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Update of kahawai simulation model for the 1997 assessment and sensitivity analysis

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Update of kahawai simulation model for the 1997 assessment and sensitivity analysis

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1. Executive Summary

This report updates the modelling calculations for the kahawai stock assessment. The length-weight relation was changed slightly after a reinvestigation of the length-weight data and the catches for 1995 and 1996 were included to produce the 1997 assessment for kahawai. When the natural mortality, *M*, is 0.2 these changes increase B_0 by 2000 t (about 2%) and *MCY* by 900 t (about 13%) above the values given in the 1996 assessment.

No biomass indices are available for kahawai. The assessment is done by placing a bound on the total mortality. If the bound on total mortality had been chosen higher, B_0 and hence *MCY* would have been lower, and if chosen lower, B_0 and *MCY* would have been higher.

As reported in the 1996 assessment, biomasses and yields are strongly dependent on the value of *M* and results are given for a range of *M* values.

Some of the other biological parameters, used previously and in the first part of this report, differ from their observed values. Sensitivity calculations indicate that changing the biological parameters to be more consistent with their observed values gives changes in biomasses and yields which are small in comparison to the range of biomasses and yields obtained using the range of *M* values. A higher past recreational catch leads to higher biomasses and yields.

2. Review of the fishery

2.1 Catch, landings, and effort data

The catch, landings, and effort data up to 1994 were described by Bradford (1996), who gave the assumptions made in determining the non-commercial catch before data from the 1990s recreational catch and effort surveys (Teirney *et al.* 1997, Bradford 1997) were available. For the modelling described in this report, the commercial catch has been updated using the Licenced Fish Receiver return figures for the 1994–95 and 1995–96 fishing years. The commercial catch has been lower in the mid 1990s than in the late 1980s, partly as a result of the progressive reductions in the purseseine catch limits (imposed since the 1990–91 fishing year). The non-commercial catch was assumed to have remained constant at 2000 t in 1995 and 1996. The catch histories as used in the model are given in Table 1.

Table 1: Commercial catch (t), assumed non-commercial catch (t) and total catch (t) used in the base case simulation models. The commercial catches change from being calendar year to fishing year catches in 1983–84. Given the uncertainties in catches, year can be considered as either a calendar year or a fishing year

Year	Commercial	Non-commer.	Total catch
1970	294	700	994
1971	572	800	1 372
1972	394	900	1 294
1973	586	1 000	1 586
1974	812	1 100	1 912
1975	345	1 200	1 545
1976	729	1 300	2 029
1977	1 461	1 400	2 861
1978	2 228	1 500	3 728
1979	3 072	1 600	4 672
1980	3 265	1 700	4 965
1981	3 085	1 800	4 885
1982	3 236	1 900	5 136
1983	4 965	2 000	6 965
1984	4 365	2 000	6 365
1985	4 667	2 000	6 667
1986	4 606	2 000	6 606
1987	7 667	2 000	9 667
1988	9 608	2 000	11 608
1989	7 377	2 000	9 377
1990	8 696	2 000	10 696
1991	5 687	2 000	7 687
1992	5 104	2 000	7 104
1993	6 639	2 000	8 639
1994	5 164	2 000	7 164
1995	4 526	2 000	6 526
1996	4 524	2 000	6 524

Uncertainties in the commercial catch before 1988 were described by Sylvester (1989).

The Recreational Fishing Council members on the Pelagic Working Group believe that the recreational catch was higher in past years than has been assumed for modelling. Estimates were made investigating the sensitivity to a higher recreational catch in the past.

3. Biology

3.1 Biological parameters

Further estimates of the coefficients in the kahawai length-weight relation have become available (Bradford 1996). The values, given in Annala & Sullivan (1997), are reproduced in Table 2. The coefficients for relations with both sexes combined are given because no significant difference with sex could be detected.

Table 2: Coefficients in the relation weight = a(length)^b (weight in g, fork length in cm) (sexes combined)

Fishstock & method	a	b	Source
KAH 3 (purseseine)	0.040	2.76	Drummond & Wilson 1993
KAH 3 (all methods)	0.010	3.14	Drummond 1994
KAH 1 (resting)	0.082	2.56	McKenzie & Trusewich 1996, unpubl. data
KAH 1 (mature)	0.774	2.02	McKenzie & Trusewich 1996, unpubl. data
KAH 3 (purseseine summer)	0.024	2.91	Bradford 1997, unpubl. data

The biological parameters used in subsequent calculations are given in Table 3. The Pelagic Working Group decided that the most recent estimates of the coefficients in the length-weight relation (here labelled KAH 3 (purseseine summer)) were the most plausible and these were used in the 1997 assessment. This was the only change from the parameters used in the 1996 assessment. The alternative set of parameters was used in further calculations on sensitivity to parameter changes.

The changes in the von Bertalanffy parameters in the alternative parameters give better agreement with the published values (*see* table 5 in Annala & Sullivan 1997). The recruitment ogive was changed as (a) examination of length frequencies of recreationally caught kahawai showed few 1^+ kahawai were caught and (b) examination of all length frequencies showed that all kahawai above 40 cm (reached at age 4 to 5) are fully recruited (Bradford, unpubl. data). The age of maturity was lowered to 4 years, but this is inappropriate as kahawai are thought to mature at about length 40 cm (J. R. McKenzie & W. Trusewich, NIWA, unpubl. data) and kahawai of this length are mainly 5 or 6 year olds with a few 4 and 7 year olds (from the age-length data produced by Drummond & Wilson (1993), Drummond (1995), and McKenzie & Trusewich (unpubl. results)).

Table 3: Biological parameters used in the models. A single sex model with a plus group from age 15 was used

Parameter	Symbol	Assessment value	Alternative value
Natural mortality	M	0.2 yr^{-1}	0.2 yr^{-1}
Age of recruitment	A_r	4 yr	4 yr
Gradual recruitment	S_r	3 yr	2 yr
Age at maturity	A_m	5 yr	4 yr
Gradual maturity	S_m	0 yr	0 yr
von Bertalanffy parameters	L_∞	60 cm	55 cm
	k	0.3 yr^{-1}	0.25 yr^{-1}
	t_0	0 yr	0 yr
Length-weight parameters	a	0.024	0.024
	b	2.91	2.91
Recruitment steepness	h	0.95	0.95
Recruitment variability (biomass cal'n)	σ_R	0	0
Recruitment variability (yield cal'n)	σ_R	0.6	0.6

3.2 Stock structure

A single stock was assumed because of lack of information about kahawai stocks. Tagging returns suggest that kahawai remain in, or return to, the same area for several years, but some fish move throughout the kahawai habitat. The extent of kahawai movement around New Zealand will determine whether kahawai can be considered as a single stock.

4. Methods

4.1 Biomass estimates

The calculations closely follow those given by Bradford (1996), which contains an appendix giving the mathematical details of the model. In brief, the stock reduction model (Francis *et al.* 1995) was used to obtain conservative estimates of virgin and current biomasses and *MCY* for a single nationwide kahawai stock with constant recruitment ($\sigma_R = 0$). The conservative estimates were made by adjusting the maximum fishing mortality (F_{UB}) in any year (usually the year of maximum catch) to be such that Z ($F_{AV} + M$) was about 0.31 (the maximum likely value from table 6 in Annala & Sullivan 1997). The average fishing mortality (F_{AV}) was calculated over the years 1980–92. Kahawai differs from the other stocks which use simulation modelling in their assessment in that no suitable index of abundance is available.

4.2 Estimation of Maximum Constant Yield (*MCY*)

Estimates of *MCY* can be calculated for a single national Fishstock. $MCY = pB_0$ where p is determined using the simulation method of Francis (1992) such that the biomass does not go below 20% B_0 more than 10% of the time. Recruitment variability, $\sigma_R = 0.6$, is assumed in these calculations.

5. Results

Sections 5.1 and 5.2 below contain the updated values of the kahawai stock assessment model (Bradford 1996) as given in the 1997 Working Group Report for kahawai. Section 6 examines the sensitivity of the results to some changes in the biological parameters and to a higher past recreational catch.

5.1 Biomass estimates

Estimates of B_0, B_{1996}, F_{1996}, F_{AV}, and Z_{Est} made by finding the value of B_0 (to the nearest 1000 t) at which an upper bound on fishing mortality (F_{UB}) is just reached are given in Table 4 for several values of natural mortality, M, and F_{UB}. F_{AV} is the average F for 1980 to 1992 and $Z_{Est} = M + F_{AV}$.

Table 4: Estimates of B_0, B_{1996} (mid-year biomass in 1996), F_{1996}, and F_{AV} (average F for 1980–1992) for the biological parameters given in Table 3. $Z_{Est} = M + F_{AV}$. Estimates are for several values of the upper bound on fishing mortality, F_{UB}, and M

M	F_{UB}	B_0	B_{1996}	F_{1996}	F_{AV}	Z_{Est}
0.15	0.10	164 000	101 000	0.065	0.062	0.21
0.15	0.15	128 000	64 000	0.102	0.090	0.24
0.15	0.20	111 000	46 000	0.143	0.114	0.26
0.15	0.25	101 000	35 000	0.188	0.137	0.29
0.15	0.30	93 000	26 000	0.252	0.162	0.31
0.20	0.10	157 000	106 000	0.062	0.063	0.26
0.20	0.15	121 000	69 000	0.095	0.091	0.29
0.20	0.19	106 000	53 000	0.123	0.112	0.31
0.20	0.20	103 000	50 000	0.130	0.117	0.32
0.25	0.10	152 000	109 000	0.059	0.063	0.31
0.25	0.15	115 000	71 000	0.091	0.092	0.34
0.25	0.20	97 000	53 000	0.123	0.120	0.37

Table 5 selects the data from Table 4 where $Z_{UB} = M + F_{AV} \approx 0.31$ (the largest likely value of Z from the data in table 6 Annala & Sullivan (1997). The biomasses B_0 and B_{1996} are compared with B_{MSY}.

Table 5: Estimates of minimum virgin (B_0) and current (B_{1996}) biomasses compared with B_{MSY} for the biological parameters given in Table 3. F_{AV} is the average fishing mortality between 1980 and 1992. Estimates are calculated for different values of natural mortality (M), such that $Z_{UB} = (M+F_{AV}) \approx 0.31$. F_{UB} was found by trial and error

M	F_{AV}	B_0	B_{MSY}/B_0(%)	B_{1996}/B_0(%)	B_{1996}/B_{MSY}(%)	F_{UB}
0.25	0.063	152 000	13.9	71.7	520	0.10
0.20	0.112	106 000	16.1	50.0	310	0.19
0.15	0.162	93 000	17.8	28.0	160	0.30

5.2 Estimation of Maximum Constant Yield (*MCY*)

The estimates in Table 6 are for the range of M values used in Table 5. The productivity parameters are those used for biomass estimation. The values for MCY are slightly higher (900 t for $M = 0.2$) that those in the 1996 assessment in Annala & Sullivan (1996).

Table 6: Natural mortality (M), MCY/B_0 (%), and MCY estimates in tonnes for kahawai for the biological parameters given in Table 3

M	MCY/B_0(%)	MCY
0.25	8.32	12 600
0.20	7.13	7 600
0.15	5.47	5 100

The estimates in Tables 5 and 6 are uncertain and depend on the model assumptions (a single stock, deterministic recruitment, and the constraints on fishing mortality imposed) and input data. They may be regarded as conservative as they are based on the upper end of the Z estimates in table 6 in Annala & Sullivan (1997). The catch history is uncertain because of uncertainties in the commercial catch records, and the non-commercial catch history is based on an assumed pattern leading to a single estimate in the 1990s provided by the recreational surveys (Teirney *et al.* 1997, Bradford 1997). The upper limit of Z is uncertain and comes from data in a limited part of the range.

6. Sensitivity to changes in model parameters

6.1 Modified biological parameters

Estimates of B_0, B_{1996}, F_{1996}, F_{AV}, and Z_{Est} made using the alternative set of biological parameters (Table 3) are given in Table 7. The changes in these values are small as can be seen by comparing the values in Table 4 and Table 7. The estimates of current biomass when $F_{AV} = 0.31$ are 150–550% B_{MSY} depending on the value of the natural mortality (Table 8). Again, these values are similar to the previous values (compare Table 8 with Table 5). The values of MCY are 7–12% lower than in the previous calculation (compare Table 6 with Table 9).

Table 7: Estimates of B_0, B_{1996} (mid-year biomass in 1996), F_{1996}, and F_{AV} (average F for 1980–1992) for the alternative biological parameters given in Table 3. $Z_{Est} = M + F_{AV}$. Estimates are for several values of the upper bound on fishing mortality, F_{UB}, and M

M	F_{UB}	B_0	B_{1996}	F_{1996}	F_{AV}	Z_{Est}
0.15	0.10	165 000	100 000	0.065	0.062	0.21
0.15	0.15	130 000	63 000	0.103	0.089	0.24
0.15	0.20	112 000	44 000	0.148	0.115	0.26
0.15	0.25	102 000	33 000	0.198	0.137	0.29
0.15	0.30	96 000	26 000	0.252	0.157	0.31
0.20	0.10	158 000	105 000	0.062	0.063	0.26
0.20	0.15	122 000	68 000	0.096	0.091	0.29
0.20	0.19	107 000	52 000	0.125	0.111	0.31
0.20	0.20	104 000	49 000	0.133	0.117	0.32
0.25	0.10	153 000	109 000	0.060	0.063	0.31
0.25	0.15	116 000	71 000	0.091	0.092	0.34
0.25	0.20	98 000	52 000	0.124	0.119	0.37

Table 8: Estimates of minimum virgin (B_0) and current (B_{1996}) biomasses compared with B_{MSY} for the alternative biological parameters given in Table 3. F_{AV} is the average fishing mortality between 1980 and 1992. Estimates are for different values of natural mortality (M), such that $Z_{UB} = (M+F_{AV}) \approx 0.31$. F_{UB} was found by trial and error

M	F_{AV}	B_0	B_{MSY}/B_0	B_{1996}/B_0	B_{1996}/B_{MSY}	F_{UB}
0.25	0.063	153 000	13.0%	71.2%	550%	0.10
0.20	0.111	107 000	16.0%	48.6%	300%	0.19
0.15	0.157	96 000	18.3%	27.1%	150%	0.30

Table 9: Natural mortality (M), MCY/B_0 (%), and MCY estimates in tonnes for kahawai for the alternative biological parameters given in Table 3

M	MCY/B_0(%)	MCY
0.25	7.88	12 100
0.20	6.31	6 700
0.15	4.74	4 500

6.2 Modified biological parameters and increased recreational catch

The alternative recreational catch assumption from Bradford (1996) is used with the biological parameters given in Table 3. This catch assumption takes the catch history back to 1945 and has a higher non-commercial catch in the 1980s. The non-commercial catch (including traditional catch and some commercial catch before 1970) was taken as: rising from 375 t to 4000 t in steps of 125 t for 1945 to 1974; constant at 4000 t from 1975 to 1984; then 3600 t (1985), 3200 t (1986), dropping in steps of 200 t to 2000 t in 1992 and then remaining constant at 2000 t. The results of these calculations are given in Tables 10, 11, and 12.

Table 10: Estimates of B_0, B_{1996} (mid-year biomass in 1996), F_{1996}, and F_{AV} (average F for 1980 to 1992) for the alternate biological parameters given in Table 3. $Z_{Est} = M + F_{AV}$. Estimates are for several values of the upper bound on fishing mortality, F_{UB}, and M. The non-commercial catch is higher in the 1980s than that used for Table 4 and Table 7, and the catch history is longer

M	F_{UB}	B_0	B_{1996}	F_{1996}	F_{AV}	Z_{Est}
0.15	0.10	191 000	117 000	0.056	0.068	0.22
0.15	0.15	149 000	74 000	0.088	0.102	0.25
0.15	0.20	131 000	54 000	0.121	0.130	0.28
0.15	0.25	121 000	42 000	0.154	0.156	0.31
0.15	0.26	119 000	40 000	0.162	0.162	0.31
0.15	0.30	114 000	34 000	0.191	0.181	0.33
0.20	0.10	198 000	122 000	0.053	0.068	0.27
0.20	0.15	138 000	79 000	0.082	0.102	0.30
0.20	0.17	129 000	70 000	0.094	0.114	0.31
0.20	0.20	118 000	58 000	0.113	0.134	0.33
0.25	0.09	185 000	139 000	0.047	0.062	0.31
0.25	0.10	171 000	126 000	0.052	0.069	0.32
0.25	0.15	130 000	82 000	0.079	0.102	0.35
0.25	0.20	110 000	61 000	0.106	0.134	0.38

With a higher catch, the virgin biomass has to be higher if the same constraint on the average fishing mortality is imposed ($M + F_{AV} \approx 0.31$). The current biomass (B_{1996}) is also higher (compare Table 7 with Table 10). The comparisons with B_{MSY} are more optimistic with a higher catch (compare Table 8 with Table 11) and the *MCY* estimates are higher (compare Table 9 with Table 12). Thus the assumption of a higher past recreational catch gives a more optimistic assessment at the present time.

The estimate of a recreational catch of 4000 t in 1984 comes from a comparison of the number of tagged kahawai caught by recreational and commercial fishers after the 1981–84 kahawai tagging study. This estimate will have ignored the requirement of statistical independence in the kahawai tag returns. The assumption of independence is unlikely to be valid because of the schooling nature of kahawai. It may be reasonable to assume that recreational *catch rates* were higher in the past (the early 1980s), but this does not imply higher kahawai catches.

Table 11: Estimates of minimum virgin (B_0) and current (B_{1996}) biomasses compared with B_{MSY} for the alternative parameters given in Table 3. A higher recreational catch is assumed. F_{AV} is the average fishing mortality between 1980 and 1992. Estimates are calculated for different values of natural mortality (M), such that $Z_{UB} = (M+F_{AV}) \approx 0.31$. F_{UB} was found by trial and error

M	F_{AV}	B_0	B_{MSY}/B_0(%)	B_{1996}/B_0(%)	B_{1996}/B_{MSY}(%)	F_{UB}
0.25	0.062	185 000	13.0	75.1	580	0.09
0.20	0.114	129 000	16.0	54.3	340	0.17
0.15	0.162	119 000	18.3	33.6	180	0.26

Table 12: Natural mortality (*M*), MCY/B_0 (%), and *MCY* estimates in tonnes for kahawai for the alternative biological parameters given in Table 3 and alternative catch levels

M	MCY/B_0 (%)	*MCY*
0.25	7.88	14 600
0.20	6.31	8 100
0.15	4.74	5 600

6.3 Sensitivity summary

To examine the sensitivity of the results to the changes in parameters, the values of k and L_∞ are separately returned to their values in Table 3, and the age of maturity is increased by one year. The mean age of recruitment is increased and decreased by 1 year. As *MCY* is better defined in terms of the way the calculations are done than B_{MSY}, and can be simply compared to the current total catch levels, the results focus on the range of *MCY* values which are such that $M + F_{AV} \approx 0.31$ for $M = 0.15$, 0.2, and 0.25. In two cases with $M = 0.25$, F_{MSY} appeared to increase indefinitely with fishing mortality and B_{MSY} was not estimated. The summary results are given in Table 13.

Increasing the growth rate, k, caused a contraction of the range of *MCY* values, with *MCY* being higher for $M = 0.15$ and lower for $M = 0.25$. Values of k seem to vary around the country (between 0.24 and 0.33, *see* Annala & Sullivan 1997). However, the determinations of the von Bertalanffy parameters may be suffering from small and biased length samples at age. Such an effect is particularly important with the younger ages. Kahawai may well have a wide range of growth parameters for individual fish. Values of the mean growth parameters will be better determined as more data are collected.

Increasing the value of L_∞ from 55 to 60 cm increased the values of *MCY* for the lower values of *M*. The value of 55 cm is more consistent with the available data (*see* Annala & Sullivan 1997).

Increasing the age of maturity to age 5 decreased the values of *MCY* for all the *M* values used. Age 5 is a reasonable choice for a knife-edge age at maturity. Ideally, a gradual maturity ogive should be used.

Increasing the age of recruitment to the fishery increased the value of *MCY* for all the values of *M* used, as might be expected. The implied assumption that kahawai are only 50% recruited to the fishery at age 5 years is unlikely as the catch sampling data show substantial catches of 3 year olds and the recreational fishery catches substantial numbers of 3 year olds. To achieve an increased age of recruitment to the fishery would require voluntary or enforced changes in fishing activities. Reducing the mean age of the recruitment ogive to 3 years (and the spread of the recruitment ogive to 1 year – for technical simplicity) reduces the values of *MCY*. The latter assumption about recruitment to the fishery at young ages may not be too unreasonable.

Table 13: Summary values of B_0, B_{MSY}/B_0, B_{1996}/B_0, and *MCY*. The biological parameters are given by the alternative set in Table 3 (reference case) except for the indicated change. The increased recreational catch is as used in Tables 10, 11, and 12

M	F_{UB}	F_{AV}	B_0	$B_{MSY}/B_0(\%)$	$B_{1996}/B_0(\%)$	$MCY/B_0(\%)$	MCY
Reference case (Tables 7, 8, and 9)							
0.25	0.10	0.063	153 000	13.0	71.2	7.88	12 100
0.20	0.19	0.111	107 000	16.0	48.6	6.31	6 700
0.15	0.30	0.157	96 000	18.3	27.1	4.74	4 500
k=0.3							
0.25	0.10	0.063	151 000	n/a	72.9	7.78	11 700
0.20	0.19	0.112	105 000	13.6	51.4	6.42	6 700
0.15	0.30	0.160	93 000	16.2	29.0	4.93	4 600
L_∞ = 60 cm							
0.25	0.10	0.063	153 000	13.0	71.2	7.88	12 100
0.20	0.19	0.112	107 000	16.0	48.6	6.31	6 800
0.15	0.30	0.157	96 000	18.3	27.1	4.74	4 600
A_m = 5 years							
0.25	0.10	0.063	153 000	16.4	71.2	7.24	11 100
0.20	0.19	0.112	107 000	18.1	48.6	5.96	6 400
0.15	0.30	0.157	96 000	19.4	27.1	4.58	4 400
A_r = 5 years, S_r = 2 years							
0.25	0.10	0.063	151 000	n/a	73.5	8.98	13 600
0.20	0.19	0.113	104 000	11.2	51.9	7.18	7 500
0.15	0.30	0.161	92 000	14.7	29.3	5.31	4 900
A_r = 3 years, S_r = 1 year							
0.25	0.10	0.063	155 000	20.4	69.0	6.46	10 000
0.20	0.19	0.111	110 000	21.5	45.5	5.83	6 400
0.15	0.30	0.154	100 000	22.4	23.7	4.09	4 100
Increased recreational catch in the past (Tables 10, 11, and 12)							
0.25	0.09	0.062	185 000	13.0	75.1	7.88	14 600
0.20	0.17	0.114	129 000	16.0	54.3	6.31	8 100
0.15	0.26	0.162	119 000	18.3	33.6	4.74	5 600

A higher catch in the past leads to a higher value of *MCY* under the constraint of bounded total mortality.

7. Conclusions

This assessment shows the kahawai biomasses and yields (given in Section 6) are higher than those reported earlier (Bradford 1996). Notably, for M = 0.2, the *MCY* estimates are 900 t, or 13%, higher.

No biomass indices are available for kahawai. The assessment is done by placing a bound on the total mortality. If the bound on total mortality had been chosen higher,

B_0 and hence *MCY* would have been lower, and if chosen lower, B_0 and *MCY* would have been higher (*see* Tables 4, 7, and 10).

The results are sensitive to the value of M and all calculations are done for a range of M values. Some of the other biological parameters differ from the observed values. Sensitivity analyses showed how the assessment changes when these parameters are changed. Using an alternative set of biological parameters (*see* Table 3) for the reference case, the restriction $M + F_{AV} \approx 0.31$, $M = 0.2$, and a current total catch level of about 6500 t, shows (*see* Table 13):

- The reference case *MCY* is greater than 6500 t by 200 t
- Increasing k and L_∞ separately to their old values leaves *MCY* unchanged or slightly increases it by 200 and 300 t respectively
- Increasing the age of maturity by 1 year (to 5) or decreasing both the age of recruitment and the gradual recruitment parameter both decrease *MCY* by 300 t to slightly below the current catch level
- Increasing the age of recruitment to the fishery, or assuming a higher past catch, increases the *MCY* by 800 and 1400 t respectively

These changes in *MCY* are small compared with the changes which occur when M is varied: *MCY* goes from 4500 to 12 100 as M goes from 0.15 to 0.25 in the reference case.

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