Key to information in the Watershed Atlas

The production of the *Atlas of Hawaiian Watersheds & Their Aquatic Resources* was a large undertaking, and the information displayed in this *Atlas* reflects the data stored in the DAR Aquatic Surveys Database, as well as information from different GIS datasets developed by various parties concerning land or stream characteristics observed in Hawai‘i. The DAR Aquatic Surveys Database is hierarchically designed with observations of animals occurring within a site, sites occurring in a stream segments, stream segments in a stream, streams in a watershed, watersheds within a region, regions within an island, and islands within an island chain (Kuamo‘o, Higashi, & Parham, 2007). As a result, the *Atlas* is a summary of the information at the watershed level. Data collected at the observation site, stream segment, and at stream levels are grouped to provide an accounting of the information for each watershed.

In the development effort for the DAR Aquatic Surveys Database, all watersheds for the state were recreated and coded. To accurately determine watersheds for the state, GIS techniques were used that predict the direction of runoff for each cell in a digital elevation model. Digital elevations models developed by the US Geological Survey with a resolution of 10m for Hawai‘i were used. The process resulted in well over 1000 large watersheds of which approximately 400 contained some type of perennial or intermittent stream channel. Watersheds selected for inclusion in this *Atlas* were those that contained at least one biological survey or, in the absence of survey information, are those watersheds with streams longer than 1 km.

The watersheds for each island are arranged by regions and listed individually with a numerical watershed code.

The following section describes the information contained in each watershed summary.

Name: Watershed name recognized by DAR.

Island: The island on which the watershed occurs.

Watershed code: a five digit code that identifies the island, region, and specific watershed. The DAR watershed coding system was first developed in 1992 (Higashi, 1992) and underwent further improvement by Darrell Kuamo‘o (DAR Hilo) in 2002 to provide a complete coding system for all watersheds in Hawai‘i. This watershed code is similar to codes used in early watershed coding efforts, especially the Hawaii Stream Assessment (Hawaii Cooperative Park Service Unit, 1990). Where possible, similar digits were used in the newer DAR watershed code, but, as a result of the much larger number of watersheds coded by DAR (1000+ versus 376), many new codes were needed. The watershed codes displayed in the *Atlas* generally follow a circular geographic pattern around an island comparable to the HSA system. Some of the newer watershed codes may not follow the next closest watershed pattern because watersheds not included in the HSA system were added to the end of the numbering system for a region.

In this *Atlas*, we have chosen to present the watersheds in geographic order, so in some cases the watershed code may seem out of order in relation to their positions in the *Atlas*. While the watershed code is useful for finding information in the DAR Aquatic Surveys Database, it seems more intuitive to the general reader to view the watersheds in a normal geographic context. The watershed codes are especially useful for requesting information from DAR on specific watersheds because the codes are unique and do not repeat on the different islands. This is in contrast to watershed names, some of which occur on multiple islands (e.g., Punalu‘u on O‘ahu, Maui, and Hawai‘i).

Map: A map of the watershed includes information on the topography, stream reach type, tributary names, biotic sample location and types, diversion ditches, roads, USGS stream gages, dams, and land use/land cover. See map legend for more information. The following describe data sources not covered later in the key.

Streams: Stream information was downloaded from the State of Hawai‘i’s Office of Planning Statewide GIS Program website (http://www.hawaii.gov/dbedt/gis/). Lines were extracted from the 1983 USGS Digital Line Graphs hydrography layers. Stream Types were based on USGS hydrography major codes. Office of Planning Staff edited the information and merged islands together and projected it in NAD83. DAR further modified the stream information by coding each stream and stream segment to match the DAR Aquatic Surveys Database coding system.

Diversion Ditches: Ditch information was downloaded from the State of Hawai‘i’s Office of Planning Statewide GIS Program website (http://www.hawaii.gov/dbedt/gis/). Lines were extracted from the 1983 USGS Digital Line Graphs hydrography layers. Ditch Types were based on USGS hydrography major codes. Office of Planning Staff edited the information and merged islands together and projected it in NAD83.

Roads: Major road information was downloaded from the State of Hawai‘i’s Office of Planning Statewide GIS Program website (http://www.hawaii.gov/dbedt/gis/). "Major roads" extracted from the 1983 USGS Digital Line Graphs for the main Hawaiian Islands. H-3 was added to the layer by the Office of Planning. The roads are provided as a reference to the reader as to the location of the surveys.

USGS Stream Gages: Stream gage information was downloaded from the State of Hawai‘i’s Office of Planning Statewide GIS Program website (http://www.hawaii.gov/dbedt/gis/). The stream gage data is from the Commission on Water Resource Management as provided by the USGS in 1994.

Dams: Dam information was downloaded from the State of Hawai‘i’s Office of Planning Statewide GIS Program website (http://www.hawaii.gov/dbedt/gis/). Dam locations were based on the National Inventory of Dams. Edits to the locations have been made by Office of Planning and DAR staff.

WATERSHED FEATURES

Hawaiian Name Meaning: A description or translation of the meaning of the Hawaiian name. The translation was done by Darrell Kuamo‘o (DAR Hilo) using the *Place Names of Hawaii* by Mary Kawena Pukui, Samuel H. Elbert, and Esther T. Mookini and the *Hawaiian Dictionary* by Mary Kawena Pukui and Samuel H. Elbert.

Maximum Elevation: This is the maximum elevation of the watershed.

Watershed Cluster Type: This is a category with range of 1 to 8 that identifies geomorphologically similar watersheds (Parham, 2002). A total of 150 watersheds were grouped into categories in the original work, and any additional watersheds presented in this *Atlas* were classified by using the key.

Zoning: Zoning information was downloaded from the State of Hawai‘i’s Office of Planning Statewide GIS Program website (http://www.hawaii.gov/dbedt/gis/). The State of Hawai‘i zones all land into four districts, each of which has its own regulatory agency and laws, administrative rules and procedures. The zones are urban, rural, agricultural, and conservation.

Land Stewardship: Land stewardship information comes from the Hawai‘i GAP program (http://www.higap.org). We combined some of their categories into the more general categories of military, federal, state, Hawaiian homes, county, The Nature Conservancy of Hawai‘i, and other private landowners. Land Stewardship is not necessarily land ownership; instead, stewardship reflects who is taking care of the land.

Land Management Status: These data also come from the Hawai‘i GAP program. They represent 4 levels of biodiversity protection. The highest involves permanent biodiversity protection. The next highest level represents lands that are partly managed for biodiversity but have multiple use mandates that may be inconsistent with biodiversity protection (e.g., game hunting areas). The next level down in biodiversity protection includes lands that have some protection but are currently unmanaged, and the lowest level is lands that are unprotected.

Land Use/Land Cover: Land use and land cover information was downloaded from NOAA Coastal Services Center (http://www.csc.noaa.gov/crs/lca/ccap.html). Data from the Costal Change Analysis Program (C-CAP) were used to classify land cover. The information is based on images collected in 2000 for all islands except Hawai‘i where the information was collected in 2001. Land cover categories are:

> ***High intensity developed:*** urban land cover with greater than 75 percent impervious surface.
> ***Low intensity developed:*** urban land cover with greater than 25 percent and less than 75 percent impervious surface.
> ***Cultivated land:*** area under active agriculture.
> ***Evergreen forest:*** forest without a pronounced seasonal dormancy period.
> ***Scrub/Shrub:*** woody vegetation less than 20 feet tall.

Grassland: both managed and unmanaged grasslands.
Emergent Wetland: wetland-rooted emergent species.
Unconsolidated shoreline: tidal flats, shoals, and intertidal areas.
Bare land: bare exposed rock, sand, and soil.

The addition of the category ***Estuarine*** signifies that the area has species commonly found in tidally influenced areas and the addition of the term ***Palustrine*** signifies that the area has species commonly associated with non-flowing freshwaters.

STREAM FEATURES

Length: the length of all stream segments within the watershed.

Stream Order: The reported stream order was determined from the Strahler stream ordering system (Strahler, 1952).

Stream Reach Type: The reach classification system (Parham and Lapp, 2006) was developed by Bishop Museum researchers in collaboration with DAR biologists to provide a general classification of stream reaches that could be applied systematically to all streams on all islands. The reach types are based on elevation and the presence of different sized barriers (waterfalls) in the stream.

Estuary: all stream segments between the coast line and 1 m. elevation.
Lower Reach: stream segments between 1 and 20 m. elevation and below any barrier of approximately 10 m. high.
Middle Reach: stream segments greater then 20 m elevation or above the first 10 m barrier and less than 200 m. elevation or below the first 20 m high barrier.
Upper Reach: stream segments greater then 200 m elevation or above the first 20 m barrier and less than 750 m. elevation.
Headwaters: stream segments greater then 750 m. elevation.

BIOTIC SAMPLING EFFORT

Biotic Sampling: The DAR Aquatic Surveys database contains data from a variety of DAR research projects including pre-1970 data from surveys by the Hawaii Division of Fish and Game. In addition to data collected by state biologists, information was gathered from published and unpublished data sources including surveys by federal researcher (USGS and USF&W Service), numerous university researcher, museum collections, and private consultants. DAR has conducted six types of sampling: point quadrat surveys, larval trapping surveys, impoundment surveys, rapid assessments, line transects, and general surveys. The point quadrat methodology is used most extensively in the surveys and was developed by DAR field biologists and technicians; its use has been described in Baker and Foster, 1992; Fitzsimons, Parham, & Nishimoto, 2004;

Parham, 2005; Higashi and Nishimoto, 2007. Survey reports are available separately by year sampled, number of samples, and distribution of reach type.

BIOTA INFORMATION

Species Lists: The complete list includes native and introduced species observed in all surveys conducted in the watershed. This list is not inclusive of only DAR's point quadrat surveys, but includes information from other survey report sources. There are a number of reports where the species are undetermined and they are placed tentatively in the native or introduced species list. See the Species Size, Average Density, and Observed Distributions and/or Appendix 1 for the undetermined species status. See Appendix 1 for a list of common names that correspond to scientific names.

Species Size: Data are provided on minimum, maximum, and average size of animals observed during DAR's point quadrat surveys.

Average Density: Average density of animals sampled during DAR's point quadrat surveys. Data are averaged over all sampling efforts and grouped by reach type.

Observed Distributions: Data are provided for species presence and are summarized by reach type from all surveys.

HISTORIC RANKINGS

Historic Rankings: Historic listing indicating whether the watershed had been ranked to be of special quality by:

- National Park Service (1982) Nationwide Rivers Inventory. Streams considered for potential Wild and Scenic River status,
- The Nature Conservancy (1985) "Priority Aquatic Sites" for biodiversity conservation,
- U.S. Fish and Wildlife Service (1988) list of "High Quality" streams,
- Hawaii Cooperative Park Service Unit (1990) Hawaii Stream Assessment. Streams rated as Outstanding, and
- M.A.P.S. - Multi-Attribute Prioritization of Streams Project (Uyeno 1998). Streams rated as Potential Heritage Streams.

Current DAR Decision Rule Status: The decision rule status reflects a yes or no assessment of the watershed for certain specific traits. The presence of these traits (a yes answer) is considered a good attribute of the watershed and the stream.

CURRENT WATERSHED AND STREAM RATINGS:

In all ratings, it should be generally assumed that if all other things are equal, then a higher score on an individual rating would indicate a watershed or stream that may have

more habitat for native species than a watershed or stream with the lower score. For example, all other things equal, if one stream is larger than another stream there would be more available habitat in the stream in the larger stream. Also, if two similar streams empty into the ocean with one flowing directly into the deep ocean waters and the other flowing into a large estuary and then into a shallow bay, more potential habitat will be influenced by the latter stream.

Most of these ratings are not "proven facts", but are our interpretation about how streams and their ecosystems work. These general patterns may not hold true for all individual species, but probably benefit overall biodiversity. The component ratings as well as the combined ratings are provided so the reader can assess the overall characteristics of the watershed, stream, or its animals in comparison to other streams on that island or among all streams statewide.

These ratings are not fixed. The biological ratings are based on the presence of species, and additional data are likely to change how a stream scores if additional species are observed. It is also important to realize that the ratings do not consider whether a stream's water is currently diverted for agriculture or municipal use, whether a stream's channel has been modified, or whether the stream's water quality is impaired. This important information is being updated by the Commission on Water Resource Management and the Department of Health and hopefully will be incorporated into future versions of this *Atlas*.

Each Rating has been standardized on a 0 to 10 scale where 0 is the lowest rating and 10 is the highest rating. To accomplish the standardization, after a score for an individual metric was calculated, the lowest score for all the watersheds in the *Atlas* was subtracted from each score to set the minimum value to zero. Next, the new maximum score was divided into each watershed's score and resulted in values between 0 and 1. This score was multiplied by 10 to provide the standardized scale. This standardization process was done for each individual rating and also for combined and overall ratings. As a result of the standardization process, each watershed was compared to all other watersheds in the *Atlas* and, as new data are added to the database, the relative rating of a watershed will need to be re-standardized against all other watersheds. No effort was made to normalize the ratings (adjust the mean rating to 5) because no single normalization process was appropriate for all rating.

Watershed Ratings:

Land Cover Rating: In general, this rating scores the amount of forested lands positively and the amount of developed lands negatively in a watershed, and other land cover types are assumed to have a neutral association with stream quality. Specifically, the percent of land cover type within the watershed was multiplied by a value to weight the land cover type with respect to its positive or negative value associated with a high quality stream. These values are:

Evergreen Forest: +1
Estuarine Forested Wetland: +1
Palustrine Forested Wetland: +1

Estuarine Forested Wetland: +1
Palustrine Emergent Wetland: +1
High Intensity Developed: -4
Low Intensity Developed: -2
Cultivated Land: -1
Bare Land: -1
Grassland: 0
Palustrine Scrub/Shrub Wetland: 0
Scrub/Shrub: 0
Unconsolidated Shore: 0
Unclassified: 0
Water: 0

The higher negative values for High Intensity Developed and Low Intensity Developed lands reflect the typical increase in pollution, sedimentation, discharge modification, and habitat degradation in comparison with streams near cultivated lands.

Shallow Waters Rating: This rating reflects the extent of estuarine and shallow marine waters associated with the stream. The length of the estuary and length from the stream mouth to the 60-ft contour line (10 fathoms) was measured and combined to estimate the amount of interaction the freshwater would have with the estuary and nearshore environments. Each category (estuary and shallow nearshore marine waters) is standardized prior to combining to weigh each category equally in the rating. This rating assumes that a stream with more associated shallow water would have greater habitat diversity than a stream that empties nearly directly into deep ocean waters.

Stewardship Rating: This rating scores the stewardship categories as 1 = no biodiversity protection; 2 = protected but unmanaged; 3 = managed for multiple uses; and 4 = biodiversity protection. The percent of land in each category is multiplied by the weighting score, and the sum for the watershed is calculated. The overall sum is standardized to provide the rating.

Size Rating: This rating compares stream size. This rating combines the standardized overall length of a stream with the standardized stream order to estimate stream size. This rating assumes a larger stream with more tributaries has more habitat than a smaller stream.

Wetness Rating: This rating compares the average annual rainfall within a watershed to estimate the wetness of a watershed. The mean value for the average annual rainfall within the watershed is used for comparison with other watersheds. This rating assumes that a wetter watershed will have a larger stream with more stable flow than a drier watershed and less consistent flow.

Reach Diversity Rating: This rating examines the type and extent of reaches within the stream to provide an estimate of the amount of different habitat types in the stream. First, the number of reach types with at least 1 km and less than 2 km of stream length are counted for each watershed. Next, the number of reach types with greater than 2 km of

stream length are counted for each watershed. The two counts are combined by multiplying the second count by 2 and adding this to the first count. This rating assumes that higher reach diversity will result in more habitat types and that the longer lengths of these reach types support more habitat than shorter sections of the reach types.

Total Watershed Rating: This rating combines the standardized ratings for Land Cover, Shallow Waters, Stewardship, Size, Wetness, and Reach Diversity to estimate the overall quality of the watershed and its stream with respect to the overall amount and diversity of aquatic habitats.

Biological Ratings:

Native Species List Rating: This rating counts the number of common native fishes and macro-invertebrates that are likely seen in most surveys. These nine species include the fishes *Awaous guamensis*, *Eleotris sandwicensis, Kuhlia xenura* (or *Kuhlia sp.* prior to name change), *Lentipes concolor, Sicyopterus stimpsoni, Stenogobius hawaiiensis*, the crustaceans *Atyoida bisulcata, Macrobrachium grandimanus*, and the mollusk *Neritina granosa.* Watersheds without survey efforts are unranked.

Introduced Genera List Rating: This rating counts the genera of potentially harmful introduced animals that are commonly observed in most surveys. The genus of an animal was used in this rating to avoid confusion in observations with taxonomic problems associated with identifying individual species of some genera (e.g., various *Tilapia* species can be difficult to identify and are reported differently in different surveys.) These genera include the fishes *Cichla, Cichlasoma, Clarias, Gambusia, Limia, Micropterus, Oreochromis, Poecilia, Sarotherodon, Tilapia, and Xiphophorus, the amphibians Bufo and Rana*, the mollusk *Corbicula, and the crustacean Macrobrachium (*excluding *the native Macrobrachium grandimanus).* Watersheds without survey efforts are unranked.

All Species Score Rating: Scoring is based on several parameters. Positive scoring attributes include the presence of endangered or candidate species (5 pts. each), presence of native species group 1 species (2 pts. each for *Awaous guamensis*, *Lentipes concolor*, *Sicyopterus stimpsoni*, and *Neritina granosa*), and all other native species (1 pt. each). Negative scoring attributes include introduced species group 1 (-2pts. each for members of the genera *Bufo, Cichla, Cichlasoma, Clarias, Corbicula, Gambusia, Limia, Macrobrachium, Micropterus, Oreochromis, Poecilia, Rana*, *Sarotherodon, Tilapia,* and *Xiphophorus*) and all other introduced genera (-1 pt. each). Species groups were based on the Hawaii Stream Assessment (1990) criteria and extended to cover all observed species. Watersheds without survey efforts are unranked.

Total Biological Rating: A combination of the Native Species List Rating, Introduced Genera List Rating, and the All Species Score Rating. Where surveys were not designed to observe the species or genera in the Native Species List Rating and the Introduced Genera Rating (e.g., only damselfly surveys), the All Species Score Rating was used as the pre-standardized Total Biological Rating. All ratings have been standardized to a 0 to 10 range based on the results for all watersheds statewide. Watersheds without survey efforts are unranked.

Overall Rating: These ratings are a combination of the Total Watershed Rating and the Total Biological Rating. All ratings have been standardized to a 0 to 10 range based on the results for all watersheds statewide. Watersheds without survey efforts are unranked.

Rating Strength: Ranking Strength represents an estimate of the level of confidence in the ratings. The ranking strength reflects the number of surveys, the types of surveys, and the distribution of surveys within the stream reaches. It is expected that the number of species observed (a major component of the rank) will increase with increased survey efforts, and the ranking strength gives the reader a way to evaluate the accuracy of the current stream rank. All ratings have been standardized to a 0 to 10 range based on the results for all watersheds statewide. Watersheds without survey efforts are unranked.

REFERENCES: Source of all data summarized for the watershed.

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