New Zealand Fisheries Assessment Research Document 94/6

Stock assessment of the elephantfish (*Callorhinchus milii*)

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April 1994

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New Zealand Fisheries Assessment Research Document 94/6. 17 p

1. EXECUTIVE SUMMARY

In this document we compile information useful for stock assessment of elephantfish, and review the literature on the fishery and general biology of the species. We present new findings on the movements of elephantfish in the Canterbury Bight, based on data collected 25 years ago and archived until now. We examined the catch and effort information, and concluded that it was seriously compromised by reporting errors. The catch and effort data do not provide a reliable history of the fishery and are unusable for estimating yields. We discuss Australian tagging data relevant to the lifespan of elephantfish and to the estimates of natural mortality used to estimate Maximum Constant Yield. Maximum age cannot be reliably estimated for the New Zealand stock, but appears to exceed 6 years and may be as high as 15 years.

2. INTRODUCTION

2.1 Overview

This is the first Fisheries Assessment Research Document for the elephantfish (*Callorhinchus milii*). Earlier technical reports were produced by Gorman (1963) and Coakley (1971). McGregor *et al.* (1985) reviewed the biology and history of the fishery. We describe the historical background of the fishery, including information on fishing methods, distribution and seasonality of commercial catches, and Total Allowable Catch (TAC). We examine the catch and effort database and consider the data unreliable. We review past research and summarise archived data from tagging studies conducted by Alan Coakley from 1966 to 1969 and not previously analysed.

2.2 Description of the fishery

2.2.1 Commercial landings and spatial distribution of catches

Elephantfish have been commercially fished since the beginning of this century. There is no deepwater fishery for elephantfish, so virtually the entire catch is taken by New Zealand inshore vessels. Foreign vessels used to fish close inshore in the Canterbury Bight, so historically the foreign catch may have been significant (M.P. Francis, MAF Fisheries Greta Point, pers. comm.). Most of the catch has always been taken in the Canterbury Bight, although fish are landed in commercial quantities from Wellington south.

Before the 1950s, elephantfish were generally regarded as bycatch and considered worthless. It was not until the late 1950s that a market was found for these fish and they were targeted directly. They were mainly consumed in the fish and chip trade, where they were sold as silver trumpeter or white fillets. Livers were also in demand for their oil content, but this market has since declined.

Most of the commercial catch comes from the Canterbury Bight (Quota Management Area 3, Fishstock ELE 3, Fishing Return Statistical Area 022; summarised by McGregor *et al* (1985)) (Figures 1 and 2). Landings were consistently low (< 400 t per year) and remained steady from 1936 to 1948. From 1948 until 1958 catches increased rapidly to a new, relatively stable level between 900 and 1200 t. In the 13 years from 1967 to 1980, commercial catches fluctuated, peaking at 1400 t in 1971. Since then, catches have slowly but steadily declined to the current level of around 600 t. The fishery is now mainly an incidental bycatch in other target fisheries, with trades and surrenders only significant in ELE 3 (Figure 1 and 3).

2.3 Literature Review

2.3.1 Distribution

Elephantfish are uncommon off the North Island, occurring south of East Cape on the east coast and south of Kaipara on the west (Ayling & Cox 1982). Reasons for their distributional pattern have not been established.

2.3.2 Diet

Elephantfish probably use the cartilaginous protuberance on the snout to locate food on the substrate (Ayling & Cox 1982). Qualitative studies of elephantfish gut contents show large numbers of molluscs, as well as some crustacea and fish (Thompson & Anderton 1921, Graham 1939). The abundance of molluscs in the diet is unusual compared to other fish species (according to Graham's (1939) data). The most consistently found item in gut contents of elephantfish collected off the Otago coast were the crushed shells of the clam *Maorimactra ordinaria* (Didier 1992). Molluscs are not dominant in the diet of the South African elephantfish, *Callorhinchus capensis* (Freer & Griffiths 1993a), so the predominance of molluscs in the New Zealand species may reflect the abundance of these molluscs in soft sediment areas where elephantfish occur.

2.3.3 Reproduction

Males reach sexual maturity at about 50 cm fork length, based on the presence of three sets of claspers (Gorman 1963) and females mature at 70 cm fork length based on examination of ovaries or presence of a cloacal plug. Tentative ages at maturity are 3 years for males and 4.5 years for females (*see* section 2.3.5).

Elephantfish are oviparous and are believed to have low fecundity (Gorman 1963). Egg cases, each containing a single large, yolky egg, are deposited in pairs on sandy or muddy substrates in water shallower than 30 m (Gorman 1963, Didier 1992). Eggs have an incubation period of 5–8 months, although it may be as long as 10 months under some circumstances (Gorman 1963.

Juveniles hatch at a fork length of about 10 cm, and are reported to remain in shallow waters for their first 2 years (Gorman 1963). After spawning, adults are believed to disperse to deeper waters (McGregor *et al* 1985). The South African elephantfish shows a similar pattern of spawning in shallow water followed by dispersal of larger females to deeper water in winter: the smallest are taken with beach seines in very shallow water, whereas more mature fish are found at depths of 80–130 m (Freer & Griffiths 1993a).

The egg-laying season is not well known: it appears to be mainly November to April on the east coast of the South Island, but may extend into June in the Marlborough Sounds. Didier (1992) collected fertile egg cases in the Marlborough Sounds in June. Known spawning sites include Iwirua Point and Kumutoto Bay in Queen Charlotte Sound and from Fitzroy Bay to Savill Bay in Pelorus Sound (Didier 1992). Egg cases at these locations were found at 5–20 m depth. There is also anecdotal evidence of spawning during March in Clifford Bay, Marlborough Sounds and during April in Pelorus Sound (C. Duffy, Department of Conservation, pers. comm.). Egg cases have been collected off the Otago coast in November (Didier 1992) and in Blueskin Bay, Otago in February (Graham 1953). Females with egg cases ready for extrusion were collected off Otago in March (Graham 1953). Elephantfish were targeted during the egg-laying season. Landings were highest in Timaru and Lyttelton from November to January (Coakley 1971).

A single female may deposit several egg pairs during the breeding season, perhaps as frequently as every 2 weeks (references cited in Didier 1992). This suggests that elephantfish may not have the low fecundity suggested by Gorman (1963). The South African elephantfish has relatively high fecundity (Freer & Griffiths 1993a).

2.3.4 Length-weight relationships

Gorman (1963) estimated the length-weight relationship for elephantfish using a curve fitted by eye to the linearised data and gave a length-weight relationship. He measured and weighed 397 fish; 254 females and 143 males. The largest male in his study weighed 3.06 kg at 70 cm, and the largest female was 8.17 kg at 94 cm. He noted that mature males are usually smaller than females in elephantfish, as in school sharks, dogfish and many finfish. His data were collected from fish at the height of the spawning season in November so weight differences between males and females may be accentuated.

It is difficult to compare length of elephantfish from different studies because large fish stretch when lifted by the tail (J.B. Jones, MAF Fisheries Greta Point, pers. comm.) and fresh elasmobranchs may shrink by as much as 4% after freezing and thawing (Francis & Francis 1992).

2.3.5 Age and growth

The otoliths and scales commonly used in ageing teleosts are absent in cartilaginous fish, such as elephantfish. An alternative is to use vertebrae or dorsal spines. Although elephantfish vertebrae do not show growth marks, the dorsal spine has markings which may represent annual growth rings (Sullivan 1977, Freer & Griffiths 1993b). Sullivan developed a technique for ageing elephantfish using spine growth rings, but the assumption that rings are annual has never been convincingly validated. He reported that growth of males and females was equal for the first 3 years, with females continuing to grow until the age of 6 years, while males die after 5 years. Sullivan's growth curve does not conform to a von Bertalanffy model and is difficult to evaluate because of uncertain validation of the spine ageing technique.

Jones & Hadfield (1985) presented growth data on elephantfish from Porirua and Pauatahanui Inlets suggesting growth to 50 cm in 200 days, in contrast to Sullivan's (1977) data which indicated a fish of this size should be at least 2 years old. However, they considered their results were influenced by small sample size.

Elephantfish are believed to have rapid growth and a short life span according to Sullivan (1977), who reported "considerable variation" in growth rates, although he did not actually calculate the rates. Some indication of growth rates is available from tagging data (*see* section 4.1.1), although rates cannot be accurately estimated. Maximum growth for tagged fish was about 20 cm per year.

Gorman (1963) drew the "tentative conclusion" from commercial length-frequency data that growth to sexual maturity was relatively rapid, but slowed after maturity. Age at 50 cm was estimated to be about 3 years, assuming length-frequency modes represented single year-classes (Gorman 1963). In contrast, McGregor *et al* (1985) reported that elephantfish were slow growing, but presented no evidence in support of this statement.

Gorman (1963) attempted to follow size frequency modes through time in commercial catches, assuming length-frequency modes represented year classes. However, his data show disappearance and reappearance of modes rather than an even progression of modal size through time. This indicates bias in the data & precludes any estimate of growth rates from the commercial catches (Hilborn & Walters 1992). Furthermore, we do not know whether older year classes are represented by overlapping length frequency modes, which would make separation of year classes difficult. We were unable to evaluate the degree of bias in the size frequency distribution due to sampling.

There are no really convincing data on growth rates derived from either modal progression analysis of length-frequency data from commercial catches (Gorman 1963) or ageing studies using dorsal spines (Sullivan 1977). The life span of elephantfish is not definitely known. Although the maximum age has been considered in New Zealand to be 4 to 6+ years (Gorman 1963, Sullivan 1977), preliminary results of Australian tagging studies suggest elephantfish may live longer than 15 years (Coutin 1992). One female elephantfish was at liberty for 11.3 years and another was recaptured after 8.75 years (M.P. Francis, pers. comm.). Both fish were presumably already adult when tagged. The largest fork lengths reported by Gorman (1963) are smaller than fork lengths from the Australian tagging study where the largest male was 80.7 cm and the largest female was 101.3 cm (M.P. Francis, pers. comm). Sullivan's largest fish was also smaller than 90 cm. The Australian situation may be quite different from that in New Zealand, but their tagging results raise the possibility that elephantfish live longer than we currently estimate in New Zealand. Elephantfish in South Africa are reported to live to at least 12 years old (Freer & Griffiths 1993b). Maximum age cannot be reliably estimated for the New Zealand stock, but appears to exceed 6 years and may be as high as 15 years.

2.3.6 Natural mortality

The only natural mortality estimate for elephantfish was derived using a life history method where natural mortality, M (years^{-1}), was estimated from $\log_e 100$/ maximum life span (in years) (Annala 1993, G. McGregor, MAF Fisheries North, pers. comm.) as 0.35.

3. REVIEW OF THE FISHERY

3.1 TACs

The TAC in 1986 for the major Fishstock (ELE 3) was 280 t, which was about half the previous year's catch (Table 1, Figure 3). At this time ELE 3 was considered overfished, and the TAC was set at this level to facilitate recovery of the stock (Annala 1993). In 1986–87 and 1987–88, landings in ELE 3 exceeded the TAC by about 80%, largely due to incidental bycatch. In 1988–89 the TAC for ELE 3 was increased to 415 t because it was considered that some stock rebuilding had occurred. Since then landings in ELE 3 have exceeded the TAC by minimal amounts. The TACs for Fishstocks ELE 5 and 7 have been relatively constant since their introduction, and are now set at 71 and 101 t, respectively. Reported landings in these areas have generally not exceeded these TACs. Catches and TACs in other Fishstocks are low.

From 1986–87 to 1987–88 the total catch of elephantfish for all Fishstocks combined exceeded the TAC by about 22–23%. After increasing the quota in 1988–89, total catches were only 84–95% of the new TAC (Figure 3).

Table 1: Reported landings (t) of elephant fish by Fishstock from 1983–84 to 1992–93 and actual TACs (t) from 1986–87 to 1992–93

Fishstock	ELE 1		ELE 2		ELE 3		ELE 5		ELE 7		ELE 10			
QMA (s)	1 & 9		2 & 8		3 & 4		5 & 6		7		10		Total	
	Landings	TAC	Landings	TAC	Landings	TAC	Landings	TAC	Landings	TAC	Landings	TAC	Landings	TAC
1983–84*	<1	–	5	–	605	–	94	–	60	–	0	–	765	–
1984–85*	<1	–	3	–	517	–	134	–	50	–	0	–	704	–
1985–86*	<1	–	4	–	574	–	57	–	46	–	0	–	681	–
1986–87†	<1	10	2	20	506	280	48	60	29	90	0	10	584	470
1987–88†	<1	10	3	20	499	280	64	60	44	90	0	10	610	470
1988–89†	<1	10	1	22	450	415	49	62	43	100	0	10	543	619
1989–90†	<1	10	3	22	422	418	32	62	55	101	0	10	510	623
1990–91†	<1	10	5	22	434	422	55	71	59	101	0	10	553	636
1991–92†	<1	10	11	22	450	422	58	71	78	101	0	10	597	636
1992–93†	<1	10	5	22	503	423	39	71	61	101	0	10	608	637

* FSU data.
† QMS data.

3.1.1 Catch and effort data

We consider that the reliability of the catch-effort data for elephantfish is largely compromised by reporting errors.

3.2 Other Information

3.2.1 Seasonality

The fishery is extremely seasonal, with most fish being caught in inshore waters during spring and summer during the annual spawning migration tc water less than 30 m (Gorman 1963). After spawning the fish move offshore and disperse in deeper waters. We do not know where elephantfish go in the winter, although Gorman (1963) suggested they are in deep water.

3.3 Recreational, traditional, and Maori fisheries

Elephantfish do not appear to be an important species for Maori, traditional, or recreational users at this time, although they are considered to be good sport by recreational fishers. Elephantfish used to be frequently caught in surfcasting competitions in Canterbury, with as many as a dozen being landed in a day. This is no longer the case, and a catch of one or two is considered unusual (Melief 1994).

4. RESEARCH

4.1 Stock Structure

4.1.1 Movements data from tagging studies

We located unpublished results of a tagging study conducted by A. Coakley from 1966 to 1969 and present some limited analysis on fish movements.

The tagging results permit us to describe movements of elephantfish in the Canterbury Bight. Tagged fish moved 39.2 km on average. One fish was recaptured at the release site 5 months after being tagged. The maximum distance moved was 282 km after 2 years and 7 months at liberty. Tagging returns show that all but 5 of the 77 fish stayed within the Canterbury Bight during their liberty (Figure 4a). Of the fish leaving the Canterbury Bight, one was captured north of Kaikoura, two north of Banks Peninsula, one off the Otago Peninsula, and one off the Waitaki River. Forty-five percent of the tagged fish moved less than 20 km from their release point, and the distribution of returns clearly shows a predominance of fish staying close to the point at which they were released (Figure 4b). The tagging data do not provide any information about seasonal movements on and offshore which are believed to be associated with spawning.

The limited movements of tagged fish meant that no returns were from outside ELE 3 where the fish were tagged and released. The results support the current Fishstock boundaries.

4.2 Trawl Surveys

Two-phase random stratified trawl surveys using the *Kaharoa* were undertaken in May 1990 (KAH9008), 1991 (KAH9105), 1992 (KAH9205), and 1993 (KAH9306) along the east coast of the South Island from the Otago Peninsula to Kaikoura in the depth range 30–400 m

(M. Beentjes and R. Wass, MAF Fisheries Dunedin, in press and in prep.). These surveys provide distributional data, length frequencies, and biomass estimates of elephantfish. The data from 1990 are not comparable with the 1991–93 surveys due to different trawl gear being used in the 1990 survey (M. Beentjes, pers. comm.).

Length-frequency data from the *Kaharoa* trawl surveys show a predominance of immature females (< 70 cm) in 1991, 1992, and 1993. Immature males (< 50 cm) were also predominant in 1992, but not in 1991 or 1993. It is probable that the size frequency distribution is biased towards smaller fish. Bias in the size distribution is suggested by the totally different size distributions in 1991, 1992, and 1993 (Figure 5), and the small number of fish measured per survey. As the trawl survey appears to catch mainly immature fish with widely different size structure in different years the surveys may not provide a good estimate of relative inter-annual abundance for elephantfish.

Research data from 1991 to 1993 show highest catch rates for elephantfish in the inshore areas (strata 1–4) of the trawl survey (Figure 6 from Beentjes and Wass, in press, Table 2). Spatial distributions differed between surveys.

Table 2: Total relative biomass of elephantfish (t) by stratum estimated from Kaharoa surveys in 1991, 1992, and 1993.

	Stratum							
	1	2	3	4	5	6	7	89
Depth (m)	30–100	30–100	30–100	30–100	100–200	100–200	100–200	200–400200–400
1991	59	231	14	18	0.8	3	0	00
1992	19	64	55	57	0	0	0	00
1993	171	36	238	87	0	0.9	3	00

4.3 Other studies

4.3.1 Length-weight relationships

Gorman (1963) provided data based largely on commercial trawls with cod end meshes of 4–5 inches (10–13 cm). To check Gorman's equation, we digitised all the discrete points we could see in Gorman's data (322 out of 397 points) and fitted a power function to them (Statsoft Inc 1992) (Figure 7). The female:male sex ratio in our digitised data was 212:108 or 1.96: compared to 1.78: for Gorman's original dataset. The regression was very close to the original and we found no difference between the curves for males and females (tested by ANCOVA).

Length-weight coefficients in the trawl database are based on fish of a limited size range from 62 fish sized between 58 and 92 cm (voyage TAN9301). An error in the length-weight intercept in the 1993 stock assessment summary document has been corrected to predict weights in grams rather than kilograms.

The various length-weight regression coefficients are compared below.

Table 3: Comparison of the intercept and slope on regressions relating length (cm) to weight (g) in elephantfish ($W = a \bullet L^b$)

Source	Size Range (cm) (No. fish)	Intercept	Slope
Trawl database	58–92 [62]	0.015	2.99
1994 Stock assessment summary (from Gorman 1963)	18–94 [397]	0.0091	3.02
This study (digitised from Gorman 1963)	18–94 [322]	0.0062	3.12

4.3.2 Sex ratio

Gorman (1963) found that sex ratio was about 50:50 in immature fish, but that females were more abundant in samples of mature fish. Our analysis of the 1990–92 South Island east coast trawl survey data show that sex ratio is approximately 50:50 and can be reliably estimated only for samples larger than 30 fish (Figure 8). If samples with fewer than 30 fish are excluded, we can find no evidence for any difference in the sex ratio in the different size classes of fish (Table 4). We restrict our conclusions to the sizes classes 0–25, 26–50, and 51–75 cm where we have adequate sample sizes. Since males mature at about 50 cm and females at about 70 cm, our samples were largely immature fish and our results do not contradict Gorman (1963).

Many elasmobranchs segregate by size and sex, so small sample sizes probably represent individual schools rather than the population (M.P. Francis, pers. comm.). This is supported by Freer & Griffith's (1993a) observation that gill net catches of *C. capensis* in a single area are generally all the same sex and of a narrow size range.

Table 4: Percentage of male/ female elephantfish from the South Island east coast Kaharoa trawl survey, for the years 1990–92. Sample size is given in brackets. Only samples > 25 are included (*see* Figure 8). Fish are divided into 4 size classes, and the sex ratio for all sizes is also shown. –, no data

	Size				
	0–25 cm	26–50 cm	51–75 cm	76–100 cm	Total
1990	–	–	–	–	0.5/0.5 (38)
1991	–	–	0.5/0.5	–	0.47/0.53 (137)(162)
1992	0.48/0.52 (56)	0.47/0.53 (92)	0.49/0.51 (47)	–	0.45/0.55 (205)

4.4 Biomass estimates

At present there are no data from which absolute biomass can be estimated. Relative biomass estimates were presented in Table 2. Reasons for suspecting these estimates of relative biomass may be biased and not representative of adult, recruited biomass are given in section 4.2.

4.5 Yield estimates

4.5.1 Estimation of Maximum Constant Yield

Maximum Constant Yield (MCY) was estimated from c Y_{av} (method 4, Annala 1993). The natural variability factor, c, is determined from the estimated natural mortality rate, M(= 0.35), and is applied to all stocks (Annala 1993). This was apparently derived from $\log_e 100/$ maximum age (using a maximum age of 13.2 years). However, it is unclear where this maximum age came from. Using the maximum age from Sullivan of 6 years would give M = 0.77, while using the estimated maximum age from the Australian tagging study of 15 years gives M = 0.31. Y_{av} was calculated for the stocks ELE 3, ELE 5, and ELE 7 for the years 1983–84 to 1985–86 because the fishery appeared to stabilise after a period of decline (Annala 1993). MCY estimates were as follows:

South-East (Coast) and South-East (Chatham Rise) (ELE 3)

MCY = 0.7 * 565.5 = 396 t (rounded to 400 t)

Southland and Sub-Antarctic (ELE 5)

MCY = 0.7 * 94.9 = 66 (rounded to 70 t)

Challenger/Central Plateau (ELE 7)

MCY = 0.7 * 52.3 = 37 t (rounded to 40 t).

Both maximum age and c are unknown for elephantfish. The value of c = 0.7 has been used for several years and until there are validated ages and/or data on recruitment variability there is no reason to change it.

4.5.2 Estimations of Current Annual Yield (CAY)

CAY cannot be estimated because of the lack of current biomass estimates.

5. ACKNOWLEDGMENTS

We are grateful to Mike Beentjes and Eunice Warren for helpful discussions on the data, and for digging out results collected by Alan Coakley which had been archived since 1966. Martin Robinson provided access to the catch and effort data, and we are grateful for his help in checking the data. We appreciated Rob Wass preparing the Kaharoa research survey distributional data. Comments by Inshore Stock Assessment Working Group members, Stuart Hanchet, Alan Coakley, John Annala and Mike Beardsell were appreciated and improved the manuscript.

6. REFERENCES

Annala, J.H. (Comp) 1993: Report from the Fishery Assessment Plenary, May 1993: stock assessments and yield estimates. 241 p. (Unpublished report held in MAF Fisheries, Greta Point library, Wellington).

Ayling, T. & Cox, G.J. 1982: Collins guide to the sea fishes of New Zealand. Collins, Auckland, 343 p.

Beentjes, M. & Wass, R. in press: Inshore trawl survey of the Canterbury Bight and Pegasus Bay, May to June 1991 (RAH9105).

Coakley, A. 1971: The biological and commercial aspects of the elephantfish: 1. The commercial fishery. *Fisheries Technical Report No. 76.* 29 p.

Coutin, P. 1992: Sharks.....and more sharks. *Australian fisheries,* June 1992: 41–42.

Didier, D.A. 1992: Phytogenetic systematics of extant chimaeroid fishes (Holocephali, Chimaeroidei). Unpublished PhD thesis, University of Massachusetts.

Francis, M.P. & Francis, R.I.C.C. 1992: Growth estimates for New Zealand rig (*Mustelis lenticulatus*). *Australian Journal of Marine and Freshwater Research 43*: 1157–1176.

Freer, D.W.L. & Griffiths, C.L. 1993a: The fishery for, and general biology of, the St Joseph *Callorhinchus capensis* (Dumeril) off the south–western Cape, South Africa. *South African Journal of Marine Science 13*: 63–74.

Freer, D.W.L. & Griffiths, C.L. 1993b: Estimation of age and growth in the St Joseph *Callorhinchus capensis* (Dumeril). *South African Journal of Marine Science 13*: 75–81.

Gorman, T.B.S. 1963: Biological and economic aspects of the Elephant fish *Callorhynchus milii* Bory in Pegasus Bay and the Canterbury Bight. *Fisheries Technical Report No. 8* . 54 p.

Graham, D.H. 1939: Food of the fishes of Otago Harbour and adjacent seas. *Transactions of the Royal Society New Zealand 68:* 421–436.

Graham, D.H. 1953: A treasury of New Zealand fishes. First edition. A.H. & A.W. Reed, Wellington. 404 p.

Hilborn, R., & Walters, C.J. 1992: Quantitative fisheries stock assessment. Choice, dynamics and uncertainty. Chapman and Hall, New York 570 pp.

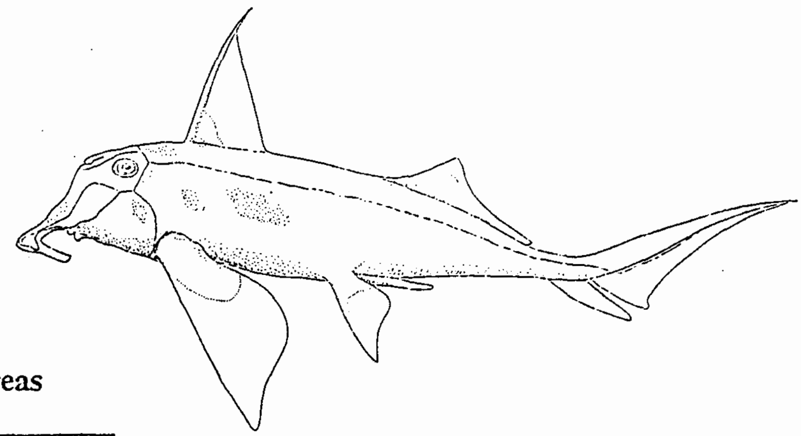
Jones, J.B. and Hadfield, J.D. 1985: Fishes from Porirua and Pauatahanui Inlets: occurrence in gill nets. *New Zealand Journal of Marine and Freshwater Research 19:* 477–484.

McGregor, G.A., Voller, R.W., & Coakley, A. 1985: Elephantfish. *In* Colman, J.A., McKoy, J.L., Baird, G.G. (Comps and Eds). Background papers for the 1985 Total Allowable Catch recommendations. Fisheries Research Division, New Zealand Ministry of Agriculture and Fisheries. (Unpublished report held at Fisheries Research Centre Library, Wellington).

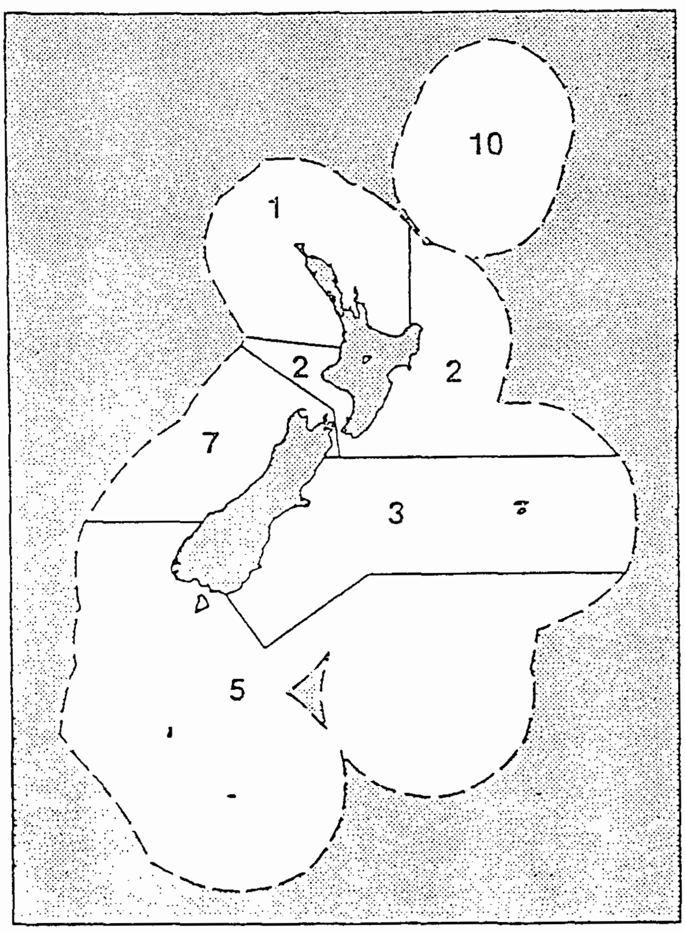
Melief, R. 1994: Elephant fish. *Southern fishing and boating,* February 1994: 56–57.

Sullivan, K.J. 1977: Age and growth of the elephant fish *Callorhinchus milii* (Elasmobranchii: Callorhynchidae). *New Zealand Journal of Marine and Freshwater Research* 11: 745–753.

Thompson, G.M. and T. Anderton 1921: History of the Portobello Marine Fish Hatchery. *Board of Science and Art 2:* 69.



(A) Fisheries Management Areas



(B) Statistical Areas

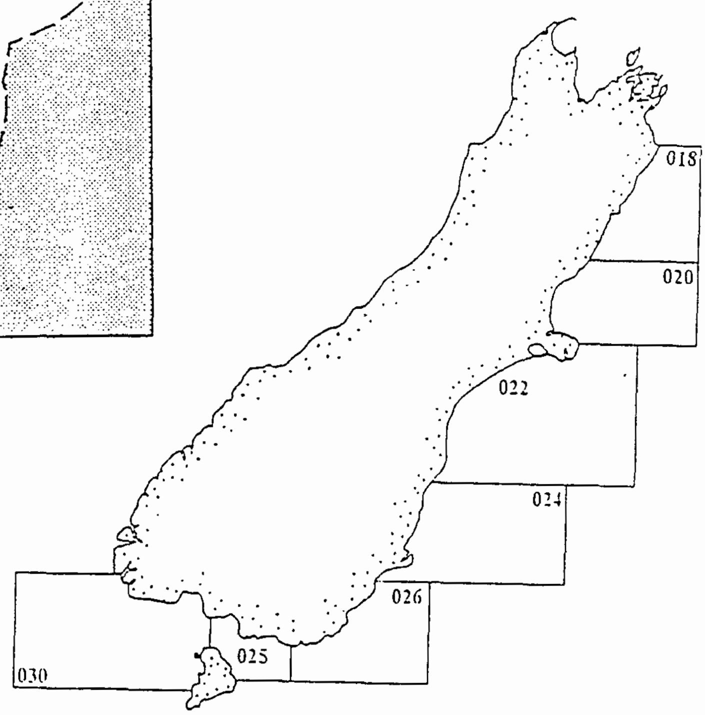


Figure 1: (A) Elephantfish Quota Management Areas. (B) Fishing Return Statistical Areas.

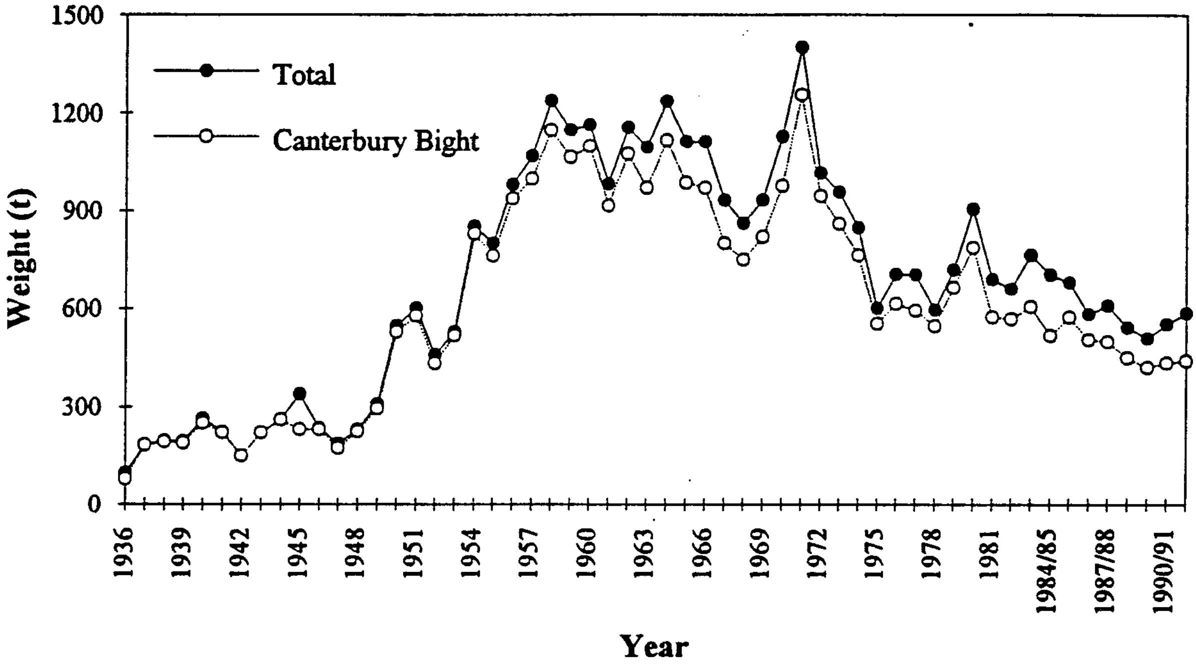


Figure 2: Total commercial landings of elephantfish compared to landings from the Canterbury Bight.

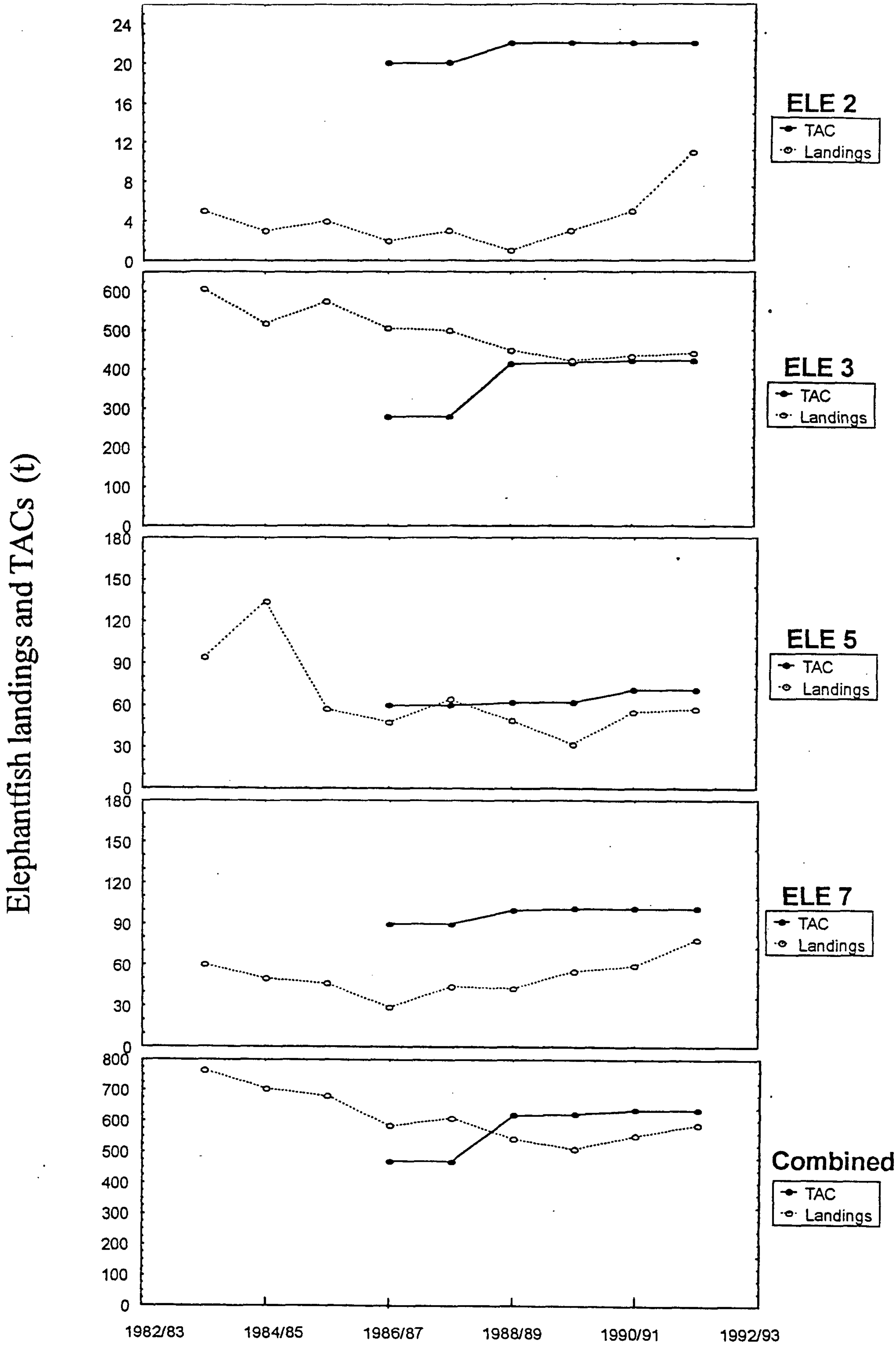


Figure 3: Commercial landings of elephantfish in relation to Total Allowable Catch (TAC) for each Fishstock and all areas combined.

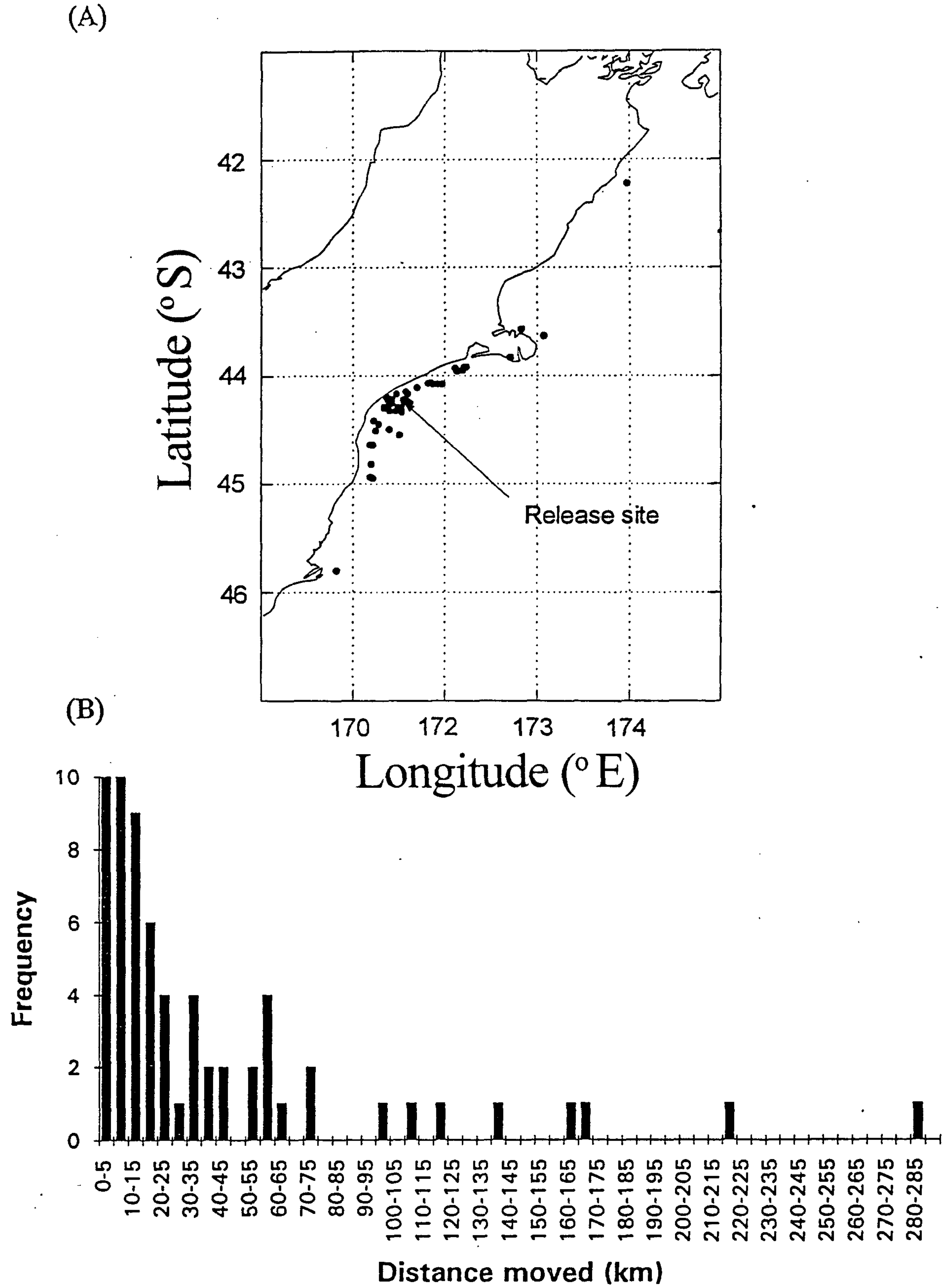


Figure 4: (A) Movements of elephantfish following tagging at the release site in the Canterbury Bight. Dots indicate recapture locations. (B) Frequency distribution of the distances moved by tagged fish.

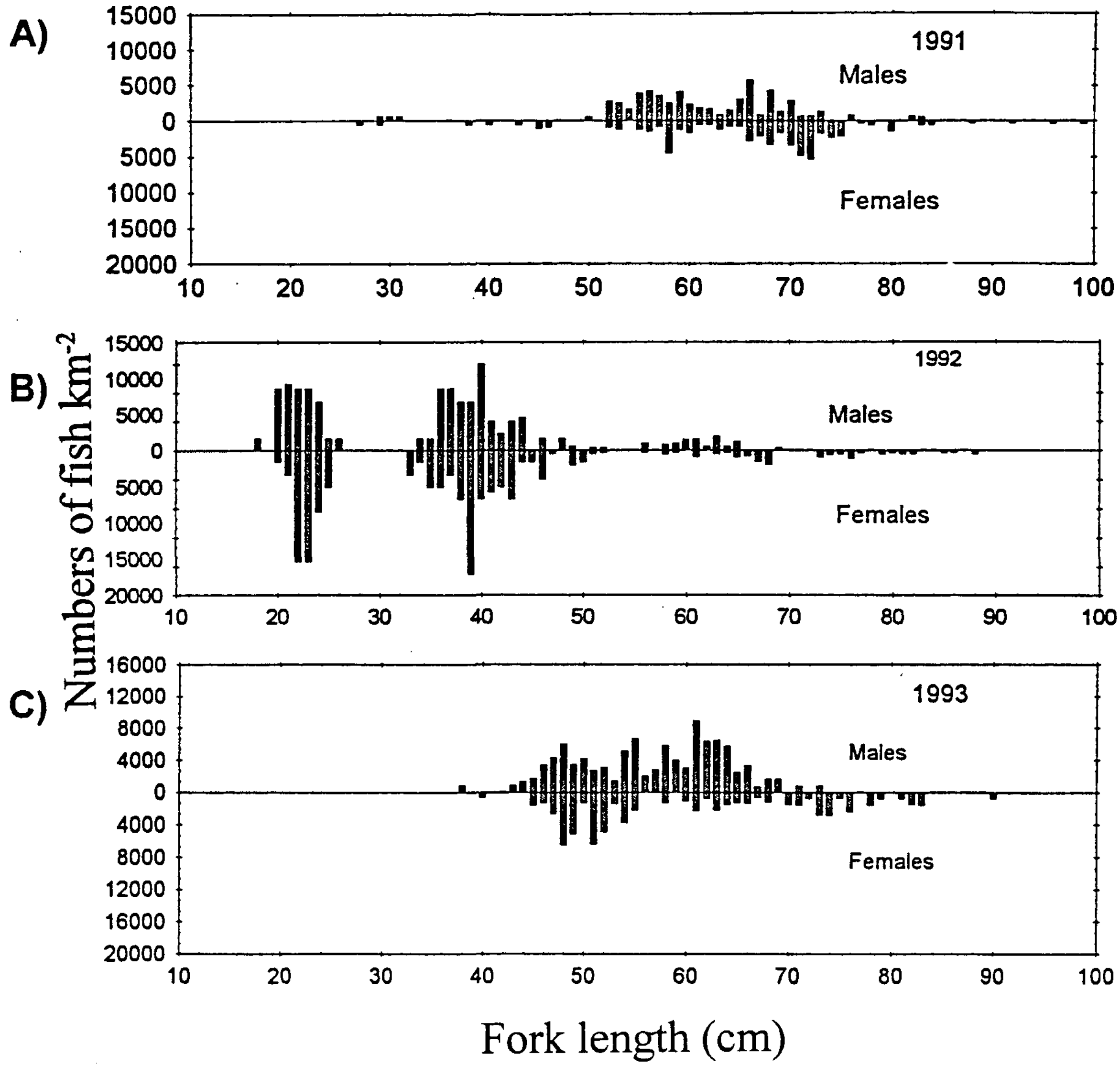


Figure 5: (A) Length–frequency distributions for male and female elephantfish collected during the 1991 *Kaharoa* trawl survey. (B) Length–frequency distributions for male and female elephantfish collected during the 1992 *Kaharoa* trawl survey. (C) Length–frequency distributions for male and female elephantfish collected during the 1993 *Kaharoa* trawl survey.

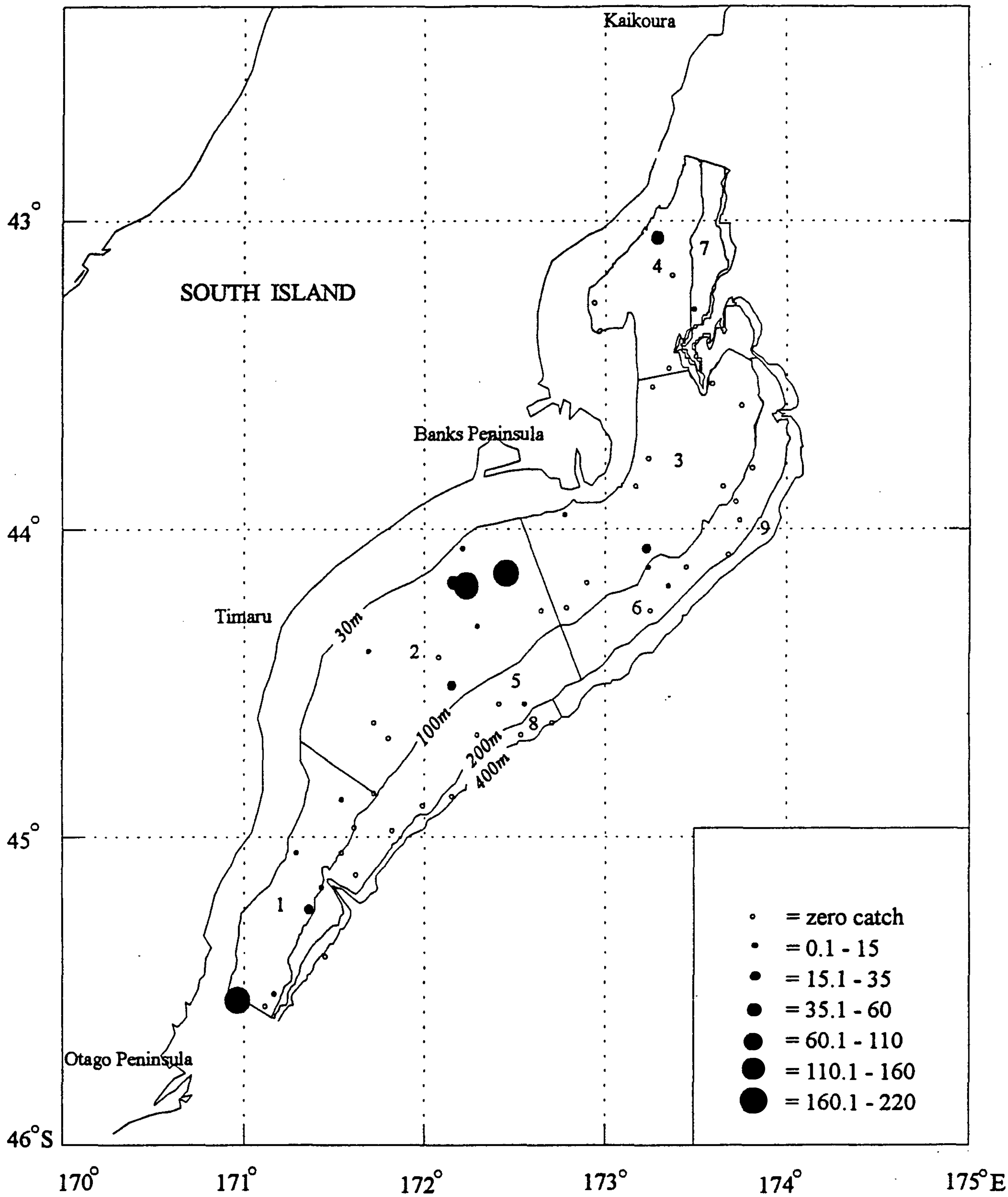


Figure 6: Spatial pattern of elephantfish abundance during the 1991 *Kaharoa* research trawl survey. Catch rates expressed as kg km^{-2}. Depth ranges for survey strata are: strata 1–4, 30–100 m; strata 5–7, 100–200 m; strata 8–9, 200–400 m.

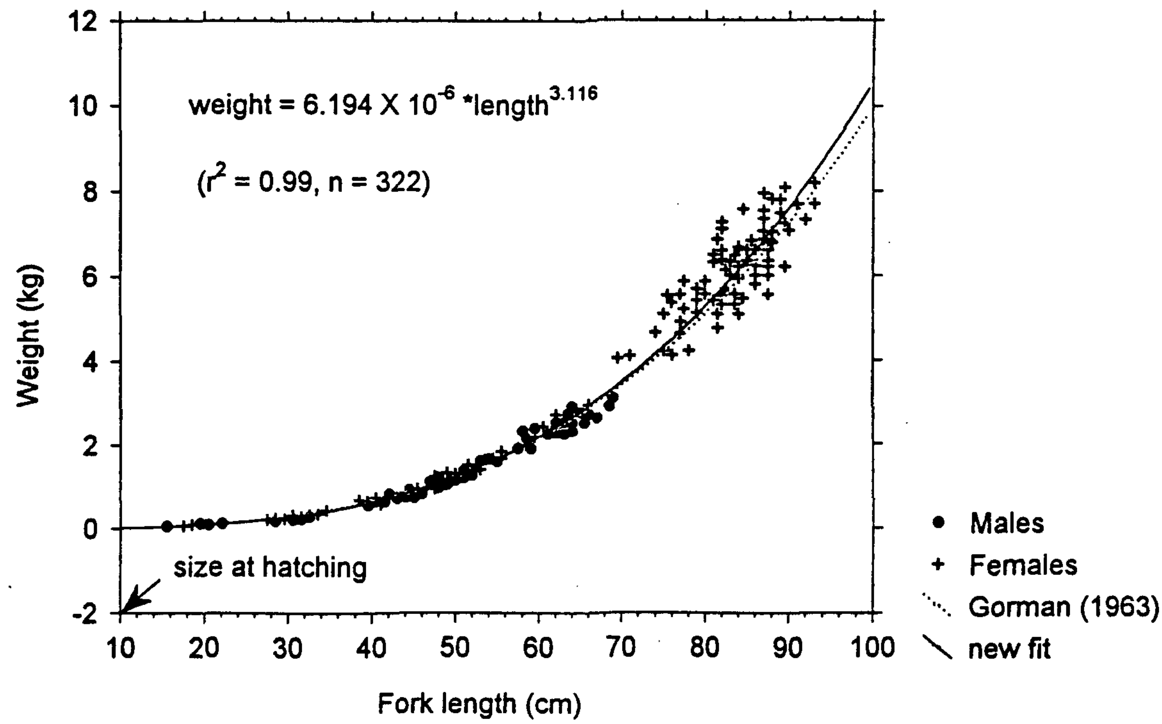


Figure 7: Length–weight predictive regression for male and female elephantfish (data from Gorman (1963)). The new fit from non–linear parameter estimation is almost identical to Gorman's (1963) model obtained by linearising the data.

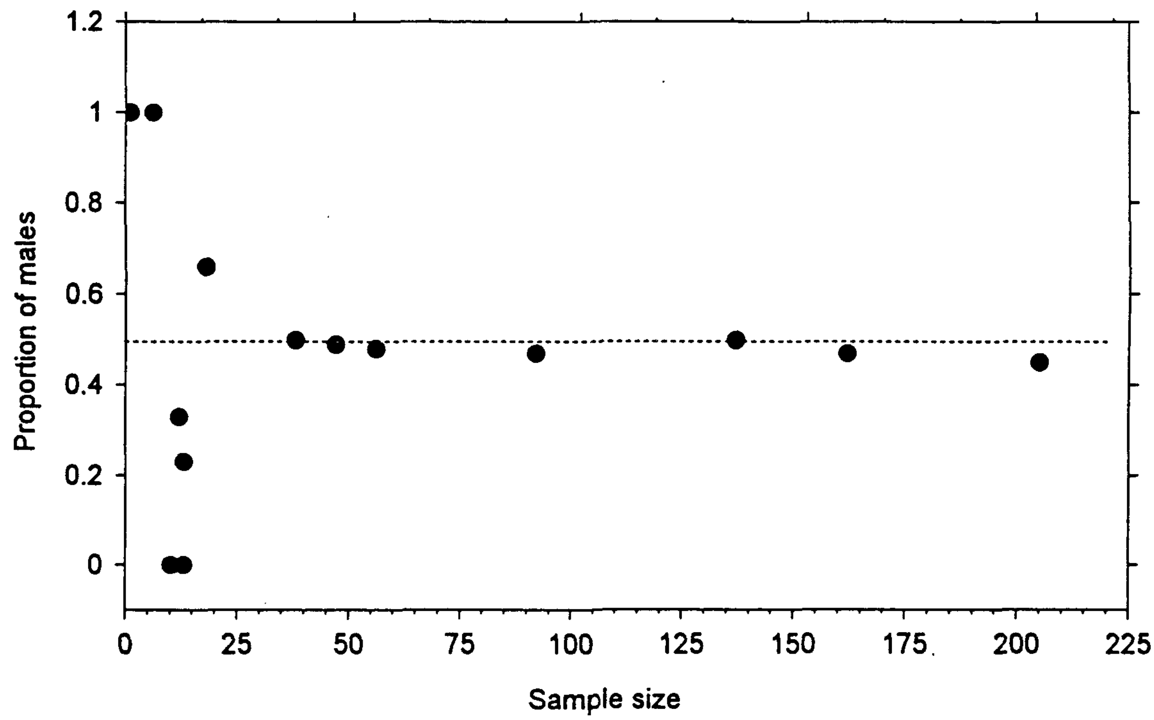


Figure 8: Sex ratio of elephantfish in relation to sample size. Data are from the 1991 and 1992 *Kaharoa* trawl surveys.