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Hoki

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This series documents the scientific basis for stock assessments and fisheries management advice in New Zealand. It addresses the issues of the day in the current legislative context and in the time frames required. The documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

HOKI STOCK ASSESSMENT

INTRODUCTION

This paper summarises current knowledge of hoki resources in New Zealand, and in particular reviews the biology, fishery and stock assessment of hoki in relation to the total allowable catch (TAC). The catch history of the commercial fleet is revised for earlier years and updated to 1986-87 (provisional figures). A summary of the 1987 west coast fishing season on spawning hoki is presented and findings of the observer coverage are discussed. Research studies in the last year are reviewed and significant results are outlined. Previous stock assessments and yield estimation based on trawl survey data (Hurst *et al.* 1987) are discussed and a yield-per-recruit model based on recent growth studies is used to determine productivity of the hoki stock and the optimum rate of exploitation. The results of acoustic studies on the west coast spawning ground (1985 survey) are also presented.

Hoki management

Hoki are widely distributed throughout the EEZ but the inter-relationships between the juvenile stocks on the Chatham Rise (areas C and D), the fish found on the Southern Plateau (areas E and F) and the west coast spawning stock (area G) are not fully understood. Consequently hoki are assumed to be a unit stock and the main TAC applies to all areas combined. No minimum size limit is required for hoki, but minimum mesh sizes apply in all areas.

Except for restrictions on chartered vessels fishing inside the 12-mile territorial sea and a size restriction of 43 metres for vessels fishing within 25 miles in certain areas, allocated quota may be taken from any area. The foreign licensed fishery however is restricted to areas outside the west coast, South Island.

Before 1986, the TAC of hoki was restricted to 20 000 tonnes (t) on the west coast (area G) and 40 000 t in the rest of the EEZ. In 1986 the area restrictions were removed and the TAC was increased to about 120 000 t. In addition a further 30 000 t was allocated to companies experimenting with hoki for surimi production. Total allocation for the 1985-86 year was 151 000 t. In the following year the main hoki quota was further increased to 250 000 t, which is the current level of TAC. Of this total, 14 100 t was allocated to foreign licensed nations for 1987-88. An administrative TAC of 10 tonnes was also gazetted for the Kermadec Fishery Management Area.

In the last 3 years the increases in TAC have resulted in a dramatic increase in fishing effort and catch on the west coast spawning grounds. The previous highest catch of hoki from this area was 54 000 t in 1977, before the declaration of the EEZ. In the last 3 years reported hoki catches from the west coast have risen from 21 000 t (1984-85) to 70 000 t (1985-86) and then in the 1986-87 fishing year to over 120 000 t. About another 28 000 t was also taken from other areas of the EEZ in 1986-87. With increased catches, problems have arisen over by-catch of hake and ling and fish loss through burst bags and discarding. In addition the dumping of fish waste may pose a potential problem on the spawning grounds.

The hoki spawning season extends through July and August in most years, but may begin in June and extend to September. The major aggregations of hoki on the west coast are found in 300-700 metres depth around the area of the Hokitika Canyon and further north. Midwater and bottom trawl gear are used in the fishery by large freezer trawlers which process their catch at sea and smaller domestic trawlers which land their fish mainly to the port of Nelson. In the last 2 years larger surimi trawlers have been introduced to New Zealand. In the 1987 season, 12 of these vessels caught over 80 000 t during the west coast spawning season. Despite the increased catching capacity, total catches of hoki fell well short of the TAC. Catches are expected to rise again this year closer to the level of the allocated quota.

Recent papers

Previous stock assessments and yield estimates for hoki have been described by Patchell (1985), Patchell and Coombs (1986), and Hurst *et al.* (1987). These assessments were based on acoustic and trawl survey estimates of abundances. Papers on the biology of hoki include Patchell *et al.* (1987) on egg and larval development, Kenchington and Augustine (draft MS) on growth of hoki in Australian waters, and Murdoch and Chapman (draft MS) on spawning of hoki in 1986 in Cook Strait. Other papers also in preparation describe the results of trawl surveys on the Chatham Rise (Fenaughty and Uozumi, March 1983; Hatanaka *et al.*, Nov-Dec 1983; Livingston *et al.*, July 1986) and the Southern Plateau (Hatanaka *et al.*, Oct-Nov 1983). Results from research studies on hoki in 1987 were reported in CATCH:

(a) Hurst (1987) - west coast fishing season
(b) Livingston and Berben (1987) - east coast spawning hoki
(c) McDiarmid (1988) - review of 1987 studies on hoki
(d) Livingston and Rutherford (1988) - dumping of hoki wastes

HOKI FISHERY

The hoki fishery was developed by foreign fishing vessels in the early 1970s. Catches reached a peak of almost 98 000 t in 1977, but were subsequently reduced in 1978 following the declaration of the EEZ. Since 1978 the fishery has mainly been operated by chartered vessels fishing for New Zealand companies, with small catches by domestic and foreign licensed vessels. With the large increase in quota in the last two years surimi vessels now take the bulk of the catch.

The Soviet fleet operated a large hoki fishery on the east coast, South Island, Mernoo Bank and Chatham Rise from 1975-77. Although no size frequency data are available from these catches, most of this fish was probably small immature hoki. Blagodyorov and Nosov (1978) refer to fish of size 35-80 cms in this area. Since 1978 the Soviet fleet has been restricted to area E and only small quantities of hoki have been caught (current allocation is 3 000 t).

The Japanese concentrated their effort on the west coast spawning grounds and in 1977 took over 50 000 t of hoki. Since 1978 annual catches of less than 10 000 t have been taken, mainly from area F, but also some fish from areas D and E (current allocation is 11 000 t).

The Koreans fished the west coast grounds in 1976 and 1977, but since 1978 they have caught very little hoki. In 1986 permission was given for nearly 500 t to be taken from the west coast (area G). However licensed vessels are not generally permitted to fish this area, and therefore the Koreans have accepted an allocation of only 100 t of hoki quota for 1987-88.

Annual reported catches of hoki are given in Table 1. The figures for 1986-87 are provisional only and are based on reported catches up to June 1987, plus an estimate of the catch taken from July to September 1987. Table 2 gives the area of reported catch for the last 4 years. As well as a large increase in catch in area G, catches in area C by the chartered fleet have risen to over 13 000 t in the last two years. Much of this fish was small juvenile hoki (< 65 cm) taken during the non-spawning period by surimi vessels.

Figure 1 shows monthly catch by chartered and foreign licensed vessels from 1978-86 in each area. Area G shows a well defined seasonal peak in July and August when the hoki are spawning. A similar pattern also appears in area F(W), which may represent fish migrating to the west coast or alternatively fish aggregating to spawn in this area (Puysegur). Catches in other areas mainly represent by-catch of hoki taken when fishing for other species, although target fishing for hoki by surimi vessels began in area C in 1986.

1987 West Coast hoki fishing season: observer results

The season began in late June and fishing activity was centred in the Hokitika Canyon for much of July (Figure 2). In August another area further north was also fished intensively before the season ended in early September. Total catch of hoki from this area was estimated to be about 140 000 t, which is higher than the reported catch. This is due to problems with the surimi conversion factor which under-estimates the green weight of spawning fish (about 25% too low). There was 100% observer coverage of surimi vessels on the west coast and they estimated a total hoki catch of 86 000 t on these vessels. When back-calculated from product weight reported catch is estimated to be about 69 000 t, using the current conversion factors.

By-catch

With the increase in hoki quota and expected rise in total catch, there was much concern about the level of by-catch of hake and ling on the west coast. In an attempt to reduce the rate of by-catch, midwater trawling was used more extensively in 1987. The rate of ling by-catch decreased from 0.7% in 1986 to 0.4% in 1987, however the by-catch of hake remained high (2.5% in 1987 against 2.1% in 1986). The increase in TAC for hake to 3 000 t (allocated as ATQ (annual transferable quota) on a proportional basis to hoki ITQ held) may have lessened efforts to avoid hake by-catch.

Size composition

Length frequency distributions of hoki from commercial vessels sampled from 1985 to 1987 in various areas are shown in Figure 3. There is a marked size difference in hoki catches taken from the east coast, Southern Plateau and the west coast. As expected the spawning fish taken in winter from the west coast are large mature hoki from 60 to 120 cm in length. The male hoki recruit to the spawning grounds at 60-65 cms (aged 4 years) while females appear to mature a year older at about 70 cms. In the southern fishery for hoki, medium-sized fish of 50 to 90 cms are taken, while on the east coast hoki are generally smaller (40 to 80 cms).

Non-commercial fishery

There is no significant recreational or traditional fishery for hoki, which are generally found in deep water (400 to 600 metres). Although there are occasional reports of hoki catches from estuarine waters, this species is not readily available to non-commercial fishers.

HOKI RESEARCH

1. Stock separation

Smith *et al.* (1981) found no difference in gene frequency in hoki samples taken from 5 areas of the EEZ. They concluded that hoki were a unit stock. Patchell (1982) considered that the distribution of juvenile hoki was consistent with recruitment from the one major spawning ground (west coast), where hoki aggregations are observed each year. However there are reports by Russian and Japanese scientists of other spawning areas on the east coast and south of New Zealand (Blagodyorov and Nosov 1978, Kurawa 1985). Hoki have since been found to spawn in Cook Strait and other areas of the east coast (Murdoch and Chapman (draft MS), Livingston 1987). Livingston reported a large hoki aggregation in the Cook Strait Canyon (up to 100 metres thick, and 10 by 1.5 miles in extent) and other smaller concentrations in other steep canyon features. The importance of spawning in this area in relation to the west coast grounds is difficult to assess, but the possibility that sub-populations of hoki are found in different areas of the EEZ must be seriously considered and further researched. In particular the future management of hoki as a unit stock with a single TAC will need to be reviewed.

2. Trawl surveys

A full list of trawl survey abundance estimates from research and commercial data from 1976-86 is presented in Table 3 (from Hurst *et al.* 1987). The table gives wingspread and doorspread biomass estimates and the mean of these two figures. The following assumptions were made in estimating hoki biomass from trawl survey data:

(a) All fish in the path of the net are caught (i.e. no escapement).
(b) All fish in the water column are within the path of the net.
(c) The performance of the net is not reduced by abundance of fish (i.e. no saturation fishing effects).
(d) Migration to and from the survey area is not important, during the survey.

Not all the trawl surveys were designed to assess hoki abundance and other target species were of prime interest in many of these surveys. However a greater number of surveys in recent years have been targeted specifically at hoki and have covered the known depth range of hoki and areas of greatest abundance. These surveys are used to estimate the minimum biomass of hoki found in the EEZ as a basis for subsequent estimation of annual yield.

3. Acoustic surveys

In 1985 an acoustic survey of hoki was completed using the *Akagi Maru* from 7 July to 17 August in the area from 43°S to 38°50'S on the west coast. A small part of this data was analysed and presented by Patchell and Coombs

(1986). The initial estimates made from these data appear to have been too high (P.L. Cordue, pers. comm.). Recalculation now suggests a minimum spawning biomass of hoki of 200 000 tonnes on the west coast in 1985. This estimate is based on the sum of 3 schools of hoki surveyed on 31 July and 1 August 1985. One school measured 150 000 t in biomass.

Two acoustic surveys of spawning hoki were carried out in 1987. From 17 July to 4 August the Hokitika Canyon area was surveyed using the *James Cook*. Recording of data was restricted to the period 24 July to 1 August due to technical problems. From 1-2 September an opportunistic survey of hoki in the Cook Strait Canyon was carried out using the *James Cook* when a large aggregation of hoki was discovered in this area. The analysis of data from these two surveys has not yet been completed. Biomass estimation from these aggregations will be based on a mean target strength of -36 dB (A. Do, pers. comm.).

Factors which affect acoustic estimates of biomass include the target strength of individual fish, turnover rate of the population on the west coast, differentiation of fish and bottom echoes and identification of layers of fish.

4. Growth rate

Length frequency distributions of hoki show well defined modes corresponding to cohorts of fish spawned in successive years. Modal progression of hoki cohorts has been studied by Patchell, Colman, Livingston and Sullivan at FRC at various times over the last 12 years. All these studies reached the same conclusions concerning growth of juvenile hoki from 0 to 4 years (pers. comm.). Assuming the first mode in length frequency data from winter samples at 26-30 cms represents fish approaching 1 year in age, the mean lengths at age of the first 4 year classes are about 27, 40, 52 and 63 cms. There are no apparent differences in average size between male and female hoki of these ages, but female hoki reach a greater maximum size than males (Figure 3). This could be due to greater longevity of female hoki or differences in growth rate of male and female adult hoki.

Sullivan (draft MS) presented a summary of growth studies on hoki carried out in January 1988. The growth curve based on otolith readings of 'annual' rings agreed closely with that of Kenchington and Augustine (draft MS). Maximum ages were 15 years for male and 17 years for female hoki, compared with 20 and 25 years respectively in the study of Kenchington and Augustine. Male and female growth rates were similar up to 6-8 years and 80 cms size, but females reach a larger size at older ages (Figure 4).

5. Natural mortality

Natural mortality in fish is one of the most difficult (and most important) life history parameters to be estimated in population studies. Estimation of M requires not only the ability to age the fish accurately but also in exploited populations it requires the facility to separate fishing and natural mortality rates. In most fish stocks no estimation is possible and M has been assumed to be 0.2 (Mace, draft MS). Methods for estimating M include analysis of the right-hand limb of catch curves, regression techniques using catch and effort data (Beverton and Holt 1957) and guestimates based on maximum age.

No age distribution data is yet available for hoki populations, therefore catch curve analysis is not possible. With an accurate ageing technique this should be possible in the future as otolith samples of hoki catches from the early years of the fishery are available. Based on maximum age (17 years) observed in samples of hoki taken in 1978, *M* for hoki would be about 0.3. However Kenchington and Augustine found maximum ages of 25 in samples from Australia, suggesting a value of *M* closer to 0.2.

For the purposes of yield estimation and yield-per-recruit analysis in this paper, natural mortality of adult hoki has been assumed to be at a constant instantaneous rate of 0.2 per year. This is a conservative approach as *M* (and therefore productivity) are likely to be higher than this rate. This value of natural mortality applies only to the adult population; juvenile hoki are likely to suffer much higher rates of mortality from predation by large fish and mammals.

6. Biomass estimation

Hurst *et al.* (1987) used the following criteria to select appropriate surveys for estimation of hoki biomass:
1. adequate station numbers in hoki depths;
2. adequate coverage of hoki distribution area;
3. low coefficient of variation (i.e. better precision);
4. statistically valid trawl survey design.

In addition more recent surveys were considered to be more applicable to the current state of stocks.

(a) Area C and D: Chatham Rise

Shinkai Maru surveys in March 1983 and July 1986 gave total biomass estimates of 1 082 000 and 791 300 t respectively. The estimates are not the most conservative possible as they are based on the average of the wingspread and doorspread biomass estimates. Of the total biomass 24% and 29% respectively were over 65 cm in length, which gives adult biomass estimates of 259 000 and 223 000 t for hoki on the Chatham Rise.

(b) Area B and H: North Island

Data from *Wanaka* cruises from May 1985 to June 1986 gave a mean total biomass estimate of hoki of 18 700 t.

(c) Area G: West Coast, South Island

This area was surveyed outside the spawning season in May 1976 by *Shinkai Maru*, which gave an estimate of 76 350 t. Large spawning aggregations are found in this area from June to September each year, however no estimate of the total adult biomass on the west coast is yet available. Trawl surveys seem inappropriate for the estimation of biomass of fish in spawning schools.

(d) Area E and F: Stewart-Snares Shelf, Sub-Antarctic

Shinkai Maru surveys in March 1982 and Oct-Nov 1983 gave total biomass estimates of 812 000 and 598 500 t respectively. About 85% of this fish was adult hoki over 65 cm in length.

(e) All areas combined

The biomass of hoki on the west coast spawning grounds during July and August is not known for any year and is unlikely to be accurately assessed using the trawl survey technique. Stock size of hoki in all other areas combined was estimated by Hurst *et al*. (1987) to be 1.9 million t, based on March 1982 and 1983 survey estimates given above. Of this total biomass about 50% would be adult hoki over 65 cm in length.

Francis and Fisher (1979) estimated the total biomass of hoki in 1976 to be 0.95 to 2.25 million tonnes. These estimates were based on the commercial catch rates of the Japanese trawl fleet relative to the CPUE of the *Shinkai Maru*.

7. Yield-per-recruit model

A yield-per-recruit (YPR) analysis of the hoki fishery on the west coast spawning fish was developed using the growth rate of Sullivan (draft MS) and the following biological parameters:

Natural mortality	$M = 0.2$
Age of recruitment	Males = 4 years
	Females = 5 years
Length/weight relationship	weight(gms) = a*length(cms)**b

where a = 0.0046 and b = 2.88

Figure 5(a) shows YPR and biomass-per-recruit (BPR) for male hoki, recruited at age 4 (weight 732 gms). The YPR curve rises to a maximum at $F = 0.62$. However the BPR curve has decreased at this point to a level of biomass corresponding to 15% of virgin biomass (BPR of an unexploited cohort). At $F = M = 0.2$, YPR is at 86% of the maximum YPR and BPR is at 39% of the unexploited level. The value of $F_{0.1}$ is at $F = 0.22$ where YPR is higher than at $F = M$ (89% of maximum), but BPR has decreased to 37% of the unexploited level.

Figure 5(b) shows YPR and BPR for female hoki, recruited at age 5 (weight 1112 gms). The absolute value of YPR is greater than for male hoki as the fish are recruited at a greater size (1.5 times the weight). YPR increases with F and no maximum is found at finite levels of fishing mortality. $F_{0.1}$ is at $F = 0.23$, where BPR is at 36% of the unexploited level. At $F = M = 0.2$, YPR is at 96% of YPR at $F = 0.23$ and BPR is at 40% of the unexploited level.

Based on the YPR model, in an unexploited population, recruitment to the adult biomass would theoretically make up about 10% of the total adult biomass. As the level of fishing mortality increases the relative contribution which recruitment makes to the adult biomass increases. At $F = M$, recruits make up 23% of the male biomass and 26% of the female adult biomass (for M of 0.2). With higher rates of natural mortality these proportions would rise.

8. Yield estimation

(a) Maximum constant yield (MCY)

A number of alternative estimates of MCY are possible, based on trawl and acoustic survey estimates of biomass and catches by the commercial fishery. The bulk of the fishery operates on the recruited adult biomass (> 65 cm total length). Therefore the yield estimates given below are based on population biomass of hoki over 65 cm in length.

(i) The average catch from 1979-85 suggests a minimum estimate of MCY equal to 29 000 t, using MCY = $c\bar{Y}$ = 0.8 * 36 000 t. The value of c is taken at 0.8 to reflect the short fishing history.

(ii) Biomass estimated from *Shinkai Maru* surveys in 1982 and 1983 give an estimate of total biomass of 1.9 million tonnes. Of this total biomass 50% was over 65 cm in length. Assuming natural mortality of 0.2 the formula MCY = M * 0.25 * B_0 gives an estimate of 48 000 t.

(iii) Francis and Fisher (1979) estimated the total biomass of hoki in 1976 to be 0.95 to 2.25 million tonnes. Assuming 50% of this biomass was recruited adult fish gives a range of estimates from 24 000 to 56 000 t.

(iv) An acoustic estimate suggests a minimum biomass of hoki of 200 000 t on the west coast in 1985 This gives a very low value of MCY equal to 20 000 t (MCY = 0.5 * M * $\overline{B}$).

In view of the conservative nature of the assumptions made in estimating biomass of hoki from trawl surveys (e.g. mean of wingspread and doorspread estimates) the value of 48 000 t is considered to be a safe estimate of MCY. It is likely that with a longer catch history MCY will prove to be at a greater level.

(b) Current annual yield (CAY)

The estimates of CAY are based on the recruited biomass of hoki in the 1988-89 fishing year. Natural mortality was assumed to be 0.2, based on maximum age observed in hoki. From the yield-per-recruit model $F_{0.1}$ was estimated to be 0.23. The biomass of hoki was projected forward using a simulation model to estimate CAY for the fishing year 1988-89 and also for a longer period to approximate the long-term equilibrium situation. In this model it was assumed that total catch of hoki in the current year (1988) will be within the range 150 000 to 300 000 t, and also that hoki biomass was relatively stable from 1982-83 to 1986 and was close to the level of B_0. The maximum projected catch for 1987-88 was based on a knowledge of quota allocations held by individual companies, a carry over of 10% of quota uncaught from the previous fishing year, the conversion factor used in the surimi fishery and the catch of hoki taken already in the current fishing year.

The estimate of unexploited biomass was based on 1982-83 trawl survey results for Southern Plateau and east coast/Chatham Rise. The mean of the wingspread and doorspread estimates was considered to be a conservative estimate of biomass. The figures represent recruited adult biomass (over 65 cm).

Recruited adult biomass of hoki was estimated to be 955 000 t from 1983 to 1985. The projected recruited adult biomass of hoki in the 1988-89 year ranged from 650 000 to 800 000 t, giving CAY of 150 000 to 185 000 t. Exploitation is expected to reduce the biomass to about 35-50% of the unexploited level (335 000 to 480 000 t). The long-term equilibrium yield from this biomass indicates a future CAY ranging from 77 000 to 110 000 t. These figures assume that biomass will reach an equilibrium at 35-50% of virgin biomass, the fishery will operate at F = 0.23, and B_0 was equal to 955 000 t.

9. Discussion

The estimates of biomass used are the mean of the wingspread and doorspread estimates. A less conservative approach would be to use wingspread estimates of biomass. This would increase the estimates of biomass and yield by about 60%. Saturation fishing effects at spawning times could result in underestimation of biomass using the mean of wingspread and doorspread estimates. However with a dispersed distribution of fish, herding by doors and sweeps is very likely to occur. The data used here are from surveys in 1982 and 1983 from the dispersed phase of hoki distribution. Therefore a conservative stance has been taken in using the lower estimates.

The short history of fishing for hoki on the scale currently being undertaken means that it is difficult to judge what level of variability to expect in population size. With exploitation, the biomass of hoki will decrease, however an increase in the productivity of the population can be expected. The number of year classes in the population will also decrease as a result of exploitation. This means that the recruiting year class will make up a larger proportion of the recruited biomass, and may increase variability in abundance of adult hoki.

Natural mortality has been assumed to be 0.2 for adult hoki. The maximum age recorded in New Zealand from otolith readings is 17 years, but in Australia maximum age was 25 years. Neither of these studies have validated the ageing technique used. From these preliminary indications of longevity in hoki, natural mortality should lie in the range 0.2 to 0.3. Until validation of these ages is possible the more conservative value of 0.2 should be used.

The yield estimates produced for the 1988-89 year assume the fishery operates on adult fish. However a certain amount of fishing occurs throughout the EEZ outside the spawning season and mainly smaller hoki are taken at these times. The effect of a juvenile fishery is unlikely to be significant unless it becomes a larger proportion of total catch. Natural mortality in juvenile hoki is likely to be higher than in adult fish because of greater predation mortality. The effect of any large scale fishery for small hoki would be to reduce recruitment to the adult stock. This is not currently considered to be a major problem. Size composition of catches will be monitored in the future to allow any impact to be assessed.

The yield estimates presented above depend critically on the biomass estimates from trawl surveys carried out in 1982 and 1983. There is an urgent need to survey the hoki population in all areas of the EEZ to update estimates of biomass.

10. Summary

Assuming the unexploited recruited adult biomass was 955 000 t
Maximum constant yield = 48 000 t
Current annual yield = 150 000 to 185 000 t
Long term equilibrium yield = 77 000 to 110 000 t.

These yield estimates differ from those of Hurst *et al.* (1988) despite the fact that they are based on the same estimate of total biomass, 1.9 million tonnes (from trawl surveys in 1982 and 1983). The difference between the estimates of sustainable yield relate to the assumption made concerning the productivity of the stock, the definition of the exploited population and the long-term equilibrium to be expected in future years.

(a). Productivity

Previously the productivity of the total biomass of hoki (adults and juveniles) was assumed to be 15% per year. The growth rate of hoki has now been measured from ageing studies and the productivity of the adult biomass is assessed at about 20% per year. This figure is conservative but only applies to the adult part of the stock.

(b) Exploited population

In this paper it is assumed that the fishery operates on the adult recruited biomass of hoki. Any exploitation of younger age classes could reduce recruitment to the adult biomass and therefore reduce the sustainable yield. The total biomass estimate of 1.9 million tonnes includes both juvenile and adult hoki; the adult population makes up about 50% of the total biomass.

(c) Long-term equilibrium

The effect of fishing on a stock is to reduce the biomass to a lower level of abundance. The optimum level is considered to be about half the unexploited biomass. The sustainable yield which can be taken on a long-term basis is therefore lower than the short-term yield which is available from a lightly exploited or virgin population.

Until 1986 hoki was only lightly exploited and the population was probably close to the level of virgin biomass. However catches have now increased to the level where a significant decline in abundance is likely to occur. The expected long-term sustainable yield is about half the current annual yield (CAY). Catches in excess of CAY result in a decrease in biomass. The rate of decline is determined by the amount by which catch exceeds CAY.

11. Management Implications

The long-term yield of hoki appears to be lower than the current TAC of 250 000 t. The effect of this level of catch would be to reduce the biomass closer to the long-term equilibrium level. However continued fishing at this level would reduce biomass below optimal levels within 2-3 years.

A conservative approach was taken in deriving both the productivity and biomass estimates. As they are based on trawl surveys the biomass estimates are weak. Higher yield estimates are possible if wingspread estimates of biomass are used. However even for the least conservative estimate, in the long term the TAC may not be sustainable. A strategy to balance TAC to long-term yield is needed.

It is also suggested, as a result of the stock structure of hoki, that the catch from the west coast spawning grounds be limited to less than the full TAC. The ratio of the biomass estimate on the Chatham Rise to the estimate for the Southern Plateau could be used as a basis for splitting the TAC between the west coast and the rest of the EEZ. This limit could be reviewed in September 1988 when the results of the 1988 fishery on the west coast are available.

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TABLE 1: Annual trawl catches (t) of hoki from the New Zealand EEZ, 1969-83 by calendar year, 1983-84 to 1987 by fishing year (Oct-Sept).

				New Zealand		
Year	U.S.S.R.	Japan	South Korea	Domestic	Chartered	Total
1969		95				95
1970		414				414
1971		411				411
1972	7 300	1 636				8 936
1973	3 900	4 758				8 658
1974	13 700	2 160		125		15 985
1975	36 300	4 748		62		41 110
1976	41 800	24 830		142		66 772
1977	33 500	54 168	9 865	217		97 750
1978*	2 028†	1 296	4 580	678		8 581
1979	4 007	8 550	1 178	2 395	7 970	24 100
1980	2 516	6 554		2 658	16 042	27 770
1981	2 718	9 141	2	5 284	15 657	32 802
1982	2 251	7 591		6 982	15 192	32 018
1983	3 853	7 748	137	7 706	20 697	40 141
1983-84	4 520	7 897	93	9 229	28 668	50 407
1984-85	1 547	6 807	35	7 213	28 068	43 670
1985-86	4 056	6 413	499	8 280	80 375	99 623
1986-87**	1 846	3 801	7	7 244	137 271	150 000

* Catches for foreign licensed and New Zealand chartered vessels from 1978 to 1984 are based on estimated catches from vessel logbooks. Few data are available for the first 3 months of 1978 because these vessels did not begin completing these logbooks until 1 April 1978.

† Soviet hoki catches are taken from the estimated catch records and differ from official MAF statistics. Estimated catches are used because of the large amount of hoki converted to meal and not recorded as processed fish.

** Provisional.

TABLE 2: Reported catch (t) of hoki by EEZ area, 1983-87 by fishing year (Oct-Sept)

Area	New Zealand		Foreign Licensed			
	Domestic	Chartered	Japan	Korea	USSR	Total
1983-84						
B	631	0	0	0	0	631
C	1 478	5 630	0	0	0	7 108
D	0	1 696	832	18	0	2 546
E	0	1 576	1 281	62	4 520	7 439
F	4	4 417	5 783	12	0	10 216
G	6 480	14 363	0	0	0	20 843
H	295	982	0	1	0	1 278
Unknown	341	4	1	0	0	346
1984-85						
B	457	0	0	0	0	457
C	792	3 182	0	0	0	3 974
D	2	1 885	1 513	17	0	3 417
E	0	2 274	1 888	18	1 547	5 727
F	3	3 313	3 406	0	0	6 722
G	5 755	14 692	0	0	0	20 447
H	121	1 120	0	0	0	1 241
Unknown	83	1 602	0	0	0	1 685
1985-86						
B	496	0	0	0	0	496
C	752	13 592	0	0	0	14 344
D	30	1 027	1 139	12	0	2 208
E	0	340	1 592	2	4 056	5 990
F	2	2 511	3 682	3	0	6 198
G	6 188	62 900	0	482	0	69 570
H	126	5	0	0	0	131
Unknown	686	0	0	0	0	686
1986-87 (provisional)						
B	558	2	0	0	0	560
C	625	13 220	0	0	0	13 845
D	8	2 157	190	5	0	2 360
E	1	1 163	1 260	0	1 846	4 270
F	1	4 727	2 351	2	0	7 081
G	6 000	116 000	0	0	0	122 000
H	51	2	0	0	0	53
Unknown					Approx.	150 000

TABLE 3 (continued): Biomass estimates (t) of hoki from trawl survey data (research and commercial) held at Fisheries Research Centre, Wellington

Area	Wingspread biomass	Doorspread biomass	c.v. (%)	Mean biomass	Vessel	Cruise date	Documentation of wingspread biomass
E + F	1 313 200	312 700	9	812 950	Shinkai Maru	Mar 1982	Hurst and Fenaughty (1985)
	890 200	306 900	10	598 550	Shinkai Maru	Oct-Nov 1983	Hurst and Fenaughty (1985)
EA + F	112 300	26 300	33	69 300	Shinkai Maru	Feb 1981	Hurst and Fenaughty (1985)
	158 200	37 600	29	97 900	Shinkai Maru	Apr 1983	Hurst and Fenaughty (1985)
G	92 400	10 400	44	51 400	W.J. Scott	Jun-Sep 1981	Hurst and Fenaughty (1985)
	2 200	10 400	34	1 225	W.J. Scott	Oct 1981-Feb 1982	Hurst and Fenaughty (1985)
	3 100	350	50	1 725	W.J. Scott	Mar-May 1982	Hurst and Fenaughty (1985)
	12 600	1 420	28	7 010	W.J. Scott	Jul-Oct 1982	Hurst and Fenaughty (1985)
	1 700	190	27	945	W.J. Scott	Nov 1982-Feb 1983	Hurst and Fenaughty (1985)
	2 400	270	38	1 335	W.J. Scott	Mar-Apr 1983	Hurst and Fenaughty (1985)
	2 100	400	34	1 250	James Cook	Sep-Oct 1983	Hurst and Fenaughty (1985)
	1 100	250	32	165	James Cook	Aug-Sep 1983	Hurst and Fenaughty (1985)
	125 000	27 700*	?	76 350	Shinkai Maru	May 1976	Francis and Fisher (1979)
	480 000§	-	-		Japanese commercial	Jul 1977	Kono (1979)
	810 000§	-	-		Japanese commercial	Jul 1977	Kono (1979)
	690 000§	-	-		Japanese commercial	Aug 1977	Kono (1979)
	0-270 000	(upper bound)† 67 500	?	168 750	Wesermünde	Aug 1977	Francis (1981)
	4 600	1 150	52	2 875	Wesermünde	Nov 1979	Francis (1981)
West coast N.I.		2 000	15	6 350	Wanaka	May 1985-86	Clark and King (in press)
N.E. coast N.I.	16 500	3 100	21	9 800	Wanaka	May 1985-86	Clark and King (in press)
East coast N.I.	4 300	800	17	2 550	Wanaka	May 1985-86	Clark and King (in press)

* Assumed ratio of wingspread to doorspread = 4.5.
† Assumed ratio of wingspread to doorspread = 4.0.
§ Escapement = 0.33.

TABLE 3: Biomass estimates (t) of hoki from trawl survey data (research and commercial) held at Fisheries Research Centre, Wellington. (Table from Hurst *et al*. 1987)

Area	Wingspread biomass	Doorspread biomass	c.v. (%)	Mean biomass	Vessel	Cruise date	Documentation of wingspread biomass
C	614 000	136 000	11	375 000	*Shinkai Maru*	Mar 1983	Fenaughty and Uozumi (in press)
	65 000	14 400*	?	39 700	*Shinkai Maru*	May 1976	Francis and Fisher (1979)
	800 000	?	?	-	*Soviet commercial*	Winter 1971	Blagodyorov and Nosov (1978)
	639 000	139 000	16	389 000	*Shinkai Maru*	Jul 1986	Livingston *et al*. (in prep.)
	125 000	31 250†	80	78 125	*Wesermünde*	Oct 1979	Francis (1981)
D	1 157 000	257 000	11	707 000	*Shinkai Maru*	Mar 1983	Fenaughty and Uozumi (in press)
	320 000	80 000†	56	200 000	*Wesermünde*	Apr 1979	Francis (1981)
	212 000	47 100*	?	129 550	*Shinkai Maru*	May 1976	Francis and Fisher (1979)
	561 000	124 000*		342 800	*Shinkai Maru*	Jul 1986	Livingston *et al*. (in prep.)
	152 000	38 000†	78	95 000	*Wesermünde*	Oct 1979	Francis (1981)
	190 000	47 500†	41	118 750	*Wesermünde*	Nov 1979	Francis (1981)
	454 000	151 300	15	302 650	*Shinkai Maru*	Nov-Dec 1983	Hurst and Fenaughty (1985)
C + D	1 772 000	393 800	11	1 082 900	*Shinkai Maru*	Mar 1983	Fenaughty and Uozumi (in press)
	282 000	62 600*	?	172 300	*Shinkai Maru*	May 1976	Francis and Fisher (1979)
	1 300 000	282 600	16	791 300	*Shinkai Maru*	Jul 1986	Livingston *et al*. (in prep.)
	277 000	69 250†	79	173 125	*Wesermünde*	Oct 1979	Francis (1981)
F	34 500	7 900	50	21 200	*Shinkai Maru*	Jun 1986	Hurst pers. comm.
	1 800	8 500	30	1 150	*Akebono Maru No. 3*	Nov 1986	Hurst pers. comm.
E	548 000	121 700*	?	334 850	*Shinkai Maru*	May 1976	Francis and Fisher (1979)
	182 500	45 625†	40	114 062	*Wesermünde*	May 1979	Francis (1981)
	138 500	35 624†	84	86 562	*Wesermünde*	Sep 1979	Francis (1981)
	215 000	53 750†	30	134 375	*Wesermünde*	Oct 1979	Francis (1981)

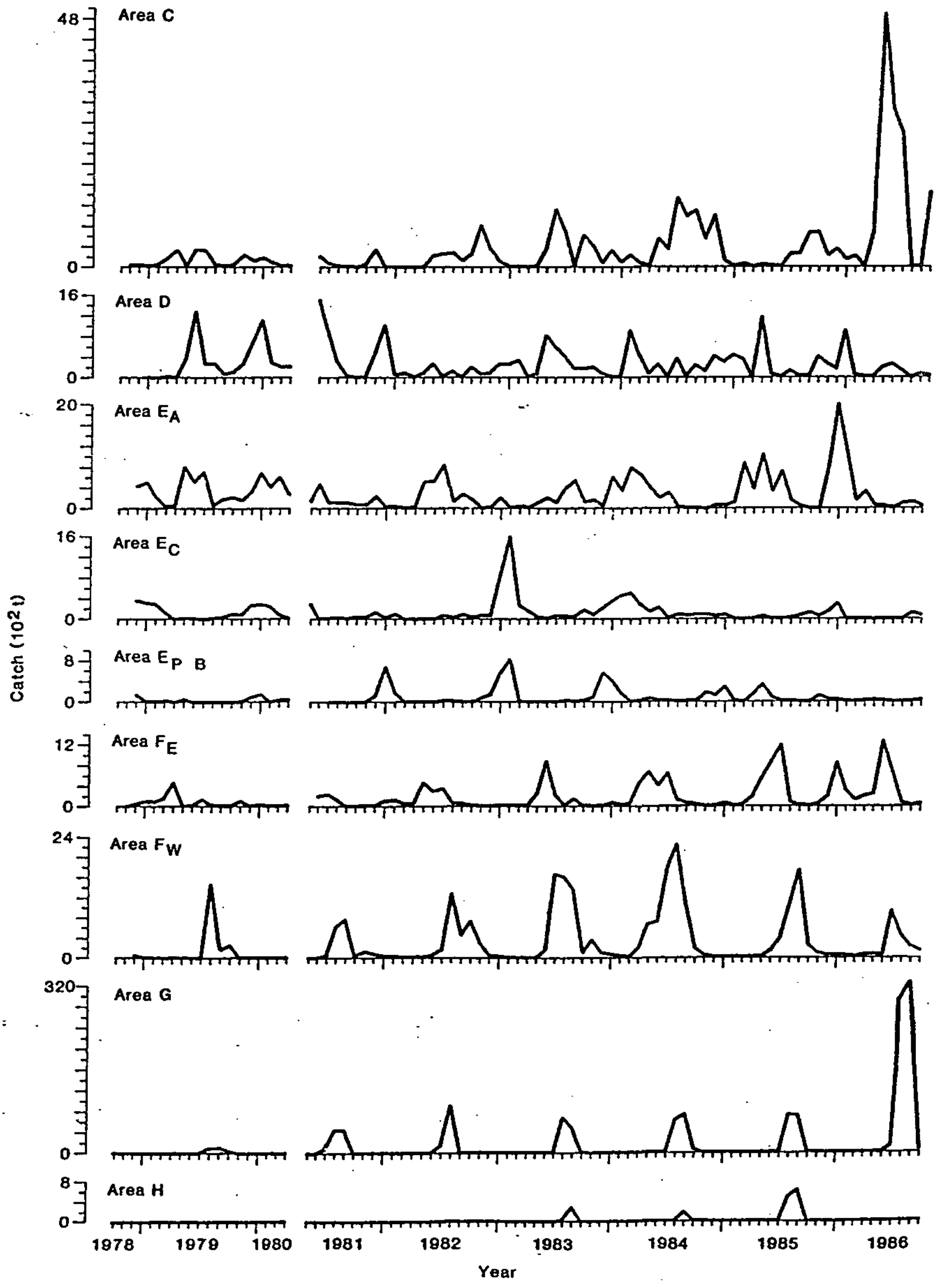

Figure 1. Monthly catch (t) of hoki by New Zealand chartered and foreign licensed vessels in each statistical area, 1978-86.

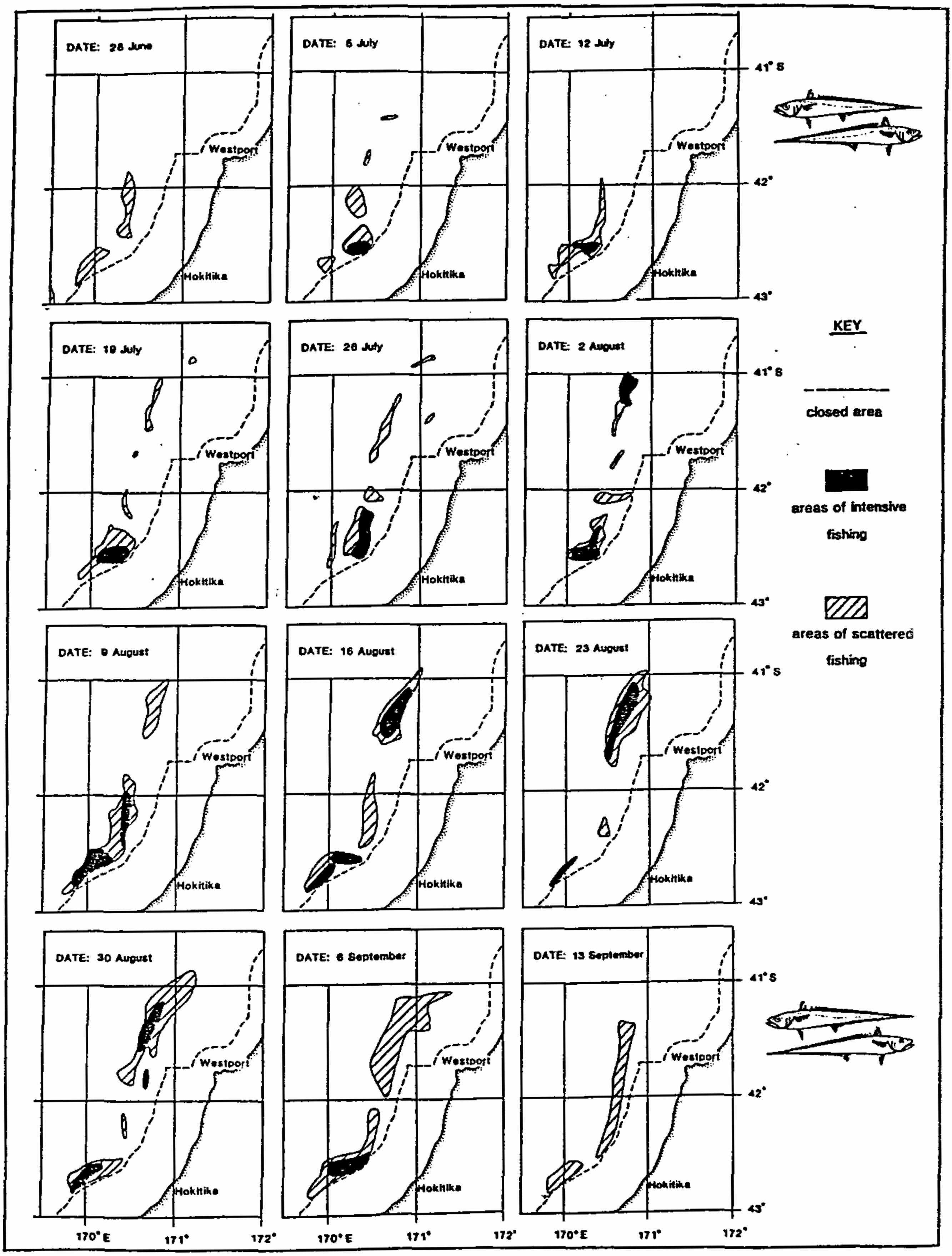

Figure 2. Fishing activity of the New Zealand chartered fleet in the West Coast hoki fishery, 22 June - 13 September 1987. Positions as reported to Fisheries Control Centre have been summarised by week. (Figure taken from Hurst 1987).

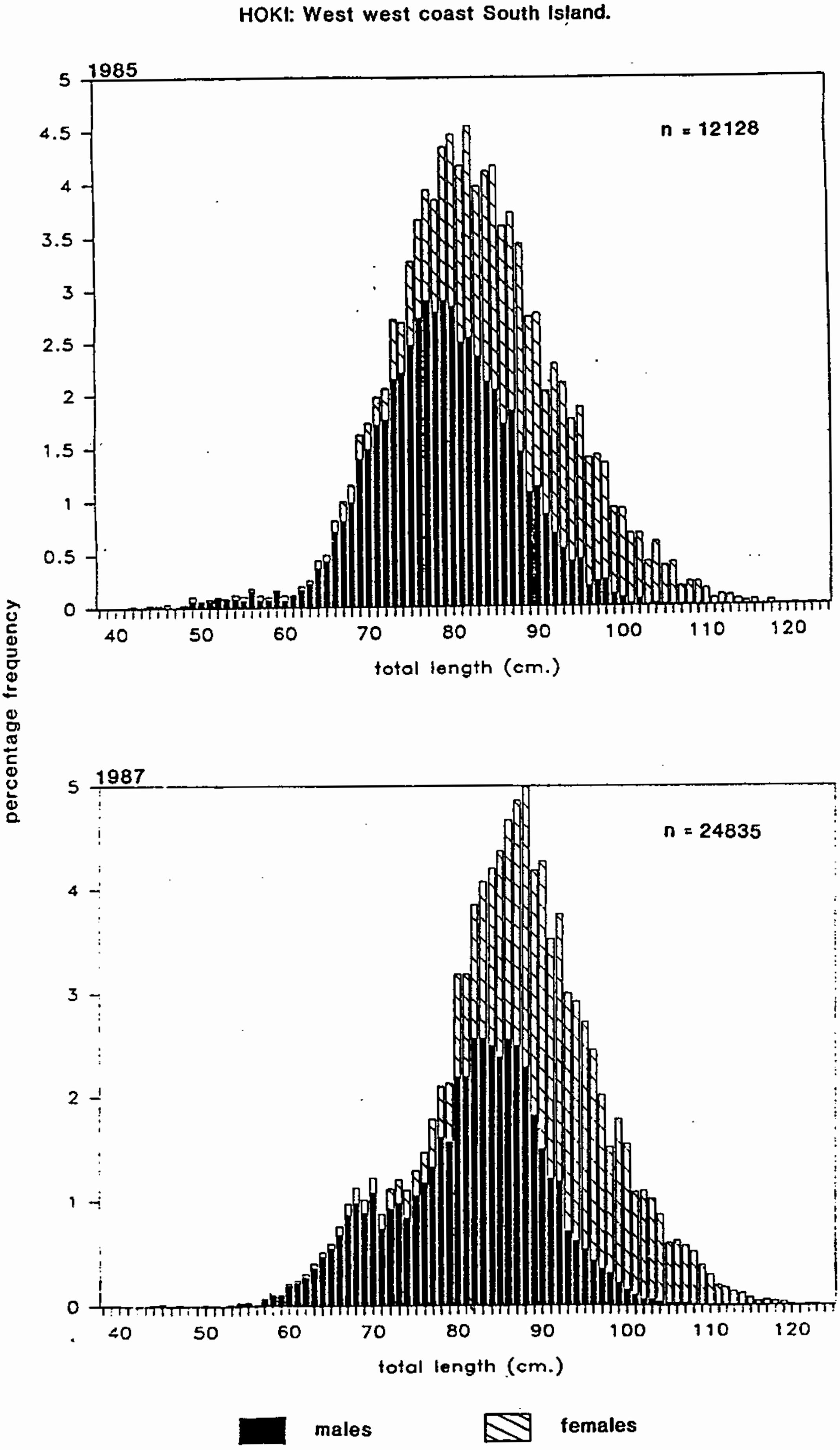

Figure 3 Length frequency distributions of hoki sampled on commercial vessels (a) West coast, South Island winter 1985 and 1987.

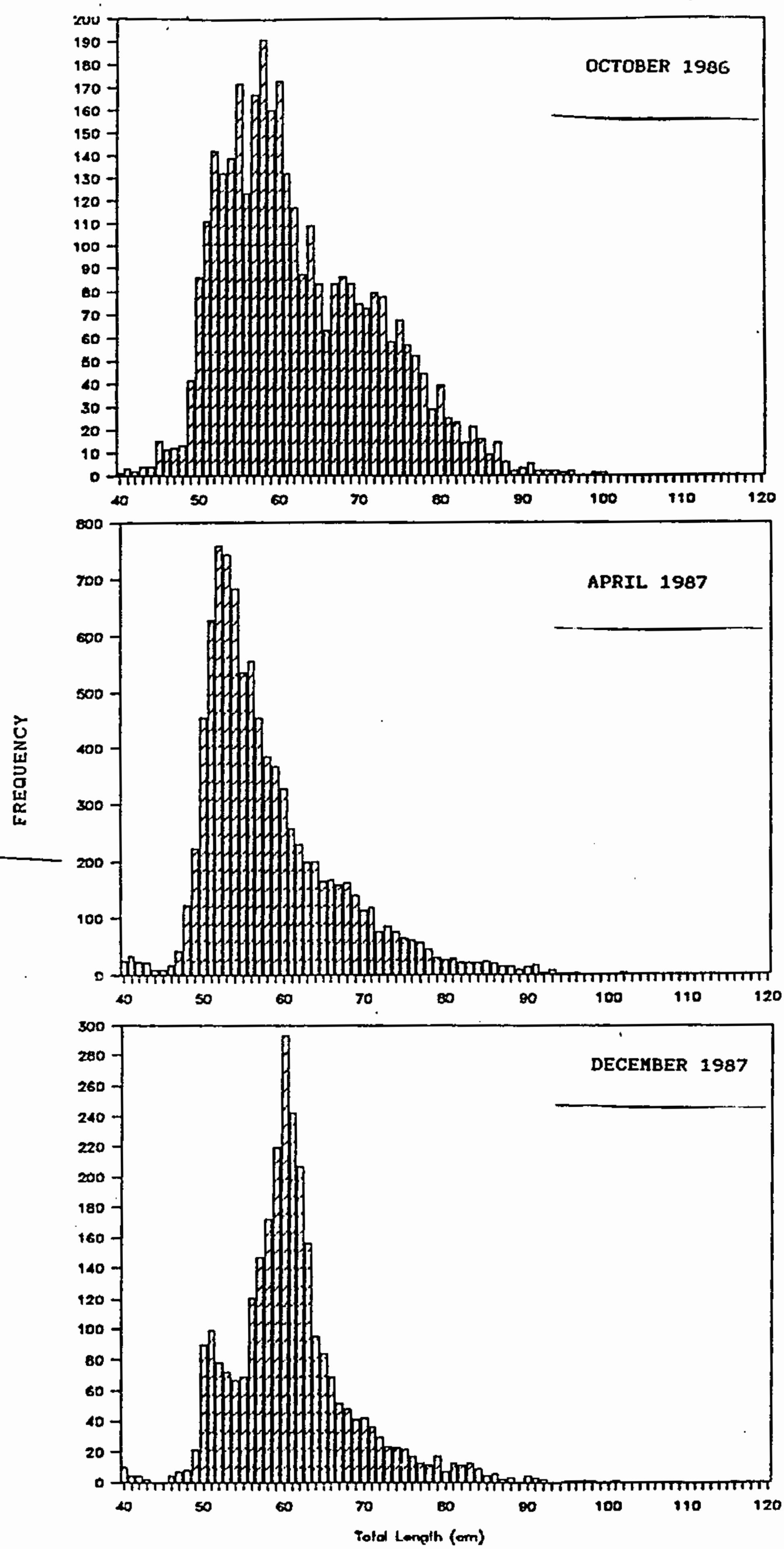

Figure 3 (continued) Length frequency distributions of hoki sampled on commercial vessels (b) East Coast, S. Island 1986-87

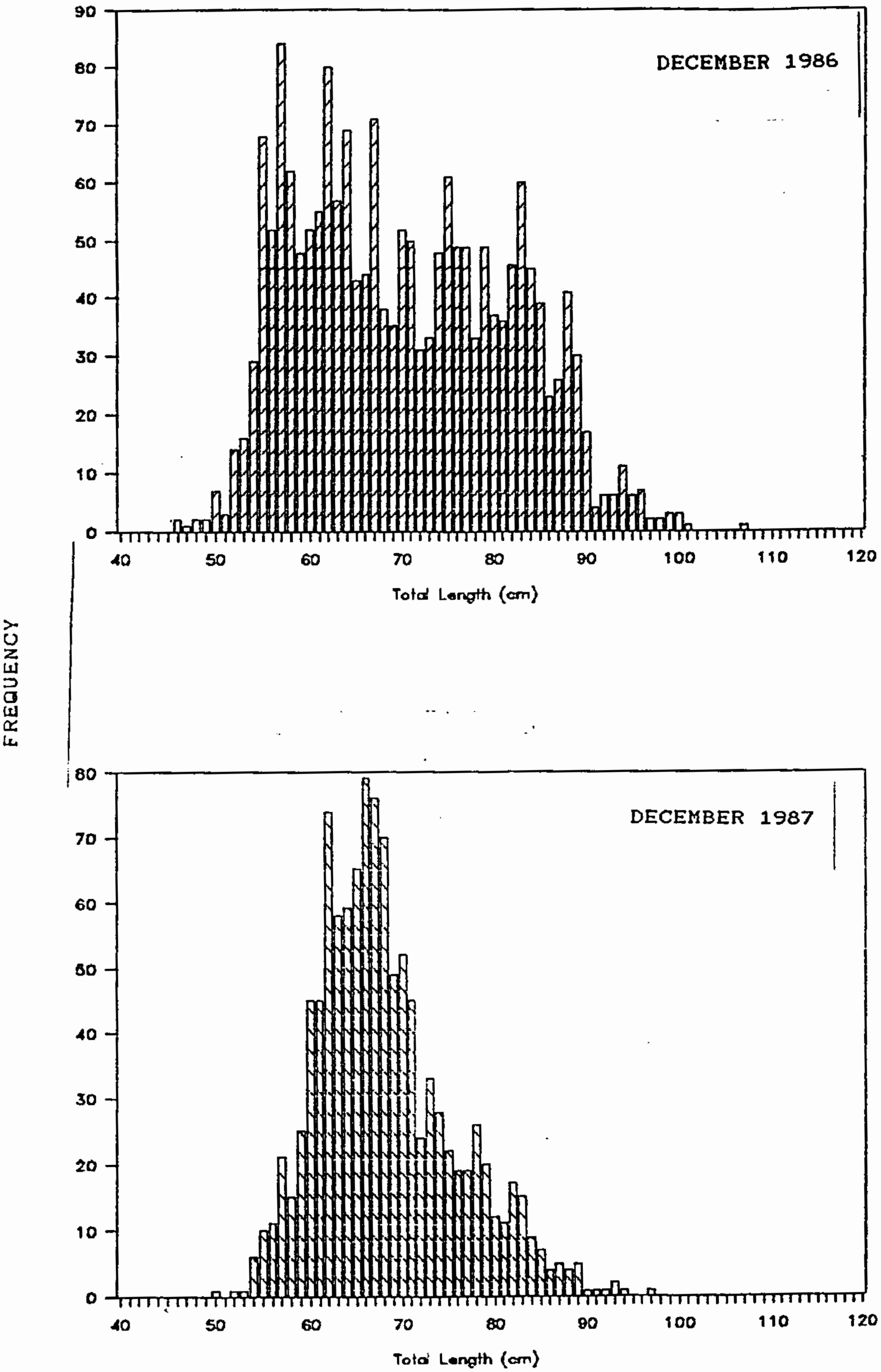

Figure 3 (continued) Length frequency distributions of hoki sampled on commercial vessels (c) Southern Plateau 1986-87

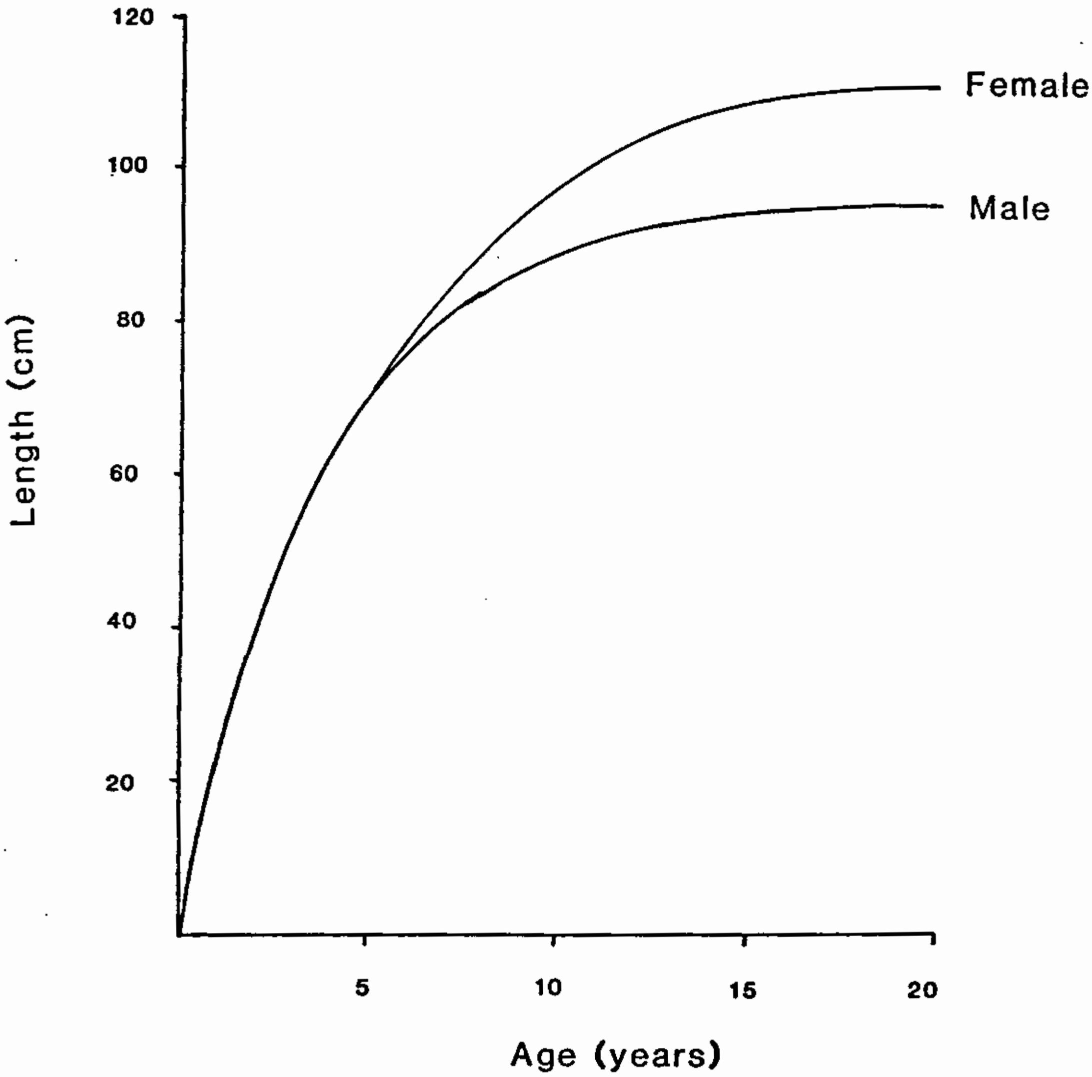

Figure 4. Growth rate of male and female hoki.

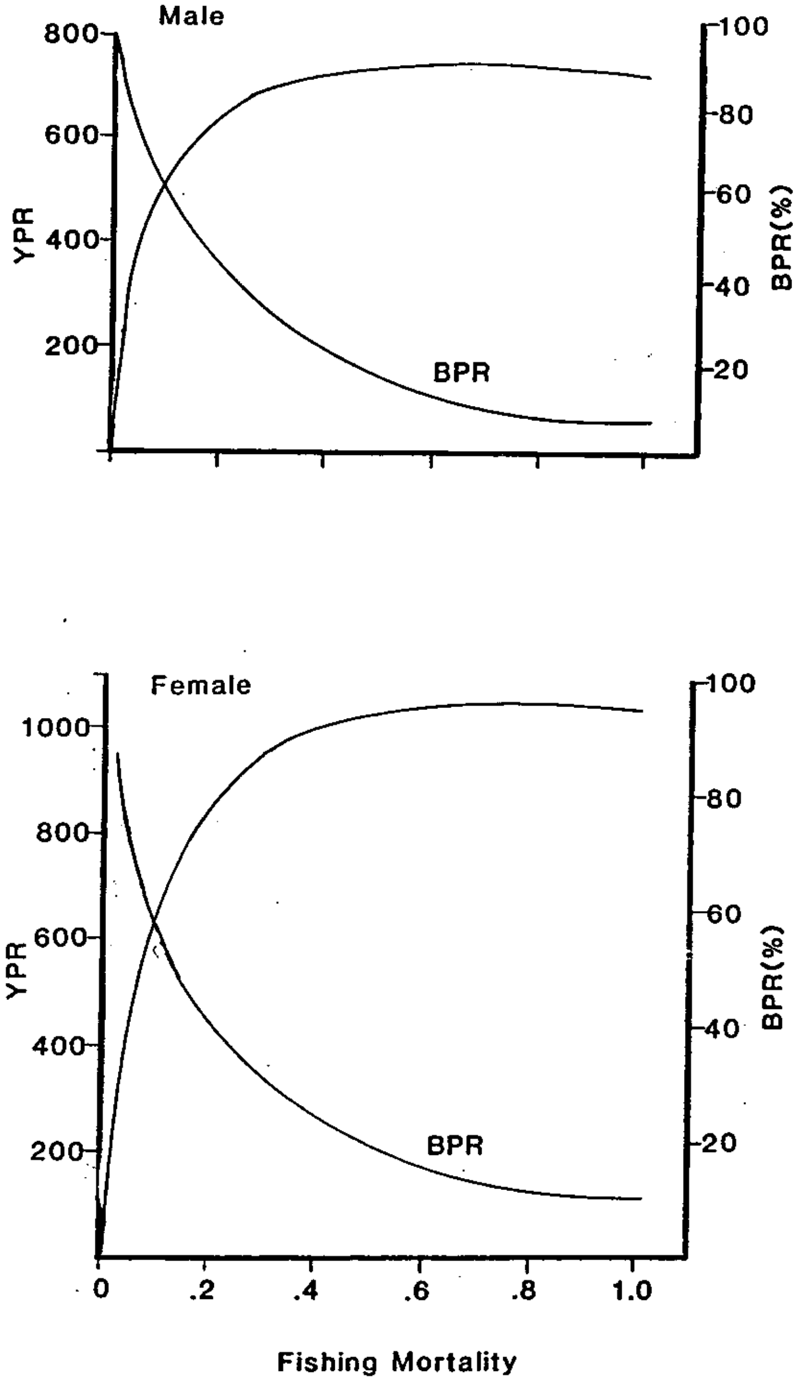

Figure 5. Yield-per-recruit (YPR) and biomass-per-recruit (BPR) curves for hoki, natural mortality = 0.2
(a) Male hoki, age of recruitment = 4 years
(b) Female hoki, age of recruitment = 5 years