COMMISSION ON WATER RESOURCE MANAGEMENT

STATE OF HAWAII

\`Īao Ground Water Management Area ) High-Level Source Water Use ) Permit Applications and ) Petition to Amend Interim Instream ) Flow Standards of Waihe\`e, Waiehu,) \`Īao, & Waikapū Streams) Contested Case Hearing) ___________________________________)	Case No. CCH-MA06-01 DECLARATION OF JAMES E. PARHAM

DECLARATION OF JAMES E. PARHAM

I, JAMES E. PARHAM, hereby declare:

1. I am a research hydrologist and aquatic biologist with the Hawaii Biological Survey at Bishop Museum, and have served in that position since June 2005.

2. I hold a Ph.D. and M.S. in Biology and a B.S. in Fisheries Management. I am a Certified Fisheries Scientist and currently serve as the President of the Tennessee Chapter of the American Fisheries Society.

3. I am the lead developer of the Hawaiian Stream Habitat Evaluation Procedure (HSHEP) model that is used to quantify impacts to native amphidromous stream animal habitat.

4. Attached hereto as Exhibit “F1" is a true and copy of my resume.

5. In September of 2013, Bishop Museum was contracted by the Commission on Water Resource Management (CWRM) to prepare an assessment report pertaining to the quantification of the impacts of water diversions in the Nā Wai ‘Ehā streams, Maui on native stream animal habitat using the Hawaiian Stream Habitat Evaluation Procedure (Nā Wai ‘Ehā HSHEP Report).

6. I served as the principal in charge of the Nā Wai ʻEhā HSHEP Report. I completed the performance of services required to complete the Nā Wai ʻEhā HSHEP model and authored the resulting report.

7. Nā Wai ʻEhā HSHEP Report addressed three broad areas associated with impacts on native stream animals' habitat resulting from the water diversion projects. These areas included the loss of habitat as a result of water diversion, barriers to animal movement and migration resulting from the diversion structures, and entrainment of animals in the diversion ditches.

8. The six scenarios modeled for each of eight native species using the HSHEP model were: (1) Natural: In this scenario, there were no diversions or channel alterations within the Nā Wai ʻEhā Streams, (2) Undiverted: Similar to the Natural Scenario conditions except the impact of the channelized section of ʻĪao Stream was included in this scenario, (3) Fully Diverted: This scenario represented stream diversions operating maximum diversion capacity, (4) 2010 IFS: This scenario reflected the proposed 2010 IFS standards, (5) Flow to Ocean: This scenario modeled continuous flow from the upstream reaches to the ocean, and (6) Flow to Ocean with ʻĪao Stream Channelization Improvements: This scenario added habitat improvement associated with a possible ʻĪao Stream Channelization improvement project.

9. Results from the model predict that restoration of baseflows to the Nā Wai ʻEhā Streams will increase substantially the amount of stream animal habitat. Under fully diverted conditions, less than 1% of natural habitat units are expected to remain suitable for native amphidromous animals. Under the flow restoration scenarios modeled, 16 to 30% of natural habitat units were restored (Scenario 4 and 6, respectively). When viewing habitat

for species individually, ʻĪao and Waiheʻe Streams consistently had the largest amount of natural habitat, and therefore the highest restoration potentials.

10. One clear result of this model is the need for both habitat and passage to achieve suitable habitat for native amphidromous animals in Nā Wai ʻEhā Streams. Diversions can entrain animals as they pass up and downstream during their required migrations. Requiring the animal to successfully pass multiple diversions greatly decreases the probability that recruitment, growth, reproduction, and migration (part of the natural lifecycle of amphidromous animals) are also successful. Water and suitable instream habitat must exist, but reducing the barriers and potential entrainment greatly enhances the reproductive productivity of the stream habitat. Improvement of passage at diversions should be a high priority with any water return scenario. While the cost may be high in the short term, the benefits to native amphidromous animals will accrue for years into the future.

11. From a system optimization perspective, enhancing passage, avoiding entrainment, and restoring habitat should all be maximized together to achieve the best "ecological impact" for the smallest "restriction of use" of the water.

12. The ability to test different management scenarios was an important product of the HSHEP model for Nā Wai ʻEhā Streams. Nā Wai ʻEhā HSHEP Report provided analyses of six different scenarios, but many more scenarios exist. As managers consider these and other options, specific details of the instream flow decision should be tested and compared with other options to better understand the costs and benefits associated with proposed management actions.

13. Attached hereto as Exhibit "F2" is a true and correct copy of my Technical Report titled "Quantification of the impacts of water diversions in the Nā Wai

‘Ehā streams, Maui on native stream animal habitat using the Hawaiian Stream Habitat Evaluation Procedure” which describes the scope of the Project, the investigations and analysis performed and conclusions associated with Nā Wai ‘Ehā HSHEP Report.

I, JAMES E PARHAM, declare, verify, certify, and state under penalty of perjury that the foregoing is true and correct.

DATED: Honolulu, Hawaii, February 14, 2014.

James E. Parham, Ph.D.

Digitally signed by James E. Parham, Ph.D.
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Professional Profile:

Dr. Parham serves as a research hydrologist and aquatic biologist with Bishop Museum in Honolulu, HI. Dr. Parham has 25 years of experience in the fisheries and water management profession with a focus on instream flow issues, habitat use and availability, and fish passage studies. Dr. Parham is an expert developer of Geographic Information System (GIS) models that integrate essential components of hydrology, geomorphology, and fish ecology to enable improved use of freshwaters while protecting the natural environment. He has wide ranging field experiences including work in most of the continental United States with extensive work in many rivers east of the Rocky Mountains. Additionally, he works in the Hawaiian and Micronesian islands and across the south coast of China. Dr. Parham has worked in collaboration with a wide variety of people and institutions, including international, federal, state, and municipal governmental agencies, university researchers, NGOs, private resource use interests, and Native American groups. He has taught at the university level, led field crews, advised students, moderated conferences, facilitated group modeling efforts, and given interviews for newspaper and radio media. Dr. Parham is responsible for project management including grant acquisition, budgeting and purchasing, employee hiring and supervision, and project completion, presentation, and publication. Overall, Dr. Parham designs and delivers coherent projects using the latest technologies to provide solutions to difficult resource management conflicts.

Education and Certification:

2011	Certified Fisheries Professional, American Fisheries Society
2002-2005	Post-Doctoral Research Associate, University of Nebraska-Lincoln
2002	Ph.D., Biological Sciences, Louisiana State University
1995	M.S., Biology, University of Guam
1989	B.S., Fisheries Management, Virginia Polytechnic Institute and State University

Professional Experience:

2013-present President of the Tennessee Chapter of the American Fisheries Society

EXHIBIT F1

2013-present	Director of Hydrologic Integration, Trutta Consulting, Birmingham, AL
2008-present	President, Parham and Associates Environmental Consulting, LLC., Gallatin, TN
2005-present	Hydrologist and Aquatic Biologist, Bishop Museum, Honolulu, HI
2005-present	Associate Fellow at the Center for Great Plains Studies, University of Nebraska
2003	Assistant Coordinator, China Tropical Lands Project, Guangzhou, China
2002-2005	Instructor, University of Nebraska – Lincoln
2002-2005	Postdoctoral Research Associate, University of Nebraska – Lincoln
1998-2001	Graduate Research Assistant, Louisiana State University
1997	Graduate Teaching Assistant, Louisiana State University
1997	Graduate Curatorial Assistant, Louisiana State University
1993-1996	Graduate Research Assistant, University of Guam
1993-1994	Graduate Teaching Assistant, University of Guam
1991-1992	Biologist, Environmental Systems Planners, Inc., Naples, FL.

University Courses Taught:

GIS in Natural Resources, University of Nebraska
GIS Modeling of Fish Habitats and Stream Hydrology, University of Nebraska
Fisheries Biology Class, University of Nebraska
Natural Resources Seminar, University of Nebraska
Introductory Biology Laboratory, Louisiana State University
Environmental Biology Laboratory, University of Guam

Publications:

Books

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King, C., E.K. Lapp, **J.E. Parham**, G.R. Higashi, S. Hau and D.G.K Kuamo'o. 2008. Survey report on Honopou Stream, Maui, Hawai'i. Division of Aquatic Resources, DLNR, State of Hawaii.

King, C., E.K. Lapp, **J.E. Parham**, G.R. Higashi, S. Hau and D.G.K Kuamo'o. 2008. Survey report on Waiokamilo Stream, Maui, Hawai'i. Division of Aquatic Resources, DLNR, State of Hawaii.

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Professional Affiliations:

The American Fisheries Society
- Tennessee Chapter
- Nebraska Chapter
- Fisheries Management Section
- Fisheries Information & Technology Section
- Introduced Fish Section

Community of Science

Technical Report:

Quantification of the impacts of water diversions in the Nā Wai ʻEhā streams, Maui on native stream animal habitat using the Hawaiian Stream Habitat Evaluation Procedure

Submitted to:

Commission on Water Resource Management
State of Hawaii
Honolulu, HI

Date:

12/31/2013

Submitted by:

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EXHIBIT F2

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Abstract:

The Nā Wai ʻEhā Streams in West Maui have been the focus of conflict regarding the allocation of streamwater for instream and offstream uses. This report uses the Hawaiian Stream Habitat Evaluation Procedure (HSHEP) model to provide a quantification of the amount and distribution of native stream animal habitat and the impacts on native stream animals' habitat resulting from the water diversion projects. Three broad areas are addressed by the HSHEP analysis. These areas include the loss of habitat as a result of water diversion, barriers to animal movement and migration resulting from the diversion structures, and entrainment of animals in the diversion ditches. The six scenarios modeled for each of eight native species using the HSHEP model were:

1) <u>Natural</u>: In this scenario, there are no diversions or channel alterations within the Nā Wai ʻEhā Streams.
2) <u>Undiverted</u>: Similar to the Natural Scenario conditions except the impact of the channelized section of ʻĪao Stream was included in this scenario.
3) <u>Fully Diverted</u>: This scenario represents stream diversion operating maximum diversion capacity.
4) <u>2010 IFS</u>: This scenario reflects the proposed 2010 IFS standards
5) <u>Flow to Ocean</u>: This scenario models continuous flow from the upstream reaches to the ocean.
6) <u>Flow to Ocean with ʻĪao Stream Channelization Improvements</u>: This scenario adds habitat improvement associated with a possible ʻĪao Stream Channelization improvement project.

Results from the model predict that restoration of baseflows to the Nā Wai ʻEhā Streams will increase substantially the amount of stream animal habitat. Under fully diverted conditions, less than 1% of natural habitat units are expected to remain suitable for native amphidromous animals. Under the flow restoration scenarios modeled, 16 to 30% of natural habitat units were restored (Scenario 4 and 6, respectively). When viewing habitat for species individually, ʻĪao and Waiheʻe Streams consistently had the largest amount of natural habitat, and therefore the highest restoration potentials.

The ability to test different management scenarios was an important product of the HSHEP model for Nā Wai ʻEhā Streams. This report provides analysis of six different scenarios, but many more exist. As managers consider these and other options, specific details of the instream flow decision should be tested and compared with other options to better understand the costs and benefits associated with the action. Ultimately maximizing water for human use and environmental needs both now and in the future is the goal of wise public trust resource management.

Introduction:

The Nā Wai ʻEhā Streams in West Maui have been the focus of conflict regarding the allocation of streamwater for instream and offstream uses. Waiheʻe, Waiehu, ʻĪao, and Waikapū Streams make up the Nā Wai ʻEhā Streams. Existing diversions are capable of diverting the majority of baseflows from the streams resulting in dry stream channels in downstream reaches (Oki et al. 2010). State of Hawaiʻi Commission on Water Resource Management (CWRM) is responsible for establishing instream flow standards that protect the public interest in beneficial instream uses balanced against existing and potential water developments (State Water Code, Hawaiʻi Revised Statutes, chapter 174C, section 71[1][C]). Beneficial instream uses (Sakoda 2007) include:

1) Maintenance of fish and wildlife habitats;
2) Outdoor recreational activities;
3) Maintenance of ecosystems such as estuaries, wetlands, and stream vegetation;
4) Aesthetic values such as waterfalls and scenic waterways;
5) Navigation;
6) Instream hydropower generation;
7) Maintenance of water quality;
8) The conveyance of irrigation and domestic water supplies to downstream points of diversion; and
9) The protection of traditional and customary Hawaiian rights.

The intent of this report is to quantify the amount and distribution of native stream animal habitat and the impacts on native stream animals' habitat resulting from the water diversion projects. To quantify the amount and distribution of native stream animal habitat, the Hawaiian Stream Habitat Evaluation Procedure (HSHEP) model was applied to the four Nā Wai ʻEhā Streams on Maui. Three broad areas are addressed by the HSHEP analysis. These areas include:

- Loss of habitat as a result of water diversion
- Barriers to animal movement and migration resulting from the diversion structures
- Entrainment of animals in the diversion ditches

The HSHEP modeling approach was detailed in Parham et al. 2009 where it was applied to instream flow issues for seventeen East Maui streams. The HSHEP model is based on modeling concepts developed by the U.S. Fish and Wildlife for impact assessment (USFWS 1980 a and b, USFWS 1981). In general, a HEP model has a number of characteristics:

- It is a habitat-based assessment method.

- It assumes that habitat quality and quantity are related to the number of animals using a habitat over the long term.
- It uses measurable attributes of habitat quality and quantity to create relationships between habitat suitability and animal occurrence and density.
- It converts suitability relationships into standardized Habitat Suitability Indexes (HSI) that encompass the range of observed habitat conditions.
- The HSI values range from 0 (unsuitable habitat) to 1 (most suitable habitat).
- It multiplies the habitat quality (value from the HSI) with the habitat quantity (area) to determine overall Habitat Units (HU) within the area of concern.

The HSHEP model addresses issues of scale by characterizing differences in habitat availability and species distributions. Native amphidromous animals are diadromous requiring a connection between the freshwater streams and the ocean to complete their life cycle (McDowall 2007). As a result of their diadromous life cycle, three issues must be addressed when modeling native amphidromous animals in Hawaiian streams. First, different amphidromous species have different upstream migratory abilities resulting in species-specific instream distributions (Ford and Kinzie 1982, Kinzie 1990, Fitzsimmons et al 2007). As a result, similar habitats found near the ocean may have different species assemblages than habitats found further inland; therefore instream distribution of adult habitat is important to model. Second, newly hatched larval animals drift downstream to the ocean and thus are susceptible to entrainment in stream diversions. Therefore downstream entrainment is important to model. Finally, postlarval animals recruit into the stream from the ocean and move upstream to adult habitat. Therefore, it is important to model barriers and entrainment facing the animals as they move upstream to their adult habitats.

By assessing species distributions and habitat suitability at multiple spatial scales, different aspects of amphidromous animal ecology can be appropriately modeled (Figure 1). As a result of the combination of the HEP method with multi-scale analysis, management issues can be addressed on a site, stream segment, stream and its watershed, or region level.

To document animals’ distribution and habitat use, information stored in the State of Hawaiʻi Division of Aquatic Resources (DAR) Aquatic Surveys Database is used, and represents over 13,000 survey locations and over 90,000 species observations (DAR 2009). The database includes results from state surveys as well as those from federal, university, and private researchers. More than 370 different literature sources support the data contained within the DAR Aquatic Surveys Database. The HSHEP model leverages the data within the DAR Aquatic Surveys Database to develop quantitative measures of habitat suitability for native stream animals.

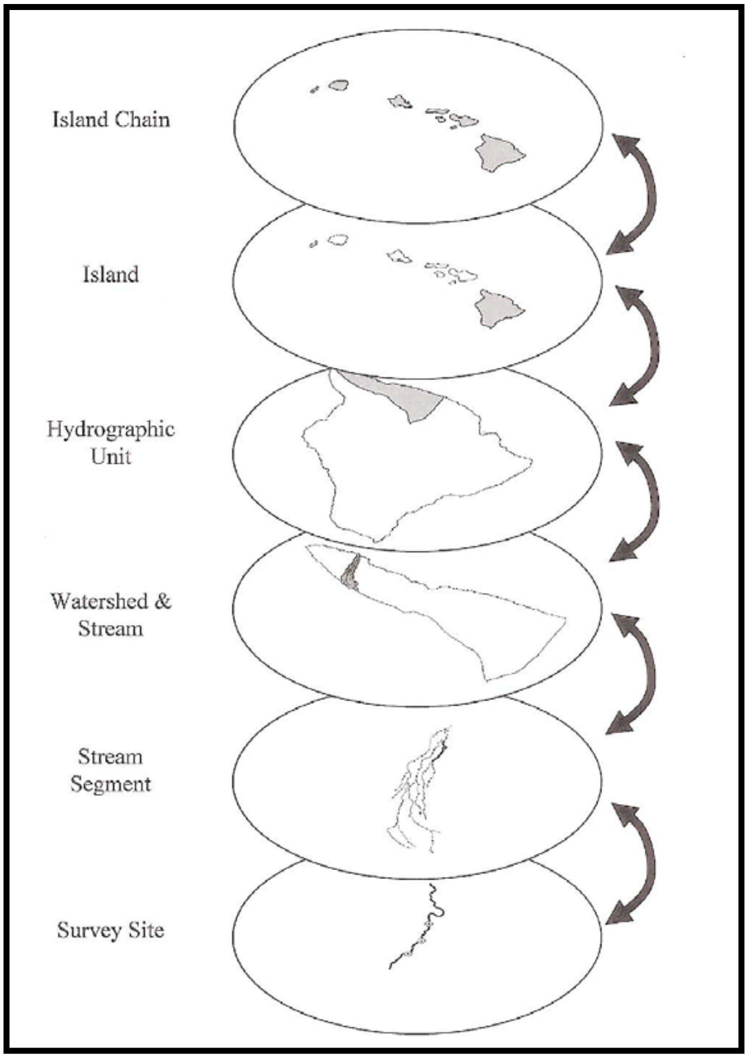


Figure 1. Spatially nested hierarchy of the DAR Aquatic Surveys Database and predictive levels within the HSHEP model.

In a similar process to the application of the HSHEP model on East Maui streams (Parham et al. 2009), the HSHEP analysis takes into account local stream conditions as described in the USGS study (Oki et al. 2010) and integrates these results with broader habitat and distribution data from region, island, and statewide data collections stored in the DAR Aquatic Surveys Database. The majority of the site-specific information used in this report was taken from the USGS Nā Wai ʻEhā study report (Oki et al. 2010). This project was not intended to either support of refute the findings in the USGS Nā Wai ʻEhā report, only to extend those findings to more fully quantify changes in native amphidromous animals habitat with respect to different water management scenarios.

The proposed plan for the Nā Wai ʻEhā Stream HSHEP model was to address two scenarios associated with water diversions. The first scenario would quantify the naturally available native stream animal habitat as determined without the presence of any stream diversions. The second scenario would quantify the currently available native stream animal habitat with barrier, entrainment, and flow conditions associated with each stream diversion as currently designed. These scenarios were intended to allow the comparison and quantification of the changes in suitable habitat as a result of the presence of the stream diversions within the Nā Wai ʻEhā streams on Maui.

In development of the HSHEP for the Nā Wai ʻEhā Streams, it became obvious that a useful understanding of the extent and distribution of impacts would not be adequately covered by these two scenarios. As a result, four additional scenarios were added with the intent of providing a more comprehensive understanding of the effects of stream diversions on the Nā Wai ʻEhā Stream and supporting a more direct assessment of some potential management actions. The six scenarios modeled using the HSHEP model for the Nā Wai ʻEhā Streams were:

1) Natural: In this scenario, there are no diversions or channel alterations within the Nā Wai ʻEhā Streams.
2) Undiverted: Similar to the Natural Scenario conditions except the impact of the channelized section of ʻĪao Stream was included in this scenario.
3) Fully Diverted: This scenario represents stream diversions operating at maximum diversion capacity.
4) 2010 IFS: This scenario reflects the proposed 2010 IFS standards
5) Flow to Ocean: This scenario models continuous flow from the upstream reaches to the ocean.
6) Flow to Ocean with ʻĪao Stream Channelization Improvements: This scenario adds habitat improvement associated with a possible ʻĪao Stream Channelization improvement project.

The four additional scenarios and their specific conditions were chosen and developed by the author and not selected by any management agency or water use group. The additional scenarios are intended to describe the impacts of a more complete range of management possibilities.

These six scenarios represent a range of possible condition for the Nā Wai ʻEhā Streams, but is not an exhaustive list of possible management scenarios. These scenarios are more fully described in the Methods – Scenarios Modeled section, but it is important to understand that numerous changes to the model conditions are possible within these scenarios and subsequently would result in changes to the modeled results. If different scenarios or specific changes within a scenario are needed to better support a proposed management action, quantification of the response in suitable habitat with respect to changes to baseflow (Q_{70}) diversion, barrier or entrainment impacts at any diversion location are possible with the HSHEP model.

The HSHEP model for Nā Wai ʻEhā Streams combined information from the site, stream segment, and watershed scales to predict changes in habitat resulting from water diversions and channel modifications. The model reflects the quality of the whole stream and its watershed, a site's location in a stream, as well as the locations of diversions, changes in local habitat with respect to water diversion, the loss of animals due to entrainment in the diversions and the impact of habitat lost to stream channelization.

Methods:

To quantify the current conditions of the stream and to estimate the effects of the stream diversion in the Nā Wai ʻEhā Streams on native stream animal habitat a similar process to the application of the HSHEP model on East Maui streams was followed (Parham et al. 2009). To document the modeling process the following sections are covered:

- general modeling process,
- selection of evaluation species,
- description of suitability indices at each spatial scale,
- watershed suitability models,
- stream reach models,
- stream and site description,
- description of model steps,
- scenarios modeled,

General Modeling Process:

To characterize habitat availability, the HSHEP model applies a nested spatial hierarchy (Figure 1). Depending on the scenario being modeled, various levels of the hierarchy are used. For the purposes of this project, the site, stream segment, and stream and its watershed scales were the most important for assessing the impact of stream diversions on the Nā Wai ʻEhā Streams. The spatial levels of island chain, island, and region were not needed to complete the analysis required in the report.

Following the previously reported HSHEP model (Parham et al. 2009), variables included at the watershed level were stream and watershed size, watershed wetness, watershed stewardship, the amount of estuary and shallow water marine habitats associated with the watershed, and the watershed land cover quality. The rating for these variables was presented in the *Atlas of Hawaiian Watersheds & Their Aquatic Resources* (Parham et al. 2008) and the variables for all 430 streams included in the atlas are used to develop the model at this level. Inclusion of the watershed scale in the HSHEP model allows for comparisons of the results for the Nā Wai ʻEhā Streams with other streams statewide.

To describe variation of instream habitat and animal distributions, variables included at the stream segment included elevation, distance inland from the ocean, and the slope of instream barriers. Native amphidromous animals are diadromous requiring a connection between the freshwater streams and the ocean to complete their life cycle (McDowall 2007). Thus the ability of the animal to move upstream from the ocean will influence its observed distribution.

At the site level, more specific habitat characteristics are important. For the HSHEP analysis developed on the Nā Wai ʻEhā streams reported here, the generalized suitability indices developed by the USGS in Oki et al. 2010 for the Nā Wai ʻEhā streams was used to estimate changes in habitat in response to changes in baseflow. Baseflow was estimated using the reported Q_{70} flow statistic and comparing Q_{70} under the model scenario to the Q_{70} expected in natural flow conditions.

The impacts of barriers and entrainment in stream diversion was estimated by grouping the diversion into a type and then applying a standard effect based on the type. The main barrier types were:

> Stream mouth barriers – These barriers were the result of no water flow in the terminal stream segment (Figure 2). These barriers had two possible conditions, either open or closed. If baseflows were calculated to be 0 mdg at in the terminal segment, then a barrier was considered closed. If any flow was calculated to be present in the terminal segment then the barrier was considered open. The barrier impact value (% of time closed to migration) for each condition was interpreted from the USGS reports (Oki et al. 2010). No entrainment was modeled with this barrier type.
>
> Side Diversion – This type of diversion removes water from the stream through a side intake structure (Figure 2). The water in natural stream channel flows downstream past the diversion and a portion is removed by the intake. These side diversions typically have a small dam to help increase the amount of water diverted. Both ditch and auwai diversion can fall into this group. Downstream entrainment is modeled at a maximum of 80% entrained and upstream entrainment is modeled at a maximum of 50%. Upstream entrainment is lower because animals moving upstream are moving against the current and this will lead them upstream as opposed to downstream into the diversion. With that said, at high diversion rates, some animals will get entrained.
>
> Bottom Grate Diversion – This diversion type removes water from a grate covered channel that usually spans the stream channel bottom (Figure 2). Bottom grate diversions are usually found on larger stream diversions and are sized to remove 100% of baseflow. Downstream and upstream entrainment rates are modeled at a maximum of 80%. Upstream entrainment is higher than with side diversion as upstream moving animals are easily trapped in the diversion as they try to pass over the bottom grate.
>
> Entrainment rate calculation for diversions - The primary barrier issue modeled with diversions is entrainment of migrating animals. Entrainment is directly related to the proportion of water removed by the diversion. When 100% of baseflow is diverted the entrainment is modeled at 80%. This would represent the entrainment of all animals drifting downstream in the baseflow and a portion of the animals at higher flows that overtop the diversion. At diversion rates lower than total baseflow removal, the

entrainment value is a portion of baseflow (Q_{70}) remaining after the diversion compared to natural baseflow (Q_{70}) multiplied by the maximum entrainment rate.

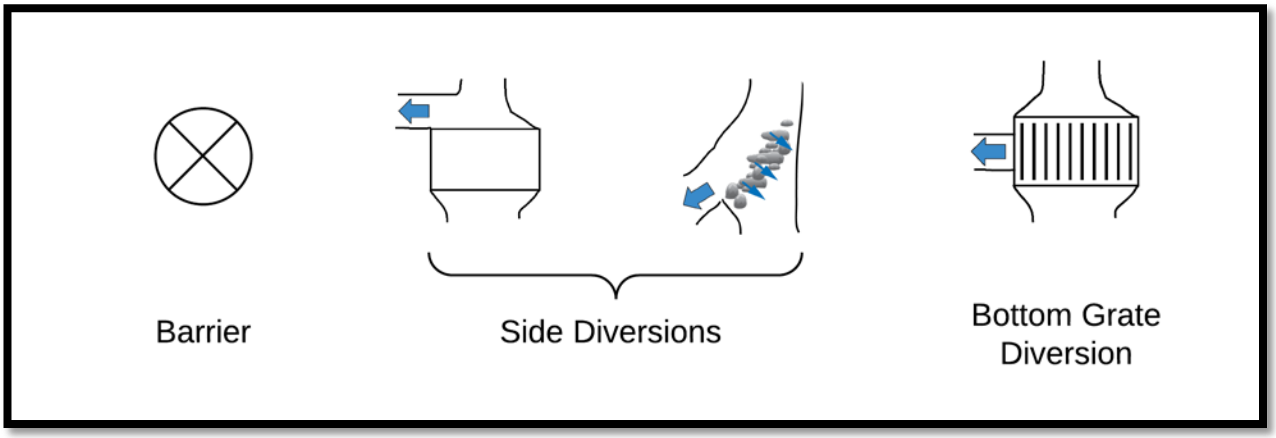


Figure 2: Barrier type graphics used in the HSHEP box models for each stream. See stream segment and site description for box models.

By combining HSHEP model results from multiple scales, the overall model provides an assessment of habitat suitability with respect to its location in a stream and is comparable to all other streams in the Hawaiian Islands. The presence of suitable characteristics at a site is not the only important variable when determining site occupancy. A site can only be occupied by a species if that species can reach the habitat. For example, a deep stream pool with a mixture of cobble and boulder habitat may be highly suitable for a number of native species, yet if that pool is found far inland and above a high waterfall, only a few species would be expected to inhabit the pool. The HSHEP models use of multiple spatial scales accounts for local, network (up and downstream conditions), and watershed differences among sites.

While comparison of the results for the Nā Wai ʻEhā Streams to other streams statewide is outside the scope of the project, the application of the HSHEP for Nā Wai ʻEhā Streams is similar to its application for the East Maui Streams and thus direct comparisons may be valid. The main differences in the models are related to differences in data collection and analysis reported by the USGS and application of discharge to habitat suitability relationships selected by DAR used to characterize the flow and habitat components of the model between the two areas.

Selection of Evaluation Species:

Eight species of native stream animals were selected for the purposes of quantifying habitat availability in Nā Wai ʻEhā Streams (Table 1). The list includes five species of fish, two species of crustaceans, and one species of mollusk. This group contains the characteristic amphidromous stream animals found in Hawaiian streams and these animals make up the majority of the native species observed during the DAR point quadrat surveys and have a substantial amount of habitat information available within the DAR Aquatics Surveys Database.

Table 1: Species habitat evaluated within the Nā Wai ‘Ehā Streams using the HSHEP model. *Identified as “Species of Greatest Conservation Need” in the Hawaii Statewide Aquatic Wildlife Conservation Strategy (Meadows et al. 2005).

Organism Type and Family	Scientific name	Hawaiian name
Freshwater fish (family Gobiidae)	*Awaous guamensis**	‘O‘opu nākea
	*Lentipes concolor**	‘O‘opu alamo‘o
	*Stenogobius hawaiiensis**	‘O‘opu naniha
	*Sicyopterus stimpsoni**	‘O‘opu nōpili
Freshwater fish (family Eleotridae)	*Eleotris sandwicensis**	‘O‘opu akupa
Freshwater shrimp (Crustacean) (family Atyidae)	*Atyoida bisulcata**	‘Ōpae kala‘'ole
Freshwater prawn (Crustacean) (family Palaemonidae)	*Macrobrachium grandimanus**	‘Ōpae ‘oeha‘a
Freshwater snail (Mollusk) (family Neritidae)	*Neritina granosa**	Hīhīwai

The selection of the complete set of amphidromous stream animals is appropriate in this case for several reasons.

- All of these species have been observed within the Nā Wai ‘Ehā streams or estuaries during prior surveys (Parham et al. 2008).
- All of these species have a diadromous life history, meaning that they migrate from the freshwater stream to the ocean and back again (McDowall 2007). This potentially exposes the migrating animals to barriers in the stream pathway, entrainment into water diversion systems, and elimination of suitable habitat resulting from water diversions or channel modifications.
- The DAR Aquatic Surveys Database has distribution and habitat use information for each of these species.
- The HSHEP model has habitat suitability indices developed for each of these species.

Description of Suitability Indices at Each Spatial Scale:

A fundamental component of any Habitat Evaluation Procedure (HEP) model is to have a positive linear relationship between the prediction variable and the observed occurrence of the animal. For the watershed variables, a linear regression was used to describe the relationship between the prediction and the actual data. Data collected statewide (Division of Aquatic Resources 2009) provide location information to develop the relationships. The majority of these data come from DAR point quadrat surveys conducted over the past 25 years (Higashi and Nishimoto 2007). Based on this large statewide dataset, linear relationships for the watershed and instream distribution scales were created for the HSHEP model.

At the site level, data and relationships used to support the impact of diversions on passage and entrainment as well as changes in habitat resulting from baseflow diversion was based primarily on Oki et al. 2010. No new field data was collected for this model and results of the HSHEP model for the Nā Wai ‘Ehā Streams represents the author’s best attempt at interpreting the USGS report and integrating their results into the HSHEP model framework.

The following figures (reproduced from Parham et al. 2009) show the linear relationships for the watershed and instream distribution scales. For more data supporting the specific variables included in the relationships see Parham et al. 2009. These are followed by maps, box models and data tables documenting the design and data used to support the site level scale within the Nā Wai ‘Ehā HSHEP model.

Watershed Suitability Models:

Awaous guamensis:

The multiple logistic regression equation with the highest prediction accuracy was:

$$P = \frac{1}{1 + e^{-(-4.043 + (0.425 * \mathrm{WWR}) + (0.543 * \mathrm{WSR}) + (0.280 * \mathrm{WENR}))}}$$

where: WWR = Watershed Wetness Rating, ($p < 0.001$)
WSR = Watershed Size Rating, ($p < 0.001$)
WENR = Watershed Estuary and Nearshore Rating, ($p < 0.001$).

This equation had a Likelihood Ratio Test Statistic of 120.7 (P = <0.001), and correctly predicted the presence or absence of *Awaous guamensis* in 322 of 430 watersheds (74.9 % correct) at a probability level of 0.5. To further confirm a positive relationship between the predicted watershed suitability value and the occurrence of *Awaous guamensis*, the proportion of samples within each 0.1 sized suitability bin was compared for all watersheds and those watersheds in which *Awaous guamensis* occurred (Figure 3).

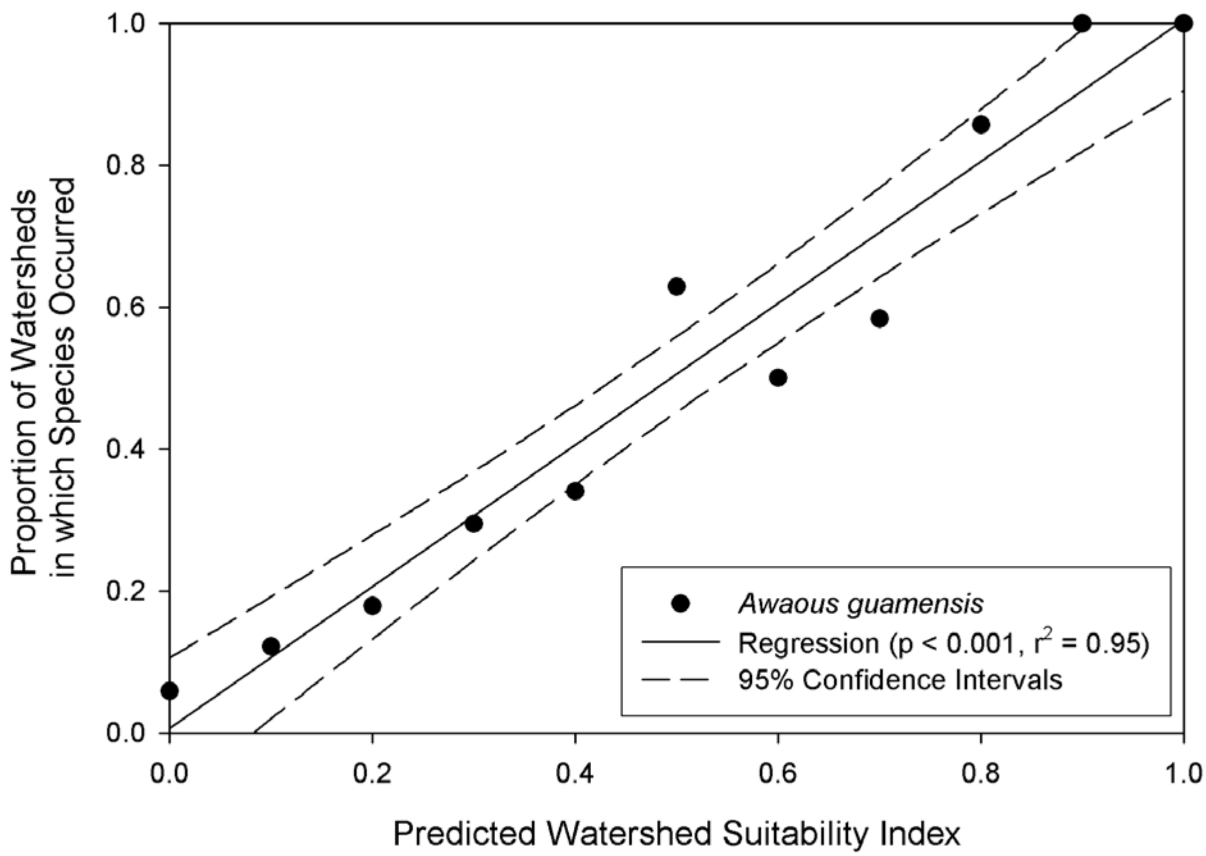


Figure 3: Proportion of the total watersheds where *Awaous guamensis* was observed within each 0.1 group of the Watershed Suitability Index equation for *Awaous guamensis*.

Lentipes concolor:

The multiple logistic regression equation with the highest prediction accuracy was:

$$P = \frac{1}{1 + e^{-(-4.164 + (0.493 * \text{WWR}) + (0.362 * \text{WSR}) + (0.121 * \text{WStR}))}}$$

where: WWR = Watershed Wetness Rating, ($p < 0.001$)
WSR = Watershed Size Rating, ($p < 0.001$)
WStR = Watershed Stewardship Rating, ($p = 0.025$).

This equation had a Likelihood Ratio Test Statistic of 117.8 (P = <0.001), and correctly predicted the presence or absence of *Lentipes concolor* in 322 of 430 watersheds (74.9 % correct) at a probability level of 0.5. To further confirm a positive relationship between the predicted watershed suitability value and the occurrence of *Lentipes concolor*, the proportion of samples within each 0.1 sized suitability bin was compared for all watersheds and those watersheds in which *Lentipes concolor* occurred (Figure 4).

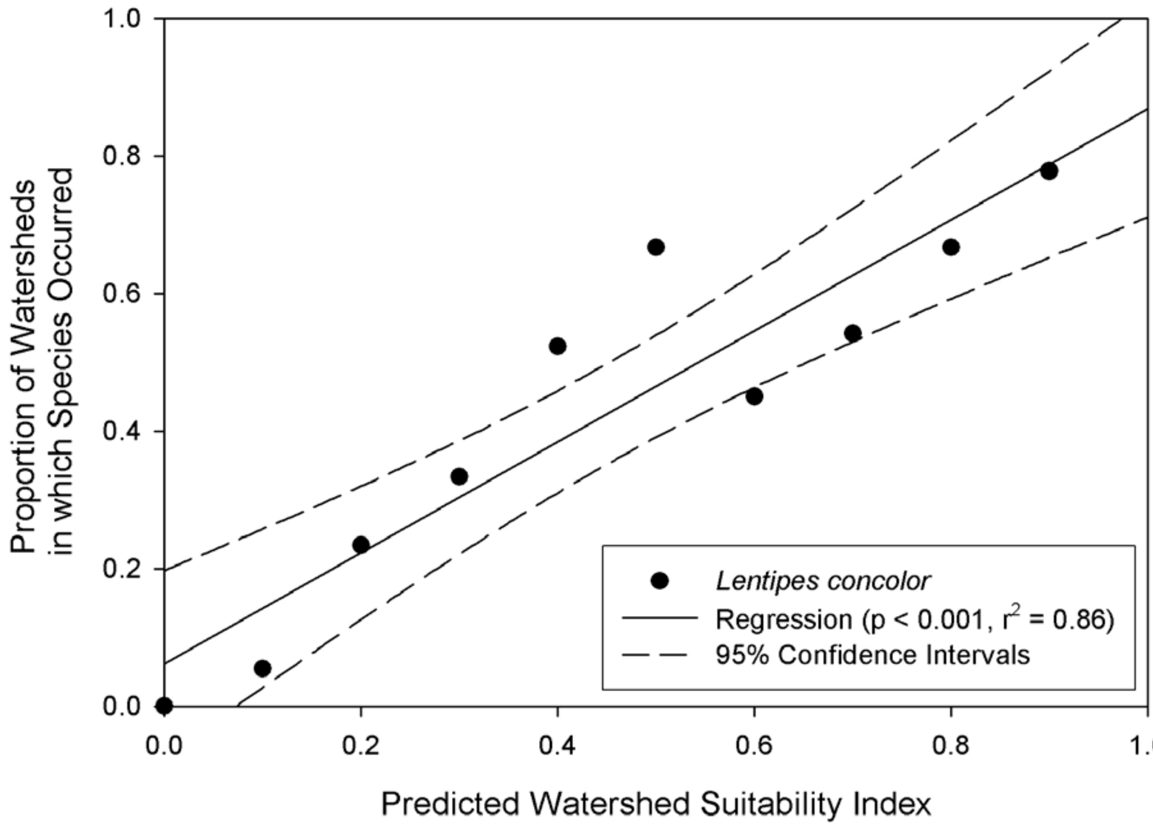


Figure 4: Proportion of the total watersheds where *Lentipes concolor* was observed within each 0.1 group of the Watershed Suitability Index equation for *Lentipes concolor*.

Sicyopterus stimpsoni:

The multiple logistic regression equation with the highest prediction accuracy was:

$$P = \frac{1}{1 + e^{-(\text{-}4.195 + (0.358 * \text{WWR}) + (0.539 * \text{WSR}) + (0.135 * \text{WStR}))}}$$

where: WWR = Watershed Wetness Rating, ($p < 0.001$)
WSR = Watershed Size Rating, ($p < 0.001$)
WENR = Watershed Stewardship Rating, ($p = 0.012$).

This equation had a Likelihood Ratio Test Statistic of 97.1 (P = <0.001), and correctly predicted the presence or absence of *Sicyopterus stimpsoni* in 340 of 430 watersheds (79.1% correct) at a probability level of 0.5. To further confirm a positive relationship between the predicted watershed suitability value and the occurrence of *Sicyopterus stimpsoni*, the proportion of samples within each 0.1 sized suitability bin was compared for all watersheds and those watersheds in which *Sicyopterus stimpsoni* occurred (Figure 5).

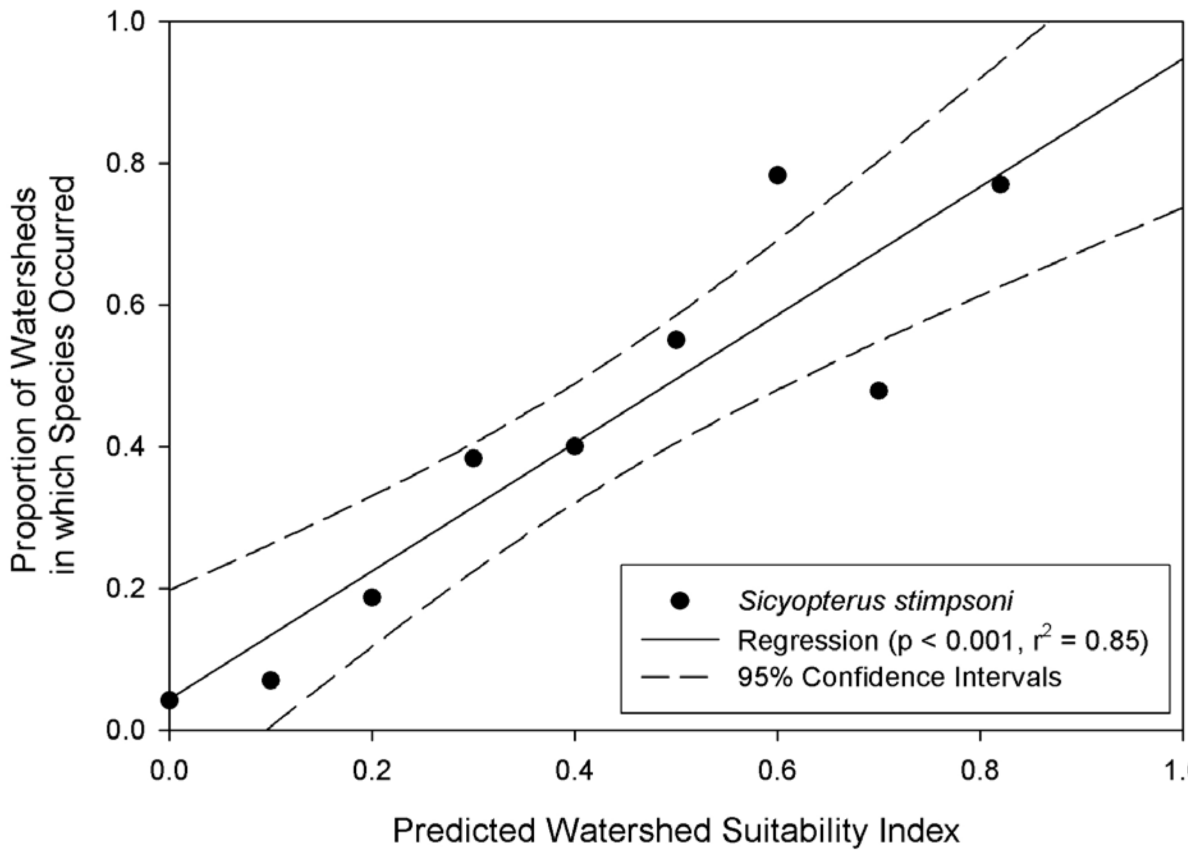


Figure 5: Proportion of the total watersheds where *Sicyopterus stimpsoni* was observed within each 0.1 group of the Watershed Suitability Index equation for *Sicyopterus stimpsoni*.

Stenogobius hawaiiensis:

The multiple logistic regression equation with the highest prediction accuracy was:

$$P = \frac{1}{1 + e^{-(-4.923 + (0.206 * \mathrm{WWR}) + (0.796 * \mathrm{WSR}))}}$$

where: WWR = Watershed Wetness Rating, (p = 0.003)
WSR = Watershed Size Rating, (p < 0.001).

This equation had a Likelihood Ratio Test Statistic of 73.4 (P = <0.001), and correctly predicted the presence or absence of *Stenogobius hawaiiensis* in 375 of 430 watersheds (87.2% correct) at a probability level of 0.5. To further confirm a positive relationship between the predicted watershed suitability value and the occurrence of *Stenogobius hawaiiensis*, the proportion of samples within each 0.1 sized suitability bin was compared for all watersheds and those watersheds in which *Stenogobius hawaiiensis* occurred (Figure 6).

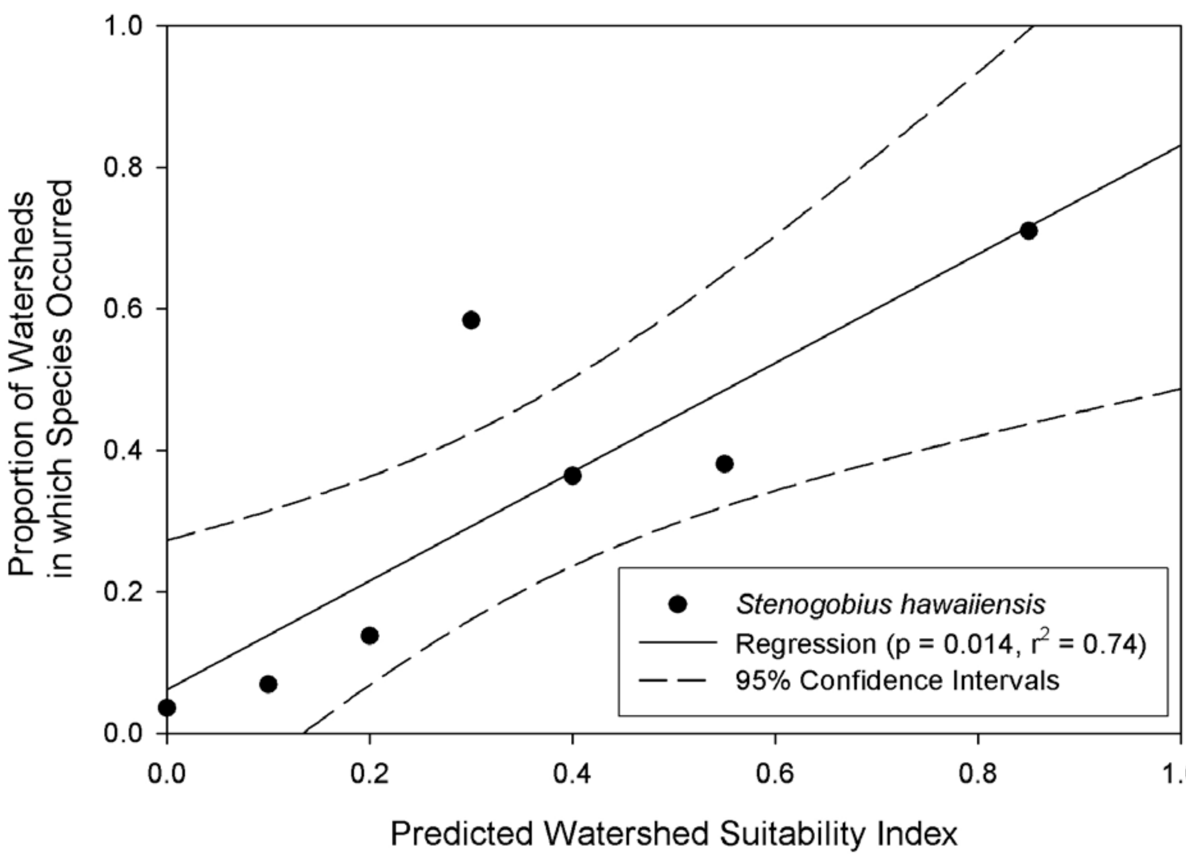


Figure 6: Proportion of the total watersheds where *Stenogobius hawaiiensis* was observed within each 0.1 group of the Watershed Suitability Index equation for *Stenogobius hawaiiensis*.

Eleotris sandwicensis:

The multiple logistic regression equation with the highest prediction accuracy was:

$$P = \frac{1}{1 + e^{-(-3.552 + (0.245 * \text{WWR}) + (0.376 * \text{WSR}) + (0.278 * \text{WENR}))}}$$

where: WWR = Watershed Wetness Rating, ($p < 0.001$)
WSR = Watershed Size Rating, ($p < 0.001$)
WENR = Watershed Estuary and Nearshore Rating, ($p < 0.001$).

This equation had a Likelihood Ratio Test Statistic of 65.4 (P = <0.001), and correctly predicted the presence or absence of *Eleotris sandwicensis* in 343 of 430 watersheds (79.8% correct) at a probability level of 0.5. To further confirm a positive relationship between the predicted watershed suitability value and the occurrence of *Eleotris sandwicensis,* the proportion of samples within each 0.1 sized suitability bin was compared for all watersheds and those watersheds in which *Eleotris sandwicensis* occurred (Figure 7).

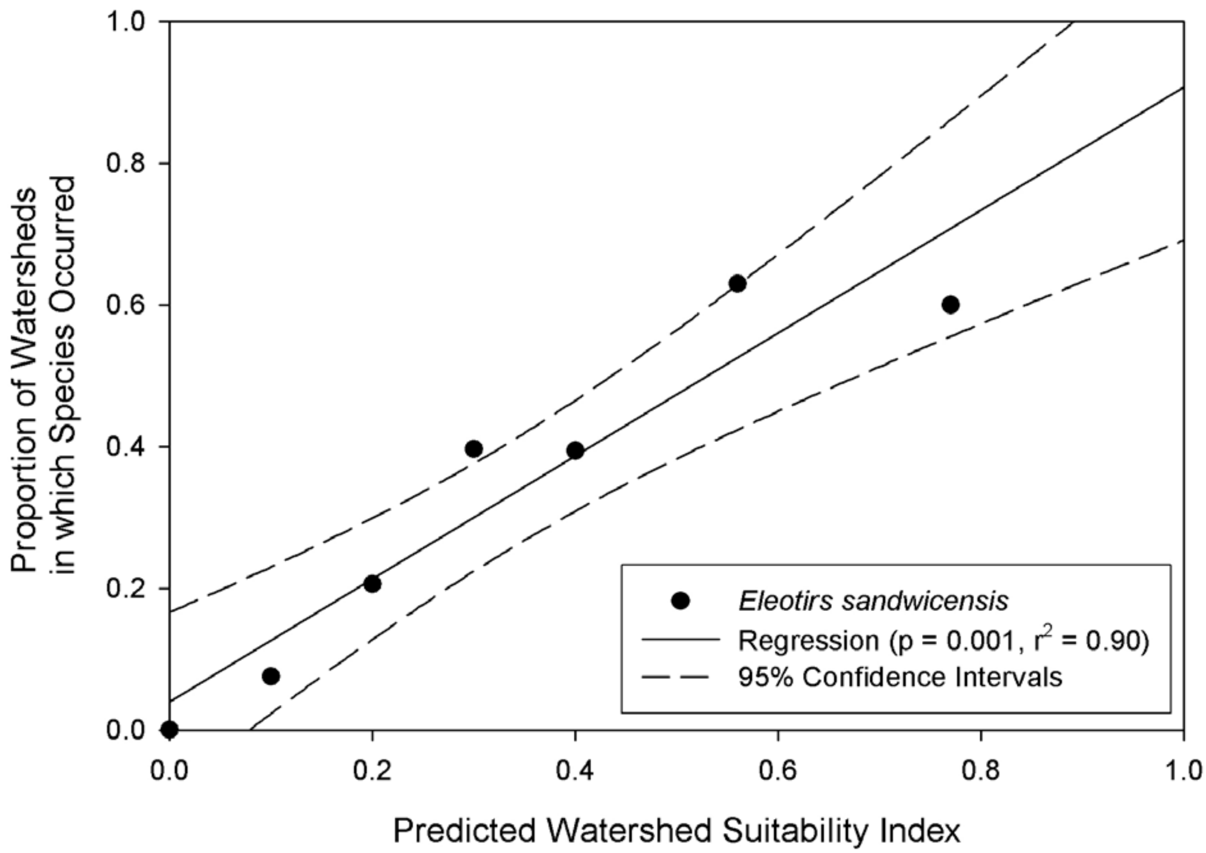


Figure 7: Proportion of the total watersheds where *Eleotris sandwicensis* was observed within each 0.1 group of the Watershed Suitability Index equation for *Eleotris sandwicensis*.

Neritina granosa:

The multiple logistic regression equation with the highest prediction accuracy was:

$$P = \frac{1}{1 + e^{-(-4.806 + (0.375 * \text{WWR}) + (0.435 * \text{WSR}) + (0.177 * \text{WStR}))}}$$

where: WWR = Watershed Wetness Rating, ($p < 0.001$)
WSR = Watershed Size Rating, ($p < 0.001$)
WENR = Watershed Stewardship Rating, ($p = 0.003$).

This equation had a Likelihood Ratio Test Statistic of 77.5 (P = <0.001), and correctly predicted the presence or absence of *Neritina granosa* in 357 of 430 watersheds (83.0% correct) at a probability level of 0.5. To further confirm a positive relationship between the predicted watershed suitability value and the occurrence of *Neritina granosa*, the proportion of samples within each 0.1 sized suitability bin was compared for all watersheds and those watersheds in which *Neritina granosa* occurred (Figure 8).

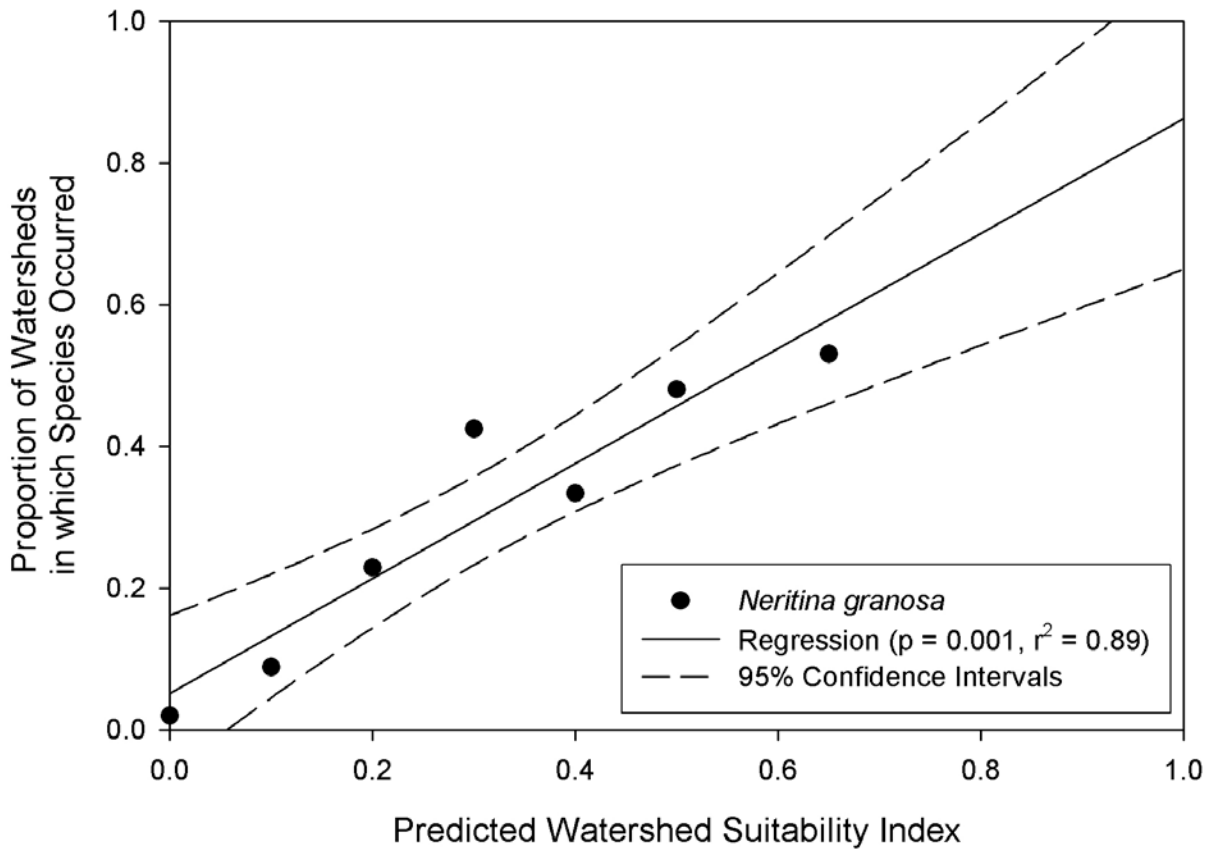


Figure 8: Proportion of the total watersheds where *Neritina granosa* was observed within each 0.1 group of the Watershed Suitability Index equation for *Neritina granosa*.

Atyoida bisulcata:

The multiple logistic regression equation with the highest prediction accuracy was:

$$P = \frac{1}{1 + e^{-(\text{-4.458} + (0.508 * \text{WWR}) + (0.497 * \text{WSR}) + (0.179 * \text{WStR}) + (0.165 * \text{WENR}))}}$$

where: WWR = Watershed Wetness Rating, ($p < 0.001$)
WSR = Watershed Size Rating, ($p < 0.001$)
WStR = Watershed Stewardship Rating, ($p = 0.001$)
WENR = Watershed Estuary and Nearshore Rating, ($p = 0.04$).

This equation had a Likelihood Ratio Test Statistic of 153.3 (P = <0.001), and correctly predicted the presence or absence of *Atyoida bisulcata* in 336 of 430 watersheds (78.1% correct) at a probability level of 0.5. To further confirm a positive relationship between the predicted watershed suitability value and the occurrence of *Atyoida bisulcata*, the proportion of samples within each 0.1 sized suitability bin was compared for all watersheds and those watersheds in which *Atyoida bisulcata* occurred (Figure 9).

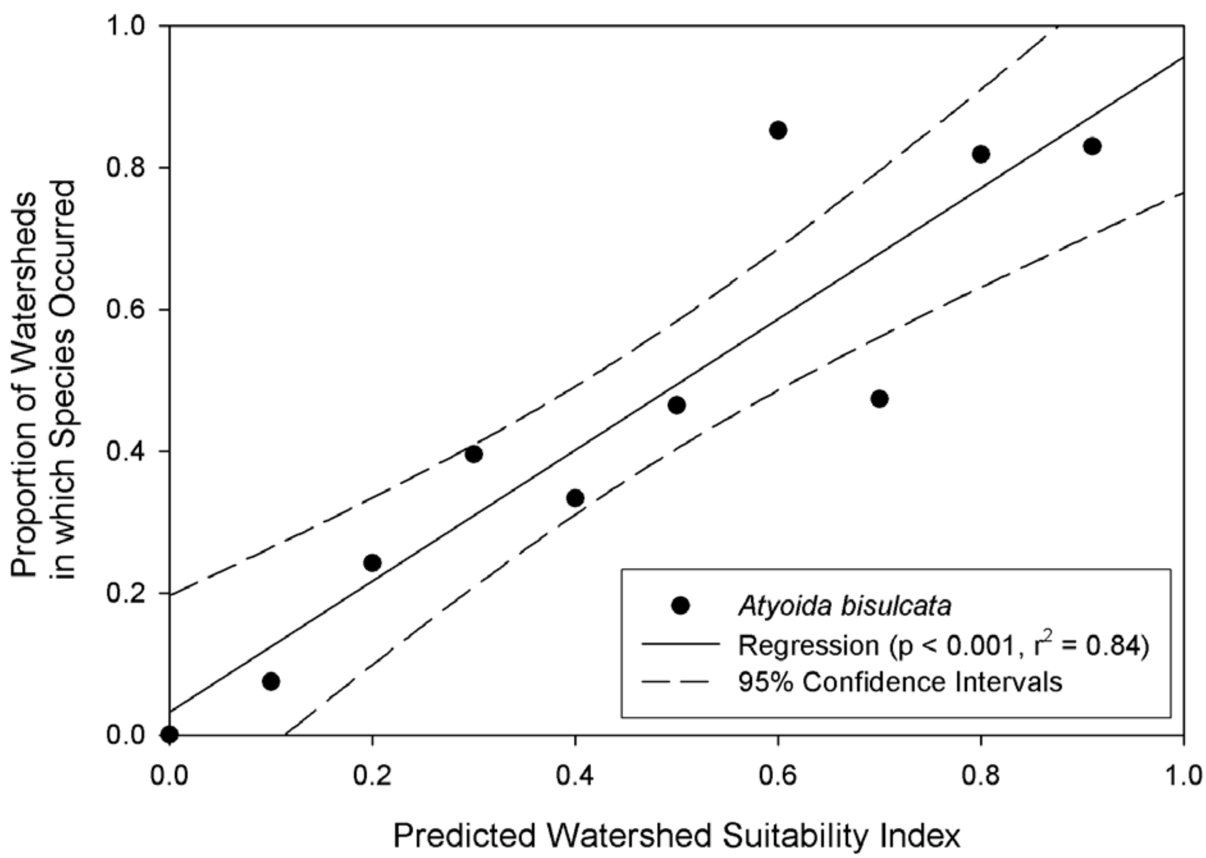


Figure 9: Proportion of the total watersheds where *Atyoida bisulcata* was observed within each 0.1 group of the Watershed Suitability Index equation for *Atyoida bisulcata*.

Macrobrachium grandimanus:

The multiple logistic regression equation with the highest prediction accuracy was:

$$P = \frac{1}{1 + e^{-(-4.942 + (0.286 * \text{WWR}) + (0.775 * \text{WSR}))}}$$

where: WWR = Watershed Wetness Rating, ($p < 0.001$)
WSR = Watershed Size Rating, ($p < 0.001$).

This equation had a Likelihood Ratio Test Statistic of 82.4 (P = <0.001), and correctly predicted the presence or absence of *Macrobrachium grandimanus* in 366 of 430 watersheds (85.1% correct) at a probability level of 0.5. To further confirm a positive relationship between the predicted watershed suitability value and the occurrence of *Macrobrachium grandimanus*, the proportion of samples within each 0.1 sized suitability bin was compared for all watersheds and those watersheds in which *Macrobrachium grandimanus* occurred (Figure 10).

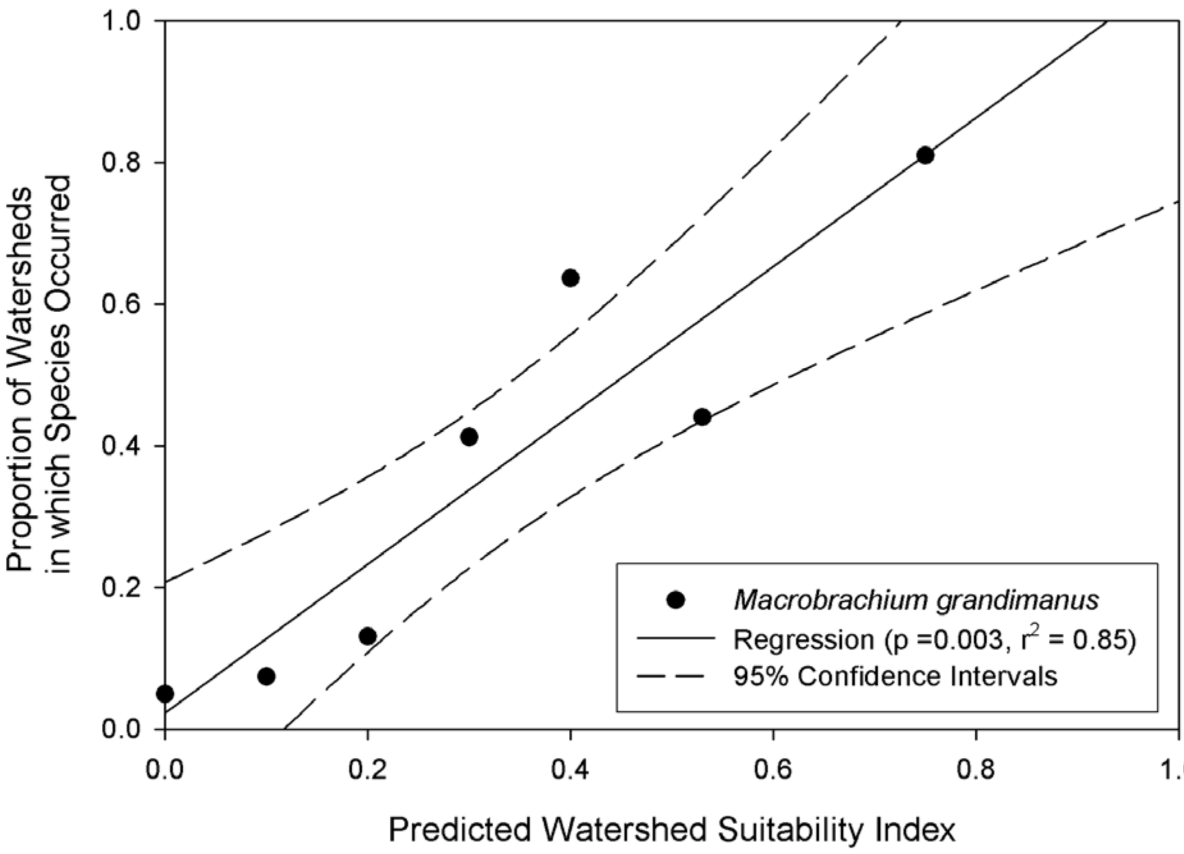


Figure 10: Proportion of the total watersheds where *Macrobrachium grandimanus* was observed within each 0.1 group of the Watershed Suitability Index equation for *Macrobrachium grandimanus*.

Stream Reach Models:

Unlike in the watershed models, the variables used in the stream reach models were not linear; therefore, multiple logistic regressions could not be used to select the relationship between the instream distribution of the animals and the reach variables. To determine the suitability index based on the instream distribution for each species, the variables for elevation, distance inland, and downstream barrier height were combined with two different relationships and then the more appropriate relationship was selected for use. The two relationships were:

1. Reach Suitability = (Elevation Suitability + Distance Inland Suitability + Downstream Barrier Height Suitability)

    where: if Elevation Suitability or Distance Inland Suitability or Downstream Barrier Height Suitability = 0, then Reach Suitability = 0

2. Reach Suitability = (Elevation Suitability * Distance Inland Suitability * Downstream Barrier Height Suitability).

Each relationship was range standardized with a minimum value of 0 and a maximum value of 1. To select the more appropriate relationship, the results of each relationship for all sites with all data for each variable in the database were calculated. The sites were grouped with the predicted results into bins from 0 to 1 by tenths, and the proportion of samples with the species of concern was determined for each group. In cases where too few samples occurred in a bin (usually fewer than 100 of the 8300 samples in a single bin), the results were averaged with the nearest bin containing the fewest samples. The results of the comparison of predicted suitability with the proportion of samples containing a species were plotted on a graph and analyzed using linear regression.

To select the more appropriate relationship, two criteria were used. First, the distribution of predicted results to observed proportions was visually compared. If predicted values between 0 and 1 resulted in a range of proportions between 0 and 1, the relationship was considered acceptable. If both relationships were acceptable to the first criteria, then the relationship with the higher r^2 value for the linear regression was chosen.

The selected relationships used to predict instream distribution of native stream animals were as follows:

Awaous guamensis:

The most appropriate relationship was:

2. Reach Suitability = (Elevation Suitability * Distance Inland Suitability * Downstream Barrier Height Suitability).

Both relationships had adequate distributions and the equation with the higher r^2 was selected (Figure 11).

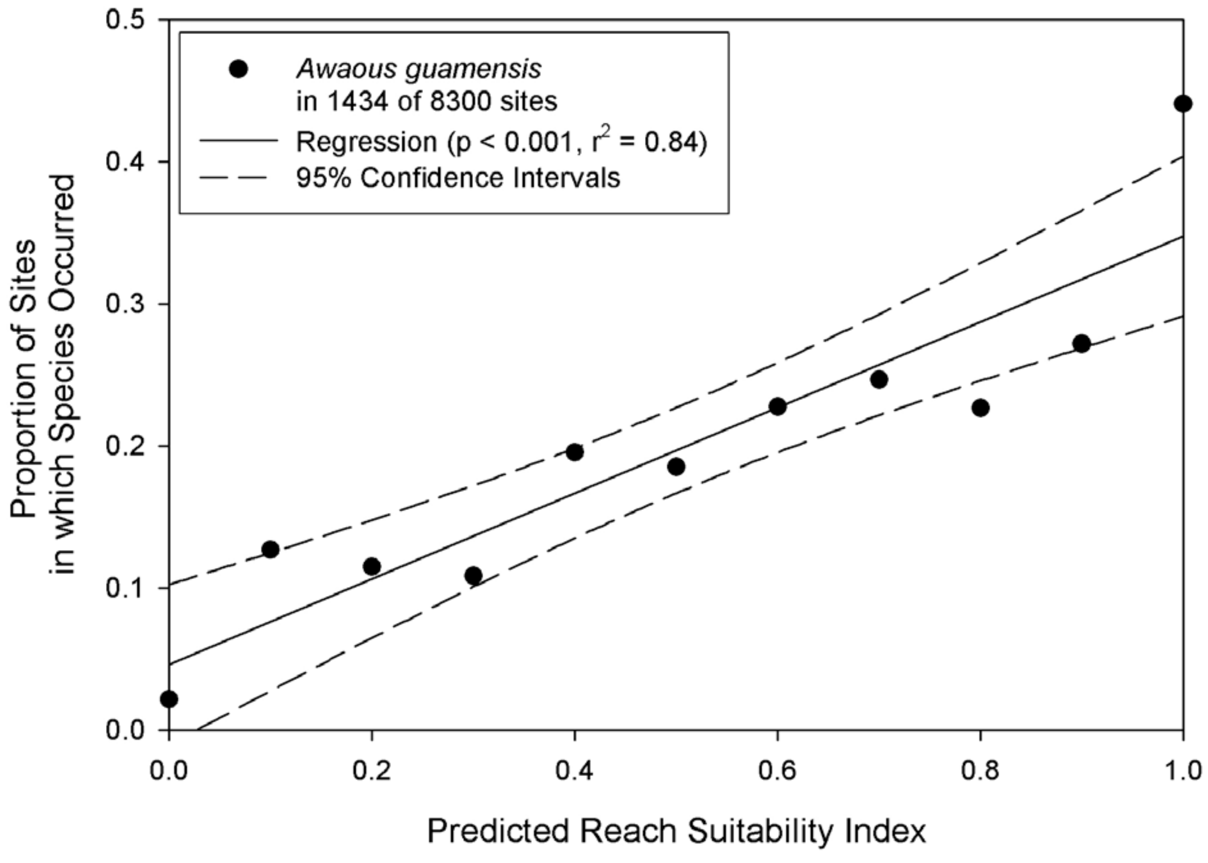


Figure 11: Proportion of the total sites where *Awaous guamensis* was observed within each 0.1 group of the Reach Suitability Index equation for *Awaous guamensis*.

Lentipes concolor:

The most appropriate relationship was:

2. Reach Suitability = (Elevation Suitability * Distance Inland Suitability * Downstream Barrier Height Suitability).

Both relationships had adequate distributions and the equation with the higher r^2 was selected (Figure 12).

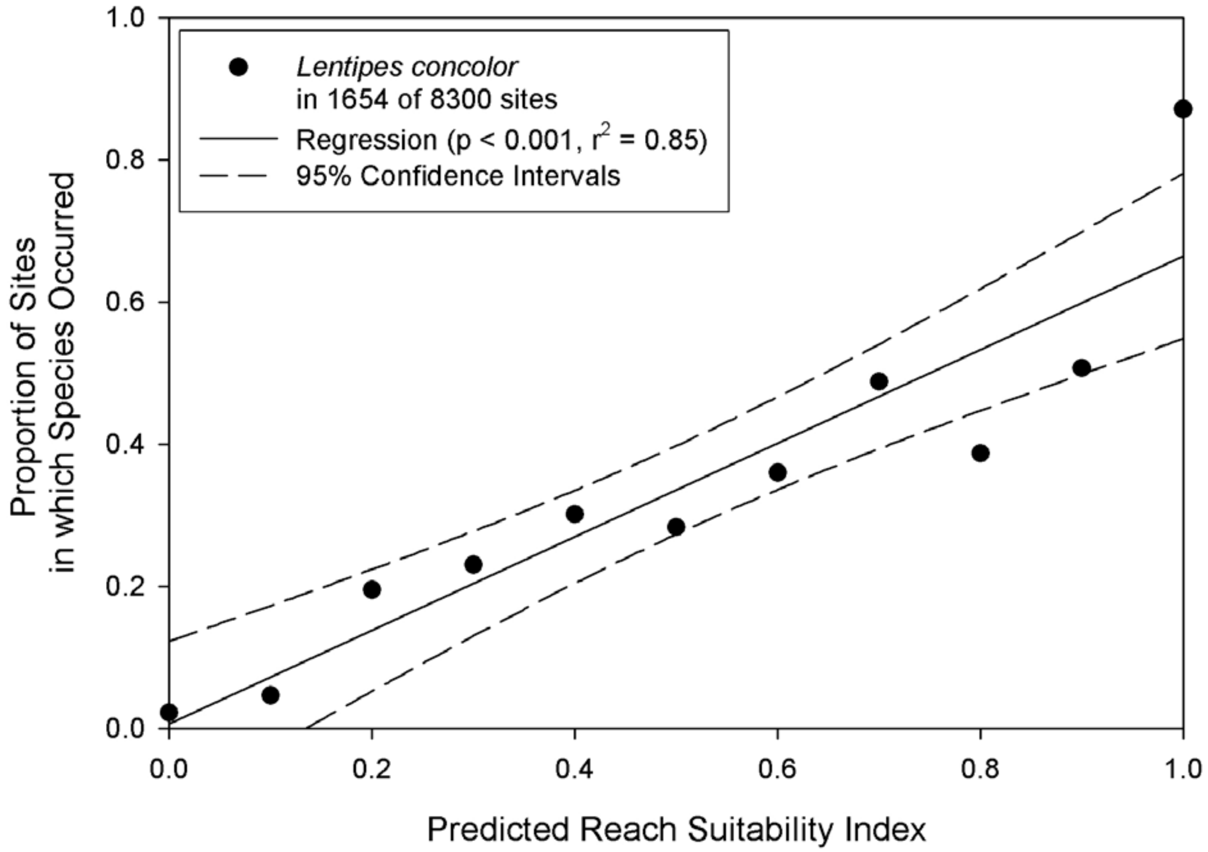


Figure 12: Proportion of the total sites where *Lentipes concolor* was observed within each 0.1 group of the Reach Suitability Index equation for *Lentipes concolor*.

Sicyopterus stimpsoni:

The most appropriate relationship was:

2. Reach Suitability = (Elevation Suitability * Distance Inland Suitability * Downstream Barrier Height Suitability).

Both relationships had adequate distributions and the equation with the higher r^2 was selected (Figure 13).

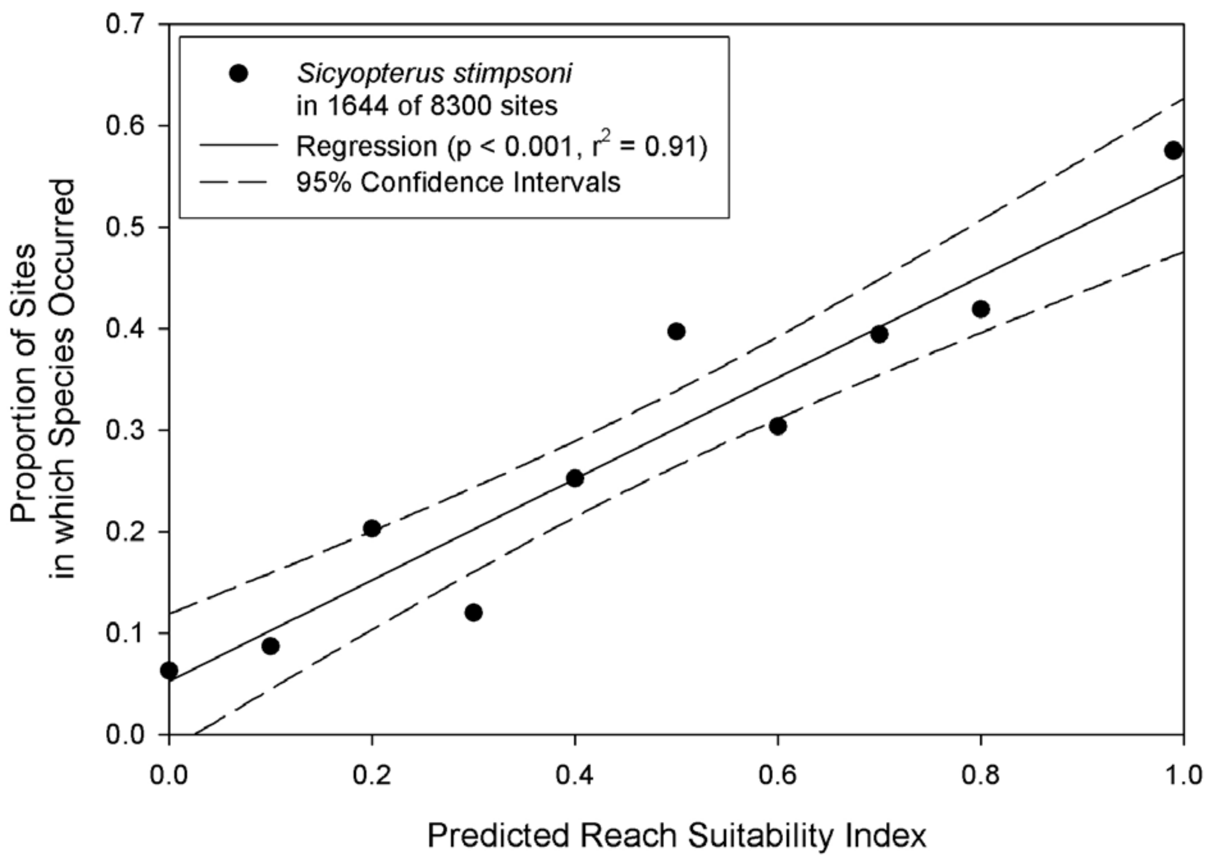


Figure 13: Proportion of the total sites where *Sicyopterus stimpsoni* was observed within each 0.1 group of the Reach Suitability Index equation for *Sicyopterus stimpsoni*.

Stenogobius hawaiiensis:

The most appropriate relationship was:

2. Reach Suitability = (Elevation Suitability * Distance Inland Suitability * Downstream Barrier Height Suitability).

Both relationships had adequate distributions and the equation with the higher r^2 was selected (Figure 14).

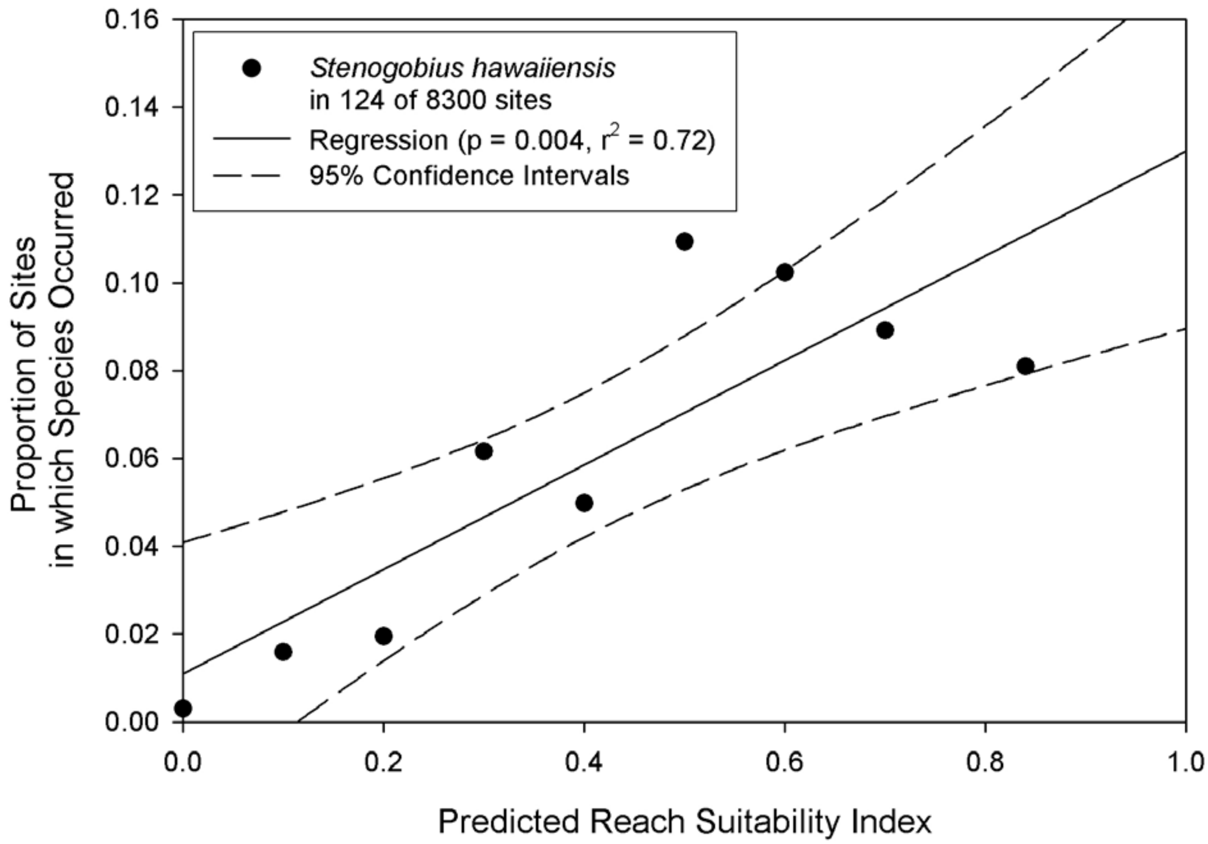


Figure 14: Proportion of the total sites where *Stenogobius hawaiiensis* was observed within each 0.1 group of the Reach Suitability Index equation for *Stenogobius hawaiiensis*.

Eleotris sandwicensis:

The most appropriate relationship was:

2. Reach Suitability = (Elevation Suitability * Distance Inland Suitability * Downstream Barrier Height Suitability).

Both relationships had adequate distributions and the equation with the higher r^2 was selected (Figure 15).

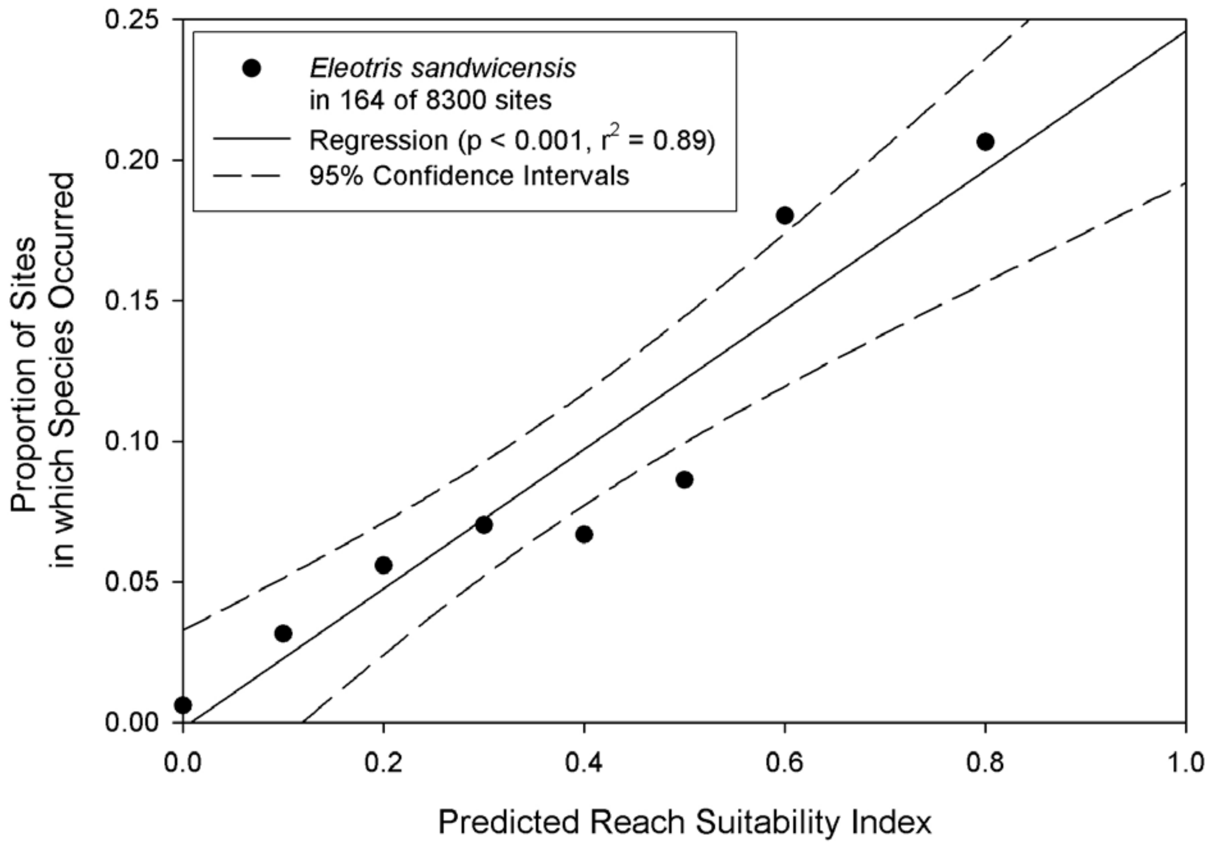


Figure 15: Proportion of the total sites where *Eleotris sandwicensis* was observed within each 0.1 group of the Reach Suitability Index equation for *Eleotris sandwicensis*.

Neritina granosa:

The most appropriate relationship was:

2. Reach Suitability = (Elevation Suitability * Distance Inland Suitability * Downstream Barrier Height Suitability).

Both relationships had adequate distributions and the equation with the higher r^2 was selected (Figure 16).

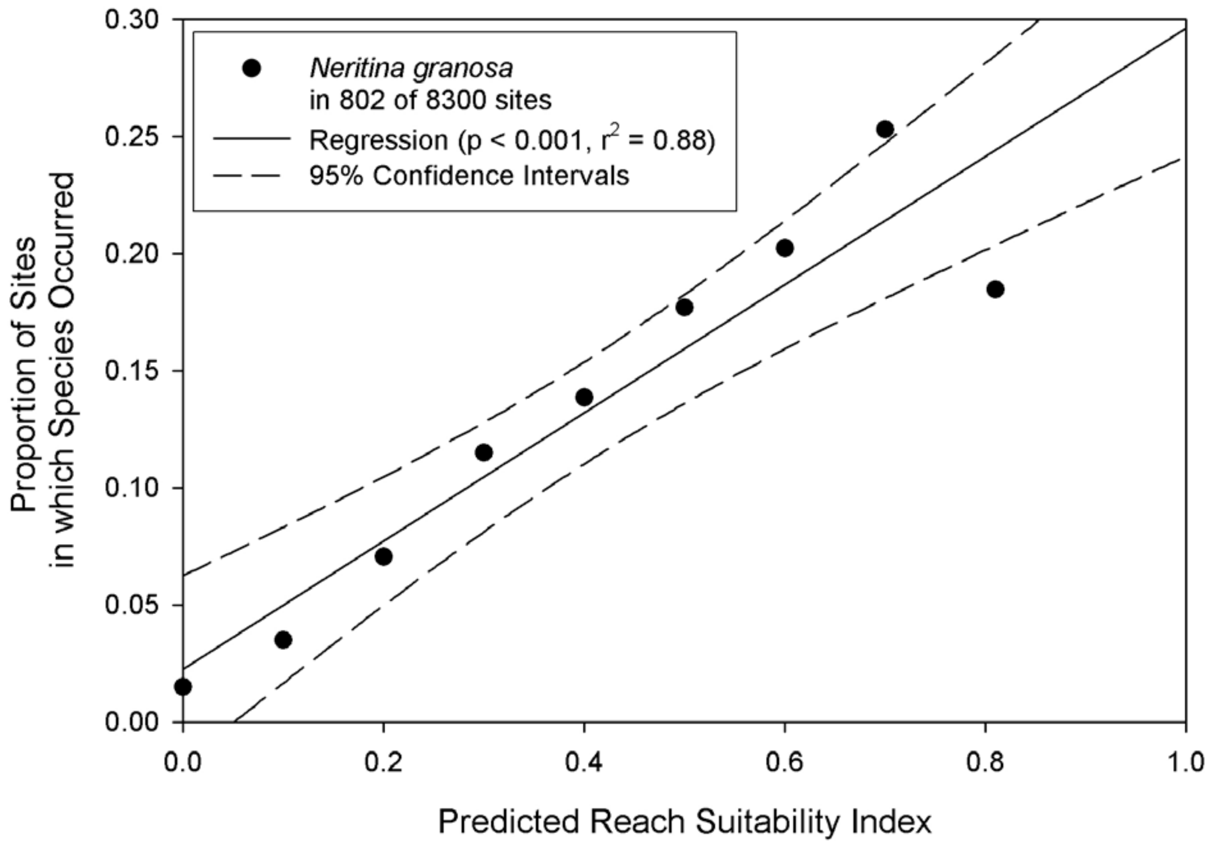


Figure 16: Proportion of the total sites where *Neritina granosa* was observed within each 0.1 group of the Reach Suitability Index equation for *Neritina granosa*.

Atyoida bisulcata:

The most appropriate relationship was:

1. Reach Suitability = (Elevation Suitability * Distance Inland Suitability * Downstream Barrier Height Suitability)

Both relationships had adequate distributions and the equation with the higher r^2 was selected (Figure 17).

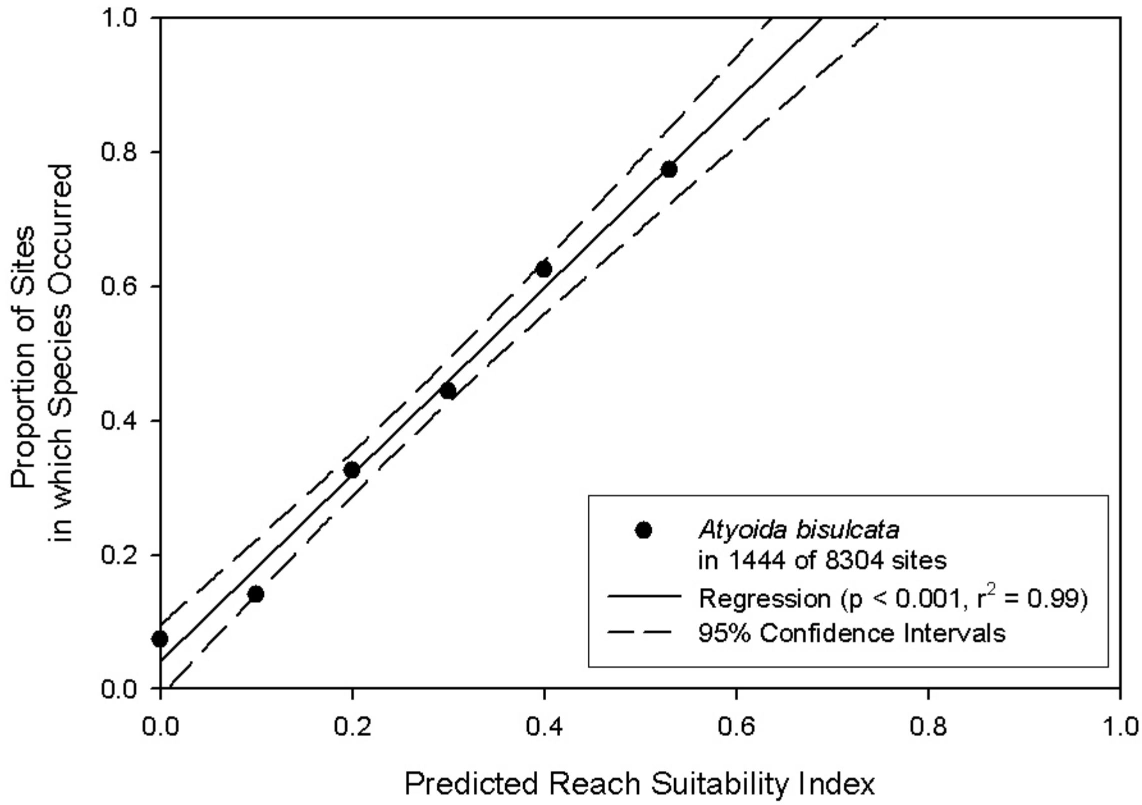


Figure 17: Proportion of the total sites where *Atyoida bisulcata* was observed within each 0.1 group of the Reach Suitability Index equation for *Atyoida bisulcata*.

Macrobrachium grandimanus:

The most appropriate relationship was:

1. Reach Suitability = (Elevation Suitability + Distance Inland Suitability + Downstream Barrier Height Suitability)

where: if Elevation Suitability or Distance Inland Suitability or Downstream Barrier Height Suitability = 0, then Reach Suitability = 0

Both relationships had adequate distributions and the equation with the higher r^2 was selected (Figure 18).

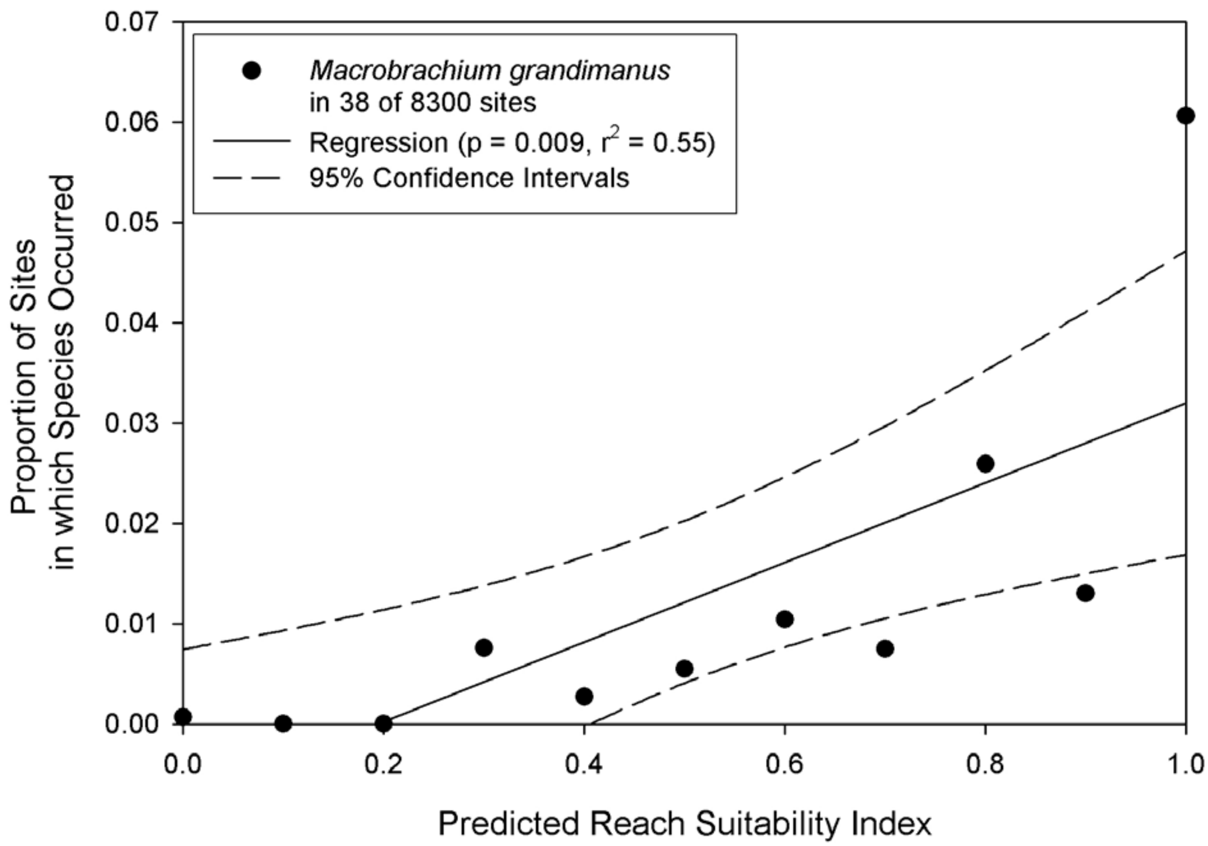


Figure 18: Proportion of the total sites where *Macrobrachium grandimanus* was observed within each 0.1 group of the Reach Suitability Index equation for *Macrobrachium grandimanus*.

Stream and Site Descriptions:

The focus of the site descriptions in this report is a modeled representation of the Nā Wai ‘Ehā Streams applied to the HSHEP model. The modeled representations of the sites are based primarily on the detailed descriptions of the streams and diversions in the USGS Nā Wai ‘Ehā report (Oki et al. 2010). In this HSHEP model, stream segment breaks are located at each diversion, barrier, channelized section, or junctions with main tributaries. After defining stream segments, habitat was assessed for each unique segment. The Nā Wai ‘Ehā HSHEP model includes Waihe‘e Stream, Waiehu Stream, ‘Īao Stream and Waikapū Stream on Maui (Figure 19).

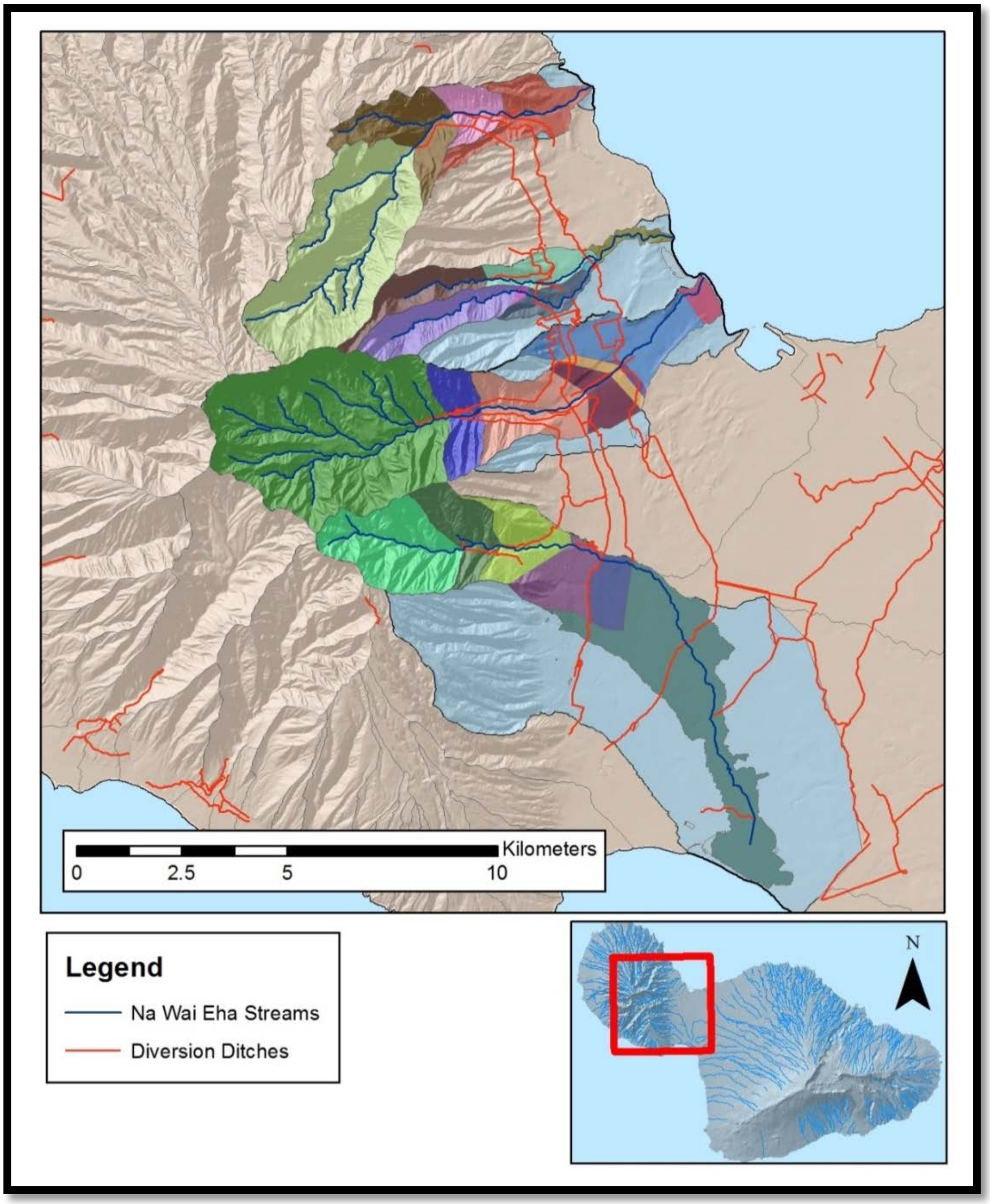


Figure 19: Map of the Nā Wai ʻEhā Stream area shows streams, major ditches, and stream segment zones.

<u>Waiheʻe Stream:</u>

Waiheʻe Stream was separated into four segments within the HSHEP model. From the ocean inland, these segments, barriers, and diversions were:

1) Wh.B.01: The barrier at the stream mouth represents the possibility of a dry stream that would prevent migrating animals from moving into or out of the stream. The USGS Nā Wai ʻEhā report notes that the stream would flow 100% of the time under natural conditions and was observed flowing to the ocean 100% of time during their study. [1] Under the full diversion scenario, no water is expected to be flowing in the last segment of the stream and as a result, it was modeled that the stream mouth would be dry (blocked) 20% of the time. It is an estimate with high uncertainty, but it is likely some periods of zero flow would exist during periods with all baseflow diverted. This dry barrier estimate is the smallest of all Nā Wai ʻEhā streams under diverted conditions.
2) Wh.Hab.1: This segment begins at the mouth of the stream as it flows into the ocean and ends at the Field 1 Diversion. The segment was modeled as natural channel.
3) Wh.D.12: The Field 1 Diversion was modeled as a side diversion type with a maximum diversion capacity of 3.2 mgd.[2]
4) Wh.Hab.2: This segment starts at the Field 1 Diversion and goes upstream to the Spreckels Ditch diversion. The segment was modeled as natural channel.
5) Wh.D.23: Spreckels Ditch diversion was modeled as a side diversion type with a maximum diversion capacity of 12 mgd.[3]
6) Wh.Hab.3: This segment goes from the Spreckels Ditch diversion upstream to the Waiheʻe Ditch Diversion. The segment was modeled as natural channel.
7) Wh.D.34: Waiheʻe Ditch diversion was modeled as a bottom grate diversion type with a maximum diversion capacity of 40 mgd.[4]
8) Wh.Hab.4: This section includes all upstream segments above the Waiheʻe Ditch diversion. The segment was modeled as natural channel.

A map of stream segment and barrier locations (Figure 20), the box model (Figure 21) and tables with barrier (Table 2) and baseflow (Q_{70}) flow values (Table 3) are provided for reference.

[1] Oki et al. 2010 page 74 (continuous flow to ocean under undiverted flow conditions) and page 77 (some sections were observed occasionally dry between Spreckels Ditch and Field 1 intake) and reach below Field 1 intake is a losing reach (page 73).
[2] Oki et al. 2010 page 80. The estimate of the diversion capacity is considered arbitrary.
[3] Oki et al. 2010 page 80.
[4] Oki et al. 2010 page 80.

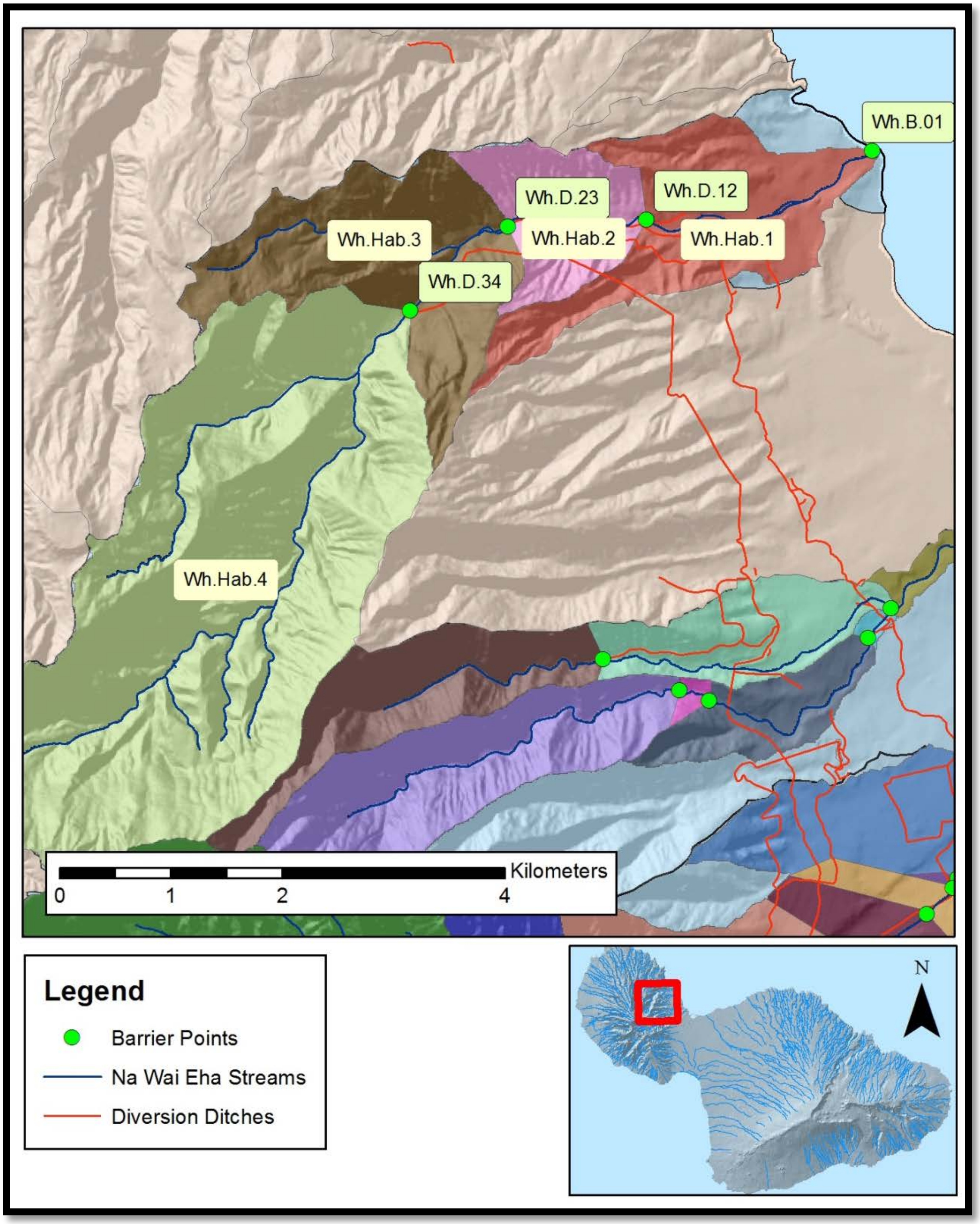


Figure 20: Map showing stream segments, barriers, and diversions associated with the Waihe'e Stream HSHEP model.

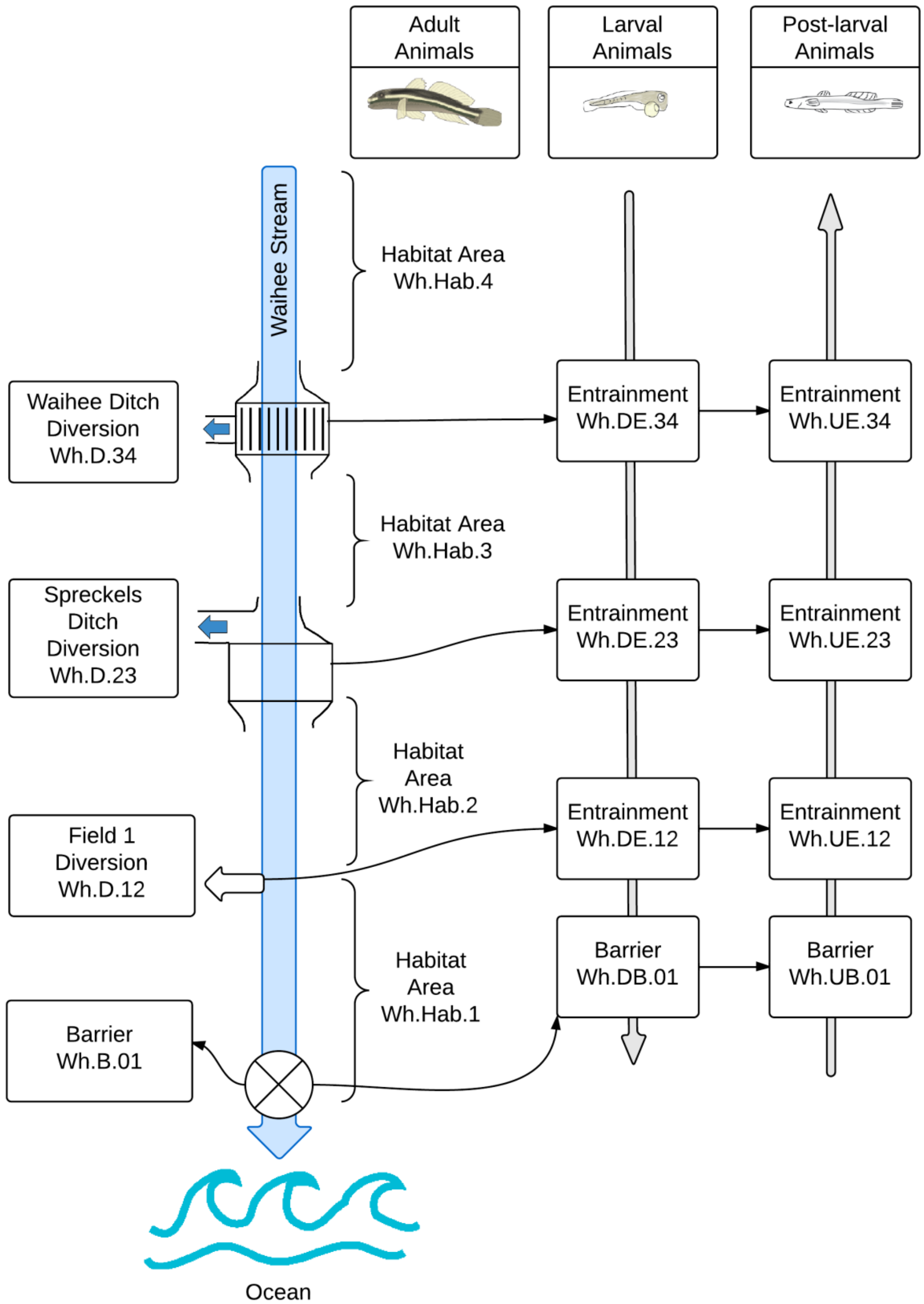
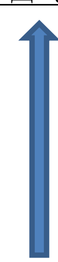


Figure 21: Box model for Waihe‘e Stream, Maui. Box model not to scale.

Table 2: Waihe‘e Stream HSHEP model segments and values for barriers, diversions and associated modifiers.

Stream segment Habitat Code	Perennial Stream Channel length within segment (m)	Channelization habitat modifier	Barrier or Diversion Code at start of segment	Barrier or Diversion Type	Maximum Upstream Barrier Impact during fully diverted conditions	Maximum Upstream Barrier Impact during undiverted conditions	Maximum Downstream Barrier Impact during fully diverted conditions	Maximum Downstream Barrier Impact during undiverted conditions
Wh.Hab.1	3,490	1	Wh.B.01	Stream mouth barrier	0.20	0	0.20	0
Wh.Hab.2	1,560	1	Wh.D.12	Side diversion	0.50	0	0.80	0
Wh.Hab.3	4,930	1	Wh.D.23	Side diversion	0.50	0	0.80	0
Wh.Hab.4	16,090	1	Wh.D.34	Bottom grate diversion	0.80	0	0.80	0

Table 3: Waihe‘e Stream HSHEP model segments and values used for natural Q_{70} flows (an estimate of baseflow) at various locations and diversion capacities associated with downstream end of segment. All values interpreted from Oki et al. 2010.

Stream segment Habitat Code	Natural Q70 at start of segment (mgd)	Natural Q70 at end of segment (mgd)	Average Natural Q70 for segment (mgd)	Gain or loss of water at Natural Q70 in segment (mgd)	Barrier or Diversion Code at start of segment	Diversion Capacity (mgd)	Direction of streamflow
Wh.Hab.1	28.00	27.00	27.5	-1.00	Wh.B.01	0.00	
Wh.Hab.2	29.00	28.00	28.5	-1.00	Wh.D.12	3.2	
Wh.Hab.3	28.00	29.00	28.5	1.00	Wh.D.23	12	
Wh.Hab.4	0	28.00	14	28.00	Wh.D.34	40	

Waiehu Stream:

Waiehu Stream was separated into eight segments (four in the South Fork, two in the North Fork, and one in the main stem) within the HSHEP model. From the ocean inland, these segments, barriers, and diversions were:

1) We.B.01: The barrier at the stream mouth represents the possibility of a dry stream that would prevent migrating animals from moving into or out of the stream. The USGS Nā Wai ʻEhā report notes that the stream would flow 95% of the time under natural conditions and was observed flowing to the ocean 55% of time during their study. [5]
2) We.Hab.1: This segment begins at the mouth of the stream as it flows into the ocean and ends at the confluence of the North and South Forks. The segment was modeled as natural channel.
3) WeS.Hab.2: This segment begins at the confluence of the North and South Forks and continues upstream on the South Fork to the Spreckels Ditch diversion. The segment was modeled as natural channel.
4) WeS.D.23: Spreckels Ditch diversion was modeled as a side diversion type with a maximum diversion capacity of 1.3 mgd.[6]
5) WeS.Hab.3: This South Fork segment goes from the Spreckels Ditch diversion upstream to the intake for the private auwai at 570ft. The segment was modeled as natural channel.
6) WeS.D.34: The private auwai at 570ft diversion was modeled as a side diversion type with a maximum diversion capacity of 0.32 mgd.[7]
7) WeS.Hab.4: This South Fork segment goes from the private auwai at 570ft diversion upstream to the intake for the private auwai at 620ft. The segment was modeled as natural channel.
8) WeS.D.45: The private auwai at 620ft diversion was modeled as a side diversion type with a maximum diversion capacity of 0.32 mgd.[8]
9) WeS.Hab.5: This South Fork section includes all upstream segments above the private auwai at 620ft diversion. The segment was modeled as natural channel.
10) WeN.Hab.2: This segment begins at the confluence of the North and South Forks and continues upstream on the North Fork to the North Waiehu Ditch diversion. The segment was modeled as natural channel.
11) WeN.D.23: The North Waiehu Ditch Diversion was modeled as a side diversion type with a maximum diversion capacity of 1.5 mgd.[9]

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[5] Oki et al. 2010 page 74 (flow to ocean 95% of time under undiverted flow conditions) and page 77 (commonly observed dry near 20ft elevation) and camera observations showed dry 45% of time in water year 2007 and 57% dry over the observation period (page 73). The 45% was used as it reflected a full water year.
[6] Oki et al. 2010 page 82.
[7] Oki et al. 2010 page 82.
[8] Oki et al. 2010 page 82.
[9] Oki et al. 2010 page 82.

12) WeN.Hab.3: This North Fork section includes all upstream segments above the North Waiehu Ditch Diversion. The segment was modeled as natural channel.

A map of stream segment and barrier locations (Figure 22), the box model (Figure 23 and Figure 24) and tables with barrier (Table 4) and baseflow (Q_{70}) flow values (Table 5) are provided for reference.

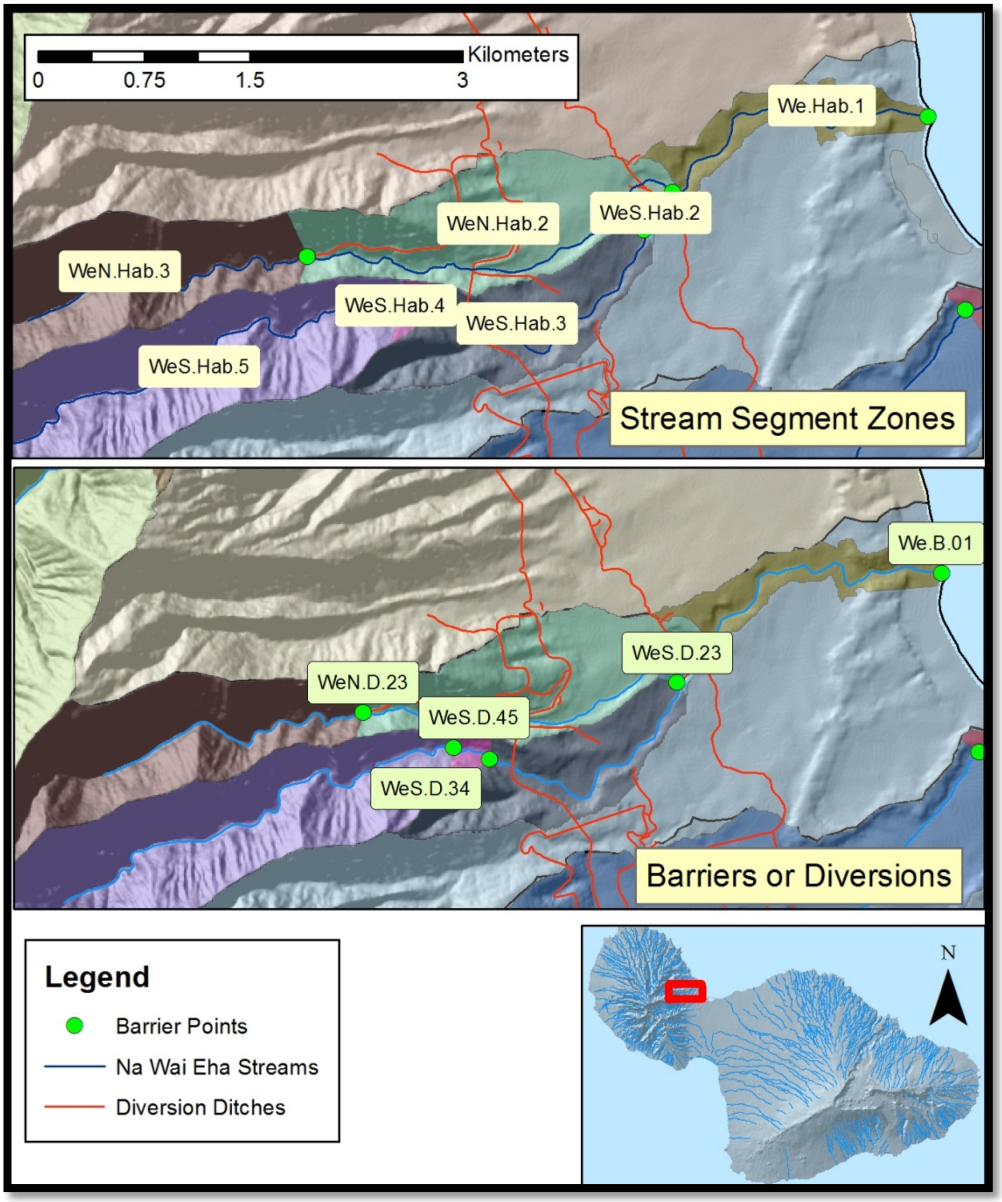

Figure 22: Map showing stream segments, barriers, and diversions associated with the Waiehu Stream HSHEP model.

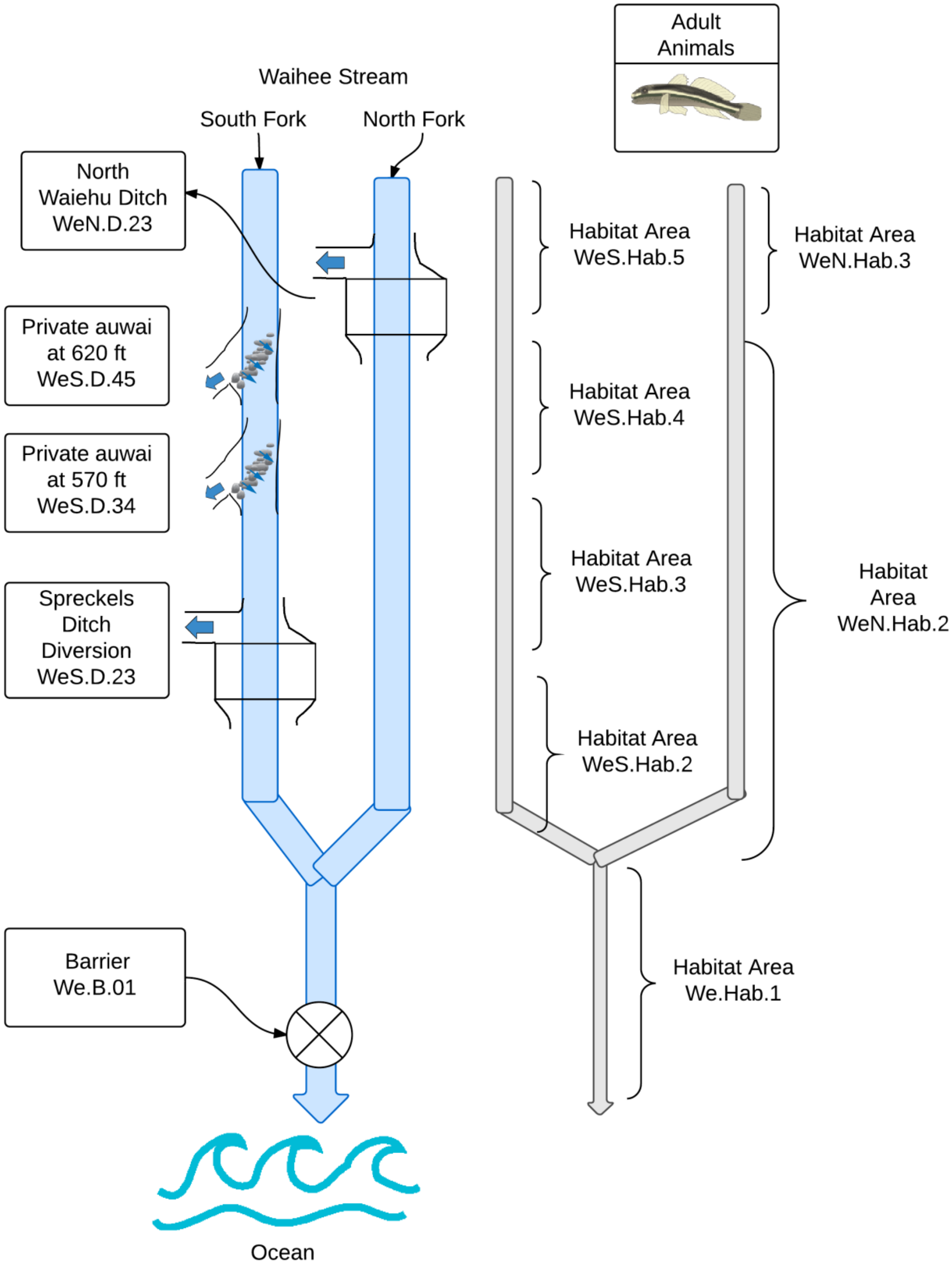

Figure 23: Box model for Waiehu Stream, Maui for habitat areas. Box model not to scale.

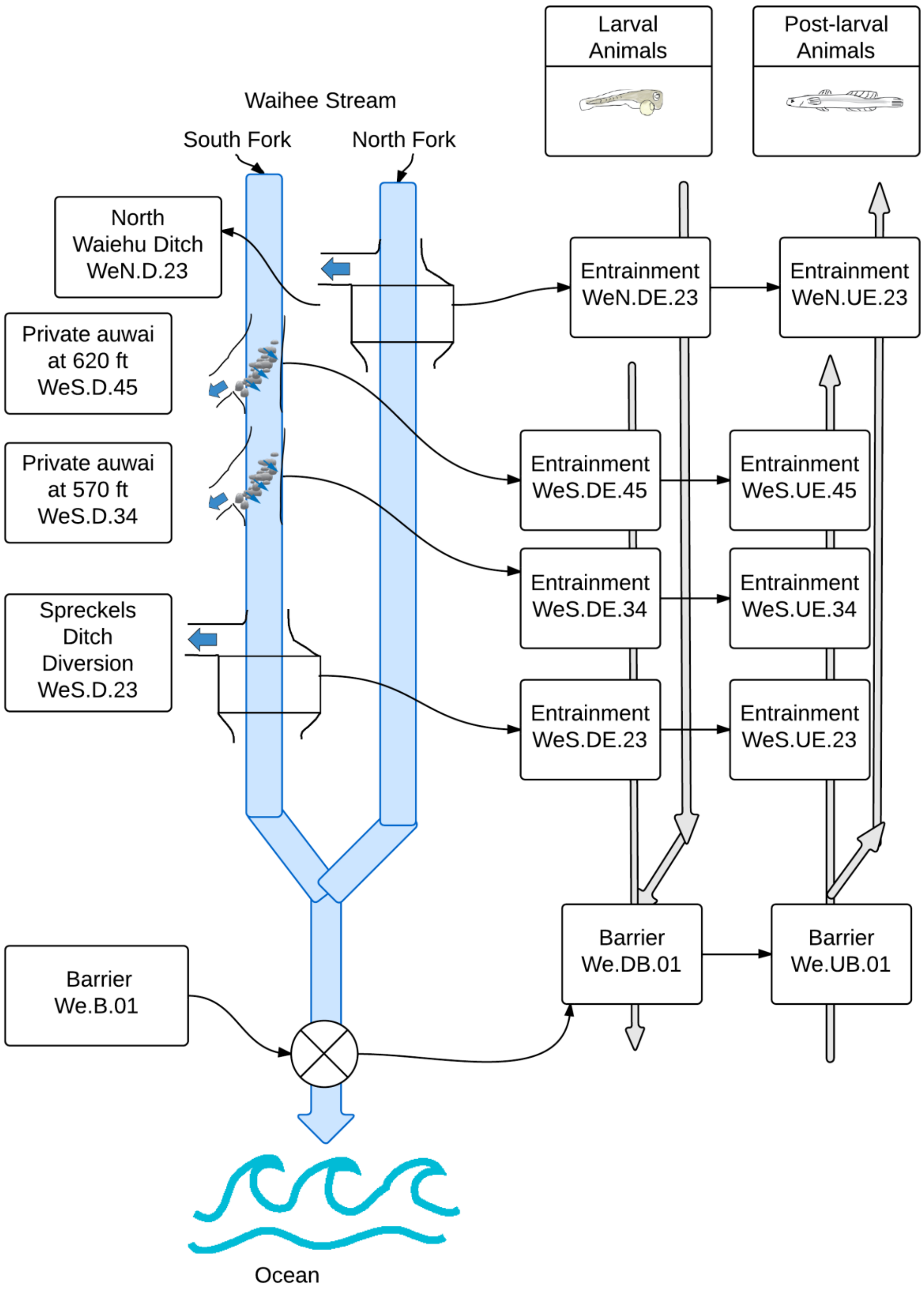

Figure 24: Box Model for Waiehu Stream, Maui for downstream drifting larvae and upstream migrating post-larvae. Box model not to scale.

Table 4: Waiehu Stream HSHEP model segments and values for barriers, diversions and associated modifiers.

Stream segment Habitat Code	Perennial Stream Channel length within segment (m)	Channelization habitat modifier	Barrier or Diversion Code at start of segment	Barrier or Diversion Type	Maximum Upstream Barrier Impact during fully diverted conditions	Maximum Upstream Barrier Impact during undiverted conditions	Maximum Downstream Barrier Impact during fully diverted conditions	Maximum Downstream Barrier Impact during undiverted conditions
We.Hab.1	2,760	1	We.B.01	Stream mouth Barrier	0.45	0.05	0.45	0.05
South Fork of Waiehu Stream								
WeS.Hab.2	410	1	None	None	0.00	0	0.00	0
WeS.Hab.3	2,450	1	WeS.D.23	Side Diversion	0.50	0	0.80	0
WeS.Hab.4	370	1	WeS.D.34	Side Diversion	0.50	0	0.80	0
WeS.Hab.5	4,400	1	WeS.D.45	Side Diversion	0.50	0	0.80	0
North Fork of Waiehu Stream								
WeN.Hab.2	3,550	1	None	None	0.00	0	0.00	0
WeN.Hab.3	2,910	1	WeN.D.23	Side Diversion	0.50	0	0.80	0

Table 5: Waiehu Stream HSHEP model segments and values used for natural Q_{70} flows (an estimate of baseflow) at various locations and diversion capacities associated with downstream end of segment. All values interpreted from Oki et al. 2010.

Stream segment Habitat Code	Natural Q70 at start of segment (mgd)	Natural Q70 at end of segment (mgd)	Average Natural Q70 for segment (mgd)	Gain or loss of water at Natural Q70 in segment (mgd)	Barrier or Diversion Code at start of segment	Diversion Capacity (mgd)	Direction of streamflow
We.Hab.1	2.40	2.20	2.3	-0.20	We.B.01	0.00	↑
South Fork of Waiehu Stream							
WeS.Hab.2	1.30	1.20	1.25	-0.10	None	0.00	↑
WeS.Hab.3	2.20	1.30	1.75	-0.90	WeS.D.23	1.30	↑
WeS.Hab.4	2.30	2.20	2.25	-0.10	WeS.D.34	0.32	↑
WeS.Hab.5	0	2.30	1.15	2.30	WeS.D.45	0.32	↑
North Fork of Waiehu Stream							
WeN.Hab.2	2.50	1.20	1.85	-1.30	None	0.00	↑
WeN.Hab.3	0	2.50	1.25	2.50	WeN.D.23	1.50	↑

‘Īao Stream:

‘Īao Stream was separated into eight segments within the HSHEP model. From the ocean inland, these segments, barriers, and diversions were:

1) Ia.B.01: The barrier at the stream mouth represents the possibility of a dry stream that would prevent migrating animals from moving into or out of the stream. The USGS Nā Wai ‘Ehā report notes that the stream flows to the ocean approximately 34% of the time under current conditions, but would flow 100% of the time under natural conditions[10]
2) Ia.Hab.1: This segment begins at the mouth of the stream as it flows into the ocean and ends at the upstream end of the first concrete-lined channelized section. Zero suitable habitat was modeled for this segment under the channelized condition.[11]
3) Ia.Hab.2: This segment is the rock-lined channelized section of ‘Īao stream between the two concrete-lined sections. A reduction of 67% suitable habitat under these conditions was modeled.[12]
4) Ia.B.23: This barrier is a general representation of the difficult upstream passage as a result of poor flow and habitat conditions through the upper channelized section. An additional reduction of 10% of postlarvae passing upstream through this segment was added to the model. There is no downstream barrier effect as downstream drifting larvae do not require benthic habitat for passage.[13]
5) Ia.Hab.3: This segment starts at the second concrete-lined channelized section and goes upstream to the 22ft drop structure. No suitable habitat was modeled in this segment and the drop structure was not modeled as an additional barrier as it is far enough upstream that few non-climbing species would reach the barrier and the climbing species could surmount the barrier.[14]
6) Ia.Hab.4: This segment goes from the drop structure to the Spreckels Ditch diversion structure. No suitable habitat was modeled in this segment.[15]
7) Ia.D.45: Spreckels Ditch diversion was modeled as a bottom grate diversion type with a maximum diversion capacity of 3.9 mgd.

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[10] Oki et al. 2010 page 77 (continuous flow to ocean under undiverted flow conditions) and page 79 (dry at 50ft elevation 66% of time). The Draft EA for the ‘Īao Flood Control Project (USACE and County of Maui 2009) reports that the stream flowed to the ocean only 11% of the time on average for year from 1993 to 2000 based on observations from DLNR-DAR staff (Table 4-4). Thus the use of the stream mouth being open 34% (closed 66%) of time may underestimate actual conditions.
[11] Suitable habitat within the channelized section of ‘Īao Stream was estimated by the author from professional judgment.
[12] *Ibid.*
[13] Trapped, dying, and dead postlarval animals were observed in the USGS report (Oki et al. 2010) and noted in USFWS 2006. The selection of a 10% barrier is highly uncertain, but it is clear that some animals are not making it successfully upstream through this section.
[14] Professional judgment and observation of instream distributions for species in the HSHEP results.
[15] Professional judgment

8) Ia.Hab.5: This segment goes from the Spreckels Ditch diversion structure to the end of the concrete-lined channelized section. No suitable habitat was modeled in this segment.[16]
9) Ia.Hab.6: This segment goes from the end of the concrete-lined channelized section to the private auwai diversion near 650ft elevation. A natural stream channel was modeled in this segment.[17]
10) Ia.D.67: Private auwai diversion was modeled as a side diversion type with a maximum diversion capacity of 0.65 mgd.[18]
11) Ia.Hab.7: This segment goes from the private auwai diversion to the ʻĪao-Waikapū and ʻĪao-Maniania Ditch diversion. A natural stream channel was modeled in this segment.
12) Ia.D.78: ʻĪao-Waikapū and ʻĪao-Maniania Ditch diversion was modeled as a bottom grate diversion type with a maximum diversion capacity of 20 mgd.[19]
13) Ia.Hab.8: This includes all upstream stream segments above the ʻĪao-Waikapū and ʻĪao-Maniania Ditch diversions. All of these segments were modeled as undiverted, natural stream channels.

A map of stream segment and barrier locations (Figure 25), the box model (Figure 26) and tables with barrier (Table 6) and baseflow (Q_{70}) flow values (Table 7) are provided for reference.

[16] Oki et al. 2010 page 84
[17] This segment includes the settling basin of the Iao Flood Control Project. The whole segment was modeled as natural channel, but may overestimate suitable habitat within the channel in the settling basin as a result.
[18] Oki et al. 2010 page 84
[19] Oki et al. 2010 page 84

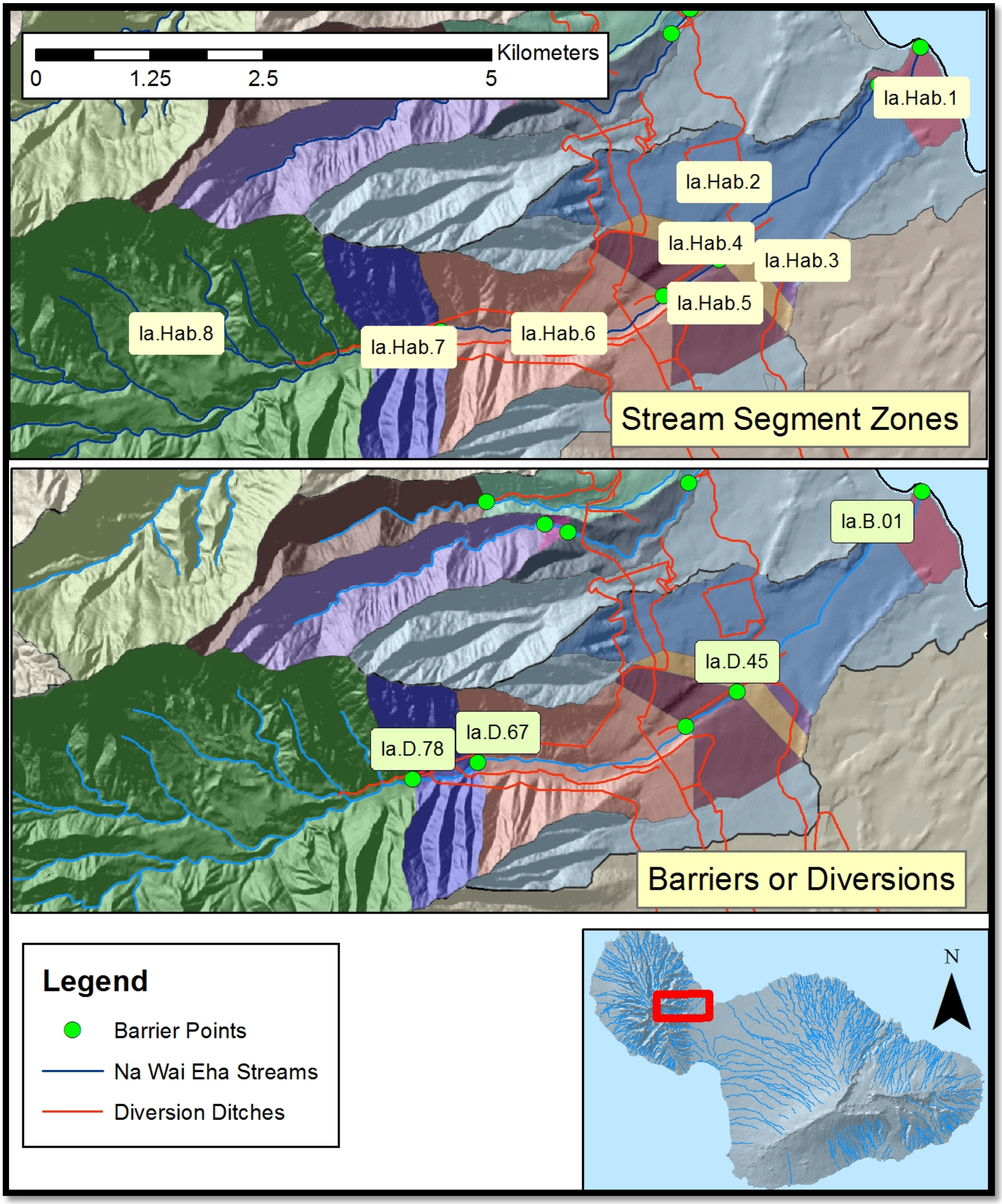

Figure 25: Map showing stream segments, barriers, and diversions associated with the ʻĪao Stream HSHEP model.

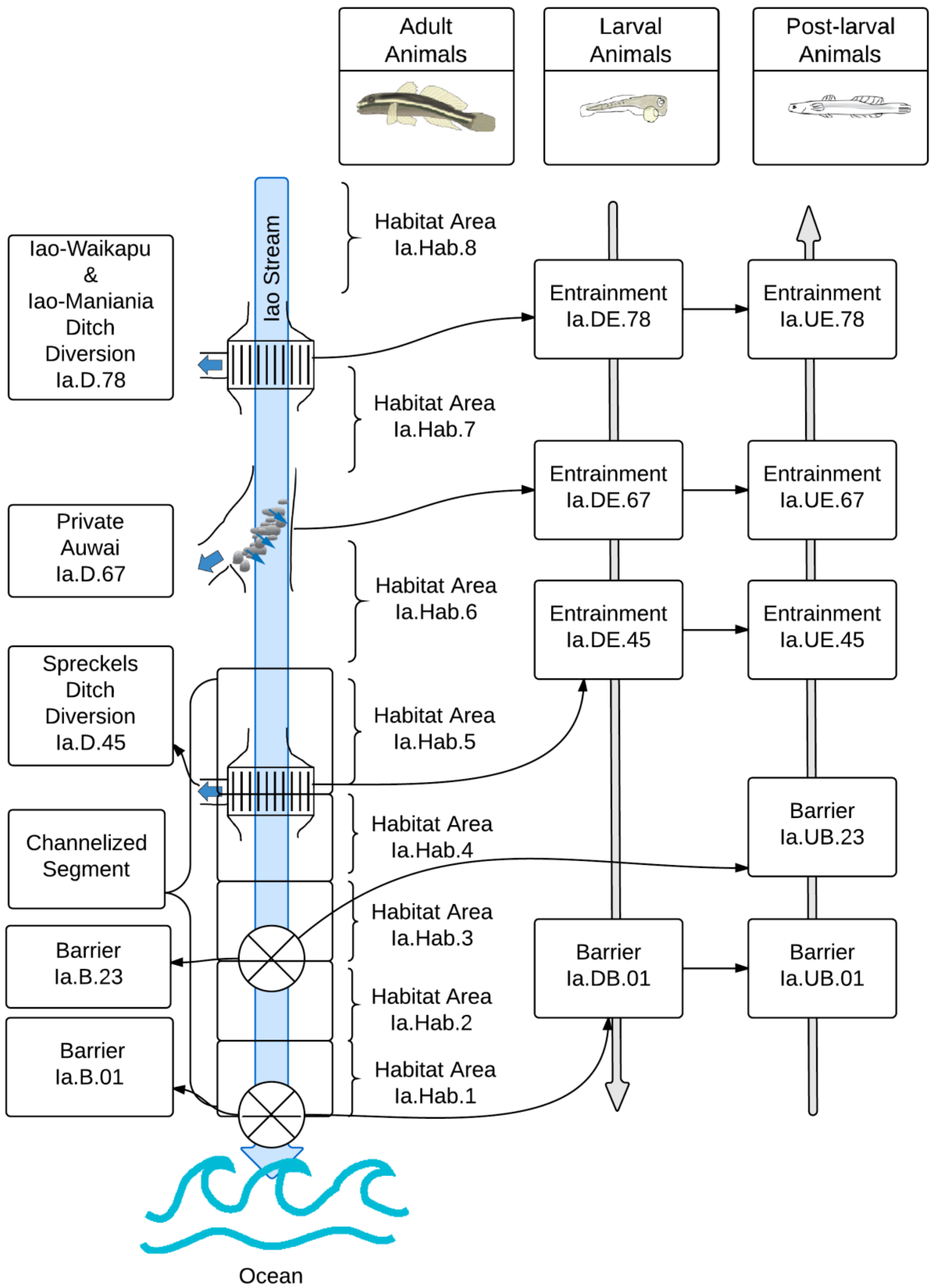

Figure 26: Box Model representation of ‘Īao Stream, Maui. Box model not to scale.

Table 6: ʻĪao Stream HSHEP model segments and values for barriers, diversions and associated modifiers.

Stream segment Habitat Code	Perennial Stream Channel length within segment (m)	Channelization habitat modifier	Barrier or Diversion Code at start of segment	Barrier or Diversion Type	Maximum Upstream Barrier Impact during fully diverted conditions	Maximum Upstream Barrier Impact during undiverted conditions	Maximum Downstream Barrier Impact during fully diverted conditions	Maximum Downstream Barrier Impact during undiverted conditions
Ia.Hab.1	830	0	Ia.B.01	Stream mouth barrier	0.66	0	0.66	0
Ia.Hab.2	2,860	0.33	None	None	0	0	0	0
Ia.Hab.3	130	0	Ia.B.23	General barrier	0.1	0	0.1	0
Ia.Hab.4	430	0	None	None	0	0	0	0
Ia.Hab.5	950	0	Ia.D.45	Bottom grate diversion	0.5	0	0.8	0
Ia.Hab.6	3,260	1	None	None	0	0	0	0
Ia.Hab.7	1,100	1	Ia.D.67	Side diversion	0.8	0	0.8	0
Ia.Hab.8	27,960	1	Ia.D.78	Bottom grate diversion	0.8	0	0.8	0

Table 7: ‘Īao Stream HSHEP model segments and values used for natural Q_{70} flows (an estimate of baseflow) at various locations and diversion capacities associated with downstream end of segment. All values interpreted from Oki et al. 2010.

Stream segment Habitat Code	Natural Q70 at start of segment (mgd)	Natural Q70 at end of segment (mgd)	Average Natural Q70 for segment (mgd)	Gain or loss of water at Natural Q70 in segment (mgd)	Diversion Capacity (mgd)	Direction of streamflow
Ia.Hab.1	14	13	13.5	-1	0	
Ia.Hab.2	15	14	14.5	-1	0	
Ia.Hab.3	15	15	15	0	0	
Ia.Hab.4	15	15	15	0	3.9	
Ia.Hab.5	16	15	15.5	-1	0	
Ia.Hab.6	18	16	17	-2	0	
Ia.Hab.7	17	18	17.5	1	0.65	
Ia.Hab.8	0	17	8.5	17	20	

Waikapū Stream:

Waikapū Stream was separated into six segments within the HSHEP model. From the ocean inland, these segments, barriers, and diversions were:

1) Wk.B.01: The barrier at the stream mouth represents the possibility of a dry stream that would prevent migrating animals from moving into or out of the stream. The USGS Nā Wai ‘Ehā report notes that the stream would flow less than half of the time under natural conditions (interpreted at 49% of time) and was observed flowing to the ocean 22% of time during their study. [20]
2) Wk.Hab.1: This segment begins at the mouth of the stream as it flows into the ocean and ends at the Reservoir 6 Diversion. The segment was modeled as natural channel, but with intermittent baseflow.[21]

[20] Oki et al. 2010 page 77 (continuous flow to ocean less than 50% of time under undiverted flow conditions) and page 80 (at elevation of 40 ft the stream cameras recorded 76% dry overall and for nearly a complete water year 2007 it was 78% dry. The 78% was used for consistency with the Waiehu model.)
[21] Oki et al. 2010 page 77

3) Wk.D.12: The Reservoir 6 Diversion was modeled as a bottom grate diversion type with a maximum diversion capacity of 1.0 mgd.[22]
4) Wk.Hab.2: This segment starts at the Reservoir 6 Diversion and goes upstream to the Waiheʻe Ditch diversion. The segment was modeled as natural channel.
5) Wk.D.23: Waiheʻe Ditch diversion was modeled as a bottom grate diversion type with a maximum diversion capacity of 1.0 mgd.[23]
6) Wk.Hab.3: This segment goes from the Waiheʻe Ditch diversion upstream to the private auwai diversion. The segment was modeled as natural channel.
7) Wk.D.34: The private auwai diversion was modeled as a side diversion type with a maximum diversion capacity of 0.6 mgd.[24]
8) Wk.Hab.4: This segment goes from the private auwai upstream to the Everett Ditch Diversion. The segment was modeled as natural channel.
9) Wk.D.45: Everett Ditch Diversion was modeled as a side diversion type with a maximum diversion capacity of 0.65 mgd.[25]
10) Wk.Hab.5: This segment goes from the Everett Ditch Diversion upstream to the South Side Ditch Diversion. The segment was modeled as natural channel.
11) Wk.D.56: South Side Ditch Diversion was modeled as a side diversion type with a maximum diversion capacity of 3.0 mgd.[26]
12) Wk.Hab.6: This section includes all upstream segments above the South Side Ditch Diversion. The segment was modeled as natural channel.

A map of stream segment and barrier locations (Figure 27), the box model (Figure 28) and tables with barrier (Table 8) and baseflow (Q_{70}) flow values (Table 9) are provided for reference.

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[22] Oki et al. 2010 page 85. Combined diversion intake capacity of 2.6 for Reservoir 6 Diversion, Waihee Ditch Diversion, and the private auwai. Divided arbitrarily into 1,1,0.6 mgd respectively.
[23] Oki et al. 2010 page 85. . Combined diversion intake capacity of 2.6 for Reservoir 6 Diversion, Waihee Ditch Diversion, and the private auwai. Divided arbitrarily into 1,1,0.6 mgd respectively.
[24] Oki et al. 2010 page 85. . Combined diversion intake capacity of 2.6 for Reservoir 6 Diversion, Waihee Ditch Diversion, and the private auwai. Divided arbitrarily into 1,1,0.6 mgd respectively.
[25] Oki et al. 2010 page 85.
[26] Oki et al. 2010 page 85.

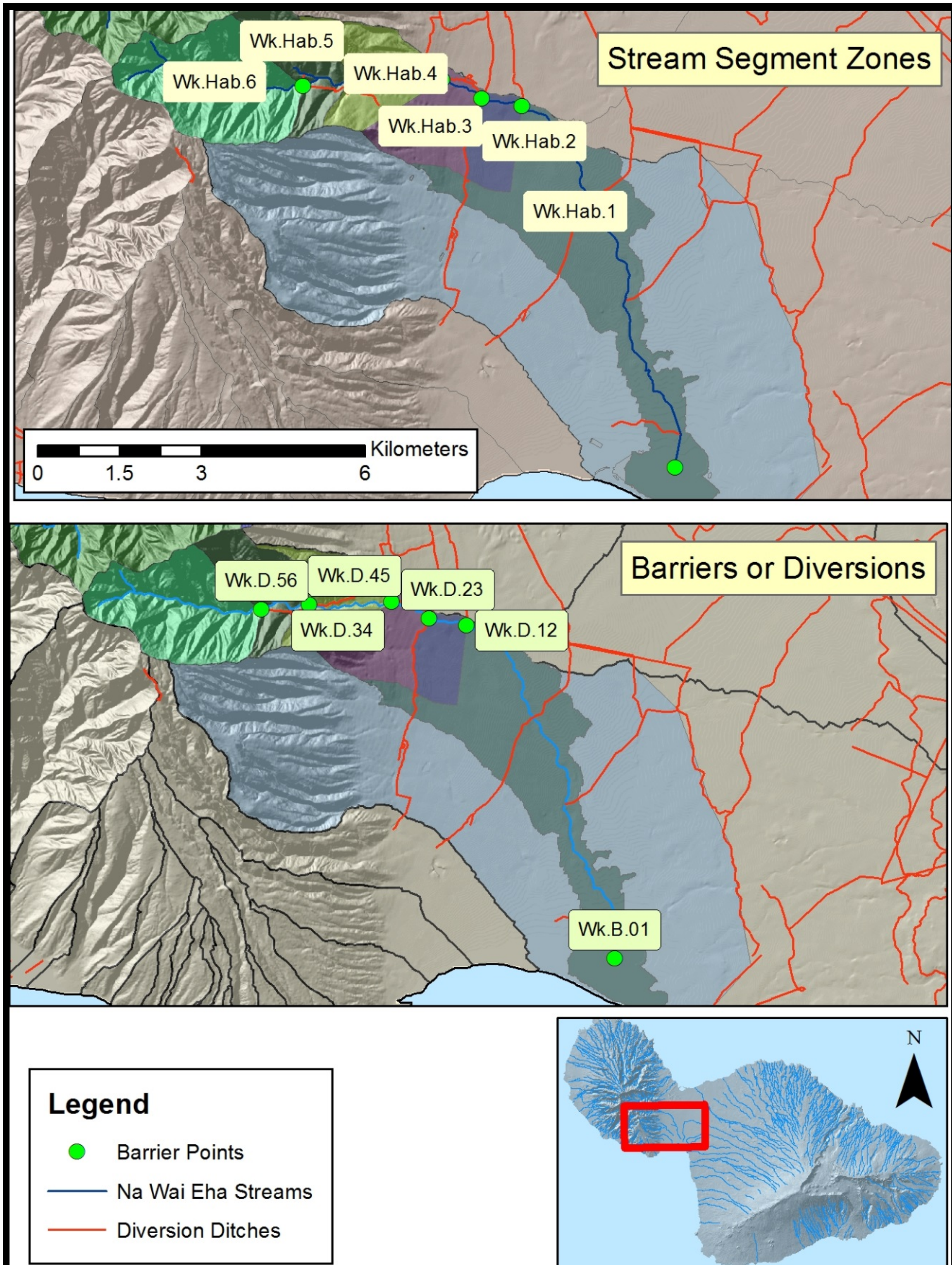

Figure 27: Map showing stream segments, barriers, and diversions associated with the Waikapū Stream HSHEP model.

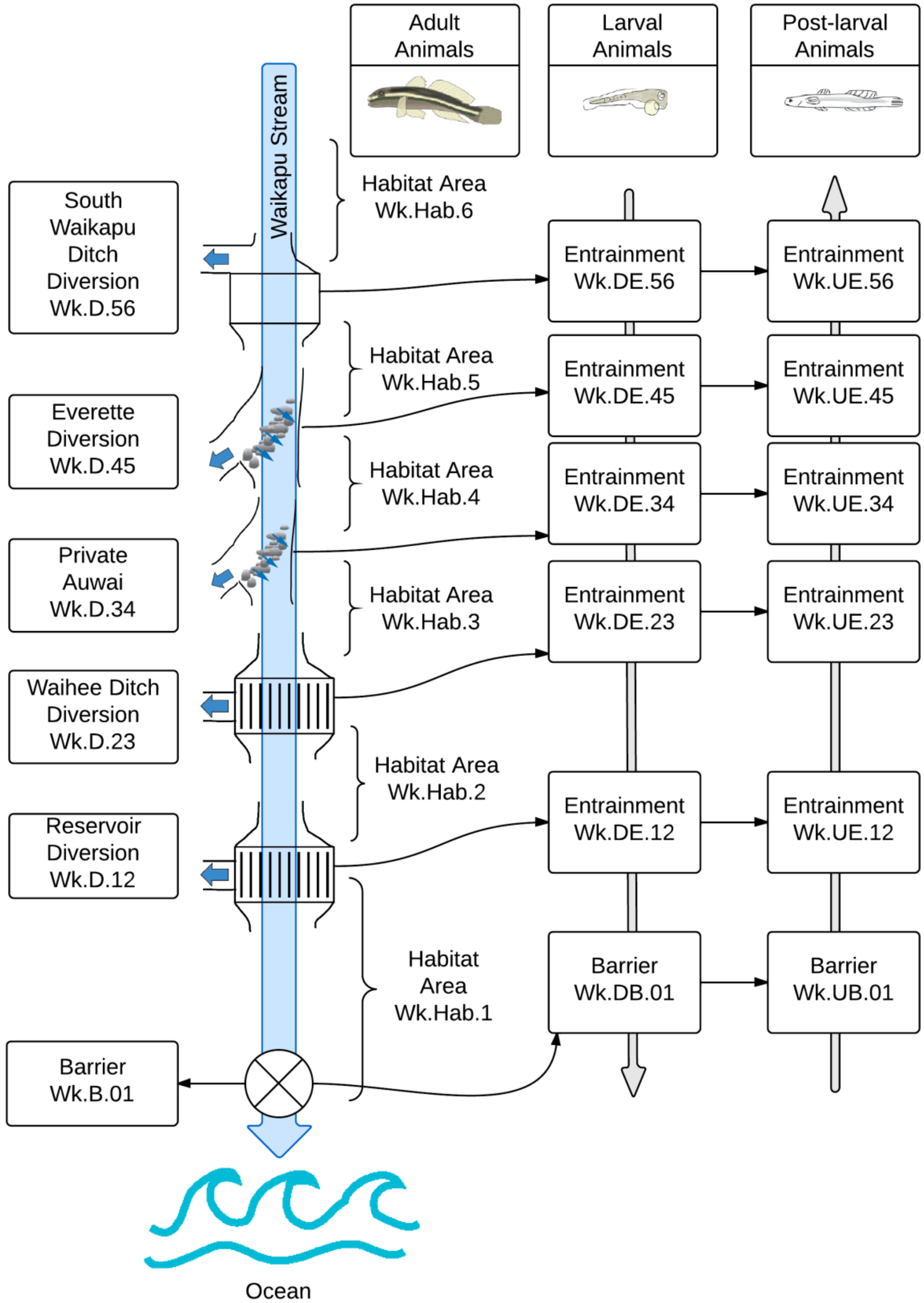

Figure 28: Box Model for Waikapū Stream, Maui. Box model not to scale.

Table 8: Waikapū Stream HSHEP model segments and values for barriers, diversions and associated modifiers.

Stream segment Habitat Code	Perennial Stream Channel length within segment (m)	Channelization habitat modifier	Barrier or Diversion Code at start of segment	Barrier or Diversion Type	Maximum Upstream Barrier Impact during fully diverted conditions	Maximum Upstream Barrier Impact during undiverted conditions	Maximum Downstream Barrier Impact during fully diverted conditions	Maximum Downstream Barrier Impact during undiverted conditions
Wk.Hab.1	0* (9,450)	1	Wk.B.01	Stream mouth barrier	0.78	0.51	0.78	0.51
Wk.Hab.2	820	1	Wk.D.12	Bottom grate diversion	0.80	0	0.80	0
Wk.Hab.3	960	1	Wk.D.23	Bottom grate diversion	0.80	0	0.80	0
Wk.Hab.4	2,130	1	Wk.D.34	Side diversion	0.50	0	0.80	0
Wk.Hab.5	1,860	1	Wk.D.45	Side diversion	0.50	0	0.80	0
Wk.Hab.6	4,800	1	Wk.D.56	Side diversion	0.50	0	0.80	0

*Segment Wk.Hab.1 is not a perennial stream segment, but is an intermittent segment is 9,450 m long.

Table 9: Waikapū Stream HSHEP model segments and values used for natural Q_{70} flows (an estimate of baseflow) at various locations and diversion capacities associated with downstream end of segment. All values interpreted from Oki et al. 2010.

Stream segment Habitat Code	Natural Q70 at start of segment (mgd)	Natural Q70 at end of segment (mgd)	Average Natural Q70 for segment (mgd)	Gain or loss of water at Natural Q70 in segment (mgd)	Barrier or Diversion Code at start of segment	Diversion Capacity (mgd)	Direction of streamflow
Wk.Hab.1	4.20	0.00	2.1	-4.20	Wk.B.01	0.00	
Wk.Hab.2	4.20	4.20	4.2	0.00	Wk.D.12	1.00	
Wk.Hab.3	4.20	4.20	4.2	0.00	Wk.D.23	1.00	
Wk.Hab.4	4.50	4.20	4.35	-0.30	Wk.D.34	0.60	
Wk.Hab.5	3.50	4.50	4	1.00	Wk.D.45	0.65	
Wk.Hab.6	0	3.50	1.75	3.50	Wk.D.56	3.0	

Description of model steps:

To create the HSHEP models that compare the expected distribution and habitat suitability in the Nā Wai ‘Ehā Streams a series of steps were required. The process followed the same steps for each species independently.

1. To predict the watershed level suitability of the Nā Wai ‘Ehā watersheds for a species, the values for each variable were determined for all 430 stream watersheds statewide. These values included ratings for watershed size, wetness, stewardship, stream reach diversity, the amount of estuary and shallow nearshore marine habitat, and land cover. For each species, the predicted values for the watershed scale model were determined using the modeled relationship for the 430 watersheds presented in Figure 3 to Figure 10.

2. The complete set of 430 watershed suitability values was range standardized so that the range of all values had a minimum value of 0 and a maximum value of 1. This resulted in a comparable range of values for each species among the watersheds statewide.

3. Following a similar process as described in the first two steps, the instream suitability was calculated for each 10 m of all streams statewide for each species as described in

Figure 11 to Figure 18. The variables at this level included site elevation, distance inland, and maximum downstream slope (a measure of waterfall size).

4. The instream suitability for all sites statewide was range standardized from a minimum of 0 and the maximum was 1 for each species. This resulted in a comparable range of values for each species among the stream segments statewide.

5. The resulting values for each of the relationships (watershed and stream segment suitability for each species) were appended to separate 10 m grids for each island in ArcGIS.

6. Each grid (watershed and stream segment suitability) was weighted by the r^2 value for the linear relationship developed for the species. The r^2 value was used as an estimator of the strength of the watershed or stream segment suitability model's results in predicting a species occurrence.

7. The grids for each scale were multiplied together in ArcGIS into a multi-scale habitat suitability grid.

8. The GIS layer for DAR streams was converted from vector to grid format and all non-stream cells were set to 0 and all stream cells were set to 1 in ArcGIS.

9. The multi-scale habitat suitability grid was multiplied by the stream grid to remove non-stream cells from the analysis in ArcGIS.

10. The resulting range of values for the multi-scale habitat suitability grid was again range standardized so that the minimum value for grid cells statewide was 0 and the maximum was 1 for each species.

At this point, we have combined and range standardized the watershed and stream scale model with the stream segment scale model and have the values for habitat suitability for each 10 m cell of 430 streams statewide. For each species, the values for the habitat units range from 0 to 1 to reflect suitability. The results of this step are predictions of the non-locally corrected amount of suitable habitat for each species within each watershed.

11. Sites where conditions may decrease habitat suitability, block passage, or entrain animals were added to the modeled stream network. A decrease in suitable habitat may be in response to changes in habitat, barriers to movement, or entrainment of individual animals. Habitat modification refers to loss of instream habitat to water removal or physical modification of the structure (e.g. conversion of a natural channel to a channelized ditch).
12. If the habitat units were lost due to blockage or entrainment during passage, then a passage impact factor was estimated for each location. For example, many stream diversions were engineered to capture low to moderate stream flows and results in near 100% removal of water approximately 70-80% of the time (Gingerich 2005, Oki et al. 2010).The removal of 100% of flow blocks upstream passage and entrains downstream

moving animals. Thus the habitat suitability of sites upstream of a barrier or entraining structure is decreased as a result of the increased difficultly of an animal reaching those sites. The passage impact factor would represent the percent of animals stopped from passing the site and would be the inverse of the percent of animals passing the site.

13. The passage impact value affected all upstream cells within the modeled stream network. For example, a barrier (A) that blocked 80% of fish passage would decrease suitable habitat in all cells above Barrier A by 80%. A second barrier (B), located upstream of Barrier A, blocks an additional 50% of fish passage. Barrier B would decrease habitat suitability at sites upstream of Barrier B an additional 50%. The combination of passage impact values for both Barriers A (80%) and B (50%) would result in a total passage impact value of 90% at sites upstream of Barrier B. The inverse of the percent of fish blocked would be the percent of fish passing the barriers. In this case, 10% of fish would be expected to pass Barrier B (10% Fish pass = 20% fish pass Barrier A * 50% fish pass Barrier B).

14. If decreases in suitable habitat were the result of physical habitat modification, the estimated percent of lost habitat was multiplied with all habitat units within the affected area. This value did not impact upstream areas as described with passage impacts as it only affected the area where habitat was lost.

15. For each species in each stream, the amount for habitat units lost to phyical habitat modification, passage, and entrainment was calculated.

16. To address changes in habitat in response to changes in discharge (flow modification), the relationships between the baseflow (Q_{70}) remaining after diversion and natural baseflow (Q_{70}) were applied from Instream Flow Incremental Methodology (IFIM) studies by USGS in the Nā Wai ʻEhā Streams (Oki et al. 2010). In general, the IFIM relationships account for changes in microhabitat variables (water depth, velocity, and substrate) with respect to changes in discharge. The microhabitat variables are weighted by their suitability to a species or species life stage, and as a result, changes in suitable habitat can be predicted from changes in discharge.

17. The amount of suitable habitat derived from the IFIM equations are intended to represent the average conditions for the area downstream of the diversion. There may be less available habitat immediately downstream of the diversion and more available habitat near the end of the stream segment after the stream has regained water. Therefore, the baseflow calculated at the start and end of the stream segment were averaged to provide an estimate of average baseflow within the whole segment.

18. The impacts associated with habitat loss due to water diversion (flow modification) were calculated within the specific area in which they occurred and did not impact areas up or downstream of the segment.

19. For each species in each area, the amount of habitat units lost due to changes in passage, entrainment, physical habitat modification, and flow modification were calculated. This approach allowed impacts associated with each type of impact to be considered separately as well as combined.

20. To assess the impact of the various modeled scenarios, the model was repeated with the appropriate scenario values (see scenario descriptions).

21. Results for each scenario were created to show Habitat Units available to each species within each stream segment and the streams as a whole.

Scenarios Modeled:

1) Natural: In this scenario there are no diversions or channel alterations within the Nā Wai ‘Ehā Streams. Modeled conditions included:
   a) All diversions were set to 0 water diverted and thus have no barrier or entrainment impact.
   b) Stream mouth barriers (due to water flow not reaching the ocean) were set to the minimum value estimated by the USGS (Oki et al. 2010) as follows:
      - Waihe‘e Stream = 0% (no barrier),
      - Waiehu Stream = 5% barrier (water flows to ocean 95% of the time),
      - ‘Īao Stream = 0% (no barrier),
      - Waikapū Stream = 51% barrier (water flows to ocean less than half of the time).
   c) The impact of the channelized segments in ‘Īao stream was removed by setting the habitat conditions to natural stream channel conditions.

2) Undiverted: Includes all of the Natural Scenario conditions except c). The impact of the channelized section of ‘Īao Stream is included in this scenario. This allows a separation of the impacts of habitat lost to channelization and habitat lost to water flow reduction. Modeled conditions included:
   a) Conditions a) and b) of the Natural Scenario were identical
   b) Concrete-lined channel sections were considered to have no habitat value as compared to a natural stream channel.
   c) Rock-lined channel sections were considered to have 0.33 habitat value as compared to a natural stream channel.
   d) An additional barrier was associated with the upper concrete-lined channel section to reflect the lack of cover and high water temperatures that migrating animals may be exposed to in this section. The maximum barrier impact was set to 10% restriction of passage and was flow moderated with higher Q_{70} flows decreasing the impact of the barrier.
   e) The impact of the Spreckels Ditch diversion within the channelized section of ‘Īao Stream was not included in the effects of the channelized section.

3) Fully Diverted: This scenario represents maximum diversion capacity. Modeled conditions included:
   a) All diversions remove their maximum capacity.
   b) Diversion type (either bottom grate or side diversion) controls maximum up or downstream entrainment estimates. (see diversion type discussion).
   c) Up and downstream diversion entrainment estimates are flow moderated. (see diversion type discussion).
   d) Stream-mouth barrier impact values are flow influenced and values increase from minimum estimates shown in the Natural Scenario (1 b) to higher values when Q_{70} discharge is calculated to be 0 in the terminal steam segment.
      - Waiheʻe Stream = 20% (water flows to ocean 80% of the time),
      - Waiehu Stream = 45% barrier (water flows to ocean 55% of the time),
      - ʻĪao Stream = 66% (water flows to ocean 34% of the time),
      - Waikapū Stream = 78% barrier (water flows to ocean 22% of the time).
   e) The impact of the channelized section of ʻĪao Stream is included in this scenario.

4) 2010 IFS: This scenario reflects the proposed 2010 IFS standards. Modeled conditions included:
   a) All conditions described in the Fully Diverted Scenario, except:
      - Diversion capacities were adjusted to allow a flow of 10 mgd below Spreckels Ditch on Waiheʻe Stream.
      - Diversion capacities were adjusted to allow a flow of 1.6 mgd below North Waiehu Ditch on the North Fork of Waiehu Stream.
      - Diversion capacities were adjusted to allow a flow of 0.9 mgd below Spreckels Ditch on the South Fork of Waiehu Stream.
      - Up and downstream entrainment impacts were flow moderated with the standard technique and were not modified to attempt to mimic specific water return and barrier improvement designs.

5) Flow to Ocean: This scenario reflects the dissenting opinion to the 2010 IFS standards. In this scenario achieving continuous flow from the upstream reaches to the ocean was the goal. Modeled conditions included:
   a) All conditions described in the Fully Diverted Scenario, except:
      - Diversion capacities were adjusted to allow a flow of 10 mgd at the mouth of Waiheʻe Stream.
      - Diversion capacities were adjusted to allow a flow of 1.6 mgd at the mouth of Waiehu Stream.
      - Diversion capacities were adjusted to allow a flow of 6.7 mgd at the mouth of ʻĪao Stream.

- Diversion capacities were adjusted to allow a flow of 4 mgd below Reservoir Diversion on Waikapū Stream.
- Up and downstream entrainment impacts were flow moderated with the standard technique and were not modified to attempt to mimic specific water return and barrier improvement designs.

6) ‘Īao Channelization Improvement: This scenario has the same flow characteristics as the Flow to Ocean Scenario, but adds improvements to the ‘Īao Stream channelized sections.
    - The impacts of the concrete-lined channelized segments in ‘Īao stream were modified by changing the habitat conditions from 0 (no habitat) to 0.5 (habitat half as good as a natural stream channel) to generally reflect improved conditions if a semi-natural low flow channel was added to the channelized segments.
    - Rock-lined channel sections were modified from a 0.33 habitat value to a 0.5 habitat value for the same reasons as the change for the concrete-lined sections.
    - The barrier was associated with the upper concrete-lined channel section that reflected the lack of cover and high water temperatures facing migrating animals was eliminated as both flow and habitat are improved in this scenario.
    - The impact of the Spreckels Ditch diversion within the channelized section of ‘Īao Stream was not included in the effects of the channelized section.

Table 10: Flow and diversion values for the HSHEP model used in Scenario 1: Natural Conditions.

Stream segment Habitat Code	Barrier or Diversion Code at start of segment	Diversion Capacity (mgd)	Water left after diversion (mgd)	Diverted Q70 flow at segment start (mgd)	Diverted Q70 flow at segment end (mgd)	Average Diverted Q70 flow in segment (mgd)	Percent diverted to undiverted Q70 flow
Waiheʻe Stream							
Wh.Hab.1	Wh.B.01	0.00	27.00	28.00	27.00	27.50	100.00
Wh.Hab.2	Wh.D.12	0.00	28.00	29.00	28.00	28.50	100.00
Wh.Hab.3	Wh.D.23	0.00	29.00	28.00	29.00	28.50	100.00
Wh.Hab.4	Wh.D.34	0.00	28.00	0.00	28.00	14.00	100.00
Waiehu Stream							
We.Hab.1	We.B.01	0.00	2.20	2.40	2.20	2.30	100.00
WeS.Hab.2	None	0.00	1.20	1.30	1.20	1.25	100.00
WeS.Hab.3	WeS.D.23	0.00	1.30	2.20	1.30	1.75	100.00
WeS.Hab.4	WeS.D.34	0.00	2.20	2.30	2.20	2.25	100.00
WeS.Hab.5	WeS.D.45	0.00	2.30	0.00	2.30	1.15	100.00
WeN.Hab.2	None	0.00	1.20	2.50	1.20	1.85	100.00
WeN.Hab.3	WeN.D.23	0.00	2.50	0.00	2.50	1.25	100.00
ʻĪao Stream							
Ia.Hab.1	Ia.B.01	0.00	13.00	14.00	13.00	13.50	100.00
Ia.Hab.2	None	0.00	14.00	15.00	14.00	14.50	100.00
Ia.Hab.3	Ia.B.23	0.00	15.00	15.00	15.00	15.00	100.00
Ia.Hab.4	None	0.00	15.00	15.00	15.00	15.00	100.00
Ia.Hab.5	Ia.D.45	0.00	15.00	16.00	15.00	15.50	100.00
Ia.Hab.6	None	0.00	16.00	18.00	16.00	17.00	100.00
Ia.Hab.7	Ia.D.67	0.00	18.00	17.00	18.00	17.50	100.00
Ia.Hab.8	Ia.D.78	0.00	17.00	0.00	17.00	8.50	100.00
Waikapū Stream							
Wk.Hab.1	Wk.B.01	0.00	0.00	4.20	0.00	2.10	100.00
Wk.Hab.2	Wk.D.12	0.00	4.20	4.20	4.20	4.20	100.00
Wk.Hab.3	Wk.D.23	0.00	4.20	4.20	4.20	4.20	100.00
Wk.Hab.4	Wk.D.34	0.00	4.20	4.50	4.20	4.35	100.00
Wk.Hab.5	Wk.D.45	0.00	4.50	3.50	4.50	4.00	100.00
Wk.Hab.6	Wk.D.56	0.00	3.50	0.00	3.50	1.75	100.00

Table 11: Barrier passage and habitat values for the HSHEP model used in Scenario 1: Natural Conditions.

Stream segment Habitat Code	Barrier or Diversion Code at start of segment	Stream Length (m)	Upstream Passage Value	Downstream Passage Value	Natural Channel Value	Perennial Flow Value	Habitat Suitability Value
Waiheʻe Stream							
Wh.Hab.1	Wh.B.01	3,490	1.00	1.00	1.00	1.00	1.00
Wh.Hab.2	Wh.D.12	1,560	1.00	1.00	1.00	1.00	1.00
Wh.Hab.3	Wh.D.23	4,930	1.00	1.00	1.00	1.00	1.00
Wh.Hab.4	Wh.D.34	16,090	1.00	1.00	1.00	1.00	1.00
Waiehu Stream							
We.Hab.1	We.B.01	2,760	0.95	0.95	1.00	1.00	1.00
WeS.Hab.2	None	410	0.95	0.95	1.00	1.00	1.00
WeS.Hab.3	WeS.D.23	2,450	0.95	0.95	1.00	1.00	1.00
WeS.Hab.4	WeS.D.34	370	0.95	0.95	1.00	1.00	1.00
WeS.Hab.5	WeS.D.45	4,400	0.95	0.95	1.00	1.00	1.00
WeN.Hab.2	None	3,550	0.95	0.95	1.00	1.00	1.00
WeN.Hab.3	WeN.D.23	2,910	0.95	0.95	1.00	1.00	1.00
ʻĪao Stream							
Ia.Hab.1	Ia.B.01	830	1.00	1.00	1.00	1.00	1.00
Ia.Hab.2	None	2,860	1.00	1.00	1.00	1.00	1.00
Ia.Hab.3	Ia.B.23	130	1.00	1.00	1.00	1.00	1.00
Ia.Hab.4	None	430	1.00	1.00	1.00	1.00	1.00
Ia.Hab.5	Ia.D.45	950	1.00	1.00	1.00	1.00	1.00
Ia.Hab.6	None	3,260	1.00	1.00	1.00	1.00	1.00
Ia.Hab.7	Ia.D.67	1,100	1.00	1.00	1.00	1.00	1.00
Ia.Hab.8	Ia.D.78	27,960	1.00	1.00	1.00	1.00	1.00
Waikapū Stream							
Wk.Hab.1	Wk.B.01	9,450	0.49	0.49	1.00	0.00	1.00
Wk.Hab.2	Wk.D.12	820	0.49	0.49	1.00	1.00	1.00
Wk.Hab.3	Wk.D.23	960	0.49	0.49	1.00	1.00	1.00
Wk.Hab.4	Wk.D.34	2,130	0.49	0.49	1.00	1.00	1.00
Wk.Hab.5	Wk.D.45	1,860	0.49	0.49	1.00	1.00	1.00
Wk.Hab.6	Wk.D.56	4,800	0.49	0.49	1.00	1.00	1.00

Table 12: Flow and diversion values for the HSHEP model used in Scenario 2: Undiverted Flow

Stream segment Habitat Code	Barrier or Diversion Code at start of segment	Diversion Capacity (mgd)	Water left after diversion (mgd)	Diverted Q70 flow at segment start (mgd)	Diverted Q70 flow at segment end (mgd)	Average Diverted Q70 flow in segment (mgd)	Percent diverted to undiverted Q70 flow
Waiheʻe Stream							
Wh.Hab.1	Wh.B.01	0.00	27.00	28.00	27.00	27.50	100.00
Wh.Hab.2	Wh.D.12	0.00	28.00	29.00	28.00	28.50	100.00
Wh.Hab.3	Wh.D.23	0.00	29.00	28.00	29.00	28.50	100.00
Wh.Hab.4	Wh.D.34	0.00	28.00	0.00	28.00	14.00	100.00
Waiehu Stream							
We.Hab.1	We.B.01	0.00	2.20	2.40	2.20	2.30	100.00
WeS.Hab.2	None	0.00	1.20	1.30	1.20	1.25	100.00
WeS.Hab.3	WeS.D.23	0.00	1.30	2.20	1.30	1.75	100.00
WeS.Hab.4	WeS.D.34	0.00	2.20	2.30	2.20	2.25	100.00
WeS.Hab.5	WeS.D.45	0.00	2.30	0.00	2.30	1.15	100.00
WeN.Hab.2	None	0.00	1.20	2.50	1.20	1.85	100.00
WeN.Hab.3	WeN.D.23	0.00	2.50	0.00	2.50	1.25	100.00
ʻĪao Stream							
Ia.Hab.1	Ia.B.01	0.00	13.00	14.00	13.00	13.50	100.00
Ia.Hab.2	None	0.00	14.00	15.00	14.00	14.50	100.00
Ia.Hab.3	Ia.B.23	0.00	15.00	15.00	15.00	15.00	100.00
Ia.Hab.4	None	0.00	15.00	15.00	15.00	15.00	100.00
Ia.Hab.5	Ia.D.45	0.00	15.00	16.00	15.00	15.50	100.00
Ia.Hab.6	None	0.00	16.00	18.00	16.00	17.00	100.00
Ia.Hab.7	Ia.D.67	0.00	18.00	17.00	18.00	17.50	100.00
Ia.Hab.8	Ia.D.78	0.00	17.00	0.00	17.00	8.50	100.00
Waikapū Stream							
Wk.Hab.1	Wk.B.01	0.00	0.00	4.20	0.00	2.10	100.00
Wk.Hab.2	Wk.D.12	0.00	4.20	4.20	4.20	4.20	100.00
Wk.Hab.3	Wk.D.23	0.00	4.20	4.20	4.20	4.20	100.00
Wk.Hab.4	Wk.D.34	0.00	4.20	4.50	4.20	4.35	100.00
Wk.Hab.5	Wk.D.45	0.00	4.50	3.50	4.50	4.00	100.00
Wk.Hab.6	Wk.D.56	0.00	3.50	0.00	3.50	1.75	100.00

Table 13: Barrier passage and habitat values for the HSHEP model used in Scenario 2: Undiverted Flow.

Stream segment Habitat Code	Barrier or Diversion Code at start of segment	Stream Length (m)	Upstream Passage Value	Downstream Passage Value	Natural Channel Value	Perennial Flow Value	Habitat Suitability Value
Waiheʻe Stream							
Wh.Hab.1	Wh.B.01	3,490	1.00	1.00	1.00	1.00	1.00
Wh.Hab.2	Wh.D.12	1,560	1.00	1.00	1.00	1.00	1.00
Wh.Hab.3	Wh.D.23	4,930	1.00	1.00	1.00	1.00	1.00
Wh.Hab.4	Wh.D.34	16,090	1.00	1.00	1.00	1.00	1.00
Waiehu Stream							
We.Hab.1	We.B.01	2,760	0.95	0.95	1.00	1.00	1.00
WeS.Hab.2	None	410	0.95	0.95	1.00	1.00	1.00
WeS.Hab.3	WeS.D.23	2,450	0.95	0.95	1.00	1.00	1.00
WeS.Hab.4	WeS.D.34	370	0.95	0.95	1.00	1.00	1.00
WeS.Hab.5	WeS.D.45	4,400	0.95	0.95	1.00	1.00	1.00
WeN.Hab.2	None	3,550	0.95	0.95	1.00	1.00	1.00
WeN.Hab.3	WeN.D.23	2,910	0.95	0.95	1.00	1.00	1.00
ʻĪao Stream							
Ia.Hab.1	Ia.B.01	830	1.00	1.00	0.00	1.00	1.00
Ia.Hab.2	None	2,860	1.00	1.00	0.33	1.00	1.00
Ia.Hab.3	Ia.B.23	130	1.00	1.00	0.00	1.00	1.00
Ia.Hab.4	None	430	1.00	1.00	0.00	1.00	1.00
Ia.Hab.5	Ia.D.45	950	1.00	1.00	0.00	1.00	1.00
Ia.Hab.6	None	3,260	1.00	1.00	0.00	1.00	1.00
Ia.Hab.7	Ia.D.67	1,100	1.00	1.00	1.00	1.00	1.00
Ia.Hab.8	Ia.D.78	27,960	1.00	1.00	1.00	1.00	1.00
Waikapū Stream							
Wk.Hab.1	Wk.B.01	9,450	0.49	0.49	1.00	0.00	1.00
Wk.Hab.2	Wk.D.12	820	0.49	0.49	1.00	1.00	1.00
Wk.Hab.3	Wk.D.23	960	0.49	0.49	1.00	1.00	1.00
Wk.Hab.4	Wk.D.34	2,130	0.49	0.49	1.00	1.00	1.00
Wk.Hab.5	Wk.D.45	1,860	0.49	0.49	1.00	1.00	1.00
Wk.Hab.6	Wk.D.56	4,800	0.49	0.49	1.00	1.00	1.00

Table 14: Flow and diversion values for the HSHEP model used in Scenario 3: Fully Diverted Flow.

Stream segment Habitat Code	Barrier or Diversion Code at start of segment	Diversion Capacity (mgd)	Water left after diversion (mgd)	Diverted Q70 flow at segment start (mgd)	Diverted Q70 flow at segment end (mgd)	Average Diverted Q70 flow in segment (mgd)	Percent diverted to undiverted Q70 flow
Waiheʻe Stream							
Wh.Hab.1	Wh.B.01	0.00	0.00	0.00	0.00	0.00	0.00
Wh.Hab.2	Wh.D.12	3.20	0.00	0.00	0.00	0.00	0.00
Wh.Hab.3	Wh.D.23	12.00	0.00	0.00	1.00	0.50	1.75
Wh.Hab.4	Wh.D.34	40.00	0.00	0.00	28.00	14.00	100.00
Waiehu Stream							
We.Hab.1	We.B.01	0.00	0.00	0.00	0.00	0.00	0.00
WeS.Hab.2	None	0.00	0.00	0.00	0.00	0.00	0.00
WeS.Hab.3	WeS.D.23	1.30	0.00	1.56	0.66	1.11	63.43
WeS.Hab.4	WeS.D.34	0.32	1.56	1.98	1.88	1.93	85.78
WeS.Hab.5	WeS.D.45	0.32	1.98	0.00	2.30	1.15	100.00
WeN.Hab.2	None	0.00	0.00	1.00	0.00	0.50	27.03
WeN.Hab.3	WeN.D.23	1.50	1.00	0.00	2.50	1.25	100.00
ʻĪao Stream							
Ia.Hab.1	Ia.B.01	0.00	0.00	0.00	0.00	0.00	0.00
Ia.Hab.2	None	0.00	0.00	0.00	0.00	0.00	0.00
Ia.Hab.3	Ia.B.23	0.00	0.00	0.00	0.00	0.00	0.00
Ia.Hab.4	None	3.90	0.00	0.00	0.00	0.00	0.00
Ia.Hab.5	Ia.D.45	0.00	0.00	0.00	0.00	0.00	0.00
Ia.Hab.6	None	0.00	0.00	0.35	0.00	0.18	1.03
Ia.Hab.7	Ia.D.67	0.65	0.35	0.00	1.00	0.50	2.86
Ia.Hab.8	Ia.D.78	20.00	0.00	0.00	17.00	8.50	100.00
Waikapū Stream							
Wk.Hab.1	Wk.B.01	0.00	0.00	0.00	0.00	0.00	0.00
Wk.Hab.2	Wk.D.12	1.00	0.00	0.00	0.00	0.00	0.00
Wk.Hab.3	Wk.D.23	1.00	0.00	0.00	0.00	0.00	0.00
Wk.Hab.4	Wk.D.34	0.60	0.00	0.85	0.55	0.70	16.00
Wk.Hab.5	Wk.D.45	0.65	0.85	0.50	1.50	1.00	25.00
Wk.Hab.6	Wk.D.56	3.00	0.50	0.00	3.50	1.75	100.00

Table 15: Barrier passage and habitat values for the HSHEP model used in Scenario 3: Fully Diverted Flow.

Stream segment Habitat Code	Barrier or Diversion Code at start of segment	Stream Length (m)	Upstream Passage Value	Downstream Passage Value	Natural Channel Value	Perennial Flow Value	Habitat Suitability Value
Waiheʻe Stream							
Wh.Hab.1	Wh.B.01	3,490	0.80	0.80	1.00	1.00	0.00
Wh.Hab.2	Wh.D.12	1,560	0.40	0.16	1.00	1.00	0.00
Wh.Hab.3	Wh.D.23	4,930	0.20	0.03	1.00	1.00	0.38
Wh.Hab.4	Wh.D.34	16,090	0.04	0.01	1.00	1.00	1.00
Waiehu Stream							
We.Hab.1	We.B.01	2,760	0.55	0.55	1.00	1.00	0.00
WeS.Hab.2	None	410	0.55	0.55	1.00	1.00	0.00
WeS.Hab.3	WeS.D.23	2,450	0.28	0.11	1.00	1.00	0.90
WeS.Hab.4	WeS.D.34	370	0.14	0.02	1.00	1.00	0.96
WeS.Hab.5	WeS.D.45	4,400	0.07	0.00	1.00	1.00	1.00
WeN.Hab.2	None	3,550	0.55	0.55	1.00	1.00	0.73
WeN.Hab.3	WeN.D.23	2,910	0.28	0.11	1.00	1.00	1.00
ʻĪao Stream							
Ia.Hab.1	Ia.B.01	830	0.34	0.34	0.00	1.00	0.00
Ia.Hab.2	None	2,860	0.34	0.34	0.33	1.00	0.00
Ia.Hab.3	Ia.B.23	130	0.31	0.31	0.00	1.00	0.00
Ia.Hab.4	None	430	0.31	0.31	0.00	1.00	0.00
Ia.Hab.5	Ia.D.45	950	0.15	0.06	0.00	1.00	0.00
Ia.Hab.6	None	3,260	0.15	0.06	0.00	1.00	0.33
Ia.Hab.7	Ia.D.67	1,100	0.03	0.01	1.00	1.00	0.42
Ia.Hab.8	Ia.D.78	27,960	0.01	0.00	1.00	1.00	1.00
Waikapū Stream							
Wk.Hab.1	Wk.B.01	9,450	0.22	0.22	1.00	0.00	0.00
Wk.Hab.2	Wk.D.12	820	0.04	0.04	1.00	1.00	0.00
Wk.Hab.3	Wk.D.23	960	0.01	0.01	1.00	1.00	0.00
Wk.Hab.4	Wk.D.34	2,130	0.00	0.00	1.00	1.00	0.64
Wk.Hab.5	Wk.D.45	1,860	0.00	0.00	1.00	1.00	0.72
Wk.Hab.6	Wk.D.56	4,800	0.00	0.00	1.00	1.00	1.00

Table 16: Flow and diversion values for the HSHEP model used in Scenario 4: 2010 IFS.

Stream segment Habitat Code	Barrier or Diversion Code at start of segment	Diversion Capacity (mgd)	Water left after diversion (mgd)	Diverted Q70 flow at segment start (mgd)	Diverted Q70 flow at segment end (mgd)	Average Diverted Q70 flow in segment (mgd)	Percent diverted to undiverted Q70 flow
Waiheʻe Stream							
Wh.Hab.1	Wh.B.01	0.00	6.00	7.00	6.00	6.50	23.64
Wh.Hab.2	Wh.D.12	2.00	7.00	10.00	9.00	9.50	33.33
Wh.Hab.3	Wh.D.23	7.00	10.00	16.00	17.00	16.50	57.89
Wh.Hab.4	Wh.D.34	12.00	16.00	0.00	28.00	14.00	100.00
Waiehu Stream							
We.Hab.1	We.B.01	0.00	1.40	1.10	0.90	1.00	43.48
WeS.Hab.2	None	0.00	0.80	0.90	0.80	0.85	68.00
WeS.Hab.3	WeS.D.23	0.20	0.90	2.00	1.10	1.55	88.57
WeS.Hab.4	WeS.D.34	0.10	2.00	2.20	2.10	2.15	95.56
WeS.Hab.5	WeS.D.45	0.10	2.20	0.00	2.30	1.15	100.00
WeN.Hab.2	None	0.00	0.30	1.60	0.30	0.95	51.35
WeN.Hab.3	WeN.D.23	0.90	1.60	0.00	2.50	1.25	100.00
ʻĪao Stream							
Ia.Hab.1	Ia.B.01	0.00	0.00	0.00	0.00	0.00	0.00
Ia.Hab.2	None	0.00	0.00	0.00	0.00	0.00	0.00
Ia.Hab.3	Ia.B.23	0.00	0.00	0.00	0.00	0.00	0.00
Ia.Hab.4	None	3.90	0.00	0.00	0.00	0.00	0.00
Ia.Hab.5	Ia.D.45	0.00	0.00	0.00	0.00	0.00	0.00
Ia.Hab.6	None	0.00	0.00	0.35	0.00	0.18	1.03
Ia.Hab.7	Ia.D.67	0.65	0.35	0.00	1.00	0.50	2.86
Ia.Hab.8	Ia.D.78	20.00	0.00	0.00	17.00	8.50	100.00
Waikapū Stream							
Wk.Hab.1	Wk.B.01	0.00	0.00	0.00	0.00	0.00	0.00
Wk.Hab.2	Wk.D.12	1.00	0.00	0.00	0.00	0.00	0.00
Wk.Hab.3	Wk.D.23	1.00	0.00	0.00	0.00	0.00	0.00
Wk.Hab.4	Wk.D.34	0.60	0.00	0.85	0.55	0.70	16.00
Wk.Hab.5	Wk.D.45	0.65	0.85	0.50	1.50	1.00	25.00
Wk.Hab.6	Wk.D.56	3.00	0.50	0.00	3.50	1.75	100.00

Table 17: Barrier passage and habitat values for the HSHEP model used in Scenario 4: 2010 IFS.

Stream segment Habitat Code	Barrier or Diversion Code at start of segment	Stream Length (m)	Upstream Passage Value	Downstream Passage Value	Natural Channel Value	Perennial Flow Value	Habitat Suitability Value
Waiheʻe Stream							
Wh.Hab.1	Wh.B.01	3,490	1.00	1.00	1.00	1.00	0.71
Wh.Hab.2	Wh.D.12	1,560	0.63	0.40	1.00	1.00	0.77
Wh.Hab.3	Wh.D.23	4,930	0.42	0.19	1.00	1.00	0.88
Wh.Hab.4	Wh.D.34	16,090	0.28	0.13	1.00	1.00	1.00
Waiehu Stream							
We.Hab.1	We.B.01	2,760	0.95	0.95	1.00	1.00	0.82
WeS.Hab.2	None	410	0.95	0.95	1.00	1.00	0.91
WeS.Hab.3	WeS.D.23	2,450	0.80	0.72	1.00	1.00	0.97
WeS.Hab.4	WeS.D.34	370	0.77	0.66	1.00	1.00	0.99
WeS.Hab.5	WeS.D.45	4,400	0.75	0.64	1.00	1.00	1.00
WeN.Hab.2	None	3,550	0.95	0.95	1.00	1.00	0.85
WeN.Hab.3	WeN.D.23	2,910	0.78	0.68	1.00	1.00	1.00
ʻĪao Stream							
Ia.Hab.1	Ia.B.01	830	0.34	0.34	0.00	1.00	0.00
Ia.Hab.2	None	2,860	0.34	0.34	0.33	1.00	0.00
Ia.Hab.3	Ia.B.23	130	0.31	0.31	0.00	1.00	0.00
Ia.Hab.4	None	430	0.31	0.31	0.00	1.00	0.00
Ia.Hab.5	Ia.D.45	950	0.15	0.06	0.00	1.00	0.00
Ia.Hab.6	None	3,260	0.15	0.06	0.00	1.00	0.33
Ia.Hab.7	Ia.D.67	1,100	0.03	0.01	1.00	1.00	0.42
Ia.Hab.8	Ia.D.78	27,960	0.01	0.00	1.00	1.00	1.00
Waikapū Stream							
Wk.Hab.1	Wk.B.01	9,450	0.22	0.22	1.00	0.00	0.00
Wk.Hab.2	Wk.D.12	820	0.04	0.04	1.00	1.00	0.00
Wk.Hab.3	Wk.D.23	960	0.01	0.01	1.00	1.00	0.00
Wk.Hab.4	Wk.D.34	2,130	0.00	0.00	1.00	1.00	0.64
Wk.Hab.5	Wk.D.45	1,860	0.00	0.00	1.00	1.00	0.72
Wk.Hab.6	Wk.D.56	4,800	0.00	0.00	1.00	1.00	1.00

Table 18: Flow and diversion values for the HSHEP model used in Scenario 5: Flow to Ocean

Stream segment Habitat Code	Barrier or Diversion Code at start of segment	Diversion Capacity (mgd)	Water left after diversion (mgd)	Diverted Q70 flow at segment start (mgd)	Diverted Q70 flow at segment end (mgd)	Average Diverted Q70 flow in segment (mgd)	Percent diverted to undiverted Q70 flow
Waiheʻe Stream							
Wh.Hab.1	Wh.B.01	0.00	10.00	11.00	10.00	10.50	38.18
Wh.Hab.2	Wh.D.12	1.00	11.00	13.00	12.00	12.50	43.86
Wh.Hab.3	Wh.D.23	2.00	13.00	14.00	15.00	14.50	50.88
Wh.Hab.4	Wh.D.34	14.00	14.00	0.00	28.00	14.00	100.00
Waiehu Stream							
We.Hab.1	We.B.01	0.00	1.60	1.60	1.40	1.50	65.22
WeS.Hab.2	None	0.00	0.90	1.00	0.90	0.95	76.00
WeS.Hab.3	WeS.D.23	0.10	1.00	2.00	1.10	1.55	88.57
WeS.Hab.4	WeS.D.34	0.10	2.00	2.20	2.10	2.15	95.56
WeS.Hab.5	WeS.D.45	0.10	2.20	0.00	2.30	1.15	100.00
WeN.Hab.2	None	0.00	0.70	2.00	0.70	1.35	72.97
WeN.Hab.3	WeN.D.23	0.50	2.00	0.00	2.50	1.25	100.00
ʻĪao Stream							
Ia.Hab.1	Ia.B.01	0.00	6.70	7.70	6.70	7.20	53.33
Ia.Hab.2	None	0.00	7.70	8.70	7.70	8.20	56.55
Ia.Hab.3	Ia.B.23	0.00	8.70	8.70	8.70	8.70	58.00
Ia.Hab.4	None	1.10	8.70	9.80	9.80	9.80	65.33
Ia.Hab.5	Ia.D.45	0.00	9.80	10.80	9.80	10.30	66.45
Ia.Hab.6	None	0.00	10.80	12.80	10.80	11.80	69.41
Ia.Hab.7	Ia.D.67	0.20	12.80	12.00	13.00	12.50	71.43
Ia.Hab.8	Ia.D.78	5.00	12.00	0.00	17.00	8.50	100.00
Waikapū Stream							
Wk.Hab.1	Wk.B.01	0.00	0.00	4.00	0.00	2.00	95.24
Wk.Hab.2	Wk.D.12	0.00	4.00	4.00	4.00	4.00	95.24
Wk.Hab.3	Wk.D.23	0.00	4.00	4.00	4.00	4.00	95.24
Wk.Hab.4	Wk.D.34	0.10	4.00	4.40	4.10	4.25	97.70
Wk.Hab.5	Wk.D.45	0.10	4.40	3.50	4.50	4.00	100.00
Wk.Hab.6	Wk.D.56	0.00	3.50	0.00	3.50	1.75	100.00

Table 19: Barrier passage and habitat values for the HSHEP model used in Scenario 5: Flow to Ocean

Stream segment Habitat Code	Barrier or Diversion Code at start of segment	Stream Length (m)	Upstream Passage Value	Downstream Passage Value	Natural Channel Value	Perennial Flow Value	Habitat Suitability Value
Waiheʻe Stream							
Wh.Hab.1	Wh.B.01	3,490	1.00	1.00	1.00	1.00	0.79
Wh.Hab.2	Wh.D.12	1,560	0.70	0.51	1.00	1.00	0.82
Wh.Hab.3	Wh.D.23	4,930	0.50	0.29	1.00	1.00	0.85
Wh.Hab.4	Wh.D.34	16,090	0.30	0.17	1.00	1.00	1.00
Waiehu Stream							
We.Hab.1	We.B.01	2,760	0.95	0.95	1.00	1.00	0.90
WeS.Hab.2	None	410	0.95	0.95	1.00	1.00	0.94
WeS.Hab.3	WeS.D.23	2,450	0.84	0.77	1.00	1.00	0.97
WeS.Hab.4	WeS.D.34	370	0.80	0.72	1.00	1.00	0.99
WeS.Hab.5	WeS.D.45	4,400	0.78	0.69	1.00	1.00	1.00
WeN.Hab.2	None	3,550	0.95	0.95	1.00	1.00	0.93
WeN.Hab.3	WeN.D.23	2,910	0.86	0.80	1.00	1.00	1.00
ʻĪao Stream							
Ia.Hab.1	Ia.B.01	830	1.00	1.00	0.00	1.00	0.86
Ia.Hab.2	None	2,860	1.00	1.00	0.33	1.00	0.87
Ia.Hab.3	Ia.B.23	130	0.96	0.96	0.00	1.00	0.88
Ia.Hab.4	None	430	0.96	0.96	0.00	1.00	0.90
Ia.Hab.5	Ia.D.45	950	0.79	0.69	0.00	1.00	0.91
Ia.Hab.6	None	3,260	0.79	0.69	0.00	1.00	0.92
Ia.Hab.7	Ia.D.67	1,100	0.61	0.53	1.00	1.00	0.92
Ia.Hab.8	Ia.D.78	27,960	0.47	0.41	1.00	1.00	1.00
Waikapū Stream							
Wk.Hab.1	Wk.B.01	9,450	0.22	0.22	1.00	0.00	0.99
Wk.Hab.2	Wk.D.12	820	0.21	0.21	1.00	1.00	0.99
Wk.Hab.3	Wk.D.23	960	0.20	0.20	1.00	1.00	0.99
Wk.Hab.4	Wk.D.34	2,130	0.20	0.20	1.00	1.00	0.99
Wk.Hab.5	Wk.D.45	1,860	0.20	0.19	1.00	1.00	1.00
Wk.Hab.6	Wk.D.56	4,800	0.20	0.19	1.00	1.00	1.00

Table 20: Flow and diversion values for the HSHEP model used in Scenario 6: Flow to Ocean plus ‘Īao Channelization Improvements.

Stream segment Habitat Code	Barrier or Diversion Code at start of segment	Diversion Capacity (mgd)	Water left after diversion (mgd)	Diverted Q70 flow at segment start (mgd)	Diverted Q70 flow at segment end (mgd)	Average Diverted Q70 flow in segment (mgd)	Percent diverted to undiverted Q70 flow
Waihe‘e Stream							
Wh.Hab.1	Wh.B.01	0.00	10.00	11.00	10.00	10.50	38.18
Wh.Hab.2	Wh.D.12	1.00	11.00	13.00	12.00	12.50	43.86
Wh.Hab.3	Wh.D.23	2.00	13.00	14.00	15.00	14.50	50.88
Wh.Hab.4	Wh.D.34	14.00	14.00	0.00	28.00	14.00	100.00
Waiehu Stream							
We.Hab.1	We.B.01	0.00	1.60	1.60	1.40	1.50	65.22
WeS.Hab.2	None	0.00	0.90	1.00	0.90	0.95	76.00
WeS.Hab.3	WeS.D.23	0.10	1.00	2.00	1.10	1.55	88.57
WeS.Hab.4	WeS.D.34	0.10	2.00	2.20	2.10	2.15	95.56
WeS.Hab.5	WeS.D.45	0.10	2.20	0.00	2.30	1.15	100.00
WeN.Hab.2	None	0.00	0.70	2.00	0.70	1.35	72.97
WeN.Hab.3	WeN.D.23	0.50	2.00	0.00	2.50	1.25	100.00
‘Īao Stream							
Ia.Hab.1	Ia.B.01	0.00	6.70	7.70	6.70	7.20	53.33
Ia.Hab.2	None	0.00	7.70	8.70	7.70	8.20	56.55
Ia.Hab.3	Ia.B.23	0.00	8.70	8.70	8.70	8.70	58.00
Ia.Hab.4	None	1.10	8.70	9.80	9.80	9.80	65.33
Ia.Hab.5	Ia.D.45	0.00	9.80	10.80	9.80	10.30	66.45
Ia.Hab.6	None	0.00	10.80	12.80	10.80	11.80	69.41
Ia.Hab.7	Ia.D.67	0.20	12.80	12.00	13.00	12.50	71.43
Ia.Hab.8	Ia.D.78	5.00	12.00	0.00	17.00	8.50	100.00
Waikapū Stream							
Wk.Hab.1	Wk.B.01	0.00	0.00	4.00	0.00	2.00	95.24
Wk.Hab.2	Wk.D.12	0.00	4.00	4.00	4.00	4.00	95.24
Wk.Hab.3	Wk.D.23	0.00	4.00	4.00	4.00	4.00	95.24
Wk.Hab.4	Wk.D.34	0.10	4.00	4.40	4.10	4.25	97.70
Wk.Hab.5	Wk.D.45	0.10	4.40	3.50	4.50	4.00	100.00
Wk.Hab.6	Wk.D.56	0.00	3.50	0.00	3.50	1.75	100.00

Table 21: Barrier passage and habitat values for the HSHEP model used in Scenario 6: Flow to Ocean plus ‘Īao Channelization Improvements.

Stream segment Habitat Code	Barrier or Diversion Code at start of segment	Stream Length (m)	Upstream Passage Value	Downstream Passage Value	Natural Channel Value	Perennial Flow Value	Habitat Suitability Value
Waihe‘e Stream							
Wh.Hab.1	Wh.B.01	3,490	1.00	1.00	1.00	1.00	0.79
Wh.Hab.2	Wh.D.12	1,560	0.70	0.51	1.00	1.00	0.82
Wh.Hab.3	Wh.D.23	4,930	0.50	0.29	1.00	1.00	0.85
Wh.Hab.4	Wh.D.34	16,090	0.30	0.17	1.00	1.00	1.00
Waiehu Stream							
We.Hab.1	We.B.01	2,760	0.95	0.95	1.00	1.00	0.90
WeS.Hab.2	None	410	0.95	0.95	1.00	1.00	0.94
WeS.Hab.3	WeS.D.23	2,450	0.84	0.77	1.00	1.00	0.97
WeS.Hab.4	WeS.D.34	370	0.80	0.72	1.00	1.00	0.99
WeS.Hab.5	WeS.D.45	4,400	0.78	0.69	1.00	1.00	1.00
WeN.Hab.2	None	3,550	0.95	0.95	1.00	1.00	0.93
WeN.Hab.3	WeN.D.23	2,910	0.86	0.80	1.00	1.00	1.00
‘Īao Stream							
Ia.Hab.1	Ia.B.01	830	1.00	1.00	0.50	1.00	0.86
Ia.Hab.2	None	2,860	1.00	1.00	0.50	1.00	0.87
Ia.Hab.3	Ia.B.23	130	0.96	0.96	0.50	1.00	0.88
Ia.Hab.4	None	430	0.96	0.96	0.50	1.00	0.90
Ia.Hab.5	Ia.D.45	950	0.79	0.69	0.50	1.00	0.91
Ia.Hab.6	None	3,260	0.79	0.69	0.50	1.00	0.92
Ia.Hab.7	Ia.D.67	1,100	0.61	0.53	1.00	1.00	0.92
Ia.Hab.8	Ia.D.78	27,960	0.47	0.41	1.00	1.00	1.00
Waikapū Stream							
Wk.Hab.1	Wk.B.01	9,450	0.22	0.22	1.00	0.00	0.99
Wk.Hab.2	Wk.D.12	820	0.21	0.21	1.00	1.00	0.99
Wk.Hab.3	Wk.D.23	960	0.20	0.20	1.00	1.00	0.99
Wk.Hab.4	Wk.D.34	2,130	0.20	0.20	1.00	1.00	0.99
Wk.Hab.5	Wk.D.45	1,860	0.20	0.19	1.00	1.00	1.00
Wk.Hab.6	Wk.D.56	4,800	0.20	0.19	1.00	1.00	1.00

Results:

The output of the HSHEP model for Nā Wai ʻEhā Streams quantified the amount of habitat units expected to occur within each segment of the streams for each species and for each scenario. Additionally, the habitat units for each species were combined for each segment to provide a picture of how "all species combined" would be influenced by the different management scenarios. Maps and data tables for each species and all species combined area provided after the written description of the results.

The species are discussed from those that occur furthest upstream to those most likely found near the stream mouth. The grouping for "all species combined" is covered last.

***Atyoida bisulcata*:**

Under natural flow conditions, ʻĪao and Waiheʻe Streams would have the most suitable habitat in their upper reaches for *Atyoida bisulcata*. In contrast to this, under the Fully Diverted Flow Scenario most habitat units would be found in the North Fork of Waiehu Stream. The North and South Fork of Waiehu Stream continue to contain the most habitat units for *A. bisulcata* under the 2010 IFS Scenario with Waiheʻe stream following with approximately half as much habitat. Providing Flow to Ocean (Scenario 5) and combining it with habitat improvement to the ʻĪao Flood Control Project's channelized section (Scenario 6) would create the most habitat units for *A. bisulcata* in ʻĪao Stream, ultimately resulting in nearly twice as much habitat as found in Waiehu Stream. In terms of habitat suitability, Waiehu Stream would have the highest percentage of habitat compared to stream length for all scenarios except under the natural and undiverted flow scenarios. Overall, in the most favorable Scenario 6 for habitat restoration only about 1/5 of the natural amount of habitat would be restored to the Nā Wai ʻEhā Streams.

***Lentipes concolor*:**

Under natural conditions, *Lentipes concolor* would have had habitat in the middle to upper reaches of Waiheʻe , ʻĪao and Waiehu Streams with a small amount of habitat in Waikapū Stream. The most suitable reaches would be found in upper Waiheʻe Stream followed by the upper reaches of ʻĪao Stream with suitability decreasing toward the mouth of each stream. Like most species, under fully diverted conditions there is little habitat for *L. concolor*, with the exception of a small amount in Waiehu Stream. Flow restoration as defined by the 2010 IFS Scenario would return approximately 10% of natural habitat to Nā Wai ʻEhā Streams and doubling this amount under the flow to the ocean scenario. Improvements to the ʻĪao channelization sections would only add a small amount of *L. concolor* habitat as most habitat units for *L. concolor* are found upstream of the channelized section.

***Awaous guamensis*:**

Under natural conditions, *Awaous guamensis* would have been widely distributed throughout the Nā Wai ʻEhā Streams including having some habitat in Waikapū Stream. The area with the highest suitable habitat would be lower ʻĪao Stream followed by lower Waiheʻe Stream, but substantial amount of habitat units could be found in all stream segments. In contrast to the widespread habitat under natural conditions, *A. guamensis* habitat units were mostly limited to Waiehu Stream under fully diverted conditions. In each of the scenarios with flow restoration, habitat units for *A. guamensis* appear wherever continuous baseflow is present. In natural conditions, the most suitable habitat is found in the lower ʻĪao Stream followed by lower Waiheʻe Stream and flow and habitat restoration in those areas would result in large positive habitat responses. Overall, habitat restoration combined with flow to the ocean (Scenario 6) would return approximately 43% of the natural amount of habitat for *A. guamensis* to the Nā Wai ʻEhā Streams.

***Sicyopterus stimpsoni* and *Neritina granosa*:**

Sicyopterus stimpsoni and *Neritina granosa* have similar distributional patterns with more habitat found in the lower reaches of streams but having habitat throughout the lower and middle reaches. Under natural flow conditions, *S. stimpsoni* would have the most suitable habitat areas in the low end of ʻĪao and then Waiheʻe Stream. Under flow restoration scenarios (Scenarios 4, 5, and 6), the low end of Waiheʻe Stream was modeled as the most suitable habitat followed by the low end of Waiehu and ʻĪao Streams. Combining flow to the ocean with habitat improvement to the ʻĪao Flood Control Project's channelized section (Scenario 6) would restore 44% of the natural habitat for *S. stimpsoni* and 41% of the habitat for *N. granosa* in the Nā Wai ʻEhā Streams.

The results of the HSHEP model for *S. stimpsoni* in the Nā Wai ʻEhā streams highlight an interesting finding when compared with comments in the USGS report associated with *S. stimpsoni* (ʻoʻopu nōpili) observation in their surveys.

> Exceptions to the general segregation along elevation and longitudinal gradients, however, are known to exist. For example, adult ʻoʻopu nōpili were commonly observed near the mouth of Waiheʻe River during this study. The reasons these ʻoʻopu nōpili do not migrate farther upstream are unknown. (Oki et al. 2010, page 19)

By applying the multi-spatial HSHEP model that is based on the observed presence of *S. stimpsoni* in 1668 out of 8300 different survey locations among 114 streams statewide, the lowest segment of Waiheʻe Stream was modeled as some of the most suitable habitat in the Nā Wai ʻEhā area for *S. stimpsoni*. This highlights how modeled species habitat considers more than “general patterns” when predicting habitat suitability and can address local variability that may not be obvious to field surveyors.

***Eleotris sandwicensis, Macrobrachium grandimanus,* and *Stenogobius hawaiiensis*:**

Members of this group of species all share a common pattern of habitat distribution within the Nā Wai ʻEhā Streams. All of these animals are more common in estuaries or low reaches of streams and this is seen in the modeled results. *Macrobrachium grandimanus* has the most habitat and has the broadest distribution in the streams, but is still primarily found in the lower reaches of Waiheʻe, ʻĪao, and Waiehu Streams. *Eleotris sandwicensis* and *Stenogobius hawaiiensis* have similar amounts of habitat available and it is restricted to the lowest segment of the streams.

Under fully diverted conditions, habitat for this group is mostly eliminated as no water would be found in the lower reaches of the streams. In any flow restoration scenario where water is returned to a stream’s lower reach, habitat for members of this group is created. The combination of flow restoration and habitat improvements in the lower reach of ʻĪao Stream would create substantial additional habitat for these animals.

One area in which the HSHEP model could not accurately model the potential habitat for these species would be found in the Kealia Pond. Due to an incomplete understanding of the habitat and flow characteristics found in the pond, no attempt was made to model instream habitat. The general concept that increased flow into the pond would create or improve available habitat for these species is likely true, but this is only a general assumption.

All species combined:

ʻĪao Stream has longest perennial channel of all the Nā Wai ʻEhā Streams and makes up over 41% of the overall perennial stream channel length for this group of streams. In terms of perennial stream channel length, ʻĪao Stream is followed, in order, by Waiheʻe Stream, Waiehu Stream, and Waikapū Stream (Tables 47 and 48). Waikapū Stream is the only naturally interrupted stream in the Nā Wai ʻEhā group (Polhemus et al. 1992) as upstream perennial segments all flow into an intermittent lower segment.

When comparing the Nā Wai ʻEhā Streams in terms of natural conditions (no diversions and no channelized sections), the difference in the quantity of combined species habitat units is substantial and is not just related to perennial channel length. ʻĪao Stream (49%) and Waiheʻe Stream (37.8%) make up a large majority (87.8%) of combined species habitat units, while Waikapū Stream contains less than 1% of naturally occurring native amphidromous animal habitat units within the Nā Wai ʻEhā Streams.

In contrast to unaltered conditions, the quantity and distribution of combined species habitat units in the fully altered condition (maximum diversion and channelized sections) is substantially different. The overall amount of habitat units in the Nā Wai ʻEhā Streams decreases by over 99% and native species habitat units are effectively eliminated from ʻĪao and Waiheʻe Streams. Under fully altered conditions, Waiehu Stream contains the majority of the combined species habitat in the Nā Wai ʻEhā Streams (96.9%).

Under the 2010 IFS Scenario, improved flow conditions in both Waiheʻe and Waiehu Streams are reflected in the large increases in combined species habitat within these streams. Waiehu Stream gained over 3,500 combined species habitat units and went from 6.1% of natural habitat units under the fully altered condition to 55.5% of natural habitat units under the 2010 IFS Scenario. Likewise, Waiheʻe Stream gained over 2,400 combined species habitat units and went from less than 1% of natural habitat units under the fully altered condition to 11.1% of natural habitat units under the 2010 IFS Scenario. Flow conditions for ʻĪao and Waikapū Streams were unchanged in this scenario and, as expected, no improvements to their habitat units were observed.

Under the Flow to Ocean and ʻĪao Channelization Improvement scenarios (5 and 6) an increase in habitat units was observed for all species combined. The largest increases were observed in ʻĪao Stream where flow restoration (scenario 5) and additional habitat restoration (scenario 6) provided gains in animal passage and habitat quality. Flow restoration returns approximately 27% of natural habitat units to the Nā Wai ʻEhā Streams and the additional habitat improvement to the ʻĪao stream channel increase that total to over 30% of natural habitat units.

In terms of stream segments with the highest suitable habitat for all species combined (habitat units/segment length), lower ʻĪao and Waiheʻe Streams have the greatest amount of suitable habitat. As a general pattern, ʻĪao Stream had the greatest amount of suitable habitat and was followed closely by Waiheʻe and Waiehu Streams. In comparison to ʻĪao Stream, Waikapū has only 1.6% of the habitat units for all species combined and thus restoration potential is limited.

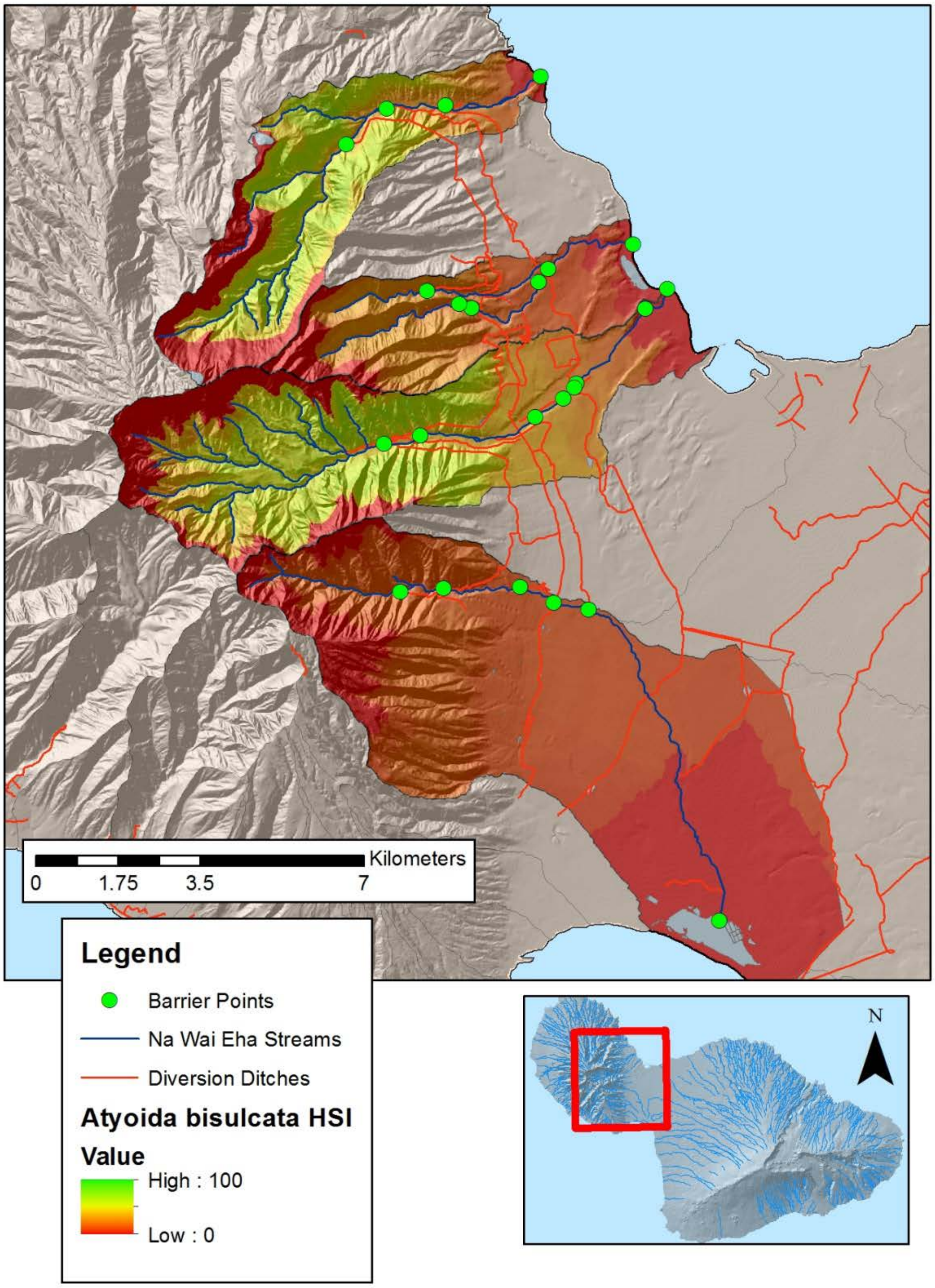

Figure 29: Map of Habitat Suitability Index (HSI) distribution for *Atyoida bisulcata* in the Nā Wai ʻEhā Streams prior to specific scenario modeling. HSI values from 0 to 1 were expanded to 0 to 100 and are shown throughout the watershed for visualization purposes. In the HSHEP model only values that occur within stream channel cells are used for habitat quantification.

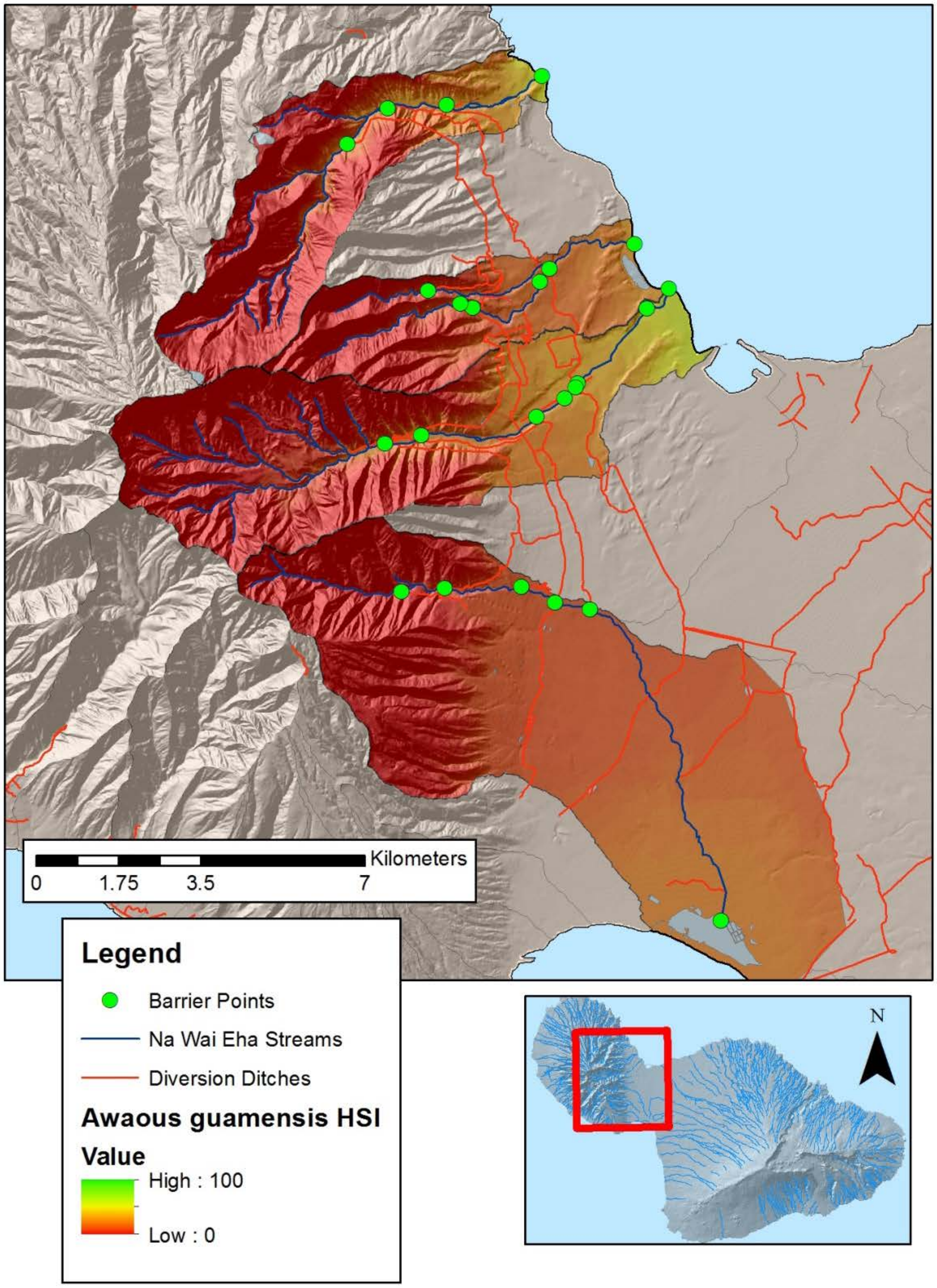

Figure 30: Map of Habitat Suitability Index (HSI) distribution for *Awaous guamensis* in the Nā Wai ʻEhā Streams prior to specific scenario modeling. HSI values from 0 to 1 were expanded to 0 to 100 and are shown throughout the watershed for visualization purposes. In the HSHEP model only values that occur within stream channel cells are used for habitat quantification.

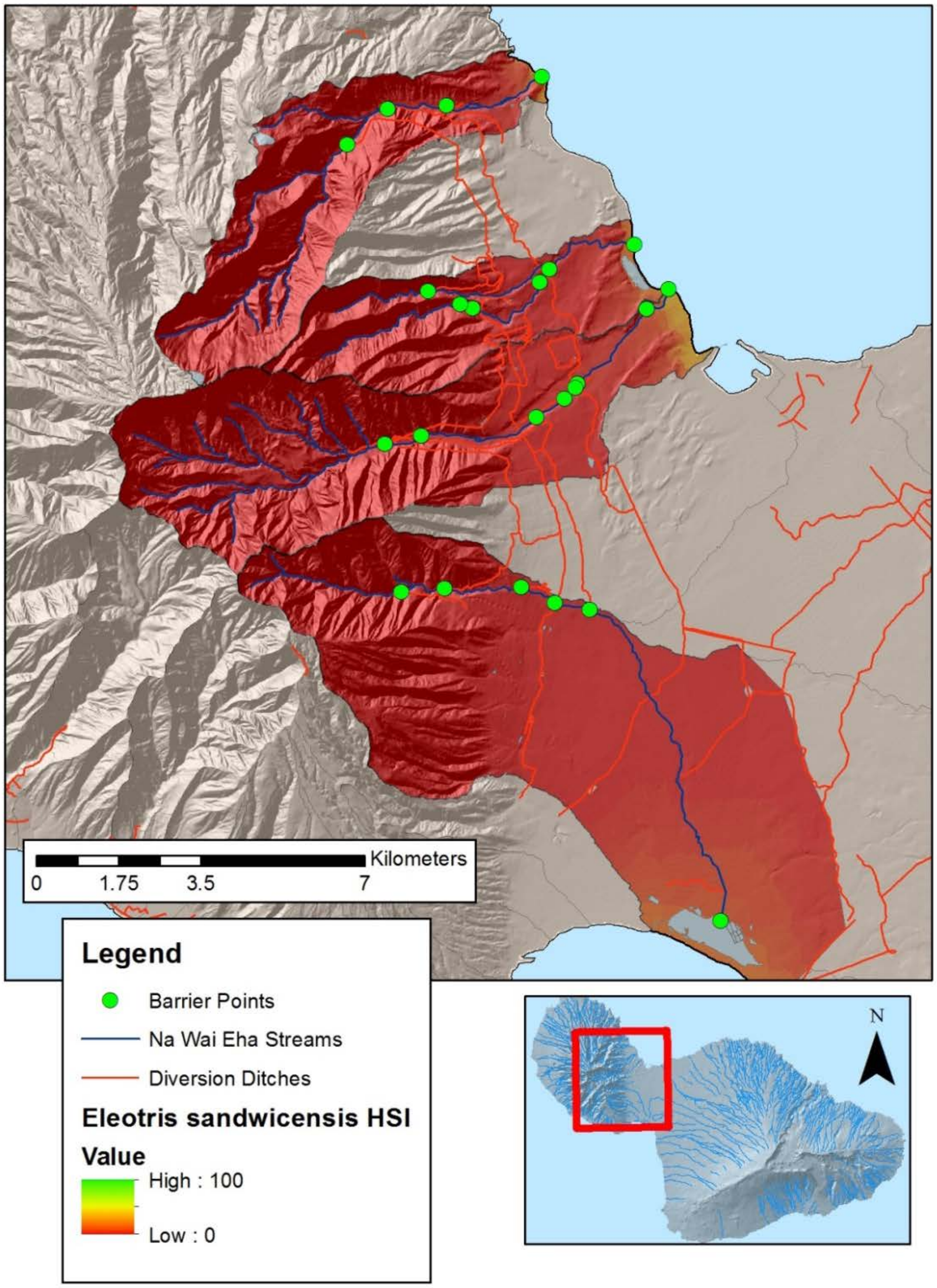

Figure 31: Map of Habitat Suitability Index (HSI) distribution for *Eleotris sandwicensis* in the Nā Wai ʻEhā Streams prior to specific scenario modeling. HSI values from 0 to 1 were expanded to 0 to 100 and are shown throughout the watershed for visualization purposes. In the HSHEP model only values that occur within stream channel cells are used for habitat quantification.

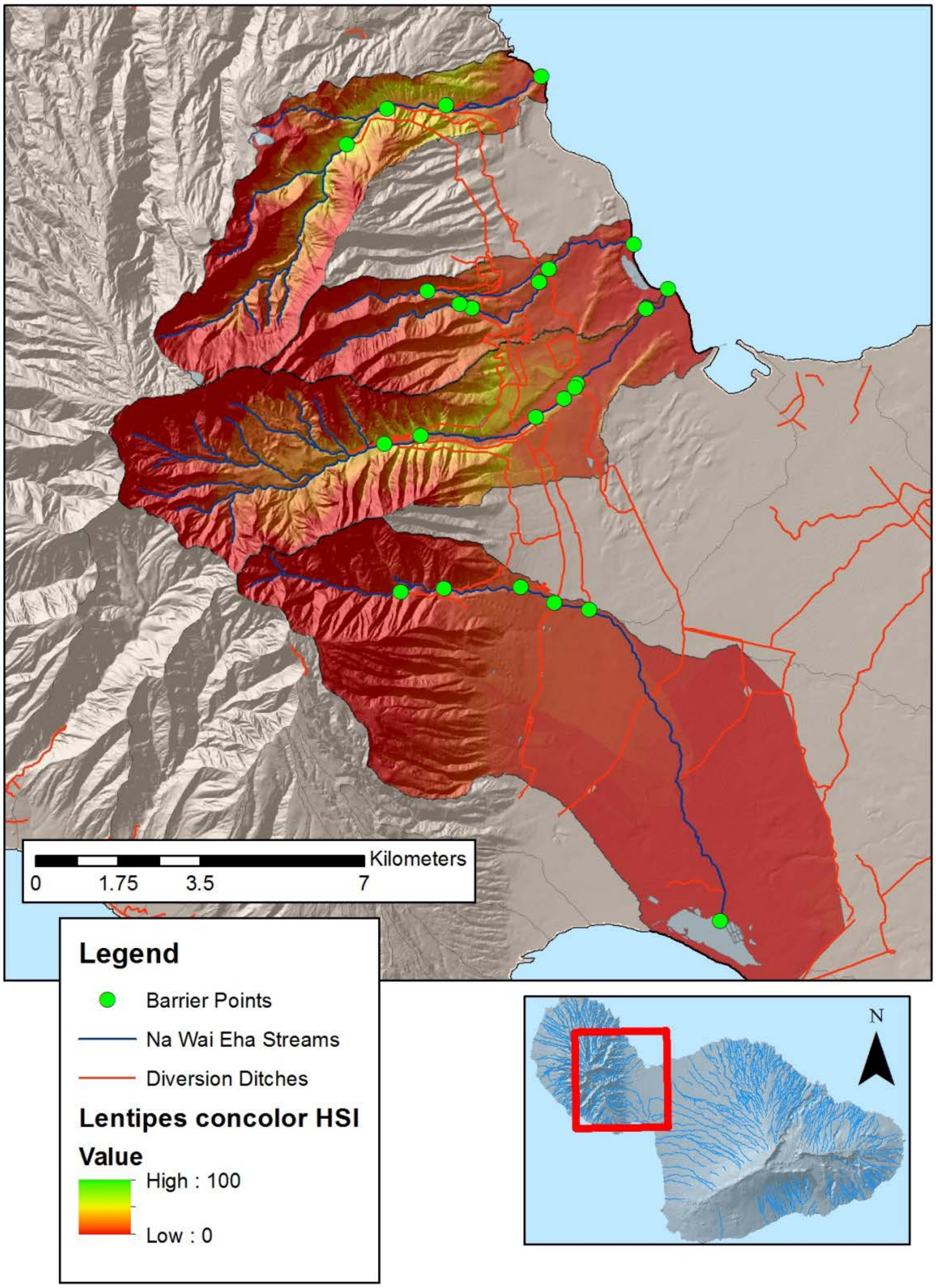

Figure 32: Map of Habitat Suitability Index (HSI) distribution for *Lentipes concolor* in the Nā Wai ʻEhā Streams prior to specific scenario modeling. HSI values from 0 to 1 were expanded to 0 to 100 and are shown throughout the watershed for visualization purposes. In the HSHEP model only values that occur within stream channel cells are used for habitat quantification.

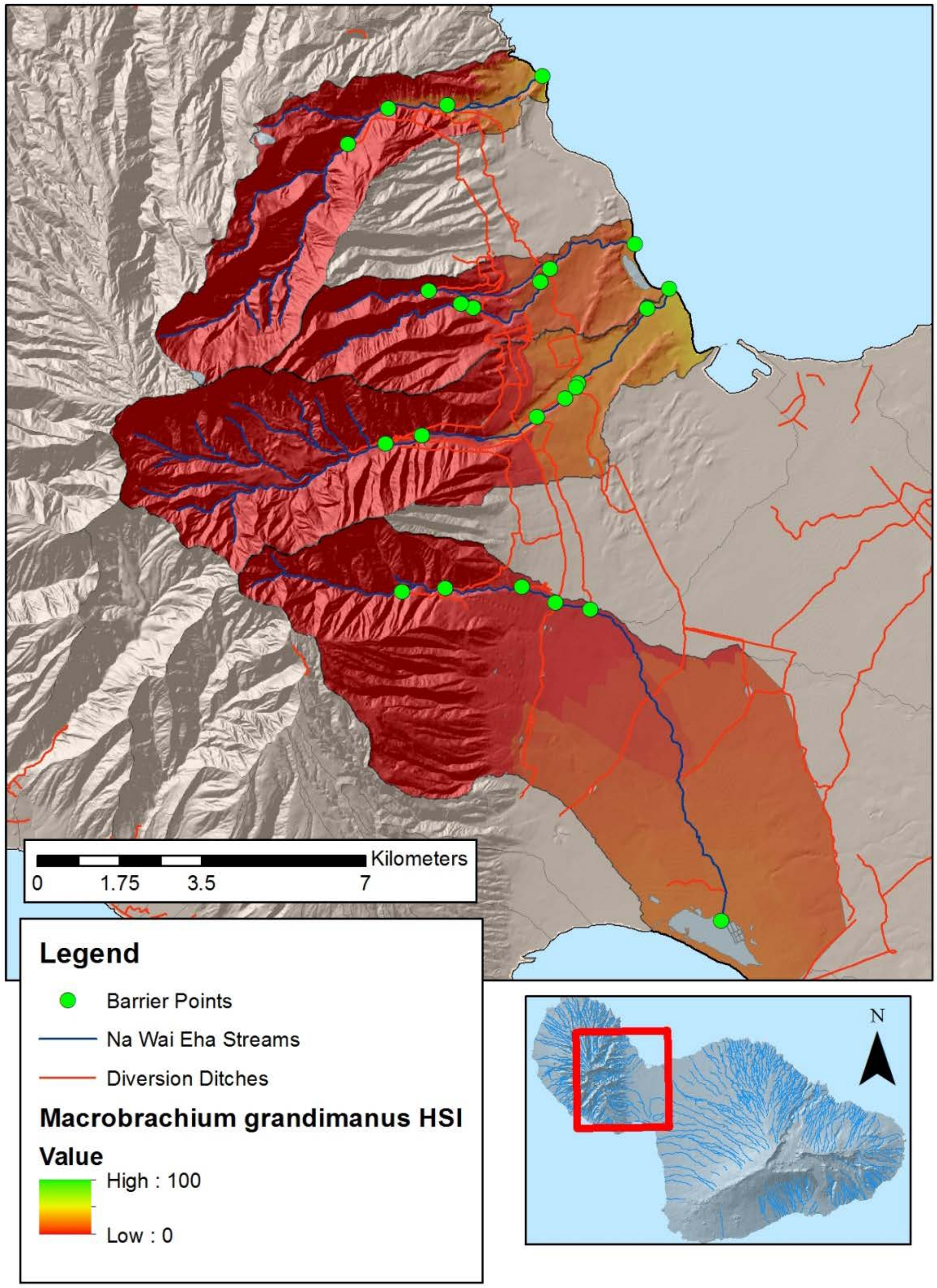

Figure 33: Map of Habitat Suitability Index (HSI) distribution for *Macrobrachium grandimanus* in the Nā Wai ʻEhā Streams prior to specific scenario modeling. HSI values from 0 to 1 were expanded to 0 to 100 and are shown throughout the watershed for visualization purposes. In the HSHEP model only values that occur within stream channel cells are used for habitat quantification.

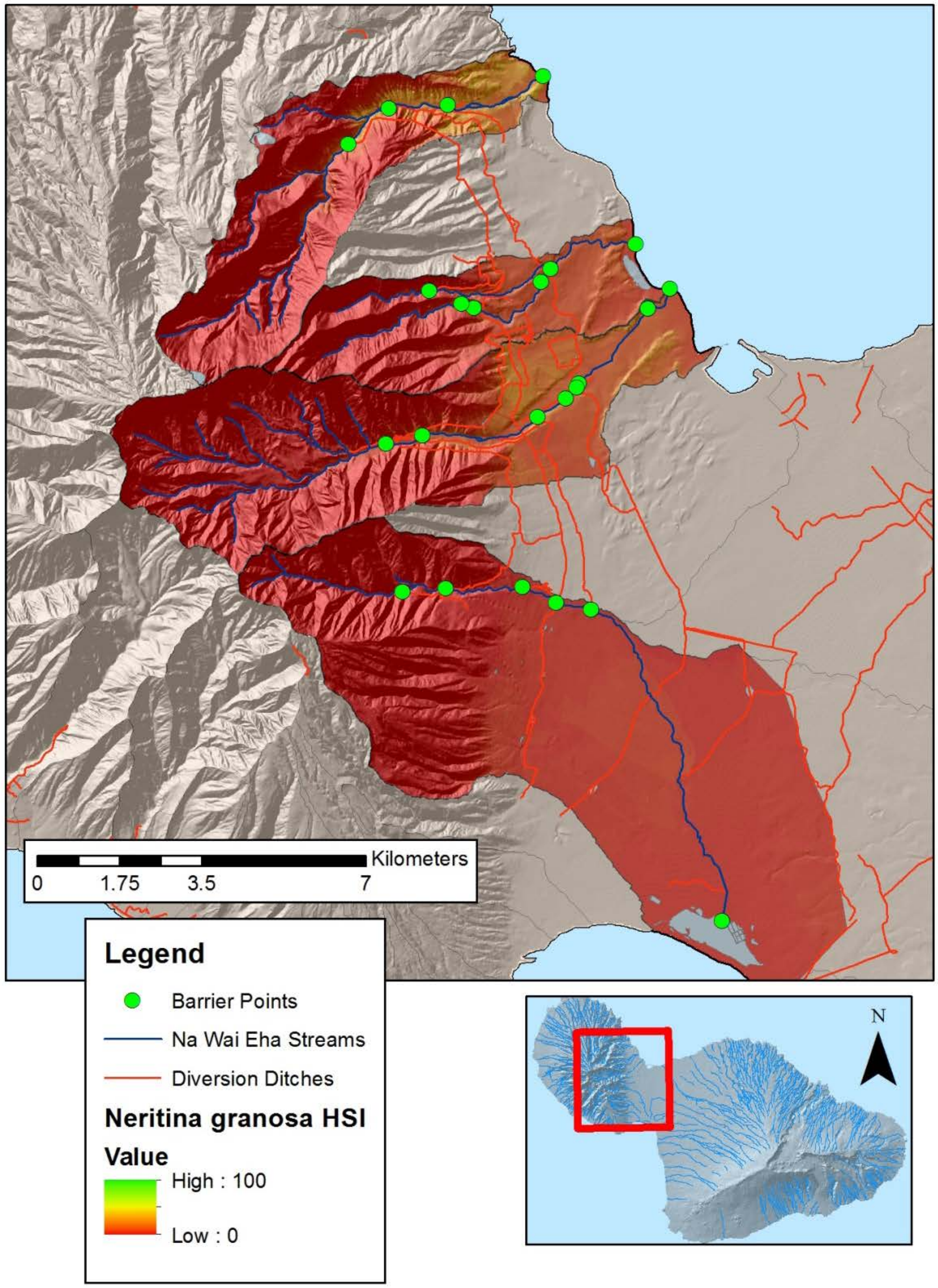

Figure 34: Map of Habitat Suitability Index (HSI) distribution for *Neritina granosa* in the Nā Wai ʻEhā Streams prior to specific scenario modeling. HSI values from 0 to 1 were expanded to 0 to 100 and are shown throughout the watershed for visualization purposes. In the HSHEP model only values that occur within stream channel cells are used for habitat quantification.

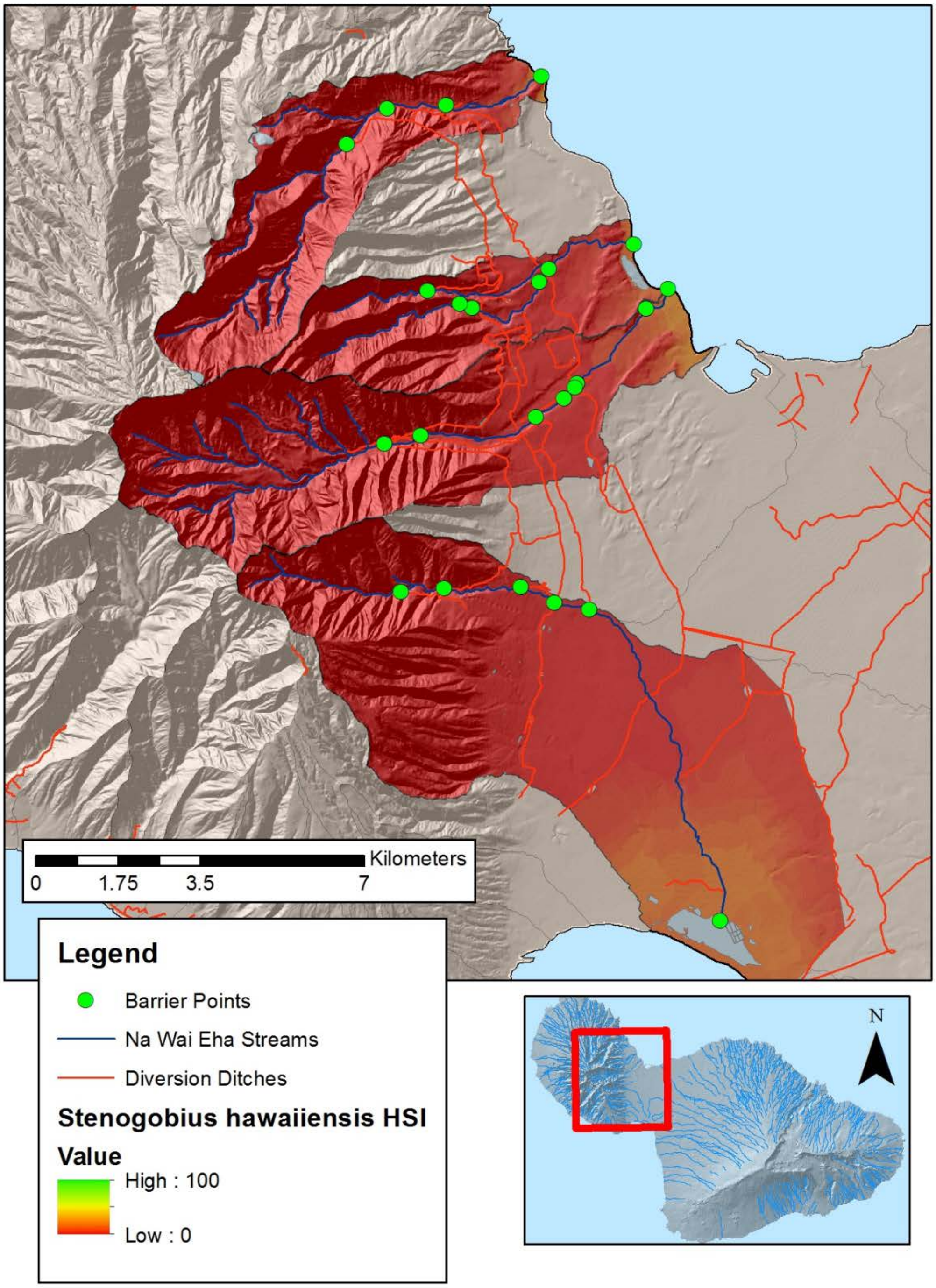

Figure 35: Map of Habitat Suitability Index (HSI) distribution for *Stenogobius hawaiiensis* in the Nā Wai ʻEhā Streams prior to specific scenario modeling. HSI values from 0 to 1 were expanded to 0 to 100 and are shown throughout the watershed for visualization purposes. In the HSHEP model only values that occur within stream channel cells are used for habitat quantification.

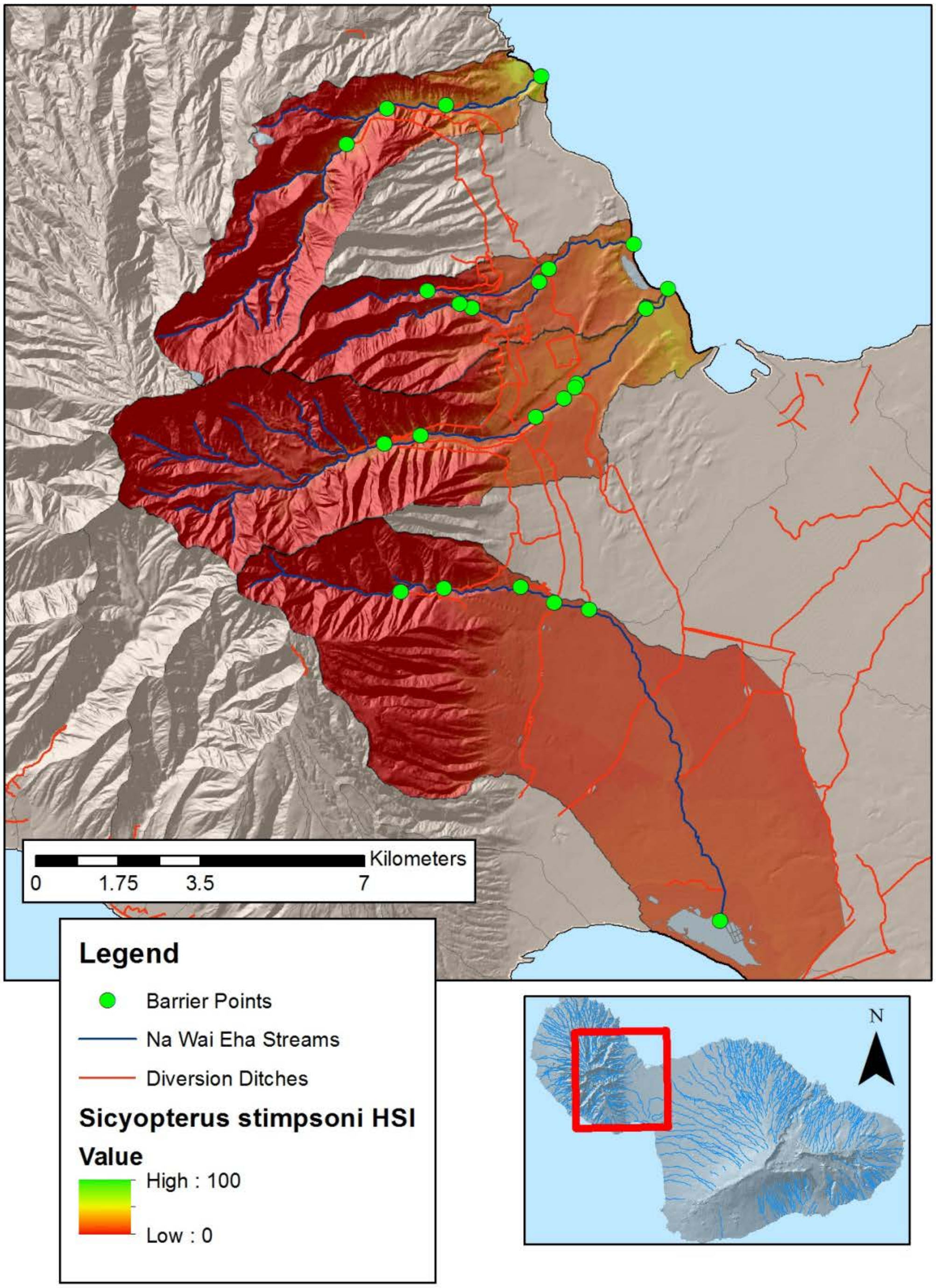

Figure 36: Map of Habitat Suitability Index (HSI) distribution for *Sicyopterus stimpsoni* in the Nā Wai ʻEhā Streams prior to specific scenario modeling. HSI values from 0 to 1 were expanded to 0 to 100 and are shown throughout the watershed for visualization purposes. In the HSHEP model only values that occur within stream channel cells are used for habitat quantification.

Table 22: HSHEP Scenario stream segment results for *Atyoida bisulcata*.

		Atyoida bisulcata						
Stream Segment Habitat Code	Barrier or Diversion Code at start of segment	Unmodified Habitat Units	Scenario 1: Natural Habitat Units	Scenario 2: Undiverted Habitat Units	Scenario 3: Fully Diverted Habitat Units	Scenario 4: 2010 IFS Habitat Units	Scenario 5: Flow to Ocean Habitat Units	Scenario 6: ʻĪao Channelizaion Improvements Habitat Units
Waiheʻe Stream								
Wh.Hab.1	Wh.B.01	345	345	345	0	244	274	274
Wh.Hab.2	Wh.D.12	374	374	374	0	72	110	110
Wh.Hab.3	Wh.D.23	2,093	2,093	2,093	5	147	258	258
Wh.Hab.4	Wh.D.34	6,782	6,782	6,782	2	234	354	354
Waiehu Stream								
We.Hab.1	We.B.01	97	87	87	0	71	79	79
WeS.Hab.2	None	39	35	35	0	32	33	33
WeS.Hab.3	WeS.D.23	298	269	269	8	167	189	189
WeS.Hab.4	WeS.D.34	53	48	48	0	27	30	30
WeS.Hab.5	WeS.D.45	869	784	784	0	418	473	473
WeN.Hab.2	None	447	403	403	99	343	374	374
WeN.Hab.3	WeN.D.23	612	552	552	19	322	417	417
ʻĪao Stream								
Ia.Hab.1	Ia.B.01	0	0	0	0	0	0	0
Ia.Hab.2	None	309	309	102	0	0	89	135
Ia.Hab.3	Ia.B.23	28	28	0	0	0	0	11
Ia.Hab.4	None	93	93	0	0	0	0	39
Ia.Hab.5	Ia.D.45	244	244	0	0	0	0	61
Ia.Hab.6	None	1,045	1,045	0	0	0	0	262
Ia.Hab.7	Ia.D.67	373	373	373	0	0	111	111
Ia.Hab.8	Ia.D.78	12,817	12,817	12,817	0	0	2,429	2,429
Waikapū Stream								
Wk.Hab.1	Wk.B.01	374	0	0	0	0	0	0
Wk.Hab.2	Wk.D.12	72	17	17	0	0	3	3
Wk.Hab.3	Wk.D.23	86	21	21	0	0	4	4
Wk.Hab.4	Wk.D.34	196	47	47	0	0	8	8
Wk.Hab.5	Wk.D.45	184	44	44	0	0	7	7
Wk.Hab.6	Wk.D.56	469	113	113	0	0	18	18

Table 23: HSHEP Scenario summary results for *Atyoida bisulcata*.

		Atyoida bisulcata					
Stream Name	Length (m)	Scenario 1: Natural Habitat Units	Scenario 2: Undiverted Habitat Units	Scenario 3: Fully Diverted Habitat Units	Scenario 4: 2010 IFS Habitat Units	Scenario 5: Flow to Ocean Habitat Units	Scenario 6: ʻĪao Channelizaion Improvements Habitat Units
Waiheʻe	26,070	9,594	9,594	7	696	995	995
Waiehu	16,850	2,180	2,180	126	1,381	1,595	1,595
ʻĪao	37,520	14,909	13,292	0	0	2,630	3,048
Waikapū	10,570	242	242	0	0	39	39
Total	91,010	26,925	25,307	133	2,078	5,258	5,677

Table 24: HSHEP Scenario summary results in percentages for *Atyoida bisulcata.*

		Atyoida bisulcata					
Stream Name	Length (m)	Scenario 1: Natural Habitat Units	Scenario 2: Undiverted Habitat Units	Scenario 3: Fully Diverted Habitat Units	Scenario 4: 2010 IFS Habitat Units	Scenario 5: Flow to Ocean Habitat Units	Scenario 6: ʻĪao Channelizaion Improvements Habitat Units
Waiheʻe	28.6%	35.6%	37.9%	5.1%	33.5%	18.9%	17.5%
Waiehu	18.5%	8.1%	8.6%	94.7%	66.5%	30.3%	28.1%
ʻĪao	41.2%	55.4%	52.5%	0.2%	0.0%	50.0%	53.7%
Waikapū	11.6%	0.9%	1.0%	0.0%	0.0%	0.7%	0.7%

Table 25: HSHEP Scenario stream segment results for *Awaous guamensis*.

		Awaous guamensis						
Stream Segment Habitat Code	Barrier or Diversion Code at start of segment	Unmodified Habitat Units	Scenario 1: Natural Habitat Units	Scenario 2: Undiverted Habitat Units	Scenario 3: Fully Diverted Habitat Units	Scenario 4: 2010 IFS Habitat Units	Scenario 5: Flow to Ocean Habitat Units	Scenario 6: ʻĪao Channelizaion Improvements Habitat Units
Waiheʻe Stream								
Wh.Hab.1	Wh.B.01	1,218	1,218	1,218	0	860	965	965
Wh.Hab.2	Wh.D.12	416	416	416	0	80	122	122
Wh.Hab.3	Wh.D.23	587	587	587	1	41	72	72
Wh.Hab.4	Wh.D.34	1,006	1,006	1,006	0	35	52	52
Waiehu Stream								
We.Hab.1	We.B.01	571	515	515	0	422	465	465
WeS.Hab.2	None	61	55	55	0	50	51	51
WeS.Hab.3	WeS.D.23	326	294	294	9	182	206	206
WeS.Hab.4	WeS.D.34	42	38	38	0	21	24	24
WeS.Hab.5	WeS.D.45	306	276	276	0	147	166	166
WeN.Hab.2	None	463	418	418	102	356	387	387
WeN.Hab.3	WeN.D.23	158	142	142	5	83	108	108
ʻĪao Stream								
Ia.Hab.1	Ia.B.01	455	455	0	0	0	0	196
Ia.Hab.2	None	1,128	1,128	372	0	0	324	491
Ia.Hab.3	Ia.B.23	40	40	0	0	0	0	16
Ia.Hab.4	None	132	132	0	0	0	0	55
Ia.Hab.5	Ia.D.45	245	245	0	0	0	0	61
Ia.Hab.6	None	720	720	0	0	0	0	181
Ia.Hab.7	Ia.D.67	235	235	235	0	0	70	70
Ia.Hab.8	Ia.D.78	1,193	1,193	1,193	0	0	226	226
Waikapū Stream								
Wk.Hab.1	Wk.B.01	1,249	0	0	0	0	0	0
Wk.Hab.2	Wk.D.12	68	16	16	0	0	3	3
Wk.Hab.3	Wk.D.23	75	18	18	0	0	3	3
Wk.Hab.4	Wk.D.34	162	39	39	0	0	6	6
Wk.Hab.5	Wk.D.45	59	14	14	0	0	2	2
Wk.Hab.6	Wk.D.56	22	5	5	0	0	1	1

Table 26: HSHEP Scenario summary results for *Awaous guamensis.*

		Awaous guamensis					
Stream Name	Length (m)	Scenario 1: Natural Habitat Units	Scenario 2: Undiverted Habitat Units	Scenario 3: Fully Diverted Habitat Units	Scenario 4: 2010 IFS Habitat Units	Scenario 5: Flow to Ocean Habitat Units	Scenario 6: ʻĪao Channelizaion Improvements Habitat Units
Waiheʻe	26,070	3,227	3,227	2	1,015	1,212	1,212
Waiehu	16,850	1,738	1,738	116	1,261	1,407	1,407
ʻĪao	37,520	4,148	1,801	0	0	621	1,296
Waikapū	10,570	93	93	0	0	15	15
Total	91,010	9,206	6,858	118	2,276	3,256	3,931

Table 27: HSHEP Scenario summary results in percentage for *Awaous guamensis.*

		Awaous guamensis					
Stream Name	Length (m)	Scenario 1: Natural Habitat Units	Scenario 2: Undiverted Habitat Units	Scenario 3: Fully Diverted Habitat Units	Scenario 4: 2010 IFS Habitat Units	Scenario 5: Flow to Ocean Habitat Units	Scenario 6: ʻĪao Channelizaion Improvements Habitat Units
Waiheʻe	28.6%	35.0%	47.0%	1.4%	44.6%	37.2%	30.8%
Waiehu	18.5%	18.9%	25.3%	98.5%	55.4%	43.2%	35.8%
ʻĪao	41.2%	45.1%	26.3%	0.0%	0.0%	19.1%	33.0%
Waikapū	11.6%	1.0%	1.4%	0.0%	0.0%	0.5%	0.4%

Table 28: HSHEP Scenario stream segment results for *Eleotris sandwicensis.*

		Eleotris sandwicensis						
Stream Segment Habitat Code	Barrier or Diversion Code at start of segment	Unmodified Habitat Units	Scenario 1: Natural Habitat Units	Scenario 2: Undiverted Habitat Units	Scenario 3: Fully Diverted Habitat Units	Scenario 4: 2010 IFS Habitat Units	Scenario 5: Flow to Ocean Habitat Units	Scenario 6: ʻĪao Channelizaion Improvements Habitat Units
Waiheʻe Stream								
Wh.Hab.1	Wh.B.01	145	145	145	0	102	115	115
Wh.Hab.2	Wh.D.12	0	0	0	0	0	0	0
Wh.Hab.3	Wh.D.23	0	0	0	0	0	0	0
Wh.Hab.4	Wh.D.34	0	0	0	0	0	0	0
Waiehu Stream								
We.Hab.1	We.B.01	70	63	63	0	52	57	57
WeS.Hab.2	None	0	0	0	0	0	0	0
WeS.Hab.3	WeS.D.23	0	0	0	0	0	0	0
WeS.Hab.4	WeS.D.34	0	0	0	0	0	0	0
WeS.Hab.5	WeS.D.45	0	0	0	0	0	0	0
WeN.Hab.2	None	0	0	0	0	0	0	0
WeN.Hab.3	WeN.D.23	0	0	0	0	0	0	0
ʻĪao Stream								
Ia.Hab.1	Ia.B.01	197	197	0	0	0	0	85
Ia.Hab.2	None	58	58	19	0	0	17	25
Ia.Hab.3	Ia.B.23	1	1	0	0	0	0	0
Ia.Hab.4	None	0	0	0	0	0	0	0
Ia.Hab.5	Ia.D.45	0	0	0	0	0	0	0
Ia.Hab.6	None	0	0	0	0	0	0	0
Ia.Hab.7	Ia.D.67	0	0	0	0	0	0	0
Ia.Hab.8	Ia.D.78	0	0	0	0	0	0	0
Waikapū Stream								
Wk.Hab.1	Wk.B.01	108	0	0	0	0	0	0
Wk.Hab.2	Wk.D.12	0	0	0	0	0	0	0
Wk.Hab.3	Wk.D.23	0	0	0	0	0	0	0
Wk.Hab.4	Wk.D.34	0	0	0	0	0	0	0
Wk.Hab.5	Wk.D.45	0	0	0	0	0	0	0
Wk.Hab.6	Wk.D.56	0	0	0	0	0	0	0

Table 29: HSHEP Scenario summary results for *Eleotris sandwicensis.*

		Eleotris sandwicensis					
Stream Name	Length (m)	Scenario 1: Natural Habitat Units	Scenario 2: Undiverted Habitat Units	Scenario 3: Fully Diverted Habitat Units	Scenario 4: 2010 IFS Habitat Units	Scenario 5: Flow to Ocean Habitat Units	Scenario 6: ʻĪao Channelizaion Improvements Habitat Units
Waiheʻe	26,070	145	145	0	102	115	115
Waiehu	16,850	63	63	0	52	57	57
ʻĪao	37,520	256	19	0	0	17	110
Waikapū	10,570	0	0	0	0	0	0
Total	91,010	464	227	0	154	189	282

Table 30: HSHEP Scenario summary results in percentages for *Eleotris sandwicensis.*

		Eleotris sandwicensis					
Stream Name	Length (m)	Scenario 1: Natural Habitat Units	Scenario 2: Undiverted Habitat Units	Scenario 3: Fully Diverted Habitat Units	Scenario 4: 2010 IFS Habitat Units	Scenario 5: Flow to Ocean Habitat Units	Scenario 6: ʻĪao Channelizaion Improvements Habitat Units
Waiheʻe	28.6%	31.2%	63.8%	0.0%	66.4%	60.9%	40.7%
Waiehu	18.5%	13.6%	27.8%	100.0%	33.6%	30.3%	20.2%
ʻĪao	41.2%	55.2%	8.4%	0.0%	0.0%	8.8%	39.1%
Waikapū	11.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Table 31: HSHEP Scenario stream segment results for *Lentipes concolor*.

		Lentipes concolor						
Stream Segment Habitat Code	Barrier or Diversion Code at start of segment	Unmodified Habitat Units	Scenario 1: Natural Habitat Units	Scenario 2: Undiverted Habitat Units	Scenario 3: Fully Diverted Habitat Units	Scenario 4: 2010 IFS Habitat Units	Scenario 5: Flow to Ocean Habitat Units	Scenario 6: ʻĪao Channelizaion Improvements Habitat Units
Waiheʻe Stream								
Wh.Hab.1	Wh.B.01	107	107	107	0	75	85	85
Wh.Hab.2	Wh.D.12	175	175	175	0	34	51	51
Wh.Hab.3	Wh.D.23	934	934	934	2	65	115	115
Wh.Hab.4	Wh.D.34	2,609	2,609	2,609	1	90	136	136
Waiehu Stream								
We.Hab.1	We.B.01	46	42	42	0	34	37	37
WeS.Hab.2	None	16	15	15	0	13	14	14
WeS.Hab.3	WeS.D.23	135	122	122	4	75	85	85
WeS.Hab.4	WeS.D.34	30	27	27	0	15	17	17
WeS.Hab.5	WeS.D.45	384	346	346	0	185	209	209
WeN.Hab.2	None	226	204	204	50	174	189	189
WeN.Hab.3	WeN.D.23	196	176	176	6	103	133	133
ʻĪao Stream								
Ia.Hab.1	Ia.B.01	5	5	0	0	0	0	2
Ia.Hab.2	None	47	47	15	0	0	13	20
Ia.Hab.3	Ia.B.23	4	4	0	0	0	0	2
Ia.Hab.4	None	19	19	0	0	0	0	8
Ia.Hab.5	Ia.D.45	65	65	0	0	0	0	16
Ia.Hab.6	None	279	279	0	0	0	0	70
Ia.Hab.7	Ia.D.67	149	149	149	0	0	45	45
Ia.Hab.8	Ia.D.78	3,523	3,523	3,523	0	0	668	668
Waikapū Stream								
Wk.Hab.1	Wk.B.01	171	0	0	0	0	0	0
Wk.Hab.2	Wk.D.12	43	10	10	0	0	2	2
Wk.Hab.3	Wk.D.23	50	12	12	0	0	2	2
Wk.Hab.4	Wk.D.34	132	32	32	0	0	5	5
Wk.Hab.5	Wk.D.45	29	7	7	0	0	1	1
Wk.Hab.6	Wk.D.56	20	5	5	0	0	1	1

Table 32: HSHEP Scenario summary results for *Lentipes concolor*.

		Lentipes concolor					
Stream Name	Length (m)	Scenario 1: Natural Habitat Units	Scenario 2: Undiverted Habitat Units	Scenario 3: Fully Diverted Habitat Units	Scenario 4: 2010 IFS Habitat Units	Scenario 5: Flow to Ocean Habitat Units	Scenario 6: ‘Īao Channelizaion Improvements Habitat Units
Waihe‘e	26,070	3,824	3,824	3	265	387	387
Waiehu	16,850	932	932	60	599	685	685
‘Īao	37,520	4,090	3,687	0	0	726	830
Waikapū	10,570	66	66	0	0	11	11
Total	91,010	8,912	8,509	63	864	1,808	1,913

Table 33: HSHEP Scenario summary results in percentages for *Lentipes concolor*.

		Lentipes concolor					
Stream Name	Length (m)	Scenario 1: Natural Habitat Units	Scenario 2: Undiverted Habitat Units	Scenario 3: Fully Diverted Habitat Units	Scenario 4: 2010 IFS Habitat Units	Scenario 5: Flow to Ocean Habitat Units	Scenario 6: ‘Īao Channelizaion Improvements Habitat Units
Waihe‘e	28.6%	42.9%	44.9%	4.7%	30.6%	21.4%	20.2%
Waiehu	18.5%	10.5%	10.9%	95.2%	69.4%	37.9%	35.8%
‘Īao	41.2%	45.9%	43.3%	0.1%	0.0%	40.1%	43.4%
Waikapū	11.6%	0.7%	0.8%	0.0%	0.0%	0.6%	0.6%

Table 34: HSHEP Scenario stream segment results for *Macrobrachium grandimanus.*

		Macrobrachium grandimanus						
Stream Segment Habitat Code	Barrier or Diversion Code at start of segment	Unmodified Habitat Units	Scenario 1: Natural Habitat Units	Scenario 2: Undiverted Habitat Units	Scenario 3: Fully Diverted Habitat Units	Scenario 4: 2010 IFS Habitat Units	Scenario 5: Flow to Ocean Habitat Units	Scenario 6: ʻĪao Channelizaion Improvements Habitat Units
Waiheʻe Stream								
Wh.Hab.1	Wh.B.01	930	930	930	0	656	737	737
Wh.Hab.2	Wh.D.12	283	283	283	0	54	83	83
Wh.Hab.3	Wh.D.23	59	59	59	0	4	7	7
Wh.Hab.4	Wh.D.34	0	0	0	0	0	0	0
Waiehu Stream								
We.Hab.1	We.B.01	338	305	305	0	250	275	275
WeS.Hab.2	None	36	33	33	0	30	31	31
WeS.Hab.3	WeS.D.23	125	112	112	3	70	79	79
WeS.Hab.4	WeS.D.34	0	0	0	0	0	0	0
WeS.Hab.5	WeS.D.45	0	0	0	0	0	0	0
WeN.Hab.2	None	136	123	123	30	105	114	114
WeN.Hab.3	WeN.D.23	0	0	0	0	0	0	0
ʻĪao Stream								
Ia.Hab.1	Ia.B.01	311	311	0	0	0	0	133
Ia.Hab.2	None	747	747	246	0	0	215	325
Ia.Hab.3	Ia.B.23	30	30	0	0	0	0	12
Ia.Hab.4	None	91	91	0	0	0	0	38
Ia.Hab.5	Ia.D.45	169	169	0	0	0	0	42
Ia.Hab.6	None	236	236	0	0	0	0	59
Ia.Hab.7	Ia.D.67	0	0	0	0	0	0	0
Ia.Hab.8	Ia.D.78	0	0	0	0	0	0	0
Waikapū Stream								
Wk.Hab.1	Wk.B.01	603	0	0	0	0	0	0
Wk.Hab.2	Wk.D.12	0	0	0	0	0	0	0
Wk.Hab.3	Wk.D.23	0	0	0	0	0	0	0
Wk.Hab.4	Wk.D.34	0	0	0	0	0	0	0
Wk.Hab.5	Wk.D.45	0	0	0	0	0	0	0
Wk.Hab.6	Wk.D.56	0	0	0	0	0	0	0

Table 35: HSHEP Scenario summary results for *Macrobrachium grandimanus.*

		Macrobrachium grandimanus					
Stream Name	Length (m)	Scenario 1: Natural Habitat Units	Scenario 2: Undiverted Habitat Units	Scenario 3: Fully Diverted Habitat Units	Scenario 4: 2010 IFS Habitat Units	Scenario 5: Flow to Ocean Habitat Units	Scenario 6: ʻĪao Channelizaion Improvements Habitat Units
Waiheʻe	26,070	1,271	1,271	0	715	827	827
Waiehu	16,850	573	573	33	453	498	498
ʻĪao	37,520	1,582	246	0	0	215	610
Waikapū	10,570	0	0	0	0	0	0
Total	91,010	3,427	2,091	34	1,168	1,540	1,935

Table 36: HSHEP Scenario summary results in percentages for *Macrobrachium grandimanus.*

		Macrobrachium grandimanus					
Stream Name	Length (m)	Scenario 1: Natural Habitat Units	Scenario 2: Undiverted Habitat Units	Scenario 3: Fully Diverted Habitat Units	Scenario 4: 2010 IFS Habitat Units	Scenario 5: Flow to Ocean Habitat Units	Scenario 6: ʻĪao Channelizaion Improvements Habitat Units
Waiheʻe	28.6%	37.1%	60.8%	0.4%	61.2%	53.7%	42.8%
Waiehu	18.5%	16.7%	27.4%	99.6%	38.8%	32.3%	25.7%
ʻĪao	41.2%	46.2%	11.8%	0.0%	0.0%	13.9%	31.5%
Waikapū	11.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Table 37: HSHEP Scenario stream segment results for *Neritina granosa*.

		Neritina granosa						
Stream Segment Habitat Code	Barrier or Diversion Code at start of segment	Unmodified Habitat Units	Scenario 1: Natural Habitat Units	Scenario 2: Undiverted Habitat Units	Scenario 3: Fully Diverted Habitat Units	Scenario 4: 2010 IFS Habitat Units	Scenario 5: Flow to Ocean Habitat Units	Scenario 6: ʻĪao Channelizaion Improvements Habitat Units
Waiheʻe Stream								
Wh.Hab.1	Wh.B.01	395	395	395	0	279	313	313
Wh.Hab.2	Wh.D.12	193	193	193	0	37	57	57
Wh.Hab.3	Wh.D.23	515	515	515	1	36	63	63
Wh.Hab.4	Wh.D.34	388	388	388	0	13	20	20
Waiehu Stream								
We.Hab.1	We.B.01	165	149	149	0	122	134	134
WeS.Hab.2	None	24	21	21	0	20	20	20
WeS.Hab.3	WeS.D.23	140	126	126	4	78	88	88
WeS.Hab.4	WeS.D.34	21	19	19	0	11	12	12
WeS.Hab.5	WeS.D.45	74	66	66	0	35	40	40
WeN.Hab.2	None	192	173	173	42	147	160	160
WeN.Hab.3	WeN.D.23	33	30	30	1	18	23	23
ʻĪao Stream								
Ia.Hab.1	Ia.B.01	42	42	0	0	0	0	18
Ia.Hab.2	None	220	220	73	0	0	63	96
Ia.Hab.3	Ia.B.23	8	8	0	0	0	0	3
Ia.Hab.4	None	34	34	0	0	0	0	14
Ia.Hab.5	Ia.D.45	77	77	0	0	0	0	19
Ia.Hab.6	None	218	218	0	0	0	0	55
Ia.Hab.7	Ia.D.67	53	53	53	0	0	16	16
Ia.Hab.8	Ia.D.78	144	144	144	0	0	27	27
Waikapū Stream								
Wk.Hab.1	Wk.B.01	162	0	0	0	0	0	0
Wk.Hab.2	Wk.D.12	10	3	3	0	0	0	0
Wk.Hab.3	Wk.D.23	9	2	2	0	0	0	0
Wk.Hab.4	Wk.D.34	11	3	3	0	0	0	0
Wk.Hab.5	Wk.D.45	0	0	0	0	0	0	0
Wk.Hab.6	Wk.D.56	0	0	0	0	0	0	0

Table 38: HSHEP Scenario summary results for *Neritina granosa.*

		Neritina granosa					
Stream Name	Length (m)	Scenario 1: Natural Habitat Units	Scenario 2: Undiverted Habitat Units	Scenario 3: Fully Diverted Habitat Units	Scenario 4: 2010 IFS Habitat Units	Scenario 5: Flow to Ocean Habitat Units	Scenario 6: ʻĪao Channelizaion Improvements Habitat Units
Waiheʻe	26,070	1,492	1,492	1	366	454	454
Waiehu	16,850	585	585	47	431	478	478
ʻĪao	37,520	796	270	0	0	1	248
Waikapū	10,570	7	7	0	0	0	1
Total	91,010	2,880	2,354	49	796	933	1,181

Table 39: HSHEP Scenario summary results in percentages for *Neritina granosa.*

		Neritina granosa					
Stream Name	Length (m)	Scenario 1: Natural Habitat Units	Scenario 2: Undiverted Habitat Units	Scenario 3: Fully Diverted Habitat Units	Scenario 4: 2010 IFS Habitat Units	Scenario 5: Flow to Ocean Habitat Units	Scenario 6: ʻĪao Channelizaion Improvements Habitat Units
Waiheʻe	28.6%	51.8%	63.4%	2.8%	45.9%	48.6%	38.4%
Waiehu	18.5%	20.3%	24.9%	97.2%	54.1%	51.2%	40.5%
ʻĪao	41.2%	27.6%	11.5%	0.0%	0.0%	0.1%	21.0%
Waikapū	11.6%	0.2%	0.3%	0.0%	0.0%	0.0%	0.1%

Table 40: HSHEP Scenario stream segment results for *Stenogobius hawaiiensis*.

		Stenogobius hawaiiensis						
Stream Segment Habitat Code	Barrier or Diversion Code at start of segment	Unmodified Habitat Units	Scenario 1: Natural Habitat Units	Scenario 2: Undiverted Habitat Units	Scenario 3: Fully Diverted Habitat Units	Scenario 4: 2010 IFS Habitat Units	Scenario 5: Flow to Ocean Habitat Units	Scenario 6: ʻĪao Channelizaion Improvements Habitat Units
Waiheʻe Stream								
Wh.Hab.1	Wh.B.01	145	145	145	0	102	115	115
Wh.Hab.2	Wh.D.12	0	0	0	0	0	0	0
Wh.Hab.3	Wh.D.23	0	0	0	0	0	0	0
Wh.Hab.4	Wh.D.34	0	0	0	0	0	0	0
Waiehu Stream								
We.Hab.1	We.B.01	73	65	65	0	54	59	59
WeS.Hab.2	None	0	0	0	0	0	0	0
WeS.Hab.3	WeS.D.23	0	0	0	0	0	0	0
WeS.Hab.4	WeS.D.34	0	0	0	0	0	0	0
WeS.Hab.5	WeS.D.45	0	0	0	0	0	0	0
WeN.Hab.2	None	0	0	0	0	0	0	0
WeN.Hab.3	WeN.D.23	0	0	0	0	0	0	0
ʻĪao Stream								
Ia.Hab.1	Ia.B.01	172	172	0	0	0	0	74
Ia.Hab.2	None	135	135	45	0	0	39	59
Ia.Hab.3	Ia.B.23	0	0	0	0	0	0	0
Ia.Hab.4	None	0	0	0	0	0	0	0
Ia.Hab.5	Ia.D.45	0	0	0	0	0	0	0
Ia.Hab.6	None	0	0	0	0	0	0	0
Ia.Hab.7	Ia.D.67	0	0	0	0	0	0	0
Ia.Hab.8	Ia.D.78	0	0	0	0	0	0	0
Waikapū Stream								
Wk.Hab.1	Wk.B.01	476	0	0	0	0	0	0
Wk.Hab.2	Wk.D.12	0	0	0	0	0	0	0
Wk.Hab.3	Wk.D.23	0	0	0	0	0	0	0
Wk.Hab.4	Wk.D.34	0	0	0	0	0	0	0
Wk.Hab.5	Wk.D.45	0	0	0	0	0	0	0
Wk.Hab.6	Wk.D.56	0	0	0	0	0	0	0

Table 41: HSHEP Scenario summary results for *Stenogobius hawaiiensis.*

		Stenogobius hawaiiensis					
Stream Name	Length (m)	Scenario 1: Natural Habitat Units	Scenario 2: Undiverted Habitat Units	Scenario 3: Fully Diverted Habitat Units	Scenario 4: 2010 IFS Habitat Units	Scenario 5: Flow to Ocean Habitat Units	Scenario 6: ʻĪao Channelizaion Improvements Habitat Units
Waiheʻe	26,070	145	145	0	102	115	115
Waiehu	16,850	65	65	0	54	59	59
ʻĪao	37,520	307	45	0	0	39	133
Waikapū	10,570	0	0	0	0	0	0
Total	91,010	517	255	0	156	213	306

Table 42: HSHEP Scenario summary results in percentages for *Stenogobius hawaiiensis.*

		Stenogobius hawaiiensis					
Stream Name	Length (m)	Scenario 1: Natural Habitat Units	Scenario 2: Undiverted Habitat Units	Scenario 3: Fully Diverted Habitat Units	Scenario 4: 2010 IFS Habitat Units	Scenario 5: Flow to Ocean Habitat Units	Scenario 6: ʻĪao Channelizaion Improvements Habitat Units
Waiheʻe	28.6%	28.0%	56.8%	0.0%	65.6%	53.9%	37.4%
Waiehu	18.5%	12.7%	25.7%	0.0%	34.4%	27.8%	19.3%
ʻĪao	41.2%	59.3%	17.5%	0.0%	0.0%	18.3%	43.3%
Waikapū	11.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Table 43: HSHEP Scenario stream segment results for *Sicyopterous stimpsoni*.

		Sicyopterous stimpsoni						
Stream Segment Habitat Code	Barrier or Diversion Code at start of segment	Unmodified Habitat Units	Scenario 1: Natural Habitat Units	Scenario 2: Undiverted Habitat Units	Scenario 3: Fully Diverted Habitat Units	Scenario 4: 2010 IFS Habitat Units	Scenario 5: Flow to Ocean Habitat Units	Scenario 6: ʻĪao Channelizaion Improvements Habitat Units
Waiheʻe Stream								
Wh.Hab.1	Wh.B.01	869	869	869	0	614	689	689
Wh.Hab.2	Wh.D.12	223	223	223	0	43	65	65
Wh.Hab.3	Wh.D.23	342	342	342	1	24	42	42
Wh.Hab.4	Wh.D.34	692	692	692	0	24	36	36
Waiehu Stream								
We.Hab.1	We.B.01	407	368	368	0	301	332	332
WeS.Hab.2	None	36	32	32	0	29	30	30
WeS.Hab.3	WeS.D.23	170	154	154	5	95	108	108
WeS.Hab.4	WeS.D.34	22	20	20	0	11	12	12
WeS.Hab.5	WeS.D.45	176	159	159	0	85	96	96
WeN.Hab.2	None	244	220	220	54	187	204	204
WeN.Hab.3	WeN.D.23	99	89	89	3	52	67	67
ʻĪao Stream								
Ia.Hab.1	Ia.B.01	250	250	0	0	0	0	107
Ia.Hab.2	None	575	575	190	0	0	165	251
Ia.Hab.3	Ia.B.23	16	16	0	0	0	0	7
Ia.Hab.4	None	54	54	0	0	0	0	22
Ia.Hab.5	Ia.D.45	89	89	0	0	0	0	22
Ia.Hab.6	None	273	273	0	0	0	0	69
Ia.Hab.7	Ia.D.67	96	96	96	0	0	29	29
Ia.Hab.8	Ia.D.78	823	823	823	0	0	156	156
Waikapū Stream								
Wk.Hab.1	Wk.B.01	571	0	0	0	0	0	0
Wk.Hab.2	Wk.D.12	39	9	9	0	0	2	2
Wk.Hab.3	Wk.D.23	41	10	10	0	0	2	2
Wk.Hab.4	Wk.D.34	85	20	20	0	0	3	3
Wk.Hab.5	Wk.D.45	63	15	15	0	0	2	2
Wk.Hab.6	Wk.D.56	29	7	7	0	0	1	1

Table 44: HSHEP Scenario summary results for *Sicyopterous stimpsoni*.

		Sicyopterous stimpsoni					
Stream Name	Length (m)	Scenario 1: Natural Habitat Units	Scenario 2: Undiverted Habitat Units	Scenario 3: Fully Diverted Habitat Units	Scenario 4: 2010 IFS Habitat Units	Scenario 5: Flow to Ocean Habitat Units	Scenario 6: ‘Īao Channelizaion Improvements Habitat Units
Waiheʻe	26,070	2,127	2,127	1	704	833	833
Waiehu	16,850	1,041	1,041	62	760	849	849
‘Īao	37,520	2,177	1,109	0	0	350	662
Waikapū	10,570	62	62	0	0	10	10
Total	91,010	5,406	4,338	63	1,464	1,691	2,354

Table 45: HSHEP Scenario summary results in percentages for *Sicyopterous stimpsoni*.

		Sicyopterous stimpsoni					
Stream Name	Length (m)	Scenario 1: Natural Habitat Units	Scenario 2: Undiverted Habitat Units	Scenario 3: Fully Diverted Habitat Units	Scenario 4: 2010 IFS Habitat Units	Scenario 5: Flow to Ocean Habitat Units	Scenario 6: ‘Īao Channelizaion Improvements Habitat Units
Waiheʻe	28.6%	39.3%	49.0%	1.6%	48.1%	40.8%	35.4%
Waiehu	18.5%	19.3%	24.0%	98.4%	51.9%	41.6%	36.0%
‘Īao	41.2%	40.3%	25.6%	0.0%	0.0%	17.1%	28.1%
Waikapū	11.6%	1.1%	1.4%	0.0%	0.0%	0.5%	0.4%

Table 46: HSHEP Scenario stream segment results for All Species Combined.

		All Species Combined						
Stream Segment Habitat Code	Barrier or Diversion Code at start of segment	Unmodified Habitat Units	Scenario 1: Natural Habitat Units	Scenario 2: Undiverted Habitat Units	Scenario 3: Fully Diverted Habitat Units	Scenario 4: 2010 IFS Habitat Units	Scenario 5: Flow to Ocean Habitat Units	Scenario 6: ʻĪao Channelizaion Improvements Habitat Units
Waiheʻe Stream								
Wh.Hab.1	Wh.B.01	4,153	4,153	4,153	0	2,933	3,292	3,292
Wh.Hab.2	Wh.D.12	1,664	1,664	1,664	0	319	489	489
Wh.Hab.3	Wh.D.23	4,530	4,530	4,530	11	318	558	558
Wh.Hab.4	Wh.D.34	11,477	11,477	11,477	3	396	599	599
Waiehu Stream								
We.Hab.1	We.B.01	1,767	1,594	1,594	0	1,304	1,438	1,438
WeS.Hab.2	None	211	191	191	0	174	179	179
WeS.Hab.3	WeS.D.23	1,194	1,078	1,078	32	668	755	755
WeS.Hab.4	WeS.D.34	168	151	151	0	84	95	95
WeS.Hab.5	WeS.D.45	1,808	1,632	1,632	1	870	984	984
WeN.Hab.2	None	1,708	1,541	1,541	377	1,312	1,429	1,429
WeN.Hab.3	WeN.D.23	1,097	990	990	33	578	749	749
ʻĪao Stream								
Ia.Hab.1	Ia.B.01	1,432	1,432	0	0	0	0	615
Ia.Hab.2	None	3,219	3,219	1,062	0	0	926	1,403
Ia.Hab.3	Ia.B.23	127	127	0	0	0	0	51
Ia.Hab.4	None	422	422	0	0	0	0	175
Ia.Hab.5	Ia.D.45	889	889	0	0	0	0	221
Ia.Hab.6	None	2,771	2,771	0	0	0	0	696
Ia.Hab.7	Ia.D.67	906	906	906	0	0	271	271
Ia.Hab.8	Ia.D.78	18,500	18,500	18,500	0	0	3,507	3,507
Waikapū Stream								
Wk.Hab.1	Wk.B.01	3,715	0	0	0	0	0	0
Wk.Hab.2	Wk.D.12	232	56	56	0	0	10	10
Wk.Hab.3	Wk.D.23	261	63	63	0	0	11	11
Wk.Hab.4	Wk.D.34	586	141	141	0	0	23	23
Wk.Hab.5	Wk.D.45	336	81	81	0	0	13	13
Wk.Hab.6	Wk.D.56	541	130	130	0	0	20	20

Table 47: HSHEP Scenario summary results for All Species Combined.

		All species combined					
Stream Name	Length (m)	Scenario 1: Natural Habitat Units	Scenario 2: Undiverted Habitat Units	Scenario 3: Fully Diverted Habitat Units	Scenario 4: 2010 IFS Habitat Units	Scenario 5: Flow to Ocean Habitat Units	Scenario 6: ʻĪao Channelizaion Improvements Habitat Units
Waiheʻe	26,070	21,824	21,824	14	3,966	4,937	4,937
Waiehu	16,850	7,177	7,177	443	4,990	5,628	5,628
ʻĪao	37,520	28,266	20,468	0	0	4,703	6,938
Waikapū	10,570	470	470	0	0	77	77
Total	91,010	57,737	49,939	458	8,957	15,345	17,579

Table 48: HSHEP Scenario summary results in percentages for All Species Combined.

		All species combined					
Stream Name	Length (m)	Scenario 1: Natural Habitat Units	Scenario 2: Undiverted Habitat Units	Scenario 3: Fully Diverted Habitat Units	Scenario 4: 2010 IFS Habitat Units	Scenario 5: Flow to Ocean Habitat Units	Scenario 6: ʻĪao Channelizaion Improvements Habitat Units
Waiheʻe	28.6%	37.8%	43.7%	3.0%	44.3%	32.2%	28.1%
Waiehu	18.5%	12.4%	14.4%	96.9%	55.7%	36.7%	32.0%
ʻĪao	41.2%	49.0%	41.0%	0.1%	0.0%	30.6%	39.5%
Waikapū	11.6%	0.8%	0.9%	0.0%	0.0%	0.0%	0.4%

Conclusions:

By combining HSHEP model results from multiple scales, the overall model provides an assessment of habitat suitability with respect to its location in a stream and is comparable to any other stream in the Hawaiian Islands. The presence of suitable characteristics at a site is not the only important variable when determining site occupancy. A site can only be occupied by a species if that species can reach the habitat. For example, a deep stream pool with a mixture of cobble and boulder habitat may be highly suitable for a number of native species, yet if that pool is found far inland and above a high waterfall, only a few species would be expected to inhabit the pool. The HSHEP models use of multiple spatial scales accounts for local, network (up and downstream conditions), and watershed differences among sites.

Results from the model predict that restoration of baseflows to the Nā Wai ʻEhā Streams will increase substantially available stream animal habitat. Under fully diverted conditions, less than 1% of natural habitat units are expected to be suitable for native amphidromous animals. Under the flow restoration scenarios modeled, 16 to 30% of natural habitat units were restored (Scenario 4 and 6, respectively). When viewing habitat for species individually, ʻĪao and Waiheʻe Streams consistently had the largest amount of natural habitat, and therefore the highest restoration potentials.

One clear result of this model is the need for both habitat and passage to achieve suitable habitat for native amphidromous animals in Nā Wai ʻEhā Streams. Diversions can entrain animals as they pass up and downstream during their required migrations. Requiring the animal to successfully pass multiple diversions greatly decreases the probability that recruitment, growth, reproduction, and migration (part of the natural lifecycle of amphidromous animals) are also successful. Water and suitable instream habitat must exist, but reducing the barriers and potential entrainment greatly enhances the reproductive productivity of the stream habitat.

Flow restoration at diversion locations is modeled with water returned to the stream passing the diversion and staying in the stream channel. Water flowing past the diversion in this way would provide an obvious wetted pathway with clear up and downstream queues for migrating animals. In contrast to this water return approach, some restoration efforts have passed a small amount of water over the diversion dam for "biological connectivity" while the bulk of the water is released downstream through the diversion structure (see Figure 37 and Figure 38). This approach may work fine for downstream drifting larvae, but it is not clear if upstream moving animals can navigate the diversion structure to find a way upstream. While water over the dam does provide a wetted pathway, how easy it is for an animal to find this small pathway in comparison to the large diversion flow is unclear.

Figure 37: Spreckels Ditch on Waiheʻe Stream showing water flowing past the diversion through a small channel. (Image from Dean Uyeno, CWRM, Maui Surface Water presentation at the 1st Annual Joint State Water Conference)

Figure 38: Water released through the Spreckels Ditch diversion back into stream. With this volume of water it may appear as the natural channel upstream to a migrating stream animal. (Image from Dean Uyeno, CWRM, Maui Surface Water presentation at the 1st Annual Joint State Water Conference)

This approach to water restoration appears to be a water return “of convenience” to minimize cost and effort associated with bypassing water over a diversion but likely does not result in the greatest ecological gain. This is not optimal as the “gain” realized by the water return may be much lower than possible and this increases the “per unit cost” associated with the water return (the same amount of water returned yields less animals in the stream). From a system optimization perspective, enhancing passage, avoiding entrainment, and restoring habitat should all be maximized together to achieve the best “ecological impact” for the smallest “restriction of use” of the water.

As an example of the impact diversion passage can have on the overall benefit to native species under a water restoration scenario, *Lentipes concolor* habitat on Waiheʻe Stream is used. By holding the 2010 IFS water return quantities steady and adjusting the maximum entrainment potential of each diversion the following results emerge. When the maximum entrainment potential is set to 80% (like a bottom grate diversion) for each of the three Waiheʻe stream diversions, then there are 167 habitat units for *Lentipes concolor.* If the maximum entrainment potential is decreased by half to 40% (eliminating the bottom grate and improving passage) then 333 habitat units for *Lentipes concolor* are restored. Another way to think of this result is lower quantity of water returned combined with passage improvement could restore similar quantities of suitable habitat when compared with greater amounts of water return only in some situations. Improvement of passage at diversions should be a high priority with any water return scenario. While the cost may be high in the short term, the benefits will accrue for years into the future.

Another situation arises that highlights the need for water and suitable habitat in the stream channel to create maximum stream animal habitat. On the lower end of ʻĪao Stream, the channelized segment of the stream provides little or no habitat (USACE and County of Maui, 2009). This reach of ʻĪao has a high potential for habitat restoration as multiple species are expected to use this area under natural conditions. If water is returned but habitat improvements are not made during the upgrading of the ʻĪao Flood Control Project, then little benefit of the restored water will be observed in the lower reach of ʻĪao Stream (there will be passage benefits for upstream habitats). Conversely, if habitat improvements are made to the stream channel during the project’s upgrading but no water is returned to the stream, then again, little benefit of the habitat improvements will be realized. Habitat restoration of the channelized section of ʻĪao Stream will require both water and habitat improvements. While these projects (ʻĪao Flood Control Project and the Instream Flow determination for Nā Wai ʻEhā Streams) are controlled by different governmental entities, lack of coordination between projects is a poor excuse for not considering joint restoration efforts in the lower reaches of ʻĪao Stream given its high potential for restoration.

Assessing the accuracy of the HSHEP model with respect to fit with recent animal observations is not straightforward. In a general sense, areas that USGS observed animals in their field studies (Oki et al. 2010) were areas of higher suitability within the streams. But none of the scenarios modeled were probably an accurate reflection of actual diversion conditions. The fully diverted scenario set all diversion at maximum diversion all of the time. The model also assumed that all water diverted from the streams did not return to the stream in any quantity. This is likely untrue as some water diverted for taro farming likely returns to the stream channel. Finally, all scenarios also assume that any animal entrained is lost to the system. There is no possibility of animals moving from one stream to another through the ditch system. As a result of these scenario assumptions, the fully diverted scenario is probably a “worst case” scenario. The other water return scenarios had not been implemented at the time of the USGS surveys so these are not likely to mimic observed species distributions.

Another confounding issue arises when comparing the modeled predictions with observations of adult animals in the streams. By definition, a suitable habitat unit is a location that an animal can migrate upstream to and then grow to an adult, reproduce, and then have its young drift back to the ocean. Just observing an adult animal does not account for possible future entrainment of its downstream drifting larvae into a diversion. Therefore, adult occupancy only accounts for upstream barriers, entrainment, and instream habitat, but discounts downstream entrainment.

Under fully diverted conditions, some adult occupancy of habitat is predicted to occur in all of the Nā Wai ‘Ehā Streams with most of the adult occupancy in Waiehu and Waihe‘e Streams. This closely mimics animal observations by the USGS. From an ecological perspective, the difference between the modeled habitat units and adult occupancy of habitat units could represent a “sink” or reproductively isolated component of the population within a stream. Amphidromous animals recruit from a large pool of larval animals that do not necessarily originate from the same stream into which they recruit. Thus, it is possible that observations of adult animals in fully diverted streams are products of other streams and their offspring are entrained in the stream diversions and therefore do not contribute to the offshore larval pool.

The HSHEP model in this report is not based on any new field data collected specifically for this report. The Nā Wai ‘Ehā HSHEP model uses the information from the USGS and DAR as the basis for its modeled habitat predictions. The HSHEP provides an accounting of habitat units for native amphidromous animals with respect to various water return, fish passage, and/or habitat restoration scenarios. This accounting of habitat provides an objective way to compare and contrast various water management scenarios to best achieve a balance between water for human use and the natural environment.

The ability to test different management scenarios is an important product of the HSHEP model for Nā Wai ‘Ehā Streams. This report provides six different scenarios, but many more exist. With the HSHEP model set up for the Nā Wai ‘Ehā Streams numerous different scenarios could be rapidly analyzed for comparison. As managers consider these and other options, specific criteria of instream flow decisions should be tested and compared with other options to better understand the costs and benefits associated with proposed actions. Ultimately maximizing water for human use and environmental needs both now and in the future is the goal of wise public-trust resource management.

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