D. J. Jellyman

NEW ZEALAND MARINE DEPARTMENT
FISHERIES TECHNICAL REPORT
No. 8

Biological and Economic Aspects of the Elephant Fish *Callorhynchus milii* Bory in Pegasus Bay and the Canterbury Bight

T. B. S. Gorman

WELLINGTON, NEW ZEALAND 1963

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BIOLOGICAL AND ECONOMIC ASPECTS OF THE ELEPHANT FISH, CALLORHYNCHUS MILII BORY, IN PEGASUS BAY AND THE CANTERBURY BIGHT

I. INTRODUCTION

(a) Purpose of Investigation

The recent big increase in the production of elephant fish in Canterbury waters has caused some concern among local fishermen and others associated with the fishing industry. The purpose of this investigation was essentially a reconnaissance of the fishery to determine what problems existed, so that future research, if required, could be directed towards well-defined, specific objectives. Owing to other commitments, it was not possible to collect data on a fully systematic basis; information was mainly collected when and where opportunity permitted. This has limited the usefulness of this work and much of the data, particularly on growth and population structure, is incomplete. However, the investigation has fulfilled to some extent its original purpose as a preliminary study.

(b) Areas of Investigation

The area subjected to the most intensive investigation was Pegasus Bay, though some sampling was done at Kaikoura and in the Canterbury Bight. Work commenced in November 1960 and was completed by December 1961.

(c) Systematic Position

The elephant fish, Callorhynchus milii Bory is the New Zealand and Australian representative of the family Callorhynchidae, of which there is a single genus

Callorhynchus. Phillipps (1927) lists the synonymy of the New Zealand species, and the naming adopted is his. Fowler (1941) lists the species of the genus, together with their description, distribution and synonymy.

(d) Distribution

The genus Callorhynchus Lacépède is restricted to the subantarctic basin, being found in South Africa, Australia, New Zealand, Patagonia, Chile and Argentina (Whitley, 1940; Fowler, 1941). In South Africa, according to Smith (1954), it is known from Walvis Bay to Durban. In Australia, it is found in Victoria, South Australia and Tasmania, and has been doubtfully recorded from Western Australia (Whitley, 1940). Whitley gives its depth range as between 5 and 30 fathoms, and records it in Tasmania as ascending rivers and harbours in large numbers.

The range of the species in New Zealand can now be defined with some degree of accuracy (Fig. 1). It occurs throughout the South Island, including Stewart Island, while on the east coast of the North Island it ranges as far north as East Cape. On the west coast of the North Island occasional specimens have been taken just to the north of the Kaipara Bar, though it is not usually found in any quantity north of Wanganui (Sampson, pers. Comm.). According to Waite (1909), it is not known from the Chatham Islands.

The distribution of the species in time and space varies according to size, with the present known range extending from very shallow water (2-3 feet) out to at least 100 fathoms. Waite (1909) records it down to 102 fathoms.

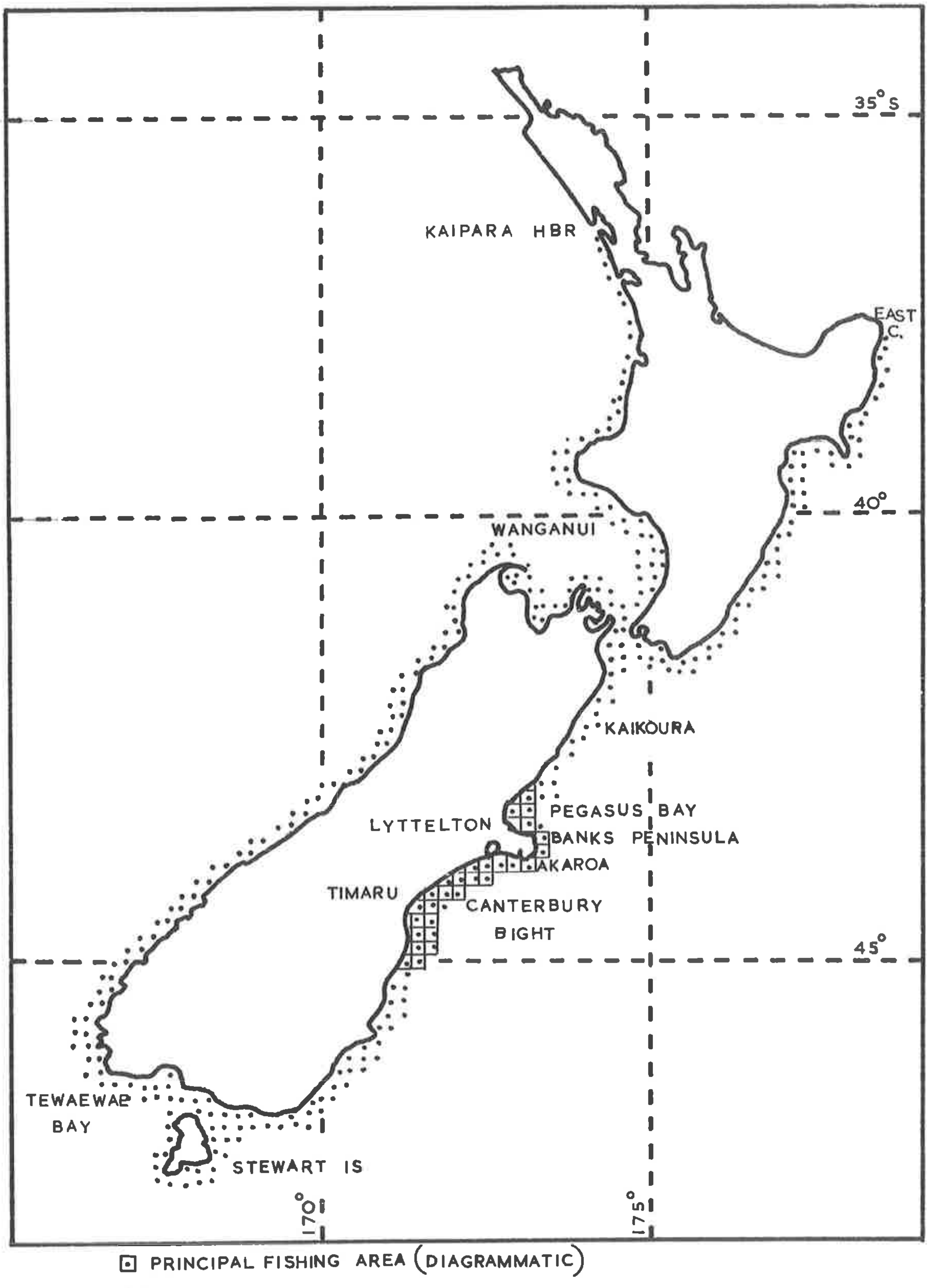


Figure 1. The general distribution and principal fishing areas for Elephant fish in New Zealand.

Owing to the present distribution of fishing effort, it has not been recorded at deeper levels, but there is some circumstantial evidence that mature adults, particularly females, move over the edge of the continental shelf and spend part of the non-spawning phase in deep water. Typically, the species is benthic, preferring smooth mud or a sandy bottom.

(e) Account of the Fishery - Past and Present

Although the species is caught throughout its range, there is little demand for it in the North Island. It is landed in commercial quantities from Wellington southwards, but it is only fished extensively in Pegasus Bay and Canterbury Bight. In Otago and Southland, due to more lucrative returns from crayfish fishing, local resources remain under-developed, although in recent years freezer-equipped vessels from Timaru are tending to take advantage of this situation. In 1960 the catch landed at the three canterbury ports, Lyttelton, Akaroa and Timaru, amounted to 20,386 cwt out of a New Zealand total of 22,386 cwt, or nearly 89% of the total. Over the period 1945-1960 the percentage of the total landings has remained high, and fairly constant, although there is possibly a small decrease in recent years, indicating that other areas are beginning to develop their own resources (Table 1).

Table 1 The Canterbury Ports' Catch of Elephant Fish expressed as a Percentage of the overall landings for New Zealand

Year	Overall Total in cwt.	Total from Canterbury ports in cwt.	Percentage of overall total
1945	4269	3825	89.5
1946	4639	4324	93.2
1947	3718	3402	91.5
1948	4701	4436	94.3
1949	6146	5652	91.9
1950	10829	9550	88.2
1951	11826	11146	94.2
1952	8945	8226	91.9
1953	10474	9507	90.7
1954	16780	16123	96.0
1955	15788	14560	92.2
1956	19296	17301	89.6
1957	21044	17430	82.8
1958	24381	20353	83.4
1959	22595	19329	85.8
1960	22908	20386	88.9

The early years of the fishery were characterized by the general prejudice against all things labelled "shark", and earlier writers, Waite (1909) and Thompson & Anderton (1921) noted that large quantities were taken and subsequently discarded as worthless. According to Graham (1956) filleted fish under various trade-names enjoyed a brief spell of popularity during the 1914-1918 war. However, by 1930 the species was again out of favour. On the other hand, Phillipps (1918, 1921) and Graham (1956) state that in 1918 and again in 1934 this species was in

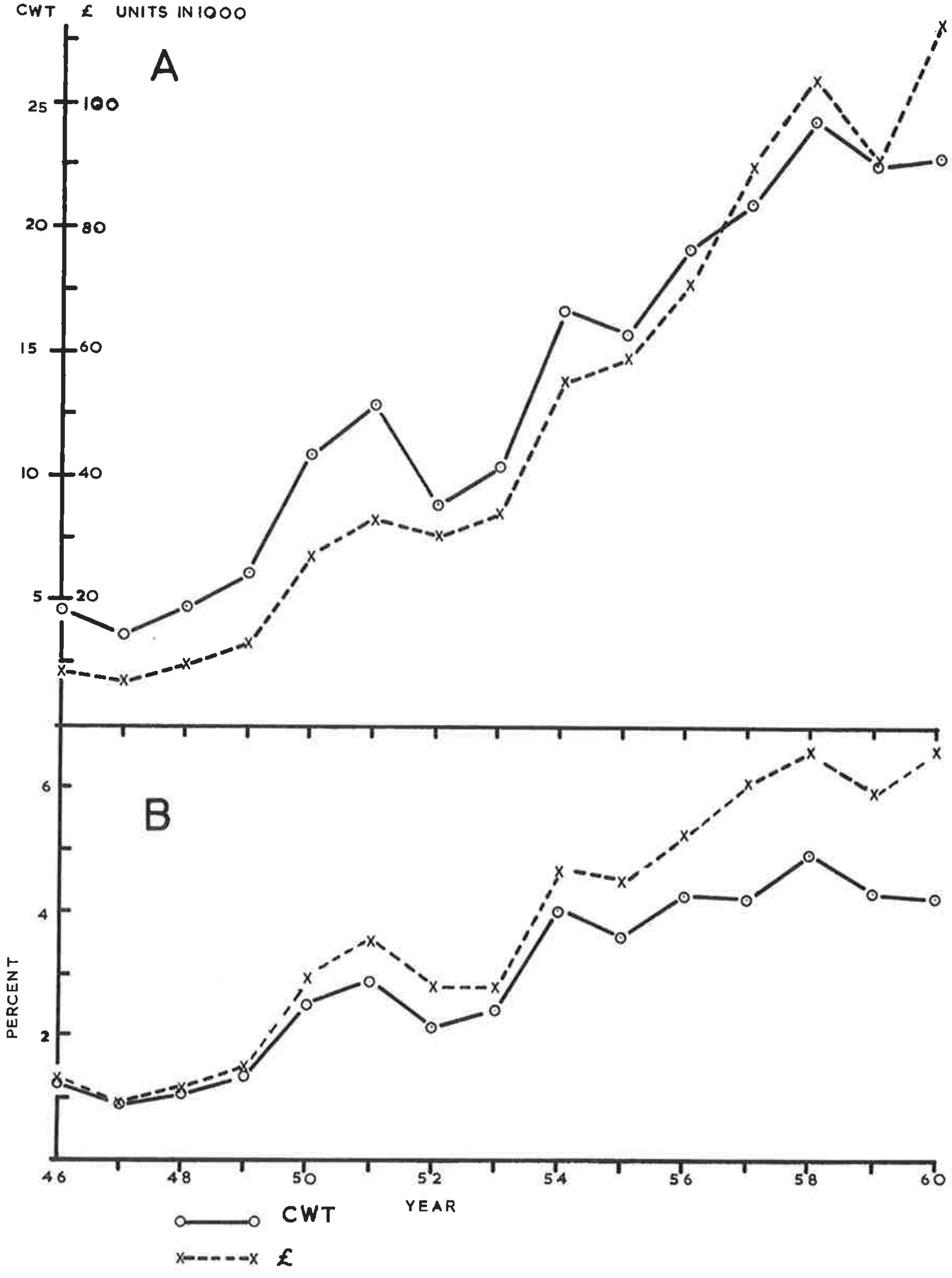


Figure 2: (a) Total value and quantity of Elephant fish landed in New Zealand.

(b) Total value and quantity of Elephant fish expressed as a percentage of the total wet fish landings in New Zealand.

demand for the fish-and-chip trade in Christchurch, the fish being marketed as "silver trumpeter". This association with the fish-and-chip trade still continues and is now the principal local outlet for the fishery. Until recently, the livers were in demand for their oil content, but this aspect of the fishery has died out. Recently the fishery has been given further impetus by the development of exports to Australia. At present these are limited to Melbourne, where the fish is sold as white fillets.

The extent of the recent expansion is shown in Figure 2. In weight, the catch has increased from 4,639 cwt to 22,908 cwt, i.e. by nearly five times in 15 years. The corresponding increase in value is from £7,122 to £111,112 - over 15 times.

The percentage of elephant fish in the total wet fish landings in New Zealand has risen similarly; from 1.2 per cent. to 4.2 per cent. in weight, and from 1.2 per cent. to 6.6 per cent. in value. The disproportionate increase in value over weight illustrates the increased demand. In addition, elephant fish has risen from 14th to 7th species in order of quantity.

The annual catch composition of the Canterbury ports is shown in Figure 3. Elephant fish, tarakihi and gurnard are the most important species and together constitute about 70% of the total catch. To summarise, elephant fish has risen since the war from the status of an unwanted pest to that of an important and sought-after species, although utilisation is still limited to only part of its range.

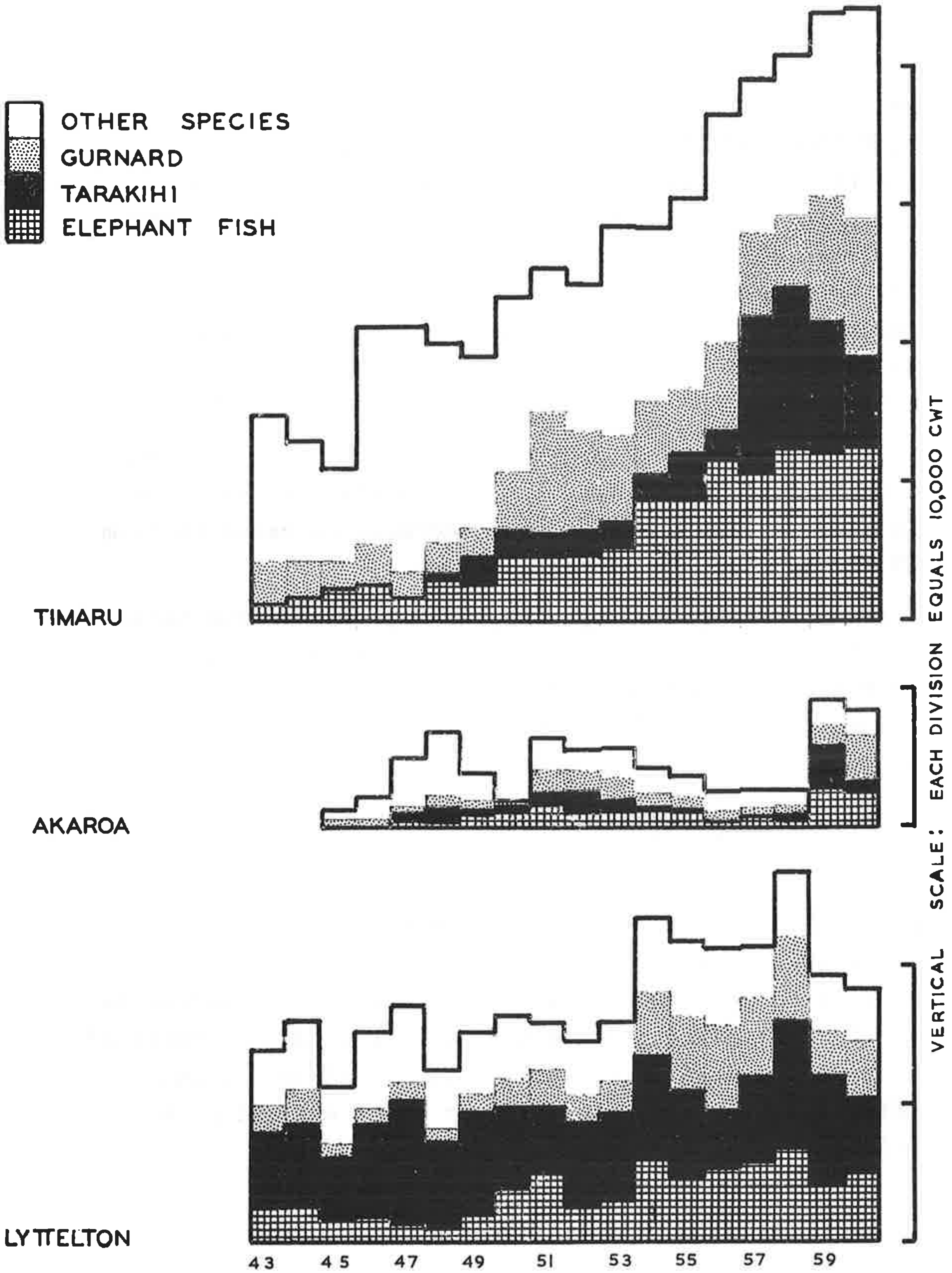


Figure 3. Annual Catch Composition for the Canterbury Ports.

Table 2 **Total catch by various fishing methods**

Method	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959
Trawl													
cwt	3687	4667	6064	10680	11845	8770	9968	16080	15376	18791	20709	23672	21838
£	7122	9755	13038	27198	33611	29961	32797	53587	57741	69523	90720	102051	88765
Nets													
cwt	1	-	75	42	-	149	340	664	404	501	327	665	653
£	1	-	181	109	-	477	885	1970	1279	1720	1383	2530	2470
Lines													
cwt	30	34	7	1	17	26	166	36	8	4	8	44	3
£	62	60	19	2	43	54	433	116	24	14	22	177	8

(f) Fishing Methods

Essentially this is an inshore shallow-water fishery, exploited principally by trawlers, with a little gill-netting and line fishing during the height of the season. Table 2 shows the quantity and value of commercial catch taken by each method for the period 1947-1960.

(i) Trawling

In 1960 there was a total of 50 otter trawlers operating out of the three main Canterbury ports. Typically, they are small wooden vessels, 25-58 ft overall length, with a crew of two or three. Generally they operate on a day trip basis, with the day's catch being landed in the late afternoon or early evening.

(ii) Gill-netting

Lyttelton has three boats using gill-nets; these vessels are also wooden, of double-ended construction, and are operated single-handed. The nets are of 10/27 cotton, with a mesh size of 7¾" to 8¾" tanned, 9-10 meshes deep. The meshes are slung, one and two halves on each sling on the corkline, and two meshes on the lead line, with 9" slings. 3½" corks are spaced every fifth mesh. One net examined had a spreader bar attached to each end of the fleet. This consisted of a 3 ft by 1½ in. by 1½ in. length of hardwood, leaded at the base. This is supposed to stop the net from twisting when fish become entangled.

(iii) Lines

Commercially this method is the least important. Few lines are set specifically for elephant fish. Those taken are largely fish caught incidentally when fishing for other species.

(g) Treatment of Catch

The catch is cleaned and boxed at sea as it comes aboard. The boxes remain on deck, covered by wet hessian sacking until the vessel docks. A recent trend has been the addition of some freezer-equipped vessels to the Timaru fleet. These boats are capable of staying out at sea for several days at a time, and range from Banks' Peninsula in the north to Te Wae Wae Bay in the south. The catch landed from freezer boats is considered superior to that landed from the day boats.

As with all shark-like fishes, tainted flesh can become a problem; temperature is critical, and even at a fairly low temperature the flesh may become unpalatable. In the early days of the fishery, suitable low temperature storage was often lacking and tainted flesh was common. This must have contributed, in part at least, to its general unpopularity. It is possible to improve tainted flesh by prolonged immersion in running water, or by treatment with dilute acetic acid. Ideal storage temperature is about 28°F, which is just above crystallization point.

For the domestic market the fish are sold in the round. For export they are filleted, wrapped in polythene and packed in boxes.

(h) Pattern of the Fishery

Fig. 4 shows the monthly landings at Lyttelton and Timaru. The fishery is distinctly seasonal, with peak production between late October and early January, i.e. during the spring and early part of the summer. Over the years, however, the period of peak production has been gradually shifting towards the midsummer months; the reasons for this are not yet known. The season in Pegasus Bay is generally slightly earlier than that of the Canterbury Bight in the area near Timaru.

(i) Behaviour Pattern of the Fish

Mature adults show a well-defined onshore/offshore migration to and from their spawning grounds. During the non-spawning phase from February to August the mature adults are dispersed over a wide depth range from about 30 to 100 fathoms or more. About September the fish tend to shoal and begin to move slowly but steadily towards the main ocean beaches. During November they reach the beaches and begin laying their eggs in very shallow water. The egg-laying zone extends from the surf line to about 20 fathoms; the substrate is sand or mud, and there appears to be some preference for the vicinity of river mouths. After spawning is completed in December or January, the adults move out into deeper water and disperse.

It is quite simple to correlate the pattern of the fishery with the behaviour pattern of the fish. During the non-spawning phase the fleet does not specifically make any effort to take this species, since the fish are dispersed over a wide area, but small quantities are taken incidentally to tarakihi

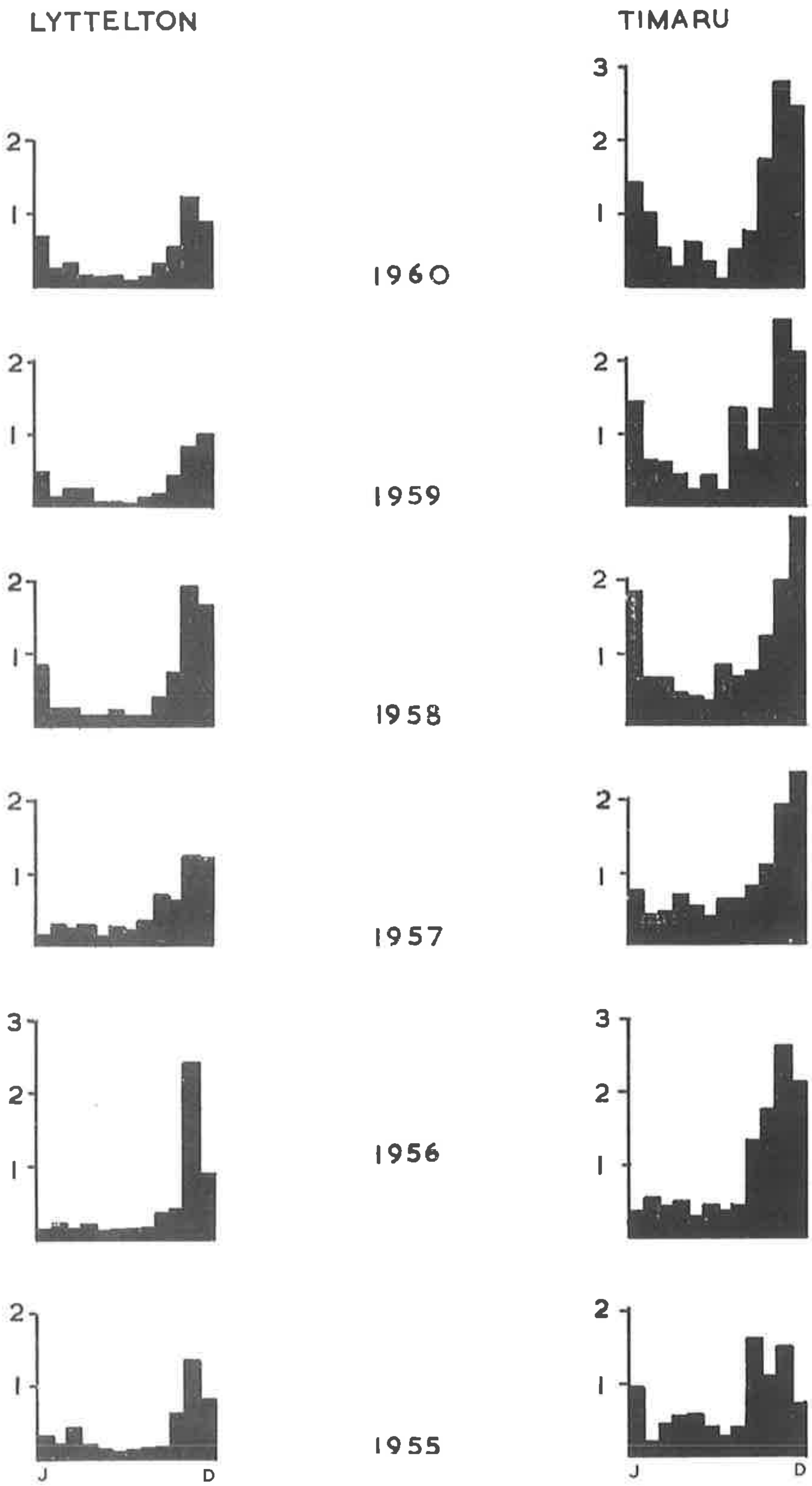


Figure 4. Monthly landings of Elephant Fish at Lyttelton, Timaru in thousands of cwt.

and gurnard. The period of maximum fishing intensity commences during the initial schooling phase prior to spawning, when the fish are in comparatively deep water, i.e. 30-40 fathoms, and continues throughout the spawning season, the fleet following the fish inshore. As the fish move off again, the boats stay with them as long as possible.

As fishing begins before and ends after spawning, and extends to greater depths than the spawning grounds, the actual fishing area encompasses an area considerably greater than that of the actual spawning grounds.

II. BIOLOGY

(a) Collection of Material

The data for this study were collected initially from trawlers engaged on normal commercial operations. This method had severe limitations because there was no control over the location of trawl shots, and further, there was probably a variable degree of selection, since the cod-end mesh size varied from 4 in. to 5 in. Towards the end of the period, therefore, a chartered fishing vessel and the research vessel "Ikatere" were employed. On these vessels, the whole of the cod end was covered with a 1 in. sleeve to avoid selection, and trawl shots of between one and two hours were arranged to give a series of samples ranging from shallow to deep water. However, a number of misfortunes severely curtailed much of the programme. Because of this, the data are rather scanty.

All total lengths are in fork lengths, the anterior point of measurement being the tip of the proboscis at the point where it is flexed ventrally.

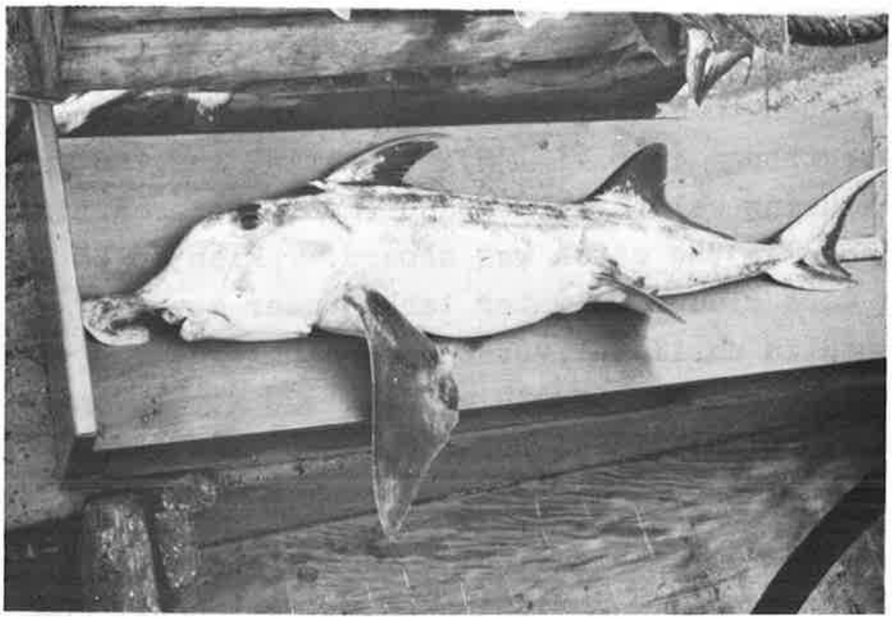
Length measurements were taken on a 1-metre measuring trough (see Fig. 5). Partial lengths were obtained using calipers. Measurements were carried out as soon as the catch was aboard. Fish to be weighed were placed in water tanks under cover of a wet tarpaulin until the vessel was alongside the wharf or anchored in smooth water. 50 x ¼ lb and 10 lb x 1 oz clock-faced balances were used in all weighings.

To avoid selection, the complete catch was sexed and measured and, if necessary, weighed. On one occasion only, on a commercial vessel, this was not possible, but it is considered unlikely that the data were unduly affected.

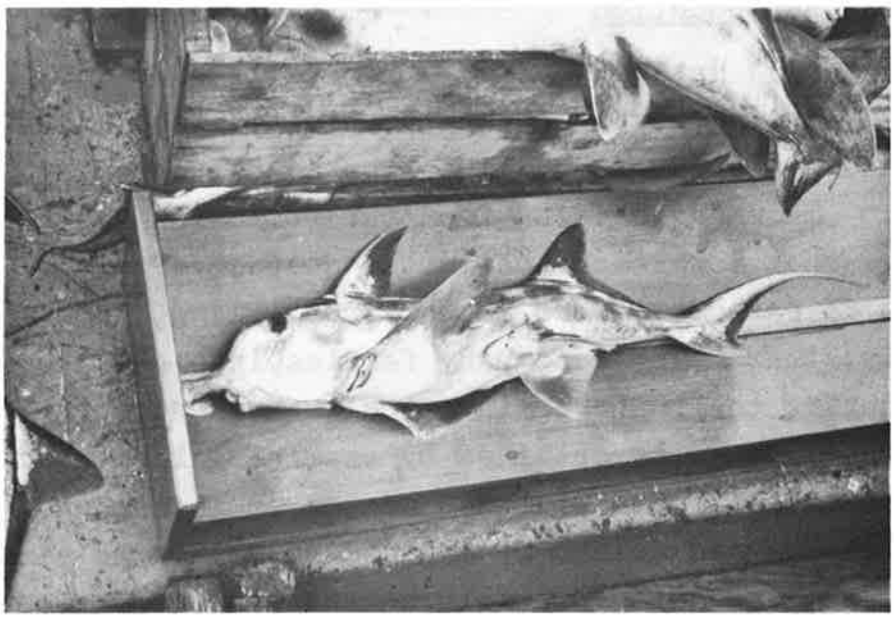
(b) Reproduction

(i) Mating

Mating begins during the initial schooling phase and probably extends into the actual spawning season. This was deduced from the following facts: firstly, that females taken in the deepest of the shots - 44 fathoms - were already fertilised, and, secondly, that males accompany females into shallow water during the inshore migration. Evidence of fertilisation can be obtained by examining the cloaca of the female for the presence of the seminal plug. This will vary in colour from green to yellow to almost colourless, depending probably on the length of time that it has been in position. Characteristically, it is eroded and is quite firm to the touch. Where a



(a).



(b).

Figure 5. (a) Mature female on measuring trough.

(b) Mature male.

plug is present it will normally be visible, but if not it can be detected by inserting the fingers into the cloaca.

(ii) Spawning

The species is oviparous, and the eggs are laid individually in a large, horny egg-case. The egg-case is soft, flexible and light brown in colour on laying, but hardens and darkens with age until at the time of hatching it is almost black. There is a central asymmetrical spindle-like portion which contains the embryo, and spreading out from this is a wide flange with radiating ridges (Fig. 6). In transverse section, the case has a convex upper and a concave lower surface. The former is covered with a mat of fine hair-like processes of unknown function. It is not uncommon to find sessile invertebrates attached to this surface when the case has aged. The concave surface is smooth and when trawled often has traces of mud still adhering to it.

Graham (1939) reported that egg cases washed ashore rarely exceeded 10" in length while samples taken from fish and from a cod-end have attained 16½". In December 1961 a sample of 27 were taken by trawl net. In length they ranged from 9½ - 11½" and weighed between 45 and 70 gms.

The more elongate extremity of the case is usually ragged and this is probably caused by the uneven parting of the material of the case on extrusion. Adhesion to the substrate seems to be achieved by means of the combined sucker- and anchor-like action of the concave ventral surface. After the egg has hatched, the cases appear to lose their power of adhesion and

Figure 6. Elephant fish egg cases. Lower surface, left; upper, right.

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ERRATA

P.18 - Fig. 6. Caption should read:
Left and right ovaries of 84 cm. female.
Pegasus Bay, 5th December 1961.

P.23 - Fig. 7. Caption should read:
Elephant fish egg cases. Lower surface, left; upper, right.

are often washed ashore in considerable numbers during or after heavy seas. Graham (1939) postulated that the ragged end, described above, was thrust into the substate by the female, and that the ruggedness was caused by corrosion or by bacterial attack. However, the case is very soft and pliable on laying, and the pointed end, which is the last to emerge, is the softest part of the whole case. It is difficult to conceive this case being stuck into anything except very soft mud which does not occur on the spawning grounds.

Examination of mature female ovaries indicates that spawning in any one female must extend over a period approaching the whole duration of the spawning season.

(iii) Incubation period

The period of incubation has not been accurately defined but it is believed to be in the region of 5 to 8 months. The N.Z. Marine Department's Annual Report for the year ended 31st March, 1938 reported that a number of egg cases were obtained from Pegasus Bay in December (?1937) and that these were deposited in the tanks at the Portobello Fish Hatchery in Otago. The incubation period from the time they were received until they hatched was 314-326 days, i.e. in excess of 10 months. However, Graham (1939) recorded an almost fully-developed embryo washed ashore in its egg case in May in Pegasus Bay. He also recorded that, on hatching, juveniles are 6 in. in length, one third of which is represented by the tail. This observation suggests that incubation was 5 to 8 months; and that juveniles would have a fork length of about 10 cm on hatching.

Collecting, using a dredge and trawl, was carried out in September, 1961. This was 10 months after the peak of the spawning season. Only spent cases were obtained but, simultaneously, a number of juveniles ranging in length from 12 to 19 cm were taken. The umbilical slit of these fish was still conspicuous, while the length of the smallest approached the length at hatching reported by Graham (1939).

The extended incubation period of the eggs in the hatchery may have been due to a retarding effect of the colder Otago water.

(c) Adults

(i) Males

Mature males can be distinguished by the presence of three sets of "claspers". They are, first, the tenaculum on the head; secondly, the prepelvic claspers, and, thirdly, the mixopterigia located between the pelvic fins. Mixopterigia are the only ones present in immature specimens and, despite their small size, they make sexual identification of even the smallest fish very simple. The other two pairs are diagnostic features of mature adults.

At the onset of maturity there is a comparatively brief and well-marked transition stage. This is defined by the eruption of the tenaculum, and takes place when the fish is about 45 cm long; by 50-51 cm, eruption is completed, although the organ is not yet armed with denticles. By 52 cm the tenaculum is fully armed and the mixopterigia are fully developed.

All specimens examined at 52 cm and above were fully mature, while conversely all those below this length were either in the transition stage or wholly immature.

The function of the tenaculum has generally been associated with some form of sexual activity, such as display, fighting, or assisting in the act of copulation. The writer prefers a suggestion put forward by local fishermen that the tenaculum is used to assist in the extrusion of the large, bulky egg case. The tenaculum is a relatively weak organ and it certainly could not be considered as an organ of offence or defence; similarly, its suggested use during copulation is difficult to reconcile with its position on the dorsal surface of the head. It could, however, obviously function as a grasping organ so that this particular theory appears more attractive than most.

The prepelvic claspers are complex, jointed organs located in a pouch immediately anterior to the pelvic fins. They are armed with strong denticles and the whole organ can be protruded forward. It is reasonably obvious that they are used to grip the female, in the vicinity of the pelvic fins, during copulation, and this is borne out by the number of parallel scratch marks usually to be found on this region in mature females.

The mixopterigia are also jointed and can be flexed forward. They take the form of flat tissue, rolled to form a hollow cylinder down which the seminal fluid can pass.

The seminal vesicles of mature males are a pair of long, green, cylindrical tubes, while in the immature of transitional stage males, these organs are rather small and inconspicuous.

(ii) Females

Females attain first maturity when 70 cm long. Initially, maturity was determined by dissection and examination of the state of the ovaries. After a number of females had been examined in this way, it became possible to use two further criteria.

Firstly, a mature female, although differing from an immature fish by as little as 1 cm, showed a considerable increase in girth.

Secondly, the cloaca was examined for the presence of the seminal plug. When in doubt, the fish in question was dissected and the ovary examined.

The immature ovary is small and the ova tend to uniformity in size, having only small quantities of yolk. They are firmly embedded in the ovary and in appearance resemble a small bunch of grapes. In mature females the ovary is comparatively large and the ova vary considerably in size (Fig. 7), ranging up to 3 cm in diameter. At this stage, they are bright yellow in colour, very fragile and loosely attached to the ovarian tissue.

The transition period between immaturity and maturity appears to be brief. All those fish examined above 71 cm in length were found to be mature, while those below this length were immature.

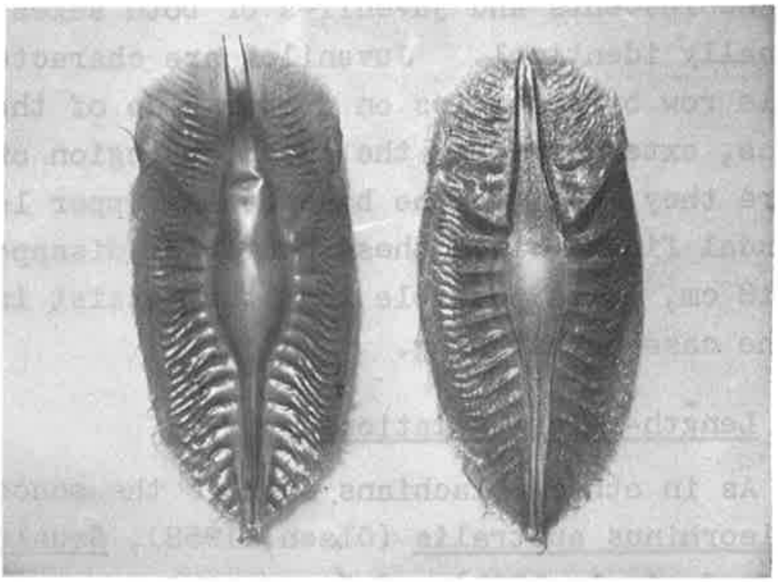

Figure 7. Left and right ovaries of 84 cm. female. Pegasus Bay, 5th December 1961.

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Elephant fish egg cases. Lower surface,
left; upper, right.

(d) Juveniles and Adolescents

With the exception of the mixopterigia in the male, adolescents and juveniles of both sexes are externally identical. Juveniles are characterised by a single row of denticles on either side of the mid-dorsal line, extending from the anterior region of the head, where they meet, to the base of the upper lobe of the caudal fin. Since these denticles disappear at about 18 cm, it is possible that they assist in opening the case on hatching.

(e) Length-Weight Relationship

As in other Selachians such as the school shark, *Galeorhinus australis* (Olsen, 1953), *Squalus sucklei* (Ford *et al*. 1921) and *S. acanthias* (Ripley, 1946), mature males are smaller than females.

The length-weight relationships for males and females are shown in Figs. 8 and 9. This study was based on 397 fish collected at sea during the height of the spawning phase in November 1961. Length measurements were grouped in 5 cm intervals and the average weight was calculated for the mid point of each interval. There was no significant difference between the sexes. Plotted logarithmically, these points lay close to a straight line. The line fitted by eye corresponded to the relationship as

$$\log W = \log 2.04 \times 10^{-5} + 3.02 \log L.$$

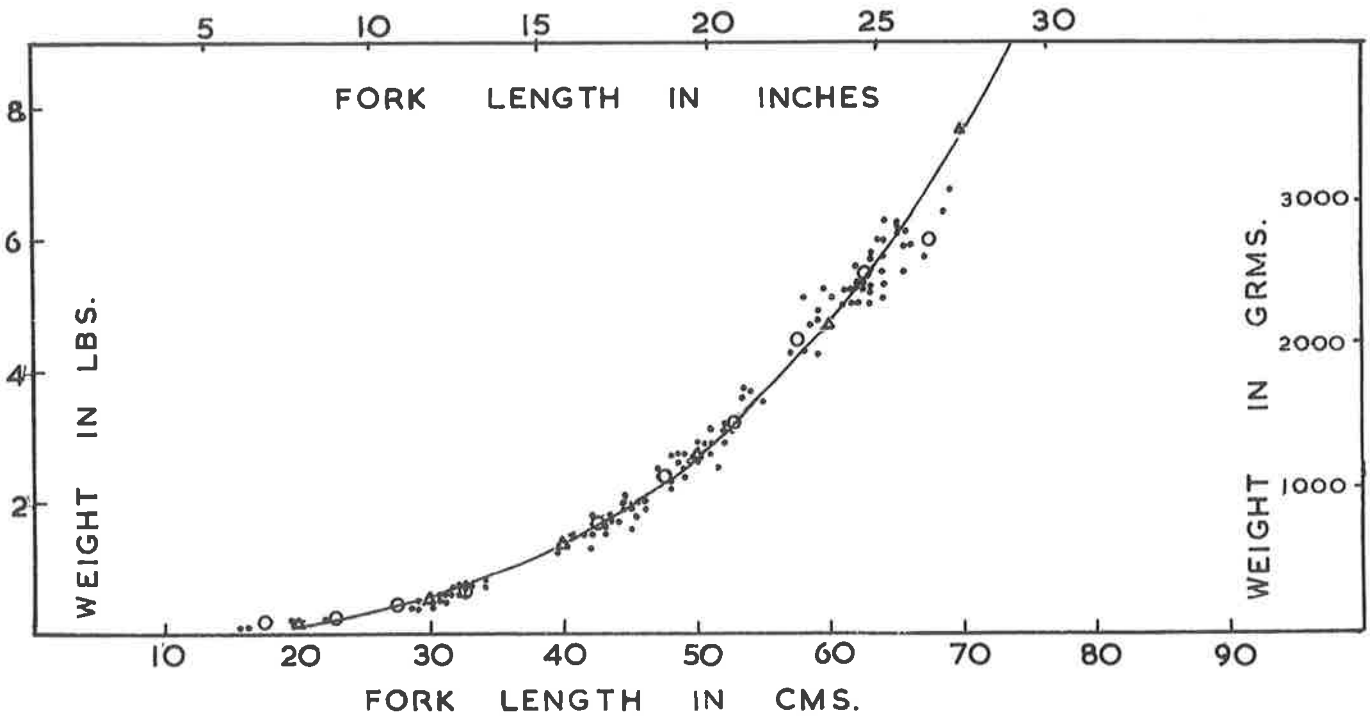
which can be expressed as

$$W = .0000204 \times L^{3.02}$$

where W = weight in lbs.

L = Fork length in cms.

The curve corresponding to this line has been drawn in on Figs. 8 and 9.



<u>Figure 8</u>. The length-weight relationship for a sample of 143 males taken in November 1961.

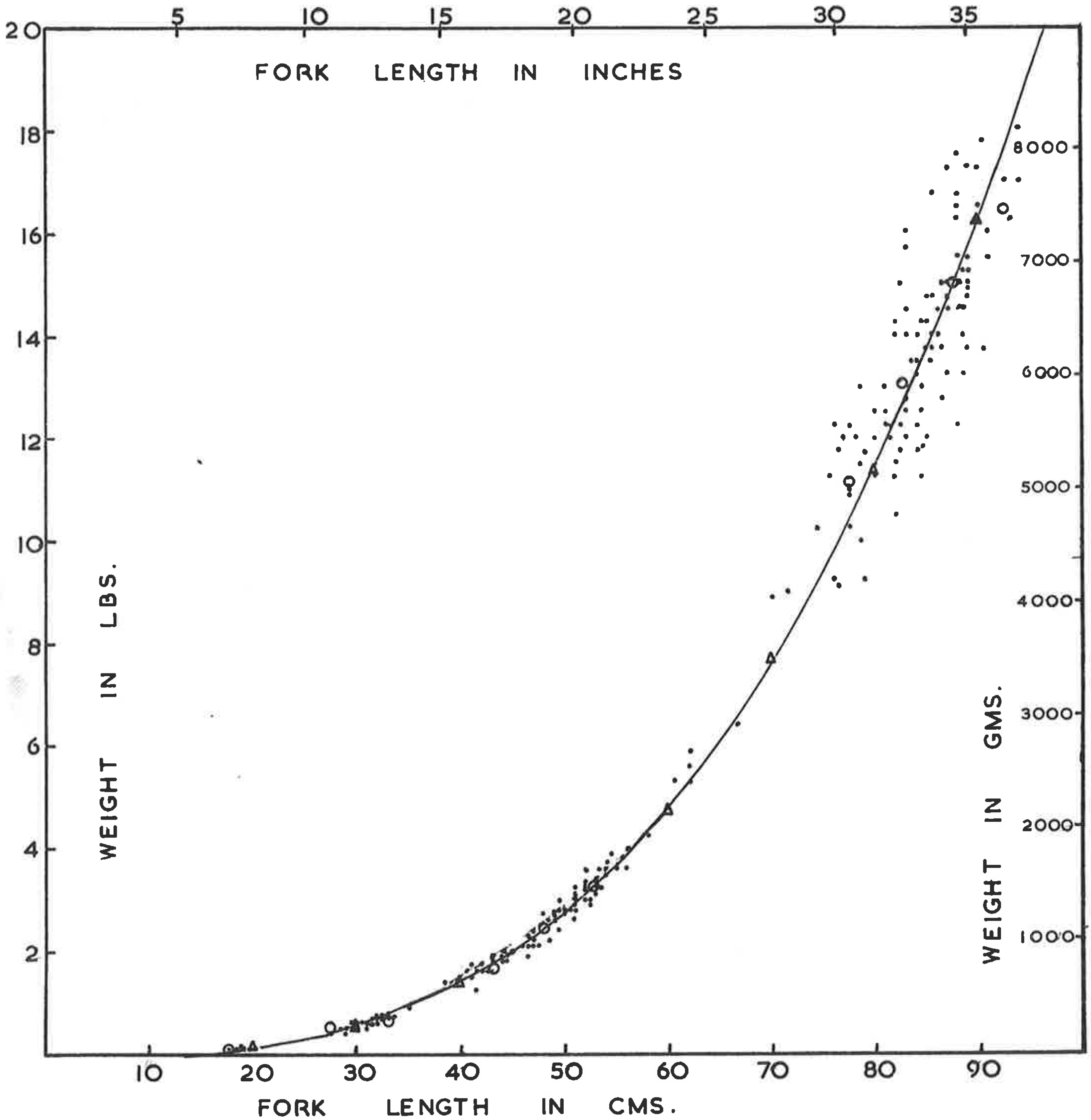
o = Calculated means for mid points of 5 cm class Intervals.

Δ = Values derived from formula.

Figure 9. The length-weight relationship for a sample of 254 females taken in November 1961.

o = Calculated means for mid point of 5 cm class Interval.

Δ = Values derived from formula.



There are no indications of changes in the relationship at the point of first maturity.

The longest male taken during this investigation measured 70 cm, while the heaviest one weighed, attained 6.75 lb at 69 cm. Similarly, the longest female measured 97 cm and the longest one weighed, was 18 lb at a length of 94 cm. This is nearly 2.7 times the weight of the largest male.

(f) Distribution in Time and Space

As mentioned in a previous section, mature adults during the non-spawning phase, January to September, are scattered and dispersed over a wide depth range from 7 to over 100 fathoms, becoming more abundant at deeper levels. On the evidence of sampling carried out over this period, males are more abundant than females in shallower water. During the spawning phase they range from very shallow water out to 40-50 fathoms.

Juveniles and adolescents exhibit shoaling behaviour during both the spawning and non-spawning phases. They do not appear to leave shallow water until they are approaching first maturity. Juveniles are usually to be found out to 15 fathoms while adolescents extend out to about 40 fathoms.

(g) Locomotion

The large muscular pectoral fins appear to be the chief means of propulsion. Trawl-caught fish placed in tanks aboard "Ikatere" swam slowly, using a "flying" movement of these fins, the rather weakly-developed caudal fin appearing to be used mainly as a rudder. It is probable that the main body musculature also contributes towards propulsion, but only in times of emergency when more speed is required, for when landed on deck these fish often exhibited a vigorous lateral flapping movement of the whole body.

(h) Defence

The species is not aggressive, and is generally regarded as harmless to man. For defence, it is equipped with a long, serrated erectile spine which has its origin immediately anterior to the first dorsal fin. Halstead (1959) records that this spine carries venom in the related Pacific species, *Hydrolagus collei*. There is little evidence, however, that in the elephant fish the spine is venomous to man. Penetration of the skin is seldom followed by other than normal irritation. On the other hand, the powerful teeth should be treated with respect.

Nothing is known of the defensive behaviour of this species in its natural environment.

(i) Predators

Remains of juveniles were found in the stomachs of school sharks (*G. australis*), trawled in 11 fathoms in Pegasus Bay during November, 1958. No further records were obtained during this investigation. It was noticed that sea birds either ignored juveniles which had escaped the net when it was brought alongside, or discarded them soon after capture.

(j) Food and Feeding

Graham (1939) carried out a qualitative study of the food of elephant fish in Otago waters. Thompson and Anderton (1921) also contributed, but in a rather general manner. Table 3 has been extracted from data presented by these workers. Graham's work indicates that molluscs constitute the principal food source. Considering the massive, highly specialised, grinding and crushing dentition, this is not unexpected.

Table 3 Food of the Elephant Fish in Otago. Thompson (1921), Graham (1939)

Graham (1939)		
FISHES	CRUSTACEA	MOLLUSCS
Red cod (Physiculus bachus) Lemon sole (Pelotretis flavilatus)	Halicarcinus sp. Hombronia depressa Brachycarpus anduini Munida gregaria	Maorimactra ordinaria Myllitella vivens Nucula nitidula Tawera spissa Notolepton sanguinea Gari stangeri Soletellina nitida Macoma (Macomona) gaimardi Solemya parkinsoni Antisolorium egenum Paphies (Amphidesma australis) Zethalia zealandica Turbonilla zealandiae Zediloma corrosa Notosetia sp.
Thompson and Anderton (1921)		
Witch (Caulopsetta scapha) Sole (Pelotretis) Sea horse and pipe fish (Sygnathidae)	Nectocarcinus Pontophilus	Various bivalve molluscs

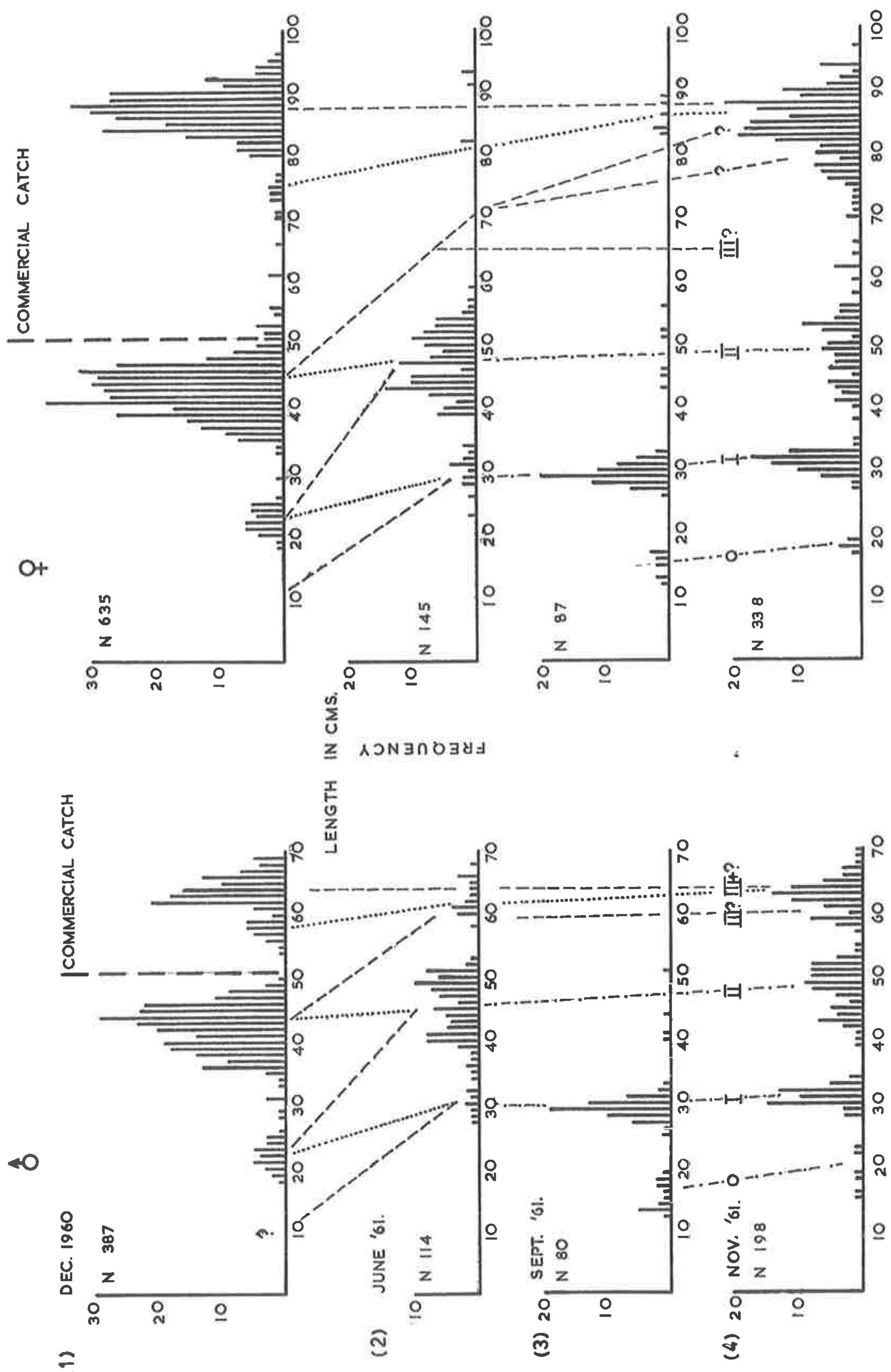
(k) Population Composition, Structure and Growth

One of the principal objects of this investigation was to build a reasonably representative model of the population, and subsequently to determine what portion was being abstracted by fishing. Size distribution curves were constructed for both sexes and found to have a characteristic form. Typically the modal groups are well defined, with little overlap.

Figure 10 (1) - (4) shows the length frequency distributions for four sampling series carried out in Pegasus Bay between December, 1960 and November, 1961. Each series consisted of 3-6 days' consecutive fishing at various depths. The first two samples were taken during normal fishing operations (10 (1) and (2)), using 4" and 5" cod ends respectively. There was some degree of selection among the smaller size groups, so that they cannot be directly compared with the two later samples. Figs. 10 (3) and (4) were taken using a 1" sleeve over the whole cod end. It is reasonable to assume that selection was avoided, and that direct comparison between these two is possible.

The first sample (Fig. 10 (1)) was taken in early December, 1960 over a depth range of 9-44 fathoms and coincided with the spawning phase. The curves were compiled from 11 trawl shots and, with the exception of one, the total catch was measured in each case. The curves for both sexes are distinctly tri-modal, with a possible secondary mode, lying between 70 and 78 cm in the case of the females, and between 54 and 60 cm in the case of the males. The

Figure 10. The length frequency distribution for successive samples taken in Pegasus Bay, showing possible growth rates based on modal progression. Males and females shown separately.



curves for each group approach normality.

The second sample was taken in June, 1961 over a depth range of 12-26 fathoms. Essentially the tri-modal pattern of the curves is repeated, although mature adults of both sexes were scarce. On the whole, the modal groups are less well defined, and owing to the 5" cod end, this sample is believed to be the least representative of the four.

The third sample was taken in late August and early September, 1961 over a depth range of 2-26 fathoms. This was the first to be taken using a 1" mesh. Recently-hatched juveniles, between 11 and 19 cm. were taken, and these are believed to be the product of the 1960 spawning season. Like the second sample, this sample coincided with the non-spawning phase. This accounts for the scarcity of the migratory adults.

The final sample in the series was taken over a depth range of from 6 to 70 fathoms during the height of the spawning phase in 1961. 1" mesh was used, so that selection was probably negligible, and consequently the curves are believed to be reasonably representative of the population composition. Essentially, the curves are similar to those obtained in the first of the series, but there is a fourth about 15 to 23 cm; this is probably the result of the more representative nature of the sample. The mean length of each major modal group is also rather higher than in the December, 1960 sample.

Since the modal length of the groups representing immature fish increase progressively with time, it is believed that the groups represent individual year classes. However, there is still some doubt about their actual age, as two interpretations are possible on the data. Tentative age groupings and growth lines for both alternatives are shown in Fig. 10. The first and more probable, assumes that the 18-25 cm group in the first sample (December, 1960) was hatched in 1960 and therefore should be designated the '0' group. Similarly, the 15-23 cm group in the November, 1961 sample should be designated the '0' group for the corresponding year. The second interpretation assumes that in 1960 hatching occurred later than in 1961 and that group '0' individuals were not taken during the course of sampling in December, 1960, but were represented in subsequent samples. This hypothesis considerably increases the annual growth rate of the younger year classes.

To clarify the age and growth relationship between immature and mature fish it is necessary to account for the large gap between immature and mature females. Two hypotheses have been considered. First, that at the approach of first maturity, growth rate accelerates rapidly, the fish spawning with the migratory adults as the latter moved inshore. The second postulates that the females move offshore into deeper water when analogous in size to mature males. They would then remain in deep water for about a year before maturing in time to take part in the next season's spawning migration. If this occurred, these immature fish would tend to be unavailable to the normal commercial fishery and consequently they would not have been represented in either the December, 1960, or the November, 1961 sample. During the November, 1961 programme, it was hoped to test this hypothesis by extensive sampling in deeper water towards the edge of the continental shelf. However, a series of misfortunes prevented this being done.

It is clear that more positive evidence is necessary to determine growth rates and population structure, but some tentative conclusions can be drawn from the available data. The length frequency models suggest that growth to sexual maturity is relatively rapid. In addition, there is evidence of seasonal variation in growth rate. The mature group of each sex could consist of several year classes, provided growth slowed after maturity was attained. Alternatively, the life span of the species could be short, so that the mature population consisted only of one or two year classes. The third obvious suggestion is a combination of slow growth rate after maturity with a relatively short life span. The age at first maturity seems most likely to be two years for males and either the same or one year older for females. Both ages could, however, be underestimated by one year.

In most viviparous and oviparous Selachians growth rate is usually slow, and the life span fairly long. This slow rate of growth, coupled with low fecundity, means that productivity is small in relation to the standing crop. Therefore, commercial exploitation of this group rapidly becomes affected by depletion.

In elephant fish, however, the length frequency curves suggest that growth relative to total length is fairly rapid, and therefore one of the factors governing production is high. If fecundity were also found to be relatively high, then this species might have greater productivity than other Selachians and be more resistant to increases in fishing intensity. However, the population would at the same time be susceptible to catastrophe since at any given moment there are so few year classes in reserve.

(1) <u>Sex Ratios</u>

Analysis of the samples for sex ratios is shown in Table 4. As there appears to be a definite relationship between the major modal groups of the December and June sample, the total number of fish in each group has been combined. The September and November samples also show a relationship, and they have been treated similarly.

<u>Table 4</u>. <u>Sex composition of samples</u>

		0 or I		I or II		II+ and or III+	
		Nos.	%	Nos.	%	Nos.	%
Dec. and June combined	♂	39	40	319	41	139	34
	♀	58	60	455	59	269	66

		0		I		II		III+	
		Nos.	%	Nos.	%	Nos.	%	Nos.	%
Sept. and November combined	♂	21	57	108	46	76	51	72	27
	♀	16	43	126	54	74	49	199	73

These figures indicate that up to maturity the sexes are more or less equal in number, but that in the mature groups there is a marked preponderance of females.

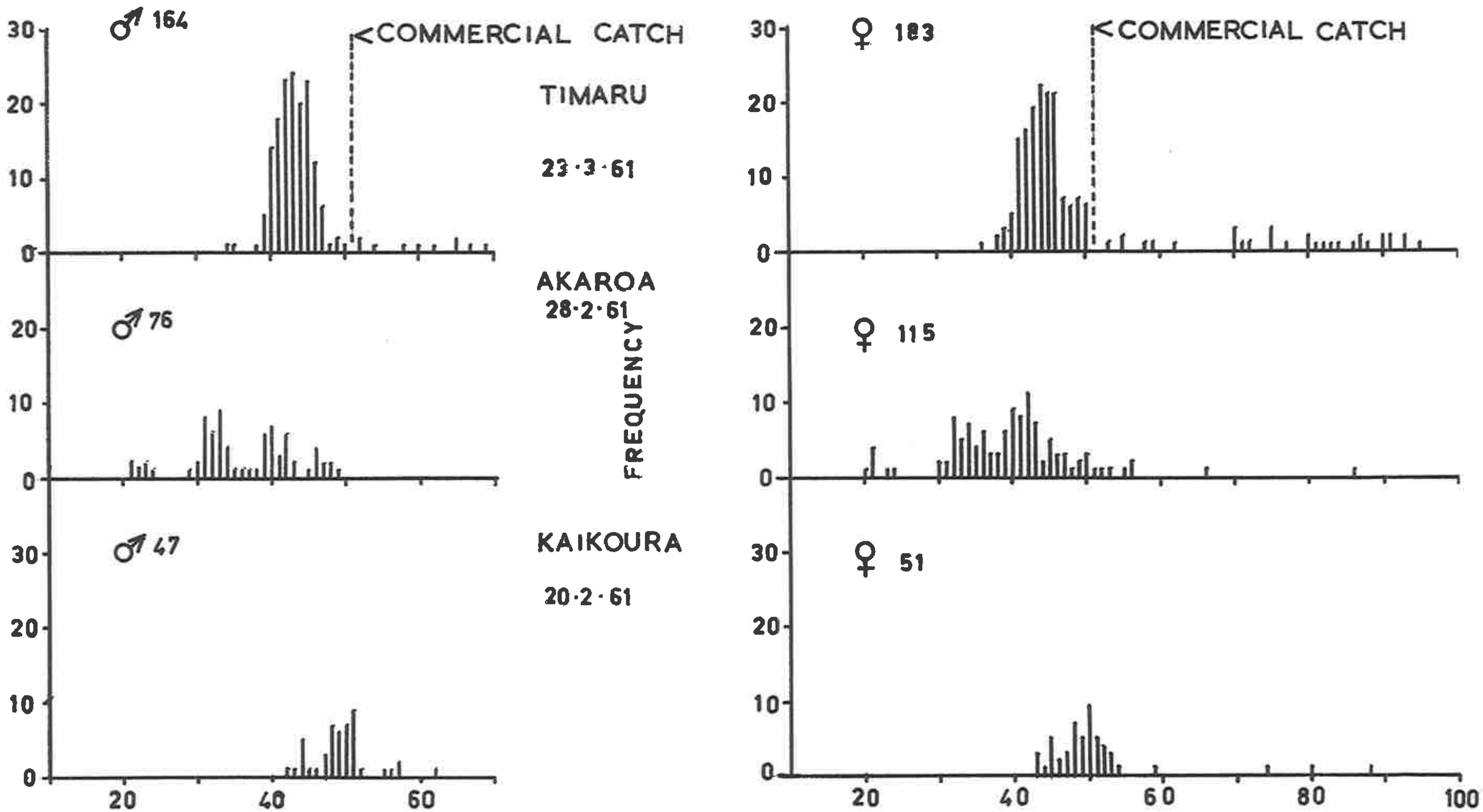
III. COMMERCIAL CATCH

(a) Commercial Catch in relation to the Total Catch

The total trawler catch (Figs. 10 and 11) probably consists of all available age groups, although there may be some degree of size selection in the two youngest year classes. In marked contrast, gill netting is much more selective (Fig. 12) and only mature fish are taken. Mesh selection favours the escape of males, so that generally the catch consists largely of females. The selection of females is deliberate because they give a higher economic return per fish than the smaller males. For the same reason, the trawl fishery is dependent in great degree on mature females, which, apart from being larger, are also more abundant.

Table 5 shows the sex composition of the total and commercial portions of the catch, taken by commercial fishing vessels during the course of this investigation. Catches obtained while using a 1" sleeve have been omitted to avoid bias. The table also shows the percentage of the total catch which was rejected as too small.

Figure 11. Length frequency distribution of samples taken on commercial vessels in 1961 at beginning of the non-spawning phase.



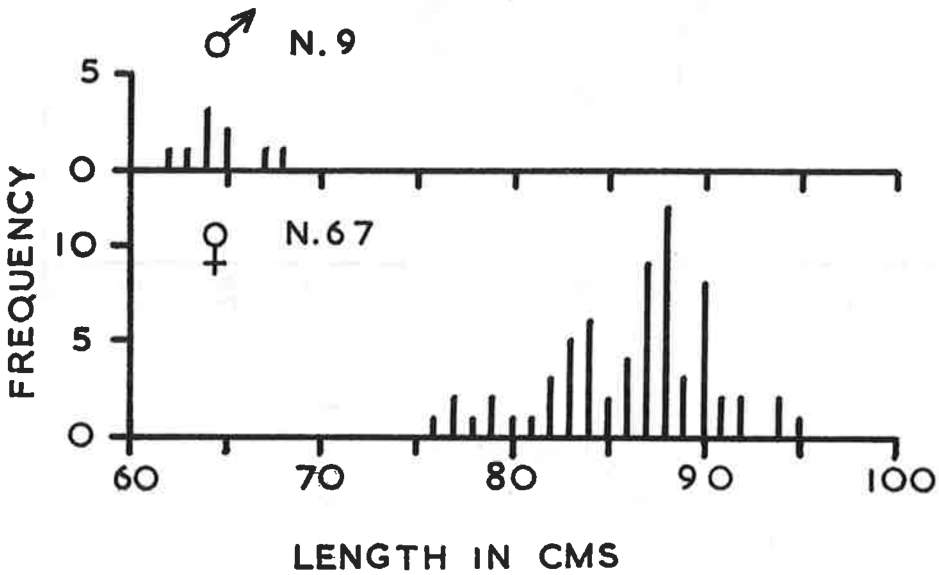


Figure 12. Length frequency distribution of a sample from the commercial gill net catch, Pegasus Bay November 1961.

Table 5 Sex composition of total catch and portion landed for sale, and percentage of total catch used and rejected, i.e. fish below 51 cm

Locality	Total catch		Commercial portion		Portion of catch used as % of total catch	Portion of catch rejected as % of total catch	Season
	% ♂	% ♀	% ♂	% ♀			
TRAWL							
Pegasus Bay Dec. 1960	37.9	62.1	30.3	69.7	39.4	60.6	Spawning phase
Kaikoura Feb. 1961	48.0	52.0	46.9	53.1	32.0	68.0	Non-spawning phase
Canterbury Bight Feb.-Mar. 1961	44.6	55.4	20.0	80.0	9.3	90.7	Non-spawning phase
Pegasus Bay June 1961	44.0	56.0	41.2	58.2	26.3	73.7	Non-spawning phase
GILL NET							
Pegasus Bay Nov. 1961	13.2	86.8	13.2	86.8	100.0	0.0	Spawning phase

The minimum desirable commercial length in 1961 was 51 cm. Smaller fish were generally rejected as unsuitable for filleting. This length approximates that of the smallest mature male. Few, if any, of these fish would normally be returned to the sea alive, since they die very quickly when removed from the water. It is common knowledge among trawler-men that destruction of small fish is high, and the data provide some indication of the magnitude of this wastage. Since the Canterbury Bight and Pegasus Bay support what is essentially a shallow water mixed trawl fishery, destruction continues throughout most of the year. The percentage wastage decreases during the spawning phase owing to the influx of mature fish. During the winter, the major portion of the Lyttelton trawler fleet concentrates on tarakihi (Cheilodactylus macropterus) which occurs from about 30-40 fathoms outwards. As most of this area is outside the normal depth range of immature and adolescent elephant fish, they may be afforded some respite. In addition, trawler-men are very much aware of the shoaling habits of immature fish for, owing to their relatively heavy weight, and to the enormous numbers in which they occur, they constitute a real threat to gear, and losses of trawl nets are not infrequent. Because of this hazard, there is an understandable desire on the part of the fishermen to avoid areas where large numbers of small fish have been located. In direct contrast with trawl fishing, gill netting is not destructive.

Essentially, therefore, the fishery depends almost entirely on mature breeding stock, particularly females, taken during the spawning season.

(b) Partial Length/Whole Length and Partial Weight/Whole Weight Relationships

When elephant fish are cleaned, the pelvic fins, the ventral portion of the abdominal wall and the viscera are cut away, together with the head and the first dorsal fin. The major lobe of the second dorsal fin is removed and so is much of both lobes of the caudal fin. This method of cleaning severely restricts the choice of reference points for partial length measurements. All partial lengths were taken from the posterior edge of the slot into which the first dorsal fin can be retracted, to the extreme posterior base of the second dorsal fin; neither of these points are mutilated during cleaning.

(i) Partial length/total length relationship

The partial length/total length relationship for both sexes (Figs. 13 (a) and (b)) gives a reasonably good fit to the same straight line. The line fitted by eye gives the regression formula as:

$$y = 2.1\ x + 4.5$$

where y = total length in cms and x = partial length in cms.

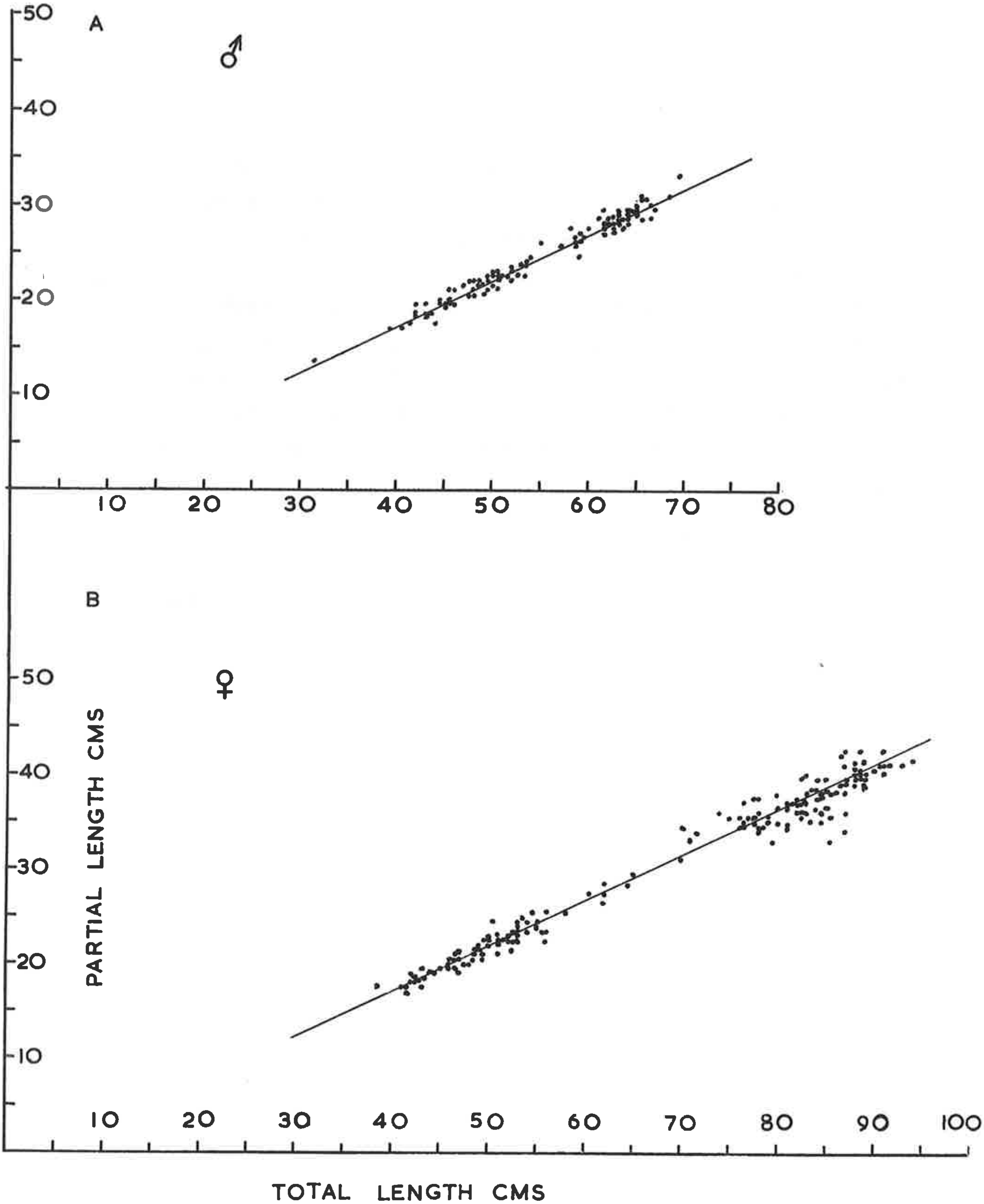
(ii) Partial weight/total weight relationship

The partial weight/total weight relationship is also the same for both sexes but is slightly curvilinear. It is quite well fitted by the relationship

$$b = 0.5a - 0.0126a^{1.83}$$

where a = whole weight in lbs.
and b = cleaned weight in lbs.
This curve is compared with the actual data in Fig. 14.

Figure 13. The partial-length/whole-length relationship.



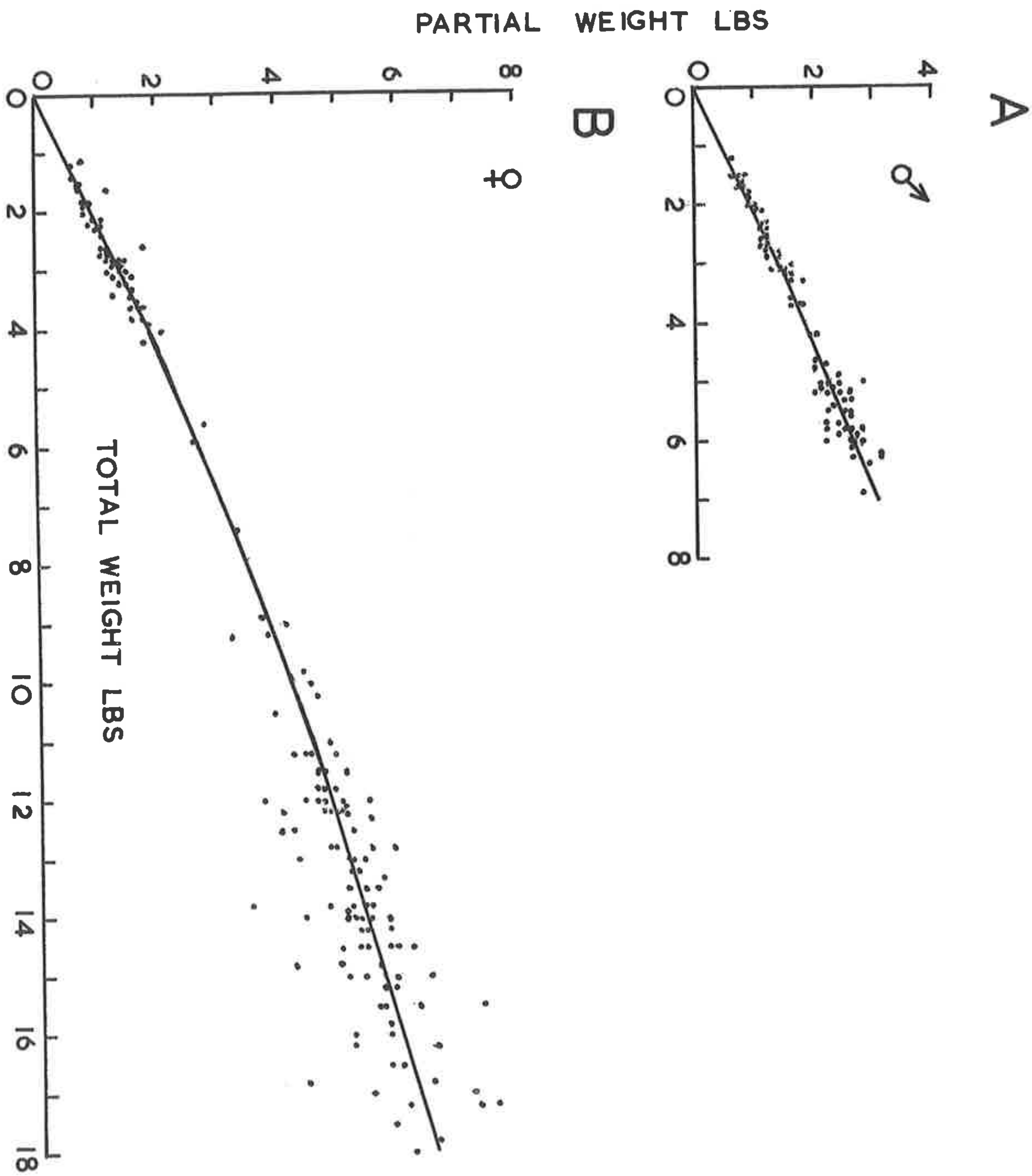


Figure 14. The partial-weight/whole-weight relationship.

On average the cleaned male carcass weighs 44.9% of the original total weight, and the female 42.4%. According to the manager of the Timaru Fishing Co., filleting losses are 20%, therefore only 35.7% of the original weight of a male and 33.8% of a female are available for food.

(d) Catch per Unit Effort

Owing to the relatively high increase in production since the war, some concern has been expressed about the state of the resource in Canterbury waters. If the New Zealand species forms a homogenous stock, theoretically there should be little cause for concern, owing to the rather restricted limits of the fishery. If, on the other hand, more localised populations exist, there is always the possibility of local depletion.

If we are to examine the present state of the fishery, it is essential that adequate statistical data should be available over a considerable period of time. Until 1937 annual total catches for each port were based on estimates made by local, part-time fisheries inspectors, consequently their value for statistical analysis is questionable. From 1939 to 1945 staff shortages within the Department affected the handling and processing of the data and in addition there was an overall reduction in fishing effort. Analysis of available data has therefore been confined to the years 1946-1960.

These data consist of the total elephant fish catch per annum, together with the total number of landings for each of the Canterbury ports. Two major weaknesses in the data are firstly, that some of the

Lyttelton and Akaroa annual catches include those from the less productive gill netters, and secondly that the figure for landings includes all landings even when no elephant fish were caught. It was impossible to make allowances for the first source of error, but it was believed the second could be largely avoided by considering the peak months only, i.e. October, November and December, when the catch would consist largely of elephant fish. An index was, therefore, calculated for each of these ports consisting of the October to December catch divided by the total number of landings for those months.

During the immediate post-war period and probably for some years afterwards, the annual catch of elephant fish at all three ports was governed by the rather restricted demand. Excess catches were dumped, and the only part utilised was the liver. The catch and effort statistics until about 1954 represent, therefore, the quantity the market could absorb, rather than the actual total catch of the species.

The annual catch and the catch per landing indices for the three Canterbury ports are shown in Fig. 15.

Lyttelton

Originally the fishing grounds of this port for elephant fish were confined to Pegasus Bay. However, there is an extensive area of rough bottom in the bay, ranging from about 22-50 fathoms. For this reason Lyttelton vessels cannot operate in deeper water during the inshore and offshore

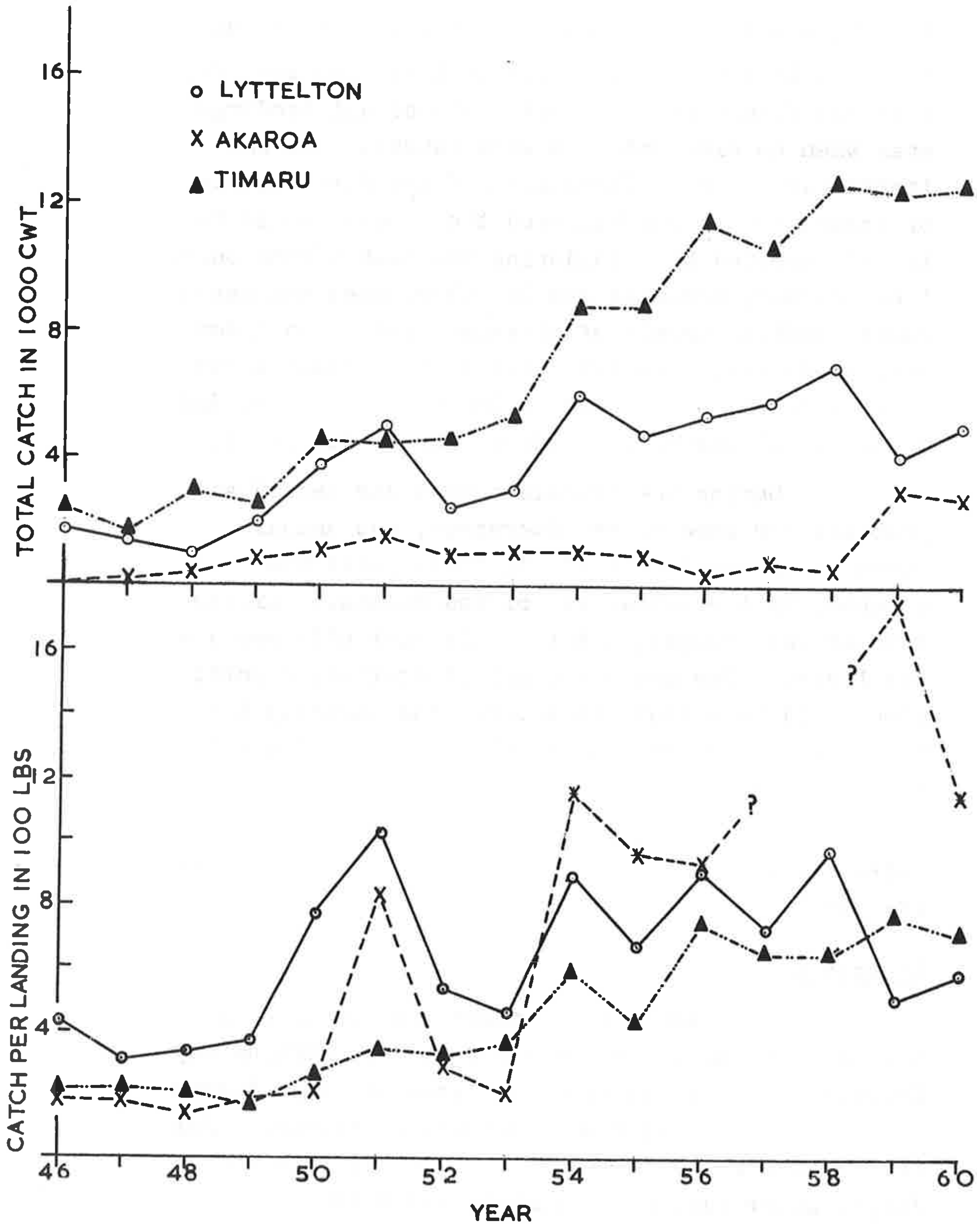


Figure 15. Total catch, and catch per unit effort by Lyttelton, Akaroa, and Timaru boats in 1946 to 1960.

migrations, unless they move elsewhere. Before elephant fish became an important commercial species, the local fleet had little incentive to range outside their 'home' waters. Since the change occurred, operations have extended southwards to the Canterbury Bight, any northerly expansion being limited by further rough bottom. Lyttelton boats operating in the Bight land their catch at Akaroa, and few, if any, venture further south than the Rakaia River.

Lyttelton has consistently occupied second place in terms of total catch, except for 1951 when its catch exceeded Timaru's. The greatest catch, 6,958 cwt, was taken in 1958, and from 1946 to 1960 it has increased by 181%.

The catch per landing was highest in 1951 at 1032.5 lbs, and then fell sharply over the next two years. After recovering in 1954, the catch tended to increase until 1958 when it stood at 977.8 lbs. In 1959 it fell by 48% to recover slightly in 1960 to 587.4 lbs. The latter figure represents an increase of only 35.8% since 1946.

Lyttelton and Akaroa vessels tend to share the same fishing grounds, and the decrease in the Lyttelton catch in 1959 and 1960 catch may, therefore, be due to the great increase in Akaroa's catch in the same years.

Akaroa

Probably due to its isolation, this port has until recently concentrated mainly on the less plentiful but more valuable species such as crayfish and groper. This is reflected in the composition of the fishing fleet which consists principally of one man operated line and crayfish vessels.

The 3 to 5 trawlers from this port work off the Lake Forsyth - Lake Ellesmere beach, sharing the fishing with vessels from Lyttelton and some from Timaru.

After reaching a maximum of 1602 cwt in 1951, the catch declined steadily, until in 1958 it was only 598 cwt. In 1959 and 1960 easier access to Christchurch markets and a more attractive price brought about a big increase in the catch of elephant fish. Since 1946 total annual production has increased by no less than 3,636%, while over the same period the catch per landing increased from 181.8 lbs to 1,146.6 lbs or 530%.

Timaru

The Timaru trawler fleet in 1960 consisted of 27 vessels; this compares with the total of 13 at Lyttelton and three at Akaroa (Marine Department Report on Fisheries 1960). Originally, boats from this port fished the Canterbury Bight only in the area around Timaru. But due to economic pressure some of the larger vessels are now ranging from Te Wae Wae Bay in the extreme south of the South Island to Banks Peninsula, while the smaller units are also extending their range to a more limited extent.

Timaru has shown the most consistent increase in total catch and catch per landing. The former rose steadily from 1946 to a maximum catch of 12,797 cwt in 1958 and has since been steady.

Between 1946 and 1953, the catches per landing were roughly similar to the figures for Akaroa though well below those for Lyttelton. In 1954 Akaroa showed a marked increase to 839.5 lbs, and has since continued at a high level. This left Timaru with the greatest catch and number of vessels, but the lowest productivity. However, production per unit effort at Timaru increased more rapidly than at Lyttelton, until in 1959 it finally exceeded Lyttelton's figure, though at 707 lbs it still remained well below Akaroa's.

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With the exception of Lyttelton, both total catch and catch per landing have risen considerably in recent years while the basic pattern of a day fishery remains unchanged. The introduction of longer ranged, freezer-equipped vessels at Timaru may possibly herald the beginning of a change in the nature of the fishery, which may in time be related to a change in the relative abundance of the stock in the present fishing areas.

While the above data cover a rather limited period of time they do at least provide some indication of past and present productivity, and also indicate that there is little evidence of depletion.

IV. DISCUSSION

Since the purpose of this investigation was a reconnaissance, it is proposed to outline some of the more basic points that require further attention.

(a) Populations

An important question still to be answered is the status of the Canterbury stocks in relation to the remainder of the population in New Zealand. Until something more is known of the presence or absence of separate stocks, the position will remain obscure, and attempts at management on a local level would be unlikely to meet with success.

(b) Growth rate and longevity

To determine growth rate and longevity, it will be necessary to resort to tagging, and two possible methods are suggested. Petersen tags attached by stainless steel wire to the second dorsal fin would probably prove successful. This method has been used by Olsen (1953) on the school shark in south eastern Australia. A full description of the necessary equipment, method and results is given in his paper. External tags of this type suffer from a major disadvantage when used on large, trawl-caught fish: either disc is liable to get entangled in the webbing of the trawl net, and the weight of the fish often pulls the tag out. An alternative method would be to use coloured spaghetti dart tags with a different colour for each size group. Using this method, it would not be necessary to number consecutively each individual tag, and the chances of tag loss occurring during fishing operations would be considerably reduced. The suggested tagging site is towards the mid-dorsal line, on the left hand side of the fish between the two dorsal fins. This region is normally visible to the fishermen when cleaning the fish. Internal tags have not been proposed because it is considered that the chances of recovery would be slight, in view of the large numbers of fish that are generally taken in each haul, and the understandable desire of the fishermen to clean them as quickly as possible. It is also believed desirable that tagging should be carried out during the spawning season and in a limited area.

(c) Fecundity

Attempts to obtain a measure of fecundity in females did not meet with great success. This is due mainly to the shortage of time. The mature ova are rather fragile and require careful handling. In an attempt to overcome the problem, the yolk was precipitated in gently-boiling water, but the shrinkage of the ova and ovarian tissue made counts very difficult. Better results could possibly be obtained on ova in their natural state or by using chemical coagulants.

(d) Incubation and Length of Fish at Hatching

Both the period of incubation and the length of the fish at hatching need to be more accurately determined. It is suggested that the use of a dredge and a 1" mesh trawl net, respectively, should provide the answer to both of these problems. If desired, supplementary data could be obtained by allowing development of the embryo to proceed in simple wire cages.

(e) Food and Feeding

A detailed study of the food and feeding habits has never been conducted, and since growth depends primarily on food supply, some understanding of the latter is essential to good management.

(f) Direct Underwater Observation

This could possibly be used with some success to elucidate some of the more basic biological phenomena, such as mating and the use of the tenaculum; and in addition, it could be used to determine accurately the extent of spawning grounds and the density of ova per unit area. It might even provide a means of calculating an index of the degree of success of spawning seasons. Access to known spawning grounds should be easy since they are in shallow water and probably do not lie far beyond 20 fathoms. However, inshore waters in Pegasus Bay and the Canterbury Bight are often turbid because the sea floor consists largely of loess deposits which are easily disturbed by wave action; therefore, it is possible that turbidity may limit the usefulness of this research tool.

V. ACKNOWLEDGMENTS

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