Macrofauna Survey Results Following Streamflow Restoration from West Wailuaiki to Hanawī, East Maui, Hawai‘i

February 2026 **PR-2026-01**

State of Hawai‘i

Department of Land and Natural Resources

Commission on Water Resource Management

Acknowledgements
The authors are grateful for the tireless assistance in the field from Douglas Kagawa, Alyssandra Rousseve, Wailana Mosses, and Dean Uyeno from CWRM staff, as well as the skillful pilots at Windward Aviation. We are forever indebted to Kathy Yoda for all her assistance with making this fieldwork possible.

Cover Photo: Kopiliula Stream at 20 feet elevation, East Maui

Citation: Strauch, A.M., Chacon, C.L., and Kimmel, J.H. 2026. Macrofauna Survey Results Following Streamflow Restoration from West Wailuaiki to Hanawī, East Maui, Hawaiʻi. Commission on Water Resource Management, Public Report PR-2026-01.

Macrofauna Survey Results Following Streamflow Restoration from West Wailuaiki to Hanawī, East Maui, Hawai‘i

By Ayron M. Strauch, Cody L. Chacon, and Jody H. Kimmel

Executive Summary

Staff at the State of Hawai‘i Commission on Water Resource Management (Commission), in cooperation with the State of Hawai‘i Division of Aquatic Resources (DAR), conducted ecological surveys of streams in hydrologic units from West Wailuaiki to Hanawī in East Maui at two elevations: stream mouths (2025) immediately upstream of the estuary (i.e., lower reach), and higher elevations (2024) immediately upstream of the Ko‘olau Ditch (i.e., upper reach). After approximately seven years of full flow restoration (2016-2023), water withdrawals at low-head dams restarted on some of these streams in 2023, with interim instream flow standards (i.e., partial flow restoration) implemented to maintain downstream flow. Staff conducted ecological surveys to test the null hypothesis that there are no statistical differences in habitat availability, species population dynamics, or community composition of aquatic macrofauna among streams with partial flow restoration compared to streams with continued full flow restoration. We specifically tested the following stream comparisons: West Wailuaiki to East Wailuaiki; and Waiohue to Kopiliula. Lower reach surveys were also compared to four other reference streams: three naturally flowing streams (Wailau, Moloka‘i; Waikama, Hawai‘i; and Pāhoehoe, Hawai‘i) and one stream with partial flow restoration (Waikolu, Moloka‘i). Staff surveyed upper reaches to test the hypothesis that there was no statistical difference in recruitment of *Atyoida bisulcata* (‘ōpae kala‘ole) to streams with partial flow restoration compared to streams with full flow restoration. Upper reach surveys were compared to identical surveys conducted at similar elevations of other streams on Maui (East Wailuanui) and Hawai‘i (Honoli‘i) islands.

Despite substantial water withdrawals from Hanawī (partial flow restoration), Kopiliula (partial flow restoration) and East Wailuaiki (partial flow restoration), sufficient habitat was available at lower reaches to support healthy, thriving, aquatic communities. We found no significant differences in stream depth, velocity, or wetted width between East Wailuaiki and West Wailuaiki (full flow restoration) or between Kopiliula and Waiohue (full flow restoration). We conclude that there was no difference in the amount of habitat in streams with full flow restoration compared to streams with partial flow restoration.

In streams with full flow restoration, we did not see an increase in the densities or abundances of *Awaous stamineus* (‘o‘opu nākea), *Sicyopterus stimpsoni* (‘o‘opu nōpili), or *Eleotris sandwicensis* (‘o‘opu ‘akupa) in lower reaches compared to streams with partial flow restoration. Community composition, as measured by trophic capacity or Normalized Canberra Distance, did not differ between East Wailuaiki and West Wailuaiki or between Kopiliula and Waiohue. The number of juveniles that recruited to streams with partial flow restoration was equal to or greater than the number that recruited to streams with full flow restoration. We did not observe a significant difference in *Lentipes concolor* (‘o‘opu ‘alamo‘o) density or *Neritina granosa* (hīhīwai) density between West Wailuaiki and East Wailuaiki or between Kopiliula and Waiohue.

In surveys conducted at upper reaches, *A. bisulcata* populations were equally abundant in streams with partial flow restoration and full flow restoration. Partial flow restoration was sufficient to meet the downstream connectivity needs of migratory *A. bisulcata*.

Existing flow standards are sufficient to maintain healthy aquatic communities, supporting reproductive adults and connectivity for the continual recruitment of juveniles. Runoff events that are not affected by low-head dams drive the flushing of accumulated organic debris, the reorganization of substrates that support freshwater habitat heterogeneity, and the recruitment of endemic aquatic fauna. As habitat availability, population size, and ecosystem structure are equivalent to reference streams, full flow restoration does not produce a quantifiable improvement in ecological function outside of the natural variability associated with stream communities.

Background

In 2018, the Commission issued its final Decision and Order (2018 D&O) regarding the contested case hearing (CCH) CCH-MA-13-01 addressing the establishment of interim instream flow standards (interim IFS) for 27 streams in East Maui originally petitioned by Nā Moku ʻAupuni o Koʻolau Hui and Native Hawaiian Legal Corporation (petitioners) in 2001. In its 2018 D&O, the Commission instructed staff to examine the ecological consequences of various types of interim IFS. Specifically, "West Wailuaiki Stream presents a unique research opportunity to collect valuable information regarding the impact of full restoration of a stream versus habitat restoration (H_{90}). East and West Wailuaiki lie in close proximity to each other with similar biological values and similar habitat and biota. The Commission intends for these two streams to be studied in the future in combination with one another to see the impact, if any, of full restoration versus habitat restoration." (p.261) Similarly, Waiohue and Kopiliula lie near each other with similar characteristics.

In streams designated for habitat restoration (i.e., East Wailuaiki and Kopiliula), the interim IFS was established by the 2018 D&O as 64% of the median baseflow (64% BFQ_{50}) using 1914-2001 data by Gingerich (2005). Further, the 2018 D&O established a connectivity flow past the Koʻolau Ditch for Hanawī Stream.

The streams studied here include the hydrologic units from West Wailuaiki to Hanawī, characterized by Hāna Volcanics overlaying Kula Volcanics (Table 1). Periods of intervening erosional material, thin ash deposits and layers of ʻaʻā and pāhoehoe lava flows filled previously incised Honomanū Volcanics, which make up the shield-building phase of the region. Unlike the perched water bodies that define most of the shallow groundwater discharge to streams in East Maui, this area is composed of vertically-extensive groundwater that produces artesian conditions in some places, resulting in some of the largest spring discharges in the state. By contrast, the Makapipi hydrologic unit lacks this hydrogeology, and the stream loses surface water to groundwater recharge, resulting in naturally dry reaches throughout the watershed under low-flow conditions[1]. For more details on groundwater in this region, see Meyer (2000).

Following the cessation of sugarcane irrigation in June 2016, East Maui Irrigation discontinued water withdrawals from study streams. After seven years of full or nearly full restoration, water

[1] See USGS fieldwork September 13-17, 2010.

withdrawals from East Wailuaiki and Kopiliula streams began in September 2023. Partial restoration was maintained by restoring 64% BFQ_{50} as defined by Gingerich (2005). To compare the consequences of different flow management actions, staff completed biological surveys at upper reaches of the Koʻolau Ditch diversions in the fall of 2024, and in lower reaches in the fall of 2025.

Table 1. Stream basin characteristics for lower reach surveys in East Maui streams [U.S. Geological Survey, 2019; reach slope percent based on Tingley et al. 2019; MAR = mean annual rainfall]

Stream	Drainage Area (mi^2)	Maximum Elevation (ft)	Reach slope (%)	Stream Length (mi)	MAR (in)	% Hāna Volcanics	% Kula Volcanics	% Forest Cover
Hanawī	5.34	8090	36.2	8.04	196	59.4	40.6	90
Waiohue	1.34	7626	13.4	7.26	233	23.1	75.5	85
Kopiliula	4.70	8370	20.4	8.42	178	31.5	67.7	85
East Wailuaiki	3.93	8520	6.5	8.48	187	0.9	97.6	86
West Wailuaiki	4.02	8850	12.3	8.78	182	0.2	98.4	83

Goal

We gathered data to test the hypothesis that habitat availability, the density and abundance of endemic aquatic macrofauna, and community composition vary in response to differing water resource management strategies in streams of East Maui (Figure 1). Streams in this region have relatively uniform topography, originating at high elevations, with narrow catchments and steep gradients (Table 1). All streams included in this study have terminal estuaries.

In 2025, we surveyed habitat availability and the abundance and composition of endemic aquatic macrofauna in five streams at lower reaches: Hanawī, Waiohue, Kopiliula, East Wailuaiki, and West Wailuaiki (Figure 1). We compared results to identical surveys conducted at stream mouths on Molokaʻi (Waikolu and Wailau) and Hawaiʻi (Waikama and Pahoehoe) islands (Supplemental Figure S1).

In 2024, we surveyed the abundance of *A. bisulcata* at the 1300-1500 ft elevation in Hanawī, Paʻakea, Waiohue, Kopiliula, West Wailuaiki (Figure 1). Results are compared to surveys conducted at similar elevations in East Wailuanui (Maui Island) and Honoliʻi (Hawaiʻi Island) streams.

Hydrology

Commission staff operate continuous record gaging stations monitoring flow conditions on Waiohue, Kopiliula, and East Wailuaiki streams downstream of the Koʻolau Ditch, in addition to natural flow monitoring conducted by the U.S. Geological Survey (USGS) at stations 16508000 on Hanawī Stream and 16518000 on West Wailuaiki Stream above the Koʻolau Ditch. Since 2016, no water has been diverted from Waiohue or West Wailuaiki (Table 2).

Table 2. Interim instream flow standards implemented for streams at Koʻolau Ditch for varying periods of time.

Stream	2011- June 2016	June 2016-2018	2018- Sept 2023	Sept 2023-present
Hanawī	Connectivity IFS	Fully restored	Fully restored	Connectivity IFS
Paʻakea*	None	Fully restored	Fully restored	Fully restored
Waiohue	Interim IFS	Fully restored	Fully restored	Fully restored
Kopiliula	None	Partially restored	Interim IFS	Interim IFS
East Wailuaiki	Interim IFS	Fully restored	Fully restored	Interim IFS
West Wailuaiki	Interim IFS	Fully restored	Fully restored	Fully restored

*Paʻakea full flow restoration has not been ordered by the Commission; modifications to withdrawal water and provide for the IFS are pending permit approvals.

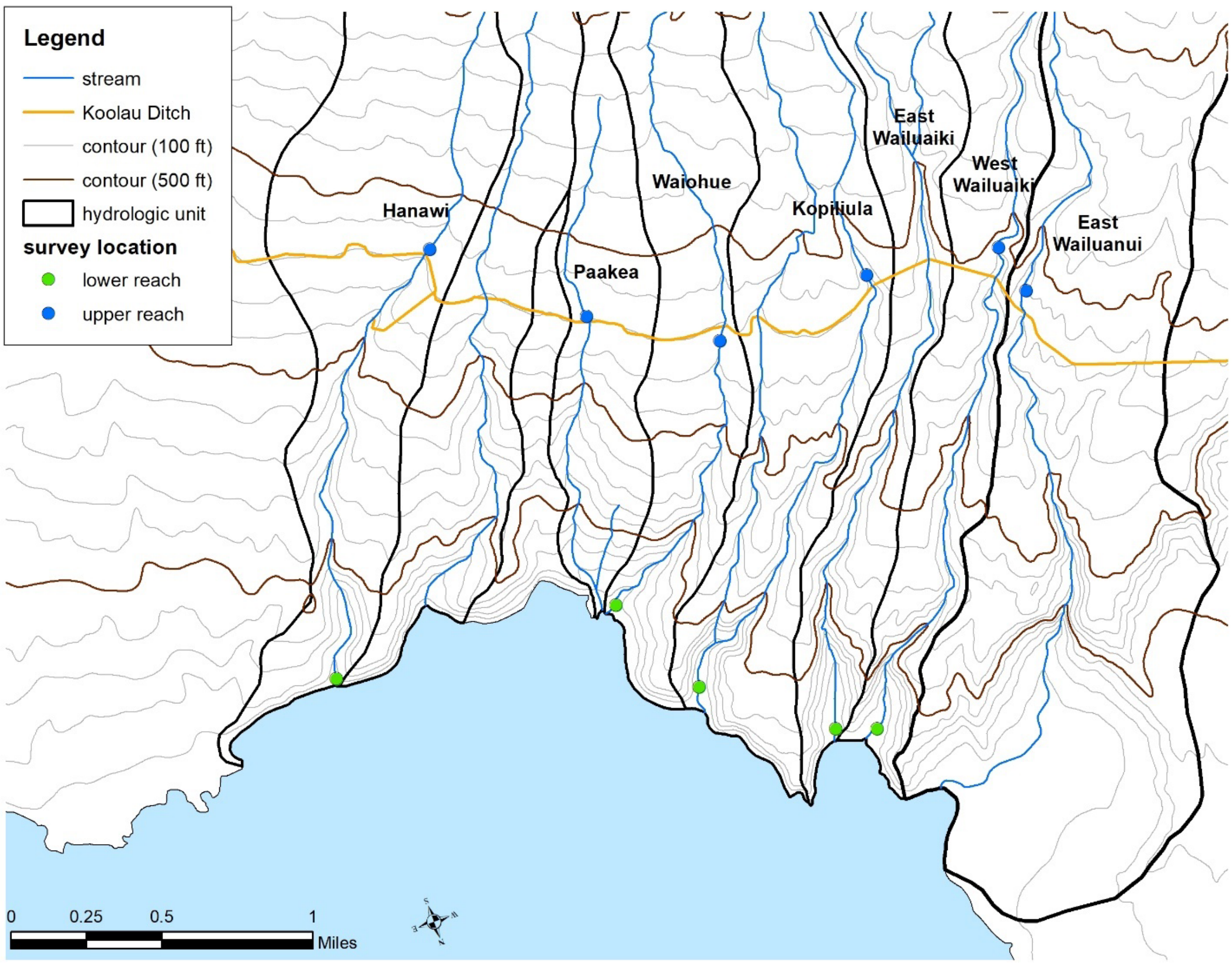


Figure 1. Locations of biological surveys conducted in relation to the East Maui Irrigation's Ko'olau Ditch in East Maui.

Immediately following each survey, streamflow was measured using standard USGS discharge measurement protocols at a suitable location with appropriate cross-sectional conditions (Turnipseed and Sauer, 2010). Discharge measurements made at the lower reach were compared to measurements made immediately below the Koʻolau Ditch to quantify groundwater gains in streamflow (Table 3). Streamflow statistics for various longer-term periods of record are provided in Table 4.

Table 3. Measured flow in cubic feet per second (million gallons per day) immediately upstream of the Koʻolau Ditch, at 5ft, and the difference between them. [note: g = gaged; t = measurement; m = modeled based on long-term overlapping stream gage records; n/a = streamflow measurements were not sufficiently distinct to quantify a difference]

Stream	date	Upstream of Koʻolau Ditch	Immediately below Koʻolau Ditch	At 5ft elevation	Difference
Hanawī	11/07/2025	$2.3\ (1.5)^{g}$	$0.5\ (0.3)^{t}$	$18.5\ (12.0)^{t}$	+18.0 (11.6)
Waiohue	11/03/2025	$2.9\ (1.9)^{g}$	$2.9\ (1.9)^{g}$	$4.2\ (2.7)^{t}$	+1.3 (0.8)
Kopiliula	11/03/2025	$2.2\ (1.4)^{m}$	$3.2\ (2.1)^{g}$	$3.8\ (2.5)^{t}$	+0.6 (0.4)
East Wailuaiki	10/24/2025	$2.1\ (1.3)^{m}$	$1.1\ (0.7)^{g}$	$1.0\ (0.6)^{t}$	n/a
West Wailuaiki	10/24/2025	$2.2\ (1.4)^{g}$	$2.2\ (1.4)^{g}$	$3.1\ (2.0)^{t}$	+0.9 (0.6)

Natural flow above the Koʻolau Ditch at East Wailuaiki and Kopiliula streams were based on long-term overlapping records using record-extension techniques as published by Cheng (2016). Natural streamflow on Paʻakea is monitored using a partial-record gaging station. At the lower reaches, we calculated the mean daily flow, median flow, coefficient of variation (i.e., flow variability; CV), and the number of days mean daily flow exceeded twice the median flow ($Q > 2xQ_{50}$) for various periods of record preceding surveys.

Table 4. Estimated Q50 and Q95 streamflow for ungagged locations of lower reaches based on Gingerich (2005).

Stream	Period of Record	Total Flow		Base Flow	
		Q_{50}	Q_{95}	Q_{50}	Q_{95}
Hanawī	1941-2001	32	22	26	19
Waiohue	1941-2001	8.8	4.5	7.5	3.6
Kopiliula	1941-2001	15	5.5	9.5	3.8
East Wailuaiki	1941-2001	11	3.4	7.2	2.9
West Wailuaiki	1941-2001	12	3.5	7.2	2.4

Point-Quadrat Survey Methods

To quantify macrofauna population density, we utilized the point-quadrat visual snorkel survey method as described by Higashi and Nishimoto (2007). Visual surveys are an efficient and accurate method of estimating species density and abundance of small benthic fish in wadable streams (Hain et al., 2016). Surveys were conducted using a stratified-random sampling design over approximately 200 meters of stream channel. The reach was divided into 10-meter segments, and 20 transects were established perpendicular to flow, beginning at the most downstream point and extending upstream. For each transect, we conducted a single point-quadrat survey at a pre-determined randomly selected lateral position – either along the left bank, center channel, or right bank. Visual surveys lasted for 120 seconds, during which all macrofauna were identified to species, enumerated, and sizes estimated to the nearest 0.5 inch (1.2 cm) for *A. stamineus*, *E. hawaiiensis*, *S. stimpsoni*, *Kuhlia* spp., and *Macrobrachium lar*. Sizes were estimated to the nearest 0.25 inch (0.6 cm) for *L. concolor*, *N. granosa*, and *A. bisulcata*. The two native *Kuhlia* species, *Kuhlia xenura* and *K. sandvicensis*, which are difficult to differentiate in the field, were grouped as *Kuhlia* spp.

All surveys were conducted by two observers alternating transects. At each survey location, we recorded the dimensions of the quadrat to calculate the area surveyed and the maximum depth.

Species density was calculated by dividing the number of individuals of each species observed by the total area of that quadrat, then averaged per stream reach (n = 20). Species abundance per 100 m were determined by multiplying density by wetted width.

Each quadrat was assigned a dominant habitat type – run, pool, or riffle – following the classification system of Higashi and Nishimoto (2007). Substrate composition within each quadrat was estimated visually, with substrate types (e.g., bedrock, boulder, cobble, gravel, sand, silt, and organic matter) recorded to the nearest 5%. Bedrock was defined to include large boulders (intermediate axis > 1 m) and continuous volcanic basalt formations, as characterized by Kinzie et al. (1984). Organic matter included leaf litter, deposited fruit, and coarse woody debris.

We measured water velocity at 60% of the total depth at the center of each quadrat using a FlowTracker 2 acoustic doppler velocimeter (SonTek, San Diego, California). At every transect, both wetted width and active channel width were recorded to characterize stream channel dimensions. Canopy cover (%) was estimated at every other transect (n = 10) using CanopyApp (version 1.0.3, University of New Hampshire), and mean canopy cover was calculated for the entire survey reach.

Lower Reach Surveys

Commission staff conducted biological surveys at lower reaches of Hanawī, Waiohue, Kopiliula, East Wailuaiki, and West Wailuaiki in 2025 (Table 1). Hydrological conditions at USGS stations 16508000 and 16518000 prior to surveys are provided in Figure 2. Lower reaches of East Wailuaiki and West Wailuaiki were surveyed on the same day, as were Kopiliula and Waiohue. We completed all lower reach surveys within a span of 14 days at the end of the dry season. For comparison purposes, data from additional lower reach surveys from Moloka‘i (Waikolu, Wailau) and Hawai‘i islands (Waikama, Pahoehoe) with similar geology and hydrology spanning a range of drainage areas were also conducted under dry season conditions (Supplemental Figure 1).

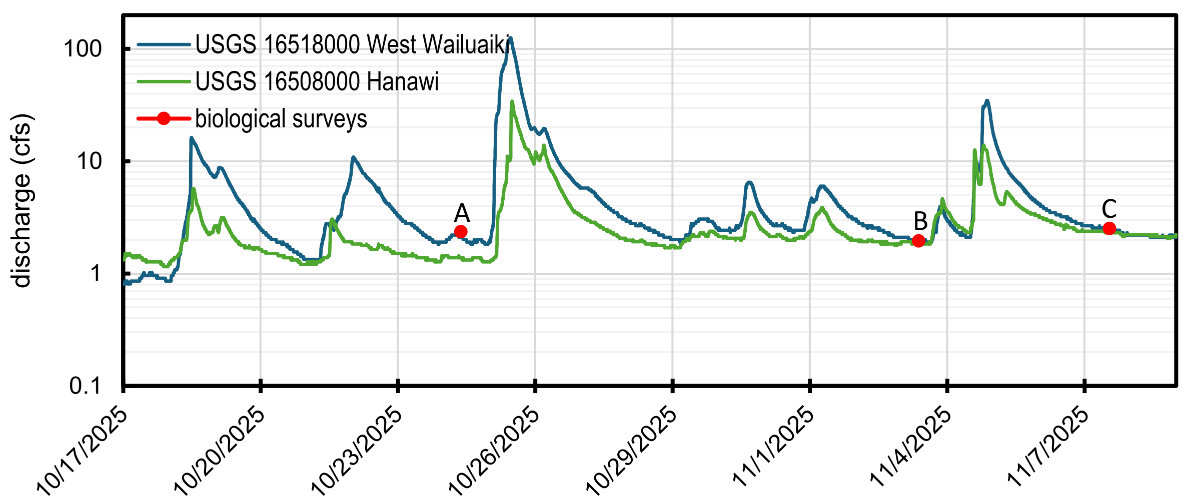


Figure 2. Continuous-record discharge values for USGS station 16518000 on West Wailuaiki and 16508000 on Hanawī Stream from October 17, 2025 to November 8, 2025. Dates with biological surveys identified in red: A = West Wailuaiki and East Wailuaiki; B = Kopiliula and Waiohue; C = Hanawī.

Upper Reach Surveys

Commission staff conducted point-quadrat surveys in 2024 at upper reaches (1300-1500 ft elevation) above the Koʻolau Ditch in Hanawī, Paʻakea, Waiohue, Kopiliula, and West Wailuaiki. For comparison purposes, data from additional high-elevation locations from other Maui (East Wailuanui, undiverted since 2016) and Hawaiʻi Island (Honoliʻi, undiverted) streams are provided (Supplemental Table S2).

Data Analysis

We tested the null hypothesis that there was a significant difference in stream channel characteristics (e.g., depth, velocity, wetted width, and active channel width) among lower reaches using a Kruskal-Wallis non-parametric analysis of variance (H statistic) and Dunn's post-hoc test to determine significant differences among streams. The Kruskal-Wallis test does not assume that the data are normally distributed or that samples have equal variances, and tests whether samples originate from the same distribution. This test is more suitable for the analysis of ecological data where outliers are more common (Underwood, 2007). The null hypothesis was rejected for H statistics corresponding to *p*-values less than or greater than $\alpha = 0.05$ for the appropriate degrees of freedom (df).

Individual species sizes were classified into post-larvae (<3 cm), juveniles (3 to 6 cm for *L. concolor* and *S. stimpsoni*; 3 to 8 cm for *A. stamineus*) and adults (> 6 cm for *L. concolor* and *S. stimpsoni;* > 8 cm for *A. stamineus*) based on Kido (2013), Kinzie (1988), and Gingerich and Wolff (2005). To quantify patterns in recent recruitment, we calculated the number of juveniles based on observed sizes and compared them among streams.

Assessment of Community Composition

Trophic capacity describes a stream's ability to support multiple trophic levels – from producers to primary and secondary consumers – and is constrained by population dynamics (Primm and Lawton, 1977). Environmental changes that alter food availability or habitat structure can shift community composition and relative species abundance. For lower reaches, we calculated the community-weighted average (CWA) trophic capacity as the proportional numerical abundance of each taxon multiplied by its assigned weighting value following Kido (2013). The CWA trophic capacity metric is a single cumulative descriptive value that cannot be statistically tested among streams. Species-specific trophic values are provided in Supplemental Table S1. Lower values indicate communities dominated by specialized consumers (e.g., *L. concolor* or *S. stimpsoni*), whereas higher values reflect greater dominance by generalist taxa (Kido, 2013).

To compare community composition between stream pairs, we calculated a derivation of the Bray-Curtis community dissimilarity index for fish species called the Normalized Canberra Distance (NCD) (Ricotta and Podani, 2017). This index is not as sensitive to large abundances of rare species due to the use of species-specific weight differences and does not exaggerate species-wise differences by squaring. The index is normalized by dividing by the total number of fish species (e.g., 6) observed across all streams resulting in a range from 0 (identical) to 1 (completely dissimilar). We calculated the NCD for each pair of lower reach stream surveys, including surveys of reference streams.

Results

Antecedent hydrological conditions of Lower Reaches

Hydrological statistics preceding lower reach surveys available via continuous gaging stations are provided in Table 5. Surveys were conducted at the end of the dry season during receding hydrographs (Figure 2). At the lower reach, Hanawī had the greatest mean and median flow and the smallest CV below the Koʻolau Ditch for the previous 90 day (Table 5). By contrast, East Wailuaiki had the smallest mean and median flow and the greatest CV for the previous 90 day. There was more flow at the mouth of Kopiliula compared to Waiohue leading up to the surveys, but Waiohue had more stable flows (i.e., lower CV). Median flow in West Wailuaiki was approximately 50% greater than East Wailuaiki for the 300 day period preceding surveys, while median flow in Kopiliula was approximately 25% greater than Waiohue. Regulated flow condition in Hanawī and East Wailuaiki streams had fewer days of flow that exceeded twice the median flow compared to Kopiliula, Waiohue, or West Wailuaiki for the 300 days that preceded stream surveys.

Table 5. Antecedent hydrological conditions (in cubic feet per second) below the Koʻolau Ditch in 2025 prior to 2025 lower reach surveys. [300d = 300 days; 90d = 90 days; 7d = 7 days; CV = coefficient of variation; $Q > 2xQ_{50}$ = number of days mean daily flow was greater than twice the natural median flow]

	mean			median			CV		$Q > 2xQ_{50}$	
Stream	**300d**	**90d**	**7d**	**300d**	**90d**	**7d**	**300d**	**90d**	**300d**	**90d**
Hanawī	24.4	19.5	20.2	19.5	19.3	19.9	1.52	0.05	9	0
Waiohue	4.4	2.2	2.6	4.4	2.0	2.4	0.89	0.41	27	1
Kopiliula	8.0	3.7	2.6	3.7	3.1	3.6	2.00	0.89	62	2
East Wailuaiki	3.9	1.2	1.1	2.1	0.9	1.2	4.58	0.45	16	0
West Wailuaiki	9.5	1.7	3.4	3.8	1.2	2.7	2.77	0.72	65	0

Channel Characteristics in Lower Reaches

Channel characteristics varied among streams, independent of streamflow, with mean wetted width (WW) and active channel width (ACW) ranging from 5.6 m to 12.8 m, and 10.4 m to 25.6 m, respectively (Table 6). There was a significant difference in WW among streams (H = 53.7, df = 4, $p < 0.001$), with Kopiliula having a significantly greater WW than Waiohue ($p < 0.05$) and East Wailuaiki ($p < 0.05$). There was no statistical difference in wetted width between East Wailuaiki and West Wailuaiki. Narrower watersheds tended to have greater canopy cover due to the presence of non-native riparian vegetation. Mean WW in reference streams were not different from either partially restored or fully restored streams, although Waikama had greater canopy cover. The estuaries of Hanawī, Kopiliula, and East Wailuaiki were closed by a gravel/cobble berm built up by wave action, which is common for these watersheds.

Depth varied significantly (H = 12.065, df = 4, $p < 0.05$) among streams, with Hanawī depth significantly greater than East Wailuaiki ($p < 0.05$), and West Wailuaiki ($p < 0.05$). However, there was no significant difference in depth between East Wailuaiki and West Wailuaiki, or between Waiohue and Kopiliula (Table 5). Similarly, velocity varied significantly (H = 13.698, df = 4, $p < 0.01$) among streams with Hanawī velocity significantly greater than Kopiliula ($p < 0.05$), East Wailuaiki ($p < 0.05$), and West Wailuaiki ($p < 0.05$). There was no significant difference in stream velocity between East Wailuaiki and West Wailuaiki, or between Waiohue and Kopiliula (Table 6). Compared to reference streams, the range of stream depths and velocities observed were similar to those observed in streams with both partial flow restoration and full flow restoration, independent of streamflow rate.

Table 6. Discharge and mean (standard deviation) stream channel characteristics in 2025 surveys in lower reaches of streams in East Maui and comparisons to reference streams.

Stream	Discharge (cfs)	Depth (cm)	Velocity (m s^{-1})	Temperature (°C)	Canopy Cover (%)	Wetted Width (m)	Active Channel Width (m)
Hanawī	18.5	58 (31)	1.31 (1.11)	19.8 (0.11)	16 (11)	9.6 (2.7)	19.2 (3.4)
Waiohue	4.2	45 (34)	0.58 (0.48)	20.9 (0.06)	25 (23)	5.6 (0.6)	10.4 (1.7)
Kopiliula	3.8	40 (17)	0.42 (0.38)	21.0 (0.04)	9 (18)	12.6 (2.9)	22.4 (3.8)
East Wailuaiki	1.0	33 (11)	0.39 (0.32)	22.9 (0.55)	30 (20)	6.8 (2.8)	14.8 (1.9)
West Wailuaiki	3.1	35 (13)	0.50 (0.59)	21.9 (0.15)	19 (15)	12.8 (4.8)	25.6 (7.5)
Waikolu	8.8	40 (21)	0.29 (0.20)	21.5 (0.19)	0.1 (0.2)	10.8 (4.8)	22.7 (3.2)
Wailau	15.7	32 (11)	0.21 (0.14)	25.2 (0.44)	9 (17)	14.7 (3.8)	25.6 (4.7)
Waikama	1.91	33 (14)	0.14 (0.12)	21.8 (0.02)	67 (14)	7.2 (6.1)	13.5 (8.2)
Pāhoehoe	13.6	64 (23)	0.23 (0.16)	23.1 (0.19)	5 (11)	12.3 (4.4)	19.8 (3.1)

Habitat Characteristics in Lower Reaches

Overall, Hanawī and Waiohue streams had more bedrock, but the relative proportion of other substrates was consistent among streams, with the exception of organic material, which was greater in Waiohue (Table 7). The larger proportions of organic material observed in Waiohue, East Wailuaiki, and West Wailuaiki also corresponded to the greater canopy cover, reflecting the deposition of coarse woody debris and leaf litter. Similar to most low-gradient stream reaches on tropical islands, we observed mostly riffle-run habitat with interspersed pools below larger riffles (Table 8). We observed similar habitat in lower reaches of reference streams, with the exception of Waikolu, which had slightly more riffle and run without pool habitat. There was no difference in habitat distribution among streams that vary in flow restoration.

Table 7. Mean (standard deviation) percent (%) substrate distribution in 2025 in lower reaches of streams in East Maui and comparisons to reference streams.

stream	Bedrock	Boulder	Cobble	Gravel	Silt	Organic
Hanawī	1 (5)	39 (24)	39 (27)	21 (26)	0	1 (2)
Waiohue	4 (19)	42 (28)	33 (19)	7 (8)	1 (2)	12 (15)
Kopiliula	0	48 (18)	29 (14)	17 (12)	5 (9)	2 (5)
East Wailuaiki	0	38 (18)	23 (12)	29 (20)	3 (6)	7 (12)
West Wailuaiki	0	44 (20)	30 (17)	16 (14)	2 (5)	9 (12)
Waikolu	0	56 (27)	20 (18)	13 (11)	5 (15)	5 (12)
Wailau	0	35 (20)	30 (18)	28 (16)	1 (4)	6 (8)
Waikama	11 (26)	29 (28)	39 (17)	11 (14)	0	10 (15)
Pāhoehoe	10 (31)	67 (37)	15 (22)	3 (7)	0	6 (17)

Species Densities in Lower Reaches

Streams with full flow restoration did not have significantly greater densities of endemic freshwater fish compared to streams with partial flow restoration (Table 9; Figure 3). The densities of *E. sandwicensis* did not vary significantly among streams ($H = 0.738$, $df = 4$, $p > 0.05$), while the densities of *A. stamineus* ($H = 17.386$, $df = 4$, $p < 0.01$) and *Kuhlia* spp (H =

23.231, df = 4, $p < 0.001$) varied significantly among streams, but there were no specific stream by stream statistical differences. By contrast, *S. stimpsoni* density varied significantly among streams (H = 46.091, df = 4, $p < 0.001$), with densities in Hanawī Stream significantly greater than Waiohue ($p < 0.05$), West Wailuaiki ($p < 0.05$), East Wailuaiki, ($p < 0.05$), and Kopiliula ($p < 0.05$). No other stream pairs had significantly different densities of *S. stimpsoni*. We observed *L. concolor* in Hanawī, Waiohue, and Kopiliula streams at similar densities, but none in East Wailuaiki or West Wailuaiki. We only observed *Stenogobius hawaiiensis* in West Wailuaiki.

Table 8. Percent (%) habitat distribution in 2025 in lower reaches of streams in East Maui and comparisons to other streams.

stream	Pool	Riffle	Run
Hanawī	10	30	60
Waiohue	25	25	50
Kopiliula	40	25	35
East Wailuaiki	30	15	55
West Wailuaiki	20	15	65
Waikolu	0	45	55
Wailau	20	15	65
Waikama	30	30	40
Pāhoehoe	25	20	55

Densities of *N. granosa* varied significantly among streams (H = 17.723, df = 4, $p < 0.001$) with densities in West Wailuaiki significantly greater than Hanawī ($p < 0.05$), owing to the absence of *N. granosa* in Hanawī. There were no significant differences in the densities of *N. granosa* between West Wailuaiki and East Wailuaiki or between Kopiliula and Waiohue. *Kuhlia* spp. density was greater in streams that maintained an open stream mouth in the estuary (e.g., Waiohue, West Wailuaiki), but we also observed them in Kopiliula and East Wailuaiki.

Species Abundances in Lower Reaches

Similar to species density, the overall abundances of freshwater species in streams with full flow restoration were not significantly greater than streams with partial flow restoration, and the abundances of many species were greater in streams with partial restoration.

The abundance of *E. sandwicensis* was not significantly different among streams (H = 0.96, df = 4, $p > 0.05$). By contrast, we observed a significant difference in *A. stamineus* abundance among streams (H = 17.157, df = 4, $p < 0.01$), with the abundance of *A. stamineus* in Kopiliula significantly greater than Waiohue ($p < 0.05$). The abundance of *S. stimpsoni* varied significantly among streams (H = 49.614, df = 4, $p < 0.001$), with abundances in Hanawī significantly greater than Waiohue ($p < 0.05$), East Wailuaiki, ($p < 0.05$), and West Wailuaiki ($p < 0.05$) and abundances in Kopiliula significantly greater than Waiohue ($p < 0.05$). The abundances of *N. granosa* varied significantly among streams (H = 17.337, df = 4, $p < 0.01$), with the abundance in West Wailuaiki significantly greater than Hanawī ($p < 0.05$). Although there was a significant difference in *Kuhlia* spp. abundance among streams (H = 22.747, df = 4, $p < 0.01$), this was due to their absence in Hanawī and there were no specific stream-by-stream statistical differences.

Recruitment of Juveniles to Lower Reaches

Despite drought conditions that impacted baseflows from 2023 to 2025, we observed many juveniles had recruited to lower reaches of all streams. We observed an equal number of juvenile *S. stimpsoni* in East Wailuaiki (12) and West Wailuaiki (12), and a greater number of juvenile *S. stimpsoni* in Kopiliula (19) compared to Waiohue (9). We observed a greater number of juvenile *A. stamineus* in East Wailuaiki (13) compared West Wailuaiki (2) and a greater number in Kopiliula (17) compared to Waiohue (0). We observed 117 juvenile *S. stimpsoni* and 1 juvenile *A. stamineus* in Hanawī. Recruitment of juvenile *S. stimpsoni* or *A. stamineus* does not appear to be improved by full flow restoration compared to partial flow restoration.

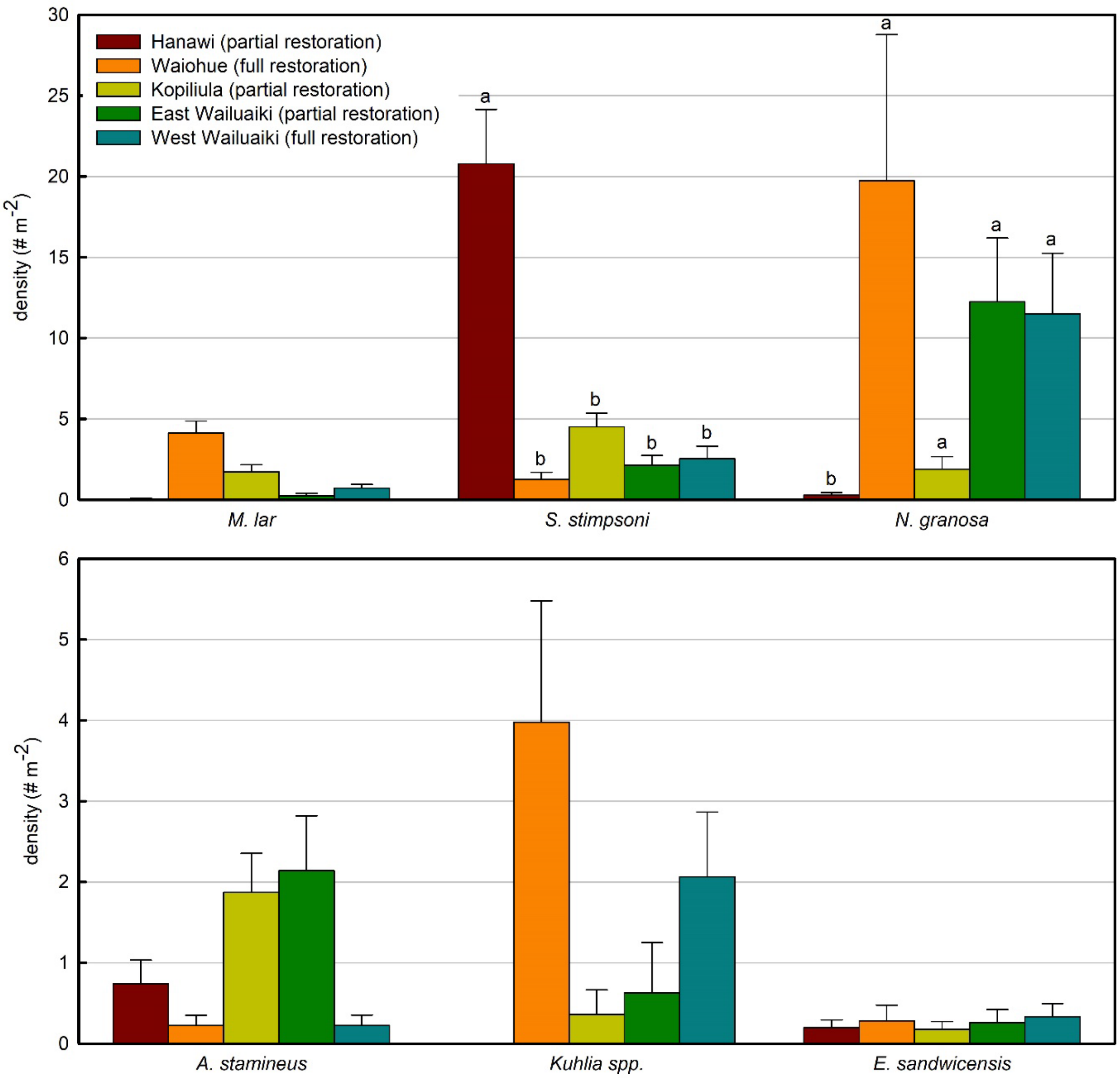


Figure 3. Mean (standard error) species density for lower reach surveys in 2025 of streams in East Maui. Letters represent streams with significant ($p < 0.05$) differences in density.

Table 9. Mean (standard error, SE) species densities observed in lower reach surveys of streams in East Maui and comparisons to reference streams.

Stream	date	*A. stamineus* mean (SE)	*S. stimpsoni* mean (SE)	*E. sandwicensis* mean (SE)	*L. concolor* mean (SE)	*Kuhlia* spp. mean (SE)	*N. granosa* mean (SE)	*M. lar* mean (SE)
Hanawī	11/07/25	0.74 (0.29)	20.8 (3.37)	0.20 (0.09)	0.10 (0.07)	0	0.28 (0.16)	0.05 (0.05)
Waiohue	11/03/25	0.22 (0.13)	1.25 (0.44)	0.28 (0.19)	0.20 (0.12)	3.98 (1.50)	19.7 (9.05)	4.13 (0.75)
Kopiliula	11/03/25	1.87 (0.48)	4.50 (0.85)	0.18 (0.10)	0.15 (0.15)	0.36 (0.30)	1.90 (0.76)	1.72 (0.44)
East Wailuaiki	10/24/25	2.14 (0.68)	2.14 (0.60)	0.26 (0.16)	0	0.63 (0.63)	12.24 (3.95)	0.23 (0.16)
West Wailuaiki	10/24/25	0.22 (0.13)	2.53 (0.78)	0.33 (0.16)	0	2.06 (0.80)	11.5 (3.75)	0.72 (0.23)
Waikolu	08/21/25	0.20 (0.14)	14.4 (2.58)	0.38 (0.29)	1.93 (0.62)	1.96 (1.07)	32.8 (17.1)	0.72 (0.41)
Wailau	10/13/25	0.31 (0.18)	6.98 (0.88)	0.14 (0.10)	0	1.31 (0.44)	0.00 (0.00)	0.09 (0.06)
Waikama	11/20/24	0.06 (0.06)	1.17 (0.48)	0	0	2.79 (1.0)	0.28 (0.15)	2.04 (0.35)
Pāhoehoe	11/05/25	0.18 (0.11)	1.07 (0.31)	0.20 (0.16)	0	0.65 (0.40)	9.4 (2.53)	0.58 (0.21)

Community Composition in Lower Reaches

Lower reaches of East Maui streams lacked non-native species and supported a greater abundance of *S. stimpsoni* and *L. concolor* compared to Hawai‘i Island streams. Community-weighted average trophic capacity varied among streams (Table 10). The lowest mean trophic capacity values were observed in Hanawī (1.21) and Wailau (1.36), indicating communities numerically dominated by specialized consumers such as *L. concolor* and/or *S. stimpsoni*. The highest mean trophic capacity values were recorded in Waiohue and Kopiliula (both 3.47), reflecting communities with a greater proportional abundance of generalist taxa (i.e., *E. sandwicensis*) compared to Hanawī. There was no difference in community composition between streams with partial flow restoration and full flow restoration.

Most East Maui stream pairs were generally similar in composition, with NCD ranging from 0.40 to 0.60 (Table 11). The exception was Waiohue, whose community composition included fewer *A. stamineus* and more *S. hawaiiensis*. The fish community in West Wailuaiki was most similar (i.e., had the lowest NCD) to Hanawī (0.28), Kopiliula (0.40), and East Wailuaiki (0.40) (Table 10). Besides West Wailuaiki, Kopiliula Stream was most similar to East Wailuaiki (0.50), Hanawī (0.56) and Waikolu (0.56) streams. Waikama Stream tended to be more dissimilar compared to East Maui and Moloka‘i streams, likely driven by the absence of *E. sandwicensis*.

Table 10. Community-weighted average trophic capacity observed in 2025 surveys in lower reach surveys of streams in East Maui, and comparisons to reference streams.

stream	Restoration status	Trophic Capacity
Hanawī	Partial	1.21
Waiohue	Full	3.47
Kopiliula	Partial	3.47
East Wailuaiki	Partial	2.30
West Wailuaiki	Full	2.26
Waikolu	Partial	1.89
Wailau	Full	1.36
Waikama	Full	3.06
Pāhoehoe	Full	2.34

Table 11. Normalized Canberra Distance for stream pairs in lower reach surveys of streams in East Maui and comparisons to reference streams.

stream	Hanawi	Waiohue	Kopiliula	East Wailuaiki	West Wailuaiki	Waikolu	Wailau	Waikama
Hanawī								
Waiohue	0.44							
Kopiliula	0.56	0.73						
East Wailuaiki	0.54	0.47	0.50					
West Wailuaiki	0.28	0.65	0.40	0.40				
Waikolu	0.53	0.56	0.56	0.44	0.49			
Wailau	0.51	0.23	0.64	0.60	0.61	0.53		
Waikama	0.68	0.45	0.96	0.62	0.89	0.75	0.59	
Pāhoehoe	0.21	0.32	0.57	0.36	0.44	0.45	0.41	0.57

Channel Characteristics of Upper Reaches

Above the Ko‘olau Ditch, mean wetted width (WW) and ACW ranged from 3.0 m (Pa‘akea) to 5.9 m (West Wailuaiki), and 6.4 m (Pa‘akea) to 14.7 m (Kopiliula), respectively (Table 12). Mean depth varied from 33 cm (Kopiliula) to 64 cm (Hanawī) while mean velocity varied from 0.07 m s^{-1} (Pa‘akea) to 0.23 m s^{-1} (West Wailuaiki). We observed the least canopy cover in West Wailuaiki (4%) and the most in Waiohue and Kopiliula (19% for both). Observed channel substrates were primarily composed of bedrock, boulder, and cobble across all streams (Table 13). Bedrock was more common at the upper reaches than the lower reaches due to the prevalence of lava flows of the younger Hāna Volcanics.

Table 12. Mean (standard deviation) stream channel characteristics in 2024 surveys in upper reaches of streams in East Maui and comparisons to two other streams at similar elevations.

stream	Discharge (ft^3/s)	Depth (cm)	Velocity (m s^{-1})	Temperature (°C)	Canopy Cover (%)	Wetted Width (m)	Active Channel Width (m)
Hanawī	3.17	64 (27)	0.14 (0.13)	21.7 (0.2)	16 (11)	5.7 (3.4)	14.7 (4.8)
Pa‘akea	0.22	33 (20)	0.07 (0.07)	24.0 (0.7)	12 (13)	3.0 (1.4)	6.4 (1.3)
Waiohue	4.69	53 (31)	0.22 (0.19)	20.5 (0.1)	19 (20)	4.0 (1.9)	8.2 (2.2)
Kopiliula	2.77	33 (14)	0.22 (0.15)	20.6 (0.04)	19 (18)	5.6 (2.0)	14.0 (4.9)
West Wailuaiki	3.49	54 (21)	0.23 (0.26)	21.5 (0.1)	4 (4)	5.9 (2.3)	11.5 (3.2)
East Wailuanui	1.28	89 (198)	0.25 (0.59)	23.2 (0.5)	3 (6)	3.3 (1.6)	9.6 (2.7)
Honoli‘i	12.4	67 (43)	0.25 (0.28)	20.4 (0.7)	11 (11)	12.8 (3.3)	19.0 (4.2)

Table 13. Mean (standard deviation) percent (%) substrate distribution in 2024 surveys in upper reaches of streams in East Maui and comparisons to two other streams at similar elevations.

stream	Bedrock	Boulder	Cobble	Gravel	Silt	Organic
Hanawī	32 (43.8)	18 (21.8)	39 (32.5)	10 (14.9)	1 (2.2)	0
Pa‘akea	57 (31.2)	9 (12.0)	31 (30.6)	0.3 (1.1)	0	4 (7.1)
Waiohue	11 (27.1)	50 (35.8)	22 (20.1)	18 (24.7)	0	0
Kopiliula	1 (3.4)	59 (27.6)	36 (25.7)	5 (9.6)	0	0
West Wailuaiki	13 (29.2)	70 (30.8)	13 (15.0)	5 (9.5)	0	0
East Wailuanui	41 (40.5)	37 (36.9)	19 (23.8)	3 (6.4)	0	1 (2.2)
Honoli‘i	16 (1.6)	54 (1.6)	25 (1.3)	4 (0.01)	0	3 (0.2)

Consistent with other high gradient stream reaches, we observed mostly riffle habitat between waterfalls and plunge pools (Table 14). We observed similar habitat in the two reference streams.

Density and Abundance of *A. bisulcata* in Upper Reaches

At upper reaches, Hanawī had the greatest density of *A. bisulcata*, followed by Pa‘akea and Kopiliula (Table 15). We observed similar densities in West Wailuaiki and East Wailuanui, and no *A. bisulcata* in Waiohue. Hanawī Stream had a mean density of *A. bisulcata* at levels similar to Honoli‘i stream. Full flow restoration did not increase recruitment of *A. bisulcata* to upper reaches compared to partial flow restoration.

Table 14. Percent (%) habitat distribution in 2024 surveys in upper reaches of streams in East Maui and comparisons to two other streams at similar elevations.

stream	Pool	Riffle	Run
Hanawi	40	20	40
Pa‘akea	40	30	30
Waiohue	20	40	40
Kopiliula	15	60	25
West Wailuaiki	45	40	15
East Wailuanui	25	55	20
Honoli‘i	45	30	25

Table 15. Mean (standard error) *Atyoida bisulcata* (‘ōpae kala‘ole) density in 2024 surveys in upper reaches of streams in East Maui and comparisons to two other streams at similar elevations.

Stream	Restoration Status	date	Mean (SE)
Hanawī	Connectivity IIFS	10/03/2024	24.8 (24.3)
Pa‘akea	Fully restored	10/03/2024	7.4 (9.7)
Waiohue	Fully restored	09/30/2024	0
Kopiliula	Interim IFS	10/03/2024	4.1 (4.6)
West Wailuaiki	Fully restored	09/30/2024	2.6 (2.9)
East Wailuanui	Fully restored	09/30/2024	2.3 (6.1)
Honoli‘i	Fully restored	11/06/2025	19.8 (3.9)

Conclusions

Hydrology and Habitat

The magnitude of flow restored past the Ko‘olau Ditch is only one factor affecting the quantity and quality of freshwater habitat at downstream reaches. Groundwater gains in streamflow, watershed topography, channel gradient, geology, water quality, riparian vegetation, and stream mouth aspect in relation to prevailing offshore wave patterns, all affect habitat availability, the recruitment, colonization, and survival of amphidromous species, and the distribution of transient nearshore species (Brasher, 2003; Kinzie et al., 1984).

Amphidromous species recruit into freshwater environments as post-larvae following a period of development in the ocean (Nishimoto & Kuamo‘o, 1997). Recruitment of post-larvae to streams occurs year-round but is especially concentrated during months of peak streamflow (Nishimoto and Kuamo‘o, 1997). Some species require refuge in the estuary for development before continuing upstream (Schoenfuss et al., 1997). Each species has unique physical preferences, morphological adaptations, and habitat requirements to successfully migrate inland and colonize habitats: *L. concolor* and *S. stimpsoni* prefer larger substrates for grading and resting, while *A. stamineus* and S. *hawaiiensis* generally prefers smaller substrates (Kinzie, 1988). Adult forms of *E. sandwicensis*, *S. hawaiiensis*, and *L. concolor* are omnivorous, opportunistically feeding on invertebrates, diatoms, and algae (Kinzie, 1988; Kido, 2013). While some amphidromous species are capable of climbing waterfalls, waterfalls are barriers to inland colonization of habitat (Fitzsimons et al., 2007). The distance inland, height of waterfall, species-specific physical limitations, and resources available during the upstream migration affect the extent of habitat colonized by individual species (Hain et al., 2019).

Comparison of Differing Instream Flow Standards

Current interim IFS for Hanawī, Kopiliula, and East Wailuaiki streams were established at the Koʻolau Ditch elevation to protect aquatic ecosystems. We found healthy populations of amphidromous species in high densities among all streams regardless of the quantity of flow restored at the Koʻolau Ditch or the magnitude of flow at the mouth. Although the interim IFS on Hanawī is a connectivity flow at the Koʻolau Ditch, groundwater gains downstream support the greatest streamflow at the mouth of any of the Maui streams studied here. This was followed by Kopiliula (partial restoration), West Wailuaiki (full restoration), Waiohue (full restoration), and East Wailuaiki (partial restoration). Despite greater streamflows, we observed lower densities of *N. granosa* in Hanawī and Kopiliula compared to the other streams, with no significant effect of flow management. Hanawī supported greater densities of *S. stimpsoni*, but not greater densities of *A. stamineus*, *E. sandwicensis*, or *Kuhlia* spp.

Interestingly, the number of juvenile *A. stamineus* or *S. stimpsoni* was not greater in streams with full flow restoration. This suggests that recruitment of amphidromous species is driven by peak flow events and occurs independently of the quantity of flow restored as long as sufficient wetted paths are maintained (Strauch et al., 2022). Lisi et al. (2022) also found that CV was associated with recruitment of *A. stamineus* in Hawaiian streams.

Other factors can affect the recruitment and survival of amphidromous species, independent of streamflow. The deposition of allochthonous organic material such as leaf litter, fruit, and coarse woody debris, can negatively affect habitat quality by reducing dissolved oxygen, blanketing preferred substrates, limiting algae and diatom growth (Larned, 2000), and shifting food webs (Peterson et al., 2017). Flood frequency is of particular importance in regulating the structure and composition of algal communities through the reassortment of substrates initiating the benthic successional cycle (Brandon, 1995; Julius, 2007). *Sicyopterus stimpsoni* prefer grazing diatom and blue-green algae on rock surfaces while *A. bisulcata* and *L. concolor* prefer feeding on diatoms in the water column (Kido, 1997; Julius, 2005; Tingley et al., 2023). The angle of the coastline in relation to the prevailing currents can affect the buildup of debris at the stream mouth and the population of pelagic larvae. Finally, competition and predation among species can directly affect the survival and use of habitat, especially in territorial species, such as *S. stimpsoni*, *M. lar*, or *L. concolor* (Fitzsimons et al., 2007).

References

Brasher, A.M.D., 2003. Impacts of Human Distrubances on Biotic Communities in Hawaiian Streams. *BioScience*, 53(11): 1052-1060.

Brandon, R.N. 1995. Adaptation and Environment. Princeton University Press, Princeton, New Jersey. 214 pp.

Cheng, C.L. 2016. Low-flow characteristics for Streams on the Islands of Kauaʻi, Oʻahu, Molokaʻi, Maui, and Hawaiʻi, State of Hawaiʻi. U.S. Geological Survey Scientific Investigations Report 2016-5103.

Fitzsimons, J.M., McRae, M.G., Nishimoto, R.T. 2007. Behavioral Ecology of Indigenous Stream Fishes in Hawaiʻi. In: Biology of Hawaiian Streams and Estuaries (N.L. Evenhuis & J.M. Fitzsimons, eds). *Bishop Museum Bulletin in Cultural and Environmental Studies*, 3: 11-21.

Gingerich, S.B. 2005. Median- and low-flow Characteristics for Streams under Natural and Diverted Conditions, Northeast Maui, Hawaiʻi. U.S. Geological Survey Scientific Investigations Report 2004-5262.

Gingerich, S.B., Wolff, R.H. 2005. Effects of Surface-Water Diversions on Habitat Availability for Native Macrofauna, Northeast Maui, Hawaii. U.S. Geological Survey Scientific Investigations Report 2005-5213.

Hain, E.F., Lamphere, B.A., Blum, M.J., McIntyre, P.B., Nelson, S.A.C., Gilliam, J.F. 2016. Comparison of Visual Survey and Mark-Recapture Population Estimates of a Benthic Fish in Hawaiʻi. *Transactions of the American Fisheries Society*, 145: 878-887.

Hain, E.F., Moody, K.N., Lamphere, B.A., Nelson, S.A.C., McIntyre, P.B., Gilliam, J.F., Blum, M.J. 2019. Migratory gauntlets on oceanic islands: Watershed disturbance increases the cost of amphidromy. Ecology of Freshwater Fish, 28: 446-459.

Higashi, G.R., Nishimoto, R.T. 2007. The point quadrat method: A rapid assessment of Hawaiian streams. In N.L. Evenhuis and J.M. Fitzsimons (Eds.), Biology of Hawaiian streams and estuaries. pp. 305-312. Honolulu.

Julius, M.L., Blob, R., Schoenfuss, H.L. 2005. The survival of *Sicyopterus stimpsoni*, an endemic amphidromous Hawaiian gobiid fish, relies on the hydrological cycles of streams: evidence from changes in algal composition of diet through growth stages fish. *Aquatic Ecology*, 39: 473-484.

Julius, M.L. 2007. Why Sweat the Small Stuff: the Importance of Microalgae in Hawaiian Stream Ecosystems. In: N.L. Evenhuis and J.M. Fitzsimons, eds., Bishop Museum Bulletin in Cultural and Environmental Studies, 3: 183-193.

Kido, M.H. 1996. Morphological Variation in Feeding Traits of Native Hawaiian Stream Fishes. *Pacific Science*, 50(2): 184-193.

Kido, M.H. 1997. Food Webs and Feeding Dynamics of Coexisting Native Hawaiian Stream Gobies. *Micronesica*, 30(1): 71-82.

Kido, M.H. 2013. A native species-based index of biological integrity for Hawaiian stream environments. *Environmental Monitoring and Assessment*, 185: 4063-4075.

Kinzie, R.A. III. 1988. Habitat utilization by Hawaiian stream fishes with reference to community structure in oceanic stream islands. *Environmental Biology of Fishes*, 22:179-192.

Kinzie, R.A. III, Ford, J.I., Yuen, A.R., Chow, S.J. 1984. Habitat utilization curves for native Hawaiian stream fish. Water Resources Research Center Special Report No. 6:20:84, University of Hawaiʻi, Mānoa, HI.

Larned, S.T. 2000. Dynamics of coarse riparian detritus in a Hawaiian stream ecosystem: a comparison of drought and post-drought conditions. *Freshwater Science*, 19(2): 215-234.

Lisi, P.J., Hogan, J.D., Holt, G., Moody, K.N., Wren, J.L., Kobayashi, D.R., Blum, M.J., McIntyre, P.B. 2022. Stream and ocean hydrodynamics mediate partial migration strategies in an amphidromous Hawaiian goby. *Ecology*, 103(11): e3800.

Meyer, W. 2000. A reevaluation of the occurrence of ground water in the Nahiku area, East Maui, Hawaii. U.S. Geological Survey Professional Paper 1618.

Nishimoto, R.T., Kuamoʻo, D.G.K. 1997. Recruitment of Goby Postlarvae into Hakalau Stream, Hawaiʻi Island. *Micronesica*, 30(1): 41-49.

Ricotta, C., Podani, J. 2017. On some properties of the Bray-Curtis dissimilarity and their ecological meaning. *Ecological Complexity*, 31:201-205.

Peterson, C.C., Keppeler, F.W., Saenz, D.E., Bower, L.M., Winemiller, K.O. 2017. Seasonal variation in fish trophic networks in two clear-water streams in the Central Llanos region, Venezuela. *Neotropical Ichthyology*, 15(2): e160125.

Primm, S.L., J.H. Lawton. 1977. Number of trophic levels in ecological communities. *Nature*, 268: 329-331.

Schoenfuss, H.L., Blanchard, T.A., Kuamoʻo, D.G.K. 1997. Metamorphosis in the Cranium of Postlarval Sicyopterus stimpsoni, an Endemic Hawaiian Stream Goby. *Micronesica*, 30(1): 93-104.

Strauch, A.M., Tingley III, R.W., Hsiao, J., Foulk, P.B., Frauendorf, T.C., MacKenzie, R.A., Infante, D.M. 2022. Population response to connectivity restoration of high elevation tropical stream reaches in Hawaiʻi. *Conservation Science and Practice*, e12836.

Tingley, R.A., Infante, D.M., MacKenzie, R.A., Cooper, A.R., Tsang, Y.P. 2019. Identifying natural catchment landscape influences on tropical stream organisms: classifying stream reaches of the Hawaiian Islands. *Hydrobiologia*, 826:67-83.

Tingley, R.A. Infante, D.M., MacKenzie, R.A., Strauch, A.M., Foulk, P.B., Roth, B. 2024. Climate-driven differences in flow regimes alter tropical freshwater ecosystems with consequence for an endemic shrimp. *Frontiers in Ecology and Evolution*, fevo.2024.1182021.

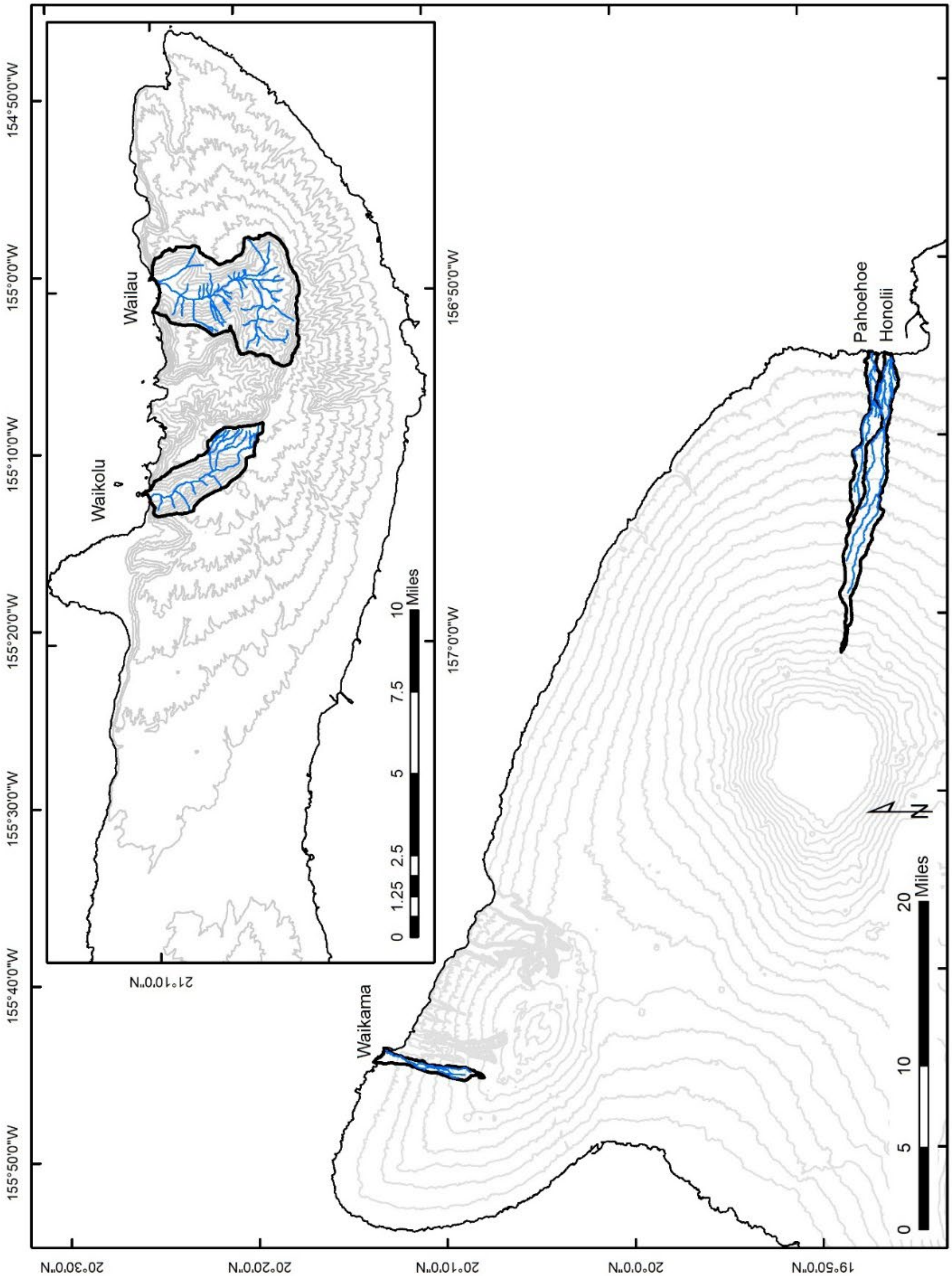
Turnipseed, D.P., Sauer, V.B. 2010. Discharge measurements at gaging stations. U.S. Geological Survey Techniquest and Methods, book 3, chap. A8. 87 p.

Underwood, A.J. 2007. Experiments in Ecology: Their logical design and interpretation using analysis of variance. Cambridge University Press, New York.

U.S. Geological Survey. 2019. The StreamStats program, online at https://streamstats.usgs.gov/ss/ , accessed on 11/16/2025.

Supplemental Figures

Supplemental Figure 1. Reference survey hydrologic units and streams on Hawai‘i and Moloka‘i islands.



Supplement Tables

Table S1. Weighting value scoring relative species sensitivities to habitat-trophic disturbance in streams for calculation of community-weighed average trophic capacity from Kido (2013).

Species	Weighting Value
Lentipes concolor	1
Sicyopterus stimpsoni	1
Neritina granosa	2
Atyoida bisulcata	3
Macrobrachium grandimanus	3
Stenogobius hawaiiensis	3
Awaous stamineus	4
Eleotris sandwicensis	4
Macrobrachium lar	9
Alien species (*Tilapia* spp., *Poeciliidae* spp., etc.)	10

Table S2. Reach characteristics for upper reach surveys on Maui and Hawaiʻi Island.

Stream	Elevation (ft)	Drainage Area (mi^2)	Disance Inland (mi)	Reach Slope (%)	MAR (in)
Hanawī	1310	3.60	1.66	14.2	187
Paʻakea	1300	0.35	1.10	17.0	251
Waiohue	1276	0.98	1.19	14.0	243
Kopiliula	1270	3.87	1.68	13.9	200
West Wailuaiki	1330	3.64	1.75	11.3	182
East Wailuanui	1309	0.51	1.96	10.9	228
Honoliʻi	1550	11.5	4.64	10.0	224