SCIENCE & RESEARCH SERIES NO.58

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Published by
Head Office,
Department of Conservation,
PO Box 10-420,
Wellington,
New Zealand

ISSN 0113-3713 ISBN 0-478-01490-2

National Library of New Zealand
Cataloguing-in-Publication data

Collier, Kevin J. (Kevin John), 1959-
Towards a protocol for assessing the natural value of New Zealand
rivers / by Kevin Collier.
1 v. (Science & research series, 0113-3713 ; no. 58) ISBN 0-478-01490-2 (pbk.)

1. Stream ecology--Research--New Zealand--Methodology. 2. Rivers--New Zealand--Management.
3. Conservation of natural resources--New Zealand. 4. Tongariro River (N.Z.) I. New Zealand.
Dept. of Conservation. II. Series: science & research
series; no. 58.

574.52632301 zbn93-055918

Keywords: rivers, natural value, aquatic reserves, evaluation, New Zealand

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ABSTRACT

Steps taken to date to develop a method for assessing the natural value of New Zealand rivers are described. Five criteria (ECOLOGICAL REPRESENTATIVENESS OR RARE TYPE OF ECOSYSTEM, DEGREE OF MODIFICATION, DIVERSITY AND PATIERN, RARITY AND UNIQUE FEATURES OR SPECIES, and LONG-TERM VIABILITY) for assessing aquatic reserve value were determined at a workshop at the 1987 Limnological Society conference, and possible quantitative descriptors for these criteria were later developed. Weightings for the suggested descriptors were obtained through a questionnaire sent to limnologists. A trial assessment was carried out on seven different sections of the Tongariro River to determine the utility of this method in defining natural value in terms of DEGREE OF MODIFICATION, DIVERSITY AND PATTERN, and RARITY AND UNIQUE FEATURES OR SPECIES. The method appeared to provide sensible scores for these criteria, but further refinement of the descriptors and weightings is necessary before the method should be generally applied.

1. INTRODUCTION

In New Zealand, the assessment of conservation value has focused largely on terrestrial environments and wetlands (Park *et al.* 1986, Simpson 1985). PNAP (Protected Natural Areas Programme) and WERI (Wetlands of Ecological and Representative Importance) both use subjective criteria to make these assessments. A widely accepted method for evaluating river systems has not yet been developed in New Zealand, and partly as a result of this, rivers are under-represented in the protected areas network compared with terrestrial environments and wetlands (see Collier 1992).

Historically, the justification behind river protection in New Zealand has mainly been to preserve the fishery value, and secondary importance has been placed on "natural value", the definition of which is embodied in the goal of natural area protection (Park *et al.* 1986): to ensure "…as far as possible, the survival of all indigenous species of flora and fauna, both rare and commonplace, in their natural communities and habitats, and the preservation of representative samples of all classes of natural ecosystems and landscape which in the aggregate originally gave New Zealand its own recognisable character."

In this report, I outline a system that, once refined, could be used to assess the "natural value" of rivers, and thereby help identify important sections or river systems for management or protection. The procedure used is based on a the River Conservation System (RCS) developed for South African rivers by O'Keefe *et al.* (1987), and has been expanded to incorporate a wider range of criteria.

2. METHODS

2.1 Establishing the conceptual framework

The conceptual framework of an assessment system for New Zealand rivers was initially established during a workshop on "Identification of aquatic reserves" held at the 1987 Limnological Society conference (see Appendix 1 for workshop report). A major outcome of this workshop was the identification of six criteria that could be used to assess aquatic reserve value:

- ECOLOGICAL REPRESENTATIVENESS OR RARE TYPE OF ECOSYSTEM
- DIVERSITY AND PATTERN
- RARITY AND UNIQUE FEATURES OR SPECIES
- LONG-TERM VIABILITY
- HISTORIC OR RESEARCH VALUE
- DEGREE OF MODIFICATION

Collier and McColl (1992; see Appendix 2) discussed the application of these criteria in assessing riverine "natural value" as embodied by the goal of natural area protection presented earlier. They listed quantitative descriptors that could be used to assess DEGREE OF MODIFICATION, DIVERSITY AND PATTERN, and RARITY AND UNIQUE FEATURES OR SPECIES. They also discussed interpretation of the LONG-TERM VIABILITY criterion and suggested that it was composed of two factors: size and fragility (sensitivity to environmental change or perturbation). Several possible descriptors of FRAGILITY were discussed (see Appendix 2). HISTORIC OR RESEARCH VALUE was not considered as it was outside the definition of natural value.

A critical pathway by which assessments of natural value could be carried out was also presented by Collier and McColl (1992). They noted that assessment of REPRESENTATIVENESS OR RARE TYPE OF ECOSYSTEM would require some form of classification system that delineates riverine eco-regions and allows sites to be grouped into classes with similar attributes. Biggs *et al.* (1990) defined aquatic eco-regions for the North Island, but were unable to differentiate regions in the South Island. A DOC funded study being carried out by the Zoology Department, University of Canterbury, is currently attempting to define aquatic eco-regions for the South Island. The next step would be to determine an ecotype classification system that groups rivers with similar attributes in different eco-regions.

2.2 Refinement of descriptors and determination of descriptor weightings

A workshop was held at the 1991 Limnological Society conference to discuss the methodology for assessing riverine natural value (see Appendix 3 for workshop report). This workshop defined threshold descriptors that could be used to minimise the number of sites assessed in a regional evaluation of rivers. The workshop also discussed descriptors that could be used to assess DEGREE OF MODIFICATION, DIVERSITY AND PATTERN, and RARITY AND UNIQUE FEATURES OR SPECIES (Appendix 3).

Further refinements of descriptors and weightings that reflected their importance in determining natural value were sought through a questionnaire sent out to 36 limnologists (Appendix 4). The questionnaire included definitions of the criteria and explanations of descriptors. Questionnaire recipients were asked to score each descriptor with an integer value in a specified range according to its perceived importance in determining natural value. Mean scores were subsequently calculated. In order to reduce the number of descriptors, those with mean scores <50% of the maximum value (indicating relatively low perceived importance) or that had coefficients of variation >50% (indicating wide variation in views amongst respondents) were not used in the subsequent trial analysis.

Recipients were also requested to comment on the descriptors used and, if they wished, to suggest new descriptors with scores. In addition, the questionnaire asked for an indication of the specific area of interest of the reader (i.e., water quality, plants, invertebrates, fish or general freshwater ecology). Recipients who circled more than one option were classified as being primarily interested in general freshwater ecology.

2.3 Trial application: Tongariro River

A method of applying the weighted descriptors for DEGREE OF MODIFICATION, DIVERSITY AND PATTERN, and RARITY AND UNIQUE FEATURES OR SPECIES was evaluated for seven sections of Tongariro River (see Fig. 1; Table 1) in response to a conservancy request for information to establish management priorities for the river.

Table 1 Channel lengths, catchment areas and locations of lower boundaries for the 7 sections of Tongariro River (see Fig. 1) used in the trial application of the natural value assessment system.

Section	Channel length (km)	Catchment Area (km^2)	Location of lower boundary
1	46*	329	Confluence of Waipakihi R. and Waikato Stm. Official start of Tongariro R.
2	5	246	Rangipo Barrage. Regulated flow beyond this point.
3	4	318	Oturere Stm. Confluence. Increase in residual flow below this point.
4	8	71	Poutu Intake.
5	10	94	Whitikau Stm. Confluence. Charge in channel morphology below this point.
6	13	104	DeLatours Pool. Channel becomes more sinuous below this point.
7	8	5	Lake Taupo.

* 25 km for Waipakihi River and 18 km for Waikato Stream.

Descriptor values for the various sections were obtained from NZMS 260 (1:50 000) maps, Land Resource Inventory (1:63 360) maps, the Freshwater Fisheries database, Geopreservation Inventory, NIWAR flow records, and information from conservancy staff. Descriptors that required on-site assessment or for which no data were available, and new descriptors suggested by questionnaire respondents were not used in this trial application (see footnotes in Tables 3 and 4).

Upper limits for each descriptor were set arbitrarily so that any descriptor equal to or exceeding that upper limit was considered to be the maximum value, as was done in the RCS developed by O'Keefe *et al.* (1987). Scores were then calculated according to the method by O'Keefe *et al.* (1987), as shown in Table 2 for a subset of DEGREE OF MODIFICATION descriptors. Where weighting factors had negative values, the result of the calculation ({*value/limit*} X *weight)* was subtracted from the weighting factor to yield positive values that represented the descriptor evaluated. The sum of scores achieved in this way was then divided by the best possible score (sum of weighting factors ignoring signs) and multiplied by 100 to provide a value between 0 and 100. This figure was subtracted from 100 for DEGREE OF MODIFICATION, but not for the other criteria.

Table 2 Simplified example of procedure for calculating scores using a subset of descriptors from the DEGREE OF MODIFICATION criterion for Tongariro River section 5 (see Tables 3 and 4 for weights, upper limits, etc).

Descriptor	Upper limit	Weight	Value
% CATCHMENT IN NATIVE VEGETATION	≥ 80	+17.1	81
% LENGTH LINED BY NATIVE VEGETATION	100	+15.7	90
% BASEFLOW ABSTRACTED	≥60	-15.4	50
NO. OF EXOTIC NUISANCE SPECIES	≥10	-10.5	2
Sum of weighting factors*		58.7	

	Calculation (value / limit × weight)		Score
% CATCHMENT IN NATIVE VEGETATION	80† / 80 × 17.1		17.1
% LENGTH LINED BY NATIVE VEGETATION	90 / 100 × 15.7		14.1
% BASEFLOW ABSTRACTED	50 / 60 × −15.4	(−12.8‡)	2.6
NO. EXOTIC NUISANCE SPECIES	2 / 10 × −10.5	(−2.1‡)	8.4
		Sum of scores	42.2

Score for section 5 on a scale of 0-100 is 42.2 / 58.7 X 100 = 71.9. This indicates the extent to which the river is <u>unmodified.</u> To indicate DEGREE OF MODIFICATION the score is subtracted from 100 (NB: this is not done for DIVERSITY AND or RARITY AND UNIQUE FEA1URES OR SPECIES).

DEGREE OF MODI FICATION score for section 5 using four descriptors = 28.1

* All factors converted to positive values to calculate sum of weightings
† Value exceeds upper limit for descriptor, therefore treated as equivalent to upper limit
± Where there are negative weights, scores calculated from the formula are subtracted from the weighting factor before being summed.

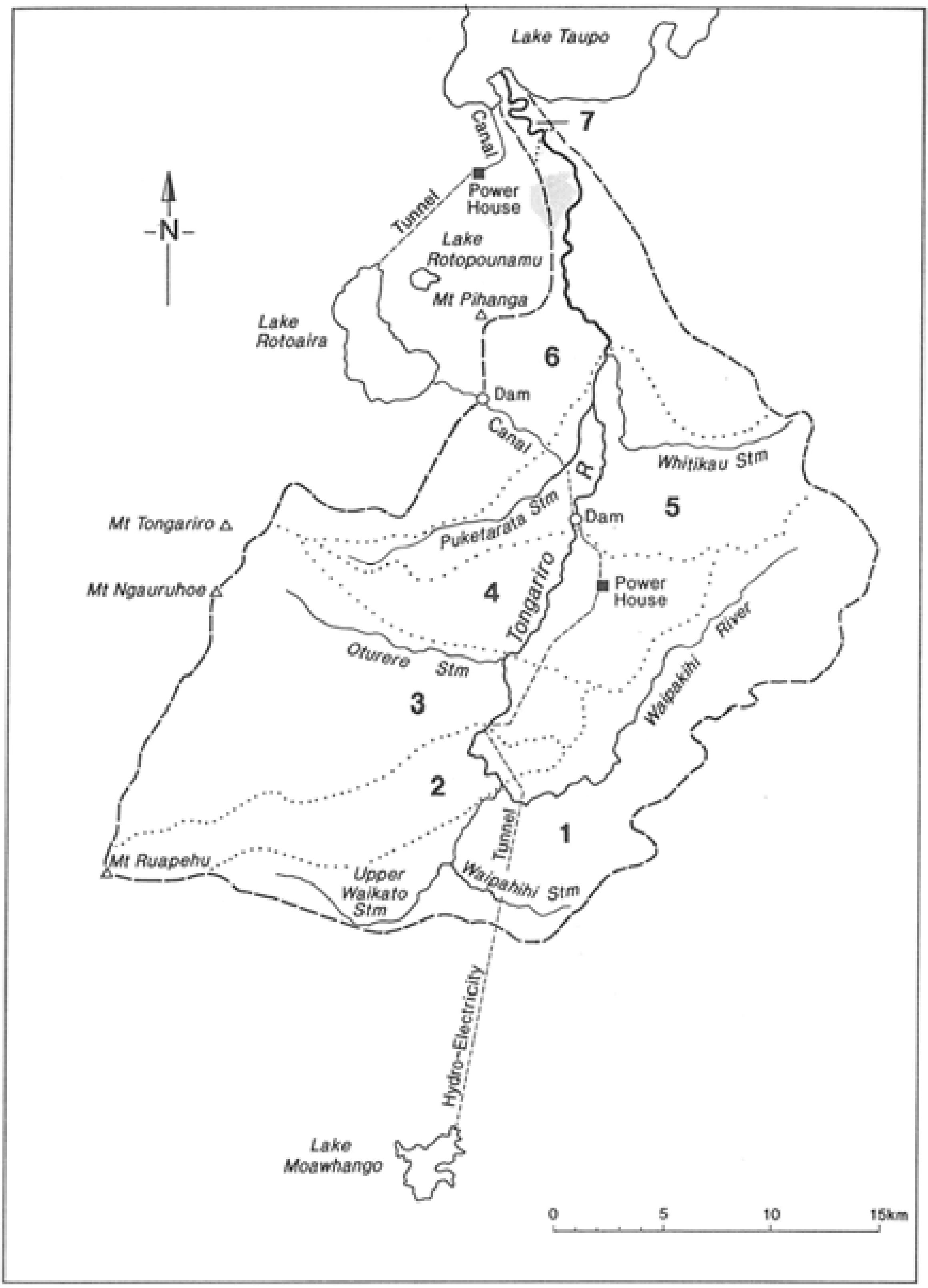

Fig. 1 Boundaries of sub-catchments of seven sections of Tongariro River used in the trial application of the natural value assessment system.

3. RESULTS

3.1 Questionnaire response

Twenty-nine replies were received out of the 36 questionnaires sent out. Most were from NIWAR (41%), and 10-17% came from universities, Regional Councils, Department of Conservation or private consultancies. Most respondents (48%) indicated that their specific area of interest was general freshwater ecology (includes those who circled more than one option). Several respondents (14-17%) indicated that their primary area of interest was water quality, invertebrates or fish, whereas only 7% were mainly interested in aquatic plants. Additional descriptors with scores suggested by respondents are listed in Table 3, and comments made on these and the other descriptors are presented in Appendix 5. It was apparent from these comments that more refinement of descriptors is needed before they should be generally applied to rivers for wide-scale natural value assessment.

Table 3 Mean weights, standard deviations (S.D.), coefficients of variation (C.V.), minimum and maximum values, and numbers of respondents for descriptors (No.), under four assessment criteria.

1. DEGREE OF MODIFICATION						
Descriptor	Mean weight	S.D.	C.V. (%)	Min.	Max.	No.
% catchment in native vegetation	17.1	4.1	24	2	20	29
% length lined by native vegetation	15.7	3.4	22	5	20	29
% length lined by non-production woodland	13.2	3.7	28	5	20	29
% length with bank fencing	13.1	4.3	33	5	20	29
road distance to nearest town*	5.0	4.1	82	0	16	29
road distance to nearest city*	6.3	4.7	74	0	15	29
% catchment in production forest	13.0	3.8	29	5	20	28
% catchment in crop/improved pasture	15.6	3.8	24	2	20	29
no. open cast mine in catchment	12.6	5.1	40	0	20	28
density goats and cattle in catchment	12.2	4.1	34	2	18	28
no. natural barriers to exotic fish movement	13.4	4.7	34	5	20	29
distance first natural barrier from headwaters†	12.0	4.3	35	1	20	29
no. exotic nuisance species	15.1	4.1	27	5	20	28
no. exotic non-nuisance species	10.5	4.6	44	2	20	29
degree native species exploitation*	8.5	3.8	44	2	15	29
no. road/rail bridges*	4.7	2.8	59	0	10	29
no. unbridged road crossings*	7.0	3.2	45	2	15	29
no. downstream culverts*	9.9	4.1	42	3	18	29
no. downstream weirs	12.2	4.4	36	3	20	29
no. downstream dams	15.2	4.4	29	5	20	29
% length channelised	16.4	3.9	23	7	20	29
no. water abstraction points*	9.8	4.5	46	3	20	29
% baseflow abstracted	15.4	4.3	28	5	20	29
% length with regulated flow	13.8	3.6	26	7	20	29
% flow from intercatchment transfer*	10.3	5.4	53	0	20	29
no. point source discharges	13.7	4.9	36	3	20	29
% baseflow as organic effluent	15.3	3.6	23	6	20	29
% baseflow as inorganic effluent	14.5	4.1	28	5	20	29
% catchment with artificial drainage‡	10	–	–	–	–	1
% catchment erosion‡	16	–	–	–	–	1

* Dropped from list because mean weight <50% of maximum or C.V. >50%

† Not relevant when assessing different sections on a single river. Not used in trial application.

‡ New descriptors suggested by questionnaire respondents. Not used in trial application.

3.2 **Descriptor weightings**

Mean weightings for the original descriptors and other relevant statistics are presented in Table 3. Signs (+ or -) associated with descriptors are indicated in Appendix 3. For DEGREE OF MODIFICATION, the highest weighted descriptor was % catchment in native vegetation (17.1 out of a possible 20), followed by % length channelised (-16.4) and % length lined by native vegetation (15.7). Eight descriptors achieved mean weights less than half the possible maximum score or had coefficients of variation >50% (see Table 3), and were dropped from use in the trial application.

The three highest scoring original descriptors for DIVERSITY AND PATTERN were number of tributaries with low degree of modification (7.6 out of a possible 10), substrate heterogeneity (7.5) and number of associated wetlands, lakes and tarns (7.3). Several descriptors, including substrate heterogeneity, were omitted from the list used in the trial application because field surveys were required to obtain measurements, and/or because mean weights were <50% of the maximum possible (see Table 3).

Table 3 *(Continued)*

2. DIVERSITY AND PATTERN

Descriptor	Mean weight	S.D.	C.V. (%)	Min.	Max.	No.
no. stream orders	6.8	3.3	49	0	10	29
altitudinal range	6.9	2.4	35	1	10	29
no. riparian vegetation types per km	5.6	2.4	43	1	10	29
no. geological rock types per km	5.1	2.5	50	0	10	29
no. associated wetlands, lakes, tarns per 100 km^2 of catchment	7.3	2.2	30	2	10	29
no. discontinuities per km	5.1	2.3	46	1	9	29
no. interconnecting headwater catchments*	4.7	2.7	56	1	10	29
no. tributaries with low modification per km	7.6	1.9	25	3	10	29
no. pool/riffle sequences per km†	6.4	2.1	33	2	10	29
no. cascades per km†	5.0	2.4	49	0	10	29
substrate heterogeneity†	7.5	1.6	22	5	10	29
% cover by native aquatic plants†	4.6	2.2	47	0	9	29
no. aquatic plant types†	5.1	2.5	50	1	9	29
no. known native aquatic plant species†	5.1	2.5	48	1	9	29
% cover for fish†	6.8	2.0	29	2	10	29
no. known native fish species	6.7	2.5	37	1	10	29
No. Ecological Regions‡	3.8	1.6	43	2	5	5
Distance from sea§	10	–	–	–	–	1
No. stable large woody debris dams§	7	–	–	–	–	1
% channelised§	9	–	–	–	–	1
% hard and soft rocks§	8	–	–	–	–	1
average slope/slope range§	8	–	–	–	–	1
flow variability§	8	–	–	–	–	1
Average depth, width§	7	–	–	–	–	1

* Dropped from list because mean weight <50% of maximum or C.V. >50%.

[Table 3 continued next page]>>

† Site visit required to make assessment. Not considered in subsequent analyses.

‡ Inadvertently excluded from questionnaire table.

§ New descriptors suggested by questionnaire respondents. Not used in trial application.

Two of the descriptors for RARITY AND UNIQUE FEATURES OR SPECIES were also excluded from the trial because mean weights were less than half the maximum possible (5) (see Table 3). The highest scoring descriptor was number of known rare/endangered species (4.4), followed by number of unusual vegetation types (3.2) and number of unusual geological formations (3.0).

Only two descriptors of FRAGILITY had C.V.s >50% or required a site visit for assessment. The highest scoring descriptors were % catchment as erosion prone land, importance for sensitive life stages (both 3.8 out of a possible 5), and proximity of areas for recolonisation (3.4). Fragility was not assessed in the trial application because of the difficulty in quantifying most of the descriptors. Final lists of descriptors used in the trial application totalled 19 for DEGREE OF MODIF1CATION, 8 for DIVERSITY AND PATTERN, and 4 for RARITY AND UNIQUE FEATURES OR SPECIES (see Table 4).

Table 3 ***(Continued)***

3. RARITY AND UNIQUE FEATURES OR SPECIES

Descriptor	Mean weights	S.D.	C.V. (%)	Min.	Max.	No.
no. large waterfalls	2.8	1.4	49	1	5	29
no. unusual rock types*	2.4	1.5	64	0	5	29
no. unusual vegetation types	3.2	1.4	44	0	5	29
no. unusual geological formations	3.0	1.4	48	0	5	29
length of river or river segment*	2.3	1.4	60	0	5	28
no. known rare/endangered species	4.4	0.8	18	3	5	29
Important spawning grounds†	5	-	-	-	-	1
No. human activities supported†	5	-	-	-	-	1

4. FRAGILITY

Descriptor	Mean weight	S.D.	C.V. (%)	Min.	Max.	No.
stability of flow *	2.7	1.7	61	0	5	28
% catchment as erosion-prone land	3.8	1.4	38	0	5	28
importance for sensitive life stages	3.8	1.2	31	0	5	27
importance of downstream conditions	3.2	1.2	37	0	5	28
vigour of riparian vegetation †	3.3	1.2	37	0	5	28
proximity of areas for recolonisation	3.4	1.3	39	0	5	26

* Dropped from list because mean weight <50% of maximum or C.V. >50%.

† New descriptors suggested by questionnaire respondents. Not used in trial application.

3.3 Trial application: Tongariro River

Values of descriptors used to assess DEGREE OF MODIFICATION, DIVERSITY AND PAITERN, and RARITY AND UNIQUE FEATURES OR SPECIES for the seven sections of Tongariro River are listed in Table 4. Descriptor scores for the three criteria (calculated as described in Table 2) are presented in Table 5, and are summarised for each criterion in Table 6.

The analysis indicated that, based on the descriptors and weightings used, DEGREE OF MODIFICATION generally increased with distance down the river. The upper two sections of Tongariro River (i.e., above Rangipo Barrage) had low DEGREE OF MODIFICATION reflecting the pristine nature of the subcatchments and the absence of flow regulation. Sections 3-5 (Rangipo Barrage-Whitikau Stream confluence) had higher DEGREE OF MODIFICATION caused largely by flow management, and scores were

Table 4 Values of descriptors used under three criteria to assess natural value of seven sections of Tongariro River.

1. DEGREE OF MODIFICATION								
		SECTION						
Descriptor	**Weight**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
% catchment in native vegetation	+17.1	100	100	100	97	81	47	90
% length channelised	-16.4	0	0	0	0	0	0	0
% length lined by native vegetation	+15.7	90	100	100	100	90	60	10
% catchment in crop/improved pasture	-15.6	0	0	0	0	5	21	0
% baseflow abstracted *	-15.4	0	0	62	42	50	35	35
% baseflow as organic effluent	-15.3	0	0	0	0	0	<O.3†	<O.3†
no. downstream dams	-15.2	2	2	1	1	0	0	0
no. exotic nuisance species	-15.1	0	0	0	0	0	0	0
% baseflow as inorganic effluent	-14.5	0	0	0	0	0	0	0
% length with regulated flow	-13.8	0	0	100	100	100	100	100
no. point source discharges	-13.7	0	0	0	0	0	1	0
no. natural barriers to exotic fish movement ‡	+13.4	2	2	2	1	0	0	0
% length lined by non-production woodland §	+13.2	100	100	100	100	100	100	90
% length with bank fencing ║	+13.1	0║	0║	0║	0║	0║	40	20
% catchment in production forest	-13.0	0	0	0	3	14	32	0
no. open cast mine in catchment¶	-12.6	0	1	0	0	0	0	0
no. downstream weirs	-12.2	0	0	0	0	0	0	0
density goats and cattle in catchment**	-12.2	0	0	0	0	0	38	20
no. exotic non-nuisance species††	-10.5	1	3	1	1	2	2	4
Sum of weighting factors ‡‡	268.0							

* Water from Moawhango diversion not considered. Mean flow used instead of base flow in trial application. See Appendix 6 for calculations.
† Maximum value used.
‡ Only barriers downstream of river sections considered (i.e., Waikato Falls and Tree-trunk Gorge). Waikato Falls is included in Section 4 as it is at the downstream end of that section.
§ Includes native forest and protection forest in this example.
║Bank fencing only relevant where goats and cattle present. Where absent, sections were given the full score in Table 3.
¶Includes quarries. Only active sites were counted. Expressed as density per km^2. Information provided by local conservancy.
†† Brook trout, rainbow trout, brown trout, brown bullhead catfish, goldfish, *Ranunculus.*
‡‡ All weights considered as positive to calculate sum.

[Table 4 continued next page]>>

highest for the lower two sections because of catchment development (for forestry and farming), and the presence of goats and cattle where the river banks were not extensively fenced.

DIVERSITY AND PATTERN was highest in Section 3 (Rangipo Barrage-Oturere Stream confluence), and this largely reflected the short length of this section (4 km) relative to the number of tributary confluences, discontinuities, and riparian vegetation and rock types. DIVERSITY AND PAITERN was low in Section 4-6, but increased in Section 7 because of the association of this section and subcatchment with wetlands and Lake

Table 4 *(Continued)*

1. DEGREE OF MODIFICATION

Descriptor	Weight	SECTION 1	2	3	4	5	6	7
no. tributaries with low modification per km*	+7.6	1.5	1.6	2.0	0.9	0.1	0	0
no. assoc. wetlands , lakes, tarns per 100km^2 †	+7.3	0	0.4	0	0	0	6.7	40
altitudinal range	+6.9	780	60	80	160	140	80	10
no. stream orders ‡	+6.8	4	1	2	1	1	1	1
no. known native fish species§	+6.7	0	0	0	0	1	3	3
no. riparian vegetation types per km ‖	+5.6	0.1	0.2	0.3	0.1	0.1	0.2	0.1
no. geological rock types per km ‖	+5.1	0.1	0.6	0.8	0.4	0.3	0.1	0.1
no. discontinuities per km ¶	+5.1	1.5	1.6	2.0	1.0	0.4	0.5	0
Sum of weighting factors	**51.1**							

* Defined as tributaries flowing through catchments predominantly in native vegetation. Expressed as number of confluences per km of main channel.
† As recorded on NZMS 260 (1:50 000) maps.
‡ As represented by the main channel.
§ Determined from NIWAR Freshwater Fisheries Database and local information.
‖Determined from Land Resource Inventory (1:63 360) maps. Only vegetation types that comprised >40% of cover were considered.
¶ Expressed as number of natural discontinuities (tributary confluences (including modified tributaries) and waterfalls) per km of channel. Determined from NZMS 260 (1:50 000) maps.
** All weights considered as positive to calculate sum.

3. RARITY AND UNIQUE FEATURES OR SPECIES

Descriptor	Weight	SECTION 1	2	3	4	5	6	7
No. known rare/ endangered species *	+4.4	1	1	1	1	1	0	2
No. unusual vegetation types	+3.2	0	0	0	0	0	1†	0
No. unusual geological formations ‡	+3.0	0	0	0	2	0	0	1
No. large waterfalls	+2.8	0	0	0	1	0	0	0
Sum of weighting factors §	**13.4**							

* Determined form local conservancy knowledge. Considered rare/ endangered if listed in Molloy and Davis (1992).
† Stand of mountain beech
‡ Determined from Geopreservation Inventory and 1:50 000 maps.
§ All weights considered as positive to calculate sum.

Table 5 Scores for descriptors, total scores and criteria scores (out of 100) calculated as described in Table 2 for 3 criteria applied to 7 sections of Tongariro River.

1. DEGREE OF MODIFICATION

Descriptor	Upper limit	SECTION 1	2	3	4	5	6	7
% catchment in native vegetation	≥80	17.1	17.1	17.1	17.1	17.1	10.0	17.1
% length channelised	≥60	16.4	16.4	16.4	16.4	16.4	16.4	16.4
% length lined by native vegetation	100	15.7	15.7	15.7	15.7	14.1	9.4	1.6
% catchment in crop/improved pasture	≥60	15.6	15.6	15.6	15.6	14.3	10.1	15.6
% baseflow abstracted	≥60	15.4	15.4	0	4.6	2.6	6.4	6.4
% baseflow organic effluent	≥60	15.3	15.3	15.3	15.3	15.3	15.2	15.2
no. downstream dams	≥1	0	0	0	0	15.2	15.2	15.2
no. exotic nuisance species	≥2	15.1	15.1	15.1	15.1	15.1	15.1	15.1
% baseflow inorganic effluent	≥60	14.5	14.5	14.5	14.5	14.5	14.5	14.5
% length with regulated flow	≥60	13.8	13.0	0	0	0	0	0
no. point source discharges	≥5	13.7	13.7	13.7	13.7	13.7	11.0	13.7
no. natural barriers to exotic fish movement	≥1	13.4	13.4	13.4	13.4	0	0	0
% length lined by non-production woodland	100	13.2	13.2	13.2	13.2	13.2	13.2	11.9
% length with bank fencing	100	13.1	13.1	13.1	13.1	13.1	5.2	2.6
% catchment in production forest	≥80	13.0	13.0	13.0	12.5	10.7	7.8	13.0
no. open cast mine in catchment	≥5	12.6	10.1	12.6	12.6	12.6	12.6	12.6
no. downstream weirs	≥2	12.2	12.2	12.2	12.2	12.2	12.2	12.2
density goats and cattle in catchment	100	12.2	12.2	12.2	12.2	12.2	7.6	9.8
no. exotic non-nuisance species	≥10	9.5	7.4	9.5	9.5	8.4	8.4	6.3
Total		251.8	246.4	222.6	226.7	220.7	190.3	199.2
DEGREE OF MODIFICATION score		**6.0**	**8.1**	**16.9**	**15.4**	**17.6**	**29.0**	**25.7**

2. DIVERSITY AND PATTERN

Descriptor	Upper limit	SECTION 1	2	3	4	5	6	7
no. tributaries with low modification per km	≥3	3.8	4.1	5.1	2.3	0.3	0	0
no. assoc. wetlands, lakes, tarns per 100 km^2	≥50	0	<0.1	0	0	0	1.0	5.8
altitudinal range	≥2000	2.7	0.2	0.3	0.6	0.5	0.3	<0.1
no. stream orders	≥6	4.5	1.1	2.2	1.1	1.1	1.1	1.1
no. known native fish species	≥10	0	0	0	0	0.7	2.0	2.0
no. riparian vegetation types per km	≥1	0.6	1.1	1.7	0.6	0.6	1.1	0.6
no. geological rock types per km	≥1	0.5	3.1	4.1	2.0	1.5	0.5	0.5
no. discontinuities per km	≥5	1.5	1.6	2.0	1.0	0.4	0.5	0
Total		13.6	11.2	15.4	7.6	5.1	6.5	10.0
DIVERSITY AND PATTERN SCORE		**26.6**	**21.9**	**30.1**	**14.9**	**10.0**	**12.7**	**19.6**

{Table 5 continued next page}»

Table 5 *(Continued)*

3. RARITY AND UNIQUE FEATURES OR SPECIES									
		SECTION							
Descriptor	**Upper limit**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
no. rare/ endangered species	≥3	1.5	1.5	1.5	1.5	1.5	0	2.9
no. unusual vegetation types	≥3	0	0	0	0	0	1.1	0
no. unusual geological forms	≥3	0	0	0	2.0	0	0	1.0
no. large waterfalls	≥3	0	0	0	0.9	0	0	0
Total		1.5	1.50	1.5	3.4	1.5	1.1	3.9
RARITY AND UNIQUE FEATURES OR SPECIES SCORE		**11.2**	**11.2**	**11.2**	**25.6**	**11.2**	**8.2**	**29.1**

Table 6 Summary of scores (rounded off, out of 100) for three criteria used to assess natural value of seven sections of Tongariro River.

	SECTION						
CRITERIA	**1**	**2**	**3**	**4**	**5**	**6**	**7**
DEGREE OF MODIFICATION	6	8	17	15	18	29	26
DIVERSITY AND PATTERN	27	22	30	15	10	13	20
RARITY AND UNIQUE FEATURES OR SPECIES	11	11	11	26	11	8	29

Taupo. RARITY AND UNIQUE FEATURES OR SPECIES was relatively low for Sections 1, 2, 3, 5, and 6, but was considerably higher in Sections 4 and 7. This was because of Treetrunk Gorge and Waikato Falls in Section 4, the presence of bittern and dabchick associated with wetlands adjacent to the lower river, and because the river delta is considered an important feature in the Geopreservation Inventory.

4. DISCUSSION

The procedure for assessing the natural value of river systems which was trialled in this report quantitatively compared different sections of river. These comparisons were based on the average opinion of limnologists with a known range of specific interests and affiliations. This quantitative approach minimises the subjectivity associated with nonquantitative evaluations, but increases the amount of information required to make an assessment.

The system proposed is probably better applied to whole river systems rather than sections of river, as this would enable different rivers in the same region to be compared. When doing this, it would be important to compare only rivers of the same general type, indicating the need for an ecotype classification system that can be applied within eco-regions. For example, some types of rivers may have naturally low diversity associated with them and would rank low for DIVERSITY AND PATTERN when compared with different types of rivers in the same region. Collier and McColl (1992) discussed some possible options for an ecotype classification and suggested that origin of flow might provide the basis for a useful first dichotomy.

It is not intended that scores for the different criteria be combined to provide a single overall score for natural value, as this would result in loss of information and may lead to erroneous decisions being made. Rather, management decisions would need to be based on the priorities perceived by managers and the feasibility of different management options. However, before this proposed system can be generally applied for assessing natural value further refinements are needed.

- Descriptors for FRAGILITY need to be re-evaluated to make them easier to assess.

- Further work is required on the definition of descriptors based on the comments listed in Appendix 5, and weightings need to be re-evaluated in the light of further refinements.

- Discussions between limnologists are necessary to define the upper limits of descriptors based on existing biological knowledge. In the trial study example, most upper limits were set arbitrarily.

- The refined system should be operated as a user-friendly, expert system computer package similar to that developed by O'Keefe *et al.* (1987) to make it easy to use.

5. ACKNOWLEDGEMENTS

I am very grateful to all those who made the time to participate in the workshops and to answer the questionnaire. Thanks also to Harry Keys, Cam Speedy, Rob McLay and other staff of the Tongariro/Taupo Conservancy for providing some of the data for the trial application, and to Ian Mackenzie for final polishing of the manuscript. Special thanks to John Wiley & Sons Ltd for permission to reproduce as Appendix 2, the entire Chapter 13: "Assessing the Natural Value of New Zealand Rivers" by K.J. Collier and R.H.S. McColl, from *River Conservation and Management* edited by P.J. Boon, P. Calow, and G.E. Petts, published in 1992.

6. REFERENCES

Biggs, B.J.F., Duncan, MJ., Jowett, LG., Quinn, J.M., Hickey, C.W., Davies Colley, R.J. and Close, M.E. 1990. Ecological characterisation, classification, and modelling of New Zealand rivers: an introduction and synthesis. *New Zealand Journal of Marine and Freshwater Research* 24: 277-304.

Collier, K.J. 1992. Linking the mountains to the sea- conserving New Zealand's rivers. *Forest & Bird November:* 26-32.

Collier, K.J. and McColl, R.H.S. 1992. Assessing the natural value of New Zealand rivers. Chapter 13 in P.J. Boon, P. Calow, and G.E. Petts (Eds): *River conservation and management* John Wiley & Sons, London. (See Appendix 2)

Molloy, J. and Davis, A. 1992. Setting priorities for the conservation of New Zealand's threatened plants and animals. Department of Conservation, Wellington.

O'Keeffe, J.H.; Danilewitz, D.B. and Bradshaw, J.A. 1987. An “Expert System” approach to the assessment of the conservation status of rivers. *Biological Conservation* 40: 69–84.

Park, G.N., Simpson, P.G., Dingwall, P.R., Ogle, C.C., Mitchell, N.D. and Myers, S.C. 1986. The New Zealand Protected Natural Areas Programme : a scientific focus. *Biological Resources Centre Publication No.4.* New Zealand Department of Scientific and Industrial Research, Wellington.

Simpson, P. 1985. WERI: a plug for protection. *The Landscape, Autumn:* 5-19.

APPENDIX 1
Proceedings of a workshop on aquatic reserve identification held during the Limnological Society Conference, Christchurch, May, 1987

IDENTIFICATION OF AQUATIC RESERVES

This workshop was suggested by the practical and administrative problems experienced in evaluating and actually setting up reserves for aquatic ecosystems, and the lack of recognition of these systems in present surveys and databases. It was an ideal opportunity to discuss mechanisms, especially with the government department reorganisation and much legislation under review.

Keynote speakers backgrounded different areas and highlighted problems which were used as the basic objectives for three working groups.

Janet Owen (Protected Ecosystems Directorate, DOC) outlined DOCs structure with reference to their quite extensive responsibilities for reserves and advocacy for freshwater areas and surrounds. They are also responsible for the Protected Natural Areas (PNA) system and are attempting to get funds for an initial N.Z. wide survey. The PNA process identifies priority and representative reserve areas. The steps involved are reconnaissance (rapid inventory into major types), survey (rapid again), analysis and evaluation, and then implementation to protect systems (see S. Myer's article for further details).

Problems with applying the PNA process to waterbodies were in both the overall structure and the survey method. PNA gives types based on land form and land vegetation and the ecological districts derived from this do not seem appropriate for representative areas for waterbodies. They do not comply with the natural catchment boundaries and some lakes or river types, e.g., glacial lakes could occur in several ecological districts. A river needed as a reserve for a fish species or a collection of waterbodies needed for migration routes for wildlife may be in a number of different districts.

The survey method seems to poorly identify and type waterbodies and the question of better ways of doing this was raised. The appropriateness of the evaluation criteria used for PNA was also queried.

Brent Cowie (Water & Soil, MWD) outlined the acts which pertain to water, or waterbody protection. He updated the water conservation order (WCO) process which highlighted the lengthy and costly process which has arisen from ambiguous legislation. The result is 12 applications over 4 years – with only 2 fully resolved.

Laurel Tierney (MAF) spoke on Faunistic Reserves which were MAF's (now DOC's) responsibility. A potentially powerful statute has been little used, because of lack of will and lack of procedures. It mainly prevents species introduction and it has been applied in situations where little threat occurs, at least from natural sources, and hence little management is required.

Participants then divided into three working groups.

1. Classification Methods for the Purpose of Prioritising Reserve Effort
Convenor: Sue Maturin, Scribe: Ann Graesser

In this group, classification methods for aquatic habitats were discussed that could be both:
- Easily and quickly used by non-experts, and
- Interpreted by experts for the assessment of protection needs and/or further biological investigation.

Terrestrial based systems do not provide enough information for the freshwater scientists to classify and assess the protection needs of the habitat.

It was suggested that particular biological groups, such as fish or aquatic macrophytes, could be used as indicators of the type and condition of aquatic habitat. However, this would involve intensive investigations of each aquatic habitat to document the diversity of the biota present, which is not feasible for DOC because of pre-existing time and financial constraints.

An alternative suggestion was to expand the currently implemented PNA system to include more information regarding the basic physico-chemical characteristics that are generally considered to be key features of aquatic habitats. Many physico-chemical parameters could be either observed in the field or determined from topographical maps. These include sources of water (depending on the timing of the survey), size of water body, channel morphology, substrate size range, and water colour and turbidity. Other characteristics could also provide useful information for protection assessment such as access for wildlife, especially fish, wildlife refuge value, "naturalness" or extent of man-made disturbance in the catchment, representativeness or uniqueness of the habitat. These could be also visually assessed in the field, or determined from discussions with experts.

Freshwater scientists working in the area (government bodies, catchment boards, acclimatisation societies, university and agricultural colleges and environmental consultancy groups) could be a source for the initial information needed to classify the aquatic habitats within an ecological district. Such discussions could be useful to both parties, reducing duplication of research effort as well as involving experts in the assessment procedures.

Recommendations

1 That “types” of waterbodies be classified using natural boundaries and taking into account the needs of the biota of those types.

2 That the PNA process use existing biological expertise (including Limsoc networks) to gather information before the field survey stage and to evaluate results.

3 That the PNA survey be expanded to include some basic physico-chemical information.

2. Criteria for Evaluation and Decision Making

Convenor & Scribe: Chris Richmond

This working group looked at the criteria for evaluating the "value" of a waterbody type once it has been identified as a type, e.g., the decision between one dune lake and another for reserve status. What criteria should we use? Should they be qualitative or quantitative? This is always easiest for obvious priority areas and less easy for representative areas.

The group worked with a number of different examples of evaluation criteria: WERI, PNA, the one used by Limsoc (previously) and a Swedish example and came up with two sets.

The first set identifies the reserve values:

1 Ecological representativeness, or, rare type of ecosystem
2 Diversity and pattern
3 Rarity and unique features or species
4 Long term viability
5 Historic or research value
6 Degree of modification

We place rarity with ecological representativeness you may value the waterbody equally for either criterion.

The second set determines the degree of modification:

1. Type of impact
2. Immediacy of impact

3. Size of impact
4. Positive or negative
5. Features that may be impacted
6. Opportunity to prevent, litigate or enhance

Quantitatively, attempting a simple sum of the "value" by using a 3-point assessment scale for each criterion did not work. The difference in "value" of Lake Hayes and Lake Taupo was not clearly distinguished. The task of providing weightings for each feature was seen to be a difficult but necessary one.

The priority for reservation then becomes a multi-function combination.

Priority = f $\sum$ value, threat, protectability.

Recommendations

1. That evaluation of aquatic ecosystems uses a set of identifying features to determine the degree of modification.
2. That priority for reservation is assigned by: Priority = f $\sum$ value, threat, protection.
3. That a weighting system should be developed by a joint MWD/DOC working party, possibly with Limsoc assistance. A pilot project in a district should aim for consensus of expert opinion using a modified Delphi technique.
4. That national databases be developed and implemented for rare plants, invertebrates and special natural features, acknowledging that the existing database for fish is adequate.

3. Legal Mechanisms for Reservation of Waterbodies

Convenor & Scribe: Brent Cowie

This group discussed what legal means were available to protect aquatic biota or habitats and what improvements to these provisions seem necessary.

Aquatic fauna can be protected in several ways. The Wildlife Act allows for the establishment of wildlife refuges, reserves and management areas. These provisions have been widely used. Faunistic Reserves can be established under the Fisheries Act, but only four such reserves have been gazetted to date. There are presently no provisions for establishing aquatic floristic reserves, which there should be.

Rivers and lakes can be protected by water conservation orders. Proposed changes to the water and soil legislation would also help facilitate aquatic habitat protection, e.g., the proposed schedule of protected waters. The water conservation order process has become bogged down in legal technicalities.

It requires simplification.

Few means are available to protect wetlands or the land-water interface in general. Conservation orders cannot cover wetlands. The Town and Country Planning Act is also deficient in this area. However, the Court of Appeal has ruled that water rights for land drainage shall not necessarily be granted in highly valued wetlands (Whangamarino decision). Wetland protection merits legislative action.

Recommendation

That the Limnological Society take an active role as a group of informed scientists in promoting legislative changes to protect highly valued aquatic or wetland flora, fauna and habitats.

PLENARY SESSION
Convenor & Scribe: Lucy Harper

In the plenary session it was suggested decision making by managers would be helped by a survey to collate existing information. This would be used to construct a list of different information held by different agencies and a list of experts in different fields. The Biological Resources Centre, as part of DOC, would be an obvious agency to co-ordinate this.

It also became clear that as well as the gaps in the protective legislation, there is also a lack of a clear mandate or ethic to use it which leads to problems in implementation. Splits of responsibility, splits of the advocacy role and a general lack of finance means that buck passing (or "no-buck" passing) continues. Even when there is a strong responsibility for advocacy, e.g., water conservation orders, the strong opposition from development agencies, the legal ambiguities and the effect of fund cutting and user pays present problems.

The synthesis of the topic discussed provides a unified and practical system to achieve the objective of gaining aquatic reserve status for some of our waterbodies. We looked at what we want to reserve, how we type it, and how ideally we want to see it protected.

The recommendations of the workshop can be passed to the DOC divisions that are responsible for reserves and are also useful input to the Limsoc subcommittee on protected natural areas and legislation.

The next stage seems to be to follow the fisheries example and put more emphasis on identifying the actual requirements of space, area, water quality, etc needed to allow managers to evaluate the suitability of an area for reservation for a particular purpose.

THE PNA SURVEY PROCESS
Shona Myers

The following is a brief description of the survey phase of the Protected Natural Areas programme, which was presented at the aquatic reserves workshop of the Limnological Society's annual meeting. Responsibility for the PNA programme now rests with the Department of Conservation.

The Aims of the PNA Programme are:

- To seek basic information about the types, diversity, pattern and quality of the natural ecosystems in an ecological district and to identify representative examples of these areas for protection.
- The achievement of a network or protected natural areas that includes adequate examples of all classes of natural ecosystems.

An Urgent Task
The design of the programme has been strongly influenced by the knowledge that the task is urgent and many remaining ecosystems are being lost or depleted. There is a need therefore for rapid and urgent coverage of ecological districts where the representativeness of the existing reserves is poor.

Primary Focus on Terrestrial Ecosystems
The primary focus for PNA survey has been on terrestrial ecosystems for the following reasons:

1. The survey programme has needed to be manageable both administratively and politically in terms of cost and rate of coverage.
2. In defining the ecological character of a district during a survey, the readily recognisable formal properties of the land are used; predominantly landform and vegetation patterns.

From the onset however the PNA surveys have not excluded freshwater and some marine ecosystems and have identified a range of wetlands, including swamps, lagoons, estuaries and lakes, as important natural areas.

The PNA Survey of an Ecological District involves:

1. Reconnaissance

The reconnaissance phase is important for careful planning of the field survey. Existing knowledge of the district is gathered (e.g., from existing data bases, previous surveys, people with knowledge of the natural history of the area), a field understanding of the natural ecosystems is developed, and study sites selected from this information. The ecological district is divided into recognisable land systems and ecological units (an ecological unit is the combination of a natural community type, usually a vegetation type, and the landform it occurs on). The ecological unit is the key to describing the natural diversity, in the sense of the ecological character, of the district.

2. Survey

A detailed vegetation and landform survey of selected natural areas is undertaken using vegetation as the primary parameter. Vegetation is used because it is generally easier and quicker to measure than other components of the ecosystems. Survey sites are chosen to represent larger tracts of land, to sample unusual vegetation or natural community types, to survey discontinuous vegetation, landform types or other important ecological units not included in the existing network of protected natural areas.

3. Evaluation

The selection of the natural areas that best represent the ecological character and range of ecosystems and landscapes in the ecological district – "Priority for Protection" - forms the heart of a PNA survey report. Selection of these areas is based on a number of criteria including:

- representativeness
- diversity
- rarity and special features naturalness
- long term ecological viability
- size and shape buffering, surrounding landscapes

Representativeness is the primary criterion for selection, i.e, typical or characteristic natural areas which were formerly common and widespread in the district. The ecological unit (vegetation and landform) is the key to determining which areas are representative. Features which are important to protect for other reasons can also be identified.

4. Implementation

Implementation involves national evaluation and publication of a survey report. After scientific review of the survey proposals, the process then involves negotiation with landowners, landholders and managers to achieve levels of protection of important sites. In advancing the protection of important natural areas DOC will be looking at protection in terms of leases, covenants, rate relief, management agreements, etc., as well as purchase by Crown. Liaison with other agencies involved in protection of natural areas (e.g., QEII National Trust, Ministry of Works, local authorities) will be advocated.

Workshop Organising Committee: Sally Davis, Philippe Gerbeaux, Don Jellyman, Ian Lineham & Jonet Ward

APPENDIX 2
Paper presented by K.J. Collier and R.B.S. McColl to the River conservation and management conference in York, U.K., in 1990.

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13

Assessing the Natural Value of New Zealand Rivers

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INTRODUCTION

Human-induced changes to the natural environment of New Zealand, especially to the lowlands, have been particularly significant since the acceleration of European colonization in the last 150 years. Continuing demands on natural resources have led to growing concern that some types of indigenous ecosystems are not represented in the existing protected areas network which predominantly consists of high country reserves (Figure 13.1). This concern led to legislative recognition that the network should ensure "as far as possible, the survival of all indigenous species of flora and fauna, both rare and commonplace, in their natural communities and habitats, and the preservation of representative samples of all classes of natural ecosystems and landscape which in the aggregate originally gave New Zealand its own recognizable character".

An outcome of this was the Protected Natural Areas Programme (PNAP), which seeks to establish a network of reserves that includes adequate examples of all types of ecosystems (Myers et al, 1987). A programme has also been set up that identifies mainly palustrine wetlands that are of representative and ecological importance (Simpson, 1985). The Department of Conservation (DOC) is responsible for administering these programmes, and is currently developing a network of marine protected areas.

Freshwater ecosystems have received comparatively little attention and remain under-represented in the New Zealand protected areas network (McColl, 1987). Insufficient recognition has been given to the international importance of the native aquatic biota, or to the diverse range of freshwater ecosystems found in New Zealand. Furthermore, modern criteria such as representativeness, diversity, and rarity that can be used to describe natural value (as embodied in the quotation above) have not been adequately interpreted for freshwater ecosystems, making assessment difficult.

In this chapter we describe significant features of New Zealand's running-water ecosystems, review anthropogenic changes that have affected the natural character of streams and rivers, and discuss the application of modern criteria for assessing their natural value with a view to identifying and prioritizing natural riverine areas for

River Conservation and Management. Edited by P. J. Boon. P. Calow and G.E. Petts

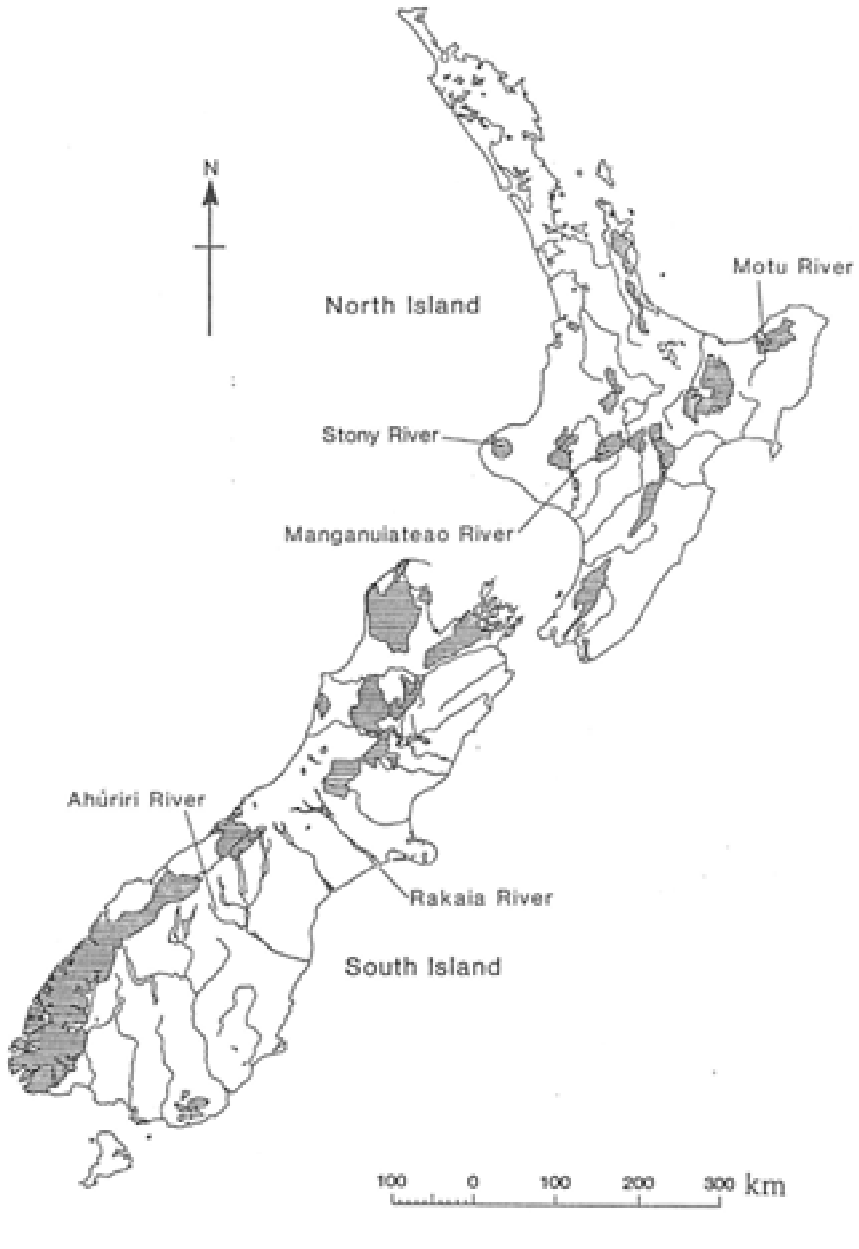


FIGURE 13.1 Map of New Zealand showing protected areas (hatched). Rivers covered by Water Conservation Orders at the time of writing are named

protection. We view rivers from a catchment perspective whereby natural value reflects not only the wetted channel and the aquatic biota therein but also the integrity of adjacent floodplains, wetlands, and terrestrial vegetation.

CHARACTERISTICS OF NEW ZEALAND RIVERS

Description of riverscape

The main islands of New Zealand span 13° of latitude, but the dominion also includes part of Antarctica and over 500 offshore islands that range from the sub-tropical Kermadec Islands at 29°S to the sub-antarctic Campbell Islands at 53°S.Several aquatic invertebrate species are restricted to some of the more distant island groups (McLellan, 1973), but little else is known of the running-water habitats on most offshore islands.

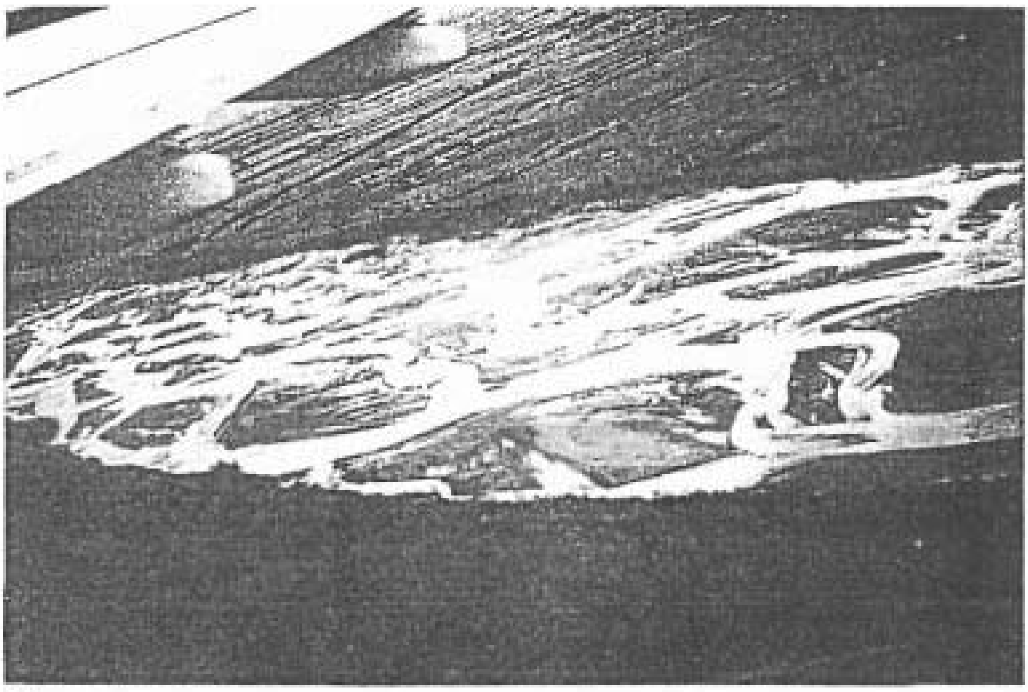
Rivers and streams are abundant on the main islands because of frequent rainfall and the presence of extensive and highly dissected mountain ranges in many areas. No point is further than 130 km from the sea and consequently river systems are short (only four exceed 250 km in length) compared with many in mainland Europe, Asia and America (Higler, 1988; *NZ Official Year Book,* 1988/89). Nevertheless, the range of river types on main islands is very diverse, reflecting the geologically young and active nature of the landscape.

Several North Island rivers flow down the slopes of dormant volcanoes or drain their extensive ash deposits, and some active volcanic centres give rise to geothermally influenced streams with unusual water chemistries and biological communities (Vincent and Forsyth, 1987). In the South Island, geothermally influenced waters occur mostly along the Alpine Fault which marks the junction of the Indian-Australian and Pacific Plates and gives rise to the axial ranges of the Southern Alps.

Shingle washed into watercourses fro m the Southern Alps and North Island mountains is deposited on the eastern lowlands to form large braided rivers (Figure 13.2(a)), examples of which are found in few other places around the world. On the west of the South Island, some large glaciers terminate near the coast and give rise to short and turbid rivers with low summer water temperatures and little aquatic life (Figure 13.2(b)). Naturally acidic, brown-water streams with distinctive microbial communities and epilithon (stone surface organic layers) emanate from wetlands on lowlands of the South Island's west coast (Collier and Winterbourn, 1987, 1990).

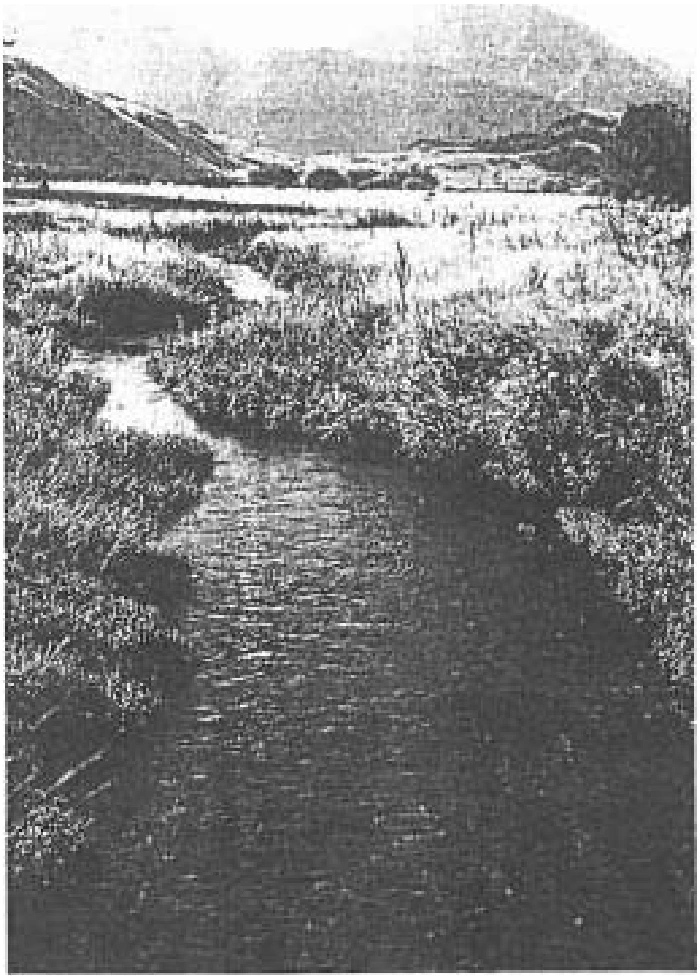
Streams with shifting, sandy substrates are common in the north of the South Island, and streams with limestone bedrock and substantial subterranean flows also occur there and at several places in the North Island (e.g. Collier and Wakelin, 1990). Spring-and lake-fed streams are found in many parts of the country and these exhibit varying degrees of constancy of flow and temperature (Figure 13.2(c)). Waikoropupu Springs in the north of the South Island is one of the largest cold springs in the world and supports impressive growths of native macrophytes (Coffey and Clayton, 1988).

In parts of the northern North Island, streams flow through kauri forest (dominated by *Agathis australis)* which is comparable in community structure to lowland tropical rain forest (Towns, 1979). Elsewhere in the North Island and in the South Island, native forest consists predominantly of beech (*Nothofagus* spp.) and mixed podocarp species.



(a)

(b)



(c)

FIGURE 13.2. Examples of different types of rivers that are found in New Zealand. (a) Large river with braided channel; (b) short turbid river fed by glacial meltwater; (c) lake-fed stream with relatively constant flow .

Like the northern kauri forests, these are evergreen and provide year-round shade and inputs of leaf litter to the streams that flow beneath their canopies. Approximately 14% of New Zealand is in the alpine zone, and consequently many river catchments extend into subalpine scrub, tussock grassland and scree (Molloy, 1980; Winterbourn, 1987). Mountain streams are typically turbulent and fast-flowing with unstable beds and poor debris-retention characteristics (Winterbourn et al, 1981).

The native biota of New Zealand rivers

The main islands of New Zealand became separated from Gondwanaland about 80 million years ago and the subsequent long isolation has resulted in a very high degree of endemism in the biota. About 90% of the arthropod species are endemic to New Zealand (Kuschel, 1975), as are a similar proportion of the freshwater fish species (McDowall, 1990). However, the diversity of aquatic invertebrate, plant, and fish communities is generally low in New Zealand compared with manylotic (running-water) ecosystems overseas, and, for fish at least, this is thought to reflect the long isolation and tectonic instability of the country (Winterbourn et al, 1981; Coffey and Clayton, 1988; McDowall, 1990).

In pre-human times, the vascular plant and bryophyte communities of New Zealand streams are thought to have consisted predominantly of species adapted to the heavily

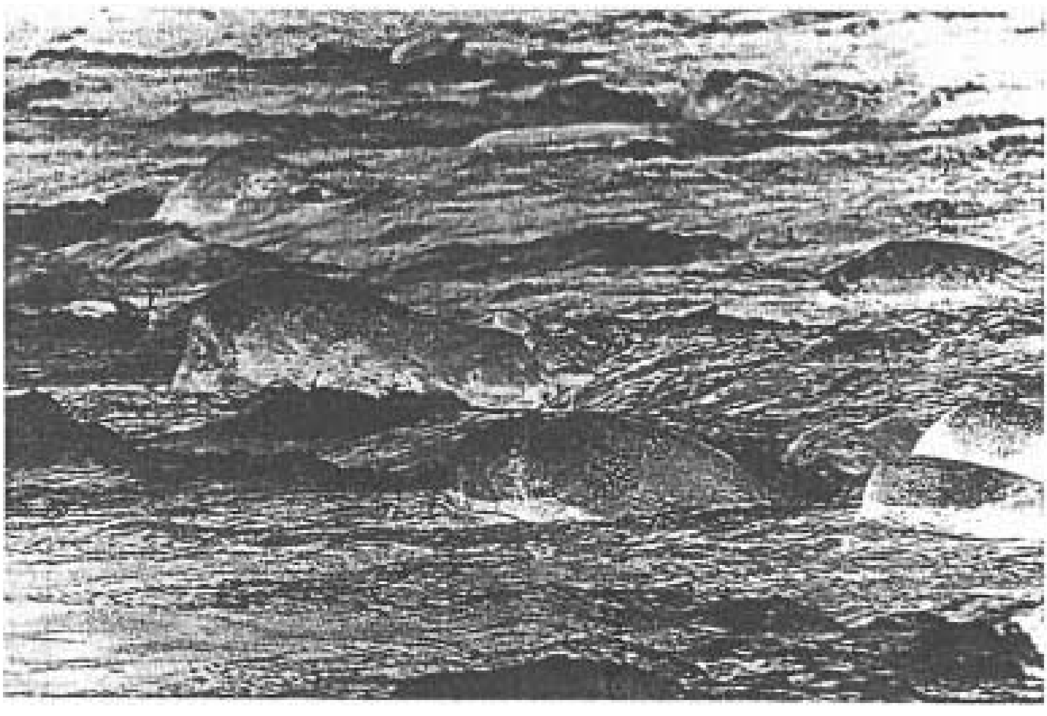


FIGURE 13.3. The blue duck (centre) is playing an increasingly important role in river conservation in New Zealand, Pairs occupy territories mostly on undisturbed, fast-flowing rivers.

shaded conditions provided by native forest cover (Howard-Williams et al, 1987). Unlike all other significant land masses, emergent flood-resistant plants (rheophytes) are absent from our streams. Similarly, several groups of invertebrates that are common elsewhere are poorly represented in New Zealand running waters. These include several families of Trichoptera and Ephemeroptera, and the Megaloptera, Odonata, Gastropoda, and Crustacea (Winterbourn et al, 1981). The native freshwater fish fauna is also comparatively sparse, with approximately half of the species belonging to the Southern Hemisphere family Galaxiidae (McDowall, 1990). A previously widespread and abundant species of native fish (*Prototroctes oxyrhynchus*) has become extinct since the arrival of Europeans, but the precise reasons for this are unclear.

One species of endemic frog (*Leiopelma hochstetteri*), now confined to the northern half of the North Island, is often closely associated with mountain streams, and an extinct species of stream-dwelling frog (*Leiopelma waitomoensis*) is thought to have occurred in parts of the North Island (Worthy, 1987). New Zealand has no native aquatic mammals, but many species of native birds utilize rivers and their associated floodplains and wetlands as breeding and feeding habitat (Hughey, 1987). The species most closely associated with rivers is the blue duck (*Hymenolaimus malacorhynchos*) (Figure 13.3), which lives year-round on single-channel, fast-flowing rivers, and was once widespread throughout most of the country. Braided rivers are used as seasonal breeding and feeding habitat by several species of Charadriiformes such as the wrybill (*Anarhynchus frontalis*) and black stilt (*Himantopus novaezealandiae*), whereas single-channel, slow-flowing lowland rivers provide feeding habitat for species such as shags (Hughey, 1987).

Anthropogenic changes to the riverscape

Since the arrival of humans in New Zealand approximately 90% of natural wetlands have been drained or otherwise lost (Howard-Williams et al, 1987), and unmodified indigenous forest cover has been reduced from 78% to about 22% of land surface (Molloy, 1980).Loss of native forest has been particularly pronounced on the lowlands, where it now represents only 15% of its pre-human extent (Anon., 1989), and deciduous Northern Hemisphere willow species (mainly *Salix fragilis)* are now the typical riparian tree (Johnson and Brooke, 1989). Consequently, no rivers in the North Island or on the east of the South Island now exist with catchments that are wholly unmodified from the headwaters to the sea, and only about 11 rivers in these areas have more than half their catchments in unmodified native vegetation.

Removal of native forest along streams and rivers has proved detrimental to the shade adapted aquatic flora which could not compete with those adventive colonists that are tolerant of high light levels (Howard-Williams et al, 1987). As result, the macrophyte flora of most of New Zealand's lowland streams is characterized by adventive species such as watercress (*Nasturtium* spp.), sweet grass (*Glyceria* spp.), and starwort (*Callitriche stagnalis*). Clearance of native vegetation from catchments is also thought to have contributed to the decline in distribution of blue duck (Kear,1972), and to have caused changes in the structure of native fish communities (Hanchet, 1990). In contrast, some aquatic invertebrate communities appear comparatively resilient to removal of riparian vegetation, suggesting adaptability to different food resources and environmental conditions (Winterbourn, 1986; Collier et al, 1989).

Soil erosion, wetland drainage, and river channelization have greatly modified habitat in some rivers (McColl and Ward, 1987), whereas nutrient enrichment from agriculture and other sources has altered the composition and structure of aquatic invertebrate communities in some areas (e.g. Stark, 1985). Construction of dams and abstraction of water have caused problems at a number of sites for some of the 17 native fish species that normally require access to and from the sea to complete their life-cycles. Predation and competition by exotic fishes has also been implicated as a factor that has detrimentally affected native fisheries and some species of aquatic invertebrates (McDowall, 1987; Glova, 1989; Townsend et al, 1990).

Twenty species of exotic fishes (including seven species of salmonids) have been introduced into New Zealand waterways, although most of these have localized distributions at present (McDowall, 1990). Many of the salmonids provide important recreational fisheries, and strong runs of quinnat salmon (*Oncorhynchus tshawytscha*) have become established in braided rivers of the South Island. Brown trout *(Salmo trlltta)* and rainbow trout *(Oncorhynchus mykiss)* have become widespread in the high-quality waters of many New Zealand rivers, and they form the basis of an important sports fishery. Several species of freshwater snail (three species of *Lymnaea, Planorbarius corneus* , and *Physa acuta*) have also been introduced to New Zealand waters, mostly from aquaria, although *Limnaea stagnalis* was introduced intentionally to provide food for trout (Forsyth and Lewis, 1987). *Physa acuta* is now widely distributed in New Zealand, and in some places is thought to have replaced the endemic snail, *Physastra variabilis.*

ASSESSMENT AND PROTECTION OF NATURAL VALUE

Approaches to assessment

Although biological communities composed of a mixture of indigenous and exotic species may be more diverse than those that occur naturally, they do not represent the situation that *"originally* gave New Zealand its own recognizable character". Nevertheless, as in most countries, physically unmodified ecosystems that have been biologically modified through human activity require careful conservation to ensure that species diversity and ecosystem integrity are maintained. The evolutionary endpoints that mixed communities attain in New Zealand are of considerable scientific interest, and examples may warrant protection on those grounds in the future.

A more pertinent goal of natural area protection should be to ensure the survival of pure examples (where possible) of indigenous communities in unmodified rivers. Indigenous communities occur most frequently away from populated areas where species introductions often originate, and on sections of river above natural barriers (e.g. waterfalls) that can inhibit the dispersal of some exotic species.

The survival of predominantly indigenous communities could be achieved by the preservation of wholly unmodified river catchments or the protection of remnants of riverine ecosystems that retain their natural character within partly modified catchments.

Protection from the headwaters to the sea is particularly desirable, as this would ensure that examples of rivers displaying the full sequence of lotic succession are included in the protected areas network. However, wholly unmodified river catchments are now found only on the west of the South Island, and thus it would not be possible to achieve regional representativeness of physically intact catchments without some form of restoration programme.

Many unmodified catchments on the west of the South Island are already included in Existing protected areas (Figure 13.1), but the status of exotic species in these systems is not well documented. Unmodified whole catchments that are not protected need to be inventoried and any threats to their natural integrity identified and contained. Management of rivers at the catchment level and as entities from the source to the sea is a more feasible option in New Zealand than in many other countries because of the relatively short lengths of most rivers, and because rivers generally do not cross regional (or national) boundaries.

Assessing remnants of river ecosystems

Protection of representative remnants of riverine ecosystems that retain their natural character requires a protocol for identification and evaluation of sites. The most feasible means of achieving this is to expand the New Zealand Protected Natural Areas Programme (PNAP) so that the evaluation of running water ecosystems can be linked to future PNA surveys. The underlying principles and mechanisms to achieve this are already in place. Furthermore, the PNAP criteria for natural area assessment are compatible with criteria recently recommended by the New Zealand Limnological Society for assessing the value of aquatic reserves. The latter criteria are:

- Ecological representativeness or rare type of ecosystem
- Degree of modification
- Diversity and pattern
- Rarity and unique features or species
- Long-term viability.

These criteria are also compatible with those employed by other assessment systems in New Zealand, and with criteria used in evaluations of freshwater ecosystems overseas (e .g. Morgan, 1982; Blyth, 1983; Newbold et aI, 1983). We have been examining the use of quantitative descriptors to assess these criteria, and have devised a preliminary list for consideration in assessing degree of modification (Table 13.1), diversity and pattern (Table 13.2(a)), and rarity and unique features or species (Table 13.2(b)).

The scale and accuracy at which assessment of riverine areas is carried out will largely be dictated by available resources, A system based mainly on physical features of rivers would be easiest to achieve, and could be augmented with information from local sources and national databases (currently available for freshwater fishes and blue duck) on the status of exotic species and of rare or endangered native species. Thus, most of the descriptors in Tables 13.1 and 13.2 are based on physical attributes of rivers that can be derived from maps, aerial photographs, or local knowledge.

TABLE 13.1. List of physical descriptors that are being considered for assessing degree of modification

Catchment in native vegetation (%) (+)
Length lined by native vegetation (%) (+)
Length lined by non-production woodland (+)
Length fenced (%) (+)
No. natural barriers to exotic fish movement (+)
Distance of first natural barrier from headwaters (+)
Road distance to nearest town (+)
Road distance to nearest city (+)
Catchment in production forest (-)
Catchment in improved pasture (%) (-)
Length channelized (-)
No. open-cast mines in catchment (-)
No. road and rail bridges (-)
No. unbridged road crossings (-)
No. water- abstraction points (-)
Baseflow abstracted (%) (-)
No. downstream weirs (-)
No. downstream dams (-)
Length with regulated flow (%) (-)
No. point- source discharges (-)
Baseflow that is waste discharge (%) (-)
No. known exotic aquatic species (-)
Density of goats in catchment (-)
Degree of native species exploitation (-)

Signs indicate whether a high value for a descriptor is likely to have a positive (+) or (-) on a river.

Assessing representativeness

Representativeness refers to the degree to which a system of reserves represents the range of variation found within a region (Austin and Margules, 1986), and this concept underpins the PNAP (Kelly and Park, 1986). Its assessment requires some form of classification system whereby sites are grouped into classes with similar attributes for subsequent evaluation, and clearly defined boundaries that delineate regions within which representativeness can be appraised.

The ecological region and district framework (McEwen, 1987) forms the yardstick against which representativeness is assessed in PNAP. However, these divisions are unsuitable for rivers, as they are based solely on topographical and botanical features of the land, and sometimes use rivers as convenient boundaries. A system of freshwater ecoregions is being developed for New Zealand (Biggs et al, 1990) based on physical and biological data from a nationwide river survey. Such a system should provide an alternative mechanism for interpreting representativeness of rivers in New Zealand, although the accuracy and level of resolution it provides for conservation assessment purposes remains to be tested.

Several classification schemes for New Zealand rivers have been proposed, but none is adequate for conservation assessment. In a survey of the geomorphological characteristics

TABLE 13.2. List of descriptors that are being considered for assessing (a) diversity and pattern, and (b) rarity and unique features or species

Criterion Descriptor
(a) *Diversity and pattern*
No. stream orders
Altitudinal range
No. riparian vegetation types
No. rock types
No. associated wetlands, lakes, tarns
No. discontinuities (e.g. confluences, waterfalls)
No. hydraulic transition zones *(sensu* Statzner and Higler, 1986)
No. unmodified interconnecting headwater catchments
No . tributaries with low degree of modification
No . pool/riffle sequences per km
No. cascades per km
Substrate heterogeneity
Substrate stability
Cover for fish (%)
Cover by native aquatic plants (%)
No. aquatic plant types
(b) *Rarity and unique features or species*
No. large waterfalls
No. unusual rock types
No. unusual riparian vegetation types
No. unusual geological formations.
Length of river or river segment
No. known rare or endangered species

of river channels in New Zealand, Mosley (1987) could distinguish only four clear types, and suggested that river characterization rather than classification would be a more appropriate means of describing rivers for management purposes. Descriptors such as amount of rainfall, mean gradient, channel morphology, dominant geology, main vegetation type, and origin of flow could be useful in physically characterizing rivers for conservation assessment purposes. Recent work suggests that of flow might provide useful dichotomies for a biologically meaningful classification of New Zealand rivers. Biggs and Close (1989) found that periphyton biomass in gravel-bed rivers of the South Island was regulated to a large extent by hydrological factors that reflected mountain, foothill, or lowland (spring-fed) sources.

Long-term viability

This criterion reflects the potential effectiveness of an area as a conservation unit, and is mainly a function of fragility and size. Fragility is a subjective measure of the sensitivity of a system to environmental change (Usher, 1986). Stream and rivers fed by mountain run-off are likely to have low fragility as repeated large spates may place natural limits on the flora and fauna that can colonize them. This scenario has been suggested for invertebrates in small streams of Westland (Winterbourn et al, 1988) and for periphyton in some Canterbury rivers (Biggs and Close, 1989). Other factors that could influence the fragility of a river include the extent of erosion-prone land in the catchment, the width, vigour, and density of riparian vegetation, the proximity of suitable areas (particularly upstream) for recolonization following a perturbation, and the importance of a site for sensitive biological processes such as native fish spawning. Similarly, a site may be more fragile if its biological integrity is dependent on the passage of migrating fishes through downstream stretches that are not managed with fish passage in mind (McDowall, 1984).

The minimum desirable size of a reserve can be determined by the space required by the top predator to maintain a viable population (Usher, 1986), and in New Zealand we are investigating the utility of blue duck to assess this. Recent genetic work has indicated that there is a naturally high degree of in-breeding in blue duck populations (Triggs et al, in press), and the minimum number required for the establishment of new populations is considered to be 20 territorial pairs (Williams, 1988). On present knowledge, this equates to 15-20 km of continuous habitat (including tributaries), and thus 15 km could be used as a minimum desirable length for riverine reserves in New Zealand. Clearly, this will not be achievable in many lowland areas, and some undisturbed sites will not represent suitable blue duck habitat, but it is nevertheless a useful target size.

Prioritizing sites for protection

The need for representativeness makes the implementation of a riverine extension of the PNAP a matter of urgency, and means that a rapid method of prioritizing sites for natural area selection is required (Figure 13.4). As the key criterion in PNAP, representativeness can be used initially to divide sites into classes, thereby ensuring that a range of river types and habitats is represented in subsequent stages of the evaluation (Kelly and Park, 1986; Margules,1986). Threshold descriptors could then be invoked to remove from immediate consideration sites that do not meet one or more minimum standards (Figure 13.4). Minimum standards would be key descriptors of degree of modification and could include the presence of a continuous strip of riparian native vegetation, and the absence of unnatural downstream barriers to native fish migration (see Table 13.1). Minimum desirable size could also be used as a threshold descriptor in some regions, although it should not be applied too stringently.

Thus, a priority list of sites in each representative class would be compiled , and could then be evaluated further to assess other aspects of degree of modification, diversity and pattern, and rarity and unique features or species (Figure 13.4). If no sites within a representative class meet minimum standards, the least-modified sites could be further evaluated if they are considered to have high potential value.

Assessment of degree of modification, diversity and pattern, and rarity and unique features or species would be carried out initially from maps, aerial photographs, and databases, and sites with relatively high ranks could then be visited to confirm evaluations and carry out further assessment (Figure 13.4). Fragility and the pragmatic criteria *(sensu* Margules, 1986) of threat and "protectability" would be assessed last.

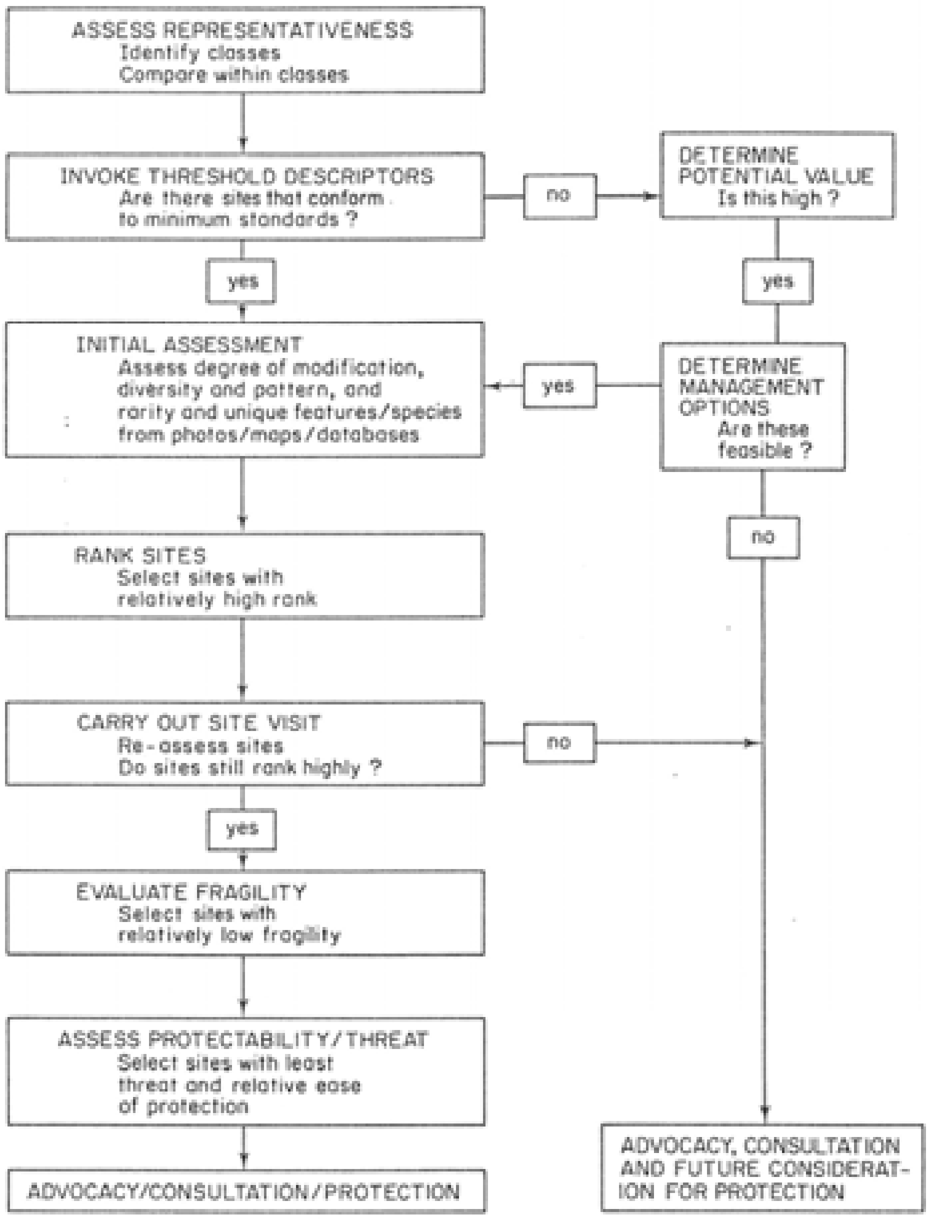


FIGURE 13.4. Proposed protocol for prioritizing sites for protection when assessing the natural value of New Zealand rivers. Classes for assessment of representativeness and minimum standards for threshold descriptors have yet to be determined

FIGURE 13.4. Proposed protocol for prioritizing sites for protection when assessing the natural value of New Zealand rivers. Classes for assessment of representativeness and minimum standards for threshold descriptors have yet to be determined.

Successful resolution of these conflicts by consultation is an encouraging sign for future issues that threaten the conservation values of rivers.
Discussion and consensus among interested parties and experts are considered essential features in the evolution of a natural areas assessment system for New Zealand rivers. In addition, endorsement is required from central, regional, and district government to ensure that protection recommendations are implemented. Identification of riverine areas with high natural value is the first step towards increasing the representation of rivers in the protected areas network. Now we are at the stage of determining an appropriate scale and classification system for assessing representativeness, and setting levels for threshold descriptors.

ACKNOWLEDGEMENTS

Members of the New Zealand Limnological Society have battled with some of the issues addressed in this chapter, and we acknowledge the ideas stimulated by those discussions. Important individual contributions to the interpretation of criteria for assessing the natural value of New Zealand rivers have been made by Robert McDowall and Stella Penny. Comments on draft manuscripts were kindly made by Barry Biggs, Department of Scientific and Industrial Research, Bob Zuur, Ministry for the Environment, Gordon Glova, Ministry of Agriculture Fisheries, and Paula Warren, Philip Simpson, Martin Cawthorn, Jan Heine, and Mick Clout, Department of Conservation.

REFERENCES

Anon. (1989). “A national policy for indigenous forests”, A discussion paper prepared by working party convened by the Secretary for the Environment, Ministry for the Environment, Wellington.

Austin, M. P., and Margules, C. R. (1986). "Assessing representativeness", in *Wildlife Conservation Evaluation* (Ed. M. B. Usher), pp. 45-67, Chapman and Hall, London.

Biggs, B: J. F., and Close, M. E. (1989). "Periphyton biomass dynamics in gravel bed rivers: the relative effects of flows and nutrients", *Fresh water Biology,* 22, 209-231.

Biggs, B.J.F., Duncan, M.J., Jowett, I.J, Quinn, J.M., Hickey, C.W., Davies-Colley, R.J., and Close, M. E. (1990). "Ecological characterisation, classification and modelling of New Zealand rivers: An introduction and synthesis", *New Zealand Journal of Marine and Freshwater Research ,* 24, 277-304.

Blyth, J. D. (1983). "Rapid stream survey to assess conservation value and habitats available for invertebrates", in *Survey Methods for Nature Conservation,* Vol. I (Eds K. Meyers, C. R. Margules and I. Musto), pp. 343-375, Proceedings of a workshop held at Adelaide University, 31 August- 2 September 1983.

Coffey, B.T., and Clayton, J .S. (1988). *New Zealand water plants: a guide to plants found in New Zealand freshwaters,* Ruakura Agricultural Centre, Hamilton.

Collier, K. J., and Wakelin, M. (1990). *Invertebrate fauna and ecological value of Ohutu Stream, Ruahine Ranges,* Science and Research Internal Report No. 81, Department of Conservation, Wellington .

Collier, K. J., and Winterbourn, M. J. (1987). "Breakdown of kamahi leaves in four South Westland streams", *Mauri Ora.* 14, 33-42.

Collier, K. J., and Winterbourn, M. J. (1990). "Structure of epilithon in some acidic and circumneutral South Westland streams" *New Natural Sciences,* 17, 1-11.

Collier, K.J., Winterbourn, M.J., and Jackson .R. J. (1989) ."Impacts of wetland afforestation on the distribution of benthic invertebrates in acid streams of Westland, New Zealand", *New Zealand Journal of Marine and Freshwater Research.* 23. 479-490.

reflects the likelihood that future human activities could impinge upon the natural value of a river, whereas protectability is largely dictated by riparian tenure and conflict of use.

Protection mechanisms

Historically, the protection of rivers in their natural state in New Zealand has been brought about by their inclusion in parks and reserves on Crown land, although this need not necessarily protect the quality of the water or the flow regime. Several statutes administered by DOC could be used to protect natural aquatic values. These include Faunistic Reserves, which can protect unique or pristine populations of aquatic species, and Ecological Areas, which can protect representative ecosystems and plant and animal communities, including those on a riverbed. DOC also has jurisdiction over strips of land (3-20 m wide) alongside rivers that flow through land currently or previously owned by the Crown, providing a useful tool for maintaining or enhancing the natural integrity of rivers.

In 1981 the amenity value provided by rivers in their natural state was recognized by an amendment to the Soil and Water Conservation Act (Wild and Scenic Rivers Legislation), which made it possible to apply for Water Conservation Orders (WCO). To qualify for a WCO, it must be proved that a river has regionally or nationally outstanding wild, scenic, or other natural characteristics, or outstanding recreational, fisheries, wildlife, scientific, or other features. Under current legislation, WCOs protect only the water and not the channel or catchment, although the presence of a surrounding undisturbed catchment can increase the eligibility of a river for a WCO. At the time of writing, only five WCOs have been gazetted for rivers (Figure 13.1), although several others are pending or under appeal.

New Zealand's environmental legislation is currently under review with the aim of integrating the laws pertaining to natural resource management in an efficient manner. Under the new legislation, minimum water quality standards will be revised and become applicable to all waters, and it will be possible to classify waters at higher standards to protect special ecosystems, fisheries, and spawning areas. There will also be closer integration between land and water management, and catchment management plans devised by Regional Councils will be given statutory backing. Although Faunistic Reserves and Ecological Areas will be unaffected by the new legislation, the principal mechanism for environmental protection of rivers is likely to remain the WCO. It will become possible to use WCOs that can protect water flow and quality in association with Heritage Orders that give protection to the land and the river channel, so that the unit of water management could become the whole catchment.

Recently, an assessment of streams on the Coromandel Peninsula of the North Island's east coast, as part of the PNAP, identified several sites of high natural value, and representative examples of these have been recommended for protection. Where high- value sites occur on private land, implementation of protected status can be pursued through advocacy and negotiation. Consultation and collaboration between private land owners, Regional Councils, developers, and conservation advocates has been a feature of at least two recent conflicts of interest involving freshwater sites in New Zealand.

Forsyth, D.J., and Lewis, M. H. (1987). "The invertebrates", in *Inland Waters of New Zealand* (Ed. A.B. Viner), pp.265-290, DSIR Bulletin 241, DSIR, Wellington.

Glova, G. (1989). "Native and salmonid fishes: are they compatible", *Freshwater Catch,* 40, 12

Hanchet, S. M. (1990). "Effect of land use on the distribution and abundance of native fish in tributaries of the Waikato River in the Hakarimata Range, North Island, New Zealand", *New Zealand Journal of Marine Freshwater Research,* 24, 159-171.

L. W. G. (1988). *A worldwide surface water classification system ,* UNESCO, Paris.

Howard-Williams, C., Clayton,J .S., Coffey, B. T. , and Johnstone, I. M. (1987). "Macrophyte invasions", in *Inland Waters of New Zealand* (Ed. A. B. Viner), pp. 307-332, DSIR Bulletin 241 , DSIR, Wellington .

Hughey, K. F. D. (1987). "Wetland birds", in *Aquatic Biology and Hydroelectric Power Development* (Ed. P. R. Henriques), pp. 264-276, Oxford University Press, Auckland.

Johnson, P.N., and Brooke, P. A. (1989). *Wetland plants in New Zealand,* DSIR Information No. 167, DSIR, Wellington.

Kear, J. (1972). Blue Duck of New Zealand", *The Bird ,* 11,175-192.

Kelly, G.C., and Park, G . N. (1986). *The New Zealand Protected Natural Areas Programme, a scientific* New Zealand Biological Resources Centre Publication No. 4, DSIR, Wellington.

Kuschel, G . (1975) . *Biogeography and Eco logy in Zealand,* W. Junk, The Hague.

Margules, C. R. (1986). "Conservation evaluation in pr actice", in *Wildlife Conservation Evaluation* (Ed. M. B. Usher), pp. 297-314, Chapman and Hall, London .

McColl, R. H. S. (1987). "Freshwater and wetland habitats", in *Protected Natural Areas in New Zealand,* pp. 22-28, Royal Society of New Zealand Miscellaneous Series 16.

McColl, R. H. S., and Ward, J. C. (1987). "The use of water resources", in *Inland Waters of New Zealand* (Ed. A. B. Viner), pp. 411-459, DSIR Bulletin 241, DSIR, Wellington.

McDowall, R.M. (1984). "Designing reserves for freshwater fish in New Zealand", *Journal of the Royal Society of New Zealand,* 14, 17-27.

McDowall, R. M. (1987). "Impacts of exotic fishes on the native fauna", in *Inland Waters of New Zeaaland* (Ed. A. B . Viner), pp. 441-459, DSIR Bulletin 241, DSIR, Wellington .

McDowall, R.M. (1990). *New Zealand freshwater fishes, a history and guide,* Heinemann Reed MAF, Wellington.

McEwen, M. (Ed.) (1987). *Ecological regions and districts of New Zealand,* New Zealand Biological Resources Centre Publication No.5, Department of Conservation, Wellington.

McLellan, I. D . (1973). "Biogeography of aquatic insects in New Zealand", *The Zealand Entomologist,* 5, 247-249.

Molloy, L. F. (1980). *Land alone endures: land use and the role of research,* DSIR Discussion Paper No.3, DSIR , Wellington.

Morgan , N. C. (1982). "An ecological survey of standing waters in north west Africa: II site descriptions for Tunisia and Algeria", *Biological Conservation,* 24, 83-113.

Mosley, M. P. (1987). "The classification and characterization of rivers", in *River Channels* (Ed . K. S. Richards), pp. 295-320, Basil Blackwell, Oxford.

Myers, S. C., Park, G. N., and Overrnars, F. B. (1987). *A guidebook f or the rapid ecological survey of natural areas,* New Zealand Biological Resources Centre Publication No.6, Department of Conservation, Wellington .

Newbold , C., Purseglove, J., and Holmes, N. (1983). *Nature conservation and river engineering,* Nature Conservancy Council, Peterborough. *New Zealand Official Yearbook* (1988/89). 93rd Annual Edition, Department of Statistics, Wellington .

Simpson, P. (1985). "WERI: a plug for protection", *The Landscape,* Autumn, 5-9.

Stark, J. D. (1985). "A macroinvertebrate community index of water quality for stony streams", *Water and Soil Miscellaneous Publication No.* 87, Ministry of Works and Development. Wellington .

Statzner. B., and Higler, B. (1986). "Stream hydraulics as a major determinant of benthic invertebrate zonation patterns". *Freshwater Biology,* 16, 127-139.

Towns, D . R. (1979). "Composition and zonation of benthic invertebrate communities in a New Zealand kauri forest stream", *Fresh water Biology,* 9, 25 1-262.

Townsend, C. R., Crowl, T.A.,andScarsbrook ,M.R.(1990) ."The effect of introduced trout on predatory stoneflies in New Zealand" (Abstract), *Bulletin of the North American Benthological Society ,* 7, 101.

Triggs, S. J., Williams, M. J., Marshall, S. J., and Chambers, G. K. (in press). "Genetic relationships within a population of Blue Duck (*Hymenolaimus malacorhynchos*)", *Wildfowl,* 42

Usher, M. B. (1986). "Wildlife conservation evaluation : attributes, criteria and values", in *Wildlife Conservation Evaluation* (Ed. M.B.Usher), pp.3-44,Chapman and Hall, London.

Vincent, W.F., and Forsyth, D.J. (1987)."Geothermally influenced waters", in *Inland Waters of New Zealand* (Ed.A.B.Viner), pp.349-377, DSIR Bulletin 241,DSIR, Wellington .

Williams, M. J. (1988). *Conservation strategy for Blue Duck 1988-1992,* Unpublished internal report, Department of Conservation, Wellington.

Winterbourn,M.J.(1986)."Forestry practices and stream communities with particular reference to New Zealand", in *Stream Protection: The Management of Rivers for Instream Uses* (Ed . I. C. Campbell), pp. Water Studies Centre, Chisholm Institute of Technology, Melbourne.

Winterbourn ,M.J.(1987). "Invertebrate communities", in *Inland Waters of New Zealand* (Ed. A . B. Viner) , pp. 167-190, DSIR Bulletin 241, DSIR , Wellington .

Winterbourn, M.J., Collier, K.J., and Graesser, A.K.(1988) ."Ecology of small streams on the west coast of South Island, New Zealand", *Verhandlungen der Internationalen Vereinigung fiir theoretische und angewandte Limnologie,* 23, .1427-1431.

Winterbourn, M. J., Rounick, J. S., and Cowie, B. (1981). "Are New Zealand stream ecosystems really different?" *New Zealand Journal of Marine and Freshwater Research,* 15, 321-328.

Worthy, T . H. (1987). "Palaeoecological information concerning members of the frog genus *Leiopelma:* Leiopelmatidae in New Zealand, *Journal of the Royal Society of New Zealand, 17,* 409-420.

APPENDIX 3
Results of Limnological Society workshop on natural value assessment held in Taupo, May 1991

METHODS FOR ASSESSING THE NATURAL VALUE OF NEW ZEALAND RIVERS

This workshop was intended to build on a workshop held in 1987 that arrived at five criteria for assessing the natural value of aquatic ecosystems:

1 REPRESENTATIVENESS OF RARE TYPE OF ECOSYSTEM,
2 DEGREE OF MODIFICATION,
3 DIVERSITY AND PATTERN,
4 RARITY AND UNIQUE OR SPECIES and
5 LONG-TERM VIABILITY.

Rob McColl and I have subsequently developed lists of potential descriptors for these criteria and a possible critical pathway for an evaluation process (see Fig. 13.4 in Appendix 2).

The workshop arrived at a general consensus that DEGREE OF MODIFICATION was the most important criterion following REPRESENTATIVENESS for assessing natural value. Concern was expressed that interpretation of RARITY AND UNIQUE FEATURES could be influenced by a lack of knowledge and collecting effort. There seemed to be general agreement on the need to minimise the number of descriptors evaluated, especially if ranking was going to be carried out.

Participants then went on to discuss various descriptors of DEGREE OF MODIFICATION that could be used as "threshold descriptors" to minimise the number of sites subsequently assessed. Three descriptors were generally agreed upon as being useful:

- >80% of catchment in vegetation
- Unnatural barriers to native fish migration absent downstream
- Where possible, a continuous strip of native vegetation present

The 80% catchment disturbance level was based on information derived from the 100 Rivers survey. Unnatural barriers to native fish migration could include chemical as well as physical barriers. Other potential threshold descriptors that were discussed included:

- Section greater than minimum desirable size (I suggested 15 km based on current knowledge of the length required to maintain a viable population of a top predator -blue duck)
- Human activities upstream unlikely to exclude native species
- Section includes >3rd order stream

For various reasons, these other descriptors did not have widespread support, although they may be useful for specific assessments.

Following this, the workshop discussed the use of other descriptors of degree of modification and diversity and pattern in an initial desk-top assessment of sites, and a range of potentially suitable descriptors was arrived at (Appendix Tables 3.1 and 3.2). Other descriptors such as number of downstream dams/weirs or % length lined by native vegetation may be useful where no rivers of a certain type meet threshold descriptors. Several other descriptors could also be used to assess DIVERSITY AND PATTERN from a site visit (Appendix Table 3.3).

Appendix Table 3.1 Descriptors of DEGREE OF MODIFICATION

- % catchment in native vegetation
- % length with no bank protection (e.g., fencing for lowland sites)
- no. natural barriers to exotic fish movement
- distance of first natural barrier from headwaters
- no. of road access points
- % catchment in production forest
- % catchment in improved pasture
- no. mines in catchment
- no. water abstraction points
- % baseflow abstracted
- % length with regulated flow
- no. of point source discharges/mass loadings of different discharge types
- no. of known exotic species
- density of goats and cattle in catchment
- degree of native species exploitation

Table 3.2 Descriptors of DIVERSITY AND PATTERN that can be assessed from maps.

- no. of stream orders
- altitudinal range
- no. of riparian vegetation types per km
- no. geological rock types per km
- no. associated wetlands, lakes, tams per km^2
- no. discontinuities per km
- no. unmodified interconnecting headwater catchments
- no. of tributaries with low degree of modification per km

Table 3.3 Descriptors of DIVERSITY AND PATTERN that can be assessed from a site visit.

- no. pool/riffle sequences per km
- no. cascades per km
- substrate heterogeneity
- % cover for fish
- % cover by native aquatic plants
- no. aquatic plant types

APPENDIX 4
Copy of questionnaire sent out to 36 experts requesting weightings for descriptors

CONSERVATION SCIENCES CENTRE

15 August 1992

XX XXXX XXXXXX
XXXXXXXXXX
XXXXXXXXXXX
XXXXXXXXXX

Dear XX XXXXXX

An ongoing project at the Science and Research Division is aimed at developing a methodology to achieve the conservation of a representative range of New Zealand rivers. This work follows on from the recommendations of a workshop which was held in 1986 by the New Zealand Limnological Society and which the Department of Conservation participated in. A follow-up workshop held in 1991 at the Limnological Society conference developed lists of descriptors for the criteria agreed to in the 1986 workshop.
I am asking you, as an expert in your field, to spare some time assist us in developing weightings for these descriptors. A similar approach has been used for deriving scores for descriptors in the River Conservation System used in South Africa. It is intended to use these scores as part of a system to rank different rivers according to their importance for nature conservation.
I have enclosed background information and tables for you to score descriptors under five criteria. A stamped self-addressed envelope is enclosed for your convenience. Your name will in no way be associated with the assessment system subsequently derived from this questionnaire. Thank you in anticipation of your help.

WE WOULD BE EXTREMELY GRATEFUL IF YOU WOULD FILL IN AND RETURN THE ENCLOSED TABLES (pGES 7, 8 AND 9) BEFORE 15 SEPTEMBER

Yours sincerely,

(Richard Sadleir)
Director, Science and Research Division

YOU ARE REQUESTED TO:

1. Please read the attached sheets. These include a definition of natural value, and explanations of descriptors. On the last page, you are asked to indicate your specific area of interest.
2. Please score each descriptor in the tables with an integer value within the specified range (note the ranges differ for each criterion) according to the importance that you perceive each descriptor to have in affecting natural value (as embodied by the quotation describing the goal of natural area protection below). Please note that you are not being asked to rank descriptors, but to score them. All descriptors could conceivably have the same score if you considered them equally important. Explanations of descriptors are given in the attached sheets.
3. Comment, if you wish, on your interpretation of the descriptor and the reason for your score. Comments are also invited on other parts of the questionnaire. You may wish to suggest new descriptors. If you do this, please also recommend a score. Space is provided for this on the tables.

GOAL OF NATURAL AREA PROTECTION:

To ensure " ...... as far as possible, the survival of all indigenous species of flora and fauna, both rare and commonplace, in their natural communities and habitats, and the preservation of representative samples of all classes of natural ecosystems and landscape which in the aggregate originally gave New Zealand its own recognisable character."

DEFINITION OF CRITERIA:

degree of modification -The degree to which rivers (the catchment, riparian zone, channel and the biota) have been changed by human disturbance and intervention.

diversity and pattern -The range of different habitats, micro-habitats and species present or likely to be present, and the natural sequences of intact succession from rivers to other aquatic (e.g., lakes), semi-terrestrial (e.g., wetlands) and terrestrial environments.

rarity and unique features/species - Species or features of a river that are rare, unique or unusual for a class of river in a given region.

fragility -Sensitivity of a river to environmental change and modification.

EXPLANATION OF DESCRIPTORS:

DEGREE OF MODIFICATION:

The Catchment(Riparian Environments:

% catchment in native vegetation (+) -The proportion of catchment in native vegetation can influence water chemistry and sediment inputs to a river and have cascading effects down the food chain.

% length lined by native vegetation (+) Riparian vegetation can reduce sediment inputs by stabilising river banks, provide shade and inputs of food, and keep water temperatures down. Native riparian vegetation is more likely to provide natural conditions in the river than exotic vegetation.

% length lined by non-production exotic woodland (+) -Where native vegetation is not present, exotic trees that have not been planted for future harvesting are probably better than nothing.

% length with bank fencing (+) - Bank fencing helps exclude stock from rivers and thereby reduces bank erosion and direct nutrient inputs to the river.

road distance to nearest town/city (+) -The further section of river is away from centre of population, the less likely the river is to have intensive recreational use which could adversely affect natural value. Cities contain more people than towns, and recreational use of rivers close to cities is therefore likely to be greater.

% catchment in production forest (-) -Production forests (usually pines or eucalypts) will be subject to felling at some stage, and this may adversely affect riverine natural value by increasing sediment inputs to rivers, changing thermal regimes etc. Exotic forest also tends to increase evapotranspiration rates thereby affecting natural hydrological regimes of rivers.

% catchment in crop/improved pasture (-) -Development of catchments for grazing and horticulture can cause increases in sediment, nutrients and toxic waste (e.g., pesticides) to rivers.

no. open cast mines in catchment (-) -Mines can release toxic leachates to drainage waters and cause increased sediment inputs. Effects may persist over long periods of time.

density of goats and cattle in catchment (-) -Goats and cattle can reduce riparian vegetation vigour by browsing and cause severe river bank erosion.

The River/Biota:

no. natural barriers to exotic fish movement (+) -The presence of natural barriers (usually waterfalls) to the upstream movement of trout and other exotic fish is likely to mean that the section of river upstream is colonised only by native fish species that have penetrated the barrier.

distance of first natural barrier from headwaters (+) -The greater the distance of the first natural barrier from the headwaters, the longer the stretch of river that is likely to be free of exotic fish species.

no. known exotic nuisance species (-) - Exotic macrophytes and fish can cause dramatic changes to the natural structure and function of aquatic systems if they have developed nuisance status.

no. known exotic non-nuisance species (-) -Exotic macrophytes, invertebrates and fish can cause changes to the natural structure and function of aquatic systems. Effects are likely to be less severe than if they were nuisance species.

degree of native species exploitation (-) -This relates mainly to the potential effects of whitebaiting and eeling on the structure of native animal communities.

no. road and rail bridges (-) -Structures in rivers such bridge pylons can cause changes to flow patterns leading to bank erosion and modifications to channel morphology.

no. unbridged road crossings (-) Road crossings can destabilise river beds, cause sediment inputs and provide access for some types of disruptive recreation.

no. downstream culverts/weirs/dams (-) -Construction of culverts, weirs or dams on river can modify flow regimes and impede passage for native fish where construction has not provided alternative routes. Dams and weirs also have adverse effects on natural flow regimes.

% length channelised (-) - Channelisation destroys natural ecotone areas of rivers and modifies natural channel morphology.

no. water abstraction points(-) - Removal of water for human use causes reduced flows. The more abstraction points, the greater the length of river likely to be affected.

% baseflow abstracted (-) -The amount of baseflow abstracted for human use will reach a critical point at which riverine biota are adversely affected. Amongst other things, this may cause growths of nuisance algae and increased silt deposition.

% length with regulated flow (-) Reduced flows upstream of dams and artefacts of flow management below dams can have adverse effects on river biota and natural river processes. Artefacts may include artificially induced surges, truncated recessions and changed thermal regimes.

% flow from inter-catchment transfer -Transfer of water between catchments occurs in some parts of New Zealand. This can alter hydrological regimes and lead to the modifcation of natural water chemistry if the mixing waters differ substantially in nutrient status, pH etc. Inter-catchment transfers of water can also lead to the spread of exotic species and the transfer of native species to catchments where they do not naturally occur.

no. point source discharges (-) -The more point source discharges along a river the greater the length likely to be affected by water pollution.

% baseflow as organic effluent (-) -Organic effluent in rivers can lead to increased oxygen demand and suspended sediment concentrations which affect river biota and natural river processes.

% baseflow as inorganic effluent (-) -Inorganic effluents can alter natural water chemistry and kill aquatic life if present in high enough concentrations.

DIVERSITY AND PATTERN:

no. of stream orders (+) -The greater the range of stream orders represented by a section of river, the greater the diversity of habitats potentially available.

altitudinal range (+) -Changes in altitude lead to differences in water temperature, rainfall and riparian vegetation type along a section of river, increasing the diversity of habitats available.

no. ecological regions (+) -the more ecological regions a river or segment of river passes through, the more diverse the range of habitats along that is likely to be.

no. of riparian vegetation types per kill (+) -Riparian vegetation can influence the energetics of rivers through inputs of different types of food such as excised leaves of various species, and by affecting light levels and water temperatures.

no. geological rock types per km (+) -The geological make-up of rocks can influence water chemistry and also the composition of the substrate.

no. associated wetland, lakes and tams per km (+) -Other aquatic/wetland habitats that merge in an undisturbed way with a section of river enhance the ecological pattern.

no. discontinuities per km (+) -Discontinuities such as stream confluences and waterfalls add to the diversity of flow environments in a river.

no. unmodified interconnecting headwater catchments (+) -These could provide routes for the natural mixing of aquatic biota between catchments (e.g., for blue duck).

no. tributaries with low degree of modification (+) -Small tributaries often have more diverse invertebrate and fish communities than larger rivers which can serve as a source for downstream colonisation.

no. pool/riffle sequences per kill (+) More pool/riffle sequences infer greater diversity of flow envimoments along a stretch of river.

no. cascades per kill (+) -Cascades add to flow heterogeneity and provide habitat for species adapted to torrential conditions.

substrate heterogeneity (+) -The greater the mix of substrate sizes and shapes on a river bed, the greater the diversity of microhabitats that is likely to be available for aquatic biota.

% cover by native aquatic plants (+) -Native aquatic plant cover may increase the diversity of habitats available for other groups.

no. aquatic plants types (+) -The greater the range of different plant morphologies present, the greater the range of microhabitats that are likely to be available for colonisation.

no. known native aquatic plant species (+) -More native plant species enhance diversity.

% cover for fish (+) -The more overhead (e.g., riparian forest) and in-stream (e.g., fallen logs) cover available, the more native fish species are likely to be present.

no. known native fish species (+) -More native fish species enhance diversity.

RARITYAND UNIQUE FEATURES OR SPECIES:

no. large waterfalls (+) -These can be unusual features of a river depending on the geology of the area.

no. unusual rock types (+) -Depending on the geology of an area, some rock types in or along rivers can be rare and impart unusual conditions in segments of rivers.

no. unusual riparian vegetation types (+) -Rare or unusual vegetation types along rivers can impart different conditions in segments of rivers that may favour the presence of rare species or unusual associations of species.

no. unusual geological formations (+) -Depending on the geology of an area, unusual geological conditions may be present along a river (e.g., segments of subterranean flow).

length of river or river segment (+) -The longer a segment of river the more likely it is to contain rare species.

no. known rare or endangered species (+) -Based on existing knowledge of the river, some species that are regionally or nationally rare, endangered or vulnerable may be present.

FRAGILITY:

stability of flow (+) -Prevailing flow regime may place natural constraints on biotic communities that can develop in a river. Thus, communities in variable mountain-fed rivers may be less "fragile" that communities in stable spring-fed rivers.

% catchment as erosion prone land (+) Large areas of erosion prone land in a catchment may make the river more susceptible to changes from extreme environmental conditions.

importance for sensitive life stages (+) -A section of river will have greater fragility if any species rely solely on an area in that section for the completion of its life histroy (e.g., native fish spawning sites).

importance of downstream conditions (+) -A section will have greater fragility if its biological integrity relies on the correct management of downstream conditions (e.g., for native fish passage).

vigour of riparian vegetation (-) -The wider and denser the riparian zone, the less likely a river will be influenced by changes to environmental conditions on the land.

proximity of areas for recolonisation (-) -Nearby areas for recolonisation, particularly upstream of a section of river (e.g., tributaries), may enhance the ability of a river to recover from environmental perturbations.

NAME : ....

TABLE 1 DEGREE OF MODIFICATION

Please indicate your score within the range 1 (low importance) to 20 (high importance). Give score of zero if you think the descriptor is not relevant.

Descriptor	**Score**	**Comments**
% catchment in native vegetation		
% length lined by native vegetation		
% length lined by non- productive woodland		
% length with bank fencing		
Road distance to nearest town		
Road distance to nearest city		
% catchment in production forest		
% catchment in crop/improved pasture		
No. open cast mine in catchment		
Density goats and cattle in catchment		
No. natural barriers to exotic fish movement		
Distance first natural barrier from headwaters		
No. exotic nuisance species		
No. exotic non-nuisance species		
Degree native species exploitation		
No road/rail bridges		
No. unbridged road crossings		
No. downstream culverts		
No. downstream weirs		
No. downstream dams		
% length channelized		
No. water abstraction points		
% baseflow abstracted		
% length with regulated flow		
% flow from intercatchment transfer		
No. point source discharges		
% baseflow as organic effluent		
% baseflow as inorganic effluent		

NAME: . ……………………………………

TABLE 2 DIVERSITY AND PATTERN

Please indicate your score within the range 1 (low importance) to 20 (high importance). Give a score of zero if you think the descriptor is not relevant.

Descriptor	Score	Comments
No. stream orders		
Altitudinal range		
No. riparian vegetation types		
No. geological rock types		
No. associated wetlands, lakes, tarns		
No. discontinuities		
No. interconnecting headwater catchments		
No. tributaries with low modifications		
No. pool/ riffle sequences		
No. cascades		
Substrate heterogeneity		
% cover by native aquatic plants		
No. aquatic plant types		
No. known native aquatic plant species		
% cover for fish		
No. known native fish species		

NAME : ....

TABLE 3 *RARI1Y AND UNIQUE FEATURES/SPECIES*

Please indicate you rscorewithintherange1 (low importance) to 5 (high importance). Give a score of zero if you think the descriptor is not relevant.

Descriptor	Score	Comments
No. large waterfalls		
No. unusual rock formations		
No. unusual vegetation types		
No. unusual geological formations		
Length of river or river segment		
No. known rare/endangered species		

TABLE 4 *FRAGILITY*

Please indicate your score within the range 1 (low importance) to 5 (high importance). Give a score of zero if you think the descriptor is not relevant.

Descriptor	Score	Comments
stability of flow		
% catchment as erosion-prone land		
importance for se nsitive life stages		
importance of downstream conditions		
vigour of riparian vegetation		
proximity of areas for recolonisation		

PLEASE INDICATE YOUR MAIN AREA OF INTEREST (circle one or specify):

1) Water quality 2) Aquatic plants

3) Aquatic invertebrates 4) Fish

5) General freshwater ecology

6) Other (specify)..

APPENDIX 5
Comments on criteria descriptors and new descriptors suggested by questionnaire respondents

DEGREE OF MODIFICATION:

The Catchment/Riparian Environments:

% catchment in native vegetation (+) -The proportion of catchment in native vegetation can influence water chemistry and sediment inputs to a river and have cascading effects down the food chain.

-this depends strongly on the rock type, e.g., 15-20 on soft sedimentary, 5-10 on basalt
-depends on species

% length lined by native vegetation (+) -Riparian vegetation can reduce sediment inputs by stabilising river banks, provide shade and inputs of food, and keep water temperatures down. Native riparian vegetation is more likely to provide natural conditions in the river than exotic vegetation.

-native vegetation may be no better than exotic vegetation, e.g., sediment reduction etc
-of much less relevance to large rivers and streams
-depends on species

% length lined by non-production exotic woodland (+) -Where native vegetation is not present, exotic trees that have not been planted for future harvesting are probably better than nothing.

-don't know whether exotics better than?? (sic) -may be worse
-of much less relevance to large rivers and streams

% length with bank fencing (+) -Bank fencing helps exclude stock from rivers and thereby reduces bank erosion and direct nutrient inputs to the river.

-stock should not have access to fenced off area
-there are also indirect benefits of fencing which allows channel and bank plants to develop which remove sediment etc.
-probably unimportant in larger streams

road distance to nearest town/city (+) -The farther a section of river is away from a centre of population, the less likely the river to have intensive recreational use which could adversely affect natural value. Cities contain more people than towns, and recreational use of rivers close to cities is therefore likely to be greater.

-recreational use not a major problem I suspect -depends on controls on use -only important if city proximity
-catchment changes -useful, but non-population density factors (e.g., dams) or high recreational value (e.g., boats, white water) may be more relevant -agree with concept, but not sure if km is the right tool

% catchment in production forest (-) -Production forests (usually pines or eucalypts) will be subject to felling at some stage, and this may adversely affect riverine natural value by increasing sediment inputs to rivers, changing thermal regimes, etc. Exotic forest also tends to increase evapotranspiration rates thereby affecting natural hydrological regimes of rivers.

-depends on how felled; riparian strip left?
-by no means all negative
-impact depends on management practices. Riparian vegetation often native in riparian forests
-catchment land use vital because of effect on hydrology and flow on effect
-may be higher -no data on fisheries impacts
-I consider this to be positive -such catchments are usually better than pasture
-higher (score) if soft sedimentary rocks or granite

<u>% catchment in crop/improved pasture</u> <u>(-)</u> *-Development of catchments for grazing and horticulture can cause increases in sediment, nutrients and toxic waste (e.g., pesticides) to rivers.*

-catchment land use vital of effect on hydrology and flow on effect

<u>no. open cast mines in catchment</u> <u>(-)</u> *-Mines can release toxic leachates to drainage waters and cause increased sediment inputs. Effects may persist over long periods of time.*

-depends on tant (sic) levels -how many have more than one? -only important if "unregulated mines". In some areas "good mines" are better than farmland -the distance of the mine from the river/stream is the important factor -importance depends on locality within catchment.

-may only be a problem if not properly controlled -is total number the right measure -% of catchment area under mines is a better criterion

<u>density of goats and cattle in catchment</u> <u>(-)</u> *-Goats and cattle can reduce riparian vegetation vigour by browsing and cause severe river bank erosion.*

-fenced in or free range
-depends on which – cattle is more dangerous
-importance depends on fencing
-is this practical/worth calculating
-depends on size of stream

<u>The River/Biota:</u>

<u>no. natural barriers to exotic movement</u> <u>(+)</u> *-The presence of natural barriers (usually waterfalls) to the upstream movement of trout and other exotic fish is likely to mean that the section of river upstream is colonised only by native fish species that have penetrated the barrier.*

-assuming these haven't been breached
- a barrier does not mean no exotics or free of native fish
- this assumes exotic fish only colonise in an upstream direction. Many trout are headwater liberated
- depends on effects on native fish
–barriers also limit migration of several native fish (e.g.,smelt, inanga), and may not preclude presence of exotic fish due to human introductions of non-migratory populations
- depends on position more than no.
- unnatural barriers should be included
- natural barriers are not a modification. Can also have a detrimental impact on lowland natives
- important for some native fishes

<u>distance offirst natural barrier from headwaters</u> <u>(+)</u> *The greater the distance of the first natural barrier from the headwaters, the longer the stretch of river that is likely to be free of exotic fish species.*

-assuming these haven't been breached
–a barrier does not mean no exotics or free of native fish
-this assumes exotic fish colonise only in an upstream direction. Many trout are headwater liberated
- area of total stream length upstream
- exotics often released above anyway
- barriers to native fish would influence score
- natural feature, not modification. Trout often stocked above natural barriers if low in system
- important for some native fishes

no. known exotic nuisance species (-) *-Exotic macrophytes and fish can cause dramatic changes to the natural structure and function of aquatic systems if they have developed nuisance status.*

-how define nuisance?

-plants and animals?

-trout not nuisance but impact native fishes

-depends on specific impacts

-is this practical/ worth calculating

-exotics are often not a nuisance if habitat is largely unmodified. Simply counting number of organisims is a poor criterion. Perhaps specify % of biomass, either plant or animal.

known exotic non-nuisance species (-) *-Exotic macrophytes, invertebrates and can cause changes to the natural structure and function of aquatic systems. Effects are to be less severe than they were nuisance species.*

-difficult to know impacts

- is this practical/ worth measuring

degree of native species exploitation (-) *-relates mainly to the potential effects of whitebaiting and eeling on the structure of native animal communities.*

-assuming fishing is quite inefficient, i.e., potentially only captures small fraction of population

-difficult to assess impact

-potentially very important but gave it a low score because few areas would not be affected by exploitation of fisheries

-how do you measure this

-is this harvesting pressure, e.g., eels?

no. road and rail bridges (-) *-Structures in rivers such as bridge pylons can cause changes to flow patterns leading to bank erosion and modifications to channel morphology.*

-the number is not relevant

-as for mines – depends on controls

- very local impact
- depends on level of traffic and stability of substrate
- minor significance unless you include all in-river structures
- effects depend on construction practices -can be similar to natural erosion/slip

no. unbridged road crossings (-) *-Road crossings can destabilise river beds, cause sediment inputs and provide access for some types of disruptive recreation.*

- effects probably mainly local
- the number is not relevant
- effects depend on construction practices -can be similar to natural erosion/slip

no. downstream culverts/weirs/dams (-) *-Construction of culverts, weirs or dams on a river can modify flow regimes and impede passage for native fish' where construction has not provided alternative routes. Dams and weirs also have adverse effects on natural flow regimes.*

-the number is not relevant

-severity rating of barrier needed

-depends on construction. Assumes barrier to passage which is not always the case

-depends on design and fish passability

-gauging weirs very different to road weirs. Position/distance from sea relevant

-assuming that culverts are the same level as the stream

-finer details of design can affect degree of modification these cause

-effects depend on construction practices can be similar to natural erosion/slip

-can impede migration of fishes if free-fall

<u>% length channelised (-)</u> -Channelisation destroys natural ecotone areas of rivers and modifies natural channel morphology.

-depends on design and fish passability

<u>no. water abstraction points (-)</u> -Removal of water for human use causes reduced flows. The more abstraction points, the greater the length of river likely to be affected.

-depends on volume extracted -no. of "significant" extraction points is more relevant, i.e., excluding domestic tanks
-position too
-isn't volume extracted more significant than no. of points

<u>% baseflow abstracted (-)</u> -The amount of baseflow abstracted for human use will reach a critical point at which riverine biota are adversely affected. Amongst other things, this may cause growths of nuisance algae and increased silt deposition.

-very important above some critical fraction baseflow abstraction
-usually 60% of Q5
-assuming that Regional Councils impose <u>some</u> minimum flows
-variable depending on original baseflow and channel configuration

<u>% length with regulated flow (-)</u> -Reduced flows upstream of dams and artefacts of flow management below dams can have adverse effects on river biota and natural river processes. Artefacts may include artificially induced surges, truncated recessions and changed thermal regimes.

<u>% flow from inter-catchment transfer (-)</u> Transfer of water between catchments occurs in some parts ofNew Zealand. This can alter hydrological regimes and lead to the modifcation of natural water chemistry if the mixing waters differ substantially in nutrient status, pH etc. Inter-catchment transfers of water can also lead to the spread of exotic species and the transfer of native species to catchments where they do not naturally occur.

-note effects on flow variation
-can be beneficial
-also implications for tangata whenua
-dependent on quality differences
-depends on water quality of rivers involved

<u>no. point source discharges (-)</u> -The more point source discharges along a river the greater the length likely to be affected by water pollution.

-needs to be further weighted as to quality of discharge and volume of dilution potential
-no. of "significant" discharges is more relevant, i.e., stormwater versus organic
- depends on nature of discharge
-depends on quality of effluent
-not best predictor of pollutant load due to inequality of discharge loads and impacts of dilution. Total BOD load as % baseflow may be better

<u>% baseflow as organic effluent (-)</u> -Organic effluent in rivers can lead to increased oxygen demand and suspended sediment concentrations which affect river biota and natural river processes.

-depends on natural v artificial sources
-probably trivial volumetrically in most cases but may have significant mass effects
-SS is not really organic . There must be a better criterion than % of baseflow
-depends on quality of effluent

<u>% baseflow as inorganic effluent (-)</u> -Inorganic effluents can alter natural water chemistry and kill aquatic life if present in high enough concentrations.

-depends on the effluent

-vague terminology -"inorganic effluents" are highly variable
-depends on type, i.e., heavy metal v others
-probably trivial volumetrically in most but may have significant mass effects
-depends on quality of effluent

DIVERSITY AND PATTERN:

no. of stream orders (+) *-The greater the range of stream orders represented by a section of river, the greater the diversity of habitats potentially available.*
-what method -Strahler blue-line?
-don't really know reln (sic) with so (sic)

altitudinal range (+) *-Changes in altitude lead to differences water temperature, rainfall and riparian vegetation type along a section of river, increasing the diversity of habitats available.*
-some low altitudinal streams are still important
-absolute elevation important too
-needs to be matched with length of system

no. ecological regions (+) *-the more ecological regions a river or segment of river passes through, the more diverse the range of habitats along that section likely to be.*

no. of riparian vegetation types per km (+) *-Riparian vegetation can influence the energetics of rivers through inputs of different types of food such as excised leaves of various species, and by affecting light levels and water temperatures.*
- not understood for fish -type (i.e., all native) more relevant than number
- given a high ranking because riparian diversity increases the value of a system, not because it increases aquatic diversity

no. geological rock types per km (+) *- The geological make-up of rocks can influence water chemistry and also the composition of the substrate.*
-doesn't seem important
-particularly limestone bearing rocks and harder types

no. associated wetland, lakes and tarns per km (+) *-Other aquatic/wetland habitats that merge in an undisturbed way with a section of river enhance the ecological pattern.*

no. discontinuities per km (+) *-Discontinuities such as stream confluences and waterfalls add to the diversity of flow environments in a river.*

no. unmodified interconnecting headwater catchments (+) *-These could provide routes for the natural mixing of aquatic biota between catchments (e.g., for blue duck).*

no. tributaries with low degree of modification (+) *Small tributaries often have more diverse invertebrate and fish communities than larger rivers which can serve as a source for downstream colonisation.*
-I would score this 18 (sic) if tributaries part of the area
-this is more relevant in Table 1

no. pool/riffle sequences per km (+) *-More pool/riffle sequences infer greater diversity of flow environments along a stretch of river.*

<u>no. cascades per km (+)</u> -Cascades add to flow heterogeneity and provide habitat for species adapted to torrential conditions.

<u>substrate heterogeneity (+)</u> The greater the mix of substrate sizes and shapes on a river bed, the greater the diversity of microhabitats that is likely to be available for aquatic biota.

<u>% cover by native aquatic plants (+)</u> -Native aquatic plant cover may increase the diversity of habitats available for other groups.

-important for lowland streams but not shaded headwater streams where aquatic plants are minimal
-more relevant in lakes than in rivers
-representative areas of native aquatic plants very uncondiered (sic) in reserves so far
-take care -dominance can reduce diversity

<u>no. aquatic plants types (+)</u> -The greater the range of different plant morphologies present, the greater the range of microhabitats that are likely to be available for colonisation.

-many oligotrophic streams naturally have no vegetation other than algal films
-important for lowland streams but not shaded headwater streams where aquatic plants are minimal
-including algae and bryophytes -more relevant in lakes than in rivers
-exotics can be detrimental

<u>no. known native aquatic plant species (+)</u> -More native plant species enhance diversity.

-plant diversity important in own right
-important for lowland streams but not shaded headwater streams where aquatic plants are minimal
-large areas of one or two species is a common habitat type which needs representation
-high numbers can imply little shading so limited riparian vegetation, both detrimental

<u>% cover for (+)</u> -The more overhead (e.g., riparian forest) and in-stream (e.g., fallen logs) cover available, the more native species are likely to be present.

<u>no. known native species (+)</u> -More native fish species enhance diversity.

-obviously the higher the better, but some areas such as South Westland have a depauperate fauna this should not detract from the importance of the rivers
-many high quality areas are very species poor because of habitat requirements
-I would have thought that more native fish species reflect habitat diversity rather than enhance it
-no. may not be as critical as type of fish (no. of priority fish as well as total diversity
-also indicative of untouched catchment

RARIIY AND UNIQUE FEATURES OR SPECIES:

<u>no. large waterfalls (+)</u> -These can be unusual features of a river depending on the geology of the area. -characteristic of many rivers here (West Coast) -area of catchment! total stream length upstream -how large

<u>no. unusual rock types (+)</u> -Depending on the geology of an area, some rock types in or along rivers can be rare and impart unusual conditions in segments of rivers.

<u>no. unusual riparian vegetation types (+)</u> - Rare or unusual vegetation types along rivers can impart different conditions in segments of rivers that may favour the presence of rare species or unusual associations of species.

no. unusual geological formations (+) - *Depending on the geology of an area, unusual geological conditions may be present along a river (e.g., segments of subterranean flow).*
-quality may be more important than quantity

length of river or river segment (+) -*The longer a segment of river the more likely it is to contain rare species.*

no. known rare or endangered species (+) -*Based on existing knowledge of the river, some species that are regionally or nationally rare, endangered or vulnerable may be present.*
-what about using "priority" species as per department (DOC) ranking system

FRAGILITY:

stability of flow (+) *Prevailing flow regime may place natural constraints on biotic communities that can develop in a river. Thus, communities in variable mountain-fed rivers may be less "fragile" that communities in stable spring-fed rivers.*
-any natural flow is acceptable
-4 if the descriptor was "predictability"
-New Zealand rivers are characterised by unstable flow but stable streams have their own set of ecosystem attributes
-if flow regime is natural, this is irrelevant

% catchment as erosion prone land (+) - *Large areas of erosion prone land in a catchment may mak e the river more susceptible to changes from extreme environmental conditions.*
-importance will depend on land use
-surely this counts against protection. Erosion prone land covered in forest should not be a problem

importance for sensitive life stages (+) -*A section of river will have greater fragility if any species rely solely on an area in that section for the completion of its life history (e.g., native fish spawning sites).*

importance of downstream conditions (+) -*A section will have greater fragility if its biological integrity relies on the correct management of downstream conditions (e.g., for native passage).*
-this is difficult to assess

vigour of riparian vegetation (-) -*The wider and denser the riparian zone, the less likely a river will be influenced by changes to environmental conditions on the land*
-linked to erosion

proximity of areas for recolonisation (-) *Nearby areas for recolonisation, particularly upstream of a section of river (e.g., tributaries), may enhance the ability of a river to recover fro m environmental perturbations.*

NEW DESCRIPTORS SUGGESTED:

DEGREE OF MODIFICATION

% catchment with artificial drainage -tile drains and ditches bypass riparian wetlands and seeps, increasing nitrogen loads and decreasing baseflow.

% of catchment erosion -

% hard and soft rocks -

DIVERSITY AND PATTERN

Length -distance from sea will affect no. of fish species.

No. stable large woody debris jams and accumulations - adds to habitat complexity (forms riffles and pools) and organic matter retention, particularly in low slope streams

% channelised -greatly reduces habitat diversity and connections between river and floodplain

% hard and soft rocks

average slope/ slope range

flow variability

average depth, width

RARITY AND UNIQUE FFATURES OR SPECIES

Important spawning grounds or staging areas -

High MCI or other stream community indices –

FRAGILITY

Damage by human visits -

Potential threats

APPENDIX 6
Calculations used to estimate % mean flow abstracted from different sections of Tongariro River

Data were supplied by NIWAR using TIDEA program PDIS using the last 10 years records to produce mean flow values which were used in lieu of baseflow in this example. Input from Lake Moawhango excluded.

Total flow above Rangipo Barrage = 37229 $l.s^{-1}$

Flow via Moawhango Tunnel = 13563 $l.s^{-1}$

Flow below Rangipo Barrage = 9068 $l.s^{-1}$

Flow at Poutu Intake = 48634 $l.s^{-1}$

Input from main tributaries in Section 4 = 48634 – 37229 = 11405 $l.s^{-1}$

Natural flow expected at Poutu =11405 + (37229 -13563) = 35071 $l.s^{-1}$

Flow below Poutu = 17694 $l.s^{-1}$

Flow via Poutu Stream = 3443 $l.s^{-1}$

Flow at Turangi = 31635 $l.s^{-1}$

Flow from Whitikau =31635 - (17694 + 3443) = 10498 $l.s^{-1}$

Expected flow at Turangi =35071 + 3443 + 10498 = 49012 $l.s^{-1}$

% baseflow abstracted in Section 3:

{1 -[9068 / (37229 -13563)]} X 100 = 62%

% baseflow abstracted in Section 4:

[1 - (9068 + 11405) / 35071] x 100 = 42%

% baseflow abstracted in Section 5:

17694/35071 = 50%

% baseflow abstracted in Section 6:

[1 - (31635 /49012)] X 100 = 35%

% baseflow abstracted in Section 7:

[1 - (31635 /49012)] X 100 = 35%