MINISTRY OF FISHERIES
Te Tautiaki i nga tini a Tangaroa

ISSN 1175-1584

Information available for the management of New Zealand kingfish (*Seriola lalandi lalandi*) stocks

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New Zealand Fisheries Assessment Report 2003/25
June 2003

Corrections to *New Zealand Fisheries Assessment Report 2003/25*

C. Walsh et al. Information available for the management of New Zealand kingfish stocks.

Page 10, paragraphs 5 & 6 should read

Three regional surveys were conducted between 1991–92 and 1993–94: the South region (representing FMAs 3 and 5) in 1991–92, the Central region (FMAs 2, 7, and 8) in 1992–93, and the North region (FMAs 1 and 9) in 1993–94 (see Figure 1, Table 2). These surveys can be combined to give an estimate of the total annual recreational harvest of kingfish for 1991–94 of 495–805 t (Table 3). This assumes that there was no inter-annual variability in catches of kingfish landed over this period. In 1993–94 the recreational catch of kingfish was comparable to that of the commercial sector in KIN 1, KIN 7, and KIN 9 where most of the recreational catch is taken (Table 3).

In 1996 a recreational survey conducted over all three regions (Table 4) produced a recreational harvest estimate for KIN 1 only, of 350–410 t (Table 5). This estimate is lower than that derived from the 1993–94 survey (415–645 t; Table 3), but it is not clear what effect the introduction of bag and minimum size limits (in October 1993) has had on the 1996 estimate. No estimate of recreational kingfish harvest is available for KIN 9 in 1996 (Table 5). This is surprising given that this was the FMA with the second highest recreational kingfish harvest estimate in 1993–94.

Tables 2, 3, & 4 should read

Table 2: *Summary of the combined* household telephone and diary survey sample designs, response rates, *diarist* kingfish *catches, and scaled* numbers of fish caught from the 1991–92 to 1993–94 regional surveys. Data from Teirney et al. (1997).

Region	Year	Households	Households interviewed	Fishers interviewed	Fishing diarists	Total diarist catch	Scaled catch (1000s)
South	1991–92	262 444	10 055	1 073	862	2	not est.
Central	1992–93	373 346	10 045	1 337	989	124	15
North	1993–94	550 625	15 015	3 363	2 728	768	101
Total		1 186 415	35 115	5 773	4 579	894	116

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New Zealand Fisheries Assessment Report 2003/25
June 2003

Published by Ministry of Fisheries
Wellington
2003

ISSN 1175-1584

Citation:
Walsh, C.; McKenzie, J.; McGregor, G.; Poortenaar, C.; Hartill, B.; Smith, M. (2003).
Information available for the management of New Zealand kingfish
(*Seriola lalandi lalandi*) stocks.
New Zealand Fisheries Assessment Report 2003/25. 57 p.

This series continues the informal
New Zealand Fisheries Assessment Research Document series
which ceased at the end of 1999.

EXECUTIVE SUMMARY

Walsh, C.; McKenzie, J.; McGregor, G.; Poortenaar, C.; Hartill, B.; Smith, M. (2003). Information available for the management of New Zealand kingfish (*Seriola lalandi lalandi*) stocks.

New Zealand Fisheries Assessment Report 2003/25. 57 p.

This document reviews and summarises information pertinent to the stock assessment of New Zealand kingfish (*Seriola lalandi lalandi*). Kingfish is an important recreational species with recent estimates of recreational catch greater than reported commercial landings. The recreational catch in the North region was estimated to be two–four times the commercial catch in 1993–94. The commercial catch information is analysed by Fishery Management Area (FMA) and season to characterise the fishery. The commercial catch of kingfish by method and target species is also reviewed. Reported kingfish landings varied from 167 to 532 t between 1983–84 and 1999–2000. These differences are primarily due to changes in fisheries management and fishing practice. The implementation of a minimum size limit has reduced the commercial and recreational catch. Tagging data and distribution of the commercial catch are reviewed and suggest that stock areas should be kept as small as is practical to reduce the risk of localised depletion. The total commercial Maximum Constant Yield (MCY) is estimated at 245 t.

1. INTRODUCTION

1.1 Overview

The kingfish, *Seriola lalandi* (Valenciennes, 1833), belongs to the family Carangidae. Other members of this family in New Zealand waters include the trevally (*Pseudocaranx dentex*) and the mackerels (*Trachurus* spp.). Kingfish are circumglobal in distribution with the same species found in temperate waters around South Australia, Japan, South Africa, and the western coast of the Americas (British Columbia to Chile) (Gillanders et al. 1997). Kingfish is thought to be one of three physically similar but geographically separate populations or subspecies which do not interact: one off California (*S. lalandi dorsalis*), one in Asia (*S. lalandi aureovittata*), and a Southern Hemisphere group (*S. lalandi lalandi*; Smith-Vaniz (1984).

The New Zealand kingfish *S. lalandi lalandi* (formerly *S. grandis*) is sometimes referred to by its common names of kingi, yellowtail kingfish, or yellowtail. It should not be confused with the southern kingfish, better known as gemfish (*Rexea solandri*), family Gempylidae. There are a number of other related *Seriola* species worldwide, some of which have been caught in New Zealand's waters on rare occasions (Paulin & Stewart 2001).

This document presents the current biological information on kingfish (*S. lalandi lalandi*) in New Zealand, and on its fisheries, including spatial, seasonal, and historical trends in catches and fishing methods. Also presented are research recommendations to assist with the future management of the species.

Note: All length measurements quoted in this report are fork-length unless otherwise stated.

1.2 Description of the fishery

Kingfish support an important North Island rod and reel recreational fishery. Kingfish is an internationally recognised gamefish species and New Zealand holds most International Game Fish Association (IGFA) records.

Total reported commercial landings have fluctuated over the past seventeen years between 167 and 532 t, and more recently have been exceeded by the recreational fishery. Although the annual commercial catch is relatively low, kingfish is a high value species and there is potential for market expansion. Kingfish is not included in the Quota Management System (QMS) and catches are controlled by a ban on the commercial targeting of kingfish. However, no restriction on the amount of kingfish taken as a bycatch to other fisheries such as snapper (*Pagrus auratus*) and trevally has yet been imposed. The main commercial methods of catching kingfish are setnetting, trawling, and bottom longlining.

1.3 Literature review

Early reviews of *S. lalandi lalandi* in New Zealand were unpublished (Allen 1992, McGregor 1995a). Allen (1992) reviewed the biology and history of the fishery and examined some options for future management (see also McGregor 1995b). McGregor (1995a) reviewed overseas literature and summarised information on commercial and recreational catches and methods (see also McGregor 1995c). Kingfish movement and growth from tagging studies in New Zealand have been investigated (Holdsworth 1994, McGregor 1995a, Hartill & Davies 1999). Kingfish is of considerable recreational importance (Bradford et al. 1998, Hartill et al. 1998, Bradford et al. 1999, James et al. 1997, James & Unwin 2000). Information on the distribution of kingfish in New Zealand waters was given by Anderson et al. (1998) and Bagley et al. (2000). More recently, a considerable amount of information on *S. lalandi lalandi* stress biology, endocrinology, and reproductive biology has been published in scientific journals and as popular articles as a basis for aquaculture development (Poortenaar et al. 1999a, 1999b, 2000, 2001). For the first time in New Zealand, *S. lalandi lalandi* eggs have been artificially fertilised and reared through to juveniles, allowing documentation of larval and juvenile growth rates, early life history characteristics, and culture techniques (Tait 2000).

The most comprehensive reviews on the biology of *S. lalandi* are by Baxter (1960) and Gillanders et al. (1997, 1999a, 1999b) and provide information on ageing methods, growth models, size at maturity, and changes in gonadal activity.

2. REVIEW OF THE FISHERY

2.1 Commercial fishery

Commercially, kingfish is a relatively high value species and is usually sold as fillets or whole chilled. In the 1997–98 and 1998–99 fishing years, approximately one-quarter of the annual national catch was exported, the main markets being the United States and Australia (unpublished data held by NZ Seafood Industry Council). In the 1999 calender year, 78 t of kingfish were exported with a value of $531 000.

2.1.1 Management controls

Although not included in the Quota Management System (QMS), there have been a number of non-QMS management controls imposed on commercial fishing for kingfish.

In the mid 1980s the commercial targeting of kingfish was restricted to certain methods and only fishers with 'kingfish' designated on their fishing permits were allowed to target; i.e., in the Auckland Fishery Management Area (FMAs 1 and 9, Figure 1), kingfish could be targeted by pole, troll, longline, and setnet. After 1988 no new targeting permits were issued for kingfish. Although kingfish could be taken as bycatch, only fishers who had been granted targeting rights before 1988 could continue to target kingfish.

In 1992 a moratorium was imposed on the catching of all non-QMS species. Fisheries could only continue to target a non-QMS species if (a) they held a target authorisation for that species as at September 1992 and (b) they had taken the species at least once in the previous two years.

A minimum legal size (MLS) of 65 cm was established for kingfish in October 1993. This restriction applied to kingfish taken by all methods except trawling between 1993 and 2000. The rationale for not applying the restriction to trawl at the time was that most trawl caught kingfish are dead upon recovery and would therefore be wasted if returned to the sea. In December 2000 the Minister of Fisheries revoked the trawl MLS exemption under the rationale that sustainability concerns, the need for equality of size limits between stakeholders, the biological reproductive data, and compliance considerations, outweighed industry concerns about wastage and economic loss. Also reinstated in December 2000 was a regulatory provision that specified a minimum net mesh size of 100 mm when taking kingfish (commercially or recreationally).

2.1.2 Commercial catch reporting systems

The detailed recording of commercial catch and effort information across all fisheries dates from 1983. Although pre-1983 catch data records are available, they are fragmented and unreliable, especially for non-target or less traditional species such as kingfish. Between October 1983 and September 1988, commercial catch data were recorded on logbooks and stored on the Fisheries Statistics Unit (FSU) database. A new reporting system was introduced in October 1988 and this system (with a few minor alterations) has been in place since that time.

Kingfish catch and effort information is currently recorded on a combination of five reporting forms: Catch, Effort and Landing Return (CELR); Trawl Catch, Effort and Processing Return (TCEPR); Catch Landing Return (CLR); Tuna Longline Effort Return (TLER); Licensed Fish Receiver Return (LFRR).

Most of the smaller method fisheries like setnetting and trolling report on the CELR form. The CELR form is made up of an 'effort' section and a 'landed catch' section. Fishers are required to provide data only for the top five species (by weight) caught in the effort section of the CELR, therefore effort information for some of the lesser bycatch species, which sometimes includes kingfish, is often unrecorded. Fishers are required, however, to record the total weights of all species caught on a trip in the landed catch section of the CELR form. For non-quota species such as kingfish, fishers are required to record species landed catch weights against the Fisheries Management Area (FMA) from which the catch was made (see Figure 1).

Tuna longline fishers are required to report fishing effort against the TLER form, whereas most trawl fishers use the TCEPR form to record effort. The data requirements for both these forms are similar to those of the CELR effort section in that only the top five species by weight are recorded. Tuna and trawl fishers provide landed catch details on a separate reporting form, the CLR, which is analogous to the landed catch section of the CELR.

Licensed fish receivers are also required to record the total weight of all species landed to them on the LFRR form. Again, for non-quota species, catch weights recorded on the LFRR are broken down by FMA (see Figure 1). If no errors are made, species catch totals recorded against the LFRR should match the combined CLR and CELR landed catch totals.

2.1.3 Conversion factors

There is a legal requirement to report all landed catch in terms of unprocessed or 'green' weight. Where fish are landed in a processed form the processed weight is converted to green weight by applying a legally defined conversion factor. Most kingfish is landed green. However up to 10% of the catch is landed as headed and gutted (HGU) and 5% landed as gutted (GUT). At present the generic conversion factors apply to these processed fish, 1.50 for headed and gutted and 1.10 for gutted. These ratios may not be appropriate for kingfish.

2.1.4 Known errors and anomalies in reported commercial kingfish catches

Licensed Fish Receivers Return (LFRR) totals and the CELR and CLR landed catch totals generally did not match. Errors were largely due to the use of incorrect species codes, but the discrepancies between the two recording systems proved too difficult to resolve so it was decided to exclude the LFRR totals from the analyses.

The single largest source of ambiguity in the recent historical catches for kingfish is the under-reporting of effort as a result of fishers recording effort only for the top five species caught. Catch summaries presented in this report were derived from the landed catch sections of the CELR and CLR forms. The landed catch form data provide the only "true" record of the legal kingfish catch. Catch totals based on the catch effort forms will exclude all kingfish catches where kingfish was not one of the top five species caught. Fishers are required only to report the FMA of capture in the landed catch sections of the reporting forms. To prorate these FMA totals to method, area, and target, it was necessary to link the landed catch data to the reported effort data by trip identifier. Where no effort information had been recorded for kingfish, the method, area, and target categories were assigned to the landed kingfish totals on the basis of effort information recorded for the other species caught on the relevant trip. Most assignments were made to areas and methods recording the highest catch of other species. However, there were a few instances where categorising the kingfish catches in this way would have led to clearly erroneous interpretations given the known spatial and depth distribution of kingfish (e.g., target being orange roughy (*Hoplostethus atlanticus*) or cardinalfish (*Epigonus telescopus*)). Therefore, other information from the trip data had to be used to assign the catches.

It is also apparent from the data that some fishers confuse statistical reporting area with FMA. For this reason it is not possible to get the statistical area totals to match the reported FMA landing form totals for any given year. Some fishers were also confused with FMA and stock boundaries. Very low catches were recorded for FMA 9 (west coast North Island) during the early nineties, with most of this catch being incorrectly allocated to FMA 1.

The species code for kingfish (*S. lalandi lalandi*) in research and fisheries statistics databases is KIN. However, some fishers incorrectly use this code to record catches of gemfish and sea urchins or kina (*Evechinus chloroticus*), and these records had to be removed from the catch totals. Removals were also done on the basis of method codes (i.e., diving, dredging, cod potting, hand gathering, and rock lobster potting) or where the target species was unlikely to be associated with kingfish being caught (e.g., orange roughy or hoki (*Macruronus novaezelandiae*).

Under the former Fisheries Statistics Unit (FSU) system fishers were able to record catch and effort information for all species caught (not just the top five) but there was no provision for them to record target species. It is likely that a significant amount of kingfish caught over the latter years of the FSU series was not reported. Many fishers were confused by the myriad of reporting requirements introduced under the QMS in 1986 and many stopped providing effort information on FSU forms because they believed this was no longer a requirement. Consequently, annual total landings for years 1985 to 1988 are likely to be underestimated. The data quality from the first year the new forms were introduced (the 1988–89 fishing year) is also doubtful, because many fishers found it difficult to become conversant with the new reporting requirements.

2.1.5 *Landed catch by Fishery Management Area*

The main fishing areas for kingfish are the east (FMAs 1 and 2) and west (FMAs 8 and 9) coast of the North Island of New Zealand (see Figure 1). The largest commercial catches generally come from FMA 1 and most likely reflect the relative abundance of kingfish compared to other areas (see Section 3.1).

FMA reported landing summaries of kingfish for the fishing years 1983–84 to 1999–2000 are given in Table 1 and for FMAs 1, 2, 8, and 9 in Figure 2. Landings were relatively large in 1983–84, especially in FMA 1, probably due to the greater number of vessels in the fishery before the introduction of the QMS in 1986. In addition, there was increased effort and better reporting as fishers sought to establish a catch history for the main species in anticipation of the introduction of the QMS. By 1988–89, catches of kingfish had reduced to their lowest levels across most FMAs. This was most likely due to the under-reporting of less common species in the catch (including kingfish) and the introduction of non-QMS restrictions. An increase in kingfish landings in FMA 1 between 1988–89 and 1992–93 and in FMA 2 between 1988–89 and 1991–92 may be due to a number of factors. These include: (a) better reporting of catches; (b) changes in fishing patterns with increased catch by setnet; (c) increased numbers of vessels reporting kingfish catch, and (d) increased targeting of kingfish. The total reported catch across all FMAs peaked in 1992–93 at 532 t, with 73% of the catch from FMA 1. By 1993–94, the reported catch of kingfish over all FMAs decreased considerably, mainly because of the reduced catch from FMA 1. Possible reasons for this decrease include: (a) the effect of a newly introduced MLS of 65 cm on all methods other than trawl; (b) changes in fishing patterns in the snapper and trevally target setnet, trawl, and bottom longline fisheries (that are responsible for most of the bycatch of kingfish); (c) decreased target fishing for kingfish, and (d) setnet area closures in FMA 1.

Since 1993–94 the reported annual catch of kingfish from FMA 1 has remained relatively stable at about 200 t, except for the 1999–2000 fishing year where the catch has dropped below 100 t. The kingfish catch from FMA 2 over the last five years has remained stable nearing 100 t, while landings from FMAs 8 and 9 approximated 20 t per year.

2.1.6 Landed catch by statistical area

The effect of the October 1993 introduction of the MLS is evident by comparing the statistical area catch breakdown in 1992–93 to that in 1999–2000 (Figures 3 and 4; Note: fishers probably mis-recorded the catch data reported for statistical area 001 as this area is not normally fished for kingfish).

The distribution of the catch in 1992–93 was mainly centred around the East Northland coast and the Bay of Plenty areas of FMA 1, with moderate catches from Hawke Bay and the central west coast of the North Island (Figure 3). No kingfish catch was recorded for the statistical areas 042–048 in 1992–93 as all kingfish was landed against FMA 1 during the early 1990s. Any kingfish caught in statistical areas 042–048 will have been prorated against catches in FMA 1 and inflated the relative estimates. The kingfish catch in 1999–2000 was considerably less than 1992–93 with the main areas being the Bay of Plenty and FMA 2. The East Northland coast and the west coast of the North Island now have only moderate to low catches of kingfish (Figure 4).

The target kingfish catches for 1992–93 and 1999–2000 by statistical area are given in Figures 5 and 6 and are considerably low. In 1992–93 most of the target-caught kingfish was from the Bay of Plenty (FMA 1), Hawke Bay (FMA 2), and the central west coast of the North Island (FMA 8). In 1999–2000 the target kingfish catch was almost zero.

2.1.7 Landed catch by method

Total reported landings from FMAs 1, 2, 8, and 9 for the three main methods (setnet, bottom trawl, and bottom longline) for 1983–84 to 1999–2000 are given in Figure 2. Despite the poor quality of data (due to under-reporting in the middle years) some trends are evident. Information relating to kingfish catch from other methods is given in Appendix 1. The long-term mean catch by method for all FMAs combined is given in Figure 7. Setnet, bottom trawl, and bottom longline accounted for 36%, 33%, and 15% respectively of the kingfish commercial catch on average from 1983–84 to 1999–2000. The highest kingfish catch for all three main methods occurred in 1992–93 with most coming from FMA 1 (see Figure 2). Troll, purse-seine, bottom pair trawl, beach seine, and Danish seine each accounted for lesser amounts, 1–4% (Figure 7).

The total setnet catch peaked at 256 t in 1991–92, decreasing to 106 t in 1993–94 as a result of the introduction of the MLS and setnet area closures (see Figure 2). Since that time annual catches have fluctuated between 45 and 151 t with most of the catch coming from FMAs 1 and 2 (see Figure 2).

The annual catch of kingfish taken by trawlers remained relatively stable across all FMAs up until 1995–96 and has gradually increased since (see Figure 2).

Most of the bottom longline kingfish catch comes from FMA 1. Landings have remained relatively stable through time, decreasing in more recent years to about 20 t per year. The reported catch of kingfish by bottom longline reduced from 79 t in 1992–93 to 35 t in 1993–94 (see Figure 2), and is likely to be due to the introduction of the 65 cm MLS regulation.

2.1.8 Landed catch by target species

The kingfish catch by nominated target species for the fishing years 1989–90 to 1999–2000 is given in Appendix 2a. A list of species codes and related common and scientific names is given in Appendix 2b. Most kingfish is a bycatch of the snapper, trevally, and tarakihi (*Nemadactylus macropterus*) fisheries. Target-caught kingfish is the fourth most important catch, but the amount caught has been declining since 1996–97 (Appendix 2a). Despite this, targeting of kingfish by particular methods can be relatively successful. Target fisheries for blue warehou (*Seriolella brama*), red gurnard (*Chelidonichthys kumu*), spotted dogfish or rig (*Mustelus lenticulatus*), hapuku (*Polyprion oxygeneios*) and bass (*Polyprion americanus*), barracouta (*Thyrsites atun*), school shark (*Galeorhinus galeus*), pilchard (*Sardinops neopilchardus*), albacore tuna (*Thunnus alalunga*), and blue moki (*Latridopsis ciliaris*) also catch moderate amounts of kingfish.

The total reported catch of kingfish by target species for the main commercial methods from 1989–90 to 1999–2000 is given in Figure 8 and for FMA 1 in Figure 9 and FMAs 2, 8, and 9 in Figure 10.

The increase in kingfish catch between 1990–91 and 1992–93 was mainly due to increased reported catch from setnet fishers targeting tarakihi (1991–92) and trevally (1992–93) in FMA 1, and to a lesser degree, kingfish (1990–91) and blue warehou (1991–92) (Figure 9).

Targeting of kingfish in FMAs 2 and 8 by setnet has been declining since the early 1990s, the exception being the 1997–98 fishing year in FMA 2. Kingfish catches in FMA 2 continued to remain high in subsequent years because the species was taken as bycatch in the tarakihi trawl fishery (1995–96 to 1999–00) and more recently the blue warehou setnet fishery (Figure 10). Setnet fisheries in FMA 8 have also landed quantities of kingfish which was bycatch to other target species (Figure 10). As trawling was exempt from the 65 cm MLS, landings of kingfish would have been unaffected by the 1993 regulation change.

The catch of kingfish by methods other than trawl or setnet is relatively small. The purse-seine fishery for pilchard in FMA 1 reported 26 t of kingfish in 1998–99. However, this fishery reported less than 8 t of kingfish in any of the other fishing years (Figure 9). Lesser amounts of kingfish were taken by purse-seine targeting trevally, trolling targeting albacore tuna, and bottom longlining targeting snapper (Figure 9).

2.1.9 Seasonality

The commercial reported landing of kingfish by season for all FMAs combined and for FMAs 1, 2, 8, and 9 from 1989–90 to 1999–2000 is given in Figure 11 and Appendix 3. The quarterly seasons were defined as spring (September–November), summer (December–February), autumn (March–May), and winter (June–August). As kingfish is predominantly a bycatch in other fisheries, the seasonal patterns in the data may partly reflect the level of fishing effort directed toward the main target species by particular methods in certain areas at that time of the year. However, they may also reflect the spatial density and abundance of kingfish in particular areas at certain times of the year. In FMA 1, the highest catch of kingfish is usually over summer and autumn. A considerable amount of the kingfish catch over this period was from bottom longline fishers targeting snapper, purse-seine fishers targeting pilchard, and setnet fishers targeting trevally, snapper, kingfish, and blue warehou, often in particular years (Figure 9). The highest catch by season in FMA 2 was usually over summer, reflecting the mixed species target catch from the trawl fishery and smaller amounts of setnet target kingfish catch. FMA 9 catches were highest in summer. FMA 8 catches were too variable to determine any trends.

2.2 Non-commercial fisheries

2.2.1 Customary fisheries

Kingfish is an important customary food fish for Maori, but no quantitative estimate of catch is available. The extent of the customary fisheries for kingfish is described in the Muriwhenua Fishing Report (Waitangi Tribunal 1988). Because of the coastal distribution of the species and its inclination to strike lures, it is likely Maori caught considerable numbers (Allen 1992). The most commonly used Maori name for kingfish is haku, but kahu, makumaku, and warehenga are also used (Strickland 1990).

The current catch of kingfish using hui/tangi permits is unknown. In 1999 new regulations applied to customary food gathering from any New Zealand fisheries waters. Tangata tiaki now cover parts of the fishery and customary harvest will be reported and recorded.

2.2.2 Recreational fishery

Kingfish is regarded as a prized species by recreational fishers in New Zealand. Kingfish are caught by two main groups of recreational fishers: those fishing from private boats launched at ramps, and those fishing from charter boats. Obtaining estimates of recreational catch for kingfish and other species is difficult. There have been a number of telephone and diary surveys conducted to estimate national recreational catch levels.

The first, conducted in 1987, was a national survey. Due to methodological differences, catch estimates from the 1987 survey are not considered to be directly comparable with the subsequent surveys and the totals are not reported here. In the 1987 survey, kingfish ranked fifth in terms of the number of fishers catching this species (Sylvester et al. 1994). An estimated 48 000 fishers caught kingfish in this survey, 43 000 in the Northern region and 5000 in other regions.

Three regional surveys were conducted between 1991–92 and 1993–94: the South region (representing FMAs 3 and 5) in 1991–92, the Central region (FMAs 2, 7, and 8) in 1992–93, and the North region (FMAs 1 and 9) in 1993–94 (see Figure 1; Table 2). These surveys can be combined to give an estimate to the total annual recreational harvest of kingfish for 1991–94 of 116 t (Bradford 1996). This assumes that there was no inter-annual variability in catches of kingfish landed over this period. In 1993–94 the recreational catch of kingfish was comparable to that of the commercial sector in KIN 1, KIN 7, and KIN 9 where most of the recreational catch is taken (Table 3).

In 1996 a recreational survey conducted over all three regions produced a combined annual estimate for kingfish of 74 t (Table 4). The 1996 estimate is 64% of that estimated from the previous survey, but it is not clear what effect the introduction of bag and minimum size limits (in October 1993) have had on the 1996 estimate. No estimate of recreational kingfish harvest is available for KIN 9 in 1996 (Table 5). This is surprising given that this was the FMA with the second highest recreational kingfish harvest estimate in 1993–94.

For 1991–94, kingfish was the 9th most commonly landed finfish species and in 1996 it was the 17th most commonly landed (Bradford 1998c).

Recreational kingfish catch rates are greatest when the species is targeted, but most kingfish are caught when targeting other species, predominantly snapper. In 1993–94, 61% of kingfish landed by diarists were caught by handline or rod and reel from boats (includes live baiting, jigging, and bait fishing), 17% by trolling, 9% by shore-based fishing, and 8% by spearfishers from boats (Bradford 1996).

Despite its popularity, kingfish catch rates are low compared with other species, and catch estimates derived from recreational catch data are likely to be based on less than adequate sample sizes. Most recreational research has focused on harvested catch rather than the number of fish caught but not landed. When interpreting changes in harvest rates and harvest estimates over time, however, changes in fishing regulations must be taken into account as these will influence harvest rates even when there is no change in fisher success in catching fish. Recreational catch estimates were derived by multiplying the catch reported by the diarists by the estimated number of fishers in the area surveyed by the average weight of the fish caught. Average weights used to estimate the total landed catch were based on data collected from boatramp surveys. Boatramp surveys sample fish caught only from trailer boats which have relatively low records of kingfish catch (Hartill et al. 1998) and may not be representative.

Bradford (1999) compared harvest rate estimates from boatramp surveys in 1991, 1994, and 1996 where the target species was snapper or unspecified and the methods of fishing were jigging or bait fishing. Harvest rate estimates are based on the landed catch, and do not include those fish caught and released. Changes in size and bag limits are therefore likely to mask any real trends in fisher catch rates. For fishers launching from boatramps the probability of not landing a kingfish is high (P_0 0.98–0.99). This is likely to have increased through time as a result of the 65 cm MLS and bag limit reductions introduced in October 1993. There is, however, a small experienced sector of the recreational fishing population which successfully target kingfish using local knowledge and specialised methods such as live baiting, poppers, and lures. There has been a marked change in the length frequency composition of kingfish recorded at boatramps since the first boatramp survey in 1991 (Figure 12). The mean size of kingfish landed in FMAs 1 and 9 has increased progressively with each survey, probably due to the introduction of the MLS. Before the MLS introduction, most kingfish landed by recreational fishers were not sexually mature.

Kingfish is highly prized as a gamefish and is recognised by the International Game Fishing Association (IGFA) as a legitimate target species. Of the 22 kingfish line class records (heaviest fish caught for a given line strength) reported on the IGFA 1999 World Record Gamefish list, 19 were taken in New Zealand, as well as all of the world saltwater flyfishing records. Some sport fishing clubs organise annual competitions for kingfish, and a competition organised by the Bay of Islands Swordfish Club has been held regularly for the past 30 years. Kingfish have been tagged in New Zealand as part of a cooperative gamefish tagging programme since 1976. In 1991 a review of this programme concluded that it had potential to provide data useful for improving management of key recreational species including kingfish. To date, data from this programme have been used to estimate growth rates and infer movement patterns (see Sections 3.6 and 3.7 respectively).

Since the inception of the recreational tagging programme in 1975, 8503 kingfish have been tagged and released by recreational anglers (this includes fish tagged and released more than once). Two charter boats, one based in Whakatane and the other in Tolaga Bay, are responsible for most of the kingfish tagged, with between 41% and 69% since 1996–97 (Davies & Hartill 1998, Hartill & Davies 1999, 2000, 2001). Although length and weight measurements and estimates supplied by tagging fishers are not always reliable, those recorded by the skippers of these two vessels are considered accurate. Annual length frequency distributions of kingfish tagged from these two boats in FMAs 1 and 2 are variable, but some patterns are evident (Figure 13). Before the 1992–93 fishing year, only mature fish were tagged. The number of fish tagged from these two boats in recent years has been variable with a noticeably larger proportion of fish below 65 cm tagged in FMA 2. There is some indication of progressing year classes in these annual length frequencies despite the inclusion of release data from all seasons. In the last four gamefish seasons most kingfish have been tagged on the northeastern coast of the North Island, mainly off the East Northland coast, in the Bay of Plenty, and off Tolaga Bay (Figure 14). Unlike other gamefish species that are tagged throughout the year, most kingfish releases usually occur around February (Figure 15). The level of mortality resulting from tag and release is unknown, but the high recapture rates observed from the tagging programme and the frequency of multiple recaptures suggests that it is relatively low.

Charter boat operations are an increasingly important part of the recreational fishing sector, with a high proportion of these fishing in northern waters (James et al. 1997). Charter boats accounted for 14.6% of the total kingfish take estimated in the 1996 diary survey (Bradford 1998b). This is likely to be an underestimate, however, as diary surveys do not include visiting fishers from overseas who made up an average of 7.3% chartering fishers in 1997–98 (James & Unwin 2000). Kingfish are a major attraction for many overseas anglers from Japan, Australia, and North America. In a survey of charter boats in the 1997–98 fishing year, kingfish were the target species of 41.1% of the deepwater charters and 3.7% of the inshore line charters (James & Unwin 2000). The success rate of those trips targeting kingfish was high, with 87% of the deepwater charters and 76% of the inshore charters catching at least one kingfish. Most kingfish caught during this survey were released: of an estimated 36 000 fish caught between November 1997 and October 1998, 14 000 were retained. About 74% of kingfish taken by surveyed charter boats were caught between November and April, and 57% were caught on deepwater line trips.

2.2.3 Regulations

The recreational daily bag limit for all areas is three kingfish per fisher, with no more than a combined quantity of five hapuku, bass, and kingfish. The minimum mesh size for setnets targeting kingfish is 100 mm. As with the commercial fishery, a MLS of 65 cm has been in place since October 1993.

2.2.4 Illegal catch

The amount of kingfish taken in excess of the commercial and recreational regulations (illegal catch) is unknown. There is some evidence to suggest that the illegal kingfish catch is significant.

3. RESEARCH

Only 554 kingfish have been taken from 49 research trawl surveys between 1961 and 2000. This small number may be due to the short duration of research tows and the ability of kingfish to out-swim the gear.

3.1 Distribution, size, and abundance

In New Zealand, kingfish are predominantly found off the northern half of the North Island, but also occur from 29° to 46° S (Kermadec Islands to Foveaux Strait (Francis 1988)), and to depths of 200 m. Kingfish are large predatory fish with adults often exceeding 1 m in length. They usually occur in schools ranging from a few fish to well over 100 animals. Kingfish tend to lead a semi-pelagic existence and occur mainly in open coastal waters, preferring areas adjacent to rocky outcrops, reefs, and pinnacles, but they are not restricted to these habitats and are sometimes caught or observed in open sandy bottom areas and within shallow enclosed bays.

Anderson et al. (1998) summarised kingfish encountered by trawl surveys between 1961–97 giving location and depth distribution of capture (Figure 16). Kingfish are only occasionally taken by midwater trawl and tuna longline methods (Bagley et al. 2000, Francis et al. 2000, Hurst et al. 2000), as these methods generally fish further offshore, and deeper, than the main distribution of kingfish. Schools of kingfish are occasionally seen from spotter planes searching for pelagic species in coastal waters (Figure 17).

In New Zealand, juvenile kingfish up to a fork length of 15 cm have been associated with a pelagic distribution and in particular with floating weed (Kingsford 1992, Holdsworth 1995).

Two kingfish caught on recreational lines during the mid 1980s each weighed 52 kg, the greatest weight recorded in New Zealand for the species (John Holdworth, pers. comm.).

3.2 Diet and feeding behaviour

Baxter (1960) found *Seriola lalandi dorsalis* were predominantly piscivorous, although squid and swimming crab were also important prey items. New Zealand kingfish are often found in association with schools of trevally and koheru (*Decapterus koheru*), circling on the outskirts in search of a weak or unwary member of the other school (Ayling & Cox 1982). They are also known to prey on small pelagic species such as pilchard, anchovy (*Engraulis australis*) (D. Allen, pers. comm.), squid (*Nototodarus* spp.), and yellow-eyed mullet (*Aldrichetta forsteri*). Kingfish use a high degree of cooperation among individuals while performing well coordinated feeding manoeuvres. The type of foraging tactic employed depends on the nature of prey defence (Schmitt & Strand 1982).

Captive fish held in aquaculture facilities and aquariums in New Zealand readily accept fresh and frozen squid, pilchard, and mackerel. Attempts to wean captive fish on to artificial pellet diets have been unsuccessful to date, although hatchery reared juveniles were easily weaned on to artificial pellets.

3.3 Reproduction

A considerable amount of information has been collected on the reproductive biology and endocrinology of *S. lalandi lalandi* in New Zealand, as a basis for aquaculture development (Poortenaar et al. 1999a, 1999b, 2000, 2001). Data were collected from wild kingfish caught along the east and west coasts of northern New Zealand. Seasonal changes in gonadosomatic index suggest that kingfish spawn October–January, although reproductively mature fish were occasionally collected during winter (Poortenaar et al. 2001) (Appendix 4).

S. lalandi lalandi have multiple group synchronous oocyte and sperm development, with the capacity to spawn more than once within a spawning season (Poortenaar et al. 2001). In the absence of information on short-term changes in ovarian and sperm cycling from individual fish, the frequency of spawning events has not been established.

No fecundity estimates have been made for *S. lalandi lalandi,* although Baxter (1960) reported fecundity estimates for *S. lalandi dorsalis* that ranged between 458 000 and 3 914 000 for fish sized from 56 cm (2.4 kg) to 105 cm (14.5 kg). Egg number increased with weight of fish.

Samples collected by Poortenaar et al. (2001) indicated that less than 1% of mature female *S. lalandi lalandi* had free flowing eggs, although males with free flowing milt were reasonably common. In other studies, no *S. lalandi* were collected with free flowing eggs (Baxter 1960, Gillanders et al. 1999a). Possible explanations for the lack of ripe females caught include cessation of feeding during spawning (although Poortenaar et al. (2001) reported two ripe females caught on baited hooks), fish moving outside normal fishing grounds to spawn, or females passing through the processes of final oocyte maturation, ovulation, and spawning quickly as in some other species, (e.g., snapper).

There are no documented observations of *S. lalandi lalandi* spawning in New Zealand waters and anecdotal evidence for *S. lalandi lalandi* spawning grounds are wide ranging (i.e. surface waters 100 km offshore or in mouths of estuaries). A recorded observation of spawning in *S. lalandi dorsalis* (Californian kingfish) describes hundreds of kingfish milling about making short circles near the surface. These behaviours occurred from 1100–1600 h and the water appeared white from copious amounts of eggs and sperm (Baxter 1960). Spawning behaviour of *S. dumerili* (a related species found in warm temperate–tropical waters throughout the world) in captivity is characterised by males chasing females from the bottom of the tank and spawning occurs at the surface (Tachihara et al. 1993). Similar observations have been made for captive *S. quinqueradiata* and *S. lalandi aureovittata* in Japan (Keitaro Kato, pers. comm.).

3.3.1 Early life history

There have been no observations of *S. lalandi lalandi* eggs or larvae in coastal waters around New Zealand. However, eggs and sperm have been stripped and fertilised from wild-caught fish induced to ovulate and spermiate using hormone therapy. Larvae and juveniles were successfully reared under hatchery conditions (Tait 2000), as detailed in Section 3.9.

There have been numerous anecdotal and two documented reports of juvenile *S. lalandi lalandi* in association with floating weed and drifting buoys (Kingsford 1992, Holdsworth 1995). In addition, six juvenile *S. lalandi lalandi* about 58 mm total length (TL) were caught in light traps set in the Hauraki Gulf (Leigh Marine Laboratory, unpublished data).

The association behaviour of juvenile *Seriola* around drifting seaweeds in the ocean forms the basis of Japan's kingfish aquaculture industry (Sakakura & Tsukamoto 1997). *S. quinqueradiata* is the dominant species associated with drift weed, although when available, *S. lalandi aureovittata* juveniles are also collected for ongrowing in seacages (Keitaro Kato, pers. comm.).

Behavioural studies and field observations showed that age composition of *S. quinqueradiata* associated with drift weed were fairly uniform, but social hierarchies existed within the groups and cannibalistic behaviours were common from 22 to 36 days post hatching (Sakakura & Tsukamoto 1996, 1997). It has not been established whether *S. lalandi* exhibit similar behaviours.

3.3.2 Size at sexual maturity

Poortenaar et al. (2001) reported that the smallest size at which female *S. lalandi lalandi* sexually matured was 78 cm, 50% reached sexual maturity at 94 cm and 100% reached sexual maturity at 128 cm FL (Figure 18). The smallest size at which males matured was 75 cm, 50% reached sexual maturity at 81 cm and 100% matured at 93 cm. Mature was defined as females that had vitellogenic or more advanced ovaries and males that had partially spermiated or more advances testes (Appendices 4a & 4b). An earlier study on New Zealand populations of *S. lalandi lalandi* reported maturity between 58 and 67 cm, with all fish mature by 70 cm (McGregor 1995). The west coast American species *S. lalandi dorsalis* reached sexual maturity between 51 cm and 63 cm at age 2–3 years and a weight of 1.8–3.3 kg (Baxter 1960). No definition of mature was provided by McGregor (1995a) or Baxter (1960), hence it is difficult to speculate on the considerable differences in size of sexual maturity between studies.

Female *S. lalandi lalandi* from New South Wales (N.S.W.) populations, first matured at 70 cm (3 years) and 50% reached sexual maturity at 83 cm (4–5 years) (Gillanders et al. 1999a, 1999b). Males first matured at under 30 cm (under 1 year) and 50% attained maturity at 47 cm (under 1 year). The application of Gillanders et al. (1999b) age-growth models to New Zealand data (Poortenaar et al. 2001), suggests first maturity and 50% maturity at 4 and 7 years respectively for females and 4 and 5 years respectively for males. Differences in size and age of sexual maturity between N.S.W. and New Zealand populations of *S. lalandi lalandi* could be attributed to different growing conditions, e.g. warmer water temperatures in N.S.W., genetically distinct growth differences for geographically discrete stocks as documented for species such as New Zealand snapper (Tait 1996), behavioural and physiological differences between populations, or the increased variation associated with data collected on males from N.S.W. populations.

Female *S. dumerili* from the Mediterranean Sea first attained sexual maturity at 80 cm standard length (SL), and 50% attained sexual maturity at 109 cm SL (Marino et al. 1995). This is larger than the size at 50% maturity calculated for female *S. lalandi lalandi* by Poortenaar et al. (2001) or Gillanders et al. (1999a). Male *S. dumerili* first matured at 61 cm SL (Marino et al. 1995), which was within the range of size at sexual maturity calculated for male *S. lalandi lalandi* by Poortenaar et al. (2001) given that

SL is shorter than FL. In contrast, 50% of male *S. dumerili* did not attain sexual maturity until 113 cm SL, which is considerably larger than reported by Poortenaar et al. (2001) or Gillanders et al. (1999a).

The MLS for wild-caught kingfish in New Zealand is 65 cm (fork length), which is considerably smaller than the size of sexual maturity reported for males and females by Poortenaar et al. (2001) and Gillanders et al. (1999a). It is not known what proportion of the annual commercial and recreational catch is immature. The impact of the current MLS on the spawning stock biomass cannot be determined.

3.4 Size-frequency distributions

The length frequencies of kingfish caught on R.V. *Kaharoa* trawl surveys from 1982 to 2000 in FMAs 1, 2, 7, and 9 around the inshore waters of New Zealand are presented in Figure 19. In an attempt to achieve comparability in the length series only data from *Kaharoa* are reported. However, different codend mesh sizes (ranging from 30 to 80 mm) and tow distances (ranging from 0.7 to 3.5 nm) were used, each being specific to the surveyed area (Table 6, Figure 19) and so the data is not directly comparable quantitatively. All surveys were undertaken during the spring and summer in coastal inshore waters to depths of about 150–200 m and with tow speeds that were generally consistent (3.0–3.5 kn). Samples of kingfish collected from FMA 1 were predominantly from the Bay of Plenty where catch rates were higher than in the Hauraki Gulf. FMA 1 samples contained a proportion of fish that were smaller (under 54 cm) than samples collected to the south in FMA 2 and FMA 7. Although the mesh size used in surveys from FMA 2 and FMA 7 was larger than in FMA 1, it alone is unlikely to account for the lack of fish under 54 cm. The average number and size of kingfish encountered per survey in FMA 2 was much higher than in other areas and is most likely related to longer tow durations (see Figure 19).

3.5 Size-weight relationships

The length-weight relationship for New Zealand kingfish is shown in Figure 20. Parameter estimates for the relationship are

$$w = 0.03651 l^{2.762} \qquad \text{where } w \text{ is weight (grams) and } l \text{ is fork length (cm).}$$

A total of 489 kingfish length and weight measurements were collected from fish ranging in size from 34 to 159 cm and weighing between 0.9 and 40.0 kg. Samples were collected from a variety of fishing methods over the year, although most were over spring and summer. All samples were measured to the nearest centimetre below fork length on a measuring board and weighed to the nearest whole gram on calibrated electronic scales. Samples measured with a measuring tape across the upper body of the fish or on uncalibrated scales were not included in the analysis. No significant difference was found between the length-weight parameter estimates for the sexes.

3.6 Age and growth

To date there are no published estimates of New Zealand kingfish growth rates based on the analysis of skeletal structures such as otoliths or vertebrae. Average annual growth of New Zealand kingfish has been estimated by applying length increment data from the gamefish tagging programme to a length-based maximum likelihood model (GROTAG, Francis 1988). Although it was evident from fitting the growth model that measurement error was high, it appeared that kingfish is a fast growing species (Hartill & Davies 1999). Annual growth increments of 11.5 cm and 4.1 cm were estimated for 50 cm (g_{50}) and 100 cm (g_{100}) kingfish respectively. Data from kingfish under 50 cm were lacking, and the availability of more data for these length intervals would improve estimates for g_{50}. Kingfish less than 65 cm in length are not often tagged as they are usually in very poor condition when recaptured (Rick Pollock, Whakatane charter boat operator, pers. comm.).

Growth estimates based on length increment data do not contain specific information relating to kingfish age and no attempt was made by Hartill & Davies (1999) to present kingfish growth as a function of age. Francis (1988) cautioned against making inferences from the length-based growth model parameters to describe length as a function of age, if age specific data has not been included in the analysis.

Growth data were collected from artificially reared *S. lalandi lalandi* grown under hatchery conditions at Pah Farm Aquaculture on Kawau Island, New Zealand. Average weight and length were 800 g and 360 mm respectively at 200 days post hatch (Figure 21). The extent to which hatchery conditions influenced growth rates is unknown. Consequently, hatchery growth rates can not be combined with growth rates from wild fish. However, in future rearing trials to be conducted as part of NIWA's ongoing kingfish aquaculture research, hatchery reared fish could be used to validate the nature of otolith rings from tetracycline marked otoliths.

There have been a number of ageing studies on various *Seriola* species. Baxter (1960) estimated age of *S. lalandi dorsalis* using microprojected scales and fitted a von Bertalanffy growth equation to the results. Growth rates were similar to growth increments established from a tagging experiment. Mitani & Sato (1959) examined scales, otoliths, and vertebral centra in *S. quinqueradiata*, a species closely related to *S. lalandi*, and concluded that vertebral centra were the best hard parts to use for age determination, largely because *Seriola* scales and otoliths are very small and difficult to read. Nishioka et al. (1985) detailed a method to make polyvinyl alcohol replicas of the vertebral centrum so that precise measurements of growth rings were possible. The frequency distributions of the rings were matched with the modes of the fork length distribution of three years of sampling kingfish and a good fit was achieved. Murayama (1992) compared growth curves from various regions in the Japan Sea. He found growth rates varied with time and area and hypothesised that differences in temperature were responsible. However, his study provides vertebral centrum growth rate data that may be used to derive an averaged growth curve for *S. quinqueradiata*.

A study evaluating methods for ageing New South Wales *S. lalandi* by Gillanders et al. (1999) probably has the most relevance to the New Zealand populations. They examined dorsal spines, otoliths, and scales for their usefulness as ageing tools for kingfish. They could identify growth zones in all three structures, but concluded that dorsal spines were unsuitable for ageing because it was likely that earlier growth zones were lost as the fish aged. From marginal increment analysis it appeared that one zone is laid down each year in otoliths and scales. Exact agreement between each repeated reading was low (50–66%), although agreement to within one zone was reasonable (92–96%). They found scales provided the most exact (repeatable) readings of the three hard structures, and concluded that further work is necessary to determine the position of the first zone and validate estimates for the calculated age classes. They provided growth estimates for kingfish (both sexes combined) based on ageing 597 kingfish between 323 and 1090 mm in length. Gillanders et al. (1999) failed to mention how these fish were collected. If there was any size selection in the way their sample was collected, then their estimates of mean length at age may be biased. The maximum age of *S. lalandi* in their sample was 10 (otoliths and scales). They report that fish up to 1200 mm had been caught by the commercial fishery, hence we can conclude that the maximum age of *S. lalandi* in New South Wales may be greater than they observed.

An ageing study by Thompson et al. (1999) on *S. dumerili* from the Gulf of Mexico indicated sexual differences in growth. Female *S. dumerili* appear to grow faster and attain a larger size than the males. Thompson et al. used otoliths to age their animals and were able to validate the annual nature of otolith rings from tetracycline marked otoliths obtained from recaptured tagged animals. As with the Gillanders study, it is not clear that the population sample the authors used to estimate growth was truly random. The maximum age Thompson et al. observed was 15 years.

3.7 Stock structure

3.7.1 Movement and behaviour

Movement of kingfish can be inferred from tag release and recapture data. It should be noted, however, that the spatial and temporal intensity of fishing effort influences the chance of a fish being recaptured and hence the nature of any patterns inferred from such data. To date, 826 kingfish recaptures have been reported by the gamefish tagging programme, more than for any other species (Hartill & Davies (2001)). For those recaptures where position is available, 86% of recaptures have occurred within the same statistical area in which the fish was released (Table 7). The reported positions of releases and recaptures are often identical, even after long periods at liberty (Figure 22). Distance travelled does not appear to be strongly related to the period of time at liberty. This is a surprising result given the migrations of other *Seriola* species and suggests that New Zealand kingfish may be susceptible to localised depletion by target fishing.

Nevertheless, a few kingfish have moved large distances from the site of release. There have been two fish recaptured in Australia, one on the Colville Ridge and one on the Wanganella Bank (Table 7). Four fish have moved from the east coast of the North Island to the west coast. Two Australian tagged kingfish have been recaptured in New Zealand (Pepperel, Australian cooperative gamefish tagging programme, pers. comm.). Despite the trans-Tasman movements, the implication of these data is that fish stock areas should be kept as small as practical to prevent localised depletion.

3.8 Natural mortality (M)

There are no published natural mortality (M) estimates for *Seriola* species. M can be estimated for kingfish using the life history method of Hoenig (1982) if the maximum age of fish in the population is known.

$$M = -\frac{\log_e(p)}{A}$$

No ageing data are available to estimate maximum age of New Zealand *S. lalandi*. There is one record of a New Zealand kingfish being recovered after 14 years at liberty; its length at the time of tagging suggests it would have been at least 2 years old. A maximum age of 16 results in an M value of 0.32. The age estimates of Gillanders et al. (1999) for *S. lalandi* in New South Wales indicate a likely maximum age of 12 years (two years added to Gillanders observed maximum of 10 because the NSW commercial fishery reports fish up to 1200 mm FL and the largest fish they aged was 1000 mm). For a p of 0.01 M is estimated to be 0.38.

3.9 Aquaculture

Japan is the world leader in *Seriola* aquaculture and currently produces about 140 000 t per annum (FAO 1999). This industry largely relies on the capture of juveniles from the wild for on-growing in seacages, but a small volume is produced via artificial rearing. The predominant farmed species is *S. quinqueradiata*, although *S. dumerili*, *S. lalandi aureovittata*, and two hybrid species are also farmed commercially. Korea cultures 302 t of *S. quinqueradiata*, and China Taiwan cultures 717 t per annum of *Seriola spp.* (species unknown) (FAO 1999). Related species *S. dumerili* and *S. mazatlana* are currently being developed as potential aquaculture species in the Mediterranean and Ecuador respectively (Garcia & Diaz 1995, Benetti et al. 1998), and a commercial hatchery in South Australia has recently produced *S. lalandi lalandi* fingerlings for on-growing in seacages. Initial trials in South Australia indicate that cultured *S. lalandi lalandi* reach 2–3 kg in 12 months.

NIWA are currently developing aquaculture techniques for kingfish in New Zealand. Kingfish may provide a valuable contribution to New Zealands domestic sushi market, which is currently limited by unreliable supply and quality of fresh fish. Kingfish aquaculture may provide a year-round predictable supply of high quality product.

NIWA have collected data on stress biology, parasitology, reproductive biology, and endocrinology of *S. lalandi lalandi* (Poortenaar et al. 1999a, 1999b, 2000, 2001). For the first time in New Zealand, *S. lalandi lalandi* eggs have been artificially fertilised and reared through to juveniles (reviewed by Tait (2000)). Egg and sperm production was stimulated in captive fish using hormone therapy, and eggs were hand stripped and fertilised. Fertile eggs floated and were 1.36 mm diameter. Eggs hatched 62 h post fertilisation and hatched larvae were 4.47 mm long, compared with 2.7 mm snapper at the same stage of development. First feeding, swim bladder inflation, and metamorphosis occurred at 4, 5–6, and 18 days post hatch respectively. Growth rates were high: average weights were 200 and 800 g at 110 and 200 days post hatch respectively (see Figure 21).

Commercial development of kingfish aquaculture in New Zealand is currently limited by inadequate egg production and larval rearing techniques. These aspects are being addressed by NIWA researchers. Positive aquaculture attributes identified by NIWA include rapid growth, good food conversion and high market acceptance (Poortenaar et al. 1999a, 1999b, 2000, 2001, Tait 2000).

4. STOCK ASSESSMENT

4.1 Biomass estimates

Few kingfish are encountered in trawl surveys which suggests that trawling is not a suitable method for monitoring changes in kingfish abundance.

Kingfish are amenable to mark-recapture. However, up to now, tagging studies have been conducted solely to describe kingfish movement patterns and to estimate growth. Data from these programmes are inadequate to estimate stock biomass.

4.2 Estimate of Maximum Constant Yield (MCY)

Six kingfish stocks are currently recognised: KIN 1, KIN 2, KIN 3, KIN 8, KIN 9, and KIN 10; these are analogous to the FMAs given in Figure 1.

The 2002 Plenary report provided estimates of Maximum Constant Yield (MCY) for four kingfish stock areas, KIN 1–8 (Table 8; Annala et al. 2002). MCY estimates were derived using the cY_{av} method (method 4, Annala et al. 2002). The natural variability factor, c, is taken to be about 0.6 which is based on the estimated natural mortality rate for New South Wales *S. lalandi* ($M = 0.38$). Average annual catch (Y_{av}) was calculated using the fishing years 1983–84 to 1992–93 because these years were relatively stable and may best balance out the many factors affecting this bycatch fishery.

The existing catch data can be interpreted in different ways, which would lead to different estimates of Y_{av}. For example, it could be reasoned that the years chosen for the Plenary estimates incorporate a known period of under-reporting. The catch totals also do not include the non-commercial catch. Given the vagaries in the data, there is probably little to be gained in revisiting the MCY estimates suffice to say they are likely to be conservative.

4.3 Estimate of Current Annual Yield (CAY)

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

5. MANAGEMENT IMPLICATIONS

Kingfish can be regarded as a "high value" species from both commercial and recreational perspectives. Although fluctuating, catches of kingfish have shown very little trend over the last 20 years (see Figure 2). There is no evidence that the current catch levels are not sustainable. However, both the recreational and commercial sectors have the ability to substantially increase their kingfish take given the incentive or freedom to do so. Effective management measures are needed to protect kingfish stocks from the threat of over-fishing. In the commercial fishery these would best take the form of quotas, as certain commercial methods appear to be able to increase their take of kingfish within the bounds of the existing management controls, e.g. setnet, purse-seine.

6. RECOMMENDATIONS FOR FUTURE RESEARCH

A summary of suggested research requirements for kingfish is presented below. To help prioritise these in management terms, we have adopted a grading system with the following scale:

✱✱✱✱	Essential requirement.
✱✱✱	Requirement to monitor stocks if increases to "status quo" annual catch levels are proposed (e.g., adaptive management).
✱✱	Requirement for estimating sustainable yield (stock assessment).
✱	Requirement for estimating Current Annual Yield (Annala et al. 2002).

The research recommendations and prioritisations presented in this section are the opinion of the authors and do not necessarily reflect the views of the Ministry of Fisheries or the Pelagic Working Group.

6.1 Catch reporting

6.1.1 Commercial

The current catch-effort reporting system is inadequate for monitoring the commercial kingfish catch. Two improvements to this system are recommended.

1. Fishers need to be instructed to use the correct species and area codes, and more compliance effort is needed to ensure this happens. Simple checks on LFRR and CELR landed catch totals would indicate gross problems in the data.

2. Kingfish effort information often goes unreported because the current forms do not allow fishers to report it. We recommend catch and effort information be collected for all kingfish caught commercially.

Priority: ✱✱✱✱

6.1.2 Recreational

The recreational take of kingfish is significant, and in some areas may be higher than the commercial catch. Although there may be bias in the telephone diary survey results, these surveys provide some insight into the likely level of recreational catch. It is important that estimates of kingfish recreational harvest be obtained on an ongoing basis, if not annually, then at least every three years. Continued effort should be put into eliminating sources of bias in survey methodologies. Specific to kingfish is the concern that charter boat catches may not be well represented by the telephone diary surveys; this issue warrants further investigation.

Priority: ●●●●

6.2 Determination of stock boundaries

Although kingfish are capable of moving very large distances, indications from tagging are that most adult kingfish stay within localised areas. This means the species is likely to be vulnerable to local depletion. To reduce the risk of localised depletion it is desirable to manage kingfish as a number of discrete stocks. The recreational tag-release programme is providing useful information on stock mixing, so it is recommended that this programme be maintained.

Further work could be done to define biological stock boundaries. A characterisation of the kingfish age composition for each stock area may show how variable each stock is in respect to recruitment and total mortality (Priority: ●●). Genetic studies could be used to determine the level of stock interchange within New Zealand and between New Zealand and South Australia (Priority: ●).

6.3 Abundance estimation

An estimate of stock size or abundance is a pre-requisite for stock assessment. It is possible to describe abundance by a series of relative indices or as absolute point estimates. It is feasible to obtain absolute and relative abundance indices for New Zealand kingfish stocks.

6.3.1 Catch per unit effort series

Kingfish is predominately taken as bycatch to other target fisheries, hence changes in kingfish catch and effort ratios may not reflect changes in abundance of the underlying stock. Kingfish does not often appear in the top five species caught and therefore goes unrecorded. It is unlikely that an abundance trend for any of the kingfish stock areas could be obtained from the historical catch and effort data.

The historical catch data indicate that setnet fishers are either able to target kingfish or control their targeting of other species such that the expectation of kingfish bycatch remains high. If kingfish was managed under quota allocation, there would be no basis to prevent setnet and other fishers from targeting kingfish provided quota allocations were not exceeded. It may then be possible to use the setnet fishery to monitor kingfish abundance in the future. The use of setnet to track abundance trends in kingfish will require improvements in the collection of catch effort data (possibly requiring the use of fisher logbooks). An investigation into the potential use of setnet CPUE to monitor kingfish abundance would be a worthwhile research project.

Priority: ●●●

6.3.2 Absolute abundance estimates using tagging

The results from the recreational tagging programme indicate kingfish are amenable to assessment by mark-recapture.

Priority: ●

6.4 Estimates of age and growth

Estimates of growth rates and maximum age are necessary to determine the basic productivity of kingfish. Our understanding of these basic parameters is poor. More work is needed to establish ageing protocols for New Zealand kingfish. More work is needed to describe the growth rates of kingfish generally and to determine if the two sexes grow differently.

Priority: ●●●●

6.5 Fishery characterisation for age and length

The selectivity characteristics of all the main methods of catching kingfish will need to be known before stock assessments can be undertaken. One way of doing this would be to characterise the length and age composition of catches taken by the main fishing methods. Sampling the kingfish populations for age and length may also provide information on total mortality (Z) and recruitment variability.

Priority: ●●●

6.6 Optimising yield from kingfish stocks

6.6.1 Estimating incidental mortality

Analyses presented in this report suggest that the current MLS of 65 cm is inadequate to protect all juvenile kingfish from exploitation as the smallest size at which kingfish have been observed to be mature is 75 cm. It would be desirable to characterise the length composition of all the main commercial and recreational methods catching kingfish (Priority: ●●●●). If a high proportion of the catch was undersized fish, this would be reason to suspect a high level of incidental fishing mortality. Further work would be needed to determine what proportion of undersize fish would manage to survive capture and release (Priority: ●●●●).

6.6.2 *Yield per recruit analysis (YPR)*

An analysis of Yield Per Recruit (YPR) is useful for deriving management strategies for various fish stocks. Estimates of growth, length and age at first maturity, and natural mortality are required to undertake a YPR analysis. Most of these basic parameters are not known with any surety for New Zealand kingfish (Priority: ●●●●).

7. ACKNOWLEDGMENTS

Thanks to Seren Penty (Ministry of Fisheries) for the provision of data from the catch effort return system; Owen Anderson and Paul Taylor (NIWA) for supplying Figures 16 and 17 in this publication; and to Larry Paul for reviewing the report and proposing some useful changes. Funding for this project, MOF1999/04G, was provided by the Ministry of Fisheries.

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Table 1: Reported landings (t) of kingfish by Fishery Management Area (FMA) from 1983–84 to 1999–2000. *Data from 1983–84 to 1988–89* are from FSU database. From 1989–90, total landings and landings by FMA are from CLRs.

FMA (s)	1	2	3	4	5	6
	Landings	Landings	Landings	Landings	Landings	Landings
1983–84	308	54	9	0	0	0
1984–85	225	48	6	0	0	0
1985–86	239	39	3	0	0	0
1986–87	188	52	9	0	0	0
1987–88	146	47	3	0	0	0
1988–89	92	16	4	0	0	0
1989–90	216	57	2	0	0	0
1990–91	292	86	4	0	0	0
1991–92	376	92	2	0	0	0
1992–93	387	85	3	0	0	0
1993–94	179	62	1	0	0	0
1994–95	198	73	1	0	0	0
1995–96	203	117	1	0	0	0
1996–97	235	107	2	0	0	0
1997–98	153	112	1	0	0	0
1998–99	159	98	2	0	0	0
1999–2000	74	73	2	0	0	0

FMA (s)	7	8	9	10	Unknown	Total	Target
	Landings	Landings	Landings	Landings	landings	landings	landings
1983–84	4	23	25	0	24	448	–
1984–85	1	20	23	0	20	345	–
1985–86	1	36	29	0	33	380	–
1986–87	1	19	28	0	22	319	–
1987–88	1	16	29	0	19	261	–
1988–89	1	6	9	0	39	167	–
1989–90	3	24	0	0	1	303	36
1990–91	2	39	0	0	0	422	68
1991–92	2	35	0	9	0	517	50
1992–93	2	52	0	1	2	532	43
1993–94	3	24	5	0	0	275	24
1994–95	2	16	8	0	2	301	30
1995–96	7	25	19	0	3	374	30
1996–97	8	25	23	6	2	409	17
1997–98	7	22	21	1	5	321	32
1998–99	11	18	31	0	0	320	8
1999–2000	6	19	23	0	0	197	6

Table 2: Summary of the combined household telephone and diary survey sample designs, response rates, diarist kingfish catches, and scaled catches from the 1991–92 to 1993–94 regional surveys. Data from Teirney et al. (1997).

Region	Year	Households	Households interviewed	Fishers interviewed	Fishing diarists	Total diarist catch	Scaled catch (t)
South	1991–92	262 444	10 055	1 073	862	2	not est.
Central	1992–93	373 346	10 045	1 337	989	124	15
North	1993–94	550 625	15 015	3 363	2 728	768	101
Total		1 186 415	35 115	5 773	4 579	894	116

Table 3: The estimated number of recreationally caught kingfish, N_R, and c.v., estimated recreational catch, C_R, commercial catch from fishing year (Oct–Sep), C_C, and the ratio C_R/C_T of the recreational catch to total catch, $C_T=C_C+C_R$. Recreational estimates are from the 1991–92 South survey, the 1992–93 Central survey, and the 1993–94 North survey. Diary data are from Teirney et al. (1997) (– denotes c.v. estimate not calculated or data not available).

Fishstock	Survey	N_R	c.v.	$C_R(t)$	$C_C(t)$	C_R/C_T
KIN 1	North	87 000	14	390–600		
	Central	6 000	35	25–45		
	South		–	–		
	Total	93 000		415–645	179	70–78%
KIN 2	North	2 000	–	5–15		
	Central	6 000	–	20–40		
	Total	8 000		25–55	85	23–39%
KIN 3	–	–	–	–	–	–
KIN 7	Central	2 000	–	5–15		
	South		–	–		
	Total	2 000		5–15	2	71–88%
KIN 8	Central	1 000	–	0–10		
	Total	1 000		0–10	52	0–16%
KIN 9	North	12 000	27	50–80		
	Central		–	–		
	Total	12 000		50–80	5	91–94%

Table 4: Summary of the combined household telephone and diary survey sample designs, response rates, diarist kingfish catches and scaled catches from the 1996 national survey by region. Data from Bradford (1998a).

Region	Year	Households	Households interviewed	Fishers interviewed	Fishing diarists	Total diarist catch	Scaled catch (t)
South	1996	281 483	11 023	1 168	882	18	3
Central	1996	388 685	10 122	1 274	987	49	7
North	1996	613 548	13 893	2 418	1 883	456	64
Total		1 283 716	35 038	4 860	3 752	523	74

Table 5: The estimated number of recreationally caught kingfish, N_R, and c.v., estimated recreational catch, C_R, commercial catch in the 1995–96 fishing year, C_C, and the ratio C_R/C_T of the recreational catch to total catch, $C_T=C_C+C_R$. Recreational estimates are from the 1996 national diary survey (Bradford 1998c) (– denotes *c.v.* estimate not calculated or data not available).

Fishstock	N_R	c.v.	$C_R(t)$	$C_C(t)$	C_R/C_T
KIN 1	64 000	8	350–410	203	63–67%
KIN 2	5 000	–	–	–	–
KIN 3	3 000	–	–	–	–
KIN 7	–	–	–	–	–
KIN 8	2 000	–	–	–	–
KIN 9	–	–	–	–	–

Table 6: Details of mesh size and tow distance for *Kaharoa* trawl surveys catching kingfish from 1982–2000 in FMA 1, 2, 7, and 9.

				FMA
	1	2	7	9
Proportion of surveys catching kingfish	0.90	1.00	0.25	0.75
Mean number of kingfish per survey	7	53	2	5
Codend mesh size (mm) used in survey	30–40	80	74	40
Average tow distance (n.mile)	0.7–1.0	3.5	3.0	1.5

Table 7: Movement of kingfish as reported by the gamefish tagging programme by statistical area of release and recapture since 1975 (Hartill & Davies 2001).

	Recapture area																							
Release area	002	003	005	006	007	008	009	010	011	012	013	014	016	039	042	043	045	047	048	???	AUS	COL	WAN	Total
002	62	11	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	75
003	6	129	3	1	3	2	1	–	–	–	–	1	–	–	–	–	–	1	–	3	–	–	1	151
005	–	2	5	–	1	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	9
006	–	1	1	3	5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	10
007	–	1	–	4	11	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	16
008	–	1	1	1	–	6	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	10
009	–	2	–	–	–	2	88	6	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–	100
010	1	1	2	–	–	3	13	407	2	1	2	–	–	1	–	–	–	–	–	–	–	–	–	433
011	–	–	–	–	–	–	–	1	7	1	1	–	–	–	1	–	–	–	–	–	–	1	–	12
012	–	–	–	–	–	1	1	1	1	7	5	3	1	–	–	–	–	–	–	–	–	–	–	20
013	–	1	–	–	–	–	–	1	–	–	4	1	–	–	–	–	–	–	–	–	–	–	–	7
014	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–	–	–	–	–	–	–	2
043	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	5	–	1	–	–	–	–	–	6
044	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	1
045	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	1
047	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	10	1	1	–	–	–	12
048	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	2	–	–	–	–	4
Total	70	149	13	9	20	14	103	416	10	9	13	7	1	1	1	6	1	13	3	6	2	1	1	869

AUS, Australia; COL, Colville Ridge; WAN, Wanganella Bank; ???, area unknown

Table 8: Summary of yields (t) from the commercial fishery (from Annala et al. 2002).

Fishstock	FMA		MCY (t)
KIN 1	Auckland East	1	195
KIN 2	Central East	2	40
KIN 3	South East, Southland, Sub-Antarctic and Challenger	3, 4, 5, 6, & 7	5
KIN 8	Central West	8	20
KIN 9	Auckland West	9	not estimated
KIN 10	Kermadecs	10	not estimated

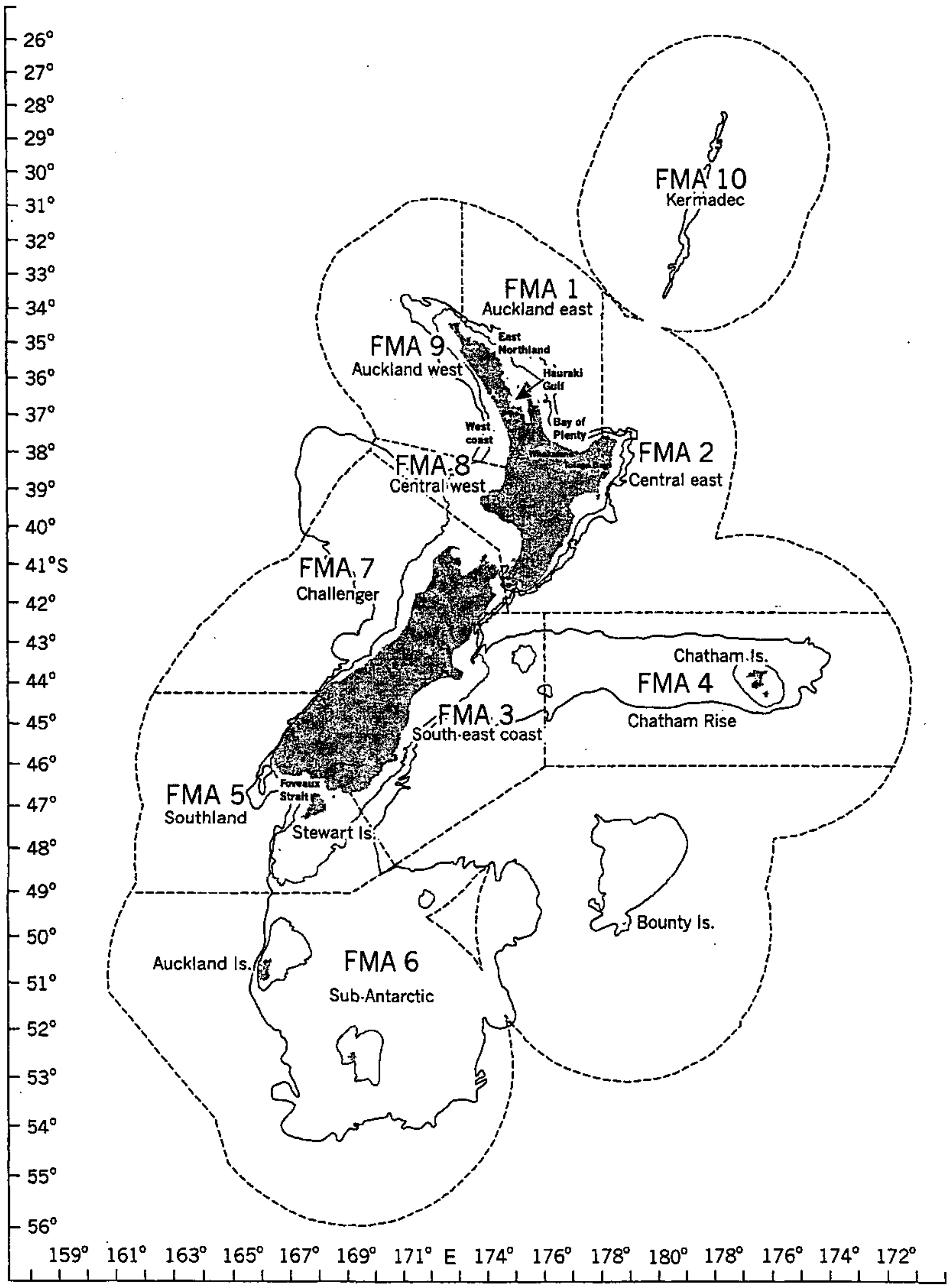

Figure 1: Fishery Management Areas (FMA) of the New Zealand 200 n. mile Exclusive Economic Zone.

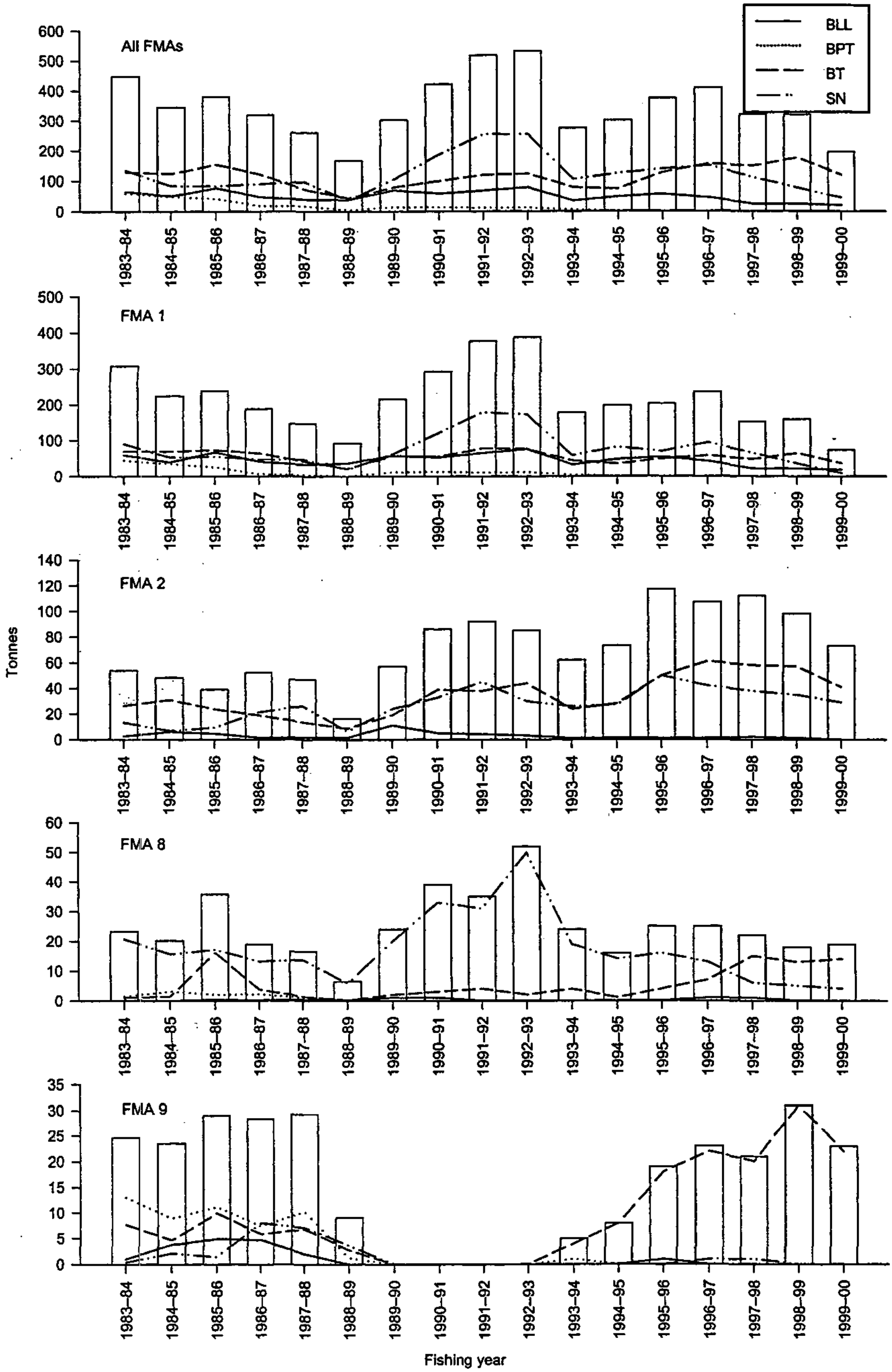

Figure 2: Total landed catch of kingfish for the main commercial methods for all FMAs combined and for FMAs 1, 2, 8, and 9 from 1983–84 to 1999–2000 (BLL, bottom longline; BPT, bottom pair trawl; BT, bottom trawl; SN, setnet).

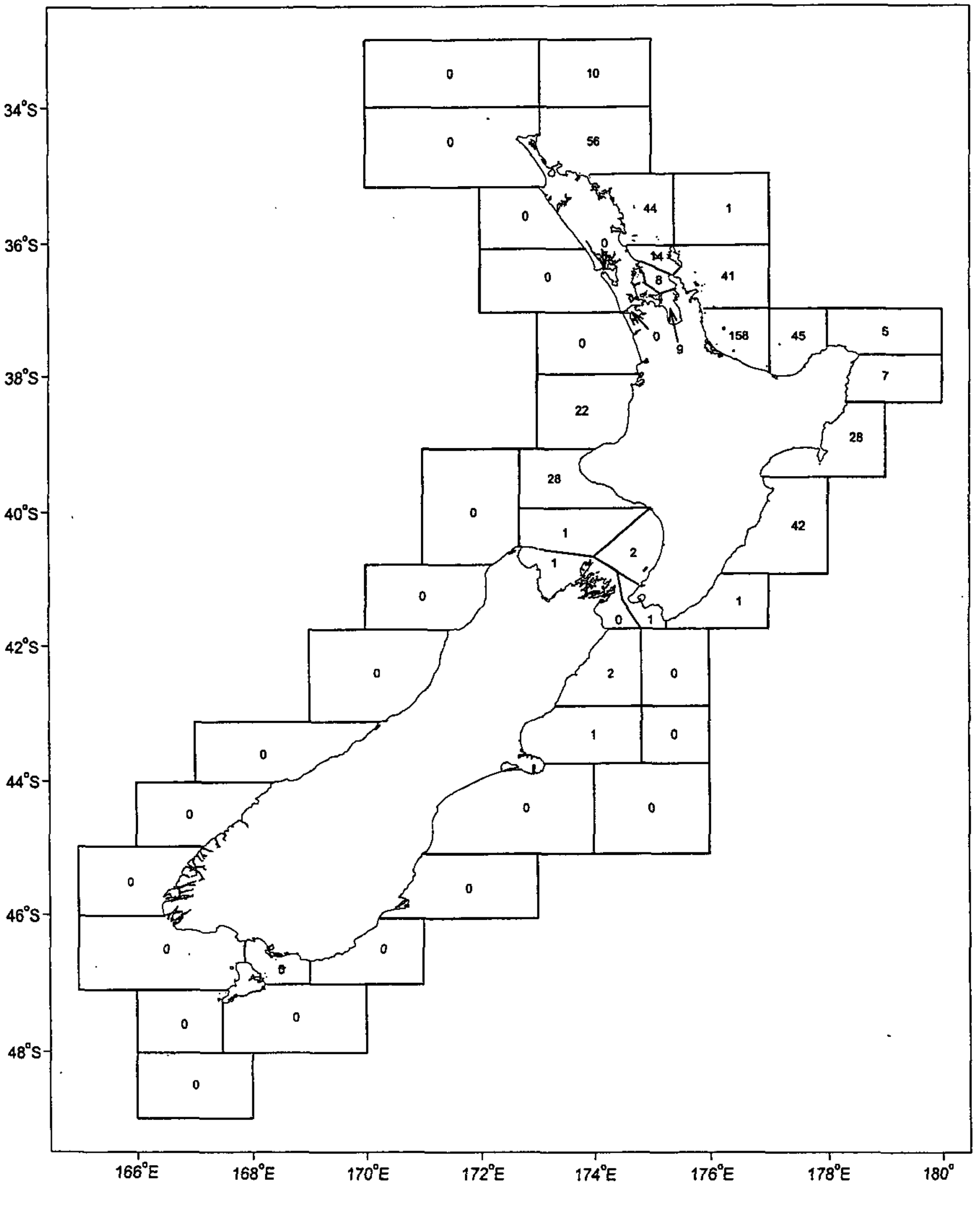

Figure 3: Kingfish total catch (t) reported by statistical area for 1992–93.

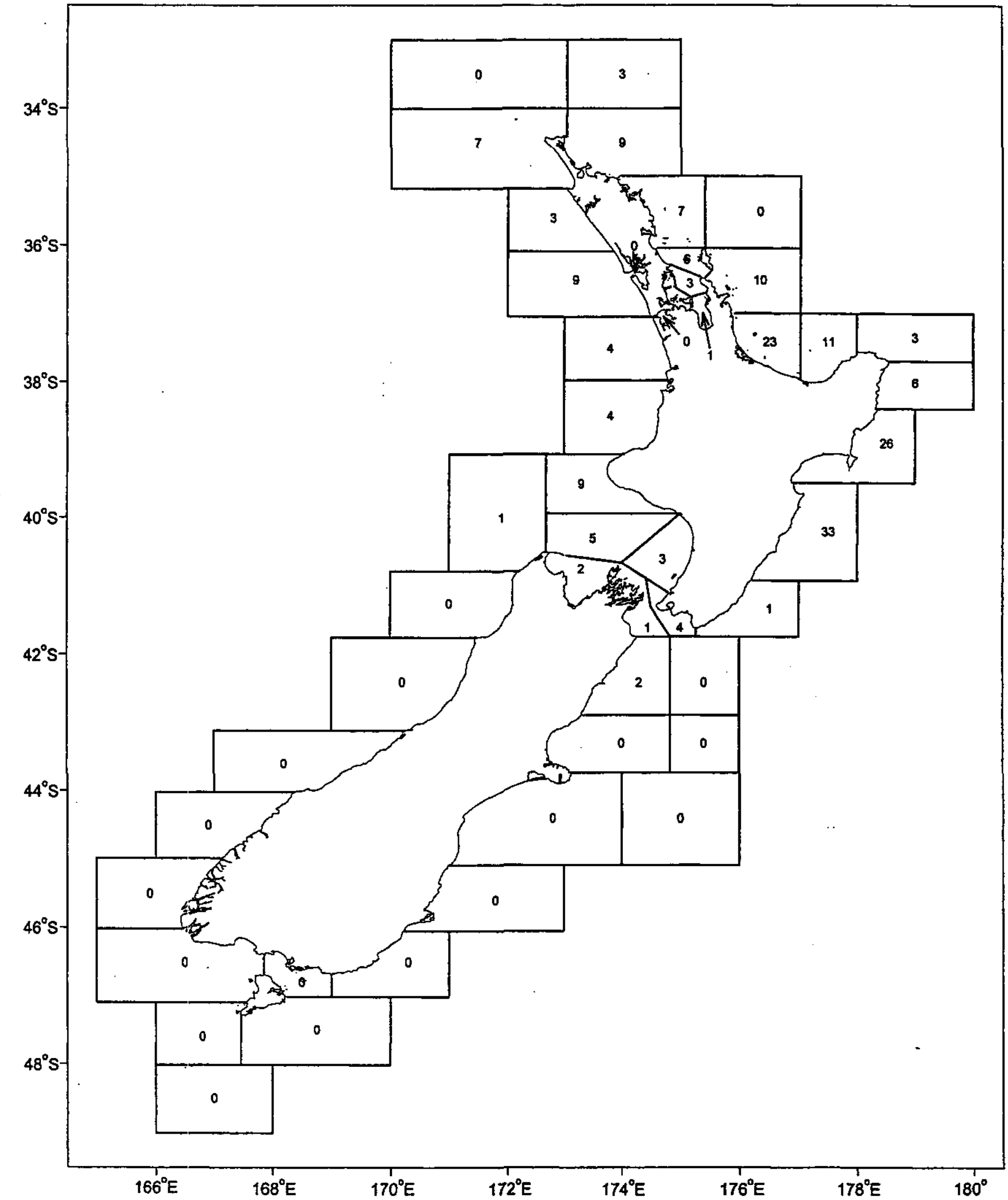

Figure 4: Kingfish total catch (t) reported by statistical area for 1999–2000.

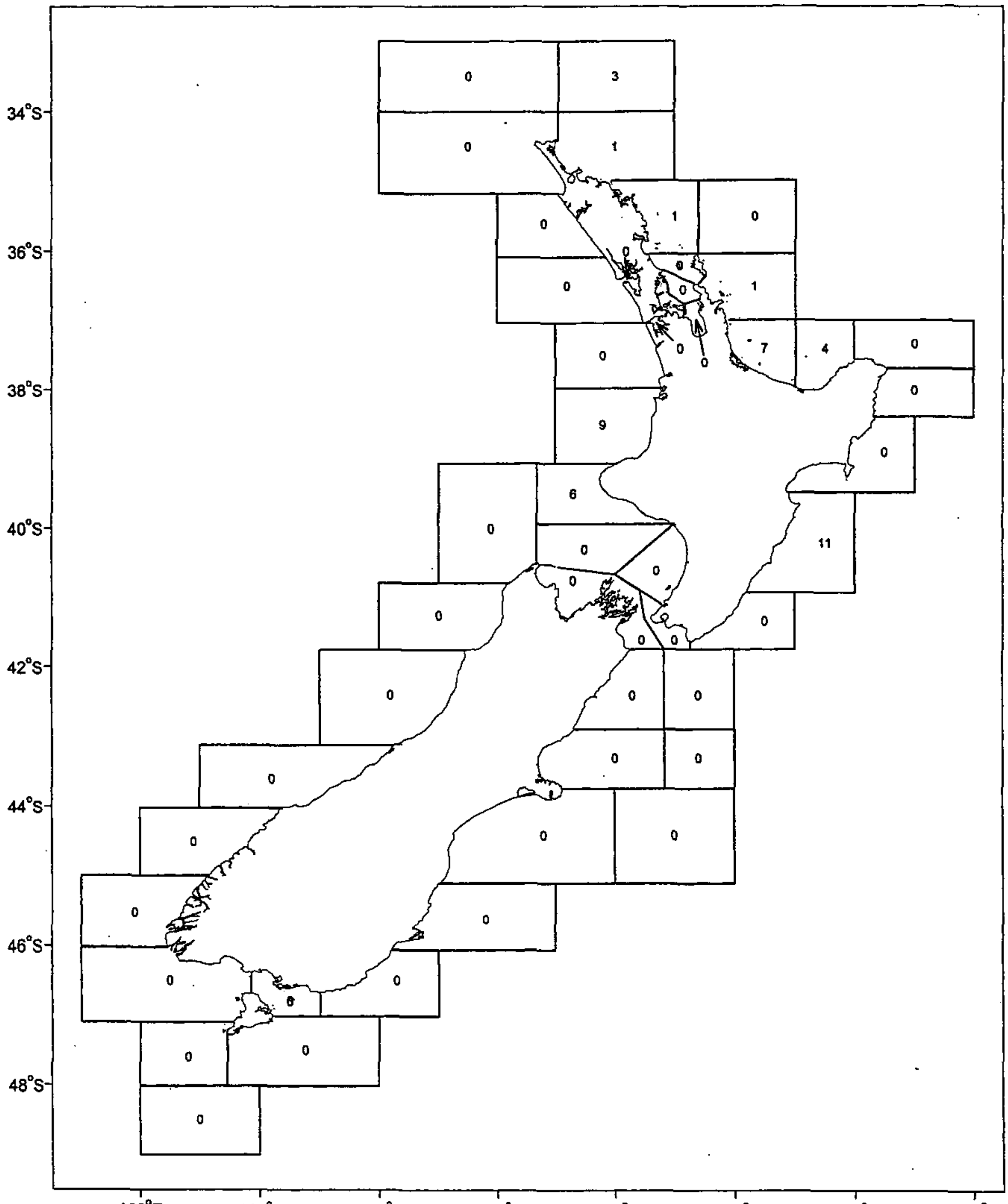

Figure 5: Kingfish targeted catch (t) reported by statistical area for 1992–93.

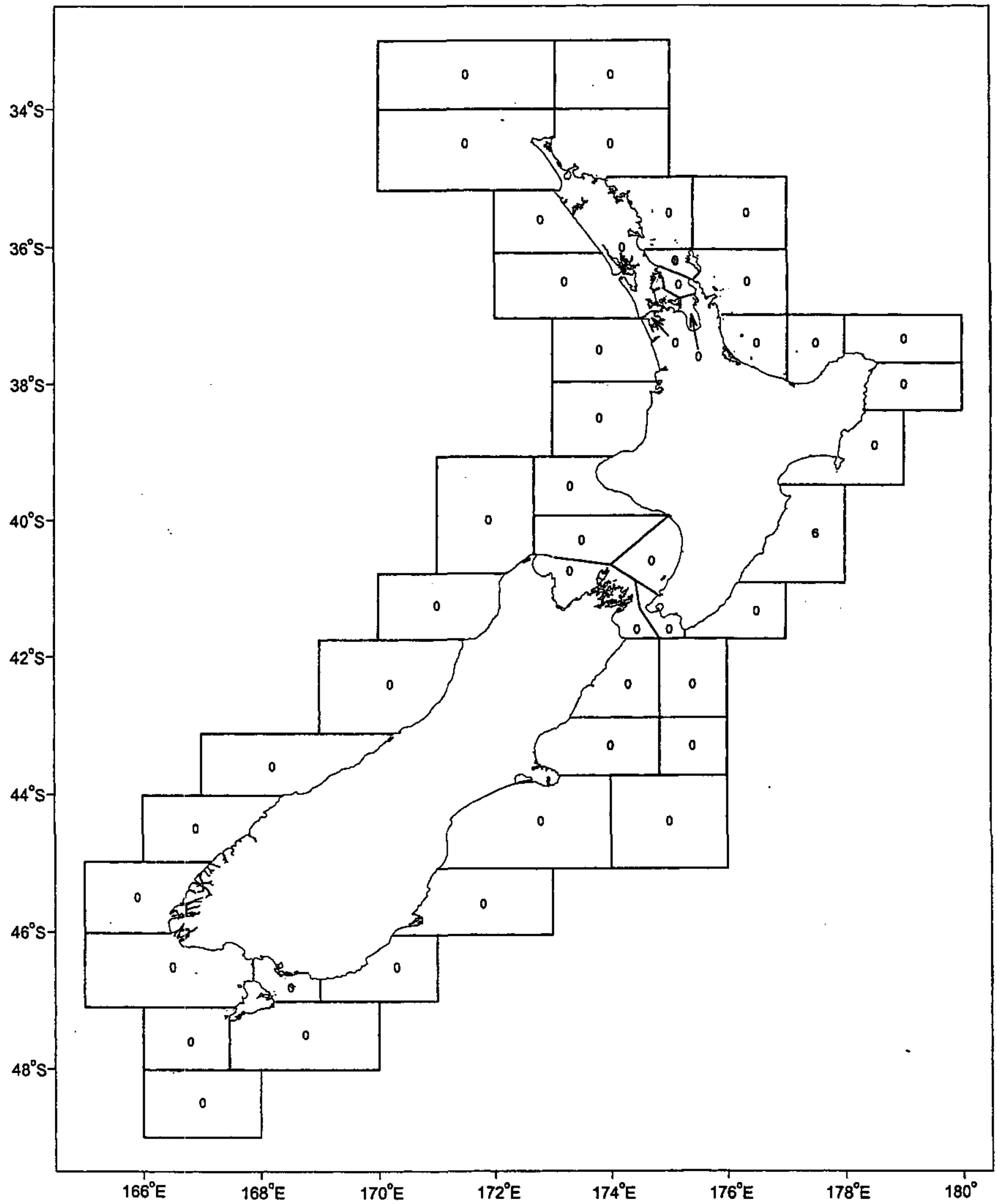

Figure 6: Kingfish targeted catch (t) reported by statistical area for 1999–2000.

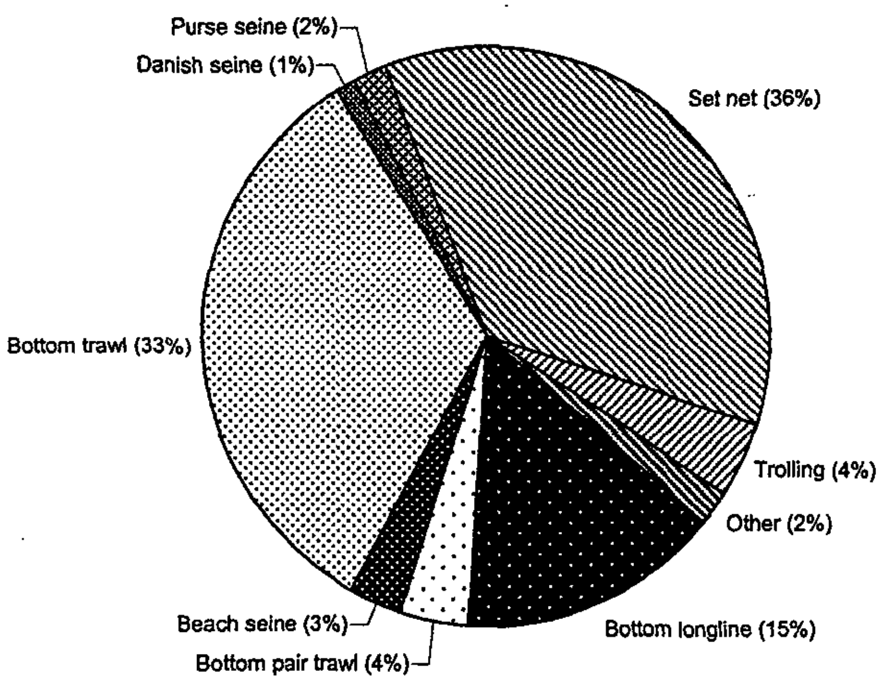

Figure 7: Mean annual catch by method for all QMAs from 1983–84 to 1999–2000.

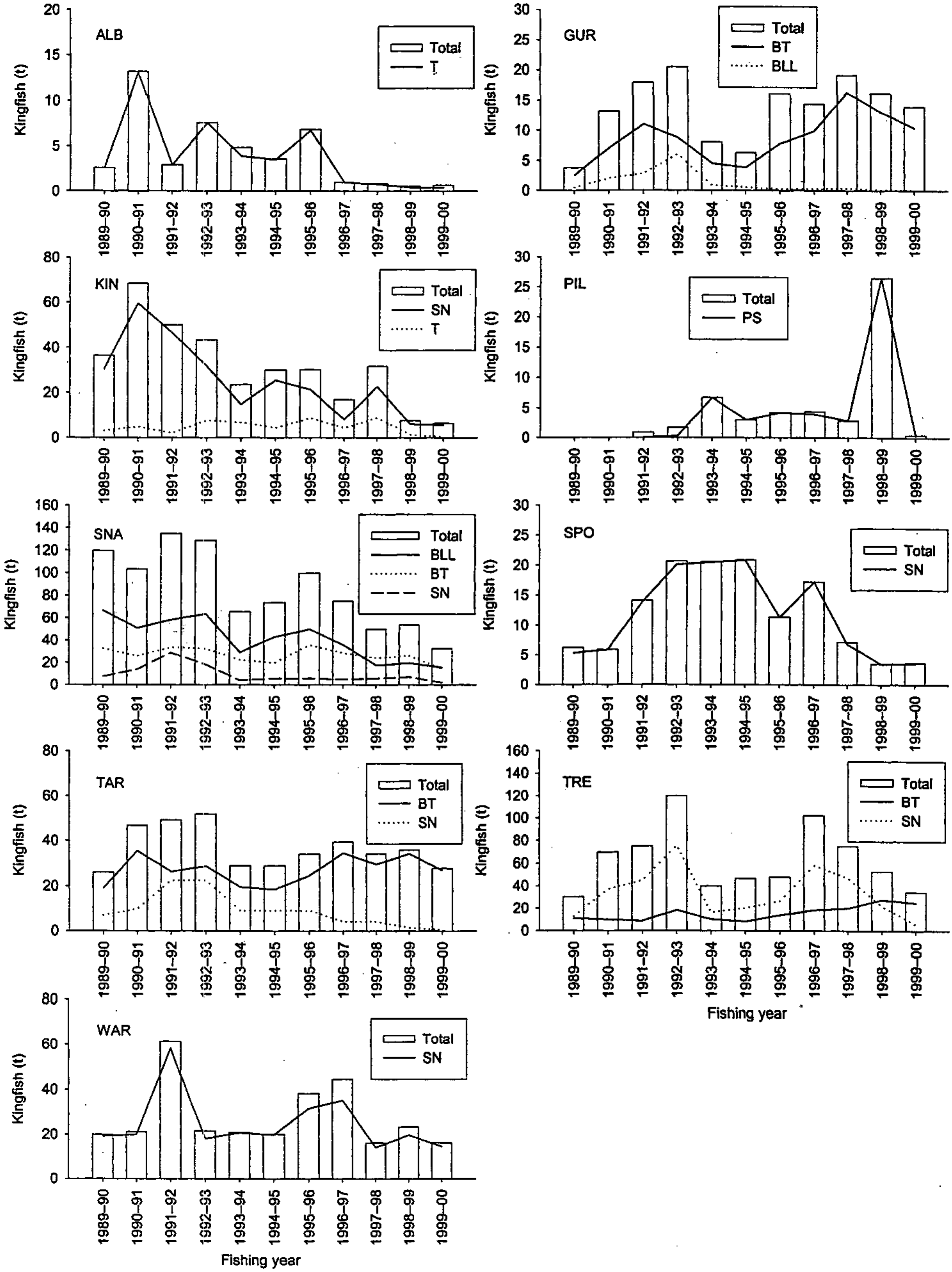

Figure 8: Total catch (t) of kingfish by target species and main commercial method for all FMAs combined from 1989–90 to 1999–2000 (Note: for species codes see Appendix 2b. BLL, bottom longline; BT, bottom trawl; PS, purse-seine; SN, setnet; T, troll).

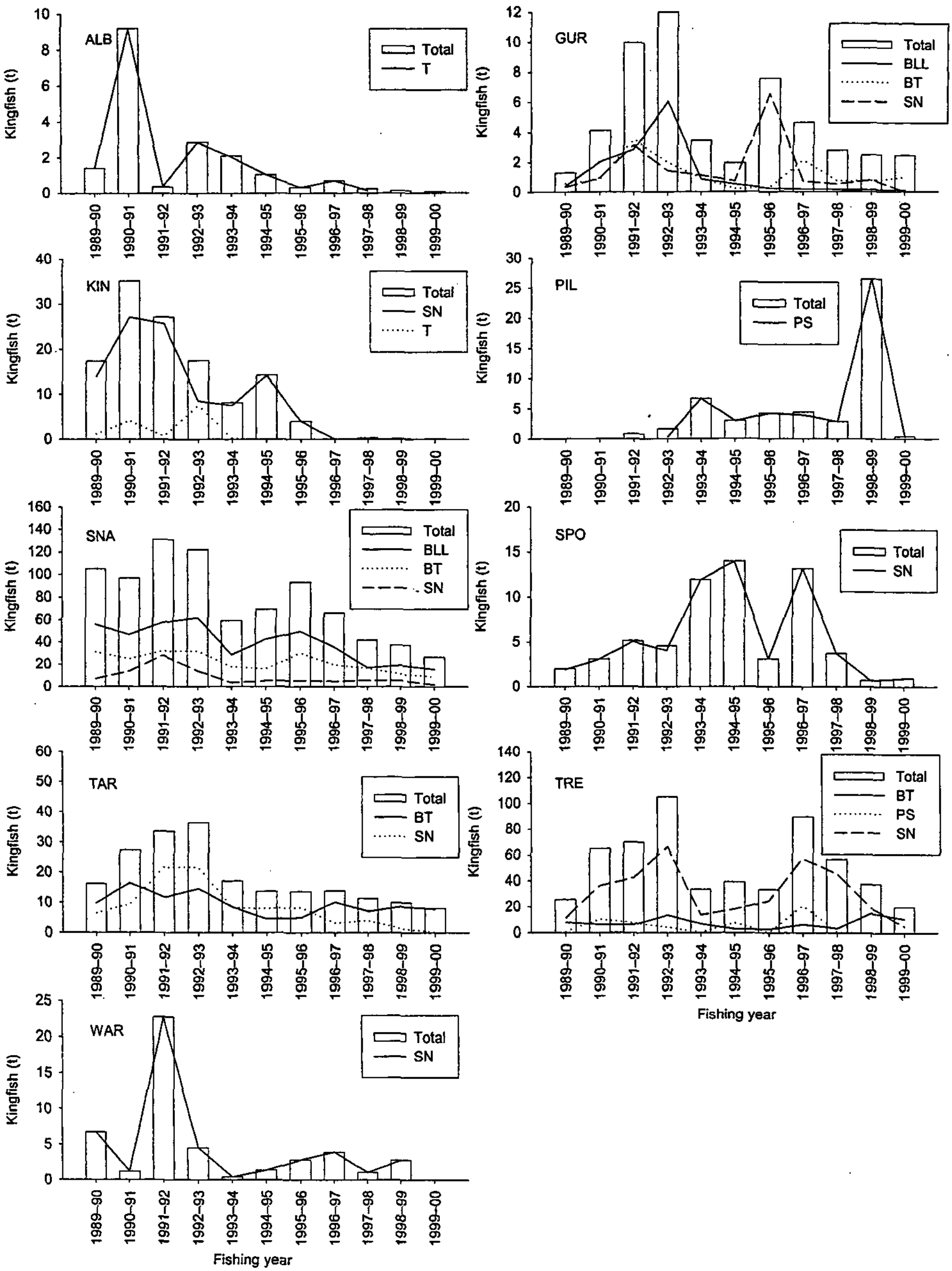

Figure 9: Total catch (t) of kingfish by target species and main commercial method for FMA 1 from 1989–90 to 1999–2000 (Note: for species codes see Appendix 2b. BLL, bottom longline; BT, bottom trawl; PS, purse-seine; SN, setnet; T, troll).

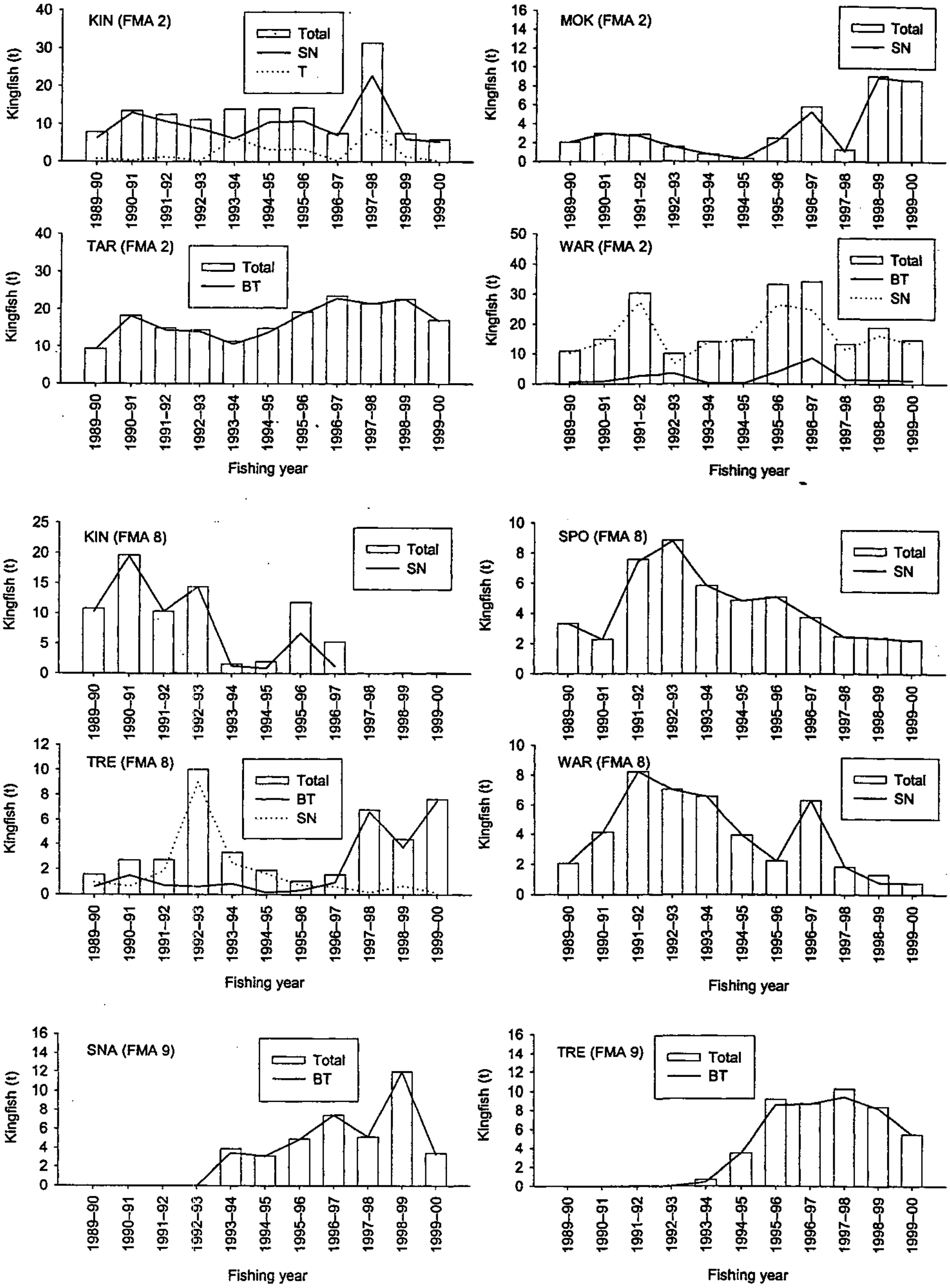

Figure 10: Total catch (t) of kingfish by target species and main commercial method for FMAs 2, 8, and 9 from 1989–90 to 1999–2000 (Note: for species codes see Appendix 2b. BT, bottom trawl; SN, setnet; T, troll).

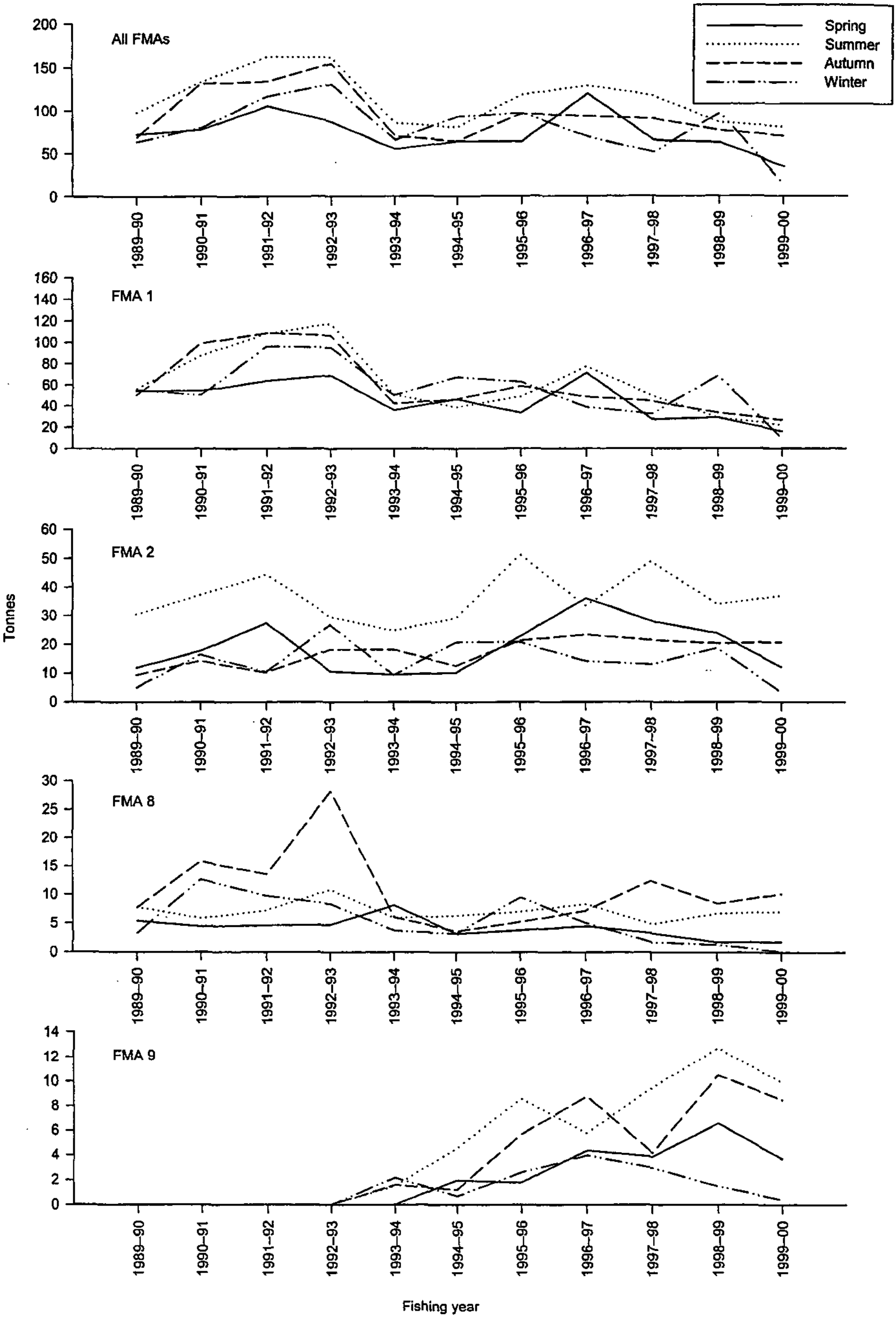

Figure 11: Total landed catch of kingfish by season for all FMAs combined and for FMAs 1, 2, 8, and 9 from 1989–90 to 1999–2000.

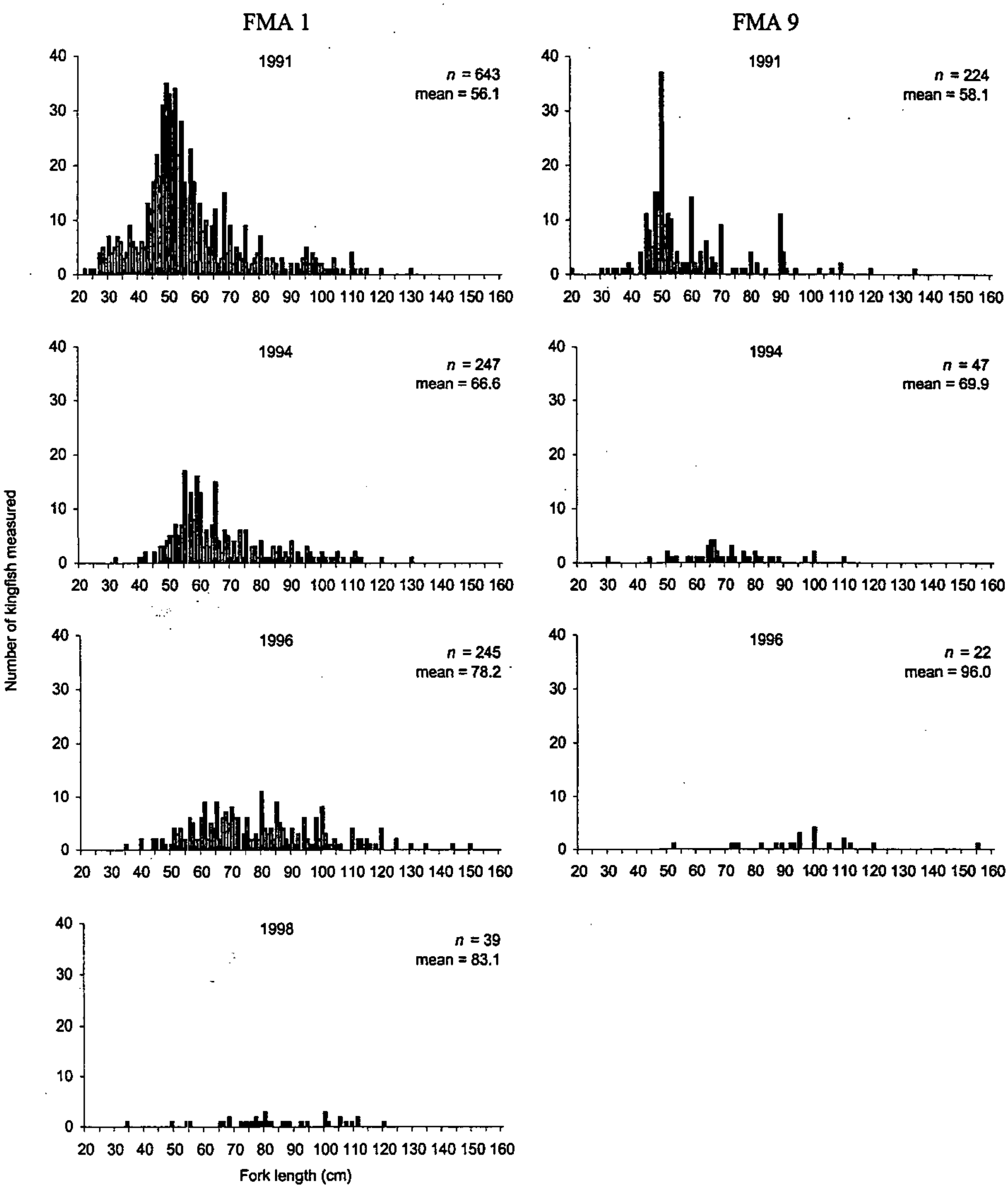

Figure 12: Length frequency distributions of kingfish caught in FMAs 1 and 9 measured by interviewers during boatramp surveys in 1991, 1994, 1996, and 1998.

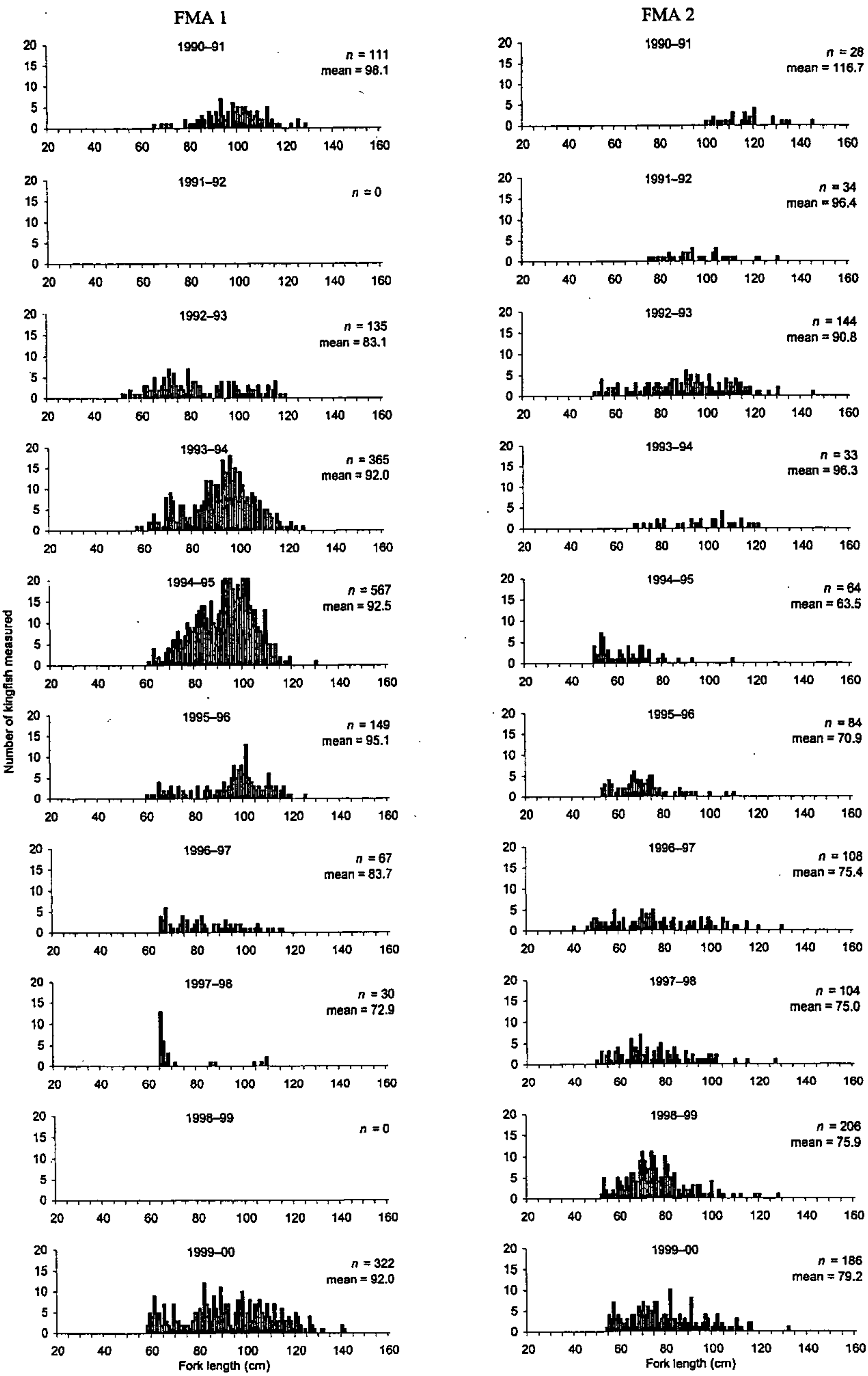

Figure 13: Length frequencies of kingfish tagged and released as recorded by reliable observers on two charter boats in FMA 1 (Statistical reporting areas 009 and 010) and FMA 2 (Statistical reporting areas 011, 012, and 013) by fishing year.

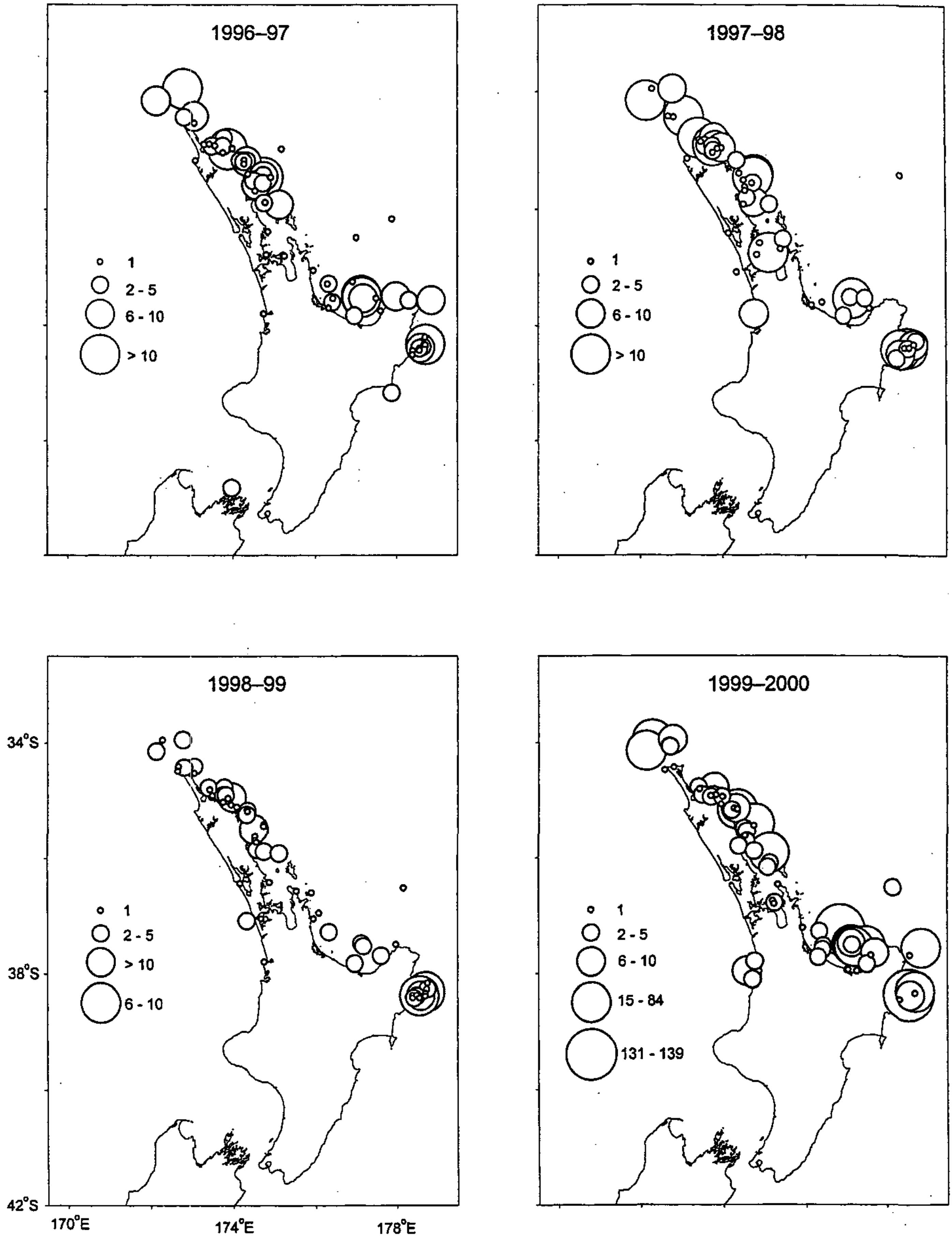

Figure 14: Spatial distribution of kingfish tagged and released during the 1996–97, 1997–98, 1998–99, and 1999–2000 gamefish seasons (July to June) as reported from the gamefish tagging programme.

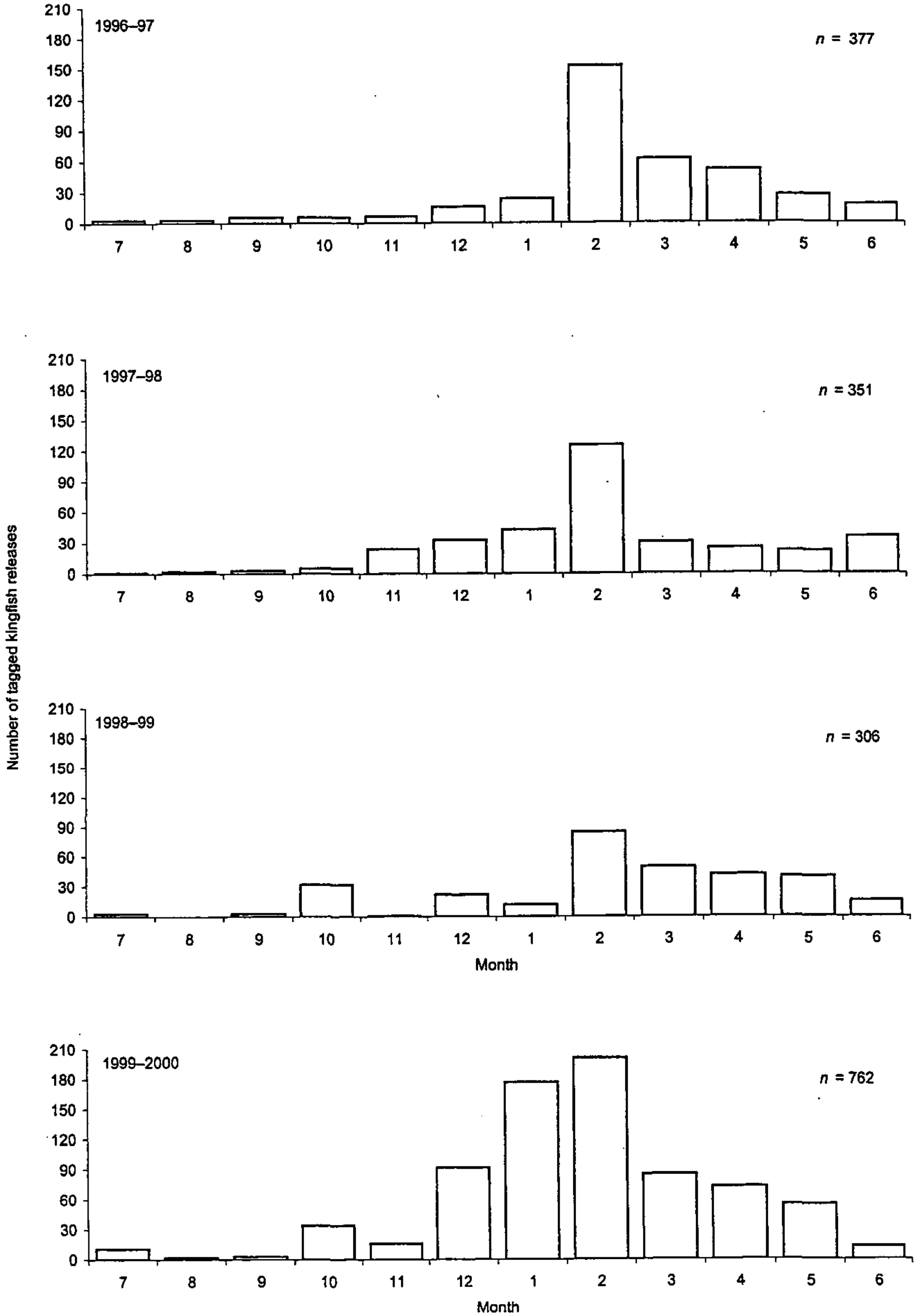

Figure 15: Temporal distribution of tagged kingfish releases by month during the 1996–97, 1997–98, 1998–99 and 1999–2000 gamefish seasons (July to June) as reported from the gamefish tagging programme.

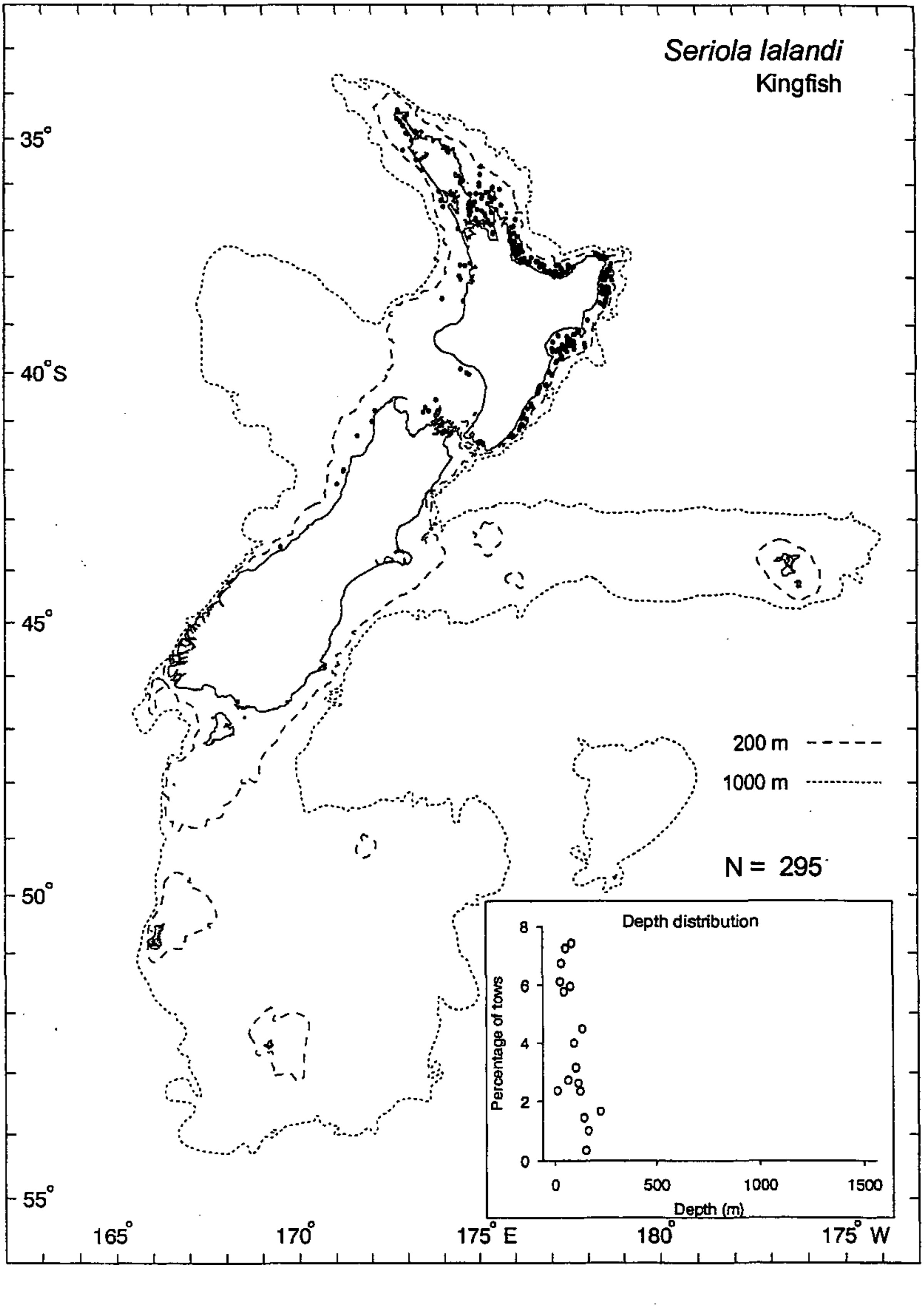

Figure 16: Location and depth distribution of kingfish from research bottom trawls 1961–97 (from Anderson et al. 1998). Note: N represents the number of tows in which kingfish were caught.

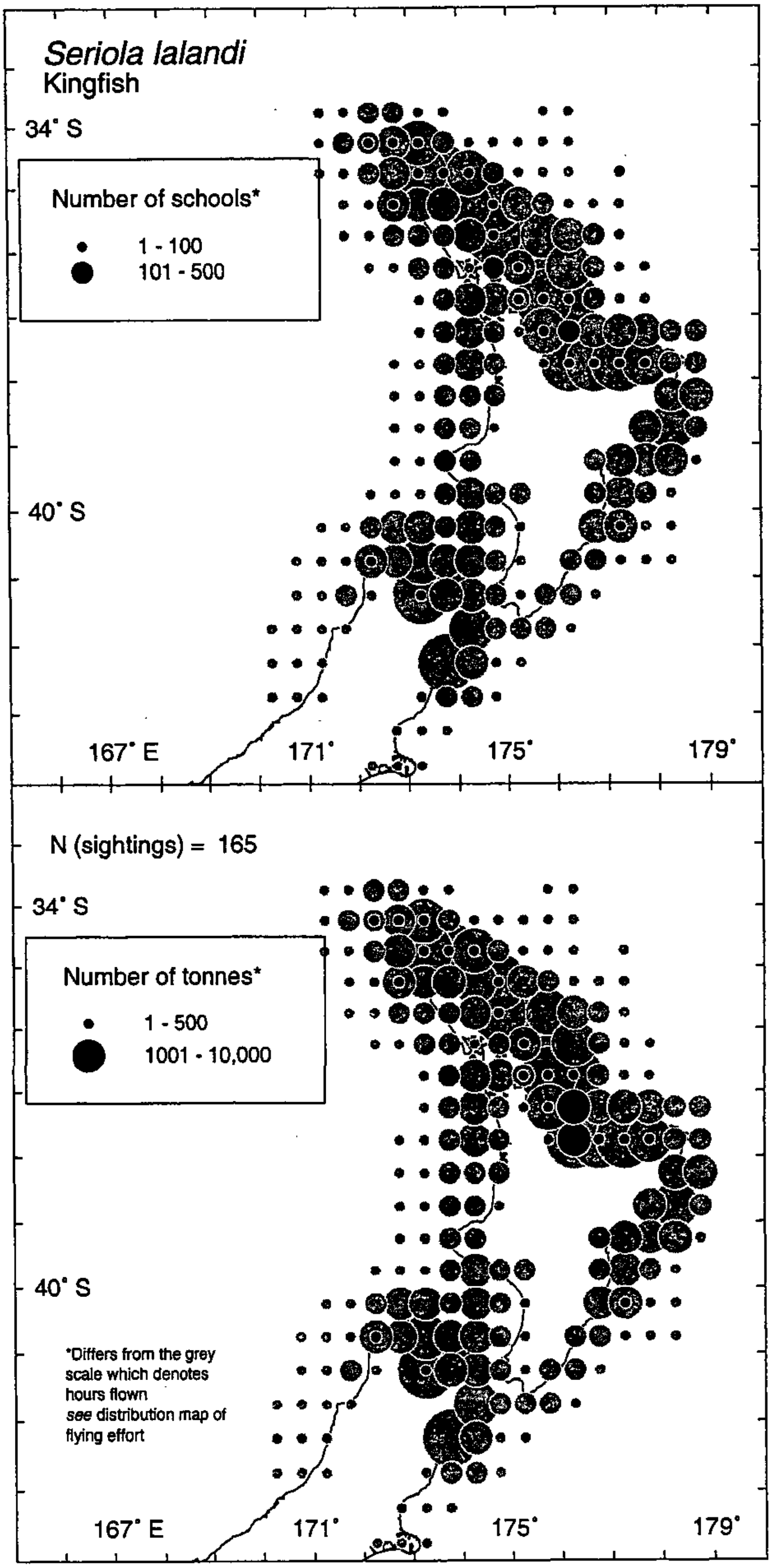

Figure 17: Aerial sightings data (number of schools and tonnes) for kingfish from 1976 to 2000 (from Bagley et al. 2000).

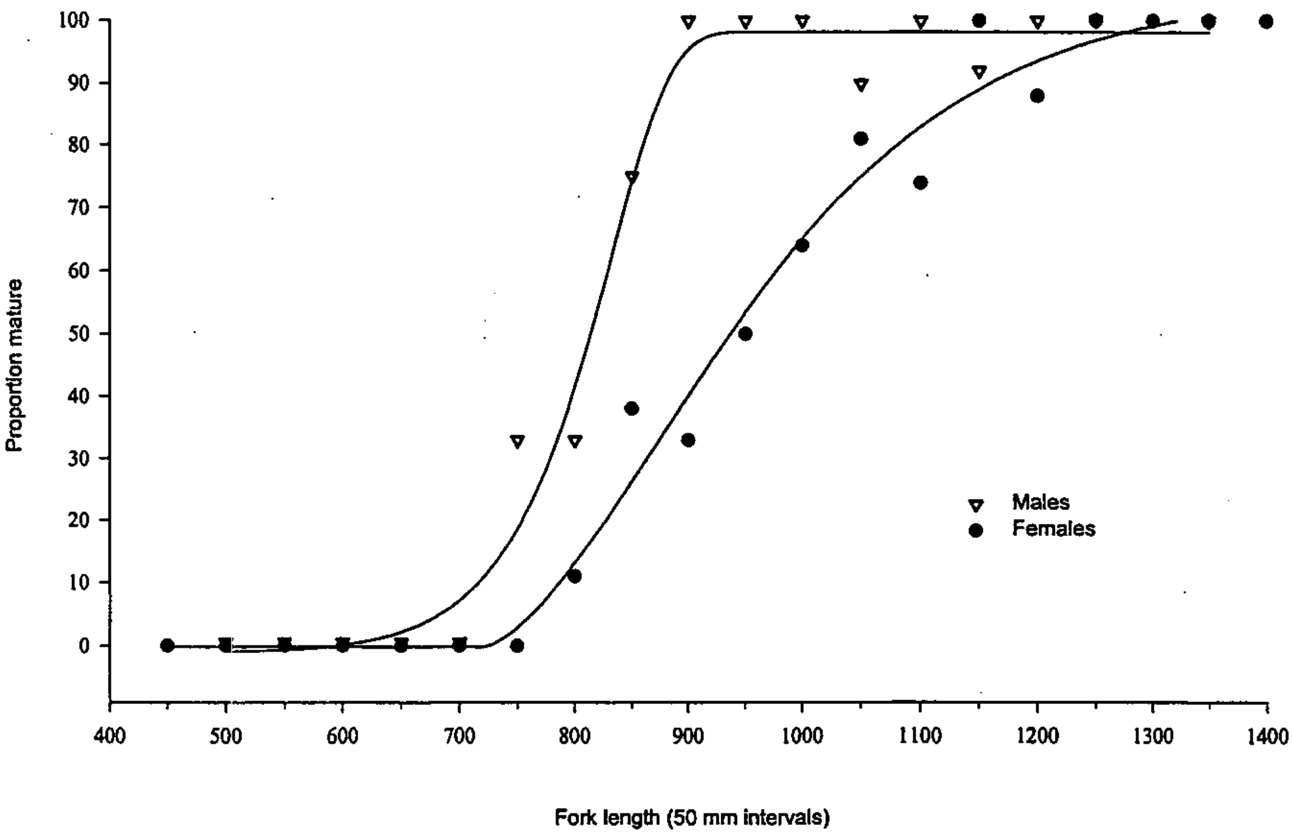

Figure 18: Distribution of mature kingfish by 50 mm fork length intervals. Weibull coefficients were a = 99.4, b = 135059.8, c = 2505.9, y0 = -1.2, L50 = 811.5 ± 8.3 2 (± S.E.), R2 = 0.99 and *n* = 194 for males and a = 103.8, b = 282.7, c = 1.6, y0 = -0.17, L50 = 943.6 ± 16, R2 = 0.99 and *n* = 205 for females (Reprinted from *Aquaculture 201*, Poortenaar, C.W.; Hooker, S.H.; Sharp, N. Assessment of yellowtail kingfish (*Seriola lalandi lalandi*) reproductive physiology, as a basis for aquaculture development. Pg 271– 286. © 2001 with permission from Elsevier).

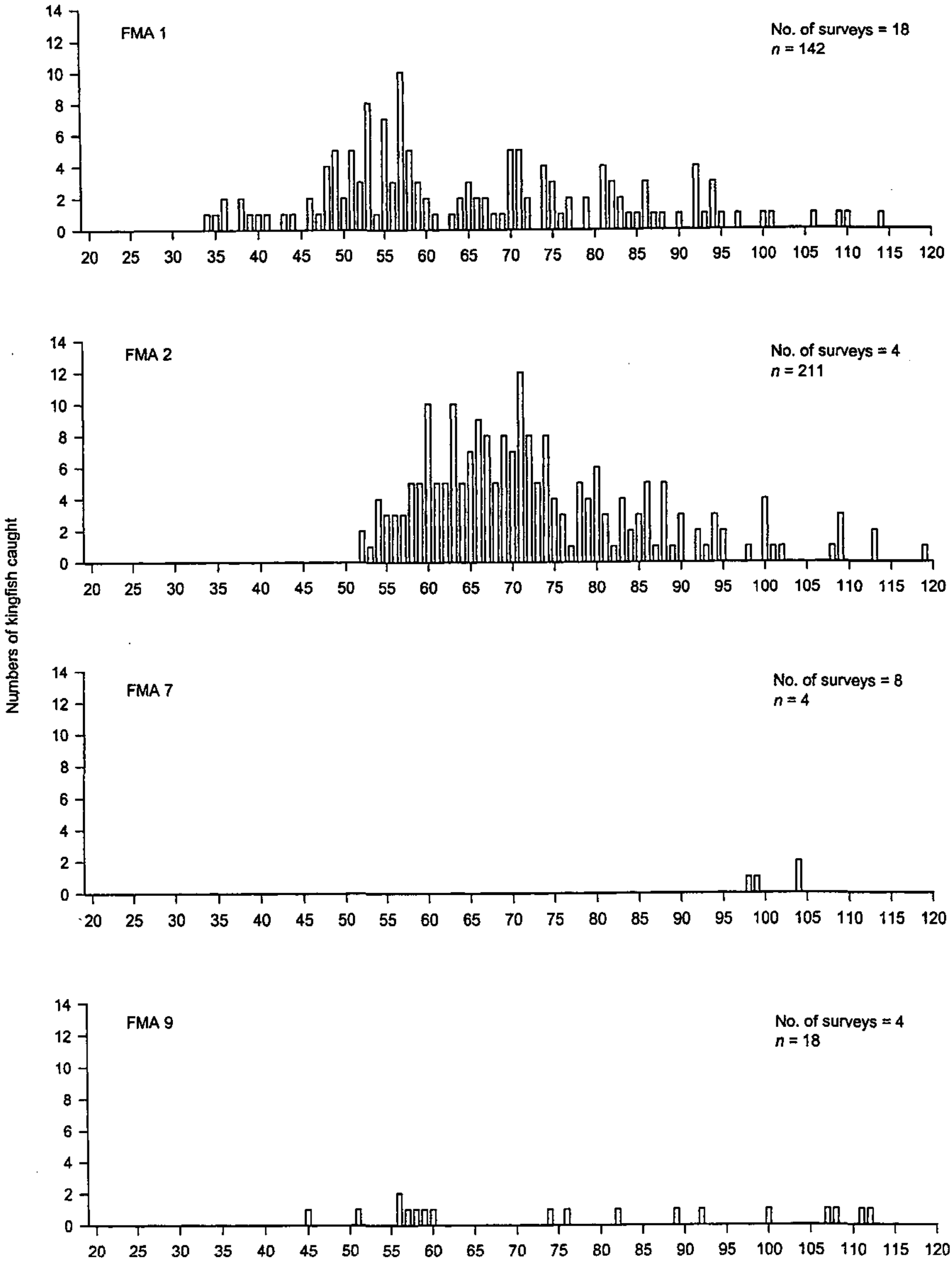

Figure 19: Length frequency distributions for kingfish caught on R. V. *Kaharoa* trawl surveys in FMAs 1, 2, 7, and 9 from 1982–2000.

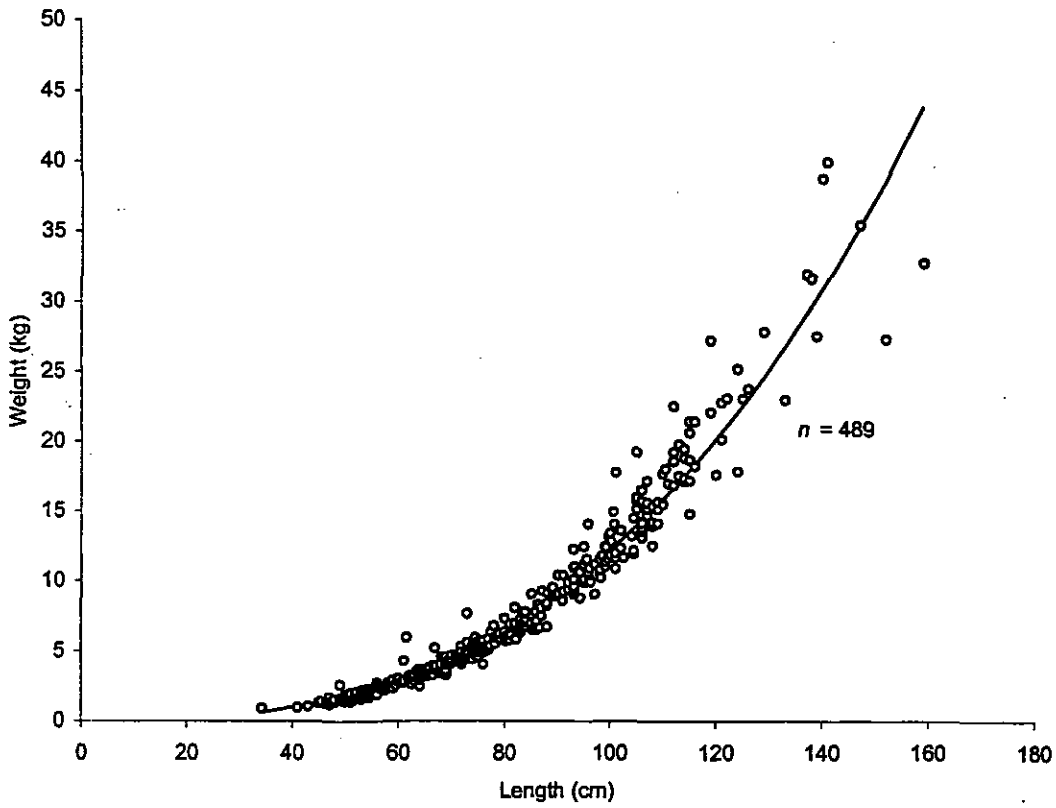

Figure 20: Length-weight relationship for kingfish.

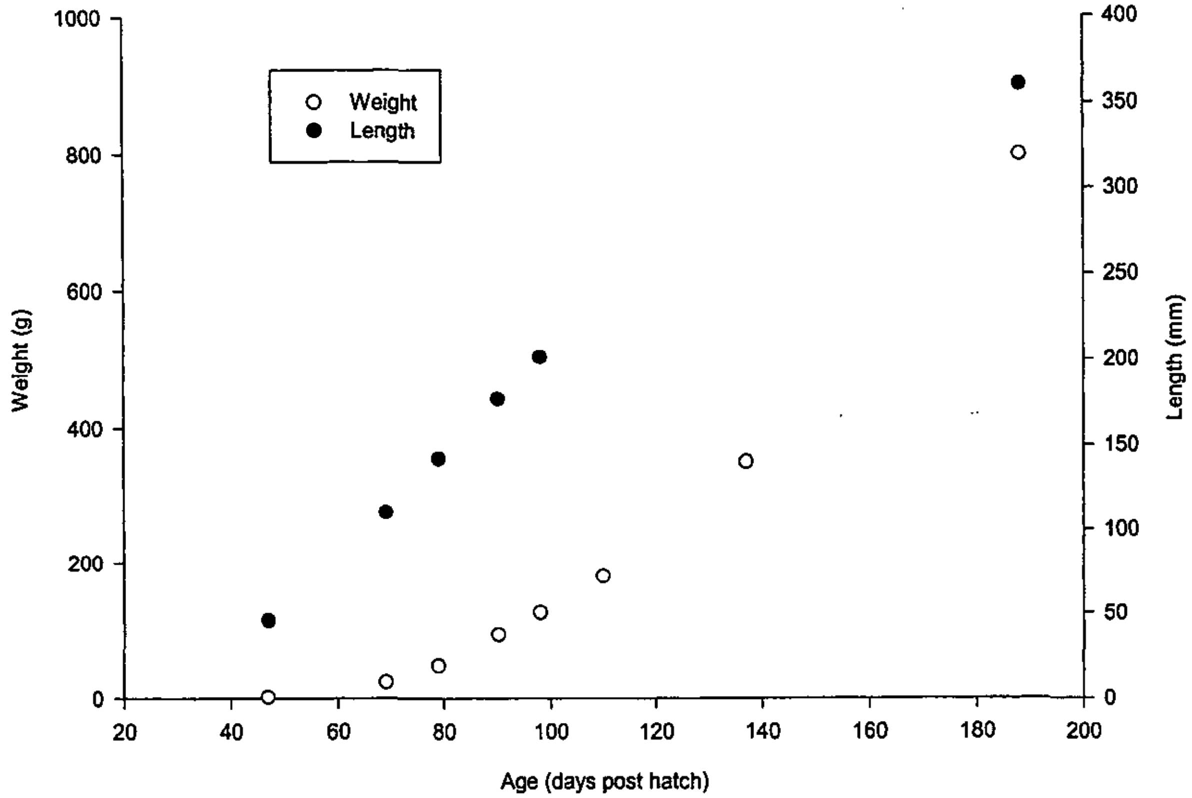

Figure 21: Length and weight of hatchery-reared kingfish in New Zealand.

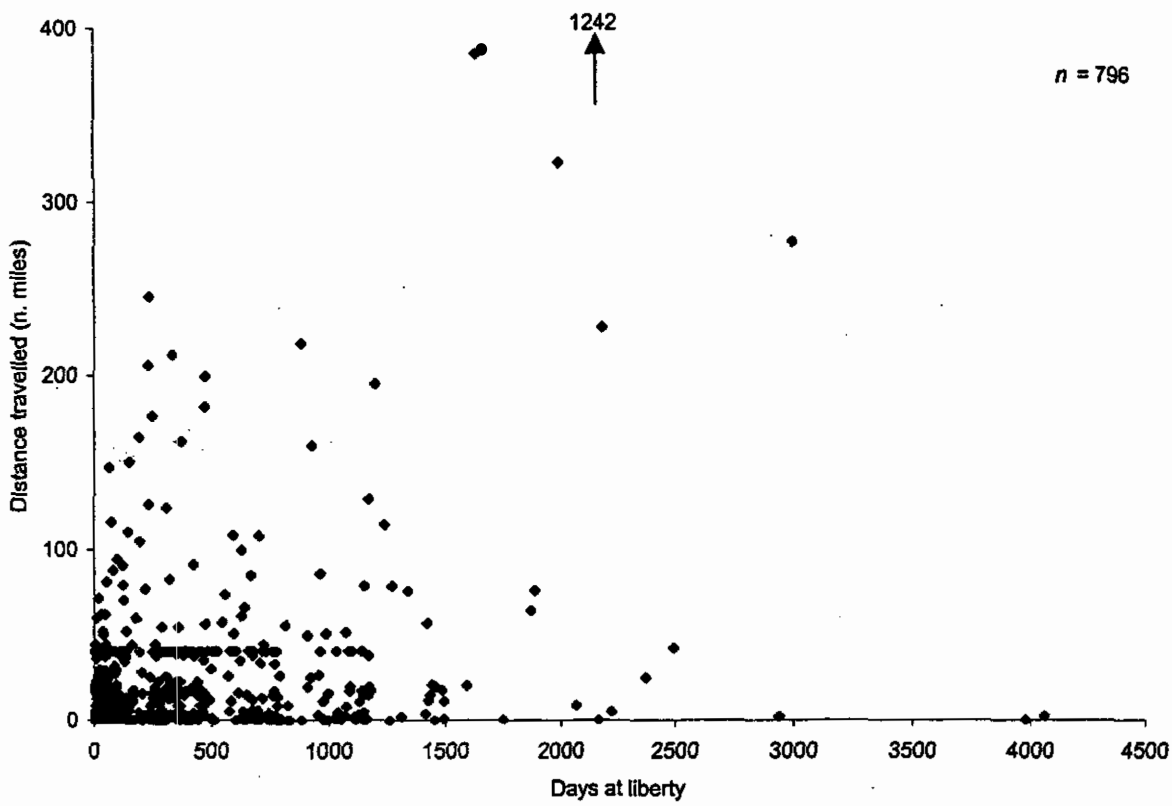

Figure 22: Net distance travelled by kingfish relative to period at liberty as reported from the gamefish tagging programme (Hartill & Davies 2001).

Appendix 1: Total kingfish catch (t) by main commercial method for all FMAs combined from 1983–84 to 1999–2000*

	Method									
Fishing year	BLL	BPT	BS	BT	DS	PS	SN	T	Other	Total
1983–84	66	60	23	129	2	2	134	31	0	448
1984–85	51	48	21	124	2	2	84	13	0	345
1985–86	77	42	12	154	4	1	84	5	0	380
1986–87	47	17	10	121	2	14	90	18	0	319
1987–88	39	17	15	73	0	1	97	12	7	261
1988–89	38	5	4	43	2	1	36	1	37	167
1989–90	70	14	4	80	2	10	106	8	8	303
1990–91	59	14	9	100	3	11	188	30	8	422
1991–92	69	12	11	121	5	8	256	12	21	517
1992–93	79	12	17	124	7	6	255	22	10	532
1993–94	35	6	13	79	5	9	106	14	8	275
1994–95	48	1	11	74	5	13	125	13	10	301
1995–96	56	0	7	128	8	8	139	22	7	374
1996–97	45	0	5	156	9	25	151	7	11	409
1997–98	24	0	6	150	4	3	112	13	9	321
1998–99	24	0	3	177	4	27	78	4	4	320
1999–2000	20	0	3	120	4	0	45	2	2	197
Total	847	248	175	1 953	71	142	2 089	226	142	5 893

* BLL, bottom longline; BPT, Bottom pair trawl; BS, Beach seine; BT, Bottom trawl; DS, Danish seine; PS, Purse-seine; SN, Setnet; T, Trolling.

Appendix 2a: Kingfish catch (t) by nominated target species and fishing year for all FMAs combined

	Fishing year											
Target	1989–90	1990–91	1991–92	1992–93	1993–94	1994–95	1995–96	1996–97	1997–98	1998–99	1999–00	Total
SNA	119.6	103.5	134.9	128.7	65.7	73.7	99.8	75.1	50.1	53.9	32.5	937.5
TRE	30.0	69.6	74.7	119.7	39.7	46.5	47.6	102.2	74.8	52.5	34.3	691.6
TAR	26.1	46.8	49.1	51.8	29.0	29.0	34.0	39.4	34.2	35.8	27.8	402.9
KIN	36.4	68.3	50.0	43.3	23.6	30.1	30.2	17.0	31.8	7.7	6.5	344.8
WAR	20.0	21.2	61.2	21.6	21.0	20.1	38.3	44.6	16.3	23.3	16.2	303.8
GUR	3.8	13.1	17.9	20.5	8.1	6.3	16.1	14.4	19.1	16.1	13.9	149.2
SPO	6.2	5.9	14.1	20.7	20.6	20.9	11.4	17.2	7.2	3.5	3.6	131.2
HPB	6.8	6.0	13.9	8.7	6.6	18.4	5.3	7.3	5.8	3.4	4.8	87.1
BAR	6.7	5.0	14.2	20.1	5.1	4.8	5.3	10.6	6.3	5.7	2.8	86.9
SCH	5.5	5.4	5.0	11.6	2.8	5.1	8.3	2.9	2.7	3.9	1.6	54.8
PIL	0.0	0.0	0.9	1.7	6.7	3.0	4.2	4.4	2.8	26.4	0.4	50.5
ALB	2.6	13.2	2.9	7.5	4.8	3.6	6.8	0.9	0.9	0.5	0.6	44.3
MOK	2.2	3.3	3.1	1.7	2.0	0.9	3.5	5.8	1.3	9.0	8.9	41.7
JDO	2.9	2.7	2.0	3.8	2.4	1.8	4.1	7.3	4.7	3.8	2.6	38.2
KAH	4.9	5.9	5.8	3.3	4.1	3.1	3.3	0.3	0.3	0.0	0.0	31.0
BNS	1.1	7.1	5.2	5.2	2.3	1.9	0.8	1.7	3.1	0.6	0.5	29.5
FLA	1.5	5.4	3.1	1.7	2.4	1.0	4.5	2.4	1.7	3.1	0.8	27.7
JMA	9.4	1.2	1.7	0.6	3.1	0.5	2.0	1.0	0.9	3.8	0.2	24.5
HOK	2.4	1.4	1.4	0.8	0.6	1.4	2.7	5.5	5.5	1.1	0.4	23.1
SWA	0.0	2.6	0.0	2.0	0.0	0.9	1.8	1.0	2.8	1.8	0.3	13.2
LIN	0.4	1.1	2.8	0.4	0.4	0.9	0.6	2.6	0.7	1.2	0.2	11.5
GMU	1.6	0.6	3.3	1.7	0.8	0.5	0.6	0.7	0.4	0.3	0.2	10.6
SPD	0.5	0.3	0.2	0.4	1.1	0.9	5.4	0.1	0.1	0.0	0.0	9.2
BUT	1.1	0.3	1.1	0.8	0.8	0.4	1.2	1.0	0.5	0.0	0.3	7.5
RCO	0.2	0.1	0.8	1.4	0.1	0.4	1.7	0.9	0.7	0.6	0.3	7.2
SKJ	0.1	0.4	0.1	0.0	0.2	1.7	2.5	0.0	0.1	1.3	0.1	6.5
BYX	0.6	0.1	0.0	0.1	0.2	0.2	0.8	0.8	1.1	0.4	0.3	4.4
YFN	0.0	0.8	0.4	0.1	0.0	0.9	0.5	0.0	0.0	0.0	0.0	2.8
SFL	0.0	0.0	0.0	0.1	0.1	0.1	0.6	0.1	0.4	0.1	0.1	1.7
EMA	0.0	0.1	0.1	0.4	0.1	0.5	0.0	0.0	0.0	0.0	0.0	1.3
Other	9.7	6.1	4.1	5.1	1.0	2.4	1.6	2.0	2.2	2.0	2.0	38.2
Unknown	0.4	24.5	43.2	46.8	20.0	19.2	29.0	39.4	42.8	57.9	34.2	357.3
Total	302.8	422.1	517.2	532.3	275.2	301.1	374.3	408.8	321.0	320.0	196.7	3 971.7

See Appendix 2b for species codes.

Appendix 2b: Species codes, common names and scientific names

Species code	Common name	Scientific name
ALB	Albacore tuna	*Thunnus alalunga*
BAR	Barracouta	*Thyrsites atun*
BNS	Bluenose	*Hyperoglyphe antarctica*
BUT	Butterfish	*Odax pullus*
BYX	Alfonsino	*Beryx splendens*
EMA	English mackerel	*Scomber australasicus*
FLA	Flatfish (gen)	
GMU	Grey mullet	*Mugil cephalus*
GUR	Red gurnard	*Chelidonichthys kumu*
HOK	Hoki	*Macruronus novaezelandiae*
HPB	Groper	*Polyprion* spp.
JDO	John dory	*Zeus faber*
JMA	Jack mackerel	*Trachurus* spp.
KAH	Kahawai	*Arripis trutta*
KIN	Kingfish	*Seriola lalandi*
LIN	Ling	*Genypterus blacodes*
MOK	Blue moki	*Latridopsis ciliaris*
PIL	Pilchard	*Sardinops neopilchardus*
RCO	Red cod	*Pseudophycis bachus*
SCH	School shark	*Galeorhinus australis*
SFL	Sand flounder	*Rhombosolea plebeia*
SKJ	Skipjack tuna	*Katsuwonus pelamis*
SNA	Snapper	*Pagrus auratus*
SPD	Spiny dogfish	*Squalus acanthias*
SPO	Rig	*Mustelus lenticulatus*
SWA	Silver warehou	*Seriolella punctata*
TAR	Tarakihi	*Nemadactylus macropterus*
TRE	Trevally	*Pseudocaranx dentex*
WAR	Blue warehou	*Seriolella brama*
YFN	Yellowfin tuna	*Thunnus albacares*

Appendix 3: Total landed catch (t) of kingfish by season for all FMAs combined and FMAs 1, 2, 8, and 9 from 1989–90 to 1999–2000

All FMAs

Fishing year	Spring	Summer	Autumn	Winter
1989–90	72.0	97.9	69.0	64.0
1990–91	77.5	133.2	131.4	80.0
1991–92	104.9	161.8	133.9	116.7
1992–93	86.5	161.1	154.3	130.5
1993–94	54.6	85.1	69.9	65.6
1994–95	64.2	80.3	64.0	92.6
1995–96	63.6	117.7	96.1	96.9
1996–97	118.9	128.2	93.0	68.7
1997–98	64.4	116.2	89.8	50.5
1998–99	62.2	85.2	76.2	96.5
1999–2000	33.9	79.8	69.3	13.8

FMA 1

Fishing year	Spring	Summer	Autumn	Winter
1989–90	54.3	56.7	50.1	55.3
1990–91	54.5	87.7	99.1	50.3
1991–92	63.7	107.9	108.5	96.2
1992–93	68.9	117.3	105.9	95.1
1993–94	35.8	50.7	42.2	50.0
1994–95	46.4	38.7	46.1	67.3
1995–96	33.0	48.5	58.9	62.6
1996–97	71.2	77.0	48.4	38.8
1997–98	27.0	49.7	44.3	31.8
1998–99	28.8	28.8	33.1	68.5
1999–2000	15.6	22.1	26.6	9.4

FMA 2

Fishing year	Spring	Summer	Autumn	Winter
1989–90	11.9	30.5	9.4	5.0
1990–91	17.7	37.4	14.3	16.5
1991–92	27.4	44.4	10.2	10.4
1992–93	10.6	29.6	18.2	26.9
1993–94	9.6	24.9	18.3	9.3
1994–95	10.2	29.2	12.6	20.9
1995–96	22.8	51.4	21.4	20.9
1996–97	36.2	33.5	23.5	14.3
1997–98	28.2	49.1	21.5	13.1
1998–99	24.0	34.1	20.5	18.9
1999–2000	12.2	37.1	20.8	3.3

FMA 8

Fishing year	Spring	Summer	Autumn	Winter
1989–90	5.4	7.8	7.7	3.3
1990–91	4.4	5.8	15.8	12.6
1991–92	4.6	7.2	13.5	9.7
1992–93	4.7	10.8	28.2	8.3
1993–94	8.1	5.9	6.0	3.7
1994–95	3.2	6.3	3.6	3.2
1995–96	3.8	7.0	5.2	9.5
1996–97	4.5	8.3	7.2	5.0
1997–98	3.3	4.8	12.4	1.7
1998–99	1.7	6.7	8.4	1.3
1999–2000	1.8	7.0	10.1	0.1

FMA 9

Fishing year	Spring	Summer	Autumn	Winter
1989–90	0.0	0.0	0.0	0.0
1990–91	0.0	0.0	0.0	0.0
1991–92	0.0	0.0	0.0	0.0
1992–93	0.0	0.0	0.0	0.0
1993–94	0.0	1.5	1.6	2.2
1994–95	2.0	4.6	1.2	0.7
1995–96	1.8	8.6	5.7	2.6
1996–97	4.4	5.8	8.8	4.0
1997–98	3.9	9.5	4.2	3.0
1998–99	6.6	12.7	10.5	1.5
1999–2000	3.7	9.9	8.5	0.4

Appendix 4a: Criteria for macroscopic staging and corresponding histological condition of kingfish ovaries (Reprinted from *Aquaculture 201*, Poortenaar, C.W.; Hooker, S.H.; Sharp, N. Assessment of yellowtail kingfish (*Seriola lalandi lalandi*) reproductive physiology, as a basis for aquaculture development. Pg 271– 286. © 2001 with permission from Elsevier)

Classification	Macroscopic appearance	Histological condition
Immature (F1)	Vary from translucent threads to oval shaped pink lobes; < 70mm in length.	Chromatin nucleolus (CN -large nucleolus, dark staining cytoplasm). Perinucleolus (PN - multiple dark staining nucleoli around nucleus periphery, dark staining cytoplasm).
Regressed (F2)	Longer than 70 mm; round in cross section; firm; no oocytes visible when dissected; colour red - orange.	CN, PN and cortical alveoli (CA - nucleoli associated with nuclear wall, yolk vesicles within cytoplasm, light staining cytoplasm).
Vitellogenic (F3)	Ovary large; vitellogenic oocytes visible when dissected; colour pale - orange.	CN, PN, CA and vitellogenic (V - oocyte increases in size, increase in yolk granules size and number, zona radiata thickens).
Final oocyte maturation (F4)	Ovary plump; hydrated oocytes visible through the epithelium; colour pale – orange.	CN, PN, CA, V, germinal vesicle breakdown (GVM - nucleus moving towards animal pole). Atretic (A- generally restricted to V, GVM and H, loss of cellular structure and spherical shape, vacuoles in cytoplasm).
Ovulated (F5)	Oocytes freely expelled from the oviduct with gentle pressure.	CN, PN, CA, V, A, hydrated (H - enlarged, misshapen, no nucleus, yolk granules coalesced, follicle layer stretched to a thin layer). Post-ovulatory follicles (PF- thin strip or irregularly shaped mass of granulosa cells).
Spent (F6)	Ovary bloody and flaccid in later stages; variable colour; degenerating ooctyes or no oocytes visible.	Mature oocytes predominantly atretic.

Appendix 4b: Criteria for macroscopic staging and corresponding histological condition of kingfish testes (Reprinted from *Aquaculture 201*, Poortenaar, C.W.; Hooker, S.H.; Sharp, N. Assessment of yellowtail kingfish (*Seriola lalandi lalandi*) reproductive physiology, as a basis for aquaculture development. Pg 271– 286. © 2001 with permission from Elsevier)

Classification	Macroscopic appearance	Histological condition
Immature (M1)	Vary from translucent threads to thin cream/white lobes.	Significant connective stroma. Spermatogonia (SPG - light staining with visible nucleus).
Spermatogenic (M2)	Elongated; oval to triangular in cross-section; colour cream-white.	SPG, primary spermatocytes (1°SPC - granular appearance). Secondary spermatocytes (2°SPC - dark staining, dense nucleus). Spermatids (SPD - small cells, dense nucleus). Spermatozoa (SPZ - small dense staining heads, tails usually visible), in lobules.
Partially spermiated (M3)	Small volumes of viscous milt expressible under pressure.	All germ cell stages present, SPZ common in the lumen.
Fully spermiated (M4)	Testis plump, firm, white and copious milt flows under gentle pressure.	All germ cell stages present, SPZ predominates, sperm ducts filled with SPZ.
Spent (M5)	Testis bloody and flaccid in later stages; varies in colour; no milt expressible.	Lumen largely empty, residue SPZ in center, other germ cell stages confined to edges of lobules.