Habitat preference of Nevis galaxias

(*Galaxias* "Nevis")

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Prepared by:
Amber Sinton
Shannan Crow
Nicholas Dunn
Nixie Boddy

For any information regarding this report please contact:

Shannan Crow
Freshwater Fish Ecologist
Freshwater Modelling
+64-3-343 7868
shannan.crow@niwa.co.nz

National Institute of Water & Atmospheric Research Ltd
PO Box 8602
Riccarton
Christchurch 8011

Phone +64 3 348 8987

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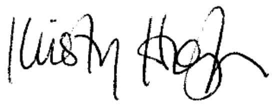	Reviewed by:	Kristy Hogsden
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Executive summary

Habitat suitability curves (HSCs) are commonly used to describe preferences of freshwater biota for water velocity, water depth, substrate, and other relevant habitat characteristics. Changes in flow affect these physical habitat characteristics, potentially altering habitat suitability for different biota. By generating quantified habitat suitability criteria these relationships can then be used to apply physical habitat models under different flow scenarios. The results from these scenarios help guide flow management decisions. HSCs have been developed for many of New Zealand's freshwater fishes; however, there are no specific HSCs for Nevis galaxias (*Galaxias* "Nevis"). Nevis galaxias has high intrinsic biodiversity value and is currently classified as 'Nationally Endangered' in New Zealand. The aim of the present study was to calculate HSCs for *G.* "Nevis". Data collected by the Department of Conservation were used to generate HSCs that could be applied to future flow assessments that use physical habitat models, such as the commonly used RHYHABSIM software.

HSCs were developed for water velocity, water depth and substrate index using habitat information collected from three streams in Otago containing *G.* "Nevis". No reliable preferences were observed for water velocity or depth due to a high degree of uncertainty within habitat categories. A possible preference was found for the substrate index category 5 to <6, which indicated that the preferred substrate of *G.* "Nevis" may be large gravels and cobbles. Results should be interpreted and used cautiously as there were large standard errors associated with all categories for all variables, especially those categories with the highest preference values. To reduce the uncertainty associated with these HSCs and further improve understanding of the habitat preferences for *G*. "Nevis", future habitat surveys should target the habitat categories with high standard errors and low sample replication.

1 Background

Information on habitat requirements of freshwater fishes is used to guide the management of Aotearoa New Zealand's freshwater resources. Studies on physical habitat requirements aim to identify the important flow-driven factors used, and/or preferentially selected, by target fish species (Jowett and Richardson 2008). Data on habitat can then be used by managers during flow assessments by examining how the availability of important habitat factors changes with differing flows. The relationships between habitat preference and flows can then be used to ensure fish habitat is maintained or enhanced under changing flow regimes or could help avoid situations where the availability of suitable habitat may become limiting (Jowett and Richardson 2008).

Habitat suitability curves (HSCs) are used to describe preferences of freshwater biota across environmental gradients (e.g., water velocity, water depth, substrate type). HSCs have been developed for many New Zealand fishes (Jowett and Richardson 2008), but not for the roundhead galaxiid, *Galaxias* "Nevis". *G*. "Nevis" is only known to occur in the upper Nevis River in Otago and is categorised as 'Nationally Endangered' (Dunn et al. 2018). There is also very limited information on the general habitat preference and use of *G*. "Nevis". Habitat requirements of this species could be inferred from similar *Galaxias* species, but this could be misleading given the different habitat requirements found between other non-diadromous *Galaxias* species (Crow et al. 2010; 2014).

The aim of the present study was to calculate HSCs for *G*. "Nevis" for water velocity, water depth and substrate index. Data collected by the Department of Conservation (DOC) were used to calculate HSCs that could be applied to future flow assessments using the software packages RHYHABSIM or SEFA (http://www.jowettconsulting.co.nz or www.sefa.co.nz, respectively).

2 Methods

2.1 Field sampling

Three streams were sampled for *G*. “Nevis” in the upper Nevis River catchment, Otago, during February 2021 (Table 2-1). Stream selection was based on the taxon being previously known at locations, and where possible: (1) an understanding of the abundance of the taxon; (2) the presence of few other non-target species; and (3) access permission from landowners/managers. The timing of sampling was designed to measure habitat preferences during lower flow conditions in late summer.

Table 2-1: Location of each stream sampled for *Galaxias* "Nevis". Coordinates are for the midpoint of sampled reaches.

Catchment	Stream	NZTM Easting	NZTM Northing
Clutha River (Nevis River)	Coal Creek tributary	1287200	4987252
Clutha River (Nevis River)	Potter's Creek	1289007	4992822
Clutha River (Nevis River)	Yellow Creek	1283701	4993155

In each stream, a sampling reach containing a variety of instream habitat types was selected. Starting at the downstream end of this reach, a minimum of 30 transects were marked at 3 m intervals. A discharge gauging was conducted at the most downstream transect. Current velocity was measured at 0.6 x depth using a Marsh McBirney Flo-Mate 2000 electromagnetic current meter.

At each transect, a 0.75 x 0.75 m quadrat was carefully placed within the stream so as to cover the dominant flow, water depth, and substratum conditions. A 1 m wide push net was placed at the downstream edge of the quadrat. Three-pass electrofishing of the quadrat was then conducted using a Kainga EFM 300 backpack electrofishing machine (NIWA Instrument Systems) in a downstream direction. Each pass consisted of 5 seconds of electrofishing machine current time, separated by a minimum electrofishing stoppage of 5 seconds between subsequent passes. After electrofishing, captured fish were anaesthetised with 2-phenoxyethanol and identified to species using the keys of McDowall (1990; 2000), if required, or knowledge of the taxa. Fish were measured to the nearest 0.5 mm maximum total length (TL). Fish were then placed in an aerated bucket of water to recover, before being released back into quiet areas of the stream.

Following electrofishing, the mid-point of the quadrat was recorded using a handheld GPS (Garmin 64s) and the distance from each bank to the mid-point of the quadrat was measured. Water depth and water velocity (at 0.6 x depth) at the midpoint of the quadrat were measured. Percentage substratum composition within the quadrat was estimated using the following size classes: bedrock (>4096 mm), boulder (256–4096 mm), cobble (64–256 mm), large gravel (8–64 mm), fine gravel (2–8 mm), sand (0.06–2 mm) and silt/mud (<0.06 mm). Percentage cover of all algal and macrophyte types were also estimated within the quadrat. Once measurements were complete, the next transect upstream was sampled for fish and habitat in the same manner.

2.2 Fish density estimates

The total number of fish in each quadrat (summed from the three passes) was used as a measure of density, rather than a calculated population estimate (e.g., the Carle and Strub (1978) method). With fish catches being low (i.e., numerical average of 0.73 fish per quadrat; Appendix A), population estimates were unable to be generated due to insufficient data.

2.3 Substrate index

A substrate index (SI) was calculated for each quadrat from estimates of percent substrate composition using the relationship:

SI= %Bedrock*0.08 + %Boulder*0.07 + %Cobble*0.06 + %Gravel*0.05 + %Fine Gravel*0.04 + %Sand*0.03 + %Silt*0.02 (Jowett and Richardson 1990).

Vegetation has previously been included in SI calculations (Jowett and Richardson 2008) but was excluded from this analysis as vegetation was absent from all quadrats and would have no effect on the SI.

2.4 Habitat suitability curve calculations

The programme HABSEL (Jowett 2011) was used to calculate HSCs for water velocity, water depth and substrate index using density data of *G*. "Nevis". This software uses an approach consistent with that suggested in Jowett and Richardson (2008), which has previously been the method used to calculate HSCs for many New Zealand fishes. The developed suitability curves are forage ratios where habitat use is adjusted for habitat availability, which is consistent with the category III curves described in Bovee (1986). The forage ratio is an index that measures preference for a particular habitat category and is calculated as the average abundance of the target organism in a given habitat category divided by the average abundance in all habitats. A forage ratio greater than 1.0 indicates preferential habitat selection, where habitat use is greater than expected by chance, a forage ratio less than 1.0 are indicates habitat use is less common than expected by chance, and a value equal to 1.0 indicates neutral selection (Jowett and Davey 2007).

Density data were available for *G*. "Nevis" in the present study and it was assumed that higher fish densities were present in higher quality habitat areas (Jowett and Richardson 2008). To account for differences in fish densities between streams, fish data at each stream were standardised by dividing observed fish densities by the maximum density observed from the stream (Jowett and Richardson 2008). This converts all density data to a value between 0–1 for each stream.

Forage ratios were calculated with observations binned by habitat values (e.g., bin 1= water velocity observations from 0 to <0.4 m/s, bin 2= water velocity observations from 0.4 to <0.8 m/s, etc.; Appendix C). All binned groups were adjusted for each forage ratio such that each bin contained a minimum of four observations, except for the three highest water velocity bins, which had two, one and no observations, respectively (note, no fish were caught within these bins/categories). Forage ratio values (+ standard error) for binned habitat values were displayed for all habitat variables as bar charts. Forage ratio values (+ standard error) for binned habitat values were displayed for all habitat variables as bar charts. Kernel smoothed curves were used to display trends across the habitat categories for the calculated forage ratios. Kernel smoothed curves were also overlaid on each bar chart that showed the relative abundance of used and available data.

Forage ratio values for habitat categories were then converted to a table for use in RHYHABSIM. To enable the data to be compatible with RHYHABSIM, each habitat variable required information linking a range of habitat values (e.g., velocity 0.2, 0.6, 1.0, 1.4, 1.8, 2.2 m/s) to a weighting value that indicates habitat preference. The habitat values were calculated from the median of the binned habitat categories on the forage ratios. The weightings were calculated by converting the forage ratio scores for each habitat category to a value ranging between 0 and 1. Habitat values for depth and velocity in the RHYHABSIM table started at 0 while SI values started at 1, despite no observations for these habitat values. This was done because a preliminary analysis in RHYHABSIM showed misleading results occurred if these variables had no data for these habitat values. A forage weighting value of 0 was set for SI index of 1–4 because no observations were completed for this habitat value and it was considered conservative to underestimate habitat quality in these areas. A depth of 0 was assigned a weighting value of 0 because fish cannot live in dry areas.

3 Results

Across the three streams, a total of 72 *G*. “Nevis” individuals were captured (Table A-1). *G*. “Nevis” were found in a similar number of quadrats in each stream (30 to 35), but Potter’s Creek had a higher density than the other two streams. Overall, of the 98 quadrats sampled, 44 contained *G*. “Nevis”.

G. “Nevis” showed weak preferences within all three habitat variables (refer to Figures 3-1, 3-2, 3-3) based on the available data. For all habitat categories except one, forage ratio values above 1.0 (indicating habitat preference) had standard errors that crossed below 1.0 and relative standard errors (RSE) were high (Appendix C). The exception was the substrate index category 5 to <6, for which the forage ratio was 1.26 and the standard error 0.19 (RSE 15%; Table C-3). For water velocity and water depth, the highest forage ratios also had the largest standard errors (Table C-1, Table C-2).

No clear trend of water velocity preference was shown by *G*. “Nevis”, although the highest forage ratio (1.25) was for the 0.8 to <1.2 m/s category (Figure 3-1). *G*. “Nevis” were absent from the three samples in categories 1.2 to <1.6 and above (Table C-1). For water depth, *G*. “Nevis” had the highest forage ratios for the categories 0.30 to <0.45 m and 0.45 to <0.60 m (1.88 and 1.76, respectively), with the 0 to <0.15 m and 0.15 to <0.30 m categories both having a forage ratio below 1.0, indicating habitat avoidance (Figure 3-2). It should be noted that there were a low number of samples for the 0.30 to <0.45 m and 0.45 to <0.60 m water depth categories (Table C-2). The highest forage ratio for substrate index was for category 5 to <6, with categories either side having a forage ratio below 1.0, though note that the 4 to <5 and 7 to <8 categories contained few samples (Figure 3-3, Table C-3). A category of 5 to <6 is likely to represent a mixture of mostly large gravels and cobbles.

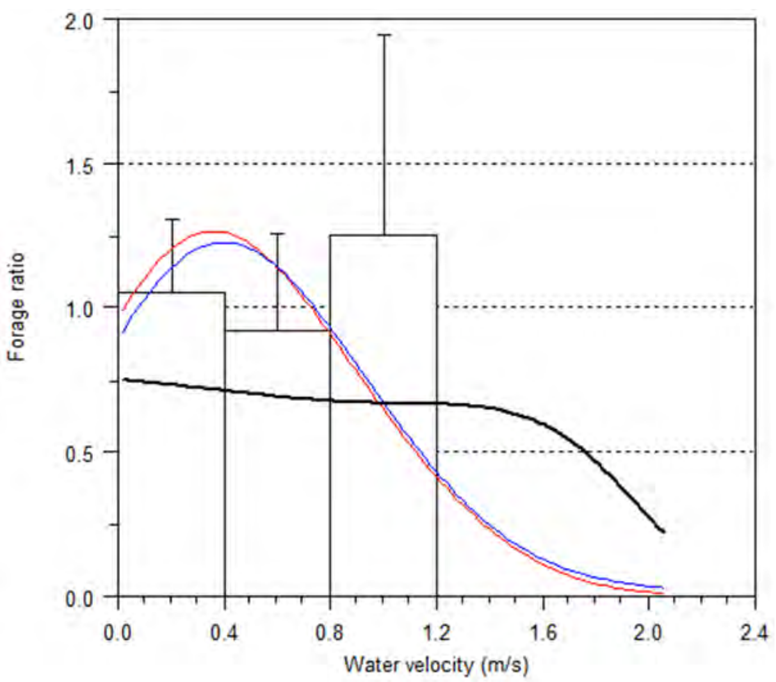

Figure 3-1: Water velocity preference by *Galaxias* “Nevis”. Data displayed as forage ratio values (+ standard error) for binned water velocity values. Kernel smoothed curves overlaid show the relative abundance of used habitat (red line), available habitat (blue line) and the selected habitat (i.e., habitat suitability curve (HSC); black line). The HSC is the ratio of the used habitat curve divided by the corresponding available habitat curve. A forage ratio of >1.0 indicates a water velocity preference while <1.0 indicates velocity avoidance.

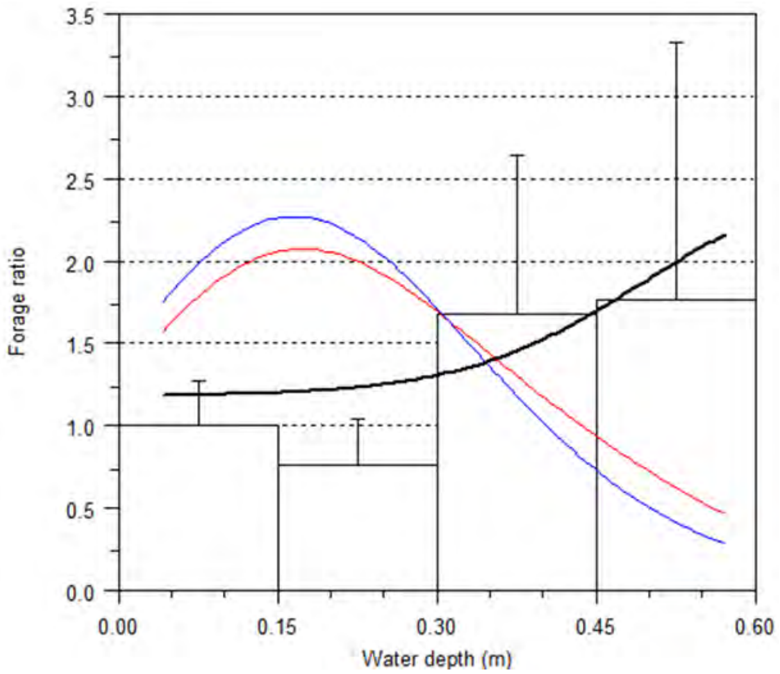

Figure 3-2: Water depth preference by *Galaxias* "Nevis". Data displayed as forage ratio values (+ standard error) for binned water depth values. Kernel smoothed curves overlaid show the relative abundance of used habitat (red line), available habitat (blue line) and the selected habitat (i.e., habitat suitability curve (HSC); black line). The HSC is the ratio of the used habitat curve divided by the corresponding available habitat curve. A forage ratio of >1.0 indicates a water depth preference while <1.0 indicates water depth avoidance.

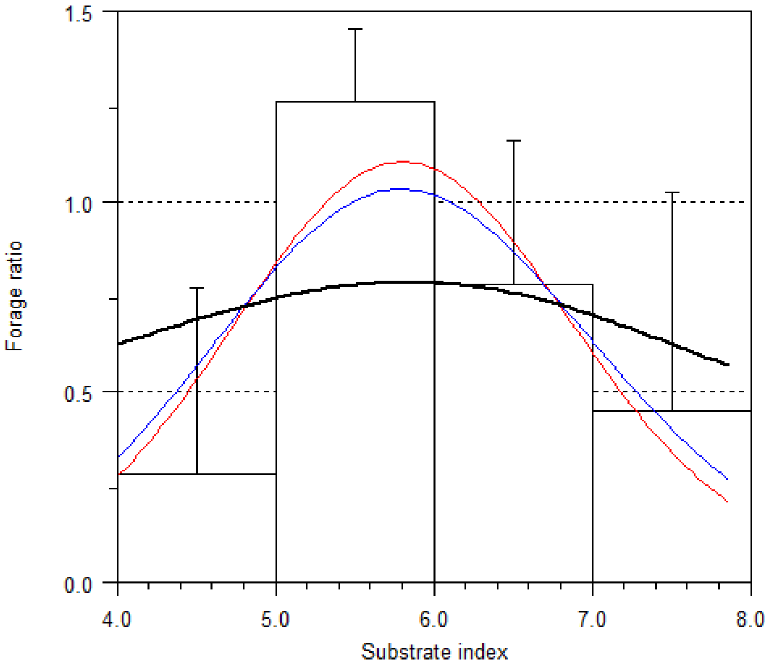

Figure 3-3: Substrate index preference by *Galaxias* "Nevis". Data displayed as forage ratio values (+ standard error) for binned substrate index values. Kernel smoothed curves overlaid show the relative abundance of used habitat (red line), available habitat (blue line) and the selected habitat (i.e., habitat suitability curve (HSC); black line). The HSC is the ratio of the used habitat curve divided by the corresponding available habitat curve. A forage ratio of >1.0 indicates a substrate index preference while <1.0 indicates substrate index avoidance.

4 Discussion and future considerations

4.1 Habitat preference of *Galaxias* “Nevis”

A potential preference for one substrate index category (large gravels and cobbles) was found for *G.* “Nevis”, but the high degree of uncertainty meant that no reliable preferences were identified for water velocity or water depth. All but one of the habitat categories with a forage ratio above 1.0 (indicating habitat preference) had standard errors that crossed 1.0, meaning results should be used cautiously.

Low levels of replication within habitat categories is one potential contributor to the high degree of uncertainty observed in the present study. A study of *G*. “southern” habitat preferences (Sinton et al. 2021) noted that only habitat categories containing 100 or more samples were likely to generate reliable estimates based on a relative standard error (RSE) of 20% or below. In this study, the greatest number of samples within a category was 57 (for the substrate index category 5 to <6), which had an RSE of 15%, with all the remaining habitat categories having a RSE above 20%. Additionally, if fish densities are low (e.g., <1 fish per m^2, as found in the streams in this study) there is an increased chance that no fish will be caught in samples of “preferred” habitats, further adding to the variability of results. Collinearity between habitat variables could also complicate interpretations of individual habitat variables, but this was not explored due to limitations in the HABSEL software.

4.2 Comparison to other studies

Adult roundhead galaxiids were found by Jowett and Richardson (2008) to prefer shallow waters with low to moderate velocities (0 to 0.8 m/s) but were tolerant a wide range of habitat conditions. Substrate preference between this study and Jowett and Richardson (2008) was similar, with both finding a preference for cobble-sized particles.

4.3 Future considerations

Patterns of habitat preference were weak when compared with those observed for other species (e.g., torrentfish (*Cheimarrichthys fosteri*), Canterbury galaxias (*G. vulgaris*) or kōaro (*G. brevipinnis*) from Jowett and Richardson (2008)). To further improve understanding of the habitat preferences for *G*. “Nevis”, the following options could be considered.

- Increased sampling in the habitat categories from the present study with low replication and/or high standard errors (see Appendix C). As many as 100 samples per category may be required to reduce uncertainty and provide meaningful results.
- Test the statistical significance of each preference curve using bootstrap re-sampling, which would further quantify the level of uncertainty in the HSCs.
- Explore collinearity between habitat variables, as there could be interactions between the variables which complicate interpretation. We recognise that this will not assist with RHYHABSIM analyses, which is unable to address collinearity, but would assist with management decisions.
- Investigate nocturnal habitat use. All data collected in the present study were sampled during the day but other studies have shown some native fish species may be more susceptible to capture during the evening (Crow et al. 2010, Graynoth et al. 2012).

Shifts in habitat use between day and night have also been observed in other freshwater fishes in New Zealand, which has been shown to influence assessments of flow requirements (Davey et al. 2011). Consideration of nocturnal habitat requirements may produce more defensible flow recommendations for these species (Davey et al. 2011).

5 Acknowledgements

The assistance of Katie Fenton and Chris Kavazos (both Department of Conservation) in the field is greatly appreciated. We appreciate permission from landowners and managers to access streams on their properties.

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Appendix A *Galaxias* “Nevis” abundance at sites

Table A-1: Abundance of *Galaxias* "Nevis" captured from quadrats in each stream.

Catchment	Stream	Number of quadrats sampled	Number of quadrats containing fish	Total number of fish caught	Fish density (number/m^2)
Nevis River	Coal Creek tributary	33	13	19	0.58
Nevis River	Potter's Creek	35	19	33	0.94
Nevis River	Yellow Creek	30	12	20	0.67
	TOTAL	**98**	**44**	**72**	**MEAN 0.73**

Appendix B Forage ratios for RHYHABSIM

Table B-1: *Galaxias* "Nevis" forage ratios prepared for RHYHABSIM analysis. The category rows contain the median of the binned habitat categories and corresponding weighting rows contain the weighted forage ratio score for each habitat category (calculated by converting the forage ratio scores for each habitat category to a value ranging between 0 and 1).

Index	Values						
Water velocity category (m/s)	0	0.2	0.6	1.0	1.4	1.8	2.2
Water velocity weighting	0	0.84	0.74	1.00	0	0	0
Water depth value (m)	0	0.08	0.23	0.38	0.53		
Water depth weighting	0	0.52	0.40	1.00	0.94		
Substrate index value	1.5	2.5	3.5	4.5	5.5	6.5	7.5
Substrate index weighting	0	0	0	0.23	1.00	0.62	0.36

Appendix C HABSEL category and selectivity value tables

Table C-1: Water velocity HABSEL categories and associated forage ratio values for *Galaxias* "Nevis". A forage ratio of >1.0 indicates a water velocity preference while <1.0 indicates water velocity avoidance.

Water velocity (m/s) category	Number of samples	Forage Ratio	Forage Ratio standard error (SE)	Forage Ratio relative SE (%)
0–<0.4	48	1.05	0.25	24
0.4–<0.8	34	0.92	0.33	36
0.8–<1.2	13	1.25	0.70	56
1.2–<1.6	2	0	0	0
1.6–<2.0	0	0	0	0
2.0–<2.4	1	0	0	0

Table C-2: Water depth HABSEL categories and associated forage ratio values for *Galaxias* "Nevis". A forage ratio of >1.0 indicates a water depth preference while <1.0 indicates water depth avoidance.

Water depth (m) category	Number of samples	Forage Ratio	Forage Ratio standard error (SE)	Forage Ratio relative SE (%)
0–<0.15	47	0.98	0.26	27
0.15–<0.30	39	0.76	0.29	38
0.30–<0.45	8	1.88	1.10	59
0.45–<0.60	4	1.76	1.57	89

Table C-3: Substrate index HABSEL categories and associated forage ratio values for *Galaxias* "Nevis". A forage ratio of >1.0 indicates a substrate index preference while <1.0 indicates substrate index avoidance.

Substrate index category	Number of samples	Forage Ratio	Forage Ratio standard error (SE)	Forage Ratio relative SE (%)
4–<5	7	0.29	0.49	169
5–<6	57	1.26	0.19	15
6–<7	26	0.78	0.38	49
7–<8	8	0.45	0.57	127