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TABLE 4. CORRELATION MATRIX OF VARIABLES USED TO DETERMINE NATURAL HERITAGE VALUE.

	CATCHMENT AREA	TRANSFORMED DISTINCTIVENESS	CATCHMENT RICHNESS	FLOW INTEGRITY	COVER BD REMAINING	WQ BD REMAINING	EXOTIC FISH	THREATENED FISH	BLUE DUCK	THREATENED BIRDS	FLOOD FOREST	THREATENED PLANTS	TOTAL THREATENED SPP.	EUCLIDIAN DISTANCE
Transformed distinctiveness	0.17													
Catchment richness	0.89	0.26												
Flow integrity	-0.35	-0.01	-0.29											
Cover BD remaining	-0.04	-0.01	0.00	0.03										
WQ BD remaining	-0.07	0.01	-0.01	0.03	0.79									
Exotic fish	-0.69	-0.15	-0.64	0.30	0.09	0.09								
Threatened fish	0.33	0.16	0.37	-0.04	0.06	0.05	-0.25							
Blue duck	0.56	0.18	0.61	-0.24	0.11	0.10	-0.40	0.24						
Threatened birds	0.39	0.18	0.44	-0.09	-0.03	-0.04	-0.28	0.29	0.31					
Flood forest	0.68	0.21	0.67	-0.18	0.11	0.09	-0.53	0.36	0.53	0.27				
Threatened plants	0.43	0.16	0.46	-0.04	-0.05	-0.03	-0.34	0.36	0.24	0.47	0.35			
Total threatened spp. scores	0.66	0.25	0.71	-0.15	0.03	0.02	-0.50	0.56	0.58	0.71	0.66	0.84		
Euclidean distance	-0.65	0.25	-0.55	0.20	-0.05	-0.03	0.40	-0.19	-0.31	-0.17	-0.41	-0.24	-0.36	
Heritage value score	0.31	0.22	0.37	0.01	0.42	0.37	-0.13	0.48	0.43	0.20	0.49	0.31	0.49	-0.22

TABLE 5. TOP 20 RIVERS RANKED BY NATURAL HERITAGE VALUE SCORE (NHV).

CATCHMENT ID	BIOGEOGRAPHIC UNIT	NAME	NHV
249	Stewart Island	Freshwater River	6.10
6	Grey-Buller	Buller River	5.94
71	Northwest Nelson-Paparoa	Karamea River	3.98
430	Stewart Island	Rakeahua River	3.68
355	Fiordland	Big River	3.12
201	Westland	Cascade River	2.75
130	Northwest Nelson-Paparoa	Mokihinui River	2.62
211	Westland	Karangarua River	2.45
192	Westland	Turnbull / Okura rivers	2.43
168	Westland	Waiatoto River	2.43
100	Westland	Arawhata River	2.30
221	Westland	Paringa River	2.27
64	Westland	Haast River	2.27
472	Stewart Island	Doughboy River	2.13
79	Westland	Hollyford River	2.11
261	Westland	Waiho River	1.99
334	Fiordland	Stillwater River	1.90
396	Stewart Island	Toitoi River	1.89
136	Fiordland	Wairaurahiri River	1.80
191	Fiordland	Waitutu River	1.68

distinctive (or unique) river reach types with few special features (Fig. 2F) and low catchment condition. These highly distinctive systems must be included on the candidate list in order to protect the full range of biodiversity. Numbers of threatened species and catchment area (Fig. 2F) were also correlated (Table 4) with the highest weighted threatened species scores occurring in larger catchments. However, there were also many large catchments that had few special features, so bigger was not always better.

Natural heritage value scores ranged from < 0.0001 to 6.1, with the highest-valued sites typically of medium catchment size (Fig. 2B) and mostly located on the west coast of the South Island (Table 5). The 20 sites with highest NHV scores were all located on the west coast of the South Island or on Stewart Island. Protection of these rivers alone would capture a small and highly biased portion of the full range of New Zealand's aquatic environments, habitats, communities, and species.

3.2 DERIVING A CANDIDATE LIST

Protection of the one river having the highest NHV score within each of the 29 biogeographic units would include just 32% of the range of river types present in New Zealand. This would not meet the objectives of WONI. This list would include the whole of the Buller, Waitaki, Mohaka, Waiau (Southland), Rakaia and Motueka Rivers (Table 6).

A list constructed from the top ten rivers (ranked by NHV) within each biogeographic unit would capture an average of 73% of the range of river classes within New Zealand, but as little as 16% of the environmental variance in any given biogeographic unit. In addition it would include many of New

Zealand's largest rivers (Fig. 2) where biodiversity protection is less practical: it would be in direct competition with existing, potentially incompatible uses such as hydro-electric power generation, irrigation, and intensification of land use. Typically, whole catchments have the highest NHV scores because they contain the greatest number of river classes in a biogeographic unit, and some populations of threatened species because of the relationship between species distribution and area. However, despite the high NHV score, biodiversity condition of specific river class may vary across a range from excellent to poor (heavily disturbed). It is likely that some smaller catchments will contain less-

TABLE 6. PERCENTAGE RIVER CLASSES INCLUDED IN: TOP CATCHMENT BY HERITAGE SCORE, TOP TEN (T10) CATCHMENTS BY HERITAGE SCORE, TOP CATCHMENT IF LARGE CATCHMENTS ARE DOWN-WEIGHTED, AND FROM PROPOSED TYPE I CANDIDATE CATCHMENTS (IN BRACKETS ARE TYPE I AND II CATCHMENTS COMBINED). REC = RIVER ENVIRONMENT CLASSES.

BIOGEOGRAPHIC UNIT	RIVER CLASSES PER UNIT	% REC TOP SITE (T10 LIST)	% REC FROM T10 RIVERS	% REC — TOP SITE (HIERARCHICAL SORT)	% REC FROM CANDIDATE LIST
Auckland	41	12.2	36.6	12.2	51.2 (56.1)
Banks Peninsula	21	23.8	81.0	23.8	85.7 (85.7)
Bay of Plenty	45	22.2	75.6	53.3	60 (86.6)
Canterbury	132	18.2	78.0	18.2	78.0 (92.4)
Clutha	97	35.1	100.0	12.4	85.5 (96.9)
Coromandel	37	16.2	54.1	16.2	81.0 (81.1)
East Cape	98	29.6	88.8	13.3	88.7 (95.9)
Fiordland	97	21.6	77.3	21.6	79.3 (79.3)
Grey-Buller	105	89.5	100.0	38.1	91.4 (98.1)
Hawke's Bay	103	27.2	95.1	27.2	70.8 (88.3)
Manawatu-Wairarapa	89	3.4	28.1	20.2	76.4 (89.8)
Marlborough	96	59.4	61.5	37.5	82.2 (82.2)
Mokau	71	1.4	26.8	1.4	84.5 (84.5)
Motueka-Nelson	86	55.8	88.4	55.8	75.5 (90.6)
Northland - eastern	49	10.2	16.3	10.2	44.8 (61.2)
Northland - northern	32	25.0	46.9	25.0	71.8 (71.8)
Northland - western	74	12.2	37.8	54.1	62.1 (67.5)
Northwest Nelson Paparoa	109	59.6	86.2	25.7	95.4 (95.4)
Otago Peninsula	22	9.1	72.7	9.1	40.9 (81.8)
Palliser-Kidnappers	45	13.3	26.7	13.3	42.2 (82.2)
Southland	166	91.6	91.6	9.6	85.5 (96.9)
Stewart Island	28	82.1	96.4	82.1	96.4 (96.4)
Taieri	80	1.3	96.3	26.3	96.2 (97.5)
Taranaki	34	38.2	85.3	70.6	88.2 (88.2)
Waikato	93	28.0	100.0	50.5	76.3 (100)
Waitaki	105	1.0	94.3	34.3	83.8 (98.1)
Wanganui-Rangitikei	96	68.8	99.0	39.6	88.5 (98.9)
Wellington	34	26.5	91.2	26.5	55.8 (94.1)
Westland	147	36.1	83.0	37.4	89.7 (89.7)
Mean		31.7	72.9	29.8	76.1 (87.1)
Range		1–91.6	16.3–100	1.4–82.1	40.9–96.4 (56.1–100)

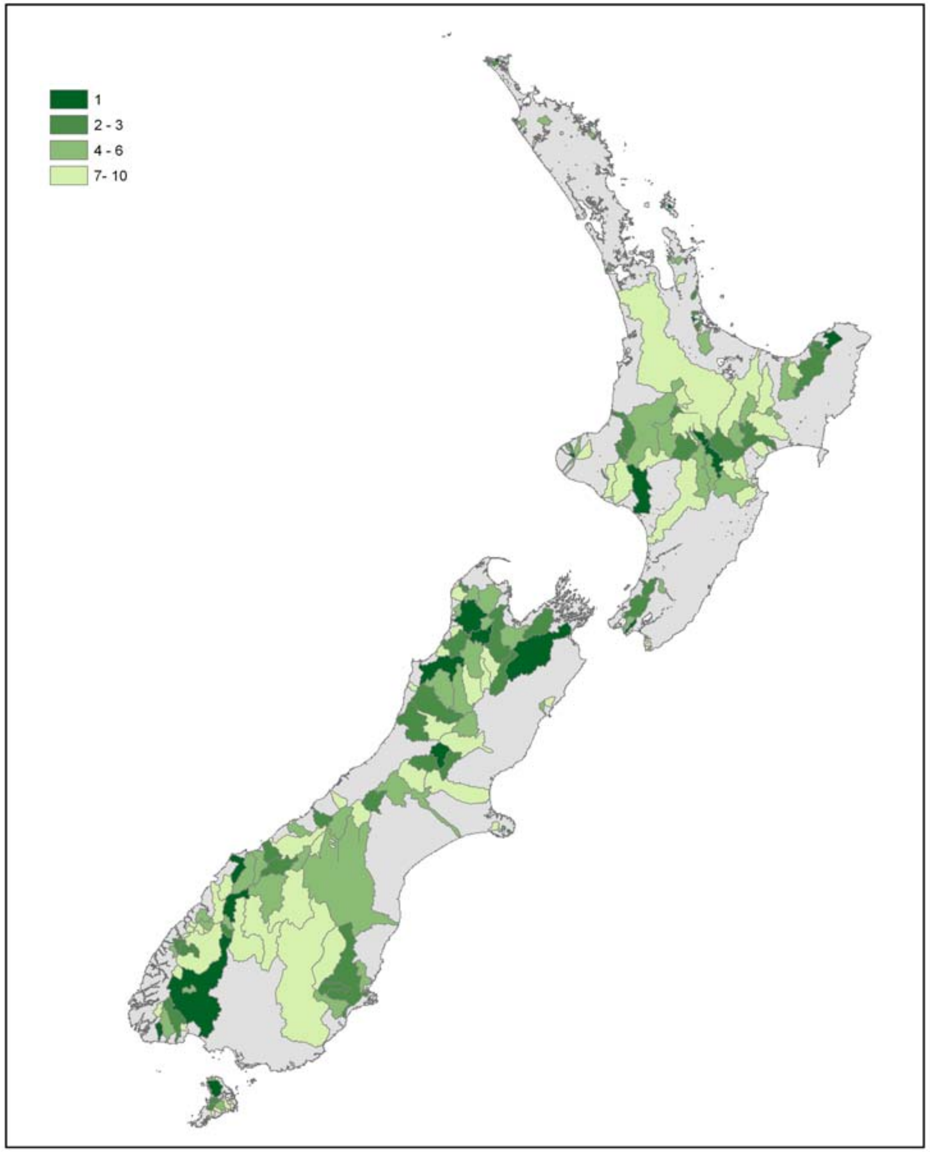


Figure 3. Top ten rivers for each biogeographic unit, ranked by Natural Heritage Value (NHV) scores.

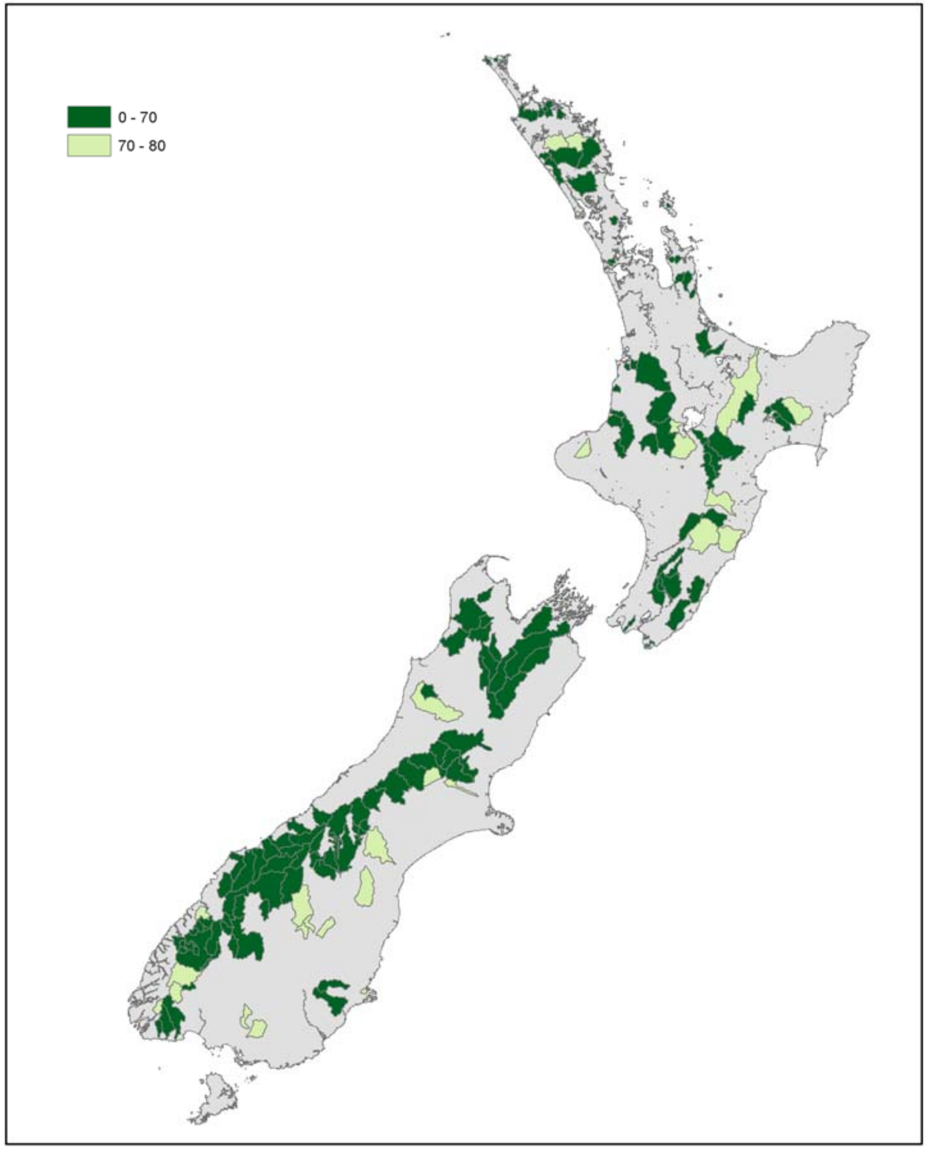


Figure 4. Minimum river catchments required to account for up to 70% (dark green) and 80% (light green) of all river classes within each biogeographic unit, derived from a hierarchical sort that down-weighted large catchments.

modified examples of some river classes and have retained a greater range of biodiversity content. Although protection of a large river may protect a full range of river classes, it may therefore not protect the full range of biodiversity.

If catchments are sorted hierarchically with priority given to the smaller sub-catchments, then less than 30% of river classes (Table 6) is usually contained within the sub-catchments with the highest heritage value score. A list of river catchments that cover 70% of river classes using a hierarchical sort, requires 180 rivers (Table 7). However, headwater catchments dominate the list in the South Island and Central North Island (Fig. 3). A list that accounts for 80 or 90% of river classes (Figs 4, 5, Table 7) is still dominated by smaller headwater sub-

TABLE 7. NUMBER OF CATCHMENTS OR SUB CATCHMENTS REQUIRED TO ACCOUNT FOR 70–100% OF RIVER CLASSES WITHIN A BIOGEOGRAPHIC UNIT, USING A HIERARCHICAL DATA SORT THAT DOWN-WEIGHTED LARGE CATCHMENTS.

BIOGEOGRAPHIC UNIT	70%	80%	90%	100%	GRAND TOTAL
Auckland	12			3	15
Banks Peninsula	4		2	3	9
Bay of Plenty	4	1	1	4	10
Canterbury	4	4	3	4	15
Clutha	6		1	4	11
Coromandel	10	2	2	3	17
East Cape	4	1	1	4	10
Fiordland	4	3	6	7	20
Grey-Buller	1		3	3	7
Hawke's Bay	4	1	1	4	10
Manawatu-Wairarapa	8	1	1	3	13
Marlborough	8		3	7	18
Mokau	9		3	5	17
Motueka-Nelson	2	3		7	12
Northland - eastern	19	2	2	4	27
Northland - northern	9	3	1	3	16
Northland - western	11	3	3	3	20
Northwest Nelson-Paparoa	2		3	8	13
Otago Peninsula	9		1	2	12
Palliser-Kidnappers	11	1	2	4	18
Southland	6		1	4	11
Stewart Island			2	3	5
Taieri	4		3	4	11
Taranaki	3	2	2	2	9
Waikato	5	1	2	1	9
Waitaki	6		2	3	11
Wanganui-Rangitikei	4		2	3	9
Wellington	4			3	7
Westland	7		4	8	19
Grand Total	180	28	57	116	381

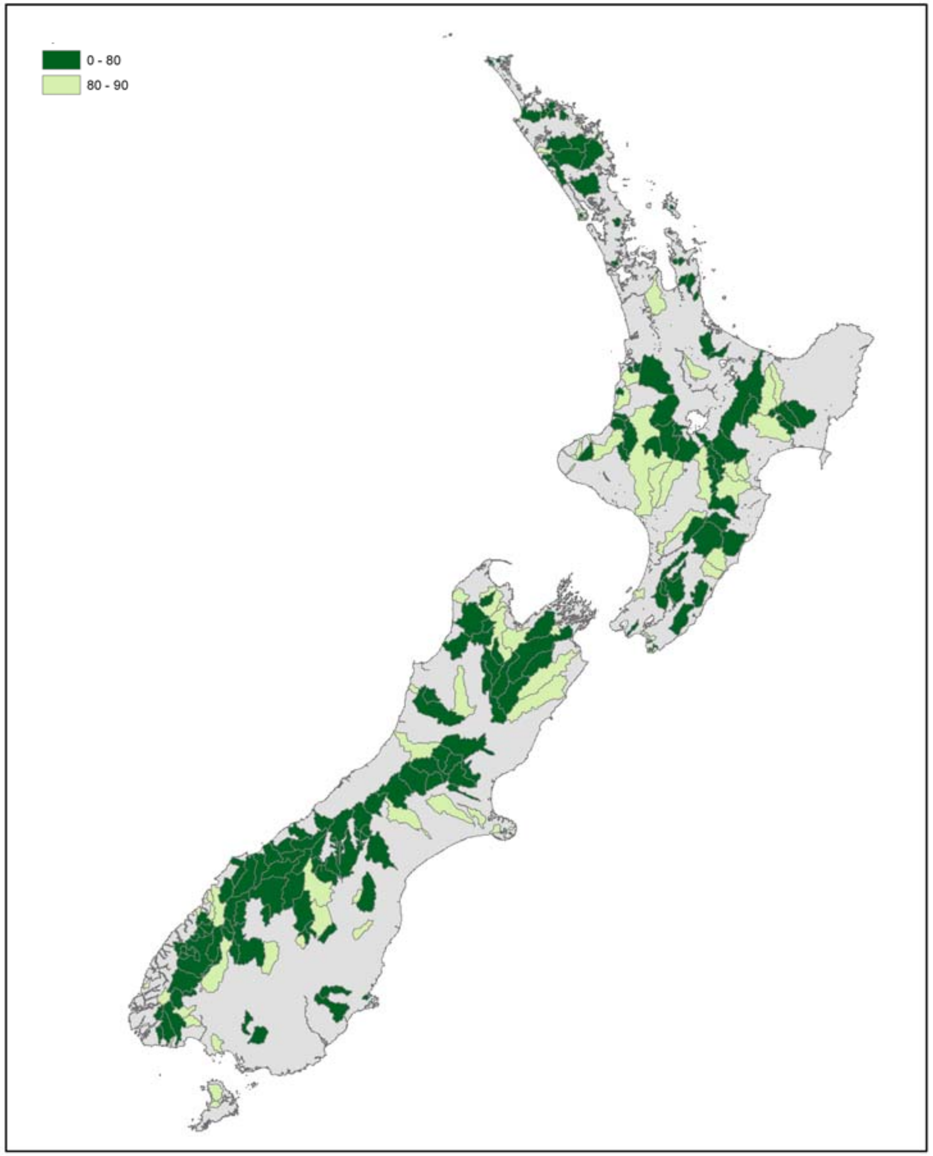


Figure 5. Minimum river catchments required to account for up to 80% (dark green) and 90% (light green) of all river classes within each biogeographic unit, derived from a hierarchical sort that down-weighted large catchments.

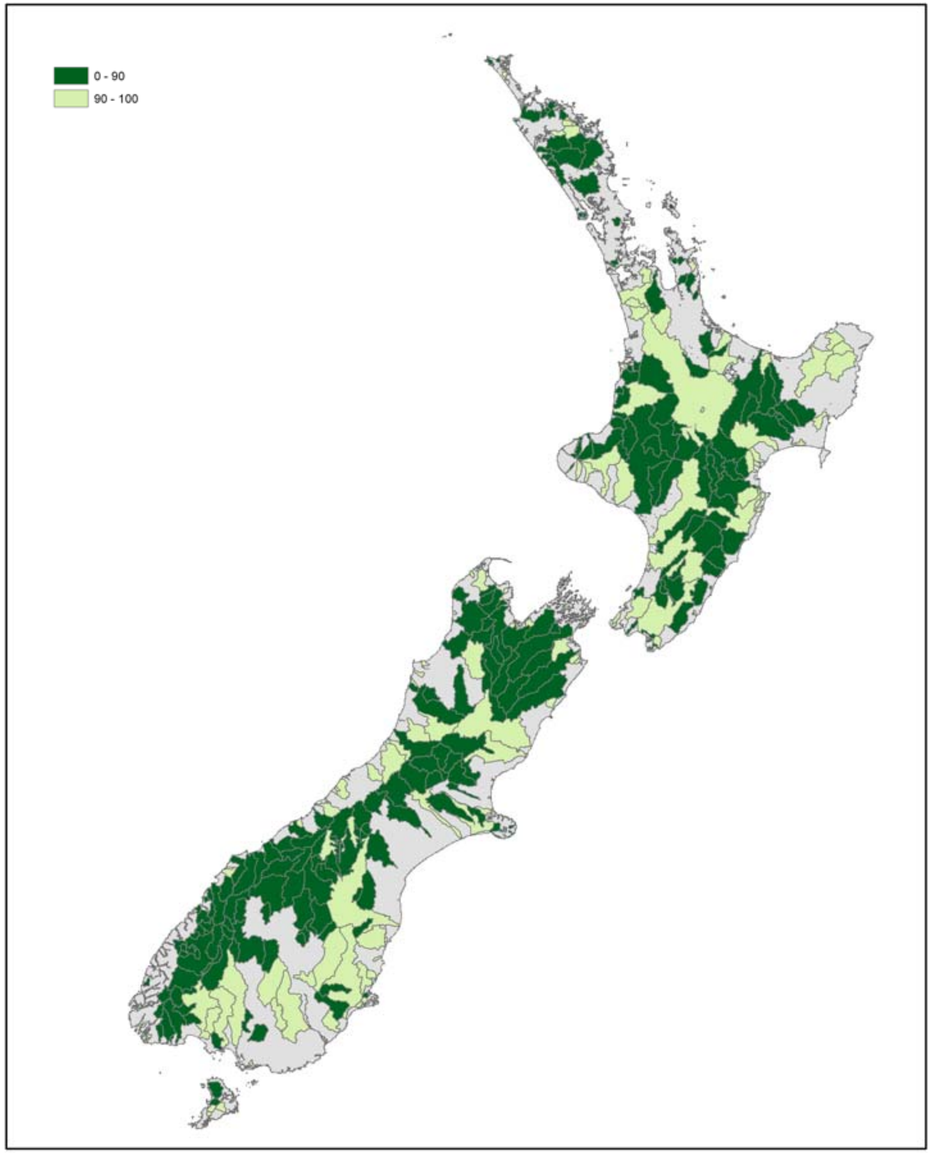


Figure 6. Minimum river catchments required to account for up to 90% (dark green) and 100% (light green) of all river classes within each biogeographic unit, derived from a hierarchical sort that down-weighted large catchments.

catchments and/or smaller rivers arising from hill country. The large Canterbury braided rivers, and lower reaches of the larger rivers like the Waikato, Wairau and Waiua (Southland) need to be included for the list to cover 100% of the river classes (Fig. 6), as the lower reaches of these rivers contain distinctive river classes. In order to incorporate the last 10% of river classes, the number of catchment or sub catchments required increases by 30% from 265 catchments to 381 catchments (Table 7). This approach still fails to adequately cater for threatened species, because some of the best populations occur in more modified catchments.

TABLE 8. COMPARISON OF THE NUMBER OF CATCHMENTS AND AREA IN EACH BIOGEOGRAPHIC UNIT SELECTED BY: HIERARCHICAL DATA SORT THAT ACCOUNTS FOR 100% OF RIVER CLASSES; TOP 10 CATCHMENTS (BY NHV SCORE); AND PROPOSED CANDIDATE LIST.

BIOGEOGRAPHIC UNIT	HIERARCHICAL SORT		TOP 10		TYPE I CANDIDATE LIST	
	CATCHMENTS	AREA (ha)	CATCHMENTS	AREA (ha)	CATCHMENTS	AREA (ha)
Auckland	15	53,052	10	8 825	10	8 374
Banks Peninsula	9	19,999	10	15 752	6	16 534
Bay of Plenty	8	541,572	10	414 401	5	126 520
Canterbury	24	1,935,928	10	1 268 877	7	1 032 378
Clutha	16	1,607,773	10	4 033 818	7	879 570
Coromandel	17	73,760	10	37 203	13	62 344
East Cape	15	965,160	10	558 509	7	475 423
Fiordland	20	271,397	10	221 602	7	216 628
Grey-Buller	10	973,863	10	1 913 728	5	467 481
Hawke's Bay	11	828,818	10	1 112 410	5	495 170
Manawatu-Wairarapa	16	1,780,120	10	52 293	9	270 627
Marlborough	20	1,336,601	10	529 393	9	781 172
Mokau	17	403,916	10	14 920	10	179 120
Motueka-Nelson	14	417,882	10	354 793	5	158 212
Northland - eastern	28	186,465	10	9 876	14	16 660
Northland - northern	16	21,283	10	16 240	11	14 093
Northland - western	15	374,544	10	26 639	10	75 380
Northwest Nelson-Paparoa	15	451,378	10	414 518	8	365 406
Otago Peninsula	5	10,482	10	7 150	8	2 091
Palliser-Kidnappers	18	342,468	10	10 435	9	11 143
Southland	27	2,647,015	10	1 240 867	9	584 016
Stewart Island	5	65,708	10	86 525	4	62 113
Taieri	14	1,036,212	10	920 525	9	482 145
Taranaki	7	93,023	10	66 941	9	75 849
Waikato	11	1,970,584	10	1 657 122	6	317 392
Waitaki	22	1,954,190	10	1 375 504	8	510 777
Wanganui-Rangitikei	12	1,947,641	10	2 136 836	6	922 052
Wellington	5	85,268	10	92 075	6	28 215
Westland	20	951,842	10	638 279	12	734 111
Grand total	**432**	**23,347,942**	**290**	**19 236 053**	**234**	**9 370 998**

3.3 CANDIDATE LIST OF NATIONALLY IMPORTANT RIVERS

The final list of candidate rivers of national importance is a combination of top sites ranked by heritage scores; the most important systems for threatened species; and those needed to make the list more representative of the range of

Figure 7. Candidate nationally important river catchments. Type I catchments shown in dark green, Type II in light green (the latter contain sections, or special features, of national importance).

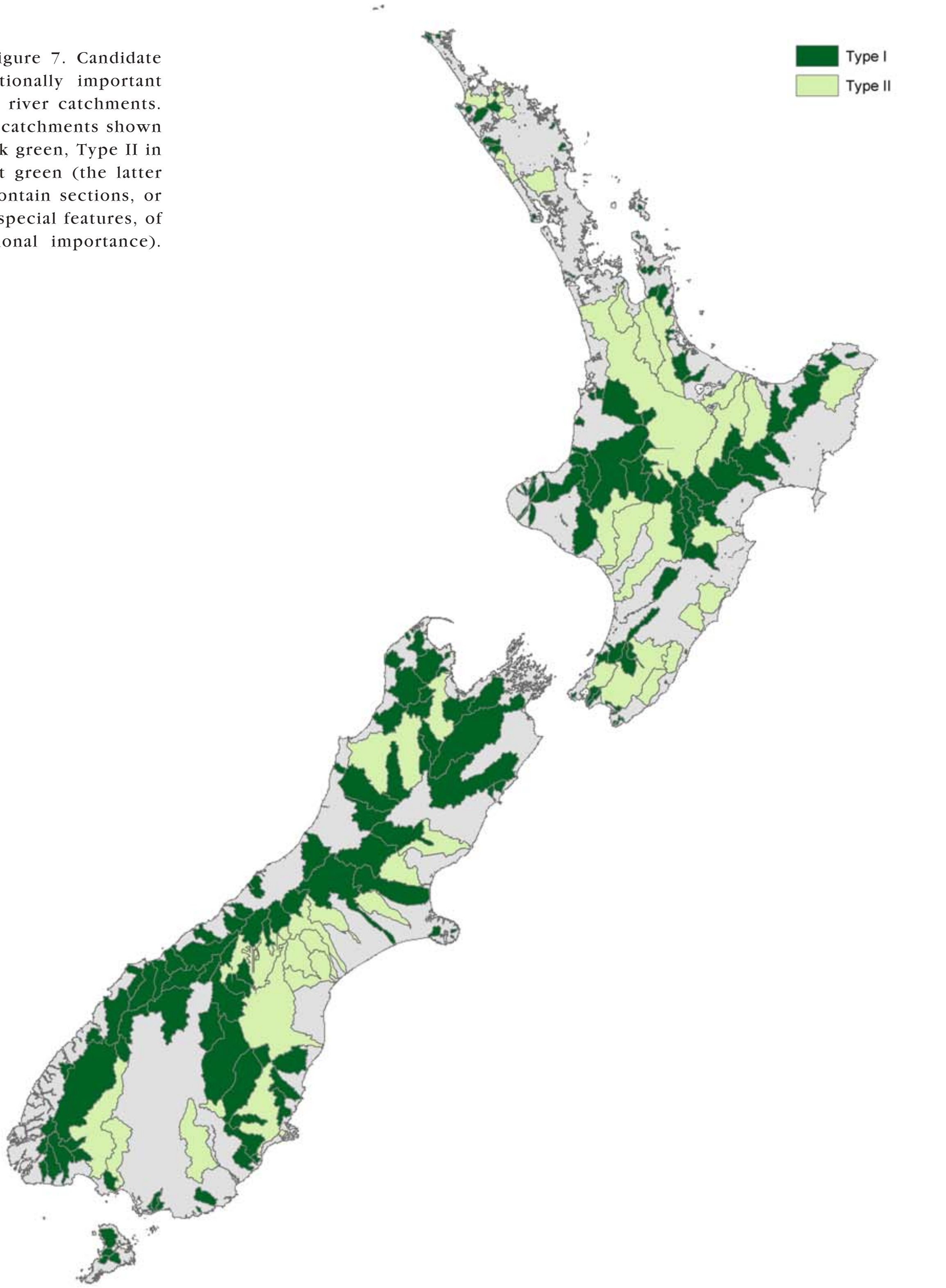
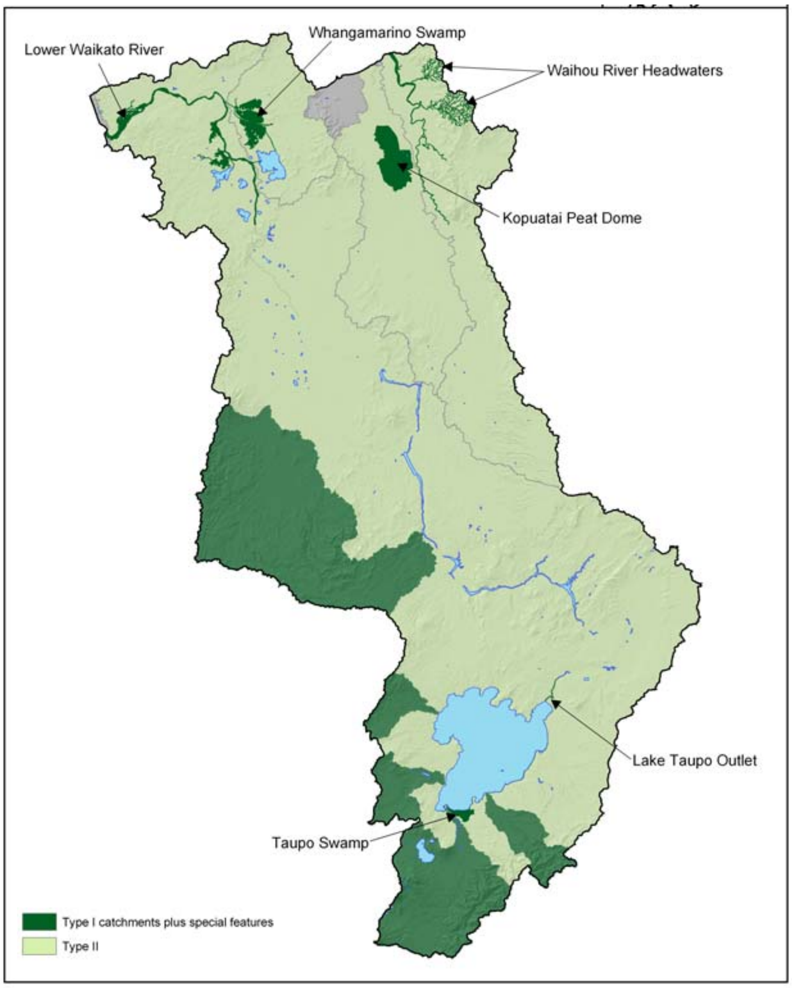


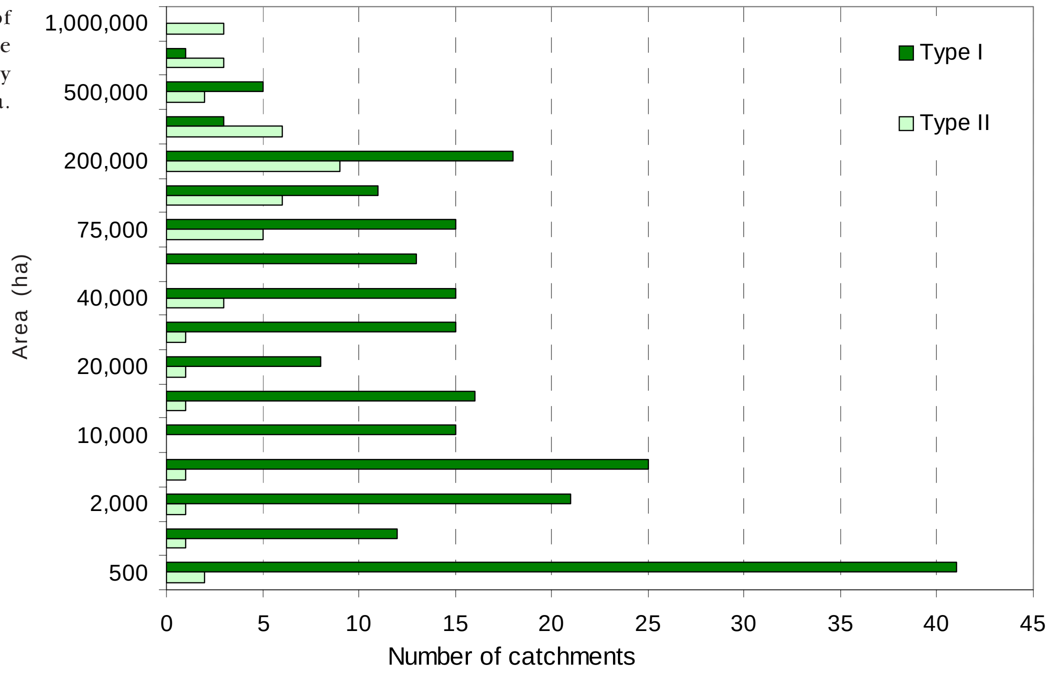
Fig. 8. Depiction of Type I (dark green) and Type II (light green) catchments in the Waikato Biogeographic unit, as illustrated in Appendix 1 (p. 102). The spatial extent of known special features (labeled) in Type II catchments is shown in dark green also.



river classes present within each biogeographic unit. The Type I list includes 177 rivers and 57 sub catchments (5% of the river assessed), with an average of 8 rivers (or sub-catchments) per biogeographic unit (range 4–14). A further 46 catchments are listed as Type II rivers: they include several major catchments (e.g. Waikato, Rangitikei, Whanganui, Motueka, Wairua, Buller, Taieri, Waitaki Waimakariri, and Waiau (Southland): Fig. 7) that contain nationally important sections in their lower reaches.

An example of the true probable spatial extent of nationally important features or sections in a Type II candidate river is illustrated for the Waikato biogeographic unit (Fig. 8). The map from Appendix 1 (p. 102) shows that almost the entire unit appears to contain sections of national importance. However, the special features requiring protection in the Type II catchments are quite localised and are usually in the lower river (Fig. 8). They include the mouth of the Waikato River which is a nationally unique river type, and listed by Cromarty & Scott (1996) as a wetland of international significance. The unit also contains Whangamarino Swamp and Kapuatai Peat Dome. Both are RAMSAR wetlands of international significance and two of New Zealand's largest remaining swamp and bog complexes. They are both contained within highly modified, intensively farmed catchments. These rivers clearly need to be managed in a manner commensurate with the ongoing survival of their special features, but they are unlikely to contain much biodiversity of significance in their own right.

Figure 9. Frequency of occurrence of candidate catchments grouped by catchment area.



The Type II catchments listed do not need to be protected in total but in part, as only sections of their rivers encompass features which are of national significance. Typically for the larger catchments, these features will be in the main stem of the lower river.

The candidate list of Type I catchments incorporates between 41 and 96.4% of the river classes present in each biogeographic unit, as well as a suite of important populations of threatened species. Inclusion of Type II rivers ensures that, with the exception of eastern and western Northland, over 70% of river classes are present within the catchments listed for each biogeographic unit (Appendix I). Inclusion of Type II rivers in Eastern and Western Northland brings the percentage representation over 60%. However, in these units there appears to be an over-estimation of number of river classes due to the REC model assigning river classes to lakes and depressions that do not contain riverine systems (e.g. Northland dune lakes are assigned REC types). In reality, the candidate catchments are likely to represent closer to 70% of the riverine environmental variability within their units. When time permits these problems will be addressed.

Over two-thirds of the Type I catchments are under 30,000 ha in size whereas the majority of Type II rivers exceed 75,000 ha (Fig. 9). The actual candidate lists are presented in Appendix I, along with the reasons for their inclusion and any special features known to be present.

The adopted approach attempts to minimise the catchment area selected within our candidate list (and hence potential for overlap with other WONI lists). A comparison between the three approaches tested, illustrates that the total catchment area contained within our Type I rivers is less than half the area incorporated in the Top 10 catchments for each biogeographic unit; and it is less than one-third of the total area required to protect 100% of river types using a hierarchical data sort (Table 8 on p.31).

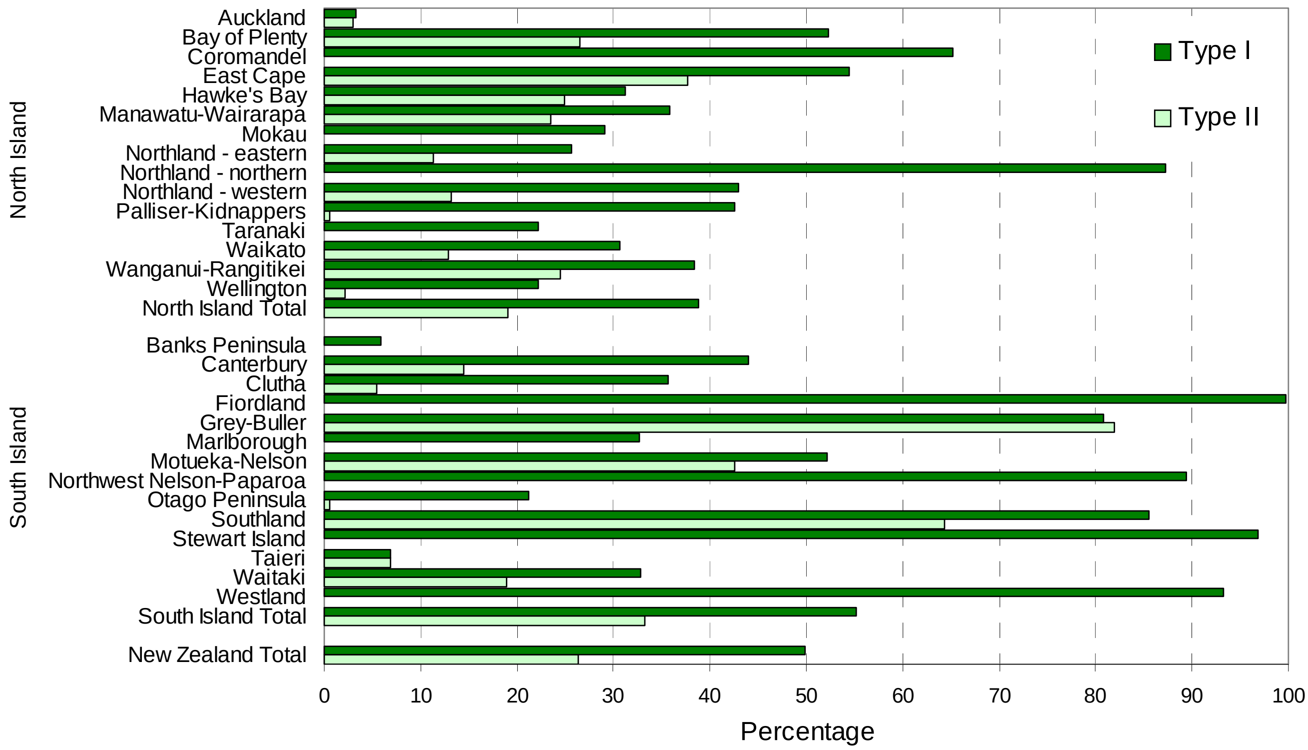


Figure 10. Percentage of catchment area contained within lands administered by the Department of Conservation, summarised by biogeographic unit.

In Fiordland, West Coast, Northwest Nelson, Grey-Buller and Stewart Island, almost 100% of the catchments areas of rivers listed are present within public land administered by the Department of Conservation (Fig. 10). Elsewhere in the South Island, and North Island, typically headwaters of candidate streams are within public conservation land. In Auckland, Otago Peninsula, and Wellington a limited area of catchments are administered by DOC, but significant areas are regional parks or water catchments managed by Local Authorities.

4. Discussion

4.1 ASSESSMENT FRAMEWORK

We adopted a technical assessment framework as this approach enabled a comprehensive, consistent and objective list to be developed. This approach lends itself to further learning, improvement and exploration of alternative assumptions in the future.

The underlying data, models and processes presented are a precursor to the Natural Heritage Management Systems (NHMS), a long-term improvement programme that aims to provide the data and necessary tools to support the Department of Conservation (DOC) with its natural heritage conservation business. These and other tools will be developed as part of a broader government agency partnership between DOC, Ministry for the Environment (MfE), regional councils, and iwi. Hence the WONI natural heritage databases, models and results will continue to be refined and extended as survey and monitoring data, models and data management systems are improved. One priority is to move beyond the limitations of our catchment-scale analysis by developing systems that allow analyses such as WONI to be undertaken from the scale of the river reach, up to whole catchments in a fully connected network.

There are some significant impediments to defining national priorities for freshwater biodiversity protection. These include the absence of any freshwater database describing observations of a full range of indigenous biodiversity; large spatial and taxonomic gaps in survey data across the country, taxonomic deficiencies and limitation in survey and inventory techniques (Collier et al. 2000). Collectively, these factors confound any direct assessment of the state of biodiversity (i.e. based on biotic distribution data). Any assessment of importance based on current biotic data sets alone, would be biased and carry significant risk of overlooking systems essential for protecting the full range of remaining indigenous biodiversity. To avoid these pitfalls, we used spatially explicit (GIS) measures of environmental pattern as a surrogate for biotic variablity, and pressure indices as surrogates for the state of native biodiversity. It was possible to define and compile these data much more consistently and comprehensively across New Zealand than is currently possible with existing data describing observations of freshwater biota.

This assessment of natural heritage value was based on the principle that measures of human-induced disturbance pressure, physical pattern and biogeography, can be used to provide an index of indigenous biodiversity value. There is support for these relationships within the current literature that demonstrate that the greatest threats to freshwater communities in New Zealand are the loss and reduced quality of habitats caused by human-induced modification (see Collier & Winterbourn 2000 for current reviews). These include modifications to catchments, riparian and channel environments, water quality, river flows and introduction of exotic species (Collier 1993; Collier et al. 2000; Quinn 2000; Chadderton & Allibone 2000; Townsend et al. 2003; Chadderton et al. 2003b).

The number of candidate rivers of national importance for biodiversity is primarily driven by three features of our model:

- The number of biogeographic units recognised
- The classification resolution used for river environment classes (i.e. the number of river classes recognised)
- How much of the full range of biodiversity is represented in the list.

The list of rivers will be longer as more biogeographic units and distinct river environment types are recognised. It is therefore important that the resolution of biogeographic units and river environments is a reasonable reflection of freshwater biological pattern. If classification resolution is excessive, then the number of units will overstate actual biological variation and more rivers will be listed than are actually needed to represent the full range of biological diversity. The converse will over-estimate the actual level of biodiversity protection provided by the list. The WONI project timeframes prevented assessment of these issues in detail. But, as noted in Sections 2.1 and 2.4, we have not been overly conservative. The resolutions of both the biogeographic classification and the river typology are more likely to under-estimate than over-estimate actual biological variation.

These issues are compounded by the rule-based way in which the river environment classification was constructed. This assumes that all river classes are equally different, yet this is most unlikely to be true. It is possible that some river classes not included in our candidate list could be highly distinctive, and represent a significant proportion of the full range of freshwater biodiversity. This risk is greatest for large lowland rivers which are probably under-represented in the list. We intend to test this issue after completing a multivariate riverine classification in 2005, which will enable distinctiveness and environmental distance to be measured.

4.2 THE CANDIDATE LIST OF RIVERS OF NATIONAL IMPORTANCE

Biological diversity encompasses the variability among living organisms from all sources and the ecological complexes of which they are part; this includes diversity within species (genotypic and phenotypic), between species and of ecosystems (Richmond 1999). Therefore in order to meet our goal of protecting a full range of biodiversity, the final candidate list had to include and provide for:

- Viable populations of all indigenous species and sub species
- A full range of remaining natural habitats, environments and ecosystem processes which yield biological pattern, and ecosystem structure.

Our candidate list for Waters of National Importance attempts to reconcile the diversity of our river ecosystem types with the collective habitat needs of New Zealand's freshwater biodiversity. We effectively have to consider the needs of 160 water-dependent bird species, 38 species of freshwater plant and 38 species of fish, as well as hundreds of species and subspecies of freshwater invertebrates and microscopic plants (diatoms). The challenge of capturing an adequate range of species is complicated by the variable distribution patterns of these taxa, in space and time. At one extreme, some endemic invertebrate species are found only in a few catchments within a single biogeographic unit (e.g. Bank Peninsula has at least 6 endemic species: Harding 2003). Paradoxically, there are migratory bird species that depend upon different river systems for just a few days of the year, and even rivers in another region during alternate seasons or stages of their life cycle (e.g. braided river birds: O'Donnell in press).

To provide for the full range of biodiversity, we needed to include a combination of distinctive, threatened, and least disturbed representative systems (Collier et al. 2003). The latter systems are priorities for protection as they are likely to have retained most indigenous biodiversity content. In contrast, the more distinctive systems and threatened environments are likely to contain sites where indigenous biodiversity is at peril. Hence to conserve a full range of biological and genetic diversity, it is necessary to protect a wide range of habitats (Ponder et al. 1996). This requires both the identification of areas of special value (biodiversity hotspots) and the assessment of complementarity (Reid 1998; Margules & Pressey 2000). For these reasons the WONI biodiversity list is a combination of the least disturbed representative and distinctive river systems, plus a range of catchments that contain rare and special features or threatened species.

The simplest approach to developing a candidate list would have been to choose the highest ranking river in each biogeographic unit. However, this approach would not sustain the full range of New Zealand's natural freshwater biological diversity, as it accounts for only a small percentage of the range of river ecosystem types and associated biodiversity. It is also unlikely to adequately protect many threatened species. The final candidate list therefore took a combination in each biogeographic unit, of the most natural sites (highest heritage value scores), catchments that made the greatest contributions to the range of river environment classes, and systems with significant populations of threatened species. A total of 177 whole-river catchments and 57 sub-catchment units were identified that incorporate an average of 76% of all river environment classes. With the inclusion of a further 46 (Type II) river catchments that contain sections or special features of national significance, our lists appears to cover almost 90% of river classes and a viable range of key sites for most threatened species.

The Type II list includes a number major catchments (e.g. Waikato, Rangitikei, Whanganui, Motueka, Wairua, Buller, Taieri, Waitaki, Waimakariri, and Waiau (Southland), Aparima). These contain nationally important wetlands, lakes or estuaries or populations of threatened species often in their lower reaches and or main stems. It also includes a number of medium-sized catchments (e.g. Tarawera River) where the values are located within their headwaters, but the catchment framework does not allow these areas to be delineated at greater resolution. The key issue here is that, in order to conserve these values, the entire catchment would not need to be protected. This is well illustrated by the mouth of the Waikato River, a unique river form listed by Cromarty & Scott (1996) as a wetland of international significance. Protection of the entire Waikato catchment would not be required in order to conserve the special features at the Waikato River mouth.

A range of protection mechanisms could be used to secure these Waters of National Importance; methods will depend upon both land tenure and the nature of a system's ecological values. The majority of headwaters reaches are within public lands managed for conservation, or in some instances they are water catchments or regional parks managed by local authorities. In the South Island (particularly Fiordland, Westland, Nelson) and Stewart Island, the catchments listed are almost entirely within the conservation estate. Protecting these may simply require appropriate rules in regional plans and riparian management. In other South Island areas (like the Clutha and Taieri biogeographic units), the High Country Tenure review process may offer a means to increase the levels of legal protection. The potential value of statutory mechanisms will be explored at a latter stage of the WONI process; such exploration is beyond the scope of the present report.

4.3 STRENGTHS OF THE WONI ASSESSMENT

Our work represents the first attempt to identify nationally important rivers systems for indigenous biodiversity. It is quite unlike previous efforts to identify New Zealand's most important wild and scenic rivers (e.g. NWASCO) that largely only considered recreation, landscape and acclimatised fish values.

The present assessment successfully identified the most natural and representative river systems that contain a reasonably comprehensive range of New Zealand's freshwater ecosystems, communities and species including threatened species. The list is objective; the framework and approach allows for further testing and refinement.

The WONI databases and candidate list also offer a framework to inform and improve planning and management of freshwater natural heritage at regional to national scales. At the very least, it provides a multi-scale context for assessing the significance of particular catchments for biodiversity maintenance. Underlying models are explicit and offer predictions that can be tested and so facilitate learning. The database provides a basis from which the level of investment required to halt the decline in freshwater biodiversity can be estimated; management effort can be directed to those catchments where the best value from biodiversity investment is likely to be obtained.

The assessment demonstrates the efficacy and power of a spatially explicit approach using data describing environments and human-induced disturbance pressure. These concepts are being developed in the department's National Heritage Management Systems programme as described by Stephens et al. (2002). The WONI project demonstrates another application of conservation assessment concepts (i.e. the identification of catchments that contribute most to New Zealand's remaining freshwater biodiversity). The challenge now is to thoroughly test the results, quantify inadequacies, design systems and better models, and focus survey and monitoring effort to fill data gaps. All these elements are required for the WONI assessment to be improved and for the value of its learning opportunities to be fully realised.

4.4 WEAKNESSES OF THE WONI ASSESSMENT

It is important to note that on current knowledge, full protection of this list will not achieve Goal Three of the New Zealand Biodiversity Strategy, i.e. protection of the full range of biodiversity. Based on our model, achieving Goal Three for New Zealand's rivers would probably require 381 river and sub-catchments to be fully protected from further degradation. However, limitations in our river catchment data mean that the redundancy (i.e. unnecessary conservation effort) in these 381 catchments would be significant.

Budget and time constraints precluded development of a network system to allow continuous analysis from headwaters to the river mouth. One consequence of this problem was that lower reaches of large catchments could not be analysed separately from their upper catchments. Hence heritage value scores for large rivers were a product of their entire catchment, resulting in high heritage values that overshadowed smaller rivers and sub-catchments. This might have resulted in a list comprising all New Zealand's major rivers. We overcame this problem by sorting catchments hierarchically to down-weight parent catchments. However, this procedure may have created another problem: exclusion of some lower main-stem river reaches that contain nationally important biodiversity. Time constraints have prevented exploration of this possibility and its consequences.

Even within Type I catchments (our primary candidate list), there are likely to be areas that are not nationally important because of the catchment scale assessment (cf. river reach scale). Many tributaries and headwater sections will have been included in the list because another part of the catchment contains river classes that make the candidate list more representative. This implies duplication and some redundancy within some listed catchments, hence overestimation of the area required to protect a full range of values. This issue will remain until New Zealand's river network can be properly analysed as a spatial network.

The gap between protection of the ideal (100% of river classes) and the percentage protected in our current list (76%) is probably overstated. This results from an artifact caused by the digital elevation models used to delineate rivers, where some lakes and depressions are defined as catchments and then assigned river classes. Especially in the Auckland and Northland units, and some high-country areas of the South Island, the number of river classes is probably overstated due to the presence of dune lakes, volcanic craters, or glacial cirques. Time constraints prevented correction of these errors.

There are no national or local population estimates for most threatened native species. Consequently our WONI rankings place little emphasis on any single population of highly threatened species. Clearly, if the loss of a population would lead to, or dramatically increase the probability of extinction, then (in accordance with Goal Three of the New Zealand Biodiversity Strategy to halt the decline) its protection would be of national importance. Absence of data to index population significance means that we have been unable to account for the irreplaceability of populations of threatened species. Therefore some critical populations of threatened species are not represented in the WONI list. These issues can only be overcome with the development and implementation of comprehensive biodiversity survey and monitoring programmes supported by national databases. These are presently beyond the resources of both this project and the Department.

Our model inadequately accounts for the connectivity and buffer functions that some rivers provide to nationally important wetlands, lakes and estuaries. The current list is incomplete, reflecting acknowledged shortcomings of previous assessments (e.g. Cromarty & Scott 1996) and our inability to develop a suitable typology for lakes (unpublished data). We have therefore applied minimal weight to buffering and connectivity services provided by rivers to these ecosystems. This issue will be re-visited once a more comprehensive and objectively derived list of nationally important wetlands, lakes and estuaries has been produced during later stages of the WONI project.

Few unmodified river systems completely free of exotic fish, remain on the New Zealand mainland (Chadderton 1990; Jowett et al. 1998; Chadderton & Allibone 2000). Those that do remain are highly significant, for two reasons:

- Scientifically — as critical role models for future restoration of other rivers (Zedler et al. 1997; Chadderton & Allibone 2000)
- Intrinsically — as the most complete examples of New Zealand's remaining freshwater biodiversity.

Detection of systems without exotic species was hampered by large gaps in survey effort. Areas apparently free of all exotic fish species on the South Island West Coast, Fiordland and East Cape North Island, are more likely to represent absence of survey effort rather than absence of exotic fish. Yet these isolated areas are also likely to contain the largest remaining systems free of exotic species. Where such systems could be positively identified, they were incorporated directly into the list of candidate rivers on this criterion alone (e.g. Company Creek, Westland National Park).

The Department of Conservation's NHMS programme will provide some opportunity to improve the databases we require for this type of assessment. In particular, an Inventory and Monitoring project aims to improve the quality and coverage of biodiversity and pressure data. The Bioweb database project will offer curation services, provide a single data access portal and promote improved data standards. We hope that the NHMS programme will eventually attract resources to build and sustain the skills and capability required to develop, test, improve and use models for applying conservation and biodiversity assessment concepts; and so realise the potential value that these concepts offer.

5. Acknowledgements

We are indebted to a wide variety of people without whose help this project would not have been completed. Numerous staff from Department of Conservation, Fish & Game Councils and Regional Councils provided data, and passed a critical eye over pressure measures, and commented upon the candidate lists, often at short notice. Chris Richmond set up the project, provided the policy context, and was a crucial sounding board and reviewer of the project outcomes. Murray Williams, Colin O'Donnell and Jo Sim developed the lists of nationally important rivers for aquatic birds. Richard Allibone compiled the threatened-fish data, with help from Eric Graynoth (eels). Andrew Townsend produced the list of threatened aquatic plants (helped by conservancy botanists) and Leigh Bull pulled this, the Hochstetter's frog and the blue duck data out of Bioweb. Joanna Drabsch spatially referenced the point source discharge data. Rob McColl and Bob Wilcock provided advice on nutrient loading, and Russell Death and Mike Joy on pressure/biodiversity relationships. Brenton Wilson, Margaret McTainsh and Lynette Hartley provided GIS support, and Jenny Christies modelling advice. Adam Smith rescued us numerous times from Excel problems. Thanks to Rod Hay and Margaret for hosting us in our days of need. Thanks also to John Leathwick and Kevin Collier for letting us plagiarise innumerable sections of their earlier report. Tracie Dean reviewed and checked the penultimate drafts, and Jaap Jasperse provided "unprecedented" editing and formatting under very tight time frames.

Finally thanks to Ned Norton, Mark Weatherhead, Helen Hurren, Ude Shanker and Ton Snelder, for their patience, and hard work in developing many of the databases used in this analysis.

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Appendix 1.

CANDIDATE LIST—BIOGEOGRAPHIC UNITS

Biogeographic units are listed in alphabetical order below (for locations, refer Fig. 1 on p. 23).

Within each biogeographic unit a general description is provided of the unit and some of its key biotic features. These are derived almost exclusively from Leathwick et al. (2003). Where possible this is supplemented with additional information although this is limited due to time and resource limitations imposed within the timeframes of the Waters of National Importance project. Candidate catchments are listed in tables by biogeographic unit. Each table contains abbreviated notes on key features or reasons for inclusion of some candidates in the lists. However, some catchments have no additional notes. These have been selected because they contain the least disturbed example of river classes not represented within the list of nationally important catchments. They have been chosen to make the list more representative of the full range of river environments and hence riverine biodiversity.

Auckland
Banks Peninsula
Bay of Plenty
Canterbury
Clutha
Coromandel
East Cape
Fiordland
Grey-Buller
Hawke's Bay
Manawatu-Wairarapa
Marlborough
Mokau
Motueka-Nelson
Northland—eastern
Northland—northern
Northland—western
Northwest Nelson-Paparoa
Otago Peninsula
Palliser-Kidnappers
Southland
Stewart Island
Taieri
Taranaki
Waikato
Waitaki
Wanganui-Rangitikei
Wellington
Westland

MAP EXPLANATIONS

Candidate nationally important river catchments are plotted out in separate figures, by biogeographic unit. Type I catchments are shaded in dark green, and within these catchments the whole system is considered to be of national significance. Catchments shaded in light green comprise Type II rivers that contain sections of national importance. For the larger catchments these are typically the lower main river stem, often because they contain habitat for significant populations of aquatic bird species (e.g. Canterbury braided rivers) or rare or special habitats or features. Some rivers simply provide a critical connectivity or buffer (hydrological) function of a designated RAMSAR wetland of international significance. Many of the smaller Type II catchments (e.g. Hutt River, Tarawera River) have highly natural headwaters that contain the least disturbed or only examples of river environment classes within that biogeographic unit. Inclusion of these sections is necessary to capture a wider range of river environment classes.

TABLE LAYOUT

Each catchment has its own unique catchment number that identifies it within the WONI river environment database. Catchments in the candidate list of rivers of national importance are divided into Type I and Type II. Type I catchments are listed first and are river systems where the majority of the catchment is nationally significant. Type II catchments contain special features of national significance, usually a wetland or nationally important population of a threatened species: sections of these river systems are of national significance.

- **Heritage value score** is total natural heritage score used to rank each catchment within each biogeographic unit (see Section 2.3).
- **Euclidean distance** is a measure of catchment distinctiveness based upon the full range of river environment classes within each biogeographic unit. A value close to 1 indicates that the catchment is highly distinctive, whereas a value close to 0 indicates that the catchment is representative of the biogeographic unit.
- **Total REC classes** are the number of river environment classes located in that catchment. The total number in the entire biogeographic unit is given in the header row, in brackets. Cumulative % REC classes represents the cumulative contribution each new river makes to the total range of river classes present within the candidate rivers, starting with the catchment within the biogeographic unit with the highest Natural Heritage Value score.
- The **Area** of each catchment is given in hectares. The percentage of the catchment in natural land cover (% Natural cover) and public lands managed for conservation (% DOC) are given. The final section of the table records reasons for inclusion and special features where these are known.

Other abbreviations used in the tables:

- **T10** This catchment was in the list of top ten sites by Natural Heritage Value score in its biogeographic unit.
- **Highly natural** Catchment cover is largely natural (refer to % natural cover). Data derived from the Land Cover Data base.
- **B.Duck** Contains records of blue duck (*Hymenolaimus malacorhynchos*) recorded in the last 10 years.
- **Teal** Contains brown teal (*Anas aucklandica chlorotis*).
- **Frog** Contains populations of Hochstetter's frog (*Leiopelma hochstetteri)*
- **Nat.Sign.** Nationally significant
- **RAMSAR** Has a connectivity or buffer function for one of four sites designated as RAMSAR wetlands of international significance.
- **Nat.Imp.Site** Catchment contains or flows into a wetland, estuary or lake that has been designated Nationally Important (see Section 2.7: Connectivity/ buffering function; and Cromarty & Scott 1996). This list is incomplete, and will be revised in later stages of WONI.
- **Nat.Sign.bird pops** Contains nationally significant bird populations
- **Threatened plant, fish and/or birds** Catchment contains populations or records of threatened plant, bird and/or fish species (see Section 2.6: Special features).