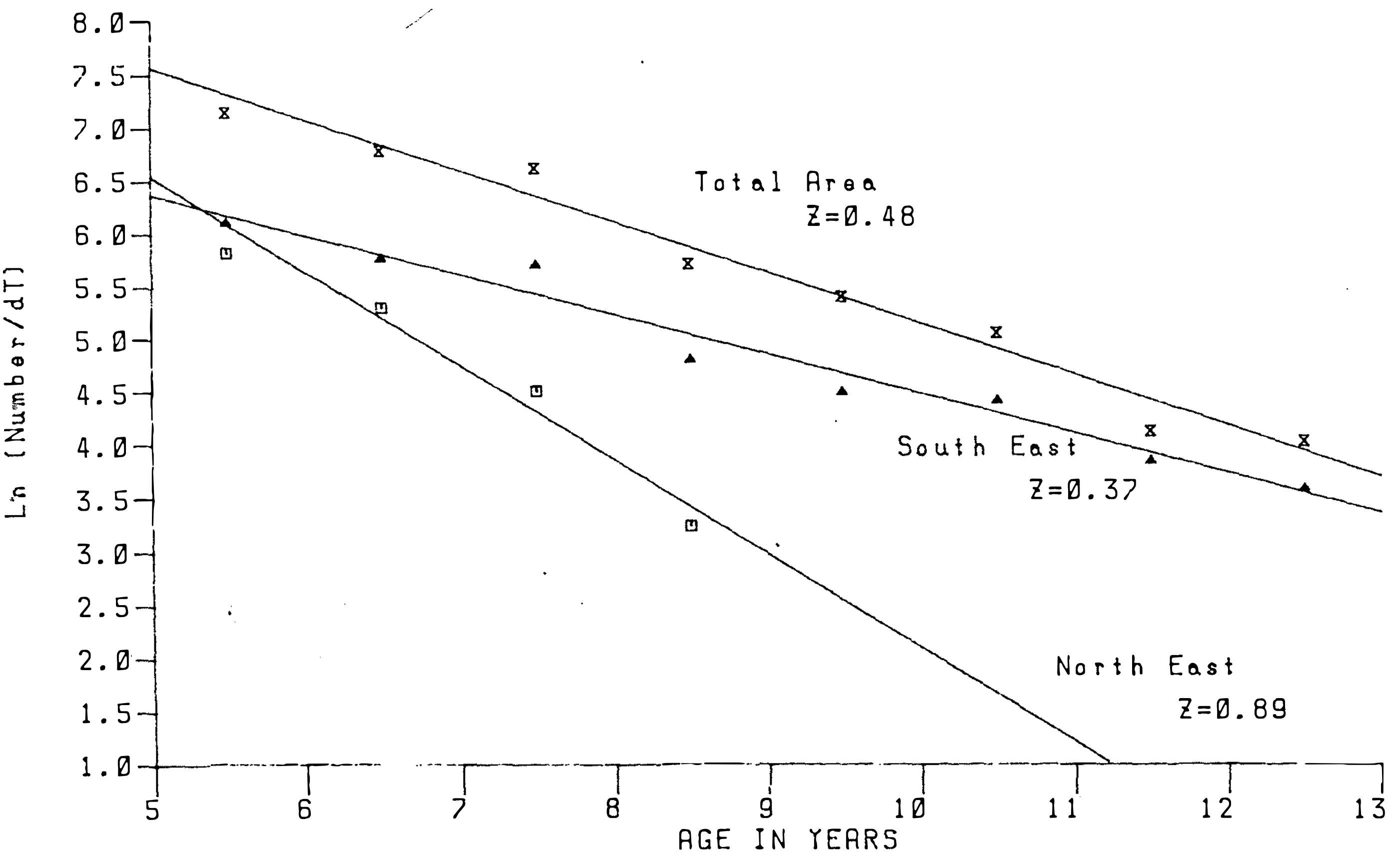


Figure 9: Log$_e$ (abundance) versus age by area of fishing operations for *L. chrysostomus* sampled on Norfolk Island during the period December, 1981 to January, 1983.



Male and female length-weight relationships were significantly different (95% confidence limits).

Total Instantaneous Mortality (Z) Estimates

The length frequency distributions for north-east (<12 nautical miles from Norfolk) and south-east (12-20 nautical miles from Norfolk) fishing areas together with the combined distribution from various areas are shown in Figure 8. The combined distributions are considered to be reasonably representative of the total stock as 41% of the distribution comes from areas other than the north east and south east areas of fishing operations.

Significant differences were observed between the Z estimates for the north-east area and those from the south-east area (t_7=3.4898, $p<0.02$) and combined distributions (t_{13}=3.37, $p<0.01$). The north east area had a significantly greater total mortality rate than the other areas. The total mortality rates for the south east and combined areas did not differ significantly (t_{11}=1.0199, $p>0.2$).

9.4. Discussion

Values of the growth curve parameter t_0 for the combined sexes were similar for the Norfolk Island and Queensland *L. chrysostomus* populations. The predicted asymptotic length L_∞ for the Norfolk Island population was considerably greater, however, than that estimated for the

Queensland population. The maximum age of individuals sampled by Walker (1975) was 7+, whereas here several 10+ to 13+ individuals were encountered. The initial growth rate of Queensland fish was found to be greater than those from Norfolk Island.

While fishing pressure may cause the greater total mortality for the north east fishing area, it should be noted that many local fishermen believe this area was never inhabited by large fish. Ease of access to the area from Cascade pier, however, and its relative closeness to the Island make it susceptible to overfishing.

Total mortality estimates have not been resolved into natural and fishing mortality components. An evaluation of methods using catch and effort data will be undertaken and reported on at a later date.

Data collected here form the basis for future comparison, particularly values of the three growth curve parameters, length frequency distributions and total mortality estimates.

10. REPRODUCTION

10.1. Introduction

Despite the commercial importance of several members of the family Lethrinidae in the Indo-Pacific region their reproductive biology is not well known.

Young and Martin (1982) who investigated protogynous hermaphroditism in eight species of Lethrinidae (including *L. chrysostomus*) from the north-west Shelf and Gulf of Carpentaria waters found that ovaries of all species formed corpora atretica at various stages including brown bodies as first described by Chan, Wright and Phillips (1967). These brown bodies were subsequently observed by Young and Martin in the testes of all species embedded in the testicular lamellae. Furthermore, all species showed secondary testes. This type of testicular structure, termed secondary male morphology by Reinboth (1967), suggests that these males had undergone a sexual transformation. Further evidence for protogynous hermaphroditism was also demonstrated by male dominance of the larger size classes and female dominance of smaller size classes in five species.

Loubens (1980) reported size-related discrepancies from the expected 0.5 ratio of males to females in six species of the family Lethrinidae from New Caledonia and suggested that in *L. chrysostomus*, *L. lentjan* and *L. variegatus* this may be due to sequential hermaphroditism. Lebeau and Cueff (1975), however, observed an overlap in the size distribution of males and females of the Indian Ocean species *L. enigmaticus* but concluded that the difference was due to sexually differential growth rates and not to sex reversal.

In consideration of the importance of sexuality and reproduction of *L. chrysostomus* in providing population stability it was decided to investigate them in detail.

Table 4.

VISUAL STAGING CATEGORIES FOR FISH GONADS*

1. Gonads small strap-like, testes with sharper edges than ovaries.

2. Developing virgin or recovering spent.Gonad smaller in developing virgin than recovering spent.

3. Ovaries opaque, eggs not discrete macroscopically. In males milt not expressed.

4. Individual ova clearly seen, ovaries not yet full sized. In males milt not expressed.

5. Ovary becoming transparent, ova not expressed by pressure on belly. Milt expressed by pressure on testes but not on belly.

6. Running ripe. Eggs and milt expressed by pressure on belly.

7. Spent. No ova or milt expressed by light stripping. Ovaries and testes blood-shot and flacid.

*Blackburn, M. and Gartner, P.E. (1959). Barracouta in Australian Waters. Aust. J. Mar. Freshw. Res. P411-468.

10.2. Methods

Amateur and commercial catches were sampled regularly at either the Cascade or Kingston piers, between December, 1981 and February, 1983. Whole catches were intercepted prior to processing and the fork length (F.L.) to the nearest centimetre, sex, gonad stage and fishing area were recorded. Sexual staging followed Blackburn and Gartner (1959) (Table 4).

A subsample of fish was weighed, then dissected and the gonads removed and preserved in 10% formalin. Upon return to the laboratory, female gonads were blotted dry and then weighed to the nearest 0.01gms.

For preliminary histological examination 56 male gonads, representative of the length range, were sectioned medially (8um) after paraffin embedding: of these, thirty four gonads were also sectioned proximaly and distaly.

Data analysis

Sex Ratio & Length-The null hypothesis that the sex ratio was unrelated to fork length was tested by a weighted linear regression of the estimated sex ratios in eight size categories against the median length of each size class. The signifcance of the regression was tested by a X^2 test with one degree of freedom (Cochran, 1954). A significant result implied changes in sex ratio linearly related to fork length.

Population Structure-The length frequency distributions of *L. chrysostomus* males and females were

Table 5: The Percentage of *L. chrysostomus* females occurring at various stages of gonad development during the spawning seasons of 1982 and 1983, Norfolk Island.

MONTH	Visual Stage of Gonad Development				
	Devlp'g	Ripen'g	Running Ripe	Spent	N=
Jan'82		9.1	77.3	13.6	44
Feb'82			51.5	48.5	101
Apr'82			9.3	90.7	86
May'82				100.0	87
Dec'82	7.2	23.2	69.6		56
Jan'83	7.6	42.4	28.3	21.7	92

TABLE 6: Sex Ratio of *L. chrysostomus* females to males sampled during the period 1981 to 1983, Norfolk Island.

FEMALES		MALES	
Obs.freq	Exp.freq	Obs.freq	Exp.freq
1107	903.5	700	903.5

Oberved Sex Ratio = 1.58:1(females to males)

X^2_1 = 91.67 ($p<0.001$)

Reject null hypothesis: the ratio of females to males differs significantly from a 1:1 ratio.

compared by establishing 95% confidence limits about their mean fork lengths. A lack of overlap implies significant differences between the length frequency distributions of the two sexes.

10.3. Results

Spawning Period

A single protracted spawning season was observed in both the summers of 1981-82 and 1982-83. The percentage of *L. chrysostomus* females occurring at various stages of gonad development during the spawning seasons are shown in Table 5. While spawning occurred from October to April each year, the main spawning events occurred from December to February.

Many partially spent females were observed during the later stages of both spawning seasons. Their ovaries were slightly flaccid and small, occupying little of the body cavity. Numerous mature oocytes could be seen through the thin ovary wall and slight pressure resulted in stripping. While females may undergo a single spawning event, a protracted sequential spawning, seems more probable.

Sex Ratio

Of the 1807 *L. chrysostomus* examined 1107 were females and 700 were males, resulting in a sex ratio of 1.58:1 (females:males). The X^2 value in Table 6 shows significantly more females than males.

TABLE 7: Comparison of sex ratios for *L. chrysostomus* males and females taken in inshore and offshore areas of fishing operations during the period 1981 to 1983, Norfolk Island.

Area of Operation	FEMALES Obs.freq.	Exp.freq.	MALES Obs.freq	Exp.freq.	X^2
INSHORE (<5.0nm)	294	261	228	261	8.3448
OFFSHORE (>5.1nm)	813	642.5	472	642.5	90.4910
	1107	903.5	700	903.5	98.8358

χ^2_{TOTALS} = 91.6707
TOTAL χ^2 = 98.8358
$\chi^2_{1\ (HET)}$ = 7.1651 (0.001<pr<0.01)

Conclusions:

The sex ratio differed significantly from a 1:1 ratio in inshore areas (0.001<pr<0.01).
The sex ratio differed significantly from a 1:1 ratio in offshore areas (pr<0.001).
The two areas were not homogeneous in respect of sex ratio.

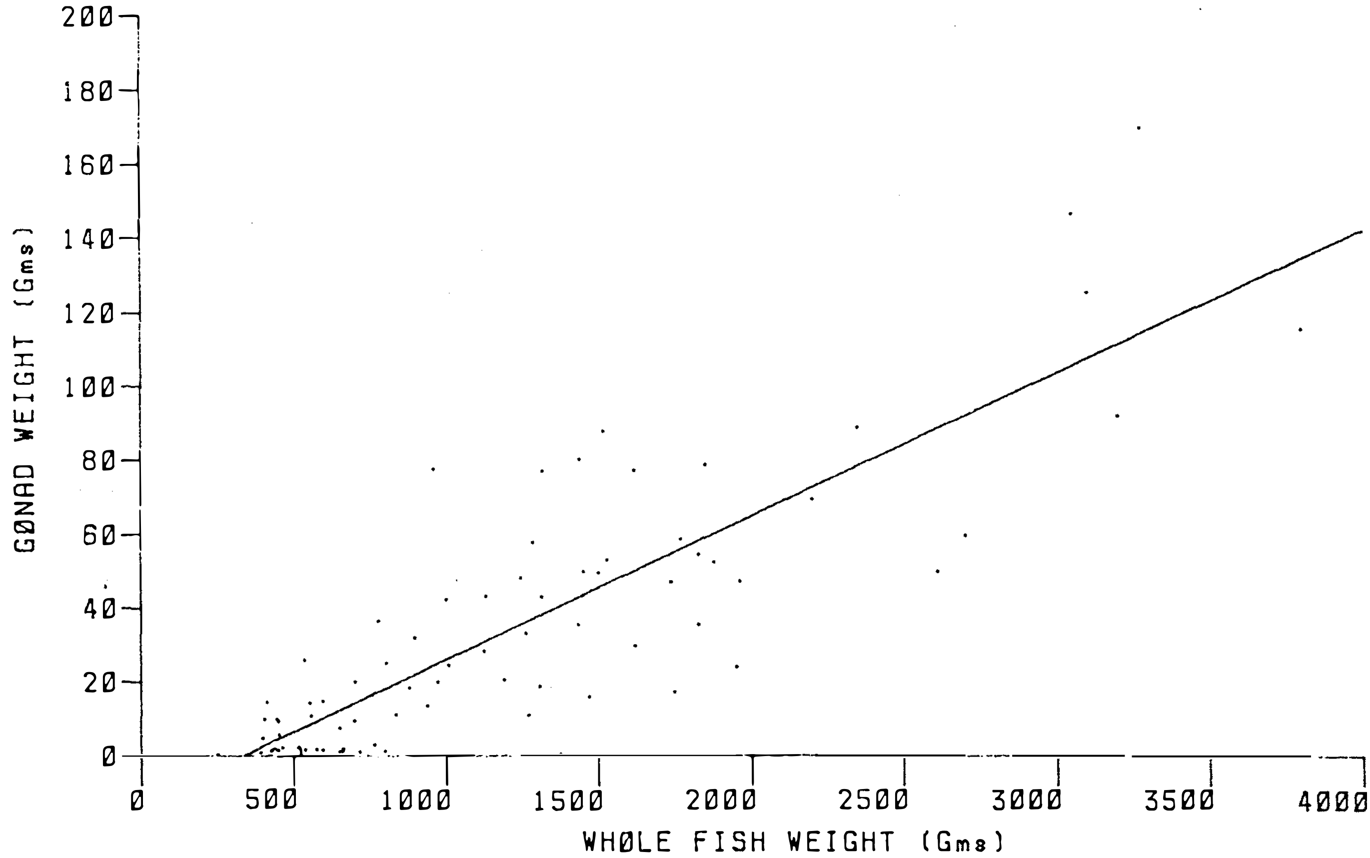
TABLE 8: Comparison of L.chrysostomus sex ratios by month during the period December, 1981 to January, 1983 Norfolk Island.

MONTH	FEMALES Obs.freq.	FEMALES Exp.freq.	MALES Obs.freq.	MALES Exp.freq.	X^2	PROB.
DEC'81	349	262.5	176	262.5	57.0076	Pr<0.001
JAN'82	44	32.5	21	32.5	8.1385	Pr<0.01
FEB'82	393	320.5	248	320.5	32.8003	Pr<0.001
APR'82	86	70.5	55	70.5	6.8156	Pr<0.01
MAY'82	87	83.5	80	83.5	0.2934	N.S.
DEC'82	56	57.5	59	57.5	0.0783	N.S.
JAN'83	92	76.5	61	76.5	6.2810	Pr<0.02
	1107	903.5	700	903.5	111.4147	

χ^2_1 TOTALS = 91.6707
TOTAL χ^2_6 =111.4147
χ^2_6 (HET) = 19.7440 (0.001<pr<0.01)

Reject null hypothesis - months are not homogeneous in respect of sex ratio.

Figure 10: The gonosomatic index for *L. chrysostomus* females sampled on Norfolk Island during the period December, 1981 to January, 1983.



Inshore and offshore areas had different sex ratios (Table 7): offshore the ratio of females to males was 1.7:1 while inshore it was 1.1:1.

Sex ratios also changed with time (Table 8). In December, 1981 the greatest variability occurred when the ratio was 1.98:1, while the ratios in May and December 1982 did not differ significantly from a 1:1 ratio.

Size at First Maturity

The smallest individual encountered was a 0+ juvenile of 20cm F.L. Juveniles ranged from 20-30cm F.L.

The smallest female found to contain ripe eggs (after Blackburn and Gartner,1959) was 23cm F.L. The mean length of females at first maturity (i.e., the mean length of developing female virgins containing differentiated eggs) was 27.8cm F.L.(n=53).

The smallest male from which milt could be expressed by applying slight pressure to the belly was 25cm F.L.

Gonad Index

The gonad index (G.I.) or relationship between gonad weight and whole fish weight (WW) for *L. chrysostomus* females is shown in Figure 10. It is best described by the linear regression where:

$$G.I. = -12.963 + 0.039*WW$$

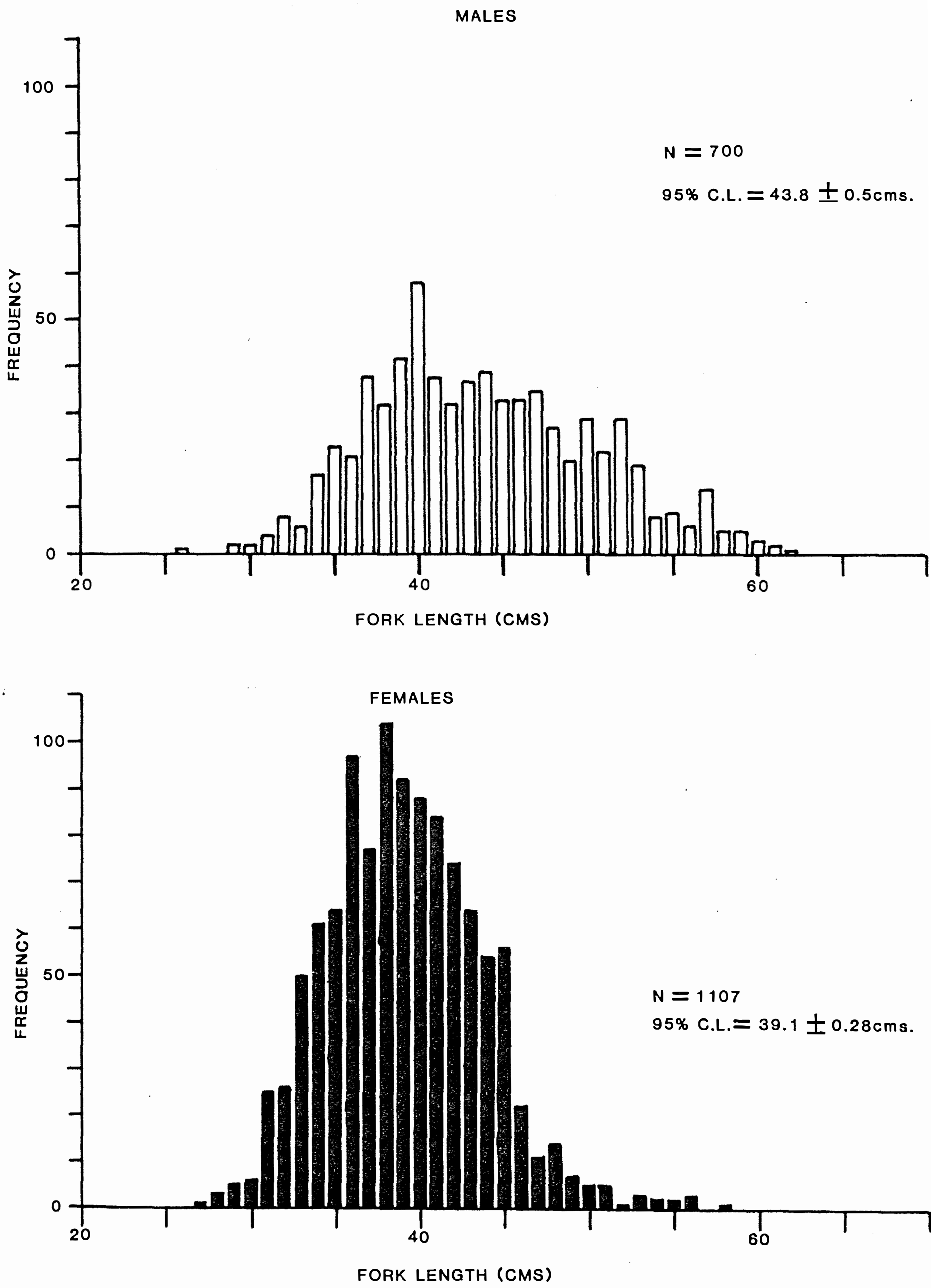
TABLE 9: The numbers of *L.chrysostomus* females and males occurring in length classes as sampled during the period 1981 - 1983, Norfolk Island.

MEDIAN LENGTH	28.5	33.5	38.5	43.5	48.5	53.5	58.5	63.5
No.of Females	15	226	458	332	59	13	4	0
No.of Males	5	58	191	179	144	87	33	3

$\chi^2_1 = 100.42 \quad (P<0.001)$

Reject null hypothesis - Sex ratio is related to length.

Figure 11: Length frequency distributions for *L. chrysostomus* males and females sampled on Norfolk Island during the period December, 1981 to January, 1983.



$(n=81, T=14.6, r^2 = 0.85)$

The mean gonad and whole fish weights were 34 grams and 1203 grams, respectively.

The whole fish weight when G.I.= 0 was 332 grams or 25.9cms F.L. (where $L = W^{0.333}$, $a = 0.697$, $b = 3.6362$).

Hermaphroditism

Sex Ratio and Length: The raw data and significant X^2 value (Table 9) show that sex ratio changes linearly with length. Changes in sex ratio with length are assumed to be indicative of sex change.

Population Structure: The length frequency distributions of males and females (Figure 11) show considerable overlap: males dominate the upper size classes (45-65cm FL) and females dominate the lower size classes (28-45cm FL). The two distributions were significantly different ($p<0.05$).

The observed differences in length frequency distributions can be explained at least partially by the different growth rates for males and females (Table 3).

Histology

Secondary Male Morphology: Histological examination of male gonads revealed secondary male morphology in all cases. No evidence of a primary male morphology or residual oviduct was encountered even in the smallest male testes sectioned (25cm FL).

Residual Ovarian Material in Male Gonads: No evidence of degenerating oocytes, brown bodies or lymphocytic infiltration was found in the testicular lamellae of male gonads.

10.4. DISCUSSION

The lack of *L. chrysostomus* juveniles (<20cm F.L.) in the catch was similarly reported by Walker (1975). He suggested that juveniles are located in deeper waters, out of the range of skindivers and fishing operations. They may also have pelagic post-larvae and early juvenile stages.

Changes in sex ratio linearly related to length and significant differences in length frequency distributions support the theory that protogynous hermaphroditism is the normal mode of sexuality in *L. chrysostomus* in Norfolk Island waters. The possession of secondary male morphology is inconclusive as evidence of sex change as a primary male morphology was not demonstrated.

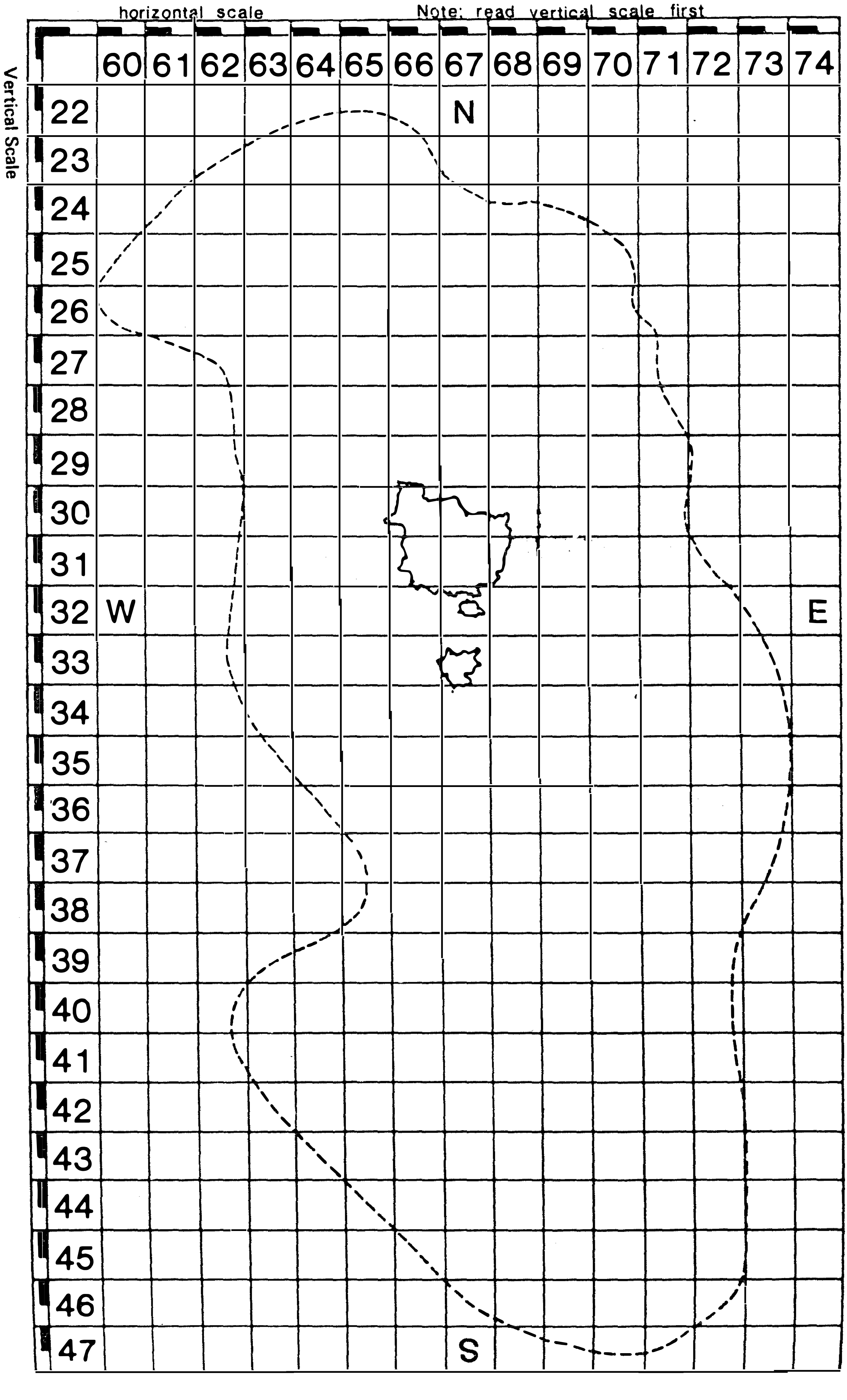
The histological examination of testes failed to detect the co-occurrence of ovarian and testicular material. This examination is inconclusive, however, due to the limited sample size. Further male gonad samples must be collected. Female gonads must also be collected to examine degenerating oocytes and brown bodies. These results will be reported later.

The female gonosomatic index indicates linearly increasing gonad and whole fish weights, implying increasing fecundity with age. This needs further research: the removal

TABLE 10: Summary of *L. chrysostomus* dietary components.

Food Item	% Occurrence	% Diet Composition
Crab	20.8	34.4
Sea urchins	13.3	19.3
Gastropods & Bivalves	15.3	10.9
Fish Remains	2.9	2.4
Plant Material	3.7	0.4
Squid	0.3	0.1
Octopus	0.4	0.3
Asteriodea	1.9	0.8
Ophiuroidea	0.8	0.6
Criniod	0.3	0.2
Polychaetes	0.4	0.1
Nematodes	0.1	0.1
Stomatopods	0.4	0.1
Bryozoans	0.6	0.3
Nudibranchs	0.2	0.1
Opisthobranchs	1.4	0.3
Prawn Remains	2.4	0.8
Semi-digested Material	21.2	22.4
Coral Debris	13.6	6.5

Figure 12: The Norfolk Island domestic fishery log book grid map.



of large females may be partially responsible for the suggested decline in stock size.

11. FEEDING HABITS

To investigate the feeding habits of *L. chrysostomus* in Norfolk Island waters, 257 stomachs and intestines were collected from fish over a representative length range for each sex between December, 1981 and January, 1983. As specimens still require identification, only preliminary results are presented here (Table 10).

The statistics shown are:

a. *Percentage Occurrence*-the proportion of the sample containing a particular food item.

b. *Percentage Diet Composition*- the relative volumes of food items making up the diet.

The major dietary items are crabs (34.4%), sea urchins (19.3%), gastropods and bivalves (10.8%) and fish remains (2.4%).

12. LOG BOOK INFORMATION

In order to obtain catch and catch per unit of effort (CPUE) statistics, a log book was designed and issued to fishermen at the commencement of the program. Log book records were kept on the basis of a grid map (Figure 12). The origin of grids occurs at the intersection of 168° E longitude and 29° S latitude. The surrounding ocean, to the 100 metre isobath, is divided into two minute grid squares

NORFOLK DROP–LINE FISHING LOG

Log No.

5	0 1	C	3666
1	2 3	4	5 … 8

Boat Name: ....

Starting Date of this page: Day [9 10] Month [11 12] Year [13 14] [15 … 22] [N F 23 24]

	Operation Number	Date: Day	Month	Year	Grid Fished	Time Fishing Started	Time Fishing Finished	Hours Fished in Grid	No. of Fishermen	No. Lines Used	Average Number Hooks per Line	Catch Details (Whole Weight in kgs): Trumpeter	Red Snapper	Snapper	Harpuka	Other
1	2 - 3	9 - 10	11 - 12	13 - 14	15 - 18	19 - 22	23 - 26	27 - 30	31	32 33	34-35	36 - 39	40 - 43	44 - 47	48 - 51	52 - 55
A	1															
A	2															
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A	5															
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A	22															
A	23															
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A	25															

F /82

FIGURE 13: Sample of a Norfolk Island log book page.

TABLE 11: Summary of the Norfolk Island Log Book Data for the period February, 1982 to December, 1983.

SPECIES	TOTAL CATCH (whole wt.in kgs)	NUMBER OF RECORDS
L. chrysostomus (Trumpeter)	38615	366
E. rhyncholepis (Red snapper)	4804	25
C. auratus (Snapper)	844	35
P. lanceolatus (Harpoeka)	3037	73
Other	2427	141
TOTAL	49727	378

FIGURE 14: Total catch of all species by grid for the period February, 1982 to December, 1983.

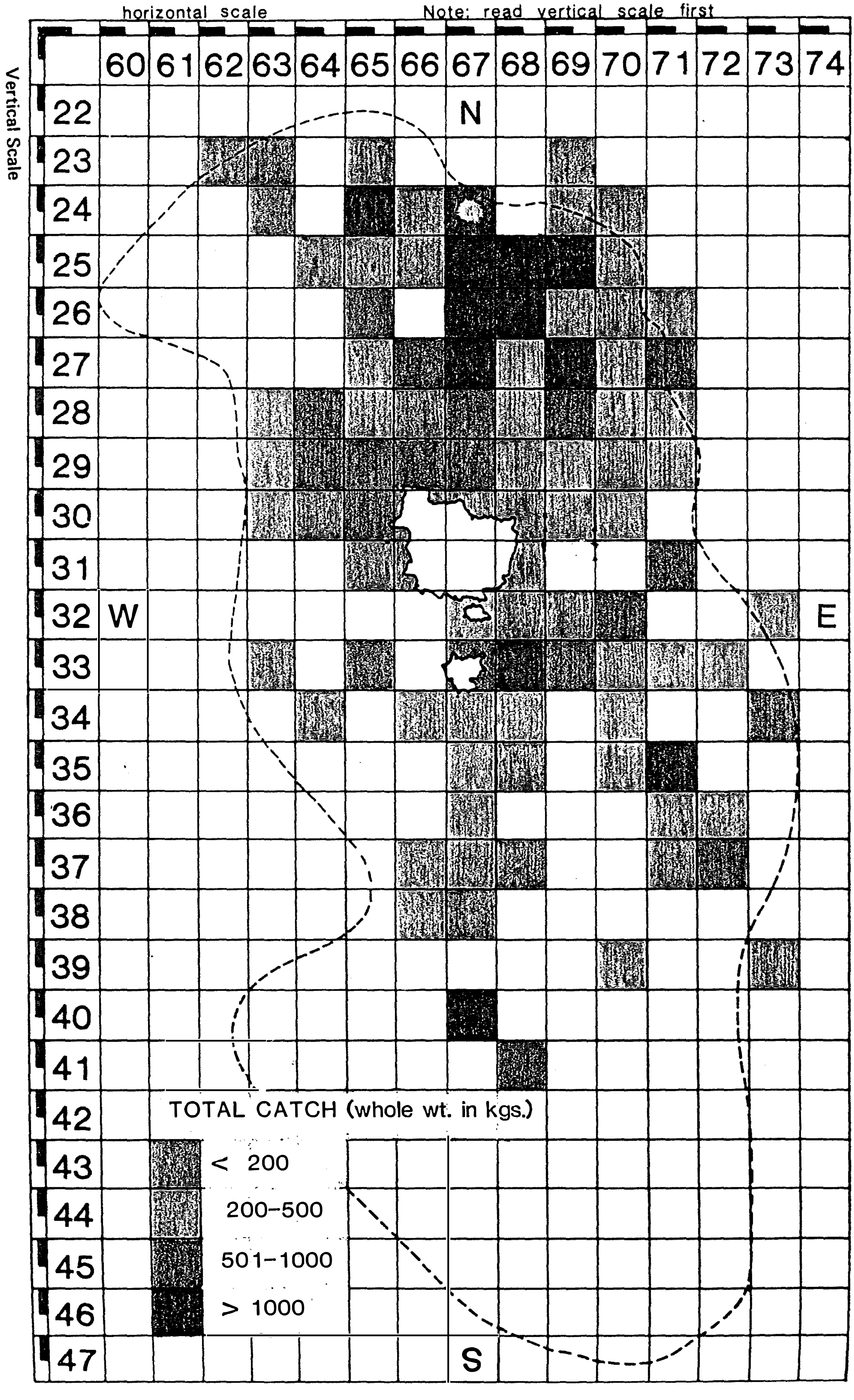
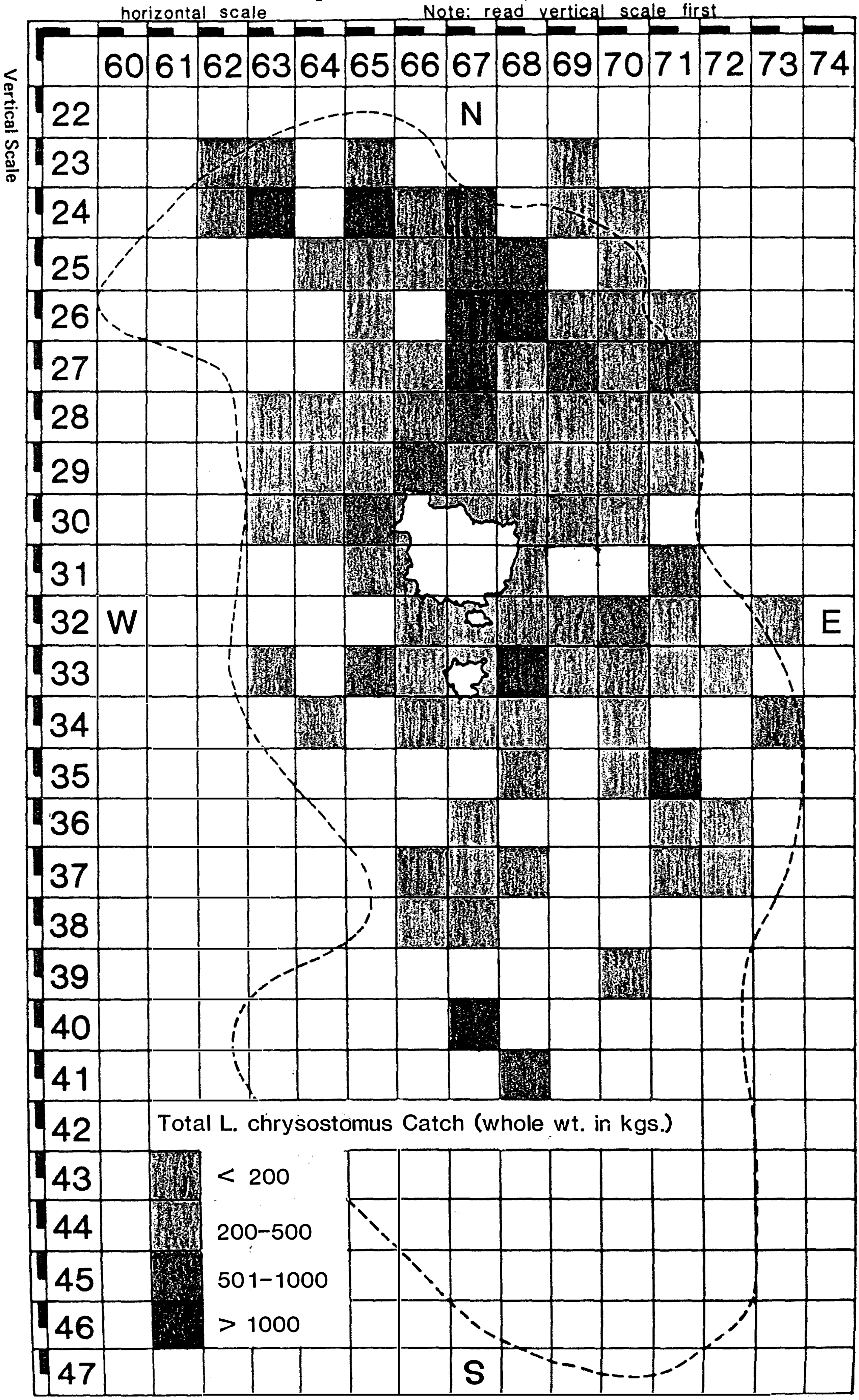


FIGURE 15: Total L. chrysostomus catch by grid for the period February, 1982 to December, 1983.



i.e., each grid square is four square nautical miles. Having located the approximate location of fishing operations relative to the island, catch and effort details were entered by the fishermen on the log book page (Figure 13).

Of the thirty-three log books issued, twelve were kept diligently to record daily fishing operations. This resulted in a total of 378 individual records between February, 1982 and December, 1983. These data are estimated to represent approximately 25% of the total landings during this time and are summarised in Table 11.

The catch is dominated by *L. chrysostomus*, constituting 77.7% of the total catch by weight followed by *E. rhyncholepis* and *P. lanceolatus* providing 9.7% and 6.1%, respectively. The 'others' catch comprises mainly pelagic species such as kingfish (*Seriola dumerili*), yellowfin tuna (*Neothunnus macropterus*) and skipjack tuna (*Katsuwonus pelamis*) some of which were taken by floating lines whilst operators handlined for demersal species.

The total catch of all species and the total *L. chrysostomus* catch for each grid between February, 1982 and December, 1983 are shown in Figures 14 and 15. While the contribution made by each grid to the total catch is evident these figures do not show relative abundance as there is no indication of the effort expended per grid.

The most useful catch and effort statistic is that given by the equation

$$\text{CPUE} = \sum_{i=1}^{n} C_i / L.H = A$$

FIGURE 16: The mean *L. chrysostomus* catch Per Unit of Effort by grid for the period February, 1982 to December, 1983.

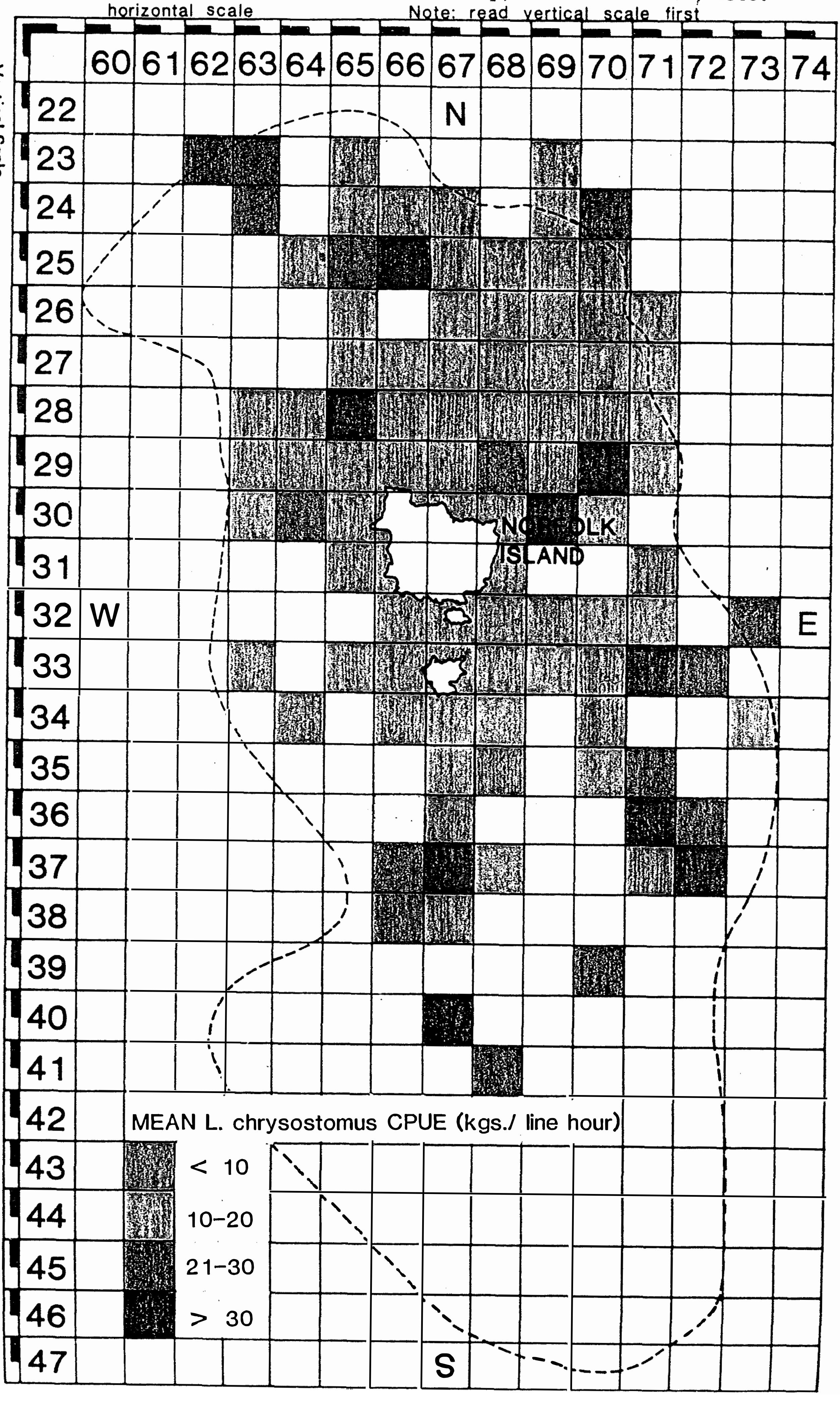
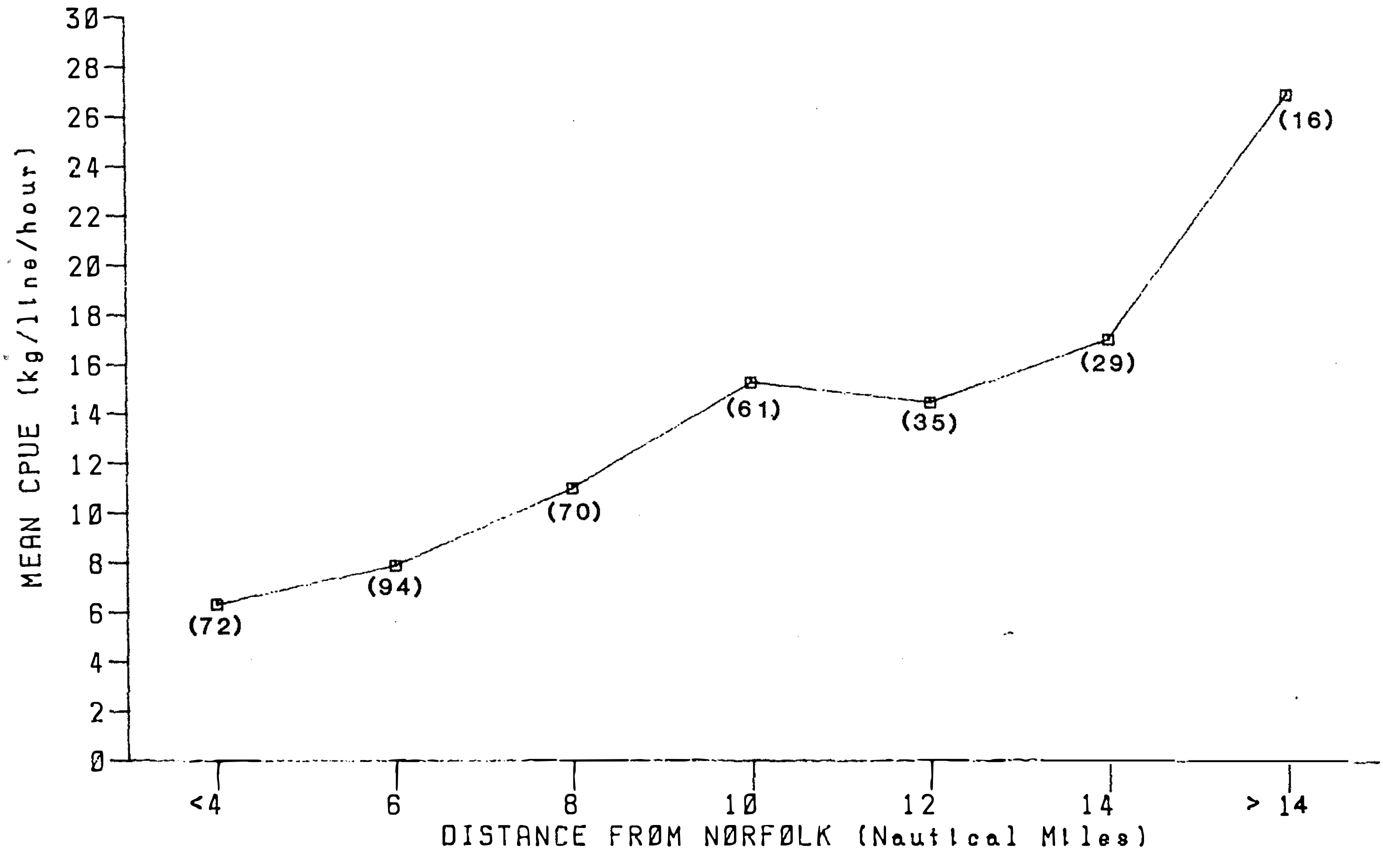


Figure 17: The mean *L. chrysostomus* catch per unit of effort with increasing distance from Norfolk Island.

(Note: Values in parentheses are the number of records for each zone)



where,

$$\sum_{i=1}^{n} C$$ = Sum of the catch (whole weight in kilograms) for grid i.

L = Total number of lines used in grid i.

H = Total number of fishing hours in grid i.

Thus, the CPUE for any grid is the total catch in that grid divided by the number of line hours. Similarly, the mean CPUE for any grid is the CPUE divided by the total number of records (N) for that grid as follows:

$$\bar{X} \text{ CPUE} = A/_{N}$$

The mean *L. chrysostomus* CPUE by grid during the period February, 1982 to December, 1983 are shown in Figure 16. It can be seen that inshore areas generally yield a lower mean CPUE than offshore areas.

To assess changes in the mean CPUE with increasing distance from Norfolk Island, the continental shelf was divided into zones. The CPUE for all grids in a zone were summed and the resultant divided by the total number of records for that zone. Figure 17 shows a plot of the mean *L. chrysostomus* CPUE with increasing distance from Norfolk. It can be seen that there is a significant increase in the mean CPUE with increasing distance from the island suggesting near-shore populations are depleted.

13. SUMMARY

Fishing enterprises, particularly those involving a central processing facility, were uneconomical due to variable weather and the lack of a small boat harbour. The fishery will probably remain a small domestic industry with one or two full-time commercial operators together with a number of part-time fishermen catering to the local domestic market. Fishing provides supplementary incomes to many families, an inexpensive source of protein, together with multiplier effects and reductions in the trade deficit.

The lack of historical data of the Norfolk Island domestic fishery, particularly catch and effort information, has limited this research. Of particular interest are increasing boat numbers and effort in the fishery. Without adequate formatted historical catch and effort information an assessment of this type cannot be made.

The current log book program yielded results on the increasing catch per unit of effort with increasing distance from the Island. In the light of the Van Pel report it appears that inshore stocks have declined.

Due to the dominance of *L. chrysostomus* in the catch, a life history study was undertaken. While certain areas remain inconclusive, these data provide the basis for future fisheries management research.

14. MANAGEMENT

Several meetings were held with members of the Norfolk Island Fishing Club to discuss fisheries management. On the one hand it was argued that variable weather conditions, lack of a harbour and the limited nature of the domestic market would provide a natural form of management. On the other hand it was suggested that a significant decrease in catch rates had already occurred and active management was required. In consideration of the data presented here, and erring on the side of caution, any significant increase in fishing effort warrants active management.

Legislation was passed in 1984 to ban the export of fresh fish products from Norfolk Island. This was a positive step in the direction of active management without placing catch restrictions on the fishermen and creating unnecessary administration.

Should any significant increase in effort occur, however, three forms of management are presented for consideration:

1. The introduction of legislation limiting the amount of fishing effort in areas of concern. This system would involve the elucidation of areas in need of restrictions and would be difficult to enforce.

2. By dividing the resource amongst a hierarchy of users. This system would involve licensing and catch restrictions according to the type of user. For example, a commercial fisherman would be entitled to a greater daily catch than a recreational fisherman.

3. A third management option exists in the form of mutual agreement amongst the Norfolk Island fishermen that particular areas be allowed to recuperate. Furthermore, increased effort could be directed towards pelagic species.

An integral part of any management system implemented on Norfolk Island, should be the introduction of a log book. The importance of these data in securing a sustainable fish yield cannot be over emphasised.

15. FUTURE RESEARCH

The following areas are indicated as those in need of further research:

1. The further investigation of protogynous hermaphroditism and age specific fecundity in *L. chrysostomus*.

2. Estimation of the natural and fishing mortality coefficients.

3. The continued collection and assessment of length frequency data.

4. The continued collection and assessment of log book data.

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