Economic Valuation of The Nature Conservancy’s Watershed Conservation on Hawai‘i Island: Ka‘ū and Kona Hema

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The Nature Conservancy’s Watershed Conservation
on Hawai‘i Island: Ka‘u and Kona Hema

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1. EXECUTIVE SUMMARY

The objective of this research was to estimate the value of ecosystem services protected by watershed conservation activities at The Nature Conservancy’s management units in the Kona Hema and Ka‘ū preserves on Hawai‘i Island. Projections of monetized benefits, together with trajectories of conservation costs, were then used to calculate net present value, payback period, and return on investment. Key results are summarized below:

1. Watershed conservation activities at Kaiholena, Maka‘ālia, and Kona Hema protect an estimated 111, 69, and 6,168 million gallons of freshwater yield respectively from the time of fence establishment until 2065.

2. Taking into account costs, 30, 26, and 383 gallons of freshwater are protected for every dollar spent at Kaiholena, Maka‘ālia, and Kona Hema respectively.

3. Assuming a discount rate of 3%, the lower bound for the present value of freshwater benefits is 0.19, 0.10, and 10.5 million dollars at Kaiholena, Maka‘ālia, and Kona Hema respectively.

4. The payback period for investment is 9, 24, and 46 years for Kaiholena, Maka‘ālia, and Kona Hema respectively.

5. The net present value of conservation, when taking into account ecosystem services in addition to freshwater provision, is 20.7, 4.5, and 6.5 million dollars at Kaiholena, Maka‘ālia, and Kona Hema respectively.

6. The return on investment (ROI) is 542%, 163%, and 38% at Kaiholena, Maka‘ālia, and Kona Hema for the planning period ending in 2065. The ROI is 134% when the three sites are considered jointly.

2. PROJECT OVERVIEW

This research began with the intent to quantify and monetize groundwater recharge services protected and enhanced by watershed conservation activities in two Nature Conservancy (TNC) preserves on Hawai‘i Island: Kona Hema and Ka‘ū. Groundwater scarcity is a particularly salient issue in Kona Hema, where population growth and development are projected to continually increase in the future. However, after further discussion with TNC staff, it became clear that the study should also include, to the extent possible, the value of other ecosystem services (ES) being protected by conservation activities. To that end, we apply benefit transfer to value habitat provision for endangered native bird species in Ka‘ū, as well as ecosystem regulation and other habitat services in both Ka‘ū and Kona Hema.

Ecosystem services at the two sites are quantified using the United States Geological Survey (USGS) LANDFIRE Dataset for Hawai‘i (http://landfire.cr.usgs.gov/viewer). The benefits of conservation are projected on an annual time-step by comparing the difference in expected ES provided under two scenarios: (1) maintenance
of current native land cover, and (2) native land cover replaced by invasive land cover over time assuming no conservation activities. Freshwater benefits are calculated as the avoided loss in water yield that would have occurred if native land cover were not maintained at its current level. Similarly, endangered bird benefits are determined by the avoided displacements that would have occurred if native habitat conversion by invasive species were left unchecked. From this we can calculate the present value cost per unit of ES provided (e.g. gallons of freshwater saved, bird displacements avoided) using detailed conservation cost data provided by TNC. Estimating a return on investment (ROI), however, requires monetized benefits that are directly comparable to costs.

Environmental valuation is challenging because ecosystem goods and services are typically not exchanged in markets. In some cases, ES values can be inferred from transactions in related markets (e.g. using travel expenditures to value recreational beach days). However, monetizing the ES provided in conservation areas more likely requires nonmarket valuation methods. While nonmarket valuation techniques have advanced in recent years, they are often costly because nearly all require collection of survey data. Moreover, each survey is typically designed to elicit values for a single ES, which means that multiple survey instruments may be required when multiple ES are under consideration. For our purposes, we implement benefit transfer to value bird habitat (Richardson et al., 2015) and regulatory services, a technique that generates monetary value estimates of ES using results of valuation studies conducted by other researchers at sites with similar attributes. Freshwater benefits are monetized using projected water prices, which serve as a lower bound to total value; consumers are willing to pay at least that much for each unit of water. Applying the appropriate values to the estimated quantity of ES protected at each site allows us to calculate the ROI for TNC conservation activities on Hawai‘i Island.

3. STUDY SITES

Benefits and costs of watershed conservation are calculated for the Ka‘ū and Kona Hema preserves on Hawai‘i Island. Sites were selected based on size and expected impact on the provision of freshwater services. The Kaiholena and Maka‘ālia fenced units, which are both located within the Ka‘ū site, are adjacent, but the benefits and costs are determined independently because detailed cost data is available for each subunit. In contrast, benefits and costs for the three connected fence units within the Kona Hema site, are calculated in aggregate due to the nature of the cost data.

3.1 Ka‘u Preserve Description and Conservation Activities

The 3,511-acre TNC Ka‘ū Preserve is located on the southeast flank of Mauna Loa volcano, below the southwest rift zone, at the southern end of Hawai‘i Island. The Preserve is part of the largest and most intact expanse of native forest in the state, ranging in elevation from 1,760 to 5,770 feet. Made up of four separate parcels of forested land, the preserve features mountainous ridgelines with narrow plateaus broken by alternating steep valleys. Closed-canopy *koa* and *ʻōhi‘a* forest shelters an understory of native *uluhe* and *hāpu‘u* tree ferns. All four
parcels consist of nearly pristine native forest and form a boundary between the largely intact native alpine and subalpine forest above, and the agricultural land below. In 2002, TNC purchased four parcels of private forestlands adjoining the Ka’ū Forest Reserve from a subsidiary of C. Brewer & Co., Ltd. Acquisition of these parcels enables management access to state forest reserve lands.

Within the larger Ka’ū management area, much of TNC’s conservation efforts are being directed toward two adjacent fenced units (Figure 1 and Table 1). TNC installed five miles of fencing in 2007 in the Kaiholena management unit and has kept roughly 1,100 acres free of pigs since 2009. Weed control is focused at the edge of an infestation in Lower Hīlea, and has ranged from 35-50 acres/year cleared, along with kahili ginger control at Kāhilipali, Kī'olokū and Kea'iwa (outside the fence) that amounts to 10 acres/year combined. Since completion of the ungulate removal project, native ferns have begun to replace pig wallows and bare soil. Volunteers visit once every other month to pull weeds, help replace rusted fence, and clear drains along roadways. Monitoring of weeds and ungulates is conducted through reading of six transects once per year. Because the area is relatively pristine, much of the labor effort is expended on searching for new and isolated invasive populations. TNC also conducts fence checks regularly. Full replacement of fences (not including the posts) is required once every five years.1 Fencing and ungulate removal have recently begun in the 800-acre Maka'ālia unit, which is located above the existing Kaiholena fence.

Table 1. List of conservation sites

<table>
<thead>
<tr>
<th>Name of Site</th>
<th>Fenced Subunit</th>
<th>Fenced Area (acres)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ka’ū</td>
<td>Kaiholena</td>
<td>1,131</td>
</tr>
<tr>
<td>Ka’ū</td>
<td>Maka’ālia</td>
<td>800</td>
</tr>
<tr>
<td>Kona Hema</td>
<td>Kona Hema</td>
<td>7,515</td>
</tr>
</tbody>
</table>

3.2 Kona Hema Preserve Description and Conservation Activities

The 7,515-acre fenced area of the Kona Hema Preserve consists of three adjoining forest parcels in South Kona on the slopes of Mauna Loa purchased between 1999 and 2003 at Honomalino, Kapu’a and Pāpā. The Kona Hema Preserve protects part of an ancient koa-ōhi’a forest that spans more than 100,000 acres along the leeward coast of the Island of Hawai’i. Pigs, goats and mouflon sheep are the preserve’s primary threats.

TNC installed 24 miles of fencing to exclude feral ungulates from 7,500 acres in Kona Hema (Figure 1 and Table 1). Through trapping and dog hunting within three fenced units, over 600 pigs and 100 sheep have been removed since 2000. It is estimated that only 2 pigs remain in the Kapu’a unit and less than three mouflon in the Honomalino unit. Much of the native understory is now returning via passive regeneration.

1 Shortly after the fence was built, Ka’ū experienced vog concentrations roughly 10,000 times historical levels, which contributed to rapid deterioration of the fence wire. Although it is difficult to predict whether the frequency of wire replacement will remain constant over time, given uncontrollable environmental factors and potential improvements in available fence materials, we conservatively assume that wire replacement in Ka’ū will occur in 5-year intervals going forward.
Weed control is restricted to relatively small priority areas. In the lower northwest corner of the preserve, 250 acres of strawberry guava have been removed so far at a rate of 50 acres per year. It is estimated that roughly 450-500 acres of strawberry guava remain in the understory. Removal methods include pulling, basal application of herbicide, and frilling. All methods have low material costs but are labor intensive. Four transects are monitored for ungulates and weeds once per year.

In addition to protecting the native forests, TNC is developing a model of sustainable *koa* forestry that will help other landowners maintain the biological and economic value of their lands. Nearly 400 acres of former pasture in the upper preserve have been put into *koa* regrowth through low-cost bulldozer scarification.

To protect the valuable replanted *koa* forested areas, as well as the many other ecosystem services provided in Kona Hema, a fire management plan was established in 2012. The plan includes fire prevention, pre-suppression, and suppression measures. Without proper fire management planning, wildfires in remote conservation areas are often able to spread rapidly and are not always detected right away, making suppression ultimately more difficult. As will be seen in the following sections, the lower bound for the gross present value benefit of conservation in
Kona Hema is in the tens of millions of dollars. The potential damages from a large wildfire may be even greater than those avoided costs because such a drastic and sudden change in land cover would likely allow for more rapid invasion by non-native species. For example, the effect of a 500-acre fire originating above the Papa management unit (4,500-foot elevation) in 1992 is evident over a decade later; much of the burned area is now covered by non-native weeds (upper-right area of Figure 7).

4. COSTS OF CONSERVATION

The pattern of expected expenditures is similar for all sites. The largest cost is associated with the initial construction of a fence and is incurred at the start of the planning timeline. Once the fence is built, maintenance within the enclosure is limited primarily to priority invasive weed control and ungulate monitoring and removal. The fence itself also requires maintenance, however, which results in intermittent spikes in the cost trajectory. In this section, we project conservation expenditures at each site for a 50-year time horizon.

4.1 Costs for Kaiholena Fenced Unit

The Ka‘ū Preserve, which includes the Kaiholena and Maka‘ālia fenced units, is part of the state Natural Area Partnership Program, which means that some of the budget is allocated to outreach and education. For this particular preserve, it is estimated that 30% of the budget was allocated to ungulate control, 30% was allocated to weed control, and the remaining 40% was split between outreach, education, and other activities in recent years. Because not much weed control occurs inside the fenced areas that we are focusing on, projected expenditures for this site include primarily those related to fence construction and maintenance and ungulate monitoring and removal.

The Kaiholena fenced unit is the largest enclosed area in the preserve, spanning roughly 1,100 acres. The fence was paid for in two installments, $217,934 in 2006 and $292,500 in 2007. In the three years that followed, pigs were removed via six volunteer hunts (Nov 2007-Feb 2008), a $50,000 ungulate removal contract (Jul-Aug 2008), and TNC staff trapping and hunting efforts (Oct 2008-Jan 2009). Although specific measures of effort (e.g. person-hours) were not available, we estimate expenditures on ungulate control based on the 30% share of total expenditures, which amounted to approximately $52,000 annually from 2008-2011. Although removal costs will decline as the ungulate populations decreases, regular monitoring will be required for both invasive ungulate and weed species. Given the upward trend in expected personnel and fringe expenditures, we assume a 1 percent annual growth rate in maintenance expenditures going forward.

In 2012 and 2013, four staff members at 0.15 FTE and 740 volunteer hours were expended to replace the wire for the Kaiholena fence. Assuming a wage plus fringe rate of $29.17 per hour (established Department of Labor wage for ungulate fencing), the total labor cost of wire replacement was estimated at $94,394. The cost of materials was roughly $45,000, resulting in a total wire replacement cost of $139,394. The wire will likely need to be replaced every 5 years because Kaiholena is directly in the vog path.
The cost of replacing the entire fence (posts included) is expected to range from one-half to two-thirds of the original installation cost. Assuming the cost is on the higher end of the spectrum, installments of approximately $145,000 and $195,000 will be required. Although the posts have not been replaced since the fence was built, we anticipate the need for full replacement once every 30 years. Actual and projected expenditures over the period 2006-2065 are presented in Figure 2. The initial installation cost is high, but maintenance costs are relatively low with the exception of wire replacement every five years. The present value (PV) cost of conservation in Kaiholena projected out to 2065 at a discount rate of 3% is $3.7 million or $3,274 per acre in 2015 dollars.

Figure 2. Historical and projected annual watershed conservation expenditures

![Figure 2. Historical and projected annual watershed conservation expenditures](image)

4.2 Costs for Maka'alia Fenced Unit

Projected expenditures over the next few years in Kaʻū (Table 2) are larger than in previous years, due primarily to the Makaʻalia fence, which is currently being constructed adjacent to the existing Kaiholena fence.

Table 2. Projected expenditures in Kaʻū

<table>
<thead>
<tr>
<th>Cost Category</th>
<th>FY2015</th>
<th>FY2016</th>
<th>FY2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personnel and Fringe</td>
<td>$271,915</td>
<td>$280,072</td>
<td>$288,475</td>
</tr>
<tr>
<td>Contractual</td>
<td>$289,433</td>
<td>$210,741</td>
<td>$37,980</td>
</tr>
<tr>
<td>Other Expenses (Supplies, Travel, Occupancy, etc.)</td>
<td>$79,816</td>
<td>$82,210</td>
<td>$84,676</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$641,164</strong></td>
<td><strong>$573,023</strong></td>
<td><strong>$411,131</strong></td>
</tr>
</tbody>
</table>

The Makaʻalia fenced unit will enclose approximately 800 acres. The fence will be paid for in two installments, $289,433 in 2014 and $210,741 in 2015. The cost of maintenance is assumed proportional (acre-wise) to that of Kaiholena, totaling $45,000 per year initially, and growing at an annual rate of one percent. We further assume that the fence wire must be replaced every five years at a cost equal to 27% of the initial installation cost, the same percentage as for Kaiholena. Similarly, total fence replacement cost is 2/3 of the original installation cost or $333,449 and is incurred once (spread over two periods) every 30 years. Projected expenditures over the period...
2014-2065 are presented in Figure 2. Like for Kaiholena, the initial installation cost is high, but maintenance costs are relatively low with the exception of wire replacement every five years. The present value cost of conservation in Maka'ālia out to 2065 is $2.6 million or $3,257 per acre.

4.3 Costs for Kona Hema Fenced Unit

Due to the remoteness of the sites in Ka‘ū—helicopter time was required to deliver materials and labor, and pathways for the fence-line were cleared by hand—fence installation costs were relatively high, exceeding $145,000 per mile. In comparison, the Kona Hema fenced unit, which spans over six times the area of Kaiholena, was constructed at a total cost of roughly $1 million. Each section of the fence was built along bulldozed roadways through a combination of contractors, TNC short term crew hires, and National Park Service labor. In 1999, Southwest Fencing was contracted at Honomalino to construct 10.5 miles of fence at $10 per foot. A temporary TNC crew was hired in 2002 to install 4.3 miles of fence at Kapu‘a at cost of $50,000 per mile. In the following year, 4.5 miles of fencing was added in Pāpā at a cost of $10 per foot. The remaining mauka Pāpā boundary fence was completed by NPS shortly thereafter. The average cost of fencing per mile in Kona Hema was approximately one-third of the cost in Ka‘ū.

Ungulate removal costs in Kona Hema are assumed proportional acre-wise to Ka‘ū and major removal efforts were undertaken mainly during the decade after fence completion, although declining in intensity over time. Thereafter annual maintenance expenditures are calculated based on projected costs (Table 3). Given the trend in expected expenditures and the fact that annual expenditures in Kona Hema have remained fairly steady at approximately $250,000-300,000 over the past few years, we assume a one percent annual growth rate in routine maintenance expenses which include fence checks and some strawberry guava removal. We further assume that fence wire needs replacement every fifteen years at 27% of the initial fence construction cost, in this case equal to $206,251. The frequency of fence replacement is lower than for Ka‘ū because the conditions are milder.

<table>
<thead>
<tr>
<th>Cost Category</th>
<th>FY2015</th>
<th>FY2016</th>
<th>FY2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personnel and Fringe</td>
<td>$160,315</td>
<td>$165,125</td>
<td>$170,078</td>
</tr>
<tr>
<td>Contractual</td>
<td>$34,900</td>
<td>$35,947</td>
<td>$37,025</td>
</tr>
<tr>
<td>Other Expenses (Supplies, Travel, Occupancy, etc.)</td>
<td>$107,178</td>
<td>$110,394</td>
<td>$113,705</td>
</tr>
<tr>
<td>Total</td>
<td>$302,394</td>
<td>$311,465</td>
<td>$320,809</td>
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</table>

Full replacement of the fence (including posts) will be required every 30 years at only a fraction of the original installation cost because clearing and post alignment will not have to be redone. The cost of replacement could range from one-half to two-thirds of the original installation cost. Assuming the cost is on the higher end of the spectrum, approximately $670,000 will be required. Historical and projected expenditures over the period 1999-2065 are presented in Figure 2. The initial installation cost is high, but maintenance costs are relatively low with the exception of wire replacement every fifteen years. The present value cost of conservation in Kona Hema through 2065 is $16.1 million or $2,145 per acre in 2015 dollars.
5. BENEFITS OF CONSERVATION

To estimate the value of ecosystem services sustained or enhanced by watershed conservation, we begin by developing counterfactual landcover scenarios. That is, we identify invasive-dominated landcover within each management area and then generate projections on how the invasive-dominated cover replaces existing native cover over space and time under the assumption that no watershed conservation occurs in the future. To the extent possible, we then link those landcover changes to quantitative changes in the provision of various ecosystem services (e.g. reductions in freshwater yield). Finally, we assign monetary values to the expected potential losses in ES using benefit transfer. Benefits are measured as the avoided losses that are expected to occur in the absence of current conservation activities.

5.1 Landcover Scenarios

Current landcover is identified using maps generated by the USGS LANDFIRE Dataset (Figure 3). Although the raw data includes a number of classifications, we focus on the difference between native and alien dominated 30m×30m parcels. In our simulations, we assume that only native parcels are converted to alien if conservation activities are ceased; other parcels remain unchanged.

Figure 3. Hawai‘i Island current landcover
In order to estimate the expected benefits of current watershed conservation activities (e.g. fencing, priority invasive weed control), we need assumptions about how landcover would convert from native to alien over time if those activities stopped. Although growth/spread rates vary according to the type of invasive species and a variety of site characteristics, we do not have enough information to project landcover conversion at that level of detail. Instead we begin with the assumption that invasive weed growth is, on average, comparable to that of strawberry guava, which has been estimated in the range of 9-12% per year on Hawai‘i Island (NPS 2008; Geometrician Associates LLC 2010). Because strawberry guava is typically considered highly aggressive relative to other invasive plant species, this may be viewed as a worst case scenario. To allow for the possibility of less aggressive invasions, we also consider land cover conversion at a rate of 5% annually. Starting with the initial coverage of alien species, we simulate alien spread according to a logistic growth function with an intrinsic growth rate equal to 10% and carrying capacity equal to the total fenced area. If the initial population of invasive landcover is low, the population grows relatively slowly at first. Eventually, the rate of growth increases, and as the population approaches its carrying capacity, it slows again. Regardless of where we are on the growth curve, the proportion of invasive-dominated landcover increases each year in the absence of conservation, the provision of ES declines, and the cumulative benefit of conservation increases. We abstract from the possibility that entry from outside the management unit boundary creates new isolated populations. Landcover change out to year 2065 is depicted for each fenced unit in Figure 4. Projections for the more conservative growth scenario (g=5%) are also included for comparison.

Under the assumption of no conservation and a 10% annual growth rate, at least 75% of native landcover is projected to be converted before year 2065 at all sites, although the approach path varies according to the size of the initial invaded area. Figures 5-8 illustrate the spatial spread of invasive landcover for each of the fenced areas.

**Figure 4. Invasive versus native landcover over time with no conservation**

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2 In some areas, non-native grasses underlie native canopy species, but such distinctions cannot easily be made using satellite imagery. We recognize that non-native species in the understory can negatively impact infiltration and other water balance components, but capturing those effects is beyond the scope of this study.
Figure 5. Maka‘alia and Kaiholena current landcover

Figure 6. Maka‘alia and Kaiholena landcover in 25 years with no conservation (10% growth rate)
Figure 7. Kona Hema current landcover

Figure 8. Kona Hema landcover in 25 Years with no conservation (10% growth rate)
5.2 Freshwater Provision

One of the main goals of watershed conservation is to increase (or avoid the loss of) groundwater storage to ensure freshwater availability for future generations. For a given landcover, groundwater storage increases with precipitation, fog interception, and inflow from adjacent freshwater bodies, and decreases with overland flow, evapotranspiration, and discharge to the ocean. Recharge or infiltration could therefore be directly calculated if maps were available for precipitation, ET, streamflow, and fog interception. Although information is available for precipitation and ET, data collection at USGS stream gauges has been greatly reduced in recent years, and there are currently no fog interception maps for Hawai‘i Island.

Over the past decade, a number of studies have been conducted on smaller scales to quantify the difference between native and invasive plant species with regard to their impacts on various water balance components (Giambelluca et al., 2008; Giambelluca et al., 2009; Kagawa et al., 2009; Cavaleri et al., 2014; Perkins et al., 2014).\(^3\) From these studies, we can generally conclude that when compared to native plant species, invasive plant species in Hawai‘i tend to have higher ET rates, generate larger throughfall rain drops, have higher sap flux density, reduce the velocity of water to depths of 1-meter, have lower canopy water storage capacity and cloud water interception capability, and generate lower net rainfall. In aggregate, these results suggest that native plants tend to use less water, thus leaving more to recharge underlying aquifers, but quantifying the exact effects of landcover conversion on recharge remains a challenge.

Given the data currently available, we believe that changes in ET are the best measure of watershed conservation benefits. Holding fog interception\(^4\) and precipitation constant, an increase in ET is equal to the aggregate decrease in recharge and overland flow. Avoiding losses to ET by maintaining the watershed, therefore, avoids reductions in recharge and overland flow (hereafter *freshwater yield*). Though we cannot confidently measure changes in overland flow independently and they technically do not increase groundwater storage, they do generate positive instream benefits,\(^5\) which should be attributed to watershed conservation. Existing ET maps (Giambelluca et al., 2014) were matched up with current landcover maps to determine the baseline for our analysis. Figure 9 depicts inches of average annual ET on Hawai‘i Island.

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\(^3\) One large scale study, a USGS groundwater recharge assessment for the island of Hawai‘i (Engott, 2011), was conducted in 2011. Results from the water budget model showed an increase in recharge of approximately 10 percent for several of the hydrological units when going from current land cover to all native landcover. The increase was smaller for the remainder of the units. We were unable to build directly off of this study due to data sharing restrictions.

\(^4\) Fog interception has been shown to vary by species (Takahashi et al., 2011), but more studies are needed to accurately quantify those differences.

\(^5\) In some situations, increased overland flow can also generate negative effects such as sedimentation. Here, we are focusing on well-maintained management units, wherein such effects are likely to be outweighed by the positive additions to freshwater storage.
Evapotranspiration varies over space, largely due to differences in climate variables such as precipitation but also partly due to differences in landcover. Although there is no way to directly measure ET for our counterfactual scenario, wherein alien forest continuously replaces native forest over time, we can extrapolate changes based on observed differences in the baseline map. We start by separately calculating mean ET across all native units and mean ET across all invasive units classified as “tree cover”. Other types of invasive landcover (e.g. herb cover, shrub cover, etc.) are not included in the baseline ET calculation because we assume that all units will eventually be converted to invasive canopy if watershed conservation is discontinued. For each year, we simulate landcover conversion as described in the previous section; the area of invasive landcover follows a logistic curve with an intrinsic growth rate of 10%, and the native landcover is reduced by enough to exactly offset that change. Baseline ET is then subtracted from post-conversion ET in each year to determine the benefits (avoided freshwater yield loss) of maintaining watershed conservation activities at their current levels. Total evapotranspiration increases out to year 2065 in each fenced unit, which means that avoided ET losses correspondingly increase, as illustrated in Figure 10.

Aggregated over time, freshwater benefits totaled 111, 69, and 6,168 million gallons at Kaiholena, Maka‘ālia, and Kona Hema respectively. The total present value (PV) cost of conservation ranges from $2.6 million in
Makaʻālia to $16.1 million in Kona Hema, assuming a discount rate of three percent, and the weighted average of per-acre PV costs is $2,374. Freshwater yield per dollar, calculated as (projected) avoided ET loss divided by the PV cost of conservation, ranged from 26 to 383 gallons, with a weighted average of 310 gallons. Equivalently, every $3.22 spent on conservation activities protect on average 1,000 gallons of freshwater yield. Results are summarized in Table 4.

The current price for general water use up to 5,000 gallons on Hawai‘i Island is $2.74 per thousand gallons, including the first block rate and a power cost charge. Since pumping and transmission are largely dependent on electricity, we assume that the price of water will grow at approximately the same rate as the price of electricity. Given the stochastic nature of energy prices, we consider three future price scenarios following Coffman et al. (2015): 6 0.3% annual growth rate (low growth scenario), 1.3% annual growth rate (moderate growth scenario), and 3.1% annual growth rate (high growth scenario). If we take the current price of water as a measure of value—the lower bound of users’ marginal willingness to pay for water7—then the PV costs of watershed conservation outweigh the PV benefits of freshwater services.

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6 The authors’ energy price forecasts for Hawai‘i are driven by Energy Information Administration data that is only available to 2030. We calculate the average annual growth rate over the available time periods and assume that the price will continue to grow at that rate through 2065.

7 The value of preventing the loss of (or adding) an additional unit of freshwater in a dynamic resource optimization model is equal to the shadow price or marginal user cost of the resource (λ). Along the optimal path, λ is equal to the difference between the efficiency price (p*) and the extraction or pumping cost (c). In Hawai‘i, the status quo price (psq) set by the water department is typically below p* (see e.g., Pitafi and Roumasset 2009), which implies that for a relatively small c, psq < p* ≈ λ. In other words, psq represents a lower bound for the true scarcity value or shadow price of the resource. The value of λ can only be determined using a more complex hydrologic-economic model, which is beyond the scope of this project.
Table 4. PV benefit of freshwater services

<table>
<thead>
<tr>
<th></th>
<th>Kaiholena g=10%</th>
<th>Maka‘alia g=10%</th>
<th>Kona Hema g=10%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>g=5%</td>
<td>g=5%</td>
<td>g=5%</td>
</tr>
<tr>
<td><strong>Water yield</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total yield saved (million gallons)</td>
<td>111</td>
<td>54</td>
<td>69</td>
</tr>
<tr>
<td>Yield per dollar (gallons/dollar)</td>
<td>30</td>
<td>15</td>
<td>26</td>
</tr>
<tr>
<td><strong>Low price growth</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PV benefit (million dollars)</td>
<td>0.13</td>
<td>0.06</td>
<td>0.07</td>
</tr>
<tr>
<td>PV benefit per acre (dollars/acre)</td>
<td>119</td>
<td>55</td>
<td>86</td>
</tr>
<tr>
<td><strong>Moderate price growth</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PV benefit (million dollars)</td>
<td>0.19</td>
<td>0.09</td>
<td>0.10</td>
</tr>
<tr>
<td>PV benefit per acre (dollars/acre)</td>
<td>169</td>
<td>80</td>
<td>124</td>
</tr>
<tr>
<td><strong>High price growth</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PV benefit (million dollars)</td>
<td>0.37</td>
<td>0.18</td>
<td>0.20</td>
</tr>
<tr>
<td>PV benefit per acre (dollars/acre)</td>
<td>330</td>
<td>162</td>
<td>245</td>
</tr>
</tbody>
</table>

However, the PV benefit calculated in this manner is an underestimate for several reasons. First, the avoided costs would be higher if the price accounted for the scarcity value of the resource; the benefit of increased water availability in the future is greater if prices are expected to be higher due to scarcity. Furthermore, the costs of all conservation activities are accounted for, including those not designed specifically to enhance the provision of freshwater (e.g., habitat protection, endangered species protection), whereas only freshwater benefits are considered. Although quantifying and monetizing every ES protected by conservation activities would be ideal for directly comparing total costs and benefits, measuring the avoided potential loss of every ES within the study sites is beyond the scope of this project. Nevertheless, we can improve our estimate of conservation benefits by adding as many other ES values as is feasible to supplement the estimates of freshwater services. To that end, the remainder of this section is focused on quantifying several other nonmarket ES sustained by conservation activities to provide a more comprehensive representation of total conservation benefits.

5.3 Habitat Provision for Endangered Bird Species

Species habitat is another important ecosystem service provided by forested areas throughout the state and worldwide. As landcover transitions from native to invasive, freshwater yield is reduced to some extent, but the consequences may be more severe for rare or endangered native species of both flora and fauna; habitat conversion may, in extreme cases, lead to extinction. While most would not argue against the idea that preventing species loss is important, monetizing the value of prevention is a challenge. Because endangered species are not (legally) bought and sold in markets, determining the monetary value of protecting them requires nonmarket valuation techniques. When the requisite data is available, revealed preference approaches such as the travel cost method typically generate the best estimates because they are based on actual spending behavior. In the case of birds, for example,
this would require information on ecotourism and travel expenditures as well as various characteristics of individual birdwatchers. When such data is not available or not easily obtainable, contingent valuation techniques are sometimes employed. Contingent valuation directly asks survey participants what they are willing to pay to protect the good or service being valued. In this section, we follow the benefit transfer approach outlined in Richardson and Loomis (2009) to value bird habitat provision at our study sites.

The Kaʻū Forest Reserve provides habitat for eight native forest birds (DLNR, 2012), including four federally listed endangered species: ‘Akiapōlā’au (*Hemignathus munroi*), Hawai‘i Creeper (*Oreomystis mana*), Hawai‘i Ākepa (*Loxops coccineus*), and ‘Io (*Buteo solitarius*). Distribution and density trends were recently documented in the Kaʻū region by Gorresen et al. (2007) for three out of the four endangered species. Populations in the Kaʻū region (statewide) totaled 1,073 (1,900) for the ‘Akiapōlā’au, 2,268 (14,000) for the Hawai‘i Creeper, and 2,556 (12,000) for the Hawai‘i Ākepa. Kaʻū also contains 245 acres of designated habitat for the endangered Picture Wing Fly (*Drosophila heteroneura*), although we do not include it in this analysis because the population for this species is not as well documented.

The Kaiholena and Maka‘ālia fenced areas, together span 1,928 acres or about 54% of the 3,548-acre TNC Kaʻū Preserve and 1.7% of the larger 117,148-acre Kaʻū region. However, Gorresen et al. (2007) found that populations of the three endangered bird species are supported only at elevations about 1,500 m, which corresponds to less than half of the total Kaʻū region. The previously discussed counterfactual landcover scenarios suggest that native landcover would be largely converted to invasive within the planning time horizon absent expenditures on watershed conservation. The conversion would result in a loss of 4.6% of the total bird habitat in the Kaʻū region by the end of the planning horizon, corresponding to 49 ‘Akiapōlā’au, 103 Hawai‘i Creeper, and 117 Hawai‘i Ākepa.\(^8\)

To estimate the economic value of preventing the displacement of the three endangered bird species, we use the results of a meta-analysis conducted by Richardson and Loomis (2009).\(^9\) Willingness to pay (WTP) for the benefits of bird habitat preservation is calculated using an estimated log-log equation, after appropriately adjusting relevant policy variables and plugging in sample means for the methodological variables. The model suggests that each household is willing to pay $4.66 per year to prevent the expected 1% loss of endangered bird species (relative

---

8 More generally, net growth of the endangered bird population will depend on natural births and deaths, which are unrelated to habitat conversion. Inasmuch as the bird population is already currently low, however, births are also likely low, assuming a logistic-type growth function. In other words, we expect that any natural net growth would be largely outweighed by the losses generated by conversion in the counterfactual scenario. We abstract from the possibility that conversion induced losses affect or are affected by the current mortality rate when calculating the expected benefit of conservation.

9 The model suggests that each household is willing to pay $4.66 per year to prevent a 1% loss of endangered bird species in the region. This is not exactly equivalent to the value of avoiding displacement because a proportion of displaced birds may survive if suitable habitat outside of the study region is available for resettlement. However, the landcover of the surrounding region would also likely be converted, at least in part, to invasive if conservation activities did not continue to contain the invasion within the fenced units. For our purposes, we use the WTP to avoid bird loss as an approximation for the benefit of avoiding habitat conversion.
to the total statewide population of each species\textsuperscript{10} projected for the end of the planning horizon. Multiplying that by the 449,771 households in Hawai‘i\textsuperscript{11} yields a total benefit of $2.1 million annually. The actual yearly benefit is lower in periods prior to the end of the planning horizon, however, because landcover change happens over time. To account for this dynamic effect, we estimate bird losses in each year, plug the result into the WTP equation, and then sum up all of the annual values to determine the present value of habitat protection.

Aggregated over time, cumulative avoided bird losses total 149 and 101 at Kaiholena and Maka‘ālia respectively (Figure 11). The total PV benefit ranges from $6.1 million in Maka‘ālia to $20.9 million in Kaiholena. Although the total number of projected bird displacements by the end of the planning horizon is similar at both sites, the PV is higher at Kaiholena because there is more invasive landcover there initially and conversion occurs more rapidly at the outset. Results are summarized in Table 5.

\textbf{Figure 11. Cumulative avoided bird displacements}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{cumulative_avoided_bird_displacements.png}
\caption{Cumulative avoided bird displacements}
\end{figure}

\begin{table}[h]
\centering
\begin{tabular}{|c|c|c|c|c|}
\hline
\textbf{} & \textbf{Kaiholena} & \textbf{} & \textbf{Maka‘ālia} & \\
\hline
\textbf{Cumulative avoided bird losses} & \textbf{g=10\%} & \textbf{g=5\%} & \textbf{g=10\%} & \textbf{g=5\%} \\
\hline
\textbf{PV benefit (million dollars)} & 20.9 & 10.5 & 6.1 & 1.7 \\
\hline
\textbf{PV benefit per acre (dollars/acre)} & 18,519 & 9,307 & 7,615 & 2,065 \\
\hline
\end{tabular}
\caption{PV benefit of habitat provision for endangered birds}
\end{table}

\textbf{Table 5. PV benefit of habitat provision for endangered birds}

\textsuperscript{10} Because the proportion of the statewide bird population accounted for within the study sites is relatively small, we expect that potential changes to the marginal rate of damage will also be small as the population evolves over time. Benefits, therefore, are calculated assuming a constant marginal bird value.

\textsuperscript{11} \url{http://quickfacts.census.gov/qfd/states/15000.html}
5.4 Ecosystem Regulation and Other Habitat Services

To the extent possible, we calculate the value of ecosystem services protected by conservation activities using existing data from our study sites. However, data for many of the services were not available and collecting them to quantify the full effect of conservation is beyond the scope of this study. To capture the value of some of these additional services, we apply benefit transfer using average values obtained from a survey of studies conducted at over 300 locations worldwide (de Groot et al., 2012). While the survey included a variety of biomes, we focus on values for services commonly provided in tropical forests. Each of over 20 different tropical forest ES was identified as falling into one of the following four general categories: provisioning services, regulating services, habitat services, and cultural services (Table 6).

Table 6. Average monetary values for different ecosystem services

<table>
<thead>
<tr>
<th></th>
<th>2007 $/ha/yr</th>
<th>2015 $/ha/yr</th>
<th>2015 $/acre/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Provisioning services</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Food</td>
<td>200</td>
<td>229</td>
<td>93</td>
</tr>
<tr>
<td>2 Water</td>
<td>27</td>
<td>31</td>
<td>13</td>
</tr>
<tr>
<td>3 Raw materials</td>
<td>84</td>
<td>96</td>
<td>39</td>
</tr>
<tr>
<td>4 Genetic resources</td>
<td>13</td>
<td>15</td>
<td>6</td>
</tr>
<tr>
<td>5 Medicinal resources</td>
<td>1504</td>
<td>1725</td>
<td>698</td>
</tr>
<tr>
<td>6 Ornamental resources</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Regulating services</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 Air quality regulation</td>
<td>12</td>
<td>14</td>
<td>6</td>
</tr>
<tr>
<td>8 Climate regulation</td>
<td>2044</td>
<td>2345</td>
<td>949</td>
</tr>
<tr>
<td>9 Disturbance moderation</td>
<td>66</td>
<td>76</td>
<td>31</td>
</tr>
<tr>
<td>10 Regulation of water flows</td>
<td>342</td>
<td>392</td>
<td>159</td>
</tr>
<tr>
<td>11 Waste treatment</td>
<td>6</td>
<td>7</td>
<td>3</td>
</tr>
<tr>
<td>12 Erosion prevention</td>
<td>15</td>
<td>17</td>
<td>7</td>
</tr>
<tr>
<td>13 Nutrient cycling</td>
<td>3</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>14 Pollination</td>
<td>30</td>
<td>34</td>
<td>14</td>
</tr>
<tr>
<td>15 Biological control</td>
<td>11</td>
<td>13</td>
<td>5</td>
</tr>
<tr>
<td><strong>Habitat services</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16 Nursery service</td>
<td>16</td>
<td>18</td>
<td>7</td>
</tr>
<tr>
<td>17 Genetic diversity</td>
<td>23</td>
<td>26</td>
<td>11</td>
</tr>
<tr>
<td><strong>Cultural services</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18 Esthetic information</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19 Recreation</td>
<td>867</td>
<td>995</td>
<td>403</td>
</tr>
<tr>
<td><strong>Total economic value</strong></td>
<td>5263</td>
<td>6036</td>
<td>2443</td>
</tr>
<tr>
<td><strong>Regulating (-Climate) + Habitat Services</strong></td>
<td>524</td>
<td>600</td>
<td>243</td>
</tr>
</tbody>
</table>
Because Table 6 draws from a large number of sources, it naturally includes some services that are not relevant to our study sites. We are particularly interested in regulation and habitat services; water provisioning services are already accounted for in our freshwater yield estimates. When the scope is limited to these two categories, the average annual value is $243 per acre. This may be an underestimate for a variety of reasons, however. While standard sedimentation and erosion prevention benefits—e.g. maintaining water quality in rivers and avoiding soil loss that can lead to invasive plant species outcompeting their native counterparts—are captured by items 10 and 12 in Table 6, coastal regions are unique in that potential damages resulting from an interruption of those regulating services are exacerbated by their natural connection to nearshore ecosystems. Although there are no streams on Mauna Loa flowing to the ocean, changes in freshwater yield can alter the nearshore environment via changes in submarine groundwater discharge (SGD) (Johnson et al., 2008; Knee et al., 2010). In particular, coral reefs along the South Kona coast and anchialine pools down-gradient of Kaiholena would likely be affected by fluctuations in SGD. We do not have the requisite data to quantify and monetize this effect, but it is clear that the PV estimates presented in Table 7 should be viewed as lower bounds.

Table 7. PV benefit of regulation and habitat services

<table>
<thead>
<tr>
<th></th>
<th>Kaiholena</th>
<th>Maka‘alia</th>
<th>Kona Hema</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>g=10%</td>
<td>g=5%</td>
<td>g=10%</td>
</tr>
<tr>
<td>PV benefit (million dollars)</td>
<td>3.3</td>
<td>1.5</td>
<td>0.9</td>
</tr>
<tr>
<td>PV benefit per acre (dollars/acre)</td>
<td>2,942</td>
<td>1,347</td>
<td>1,091</td>
</tr>
</tbody>
</table>

6. NET PRESENT VALUE AND RETURN ON INVESTMENT FOR CONSERVATION ACTIVITIES

Based on the ecosystem service values monetized in this study, we find that PV benefits outweigh PV costs at all sites in the baseline scenario (g=10%), largely due to the value attributed to the preservation of habitat for endangered bird species in Kaiholena and Maka‘alia. Under the more conservative invasion scenario (g=5%), net PV remains positive at Kaiholena and becomes slightly negative at Maka‘alia, while PV costs largely exceed benefits at Kona Hema. Even when PV net benefit is positive across the three sites, as is the case for g=10% (Table 8), the benefit-cost ratios vary. This type of result is not uncommon when conservation activities are being undertaken at multiple sites simultaneously; each site provides a different combination and quantity of services. Kona Hema generates higher freshwater benefits on a per-acre basis, while Kaiholena provides large non-water benefits. Although it would be ideal to protect the multitude of ES provided at all sites, limited resources, time, and manpower, often stand in the way. The hope is that the analysis presented in this report provides a means for examining tradeoffs, which can help to inform conservation decisions.

12 Although climate regulation is a valuable service, we do not include it in our calculation for two reasons. First, the effect of converting native to invasive land cover on climate related services such as carbon sequestration is not clear. Second, the marginal effect of Hawaii’s contribution to climate change relative to the global contribution is relatively small, so values based on world carbon prices may be skewed upward.
Table 8. Summary of PV costs and benefits (moderate growth scenario)

<table>
<thead>
<tr>
<th>Present Value (million dollars)</th>
<th>Kaiholena</th>
<th>Maka'alia</th>
<th>Kona Hema</th>
</tr>
</thead>
<tbody>
<tr>
<td>g=10%</td>
<td>g=5%</td>
<td>g=10%</td>
<td>g=5%</td>
</tr>
<tr>
<td>Benefits of freshwater yield</td>
<td>0.19</td>
<td>0.09</td>
<td>0.10</td>
</tr>
<tr>
<td>Benefits of bird habitat provision</td>
<td>20.9</td>
<td>10.5</td>
<td>6.1</td>
</tr>
<tr>
<td>Benefits of other ES</td>
<td>3.3</td>
<td>1.5</td>
<td>0.9</td>
</tr>
<tr>
<td>Costs of conservation</td>
<td>3.7</td>
<td>3.7</td>
<td>2.6</td>
</tr>
<tr>
<td>Net Total</td>
<td>20.7</td>
<td>8.4</td>
<td>4.5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Present Value Per Acre (dollars/acre)</th>
<th>Kaiholena</th>
<th>Maka'alia</th>
<th>Kona Hema</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benefits of freshwater yield</td>
<td>169</td>
<td>80</td>
<td>124</td>
</tr>
<tr>
<td>Benefits of bird habitat provision</td>
<td>18,519</td>
<td>9,307</td>
<td>7,615</td>
</tr>
<tr>
<td>Benefits of other ES</td>
<td>2,942</td>
<td>1,347</td>
<td>1,091</td>
</tr>
<tr>
<td>Net Per Acre</td>
<td>18,356</td>
<td>7,460</td>
<td>5,572</td>
</tr>
</tbody>
</table>

The return on investment for conservation is 542%, 163%, and 38% at Kaiholena, Maka'ālia, and Kona Hema respectively, calculated by dividing the difference between total benefits and costs (total net benefits) by total costs for each site. The ROI is 134% when the three sites are considered jointly. Tracking the benefits and costs over time reveals, however, that benefits do not consistently exceed costs until year 2020 (Figure 12)—the payback period for investment is 9, 24, and 46 years for Kaiholena, Maka'ālia, and Kona Hema respectively. This is primarily due to the large initial expenditures required for fence construction. The result highlights one of the challenges faced when considering the allocation of scarce resources towards watershed conservation projects. Benefits of a given project may be largely outweighed by costs over the short term, e.g. a 5 or even 10-year horizon. But as the potential damages from invasive species increases over time in the absence of conservation, the benefits of undertaking the project begin to rise rapidly and may exceed costs by several times during the decades that follow. It is important, therefore, to maintain a long term outlook when assessing the value of watershed conservation activities.

Figure 12. Total benefits and costs of conservation (dollars)
REFERENCES


Department of Land and Natural Resources (DLNR), Division of Forestry and Wildlife. 2012. Ka‘ū Forest Reserve Management Plan.


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