Appendix A Habitat model parameters

Table A-1: Species for which generalised habitat models are available in New Zealand. The model parameters c and k are displayed and optimum discharge per unit width provides an indication of relative flow demand (Source: Jowett et al. (2008)).

Species	*c*	*k*	Optimum discharge per unit width (m^2 s^{-1})
Inanga	0.19	19.74	0.01
Shortjaw kokopu	0.19	16.35	0.01
Upland bully	0.11	8.63	0.01
Cran's bully	0.09	6.84	0.01
Banded kokopu (juvenile)	0.19	13.3	0.01
Canterbury galaxias	0.03	2.29	0.01
Roundhead galaxias	0.31	10.64	0.03
Flathead galaxias	0.28	9.11	0.03
Longfin eel (<30 cm)	0.07	2.07	0.03
Lowland longjaw galaxias	0.33	9.35	0.04
Redfin bully	0.26	7.39	0.04
Shortfin eel (<30 cm)	0.13	2.32	0.05
Common bully	0.39	6.51	0.06
Brown trout fry	0.86	10.21	0.08
Brown trout yearling	0.40	4.18	0.09
Nesameletus	0.26	2.62	0.10
Brown trout spawning	1.24	9.89	0.13
Bluegill bully	1.01	6.13	0.16
Rainbow trout spawning	1.49	8.78	0.17
Deleatidium	0.33	1.92	0.17
Torrentfish	0.88	4.05	0.22
Brown trout adult	1.17	4.35	0.27
Food producing habitat	1.19	4.25	0.28
Rainbow trout feeding (30-40 cm)	0.93	2.89	0.32
Coloburiscus humeralis	1.35	4.17	0.32
Aoteapsyche	1.44	3.17	0.45
Zelandoperla	1.71	3.40	0.50

Appendix B Freshwater Management Units and EFSAP in Northland

Introduction

As part of its regional planning process, Northland Regional Council (NRC) is working towards defining and establishing Freshwater Management Units (FMUs) as required by the National Policy Statement for Freshwater Management (NPS-FM) (MfE 2014). Defining FMUs for the management of water quantity requires balancing freshwater values and objectives with the inherent natural spatial variability in the environment that contributes to differing environmental, economic and sociocultural outcomes.

NRC is seeking to understand how the information derived from EFSAP can be used to support the development of FMUs for water quantity. Furthermore, NRC wish the EFSAP modelling results to be re-collated and summarised for the proposed FMUs, supporting derivation of transparent, scientifically based default minimum flow and allocation limits for the FMUs.

Scope

The objective of these analyses is to consider the basis for defining FMUs and setting limits for water quantity in Northland using the EFSAP modelling results. This will be placed in the context of earlier studies evaluating approaches for defining environmental flow requirements in Northland (e.g., Franklin 2010; Franklin 2011). Revised EFSAP decision space plots will be derived for the proposed FMUs to support determination of appropriate default minimum flow and allocation limits.

How can EFSAP be used to inform definition of FMUs in Northland?

The NPS-FM defines a FMU as a water body, multiple water bodies, or any part of a water body determined by a regional council as the appropriate spatial scale for setting freshwater objectives and limits and for freshwater accounting and management purposes (MfE 2014). Implicit in this definition is that the delineation of FMUs is dependent on how water bodies are valued, the objectives for those values and the spatial variability in the outcomes for those values under a given set of limits.

EFSAP helps to characterise the spatially explicit outcomes of different limit scenarios for a specific set of values associated with managing water quantity. The modelling results can therefore help to understand how outcomes for different values vary across the Northland region under different water quantity limits, and therefore can be used to support the definition of spatially distinct management units.

Natural spatial variations in the environment can lead to different outcomes for freshwater values under the same resource use limits (Snelder et al. 2011). EFSAP was used to demonstrate this for Northland, with analyses of the spatial variations in consequences for the different values evaluated in EFSAP (see Section 3.1) resulting in the identification of three spatially distinct potential management units defined by river size and climate (Section 3.2 & Table B-1; Figure B-1). Subsequent analyses have shown that these spatial patterns (of change in the availability of suitable physical habitat for target species and reliability of water supply) are relatively consistent between limit scenarios ranging from relatively conservative to relatively resource enabling (Figure B-2 & Figure B-3).

Table B-1: Definition of spatial management units for default allocation limits in Northland.

Management unit	Spatial definition
Large river	Mean flow ≥ 20 m^3 s^{-1}
Small river	Mean flow < 20 m^3 s^{-1}
Warm extremely wet	REC WX climate class

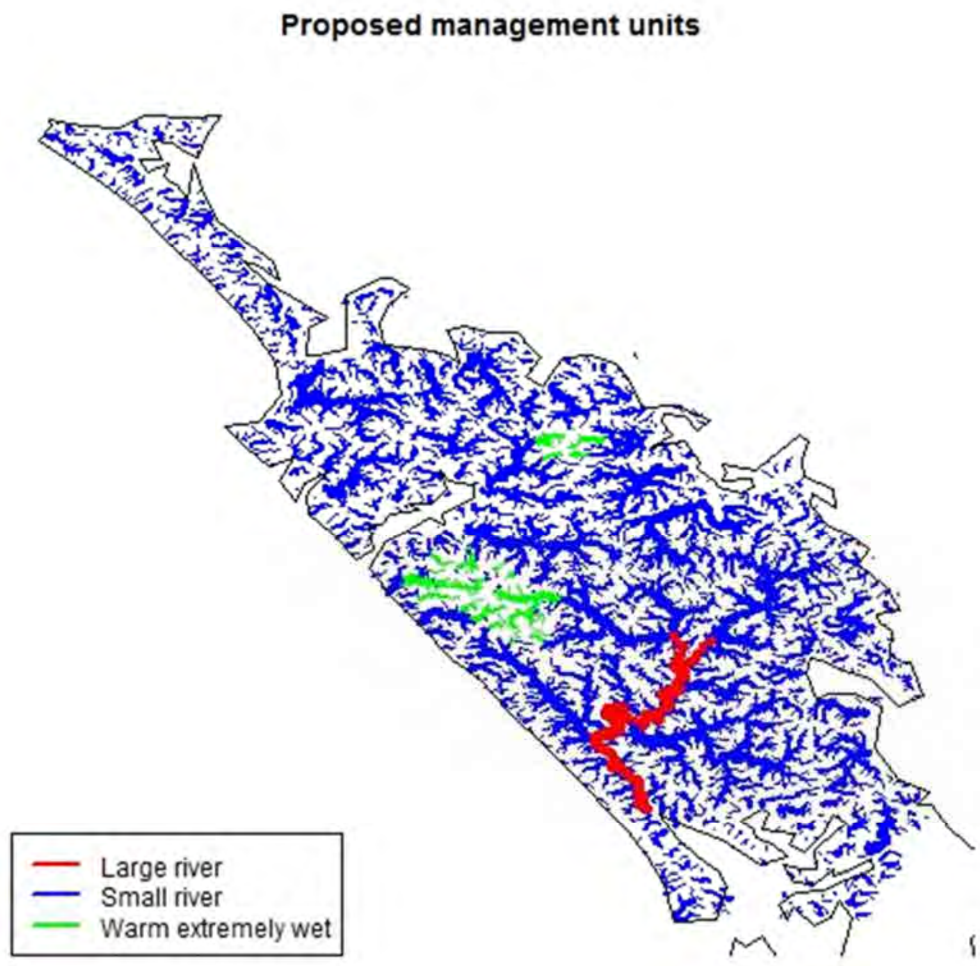

Figure B-1: Location of the three proposed management units.

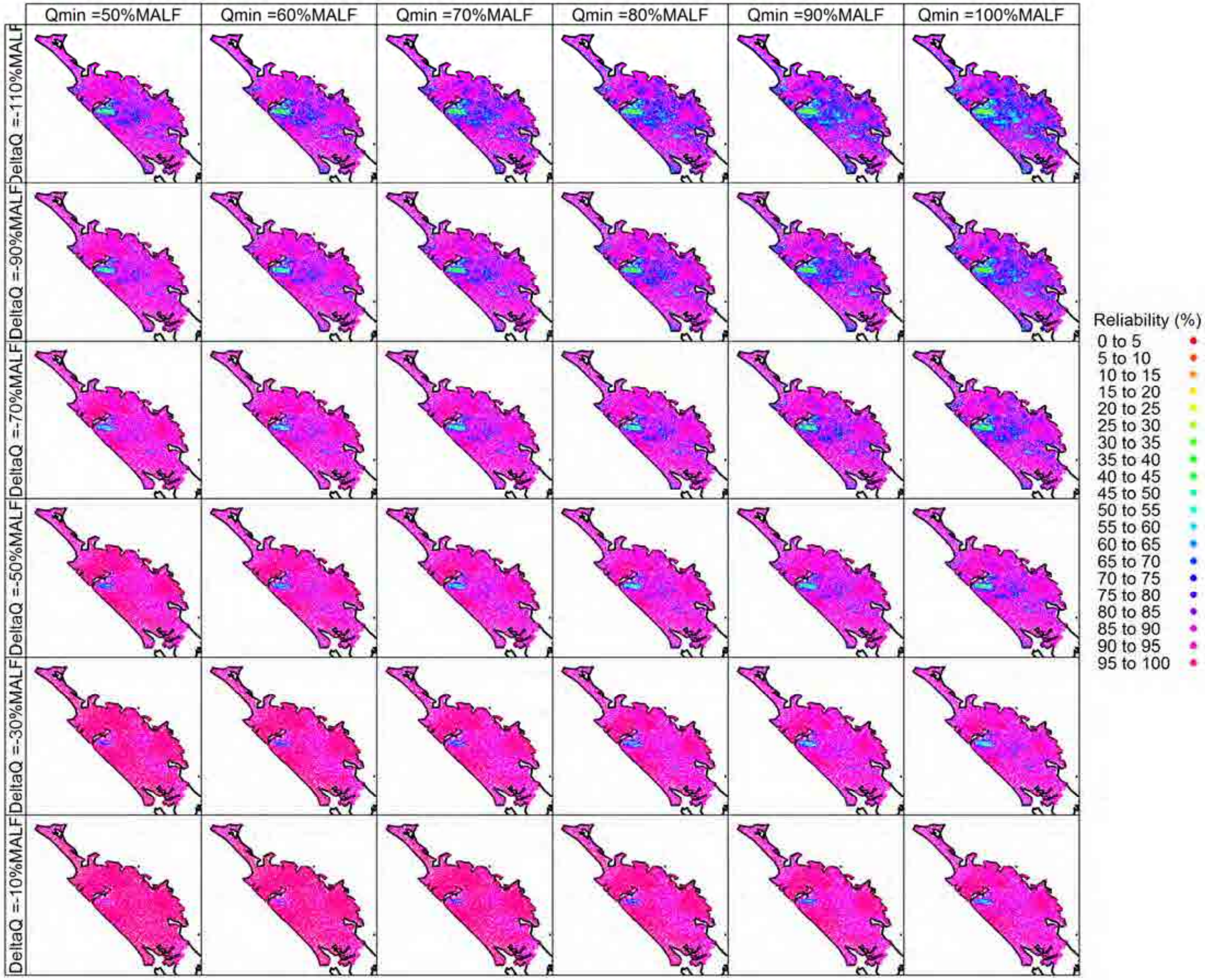

Figure B-2: Illustration of the spatial variation in predicted reliability of supply (R_1) under a range of minimum flow and abstraction limit permutations.

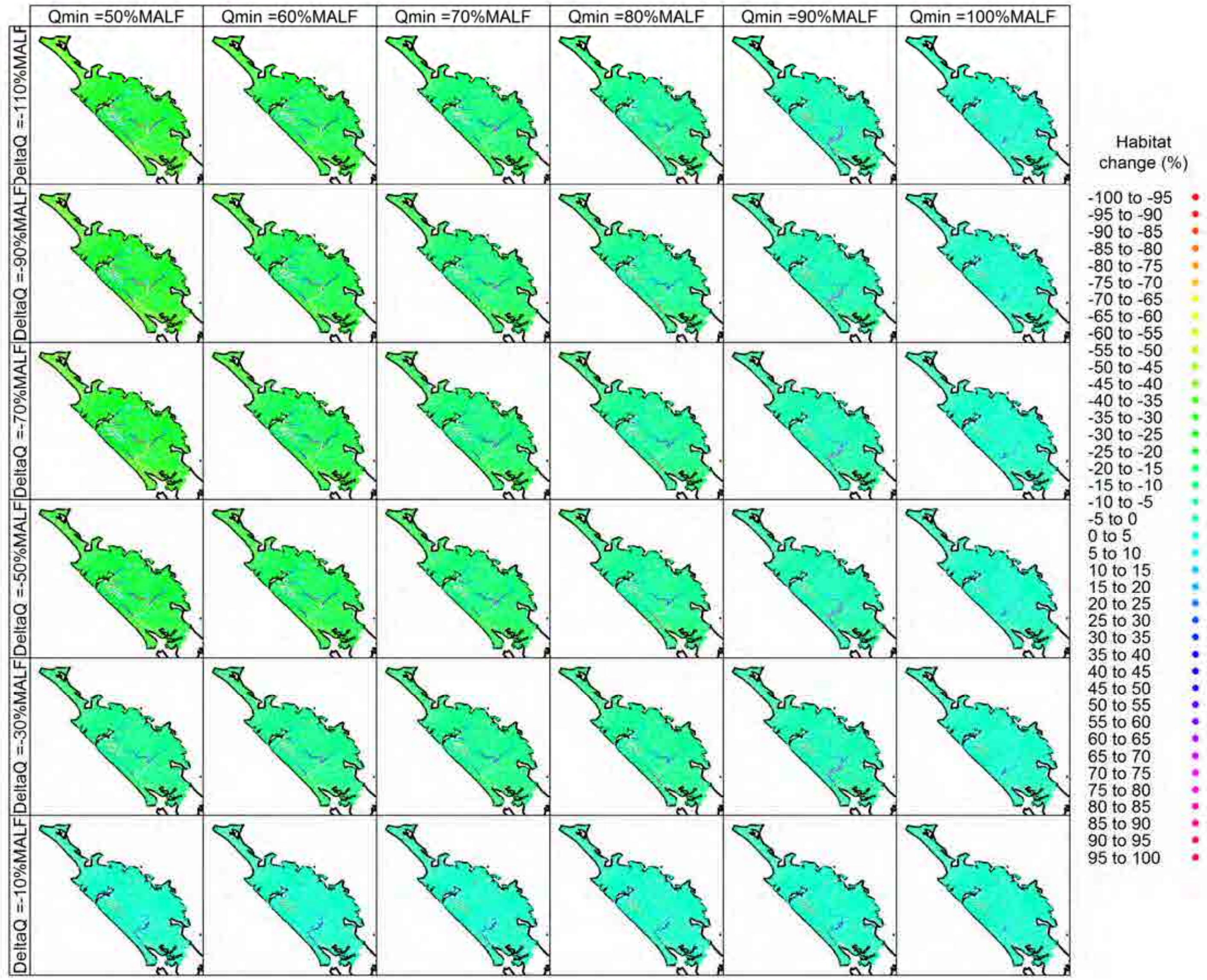

Figure B-3: Illustration of the spatial variation in predicted ΔH for banded kokopu under a range of minimum flow and abstraction limit permutations.

The three proposed management units identified in the initial EFSAP analyses (Section 3.2) are based purely on the recognition and delineation of spatial variation in the outcomes for the different attributes used to represent the instream (physical habitat for fish) and out-of-stream (reliability of supply) values characterised in EFSAP. Understanding how the attributes chosen to describe a particular value vary in their response to different limit scenarios is an important dimension to defining FMUs. Consequently, the existing EFSAP analyses provide valuable input when establishing FMUs for water quantity management in Northland. However, EFSAP only includes a limited number of attributes for describing the primary values included in the model (i.e., reliability of supply and instream physical habitat availability for selected fish species). It also makes no attempt to weight those outcomes with respect to the significance of risk to those values in any given location. For example, having very high reliability of supply may be important in the vicinity of a large public water supply take, but it may not be so important in the middle of significant natural area that is protected from development. Equally, having a high level of habitat protection in an area inaccessible to the target fish species (e.g., because of a large waterfall) is of less benefit than at a site with a high abundance and diversity of fish present.

An example of how the risk of deleterious effects on a value might be characterised to support the development of water quantity management units was presented in Franklin (2011). Beca (2008) outlined some general rules-of-thumb for identifying the potential risk of deleterious effects on instream habitat based on stream size (defined in terms of mean flow) and representative fish communities. Franklin (2011) used these rules in combination with national models of predicted fish distributions and mean flow to classify Northland streams in terms of whether they are likely to be at low, moderate or high risk of deleterious effects on instream habitat as a result of abstraction (Figure B-4). This preliminary assessment highlighted that the risk of deleterious effects on instream habitat was typically highest in low order streams close to the coast. This pattern reflects the migratory characteristics of many of New Zealand's freshwater fish species, meaning that they are more common at low elevations and close to the coast, and also the abundance of small streams that exist in Northland.

The differences in the spatial patterns identified in Franklin (2011) and those identified in this report highlight a fundamental principal for interpreting the EFSAP outputs and therefore how they can be used within the context of defining FMUs. EFSAP characterises the changes in attributes that describe a value, as a consequence of different water quantity limits. However, a certain absolute change in an attribute can have a different consequence in different locations. This can be illustrated with an example. Consider two sites with equal quantities (100 units) of suitable physical habitat available for an indicator fish species and assume that one habitat unit is required to support one fish. At one site, the abundance of fish is naturally limited to ten by the presence of a downstream migration barrier (e.g., a waterfall). Consequently there are ten habitat units available for every fish. The other site is close to the coast, has free access to the sea and therefore has a high abundance of the indicator fish species present (100). Consequently there is one habitat unit available for each fish. At the first site, a 10% reduction in the availability of suitable habitat is likely to have no significant impact on the fish community as each fish still has nine habitat units available, even though it only needs one to survive. At the second site, however, there would no longer be enough habitat available to support all the fish (i.e., 0.9 habitat units per fish). Consequently, if it is assumed that the fish population is limited by habitat availability, the population must also reduce by 10% to match the availability of suitable habitat.

The EFSAP outputs are therefore valuable in characterising potential changes in an attribute under various flow management rules and how these vary in space under different rules. This can be used to help define FMUs in terms of identifying spatially discrete units that respond in a similar way to the same flow management rules. However, the EFSAP outputs do not take into consideration the risk of adverse effects associated with the modelled changes, even though this should also be important in defining FMUs. Furthermore, EFSAP only addresses a limited number of values (reliability of supply and instream physical habitat) and those values are described by a limited number of attributes (R_1, R_2 and ΔH) that do not describe all dimensions of a value. For example, in the case of instream physical habitat, only one measure of habitat change is explicitly included in EFSAP (ΔH). This attribute only captures one dimension of how water use impacts on the quality and quantity of instream physical habitat available for a species, and also does not take into account the duration, timing or frequency with which those conditions occur. Consequently, the EFSAP outputs can be useful for defining FMUs for water quantity management, but this should be undertaken in the context of both the limitations of EFSAP and an understanding of the broader objectives of managing water quantity.

The process that NRC have taken to defining their FMUs is described in Snelder (2015).

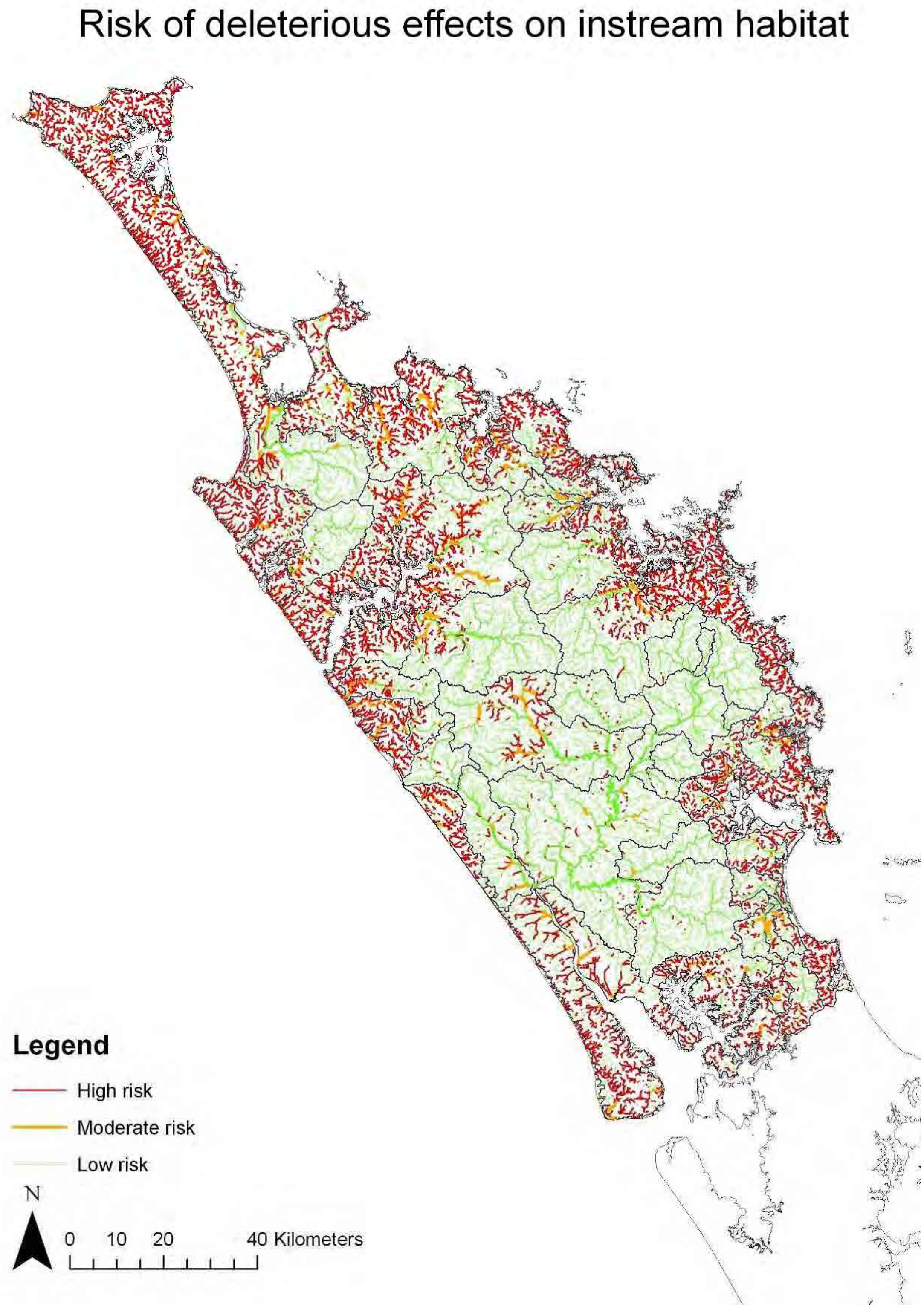

Figure B-4: Potential risk of deleterious effects on instream habitat. From Franklin (2011).

Proposed FMUs for Northland

Snelder (2015) has proposed FMUs for water quantity management in Northland. The four proposed FMUs were based on the spatial patterns observed in the EFSAP outputs (this report), combined with those in the potential risk of deleterious effects on instream habitat characterised in Franklin (2011). The process used to derive the classes and define the boundaries of the FMUs are described in Snelder (2015) and will not be repeated here. It is noted that the Large, Small and Warm Extremely Wet classes identified in Section 3.1 of this report do not match exactly with those in Snelder (2015) due to subtle differences in how the classes are defined in order to translate them into practical management units.

NRC requested that NIWA characterise the differences in the EFSAP outputs between the four FMUs under the default rules for small rivers outlined in the proposed National Environmental Standard on ecological flows and water levels (proposed NES; MfE 2008). It was demonstrated that there was relatively little differentiation in the outcomes for each of the attributes between the proposed Small River and Coastal FMUs (i.e., the green and blue lines in Figure B-5 & Figure B-6 are similar). This was expected because the Coastal FMU is essentially a sub-set of the Small River FMU that has been delineated on the basis of differential risk of deleterious effects. This reflects the requirement that FMUs reflect both spatial patterns in environmental response and freshwater values and objectives. Therefore, while there is no significant distinction in the predicted change in attributes between the proposed Small River and Coastal FMUs, there is the potential for differences in the ecological consequences of any given change in an attribute between the proposed FMUs.

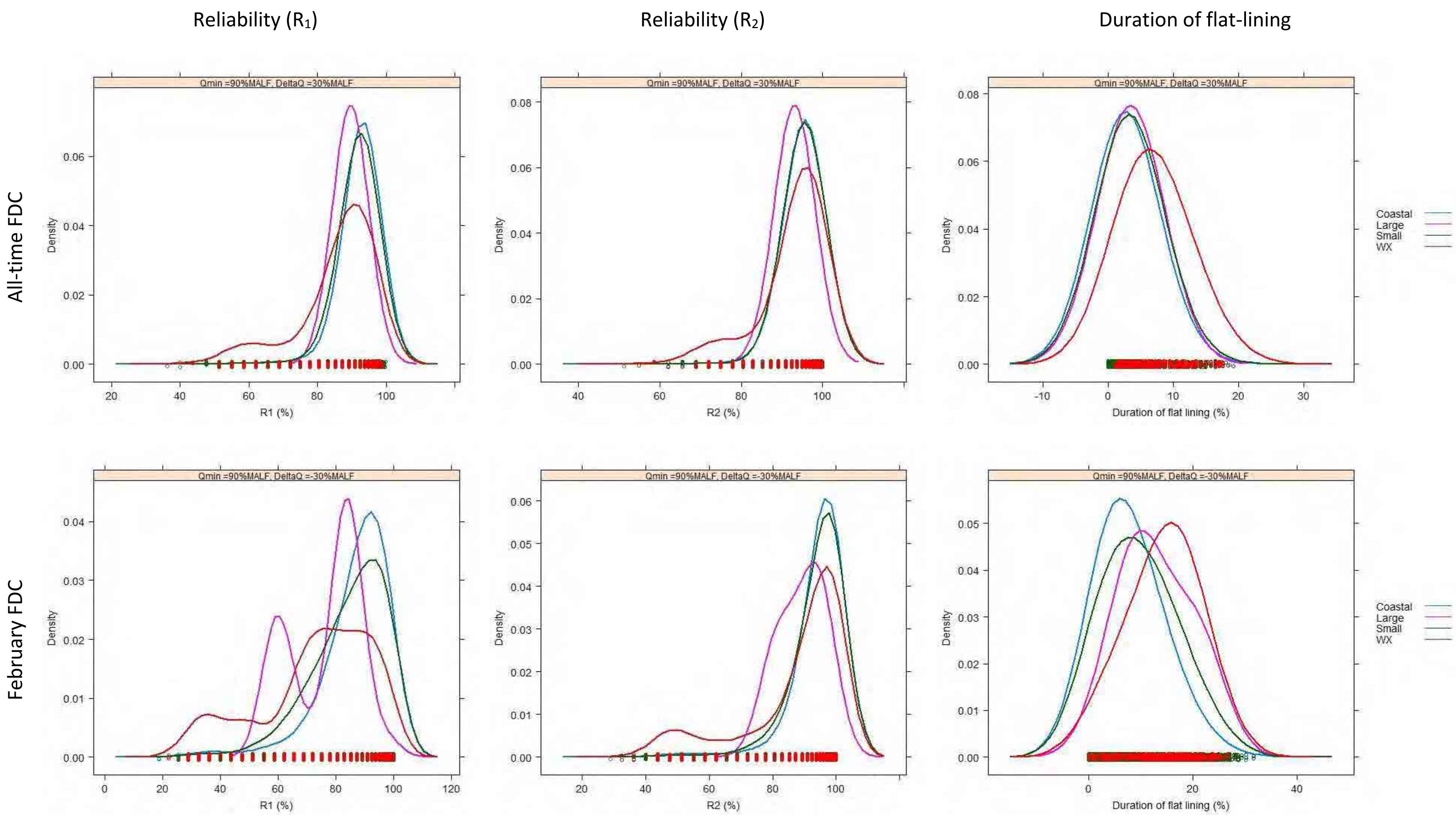

Figure B-5: Density plots showing variation in reliability and duration of flat-lining within and between the four proposed FMUs. The higher the density, the greater the proportion of reaches with that reliability. Duration of flat-lining is the total number of days and not continuous duration. Note the differences in the scale of the y-axis.

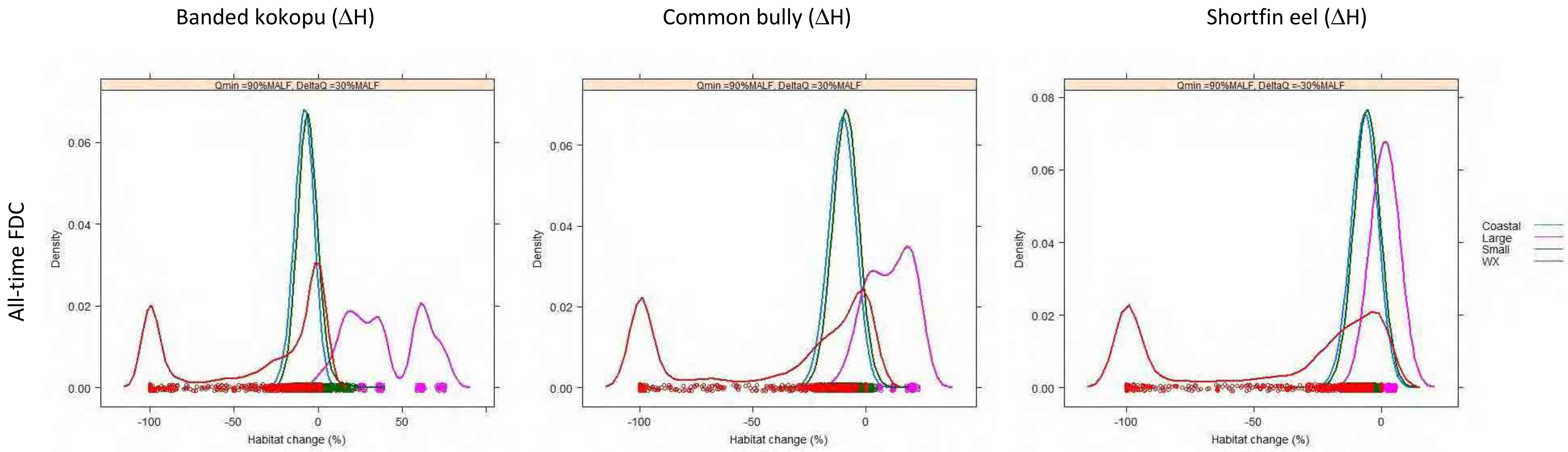

Figure B-6: Density plots showing variation in habitat for three of the indicator species within and between the four proposed FMUs. The higher the density, the greater the proportion of reaches with that reliability. Note the differences in the scale of the y-axis.

EFSAP decision space plots for the proposed FMUs

Attributes

NRC have requested that the EFSAP decision space plots for reliability of supply and instream physical habitat be recreated for the proposed FMUs. Furthermore, they have requested that decision space plots for an additional attribute, the number of days of flat-lining (tFlat), be produced. 'Flat-lining' occurs when the natural flow of the river is between the management flow (i.e., Qmin + ΔQ) and Qmin and is derived by finding the difference between R_1 and R_2. The tFlat attribute can be used as an indicator of the change in the duration of low flows. However, because it is derived from a flow duration curve, rather than a flow time-series, it does not provide any information relating to whether this represents a single consecutive period of flat-lining, or multiple individual days of flat-lining. Generally speaking, the greater the duration of low flows, the greater the risk of negative ecological effects. This can include greater accrual of periphyton (Snelder et al. 2014), changes in the relative abundance of fish (Jowett et al. 2005), shifts in the composition of macroinvertebrate communities (Dewson et al. 2007; James et al. 2009), proliferation of macrophtyes (Riis and Biggs 2003), elevated water temperatures and changes in dissolved oxygen dynamics.

A broad rule-of-thumb was proposed in Beca (2008) to characterise the hydrological alteration associated with extended periods of low flows. This was that if the duration of low flows is increased to 30 days or more, the degree of hydrological alteration is high, if it is increased to 20 days or more, it is moderate, and if it is increased to 10 days or more it is low (Beca 2008). In effect, the implication was that the greater the degree of hydrological alteration, the greater the risk of negative ecological effects. However, Beca (2008) did not provide a working definition of low flows, such as what magnitude of flow constitutes "low" flows (e.g., MALF), whether this relates only to consecutive low flow periods or the total number of days below the low flow threshold, or the timing of these low flow periods. This reflects the relatively poor quantitative understanding of how this dimension of low flow habitat change translates into ecological responses. A precautionary approach would assume that tFlat represents a single consecutive period of low flows as this is likely to be associated with the greatest risk of negative ecological consequences. In this case, for the all-time FDC tFlat thresholds of approximately 8%, 5% and 3% for would correspond to the high, moderate and low degree of hydrological alteration thresholds proposed by Beca (2008) respectively.

EFSAP updates since 2013

Refinements in the precision of some of the calculations implemented in EFSAP since the model was originally run for Northland have highlighted some minor computational inaccuracies in some of the habitat calculations. These relate to the number of points being used to represent the FDC, and how interpolation between these points is applied. The main consequences of the lower precision in the old model were that subtle differences occurred in the outcomes for ΔH between the All-time and February FDCs, when in fact there should be no difference, and non-zero values of ΔH occurred when the minimum flow (Q_{min}) was equal to 100% of MALF, even though the result should be zero for all reaches. These have been corrected in the updated decision space plots presented below.

Interpreting EFSAP predicted outcomes with respect to freshwater objectives

The NPS-FM requires that regional councils set freshwater objectives and that these must be linked to limits suitable for achieving those objectives. Defining freshwater objectives is a multi-faceted process that requires identifying freshwater values, finding appropriate attributes to describe those values and setting thresholds that ensure adequate protection of the freshwater values. Ideally, this should be done in a transparent and scientifically defensible framework.

EFSAP offers a scientifically defensible tool that can support this process for setting water quantity limits. It evaluates the consequences of alternative limit scenarios for two key values, reliability of supply and the provision of instream physical habitat for fish, for all locations on the river network. It describes these consequences in terms of changes in the attributes R_1 and R_2 for reliability of supply, and ΔH for different indicator fish species for instream physical habitat. The attribute tFlat can also be used as an indicator of potential impacts on instream physical habitat. The capability to characterise consequences for multiple attributes, and to demonstrate the trade-offs between attributes, at all locations on the river network is extremely beneficial. However, it also requires that consideration be given to how these data are interpreted with respect to freshwater objectives.

It is widely acknowledged that uniform rules can lead to non-uniform outcomes across space due to natural inherent environmental variability (Snelder et al. 2011). This presents a challenge in terms of how this spatial variability in outcomes is accounted for in setting freshwater objectives and associated limits. It may be unrealistic to expect that all reaches in a region will meet a limit, but having 90% of reaches meeting the limit might be a realistic and achievable objective. It is likely that this threshold will vary between values and it can also vary between FMUs to reflect their differing characteristics, risk of adverse effects and freshwater objectives. The EFSAP outputs can be summarised in a variety of ways to cater for characterising different objective thresholds. NRC have requested that the revised FMU decision space plots be produced for the 50th, 75th, 80th and 90th percentiles of reaches so that they can explore how options for limits might vary with differing protection levels. The revised FMU decision space plots based on the FMU classifications by Snelder (2015) are presented below in Figure B-7 to Figure B-34.

The National Policy Statement for Freshwater Management (NPS-FM) requires that environmental flows (constituting at least a minimum flow and allocation limit) be set for all rivers and streams. Where pressures on water resources are high, catchment specific environmental flow assessments will be required to set water quantity limits that fulfil freshwater objectives set under the NPS-FM. However, where current pressure on water resources is low, generalised, regional scale technical methods (such as EFSAP) can be used to help set default water quantity limits in the absence of detailed, local information.

The rationale for setting regional scale default water quantity limits is typically to provide interim protection for instream values and to cap allocation in the absence of catchment specific environmental flow assessments. Default limits should be inherently environmentally conservative, with the idea being to limit out-of-stream water resource use at levels where there is confidence that the risk of adverse ecological effects will be minimised (e.g., MfE 2015). Subsequently, if demand for water resources increases, catchment specific environmental flow assessments can be carried out and the water quantity limits revised in the light of the more specific information. This approach is consistent with the objectives of the NPS-FM (MfE 2015) and is already implemented in many regions around New Zealand. It also avoids having to claw back over-allocation if allocation limits have been set at a level that is insufficiently conservative. Avoiding this situation is a key objective of the NPS-FM (MfE 2014; MfE 2015).

NRC must make value judgements in deciding on the appropriate balance between precautionary and resource enabling objectives and associated limits. These judgements must be made in the absence of complete knowledge at a reach or catchment scale and will necessarily require trade-offs between values. The EFSAP results can help to make this process of balancing different values more transparent and therefore result in more justifiable limits. However, NRC must take a holistic approach to interpreting the EFSAP results in the context of the known limitations and uncertainties of the methodology, recognising the relative contribution of other values not represented in EFSAP, and taking into account the requirements of national policies.

A key objective of the NPS-FM is to safeguard the life-supporting capacity of waterways. This is reflected in the designation of ecosystem health as one of the compulsory national values within the National Objectives Framework (NOF). At present, only a limited number of compulsory attributes have been designated within the NOF for protecting ecosystem health. NRC must take account of these attributes in setting water quantity limits. These attributes are not currently included within EFSAP. It is expected that further attributes will be added to the NOF in future and there is an expectation that councils will have to set limits to maintain those new attributes as they are designated (MfE 2015). Consequently, it is recommended that a precautionary approach to interpreting the EFSAP results be taken, particularly given that the information is being used to set regional scale default limits.

With respect to setting objectives for the protection of instream habitat, it is recommended that for high value catchments the 90th percentile of reaches should be used for setting freshwater objectives. This means that the majority of reaches should be protected from the risk of adverse ecological effects as a result of over-allocation, thus safe-guarding the life-supporting capacity of these waterways. In lower value catchments, it may be appropriate to use the 80th or 75th percentile of reaches for setting freshwater objectives for instream habitat protection, thus allowing the potential for greater trade-offs with out-of-stream values. However, given that regional default limits should generally be set at a precautionary level and that there are a large range of additional factors not included in EFSAP that are affected by flow and influence instream values, it is recommended that a conservative approach be taken to setting objectives and limits around the EFSAP outputs.

Large river FMU

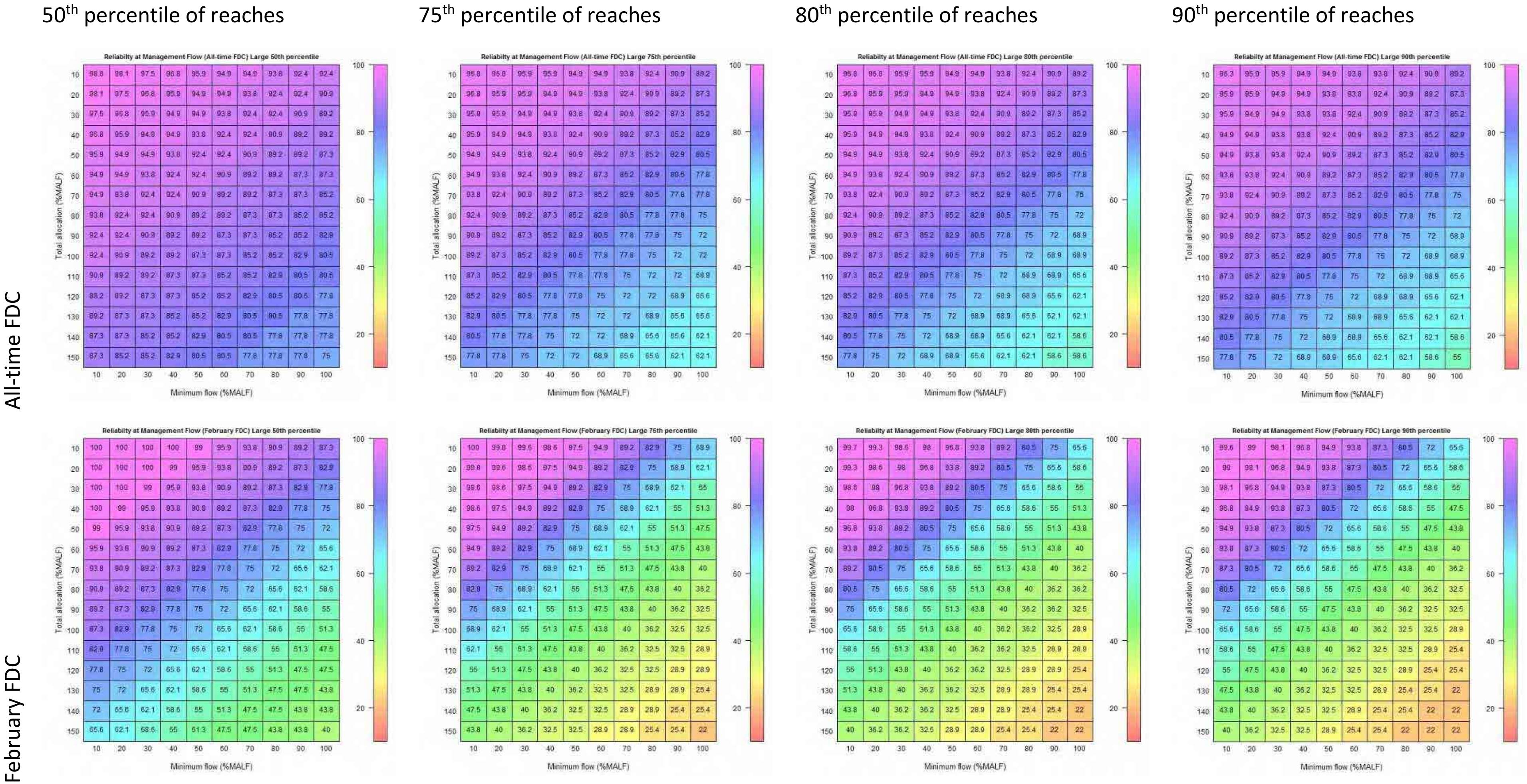

Figure B-7: Decision space plots for reliability of supply (R_1) for the all-time and February FDCs at a range of percentiles.

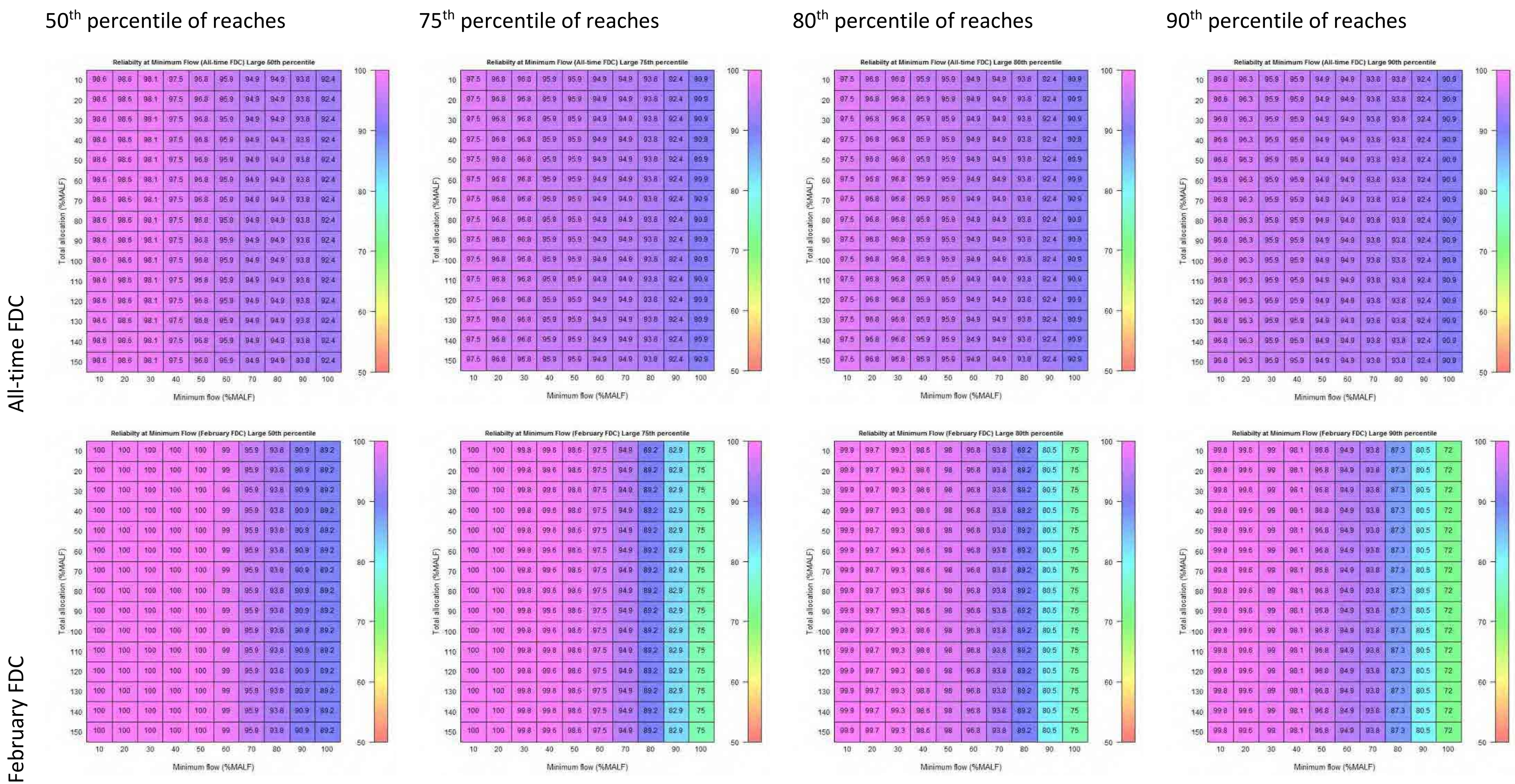

Figure B-8: Decision space plots for reliability of supply (R_2) for the all-time and February FDCs at a range of percentiles.

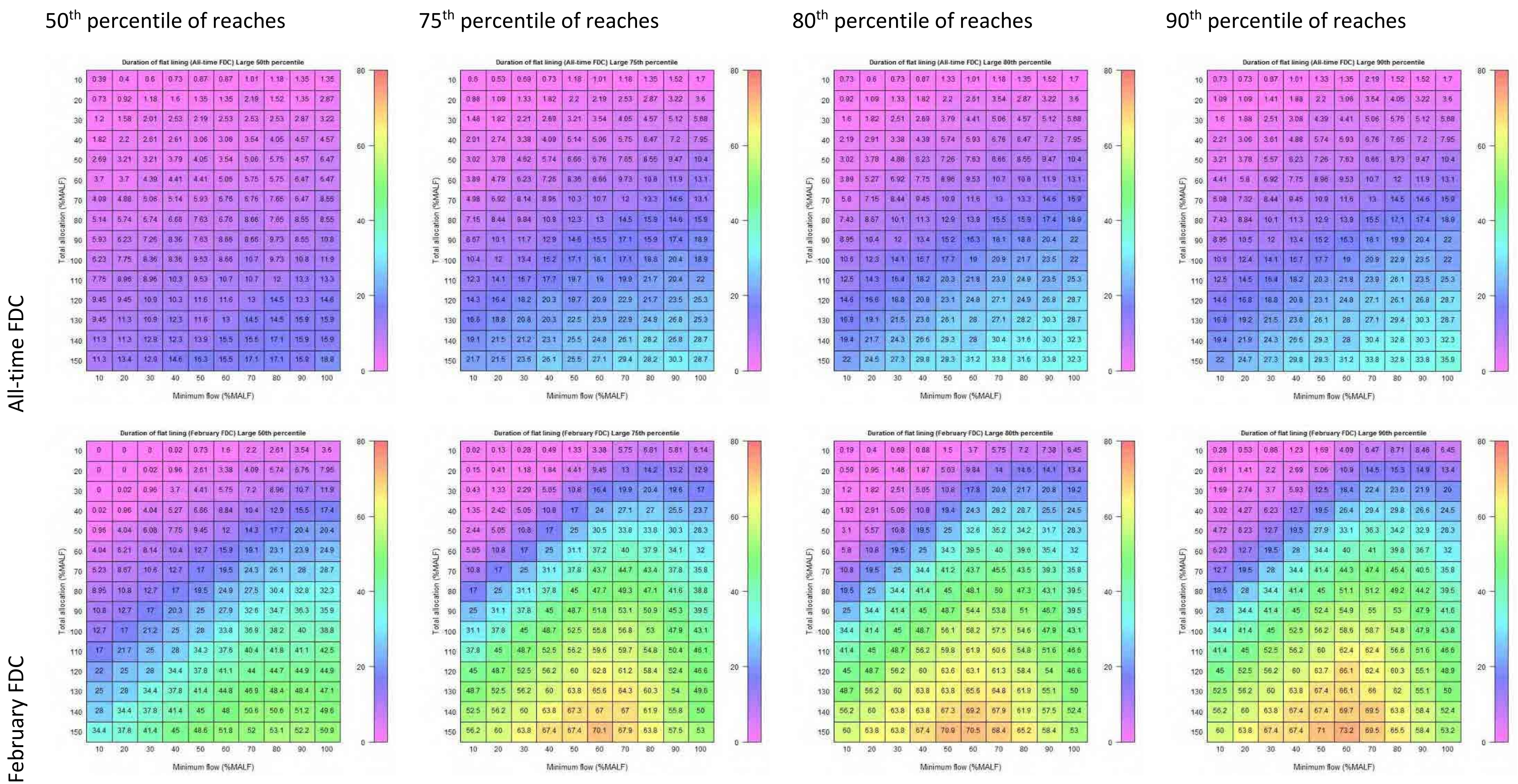

Figure B-9: Decision space plots for duration of flat-lining (tFlat) for the all-time and February FDCs at a range of percentiles.

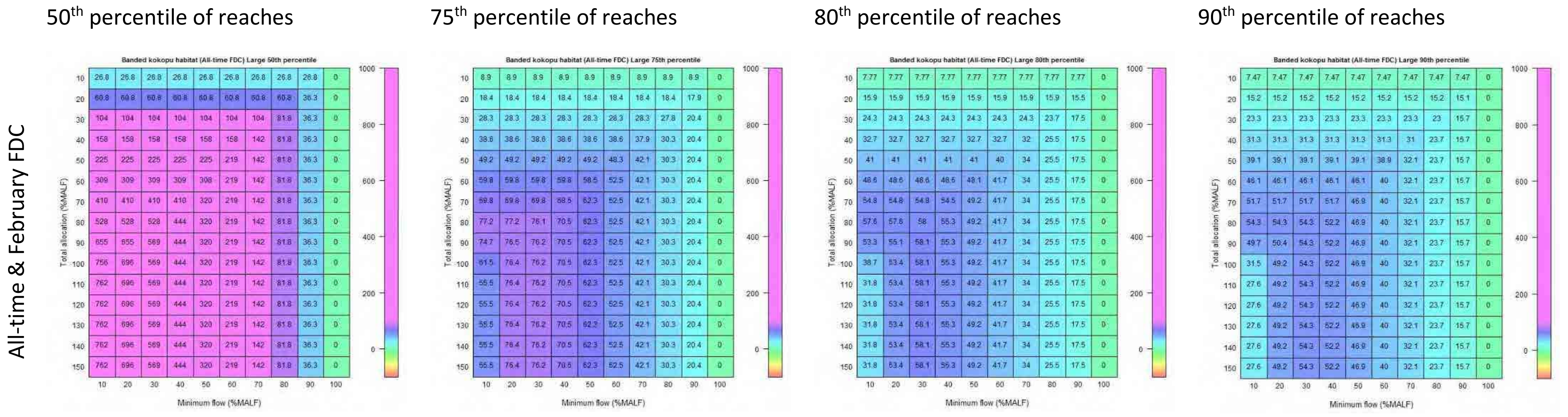

Figure B-10: Decision space plots for change in instream physical habitat for banded kokopu (ΔH) for the all-time and February FDCs at a range of percentiles.

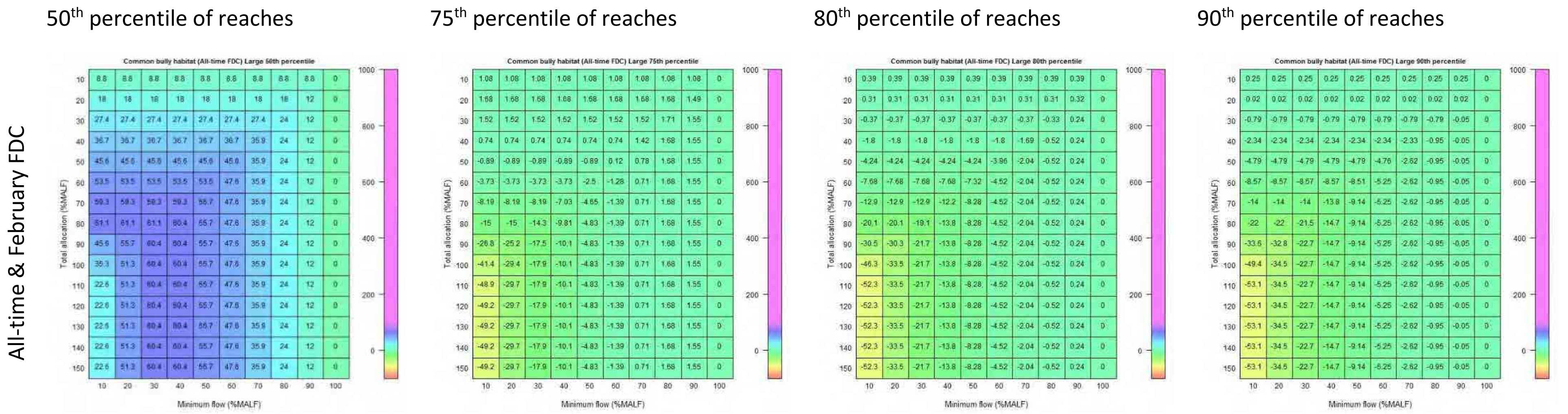

Figure B-11: Decision space plots for change in instream physical habitat for common bully (ΔH) for the all-time and February FDCs at a range of percentiles.

All-time & February FDC

50th percentile of reaches | 75th percentile of reaches | 80th percentile of reaches | 90th percentile of reaches

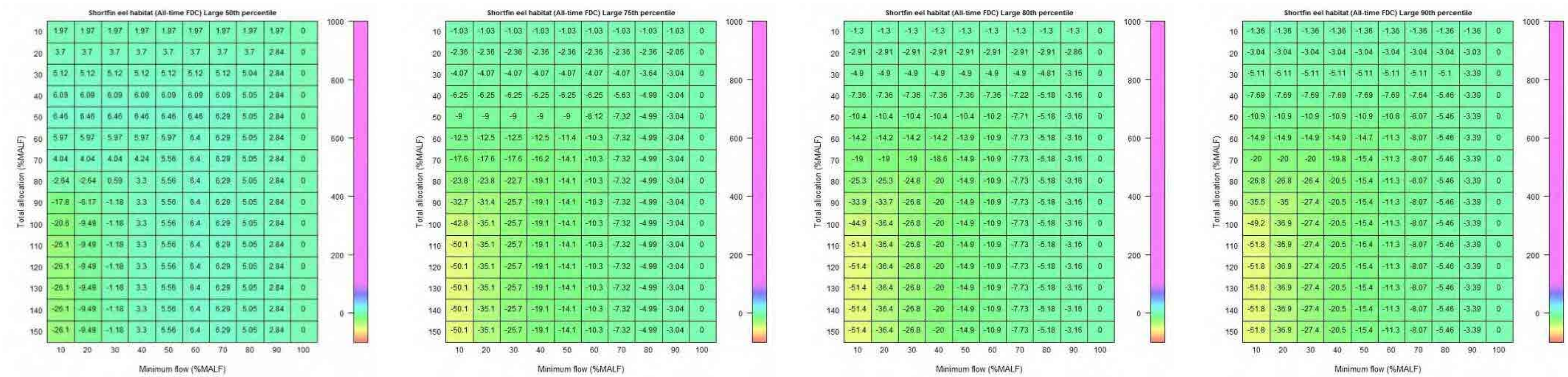

Figure B-12: Decision space plots for change in instream physical habitat for shortfin eel (ΔH) for the all-time and February FDCs at a range of percentiles.

All-time & February FDC

50th percentile of reaches | 75th percentile of reaches | 80th percentile of reaches | 90th percentile of reaches

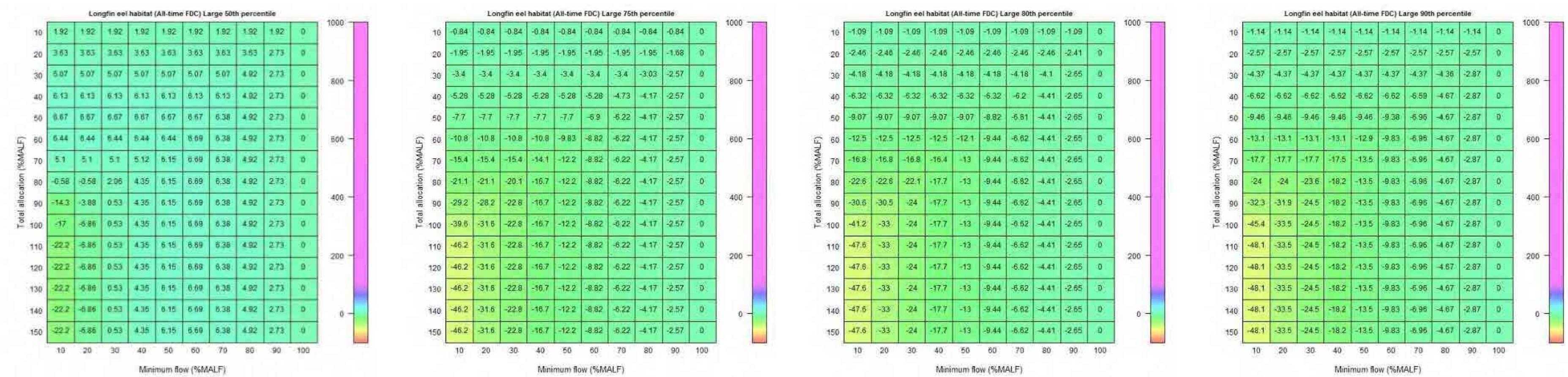

Figure B-13: Decision space plots for change in instream physical habitat for longfin eel (ΔH) for the all-time and February FDCs at a range of percentiles.

Small river FMU

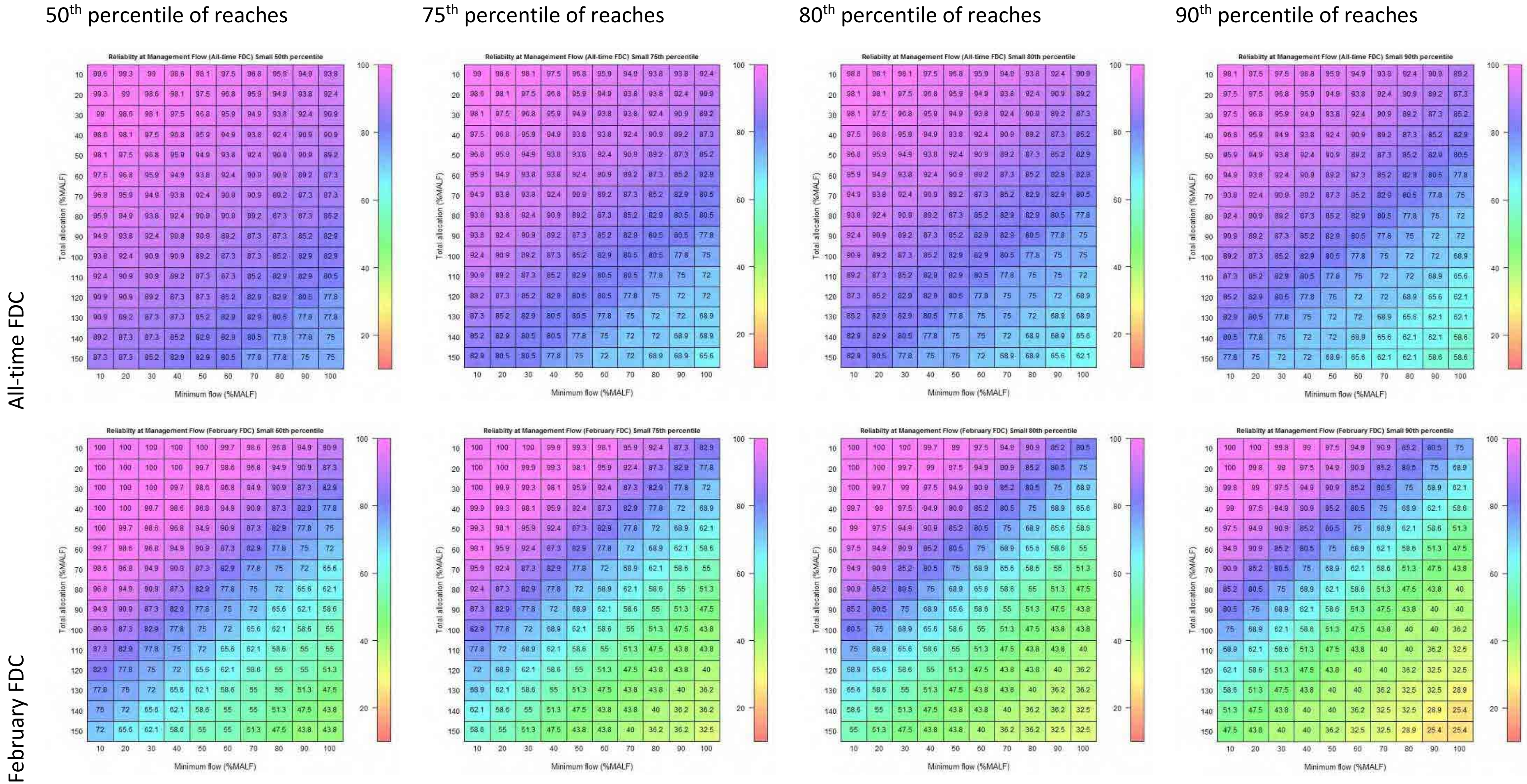

Figure B-14: Decision space plots for reliability of supply (R_1) for the all-time and February FDCs at a range of percentiles.

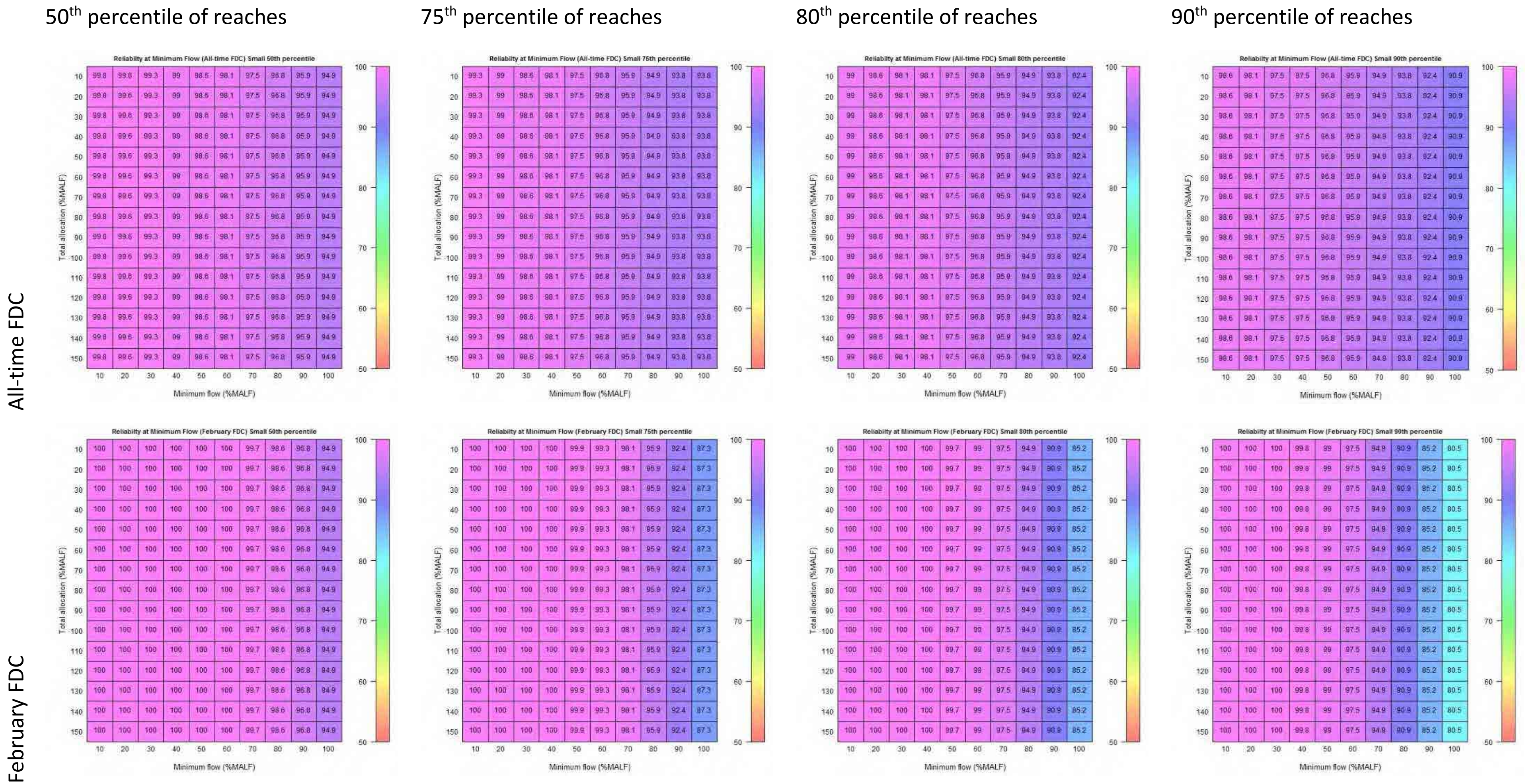

Figure B-15: Decision space plots for reliability of supply (R_2) for the all-time and February FDCs at a range of percentiles.

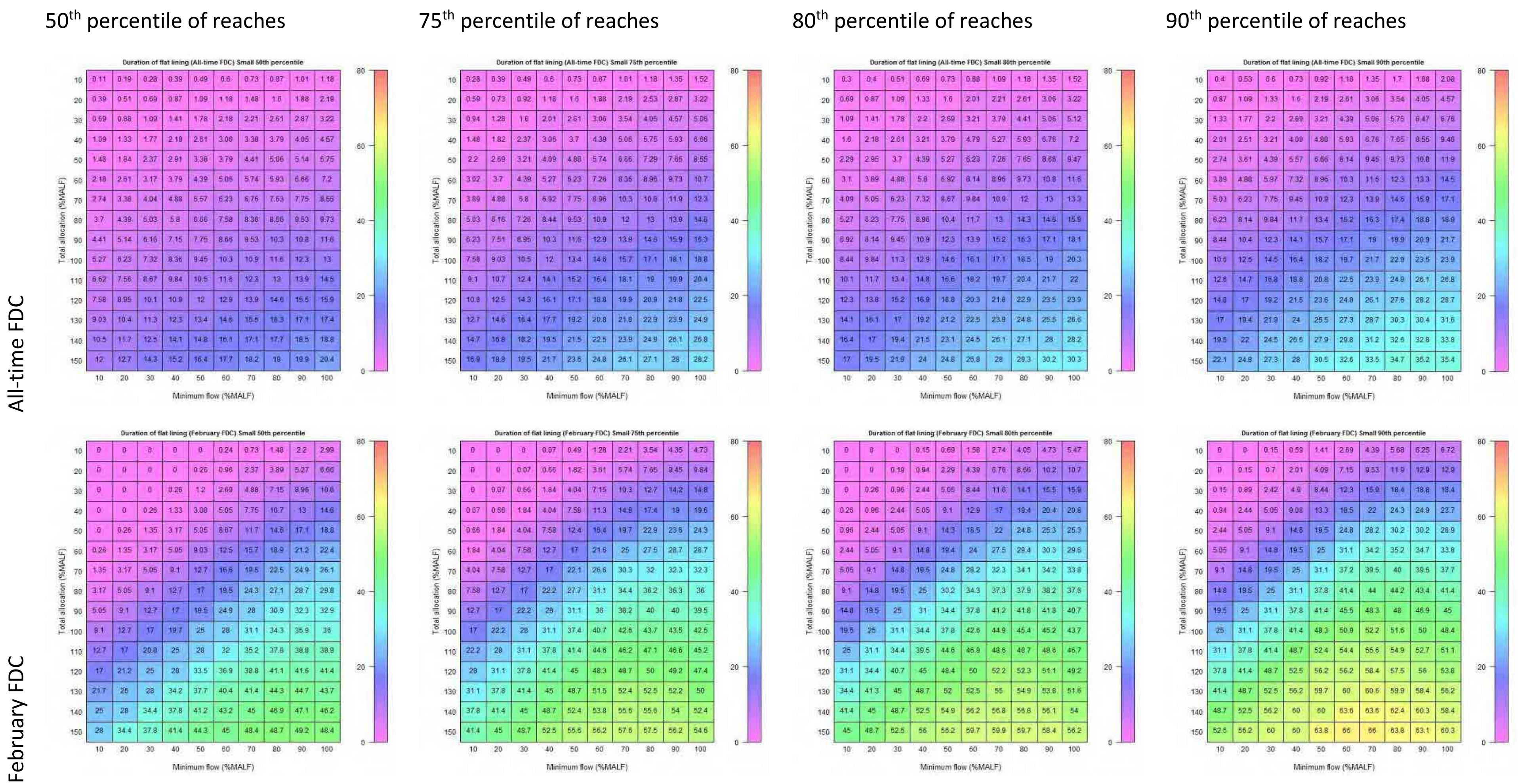

Figure B-16: Decision space plots for duration of flat-lining (tFlat) for the all-time and February FDCs at a range of percentiles.

50th percentile of reaches | 75th percentile of reaches | 80th percentile of reaches | 90th percentile of reaches

All-time & February FDC

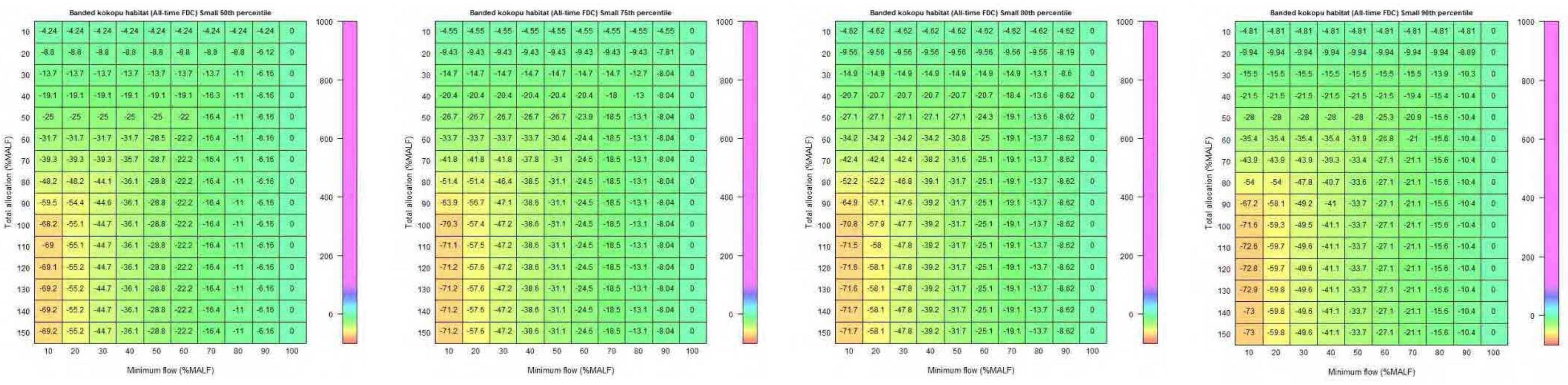

Figure B-17: Decision space plots for change in instream physical habitat for banded kokopu (ΔH) for the all-time and February FDCs at a range of percentiles.

50th percentile of reaches | 75th percentile of reaches | 80th percentile of reaches | 90th percentile of reaches

All-time & February FDC

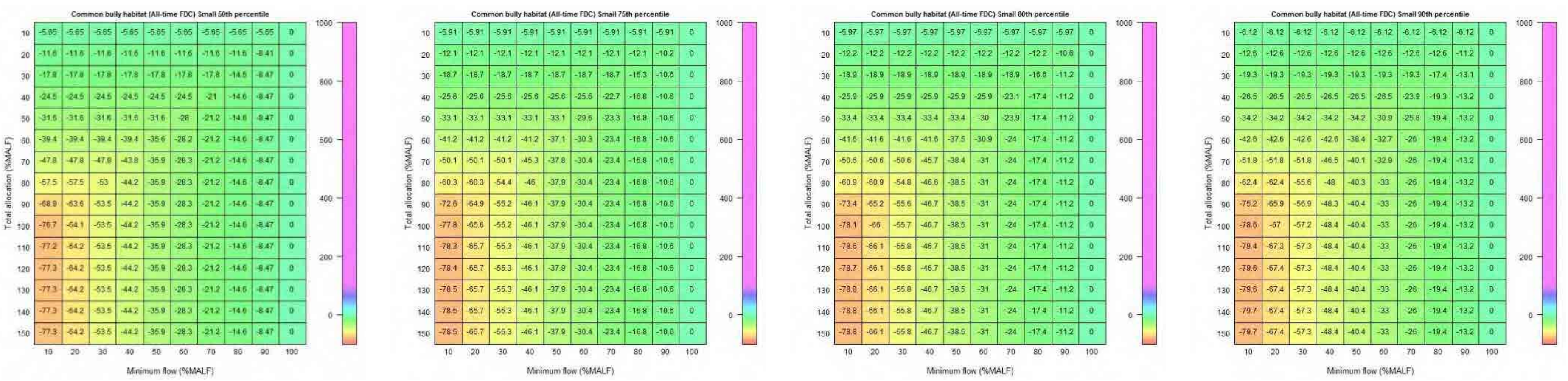

Figure B-18: Decision space plots for change in instream physical habitat for common bully (ΔH) for the all-time and February FDCs at a range of percentiles.

50th percentile of reaches | 75th percentile of reaches | 80th percentile of reaches | 90th percentile of reaches

All-time & February FDC

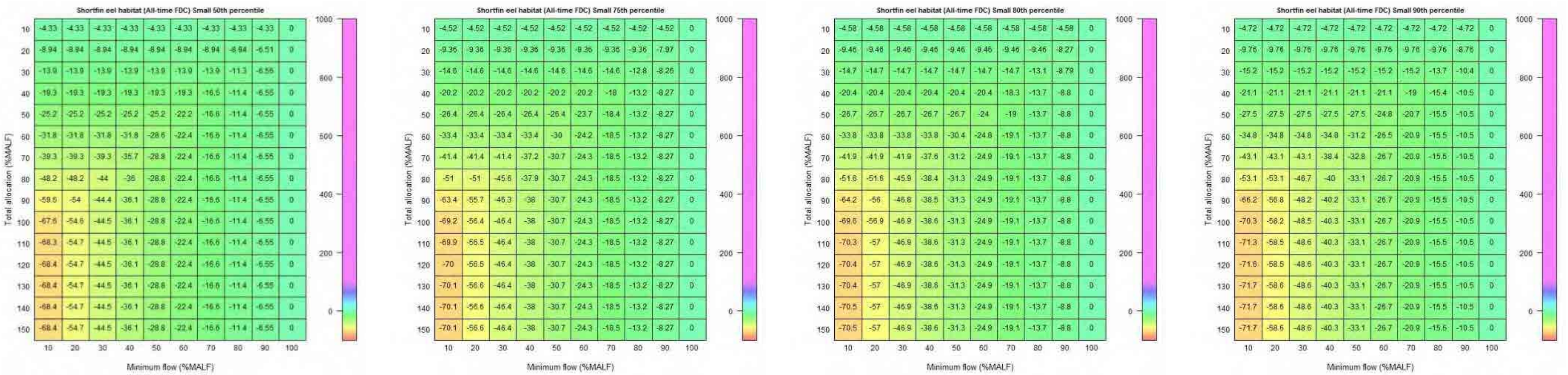

Figure B-19: Decision space plots for change in instream physical habitat for shortfin eel (ΔH) for the all-time and February FDCs at a range of percentiles.

50th percentile of reaches | 75th percentile of reaches | 80th percentile of reaches | 90th percentile of reaches

All-time & February FDC

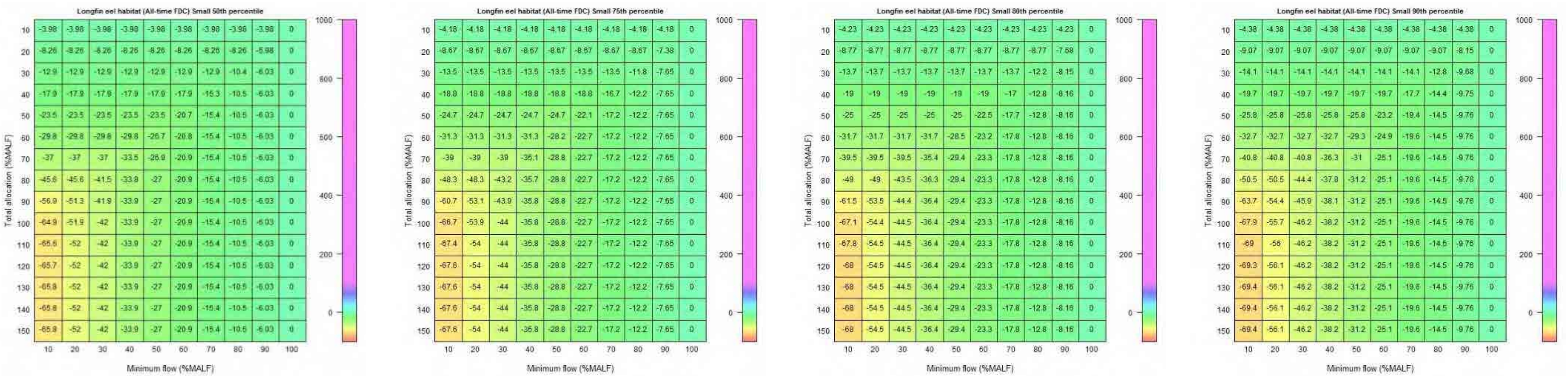

Figure B-20: Decision space plots for change in instream physical habitat for longfin eel (ΔH) for the all-time and February FDCs at a range of percentiles.

Coastal river FMU

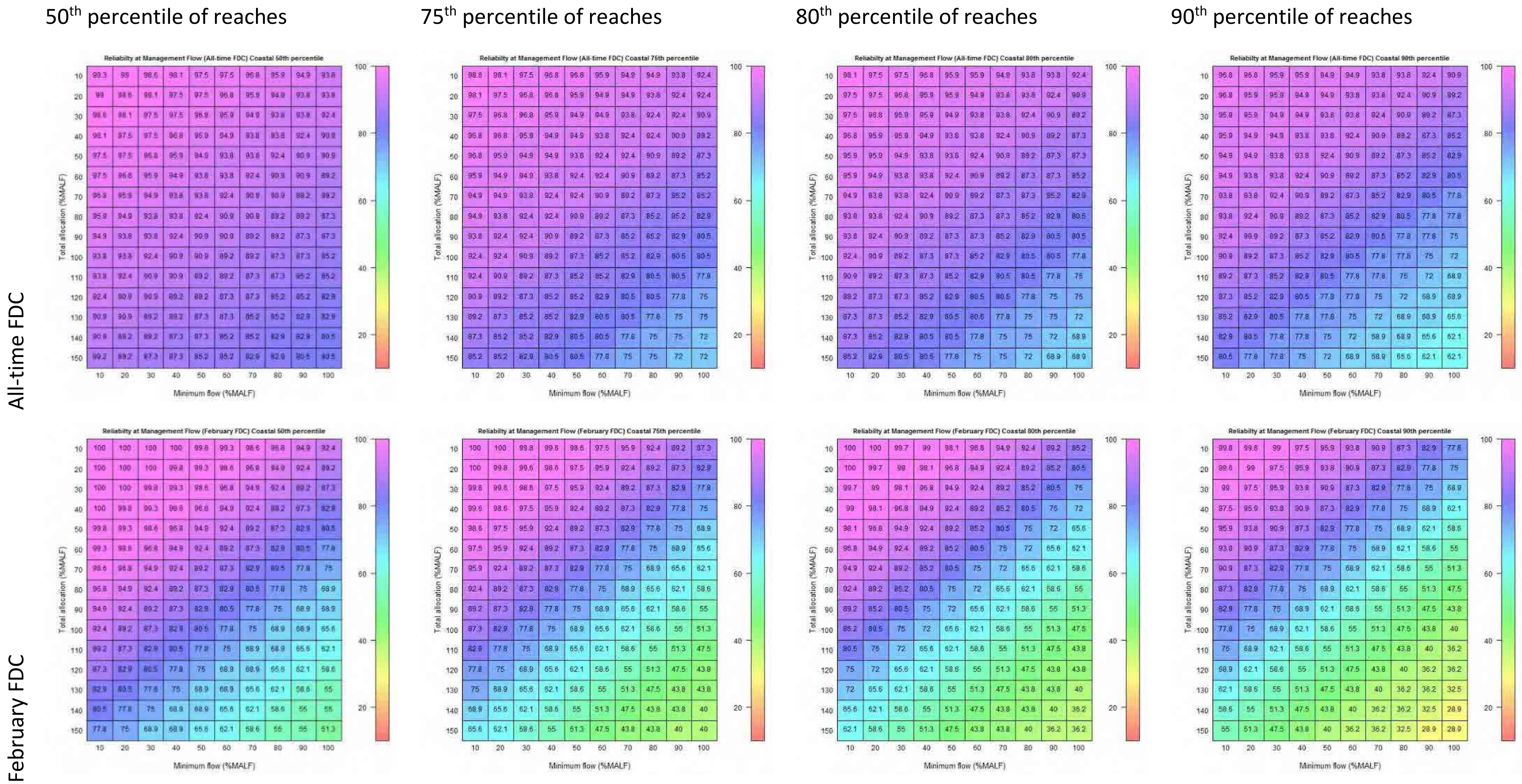

Figure B-21: Decision space plots for reliability of supply (R_1) for the all-time and February FDCs at a range of percentiles (Note different scale for February FDC).

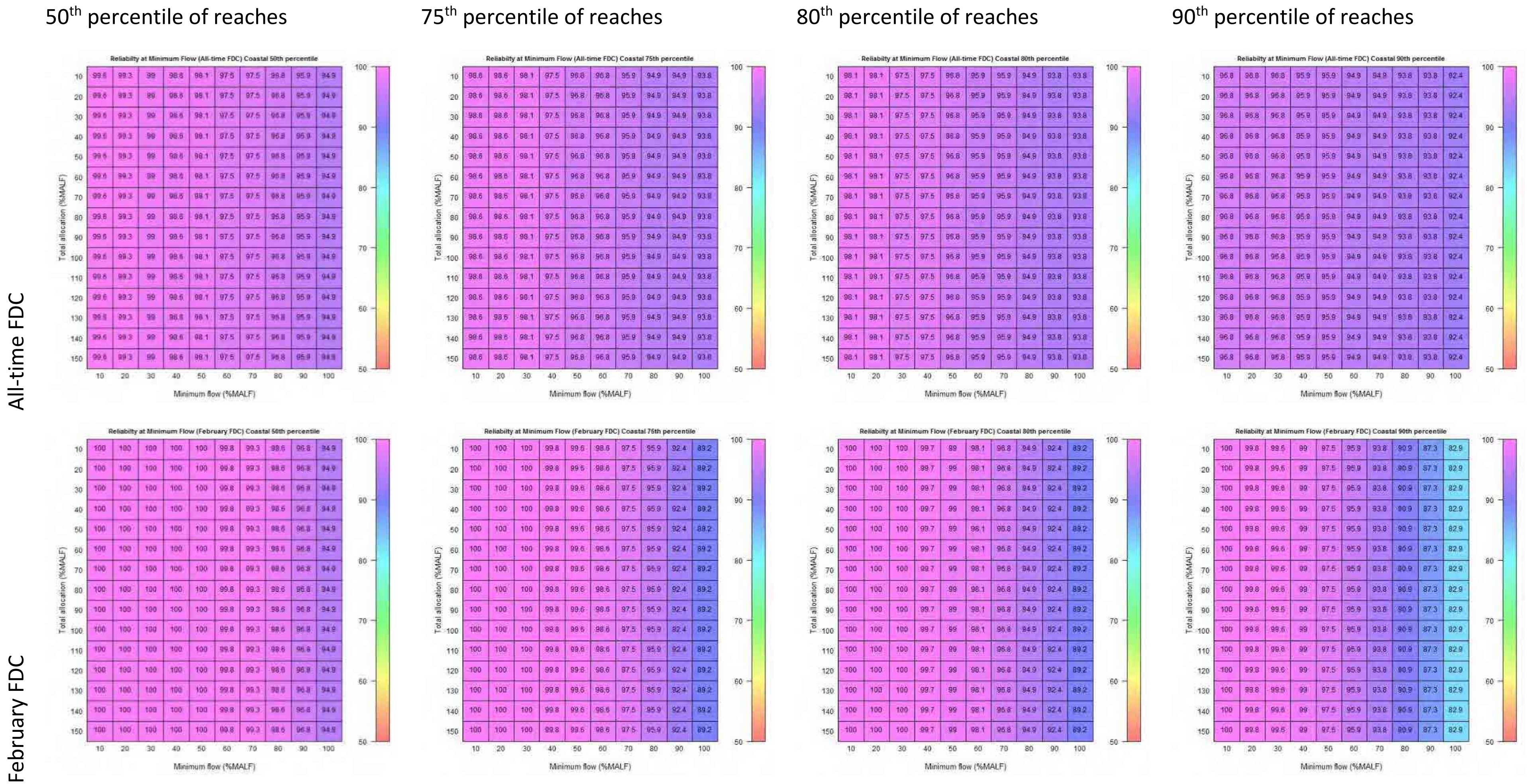

Figure B-22: Decision space plots for reliability of supply (R_2) for the all-time and February FDCs at a range of percentiles.

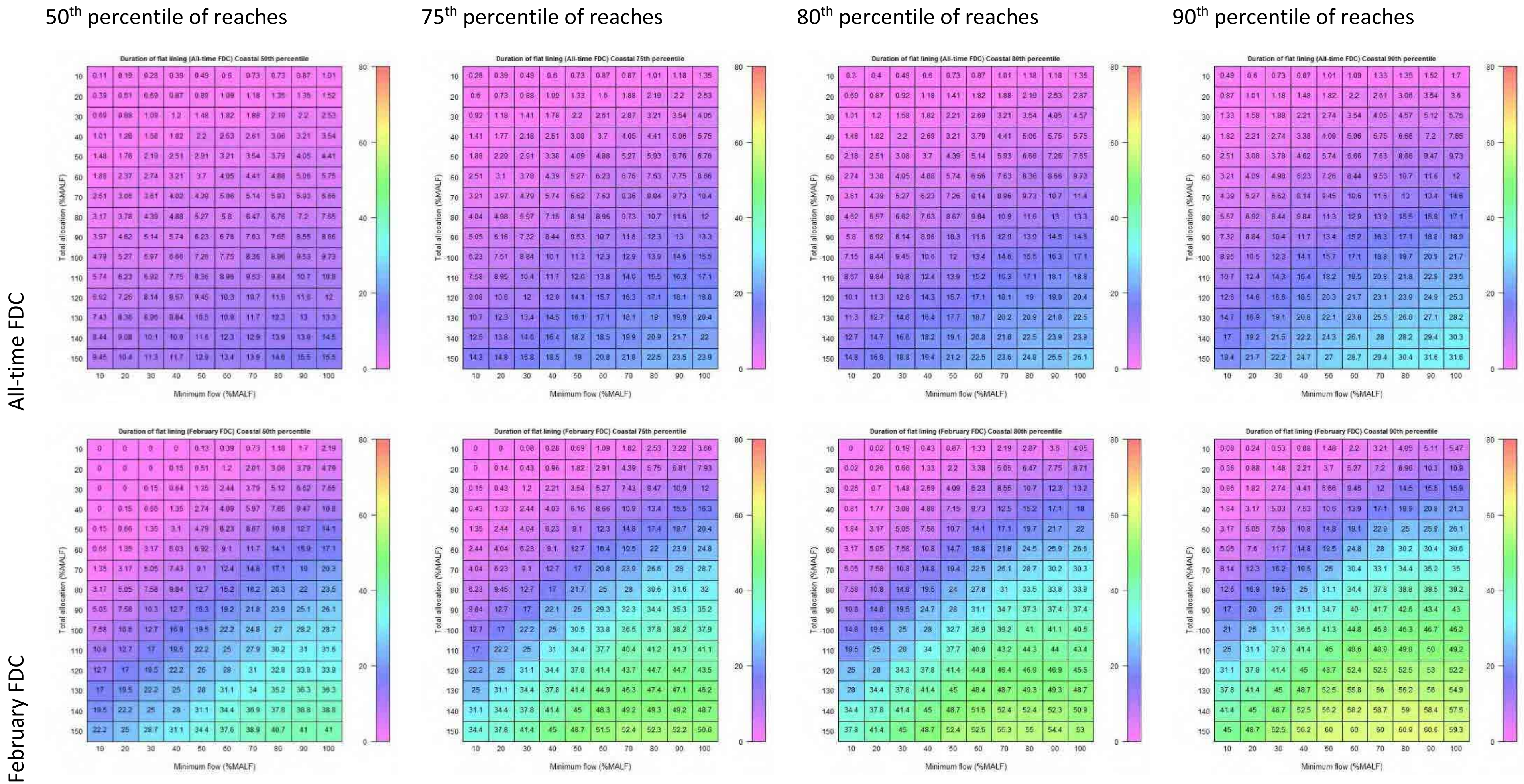

Figure B-23: Decision space plots for duration of flat-lining (tFlat) for the all-time and February FDCs at a range of percentiles.

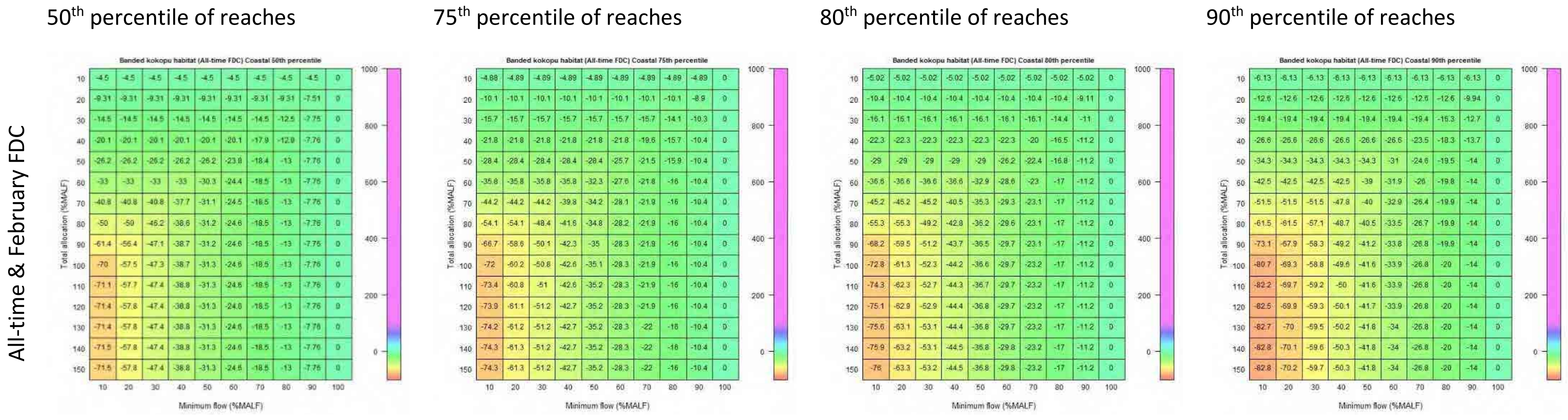

Figure B-24: Decision space plots for change in instream physical habitat for banded kokopu (ΔH) for the all-time and February FDCs at a range of percentiles.

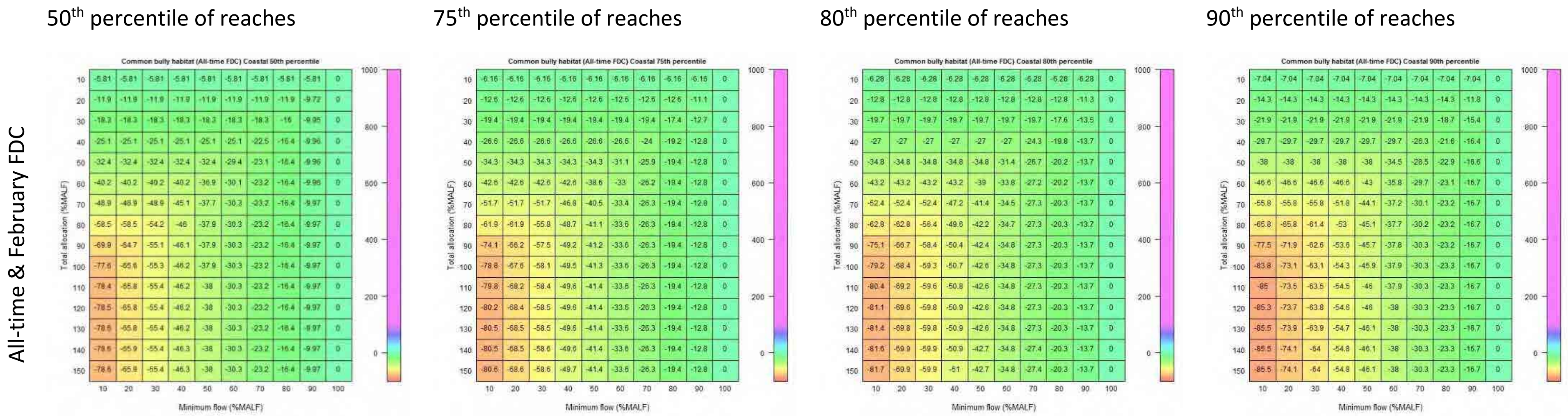

Figure B-25: Decision space plots for change in instream physical habitat for common bully (ΔH) for the all-time and February FDCs at a range of percentiles.

50th percentile of reaches | 75th percentile of reaches | 80th percentile of reaches | 90th percentile of reaches

All-time & February FDC

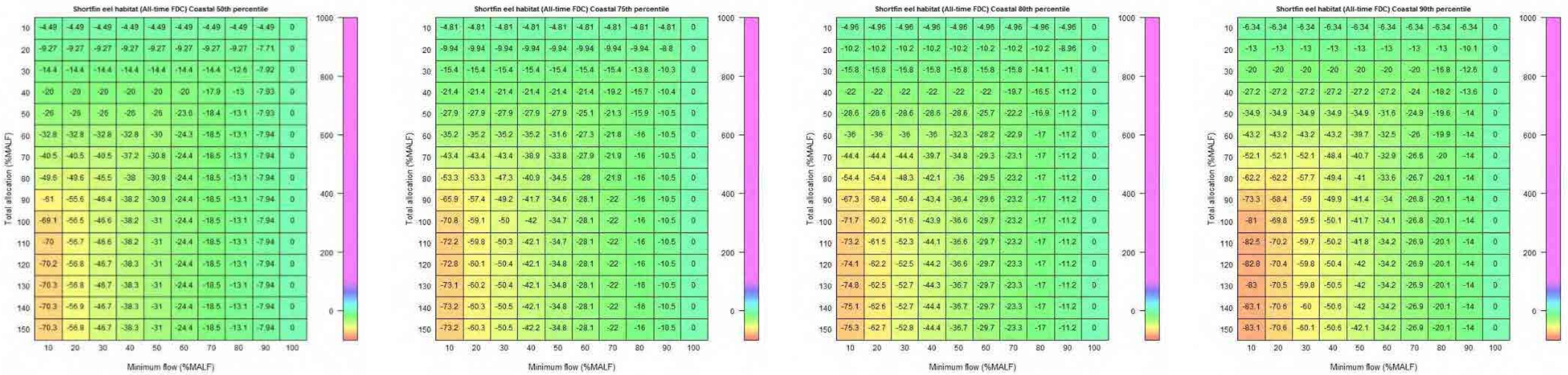

Figure B-26: Decision space plots for change in instream physical habitat for shortfin eel (ΔH) for the all-time and February FDCs at a range of percentiles.

50th percentile of reaches | 75th percentile of reaches | 80th percentile of reaches | 90th percentile of reaches

All-time & February FDC

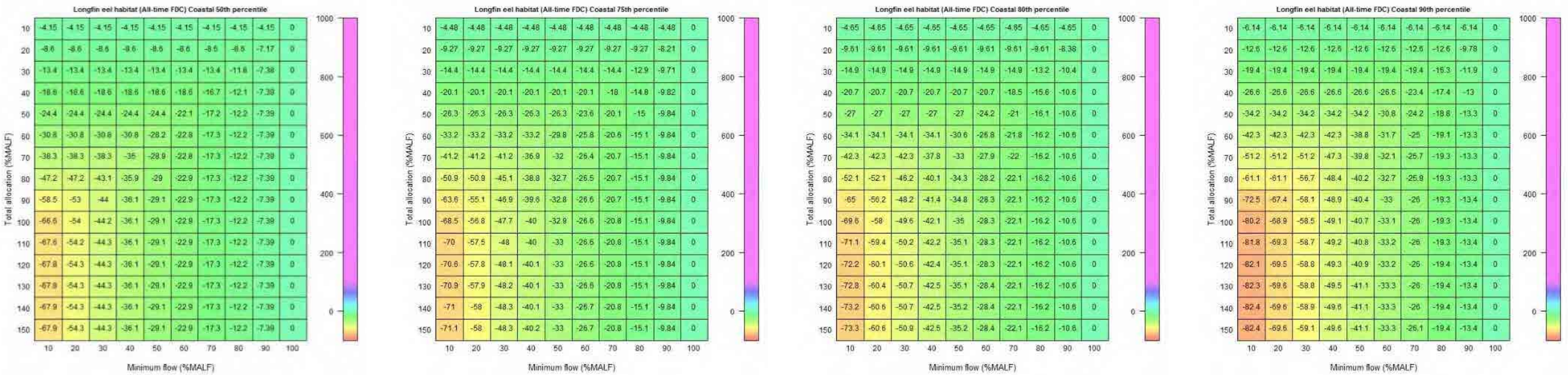

Figure B-27: Decision space plots for change in instream physical habitat for longfin eel (ΔH) for the all-time and February FDCs at a range of percentiles.

Warm extremely wet FMU

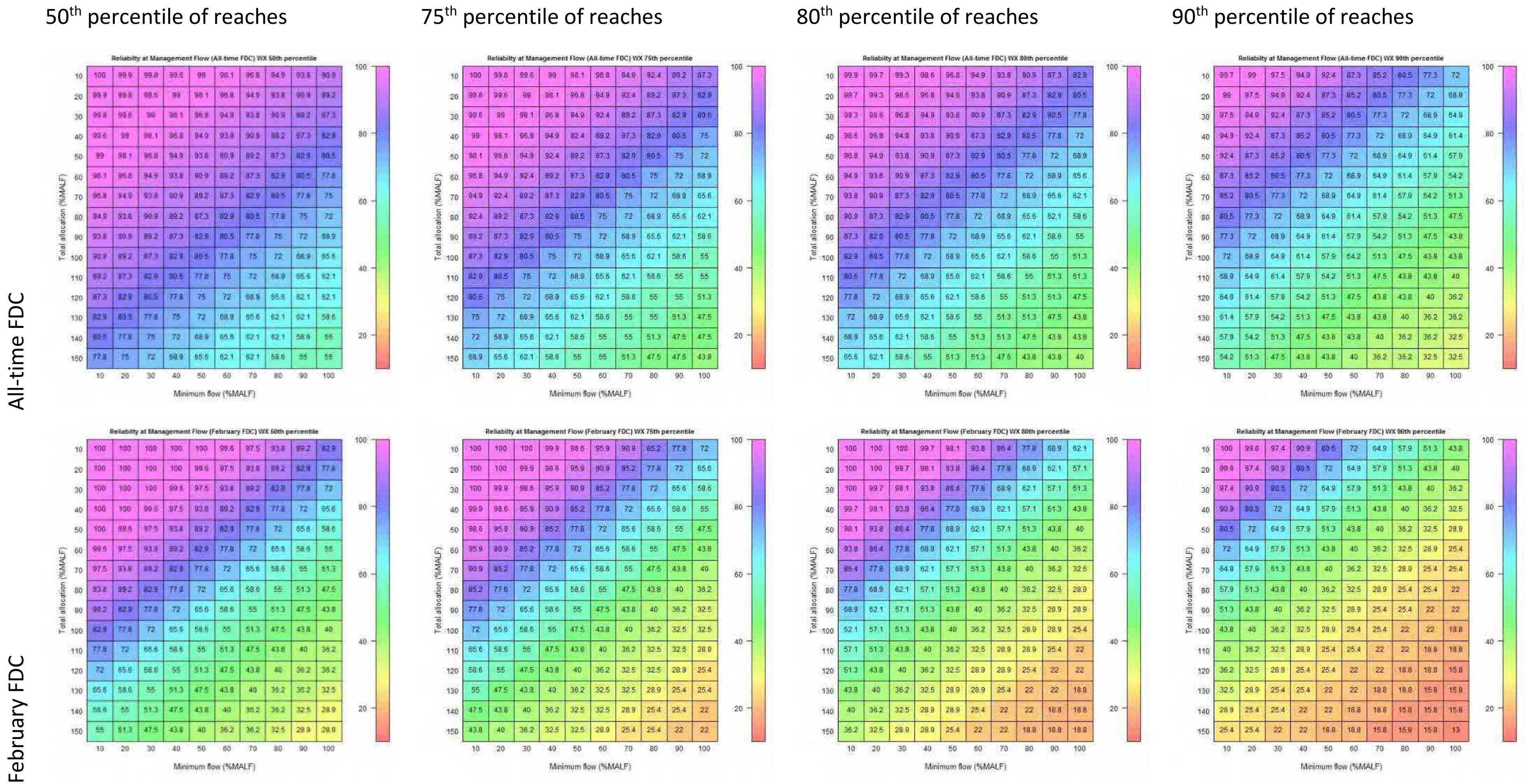

Figure B-28: Decision space plots for reliability of supply (R_1) for the all-time and February FDCs at a range of percentiles.

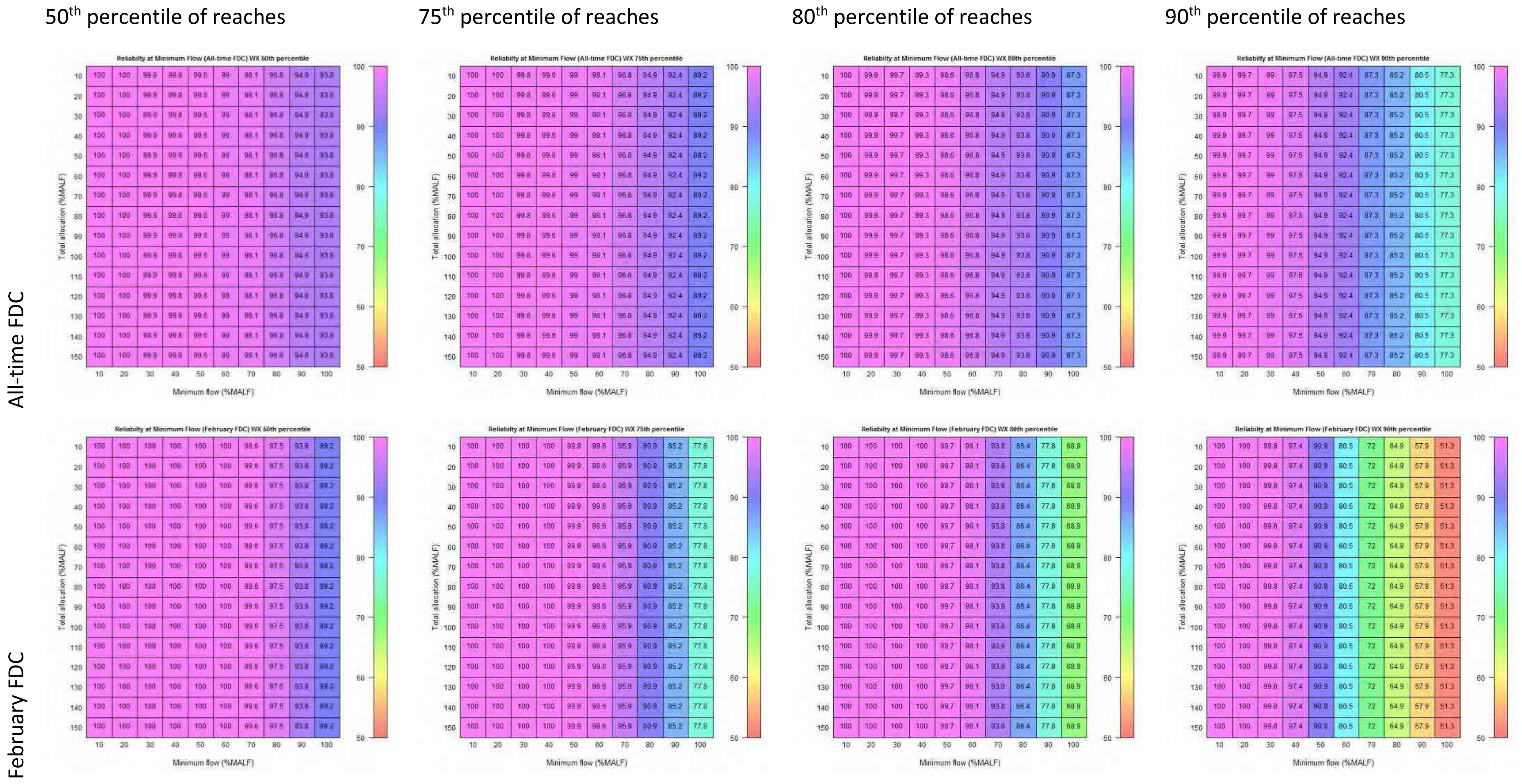

Figure B-29: Decision space plots for reliability of supply (R_2) for the all-time and February FDCs at a range of percentiles.

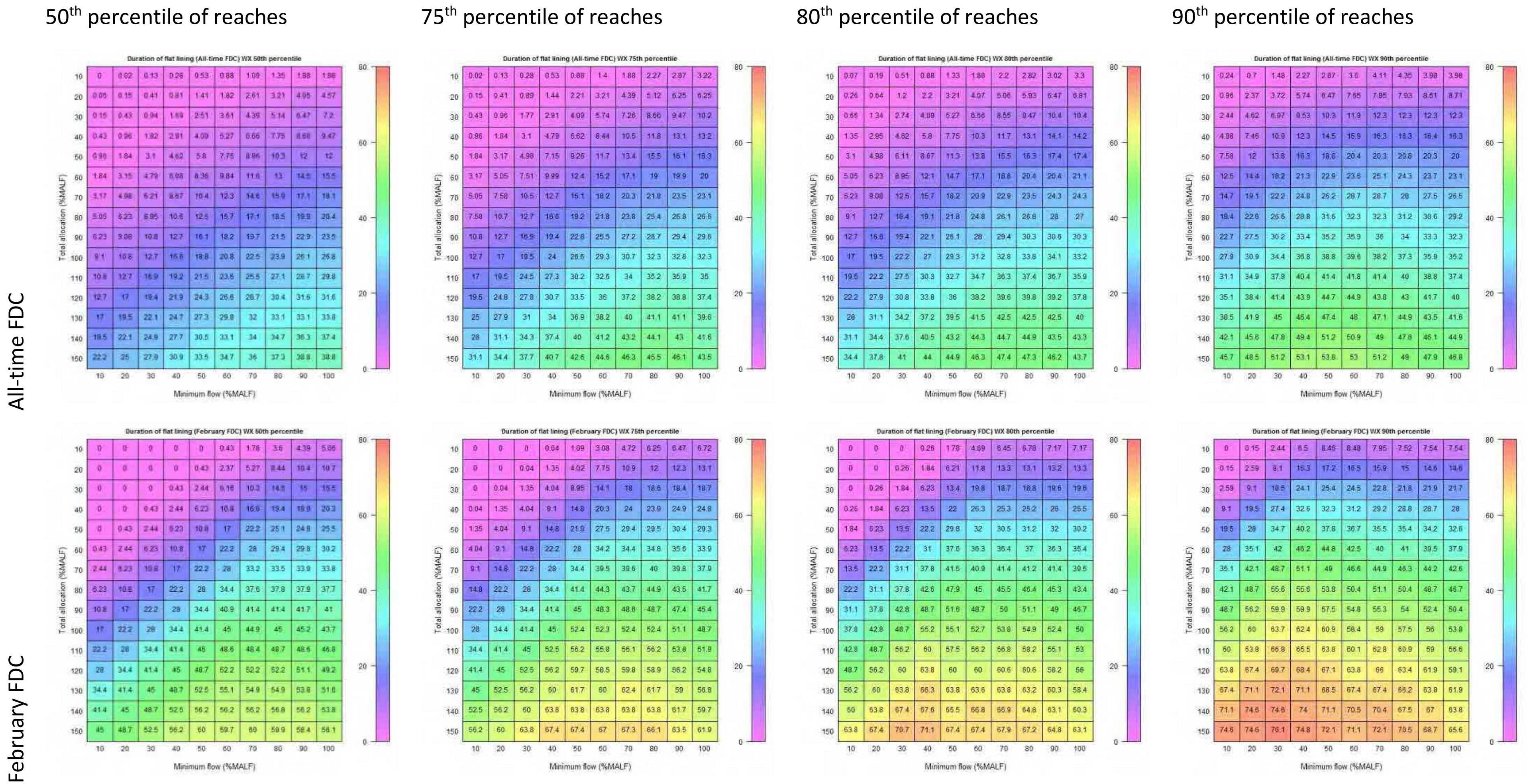

Figure B-30: Decision space plots for duration of flat-lining (tFlat) for the all-time and February FDCs at a range of percentiles.

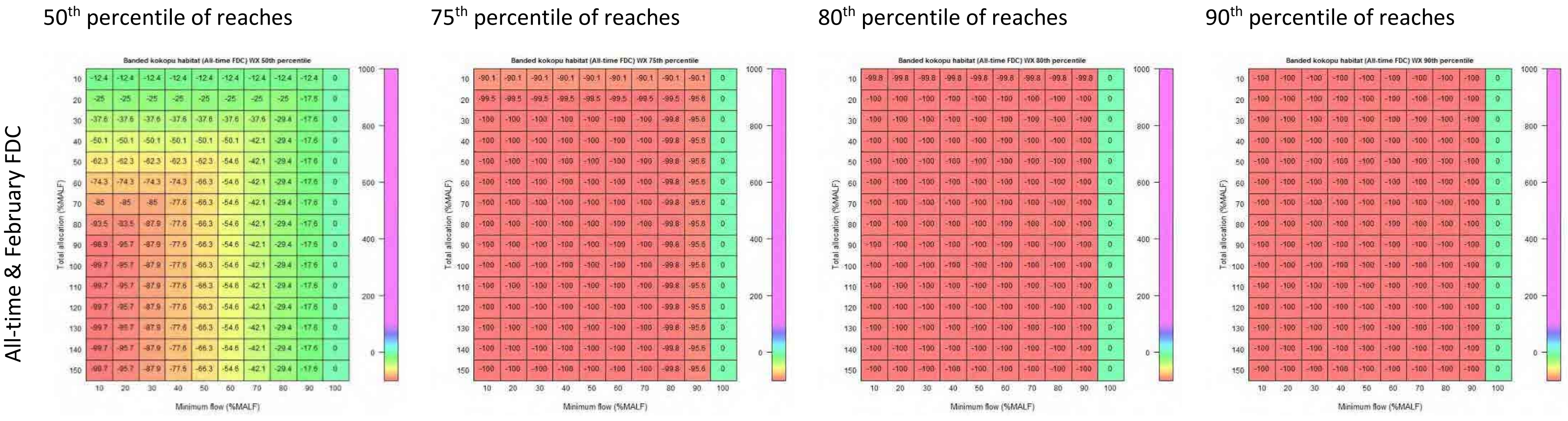

Figure B-31: Decision space plots for change in instream physical habitat for banded kokopu (ΔH) for the all-time and February FDCs at a range of percentiles.

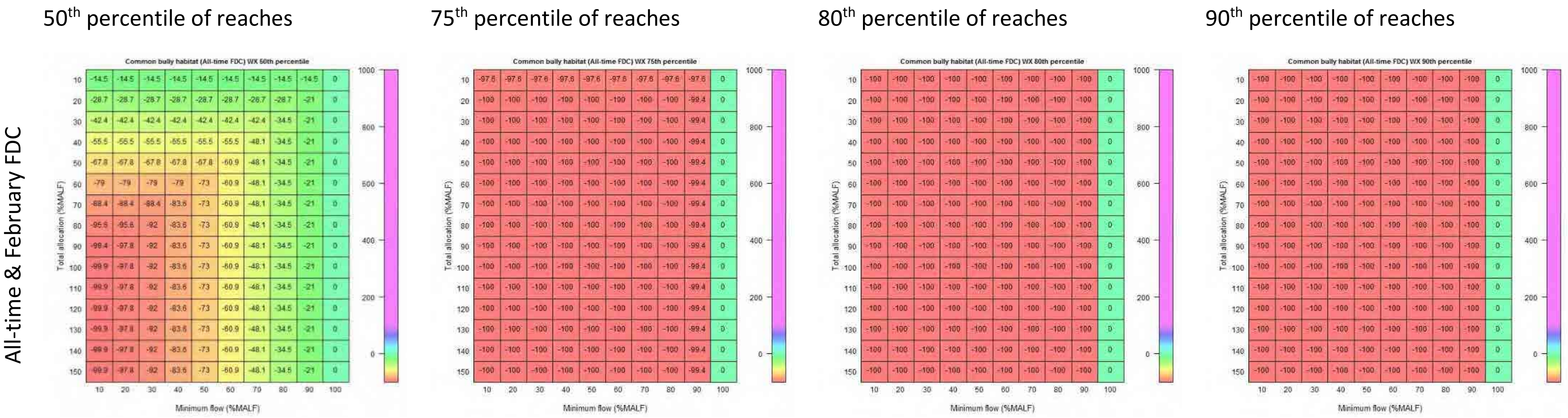

Figure B-32: Decision space plots for change in instream physical habitat for common bully (ΔH) for the all-time and February FDCs at a range of percentiles.

50th percentile of reaches | 75th percentile of reaches | 80th percentile of reaches | 90th percentile of reaches

All-time & February FDC

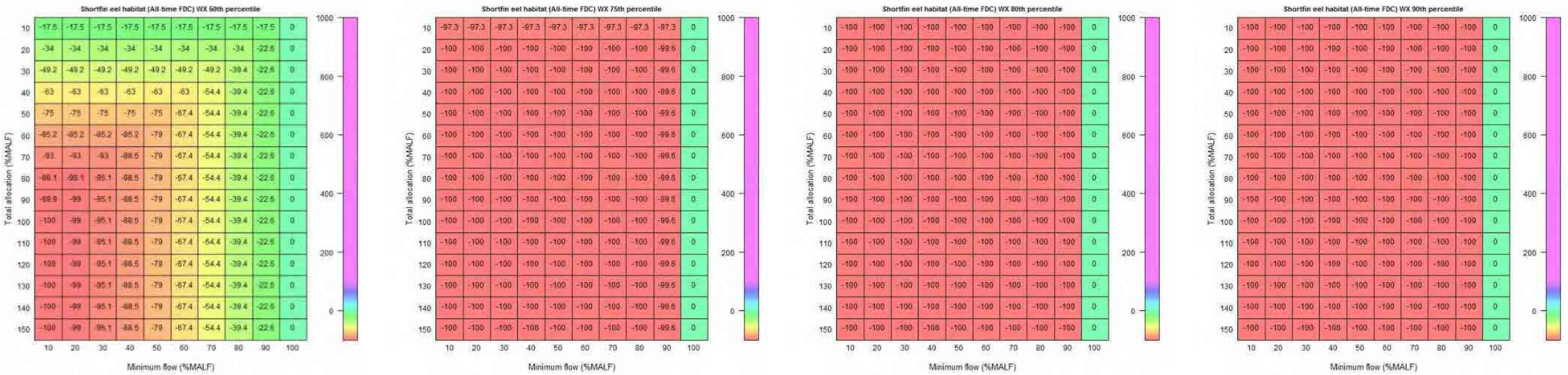

Figure B-33: Decision space plots for change in instream physical habitat for shortfin eel (ΔH) for the all-time and February FDCs at a range of percentiles.

50th percentile of reaches | 75th percentile of reaches | 80th percentile of reaches | 90th percentile of reaches

All-time & February FDC

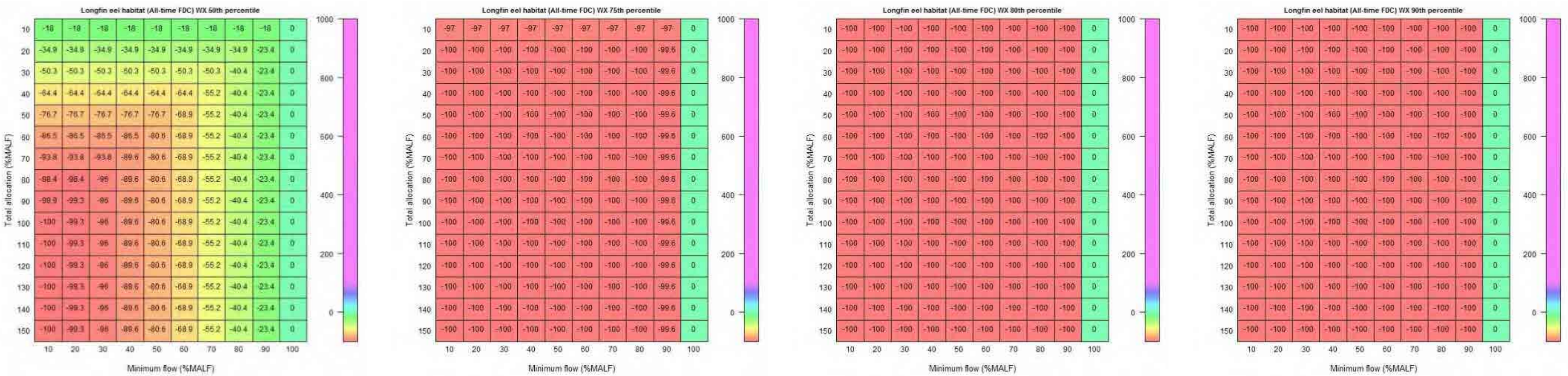

Figure B-34: Decision space plots for change in instream physical habitat for longfin eel (ΔH) for the all-time and February FDCs at a range of percentiles.

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