A Case Study in Habitat Equivalency Analysis: The Pacific Connector Gas Pipeline

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Introduction

When wildlife habitat is impacted through an adverse event, such as an oil spill, or a construction project, replacing that habitat's ecological services becomes an important issue. Just how replacement is accomplished and to what extent is often a process fraught with complex issues, legal challenges and much acrimony. This process can drag on for years, sometimes decades. A method where all parties can find common ground and that reduces value judgments would reduce costs to both taxpayers and businesses and aid in the swifter recovery of impacted habitats and species. Habitat Equivalency Analysis (HEA) is a relatively new approach that helps answer the fundamental question of how much habitat replacement is enough. In this paper, we showcase a real world use of HEA on a natural gas pipeline project that crosses threatened and endangered species habitat.

HEA was developed by the National Oceanographic and Atmospheric Administration (NOAA) and the Minerals Management Service (MMS) as a way to scale compensation for habitat damage (e.g. Penn and Tomasi 2002, Roach and Wade 2006). In effect, the method provides complete in-kind (i.e. of similar quality and quantity) replacement of lost ecological services between the time of impact (e.g., an oil spill) and the time services are restored or created to their full replacement value. HEA uses the concept of discounting to value the stream of ecological services over time. HEA makes the assumption that society values the flow of ecological services over time. Discounting theory assumes that people place a greater value on services today than those put off for future use. Every year in a discounting series thus has a specific value in terms of services provided until full restoration is complete. Typically, a standard discount rate of three percent is assumed (Peacock, 1995). So each year it takes to replace or restore services, a habitat capable of producing three percent of the remaining lost services must also be provided. This approach of equating ecosystem service flows has significant advantages over trying to place dollar values alone on complex ecosystem services. This is one reason that HEA has helped bring parties with disparate views to the table.

HEA tries to move beyond value judgments. Until recently, habitat compensation simply involved replacing impacted habit acres. HEA recognizes that in the time between impact and full restoration or compensation, ecological services need to be provided. HEA provides a framework for both compensation and restoration and can address the issue of "no net loss" of ecological function. The goal of HEA is to answer the fundamental question of how much is enough, by providing a framework for analysis.

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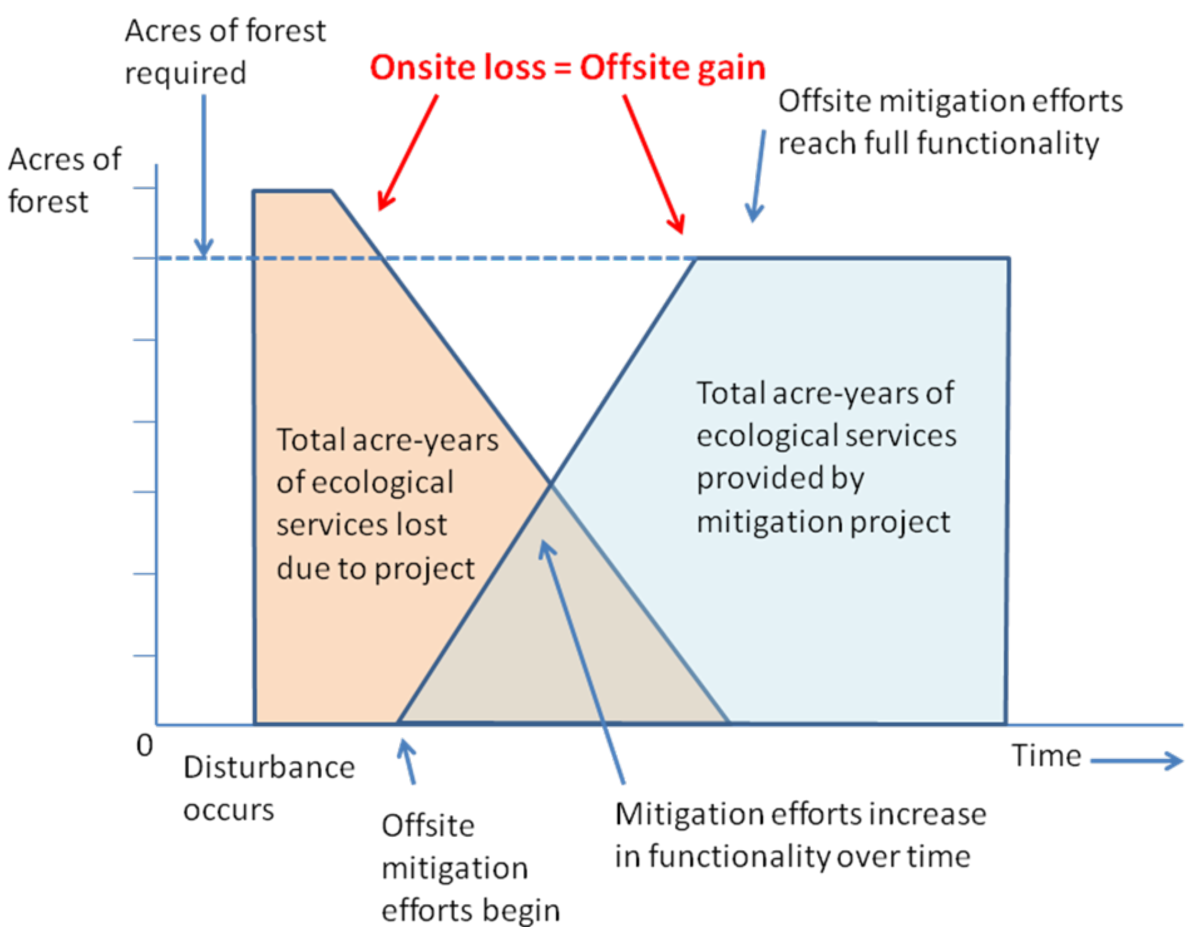
HEA has been used in at least one case where it has been accepted as a basis for settlement in federal court (United States of America vs. Melvin A. Fisher et al. 1997). Other application examples include such diverse areas as freshwater streams, sea grass beds and coral reefs (Chapman et al. 1998, Fonseca eat al. 2000, Milton and Dodge 2001). And because it is a generic method it can be adapted to a variety of situations, including those involving both habitats and individual species.

Three pieces of information are required to conduct HEA: 1) the type of ecological services that have been damaged, 2) the extent of damage, and 3) the rate at which recovery will occur. Furthermore, determining which service is most appropriate to replace and the degree to which the study area provided this service prior to impact are probably the most important and potentially the most controversial steps in the HEA process.

Figure 1. Generic representation of the HEA process.



Habitats provide multiple services and opinions may vary widely concerning which service should be the focus of the restoration efforts. HEA is not capable of, nor is it designed to resolve these issues. These issues must be negotiated by the interested parties. In addition, estimating the degree of services supplied by a specific parcel of habitat prior to damages and the extent to which it has been damaged can be difficult. Again, this is an issue for negotiation between the interested parties and is not a function of HEA.

Choosing a metric, some measure or indicator of ecological services provided, is another important step. Ecological services come in many different forms. Different species and habits both provide and require different ecological services, so it is difficult to give a broad definition. For example, Old growth timber in the Pacific Northwest provides areas for species such as the spotted owl with nesting locations. Spotted owls will only nest in Late Successional or Old Growth (LSOG) timber. So nesting is an example of an ecological service provided by LSOG timber. A metric is necessary in order to monitor the degree to which restoration efforts are meeting expectations. The metric should represent the qualities and quantities of the service provided by both the impacted and restored habitat, should be easy to measure and should have transparent characteristics. Metrics which represent multiple services have obvious advantages in that a more comprehensive assessment can be obtained. Finally, it is essential that the amount of service to be restored is small compared to the total available, so that no change occurs in the underlying value per unit of service. In order to apply HEA, replacement of a portion of the resource should not be so large as to influence the overall value of the resource; otherwise the appropriate amount of habitat would change.

The structure of HEA is relatively simple (Figure 1). Calculations of how much habitat to restore or replace are based on estimates of the total loss in services from the damaged or lost habitat. Total loss is estimated from the degree and time of initial damage and the loss in services that occur during the time between the initial damage and when the restored or replaced habitat becomes fully functional. The discounting process adjusts how these services are supplied over time until full restoration has occurred. The details of this process will be discussed in the example presented below.

Project Overview

The Pacific Connector Gas Pipeline (PCGP) project[2] is part of the larger Jordan Cove Energy Project LP[3]. Located in Coos Bay, Oregon, the Jordan Cove project proposes to build a liquefied natural gas (LNG) re-gasification terminal to import natural gas into the western United States. The PCGP will transport imported natural gas to Malin, Oregon, some 234 miles away over the Southern Oregon Cascades; a route which intersects ecologically sensitive areas. The route contains several threatened and endangered species, including the northern spotted owl (*Strix occidentalis caurina*), marbled murrelet (*Brachyramphus marmoratus*), and coho salmon (*Oncorhynchus kisutch*). A natural gas hub, the confluence of several pipelines, is located in Malin and allows imported natural gas to enter the Western US natural gas grid. Permitting work on the project began in 2007.

HEA Application Methodology

HEA is a service-to-service or resource-to-resource approach to natural resource valuation that can account for changes in the baseline while estimating interim losses. The fundamental concept is that compensation for lost ecological services can be provided by restoration/compensation projects that provide comparable services (i.e., compensatory mitigation). Compensatory services can include substitute service, out-of-kind services, and both on and off-site services. For the PCGP, the question is what services would the affected

[2] (http://www.pacificconnectorgp.com/index.php)
[3] (http://www.jordancoveenergy.com/index.htm)

habitats have provided in the absence of the PCGP Project? With HEA, the replacement services are quantified in physical, in our case, acre-years.[4] The selected project is then scaled so that the quantity of replacement services equals the quantity of lost services in present value terms. In our analysis, the quantity of acre-years is based on the age of the forest land being disturbed or provided as compensation. We assume older forest land provides more services for old-growth/mature forest-dependent species than younger forests, with the relationship assumed to be linear (non-linear comparisons are possible, but add a degree of complexity).

HEA involves three basic steps:

1) **Assess the present value of lost services relative to the base line**. In this analysis the loss (“debit”) is measured in acre-years.

2) **Select the appropriate compensatory restoration/mitigation measures**. The “relative productivity” of a proposed restoration measure compared to what was injured is evaluated in the number of acre-years restored for every acre included in the measure.

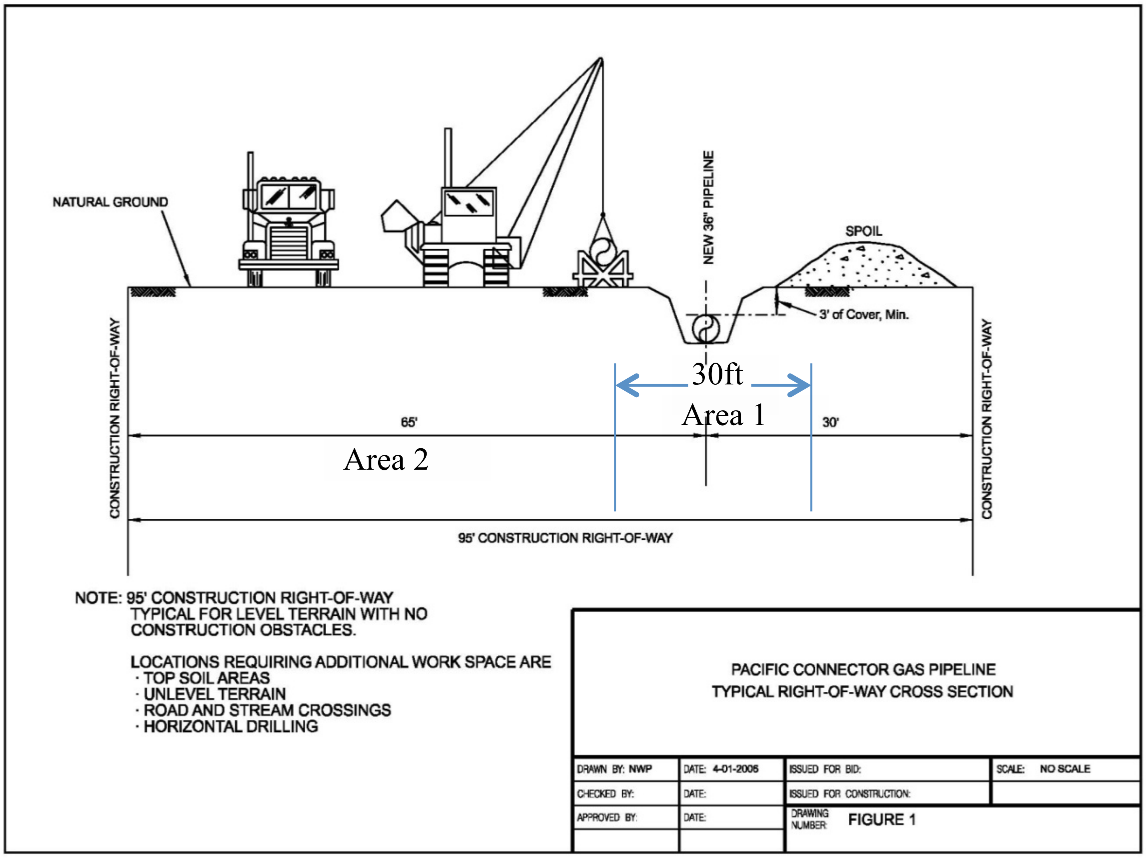
3) **Identify the area for the restoration/mitigation measure** (scaling). This is the measure that equates the total discounted quantity of lost services to the total discounted quantity of replacement services to compensate for the lost habitat.

The basic framework for the PCGP project analysis was originally developed as the Oregon Pipeline HEA spreadsheet model by Dr. Kristin Skrabis, Resource Economist, Office of Policy Analysis, U.S. Department of Interior with input from Doug Young, U.S. Fish and Wildlife Service. The parameters for the model were modified by Taylor and Foulke based on estimates from Edge Environmental, Inc. regarding the physical quantities of forest habitat injured by the PCGP project. The models went through multiple iterations following a review of the various versions and discussions with the agencies involved. Two models were eventually selected by Edge Environmental to be used in the Compensatory Mitigation Plan (CMP) prepared for the PCGP project.

In the HEA modeling application developed by Taylor and Foulke for the CMP, there are two areas, identified as Area 1 and Area 2, which will be affected differently by the PCGP project (Figure 2). Area 1 is a corridor extending to 15 feet of each side of the proposed pipeline centerline – the 30-foot maintenance corridor - which will remain in an herbaceous/shrub state for the life of the project, estimated at 50 years. In forested habitats, conifer trees will be replanted within the construction right-of-way and other cleared areas outside of the 30-foot maintenance corridor and allowed to return to its pre-construction state. Those areas are identified as Area 2.

[4] An *acre-year* refers to all natural resource services provided by one acre for one year.

Figure 2. PCGP typical right-of-way cross section.



Late Successional-Old Growth Forest HEA Model

We combine late successional and old growth (LSOG) forests into a single category to reflect landscape conditions in the region. Since the age mid-point of late successional forest is 127.5 years old and the age mid-point for old growth is estimated by biologists to be 250 years old (related to 325-year old stands), the mid-point of the combined age classes weighted by disturbed acres is 203.4 years (Table 1). This is an important parameter that is used to compute a linear slope for the production function of replanted forest. For effects to LSOG forest, ecological services associated with those seral stages are assumed to begin when replanted trees within Area 2 are 80 years old. Because Area 1 is not replanted, losses of ecological services are assumed to last in perpetuity.

The current LSOG HEA model that has been reviewed by an economist at the Department of Interior and assumes that in-kind replacement compensatory habitat will be obtained three years after construction on the PCGP Project begins. That is, all compensatory habitat obtained is assumed to provide the same ecological services as the habitat lost. Consequently, discounting (at a rate of 3 percent per year) applies only to the 3-year interim between clearing and acquisition so that the amount of compensatory habitat obtained will be about 9 percent more than the amount of habitat removed. In addition to the area of habitat within Area 1 that will be removed "in perpetuity", conifers that are planted following construction within former late successional-old growth habitat in Area 2 will not start providing equivalent ecological services for 80 years and are assumed to provide full ecological services at the end of the next 123.4 years when the habitat is 203.4 years old.

Table 1. Forest growth stage categories.

	From	To	**Mid-point***	
Mid-Seral	40	80	**60**	years
Late Successional	80	175	**127.5**	years
Old Growth	175	325	**250**	years
Late Successional plus Old Growth*	80	325	**203.4**	years

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**Weighted mid-point based on number of acres in late successional reserves in each age category.*

The HEA model only computes the amount of late successional-old growth habitat required for compensation based on the standard three percent discount rate. Three percent is the discount rate used by the USFS and the Department of Interior based on analysis done by Peacock (1995). All compensatory habitat obtained is assumed to be equivalent to the habitat affected (in this case, in-kind replacement of LSOG). An agreement between the PCGP developers and the agencies involved assumes that the compensatory habitat obtained will be held in perpetuity. This feature has been incorporated into the model to evaluate the amounts of compensatory habitat required to offset impacts to late successional-old growth habitats described for several listed species and to lands allocated under the Northwest Forest Plan, or NWFP (Forest Service and BLM, 1994), applicable to the PCGP project.

Mid-Seral Forest HEA Model

The authors also developed a second HEA model to evaluate effects to mid-seral (M-S) forests and to compute the amounts of compensatory habitat necessary to offset lost ecological services to forests between 40 and 80 years old. The assumptions applied to the M-S HEA model are similar to those described for the LSOG model. Loss of ecological services in Area 1 will continue in perpetuity, but ecological services associated with mid-seral forests begin when replanted trees within Area 2 are 40 years old. The mid-point of M-S forests is 60 years, which is used to compute a linear slope for the production function of replanted forest. This is accomplished by calculating the amount of annual recovery. For example, if it takes 20 years to reach full recovery (0 to 100 percent), then each year represents an additional 5 percent of recovery or a 5 percent slope.

M-S forests provide nesting, roosting and foraging (NRF) habitat for northern spotted, and some nesting habitat and recruitment habitat for marbled murrelets (reference?). In addition, mid-seral forests within riparian zones provide shade that affects stream water temperatures, and large woody debris, both of which are important to coho salmon (reference?). Loss of M-S forest by construction of the PCPG in Area 2 will last for 40 years. At 40yearsold, restored M-S forest begins to provide lost services and provides 100 percent of ecological services when it reaches 60 years old.

Similar to the LSOG model, the M-S HEA model computes the amount of mid-seral habitat required for compensation based on the standard three percent discount rate. All compensatory habitat obtained is assumed to be equivalent to the habitat affected (in-kind replacement). Because conifers will be planted within Area 2 following construction, they will begin providing services as mid-seral forest after 40 years and those services reduce the amount of compensatory habitat computed by the HEA model.

The assumption that compensatory habitat obtained will be held in perpetuity and that once obtained, it will remain as mid-seral habitat in perpetuity is contained within the model. Of course, that assumption is not realistic since, with the passage of time, mid-seral forest would eventually become late successional-old growth forest and contribute to offsetting impact to late seral stage forest in addition to the compensatory habitat obtained for that purpose. The assumption of being held as mid-seral forest in perpetuity is retained for simplicity, and to facilitate understanding during implementation of the HEA model. The ecological services that would be provided by mid-seral forests that eventually become late successional-old growth forests within 40 years of acquisition are not accounted for in either of the HEA models.

Example HEA Application

Table 2 lists the parameters for both the LSOG and MS models. Recall that both models are based on in-kind replacement of lost ecological services, with replacement beginning three years after disturbance. Area 1 of the right-of-way is lost in perpetuity, and Area 2 is replanted and allowed to regenerate.

Table 3 illustrates the results for the combined LSOG and the M-S models by habitat type including NWFP land use allocations and listed species impacted. The first two columns are impacted acres for Areas 1 and 2. Column three lists total impacted acres. Column 4 lists the model results of mitigation acres required. The results from the LSOG model are presented at the top of Table 3. Zero acres are shown for Marbled Murrelet, Southern Oregon/Northern California Coast Coho Salmon (SO/NCC), and Oregon Coast Coho Salmon (OC) because all their LSOG habitat overlaps with the Late Successional Reserves, Riparian Reserves, and Northern Spotted Owl acres of habitat. Thus their acres of affected habitat have already been accounted for in the other resource categories.

Table 2. Model Parameters.

	LSOG Area 1 Permanent	LSOG Area 2 Temporary	M-S Area 1 Permanent	M-S Area 2 Temporary
Date of Analysis	2008	2008	2008	2008
Start Date of Injury	2010	2010	2010	2010
State Date of Recovery	2010	2092	2010	2052
Years Until Full Recovery	0	123.4	0	20
Starting Loss of Services	100%	100%	100%	100%
Ending Loss of Services	100%	0%	100%	0%
Is Loss in Perpetuity	Yes	No	Yes	No
Annual Recovery Rate	0.00%	0.81%	0.00%	5.00%
Start Date of Acquisition	2013	2013	2013	2013
Discount Rate	3.00%	3.00%	3.00%	3.00%
Unit of Injury	Acre	Acre	Acre	Acre

The results indicate that 1.09 acres of in-kind replacement are required for each acre of LSOG habitat that is permanently disturbed. This represents the three-year lag between disturbance and in-kind replacement. The results also indicate that 1.07 acres of in-kind replacement are required for each acre of LSOG habitat that is temporarily disturbed. The latter in-kind replacement acreage is smaller since the loss is not in perpetuity. HEA results in an overall average (between losses in perpetuity and temporary losses) of 1.074 acres as compensatory mitigation that would be appropriate for every acre of LSOG habitat affected by the project.

The results from the M-S model are presented in the lower portion of Table 3. Unlike the LSOG results, acres are shown for all categories of habitat. M-S acres for Marbled Murrelet, and the salmon species are included because not all of these types of affected habitat overlap with Successional Reserves, Riparian Reserves, and Northern Spotted Owl acres of affected habitat.

The results indicate that 1.09 acres of in-kind mitigation are required for each acre of M-S habitat that is permanently disturbed. Again, this represents the three-year lag between disturbance and in-kind replacement for permanently disturbed lands. The results also indicate that 0.86 acres of in-kind replacement are required for each acre of M-S habitat that is temporarily disturbed. The latter in-kind replacement acreage is smaller since the loss is not in perpetuity. HEA results in an overall average (between losses in perpetuity and temporary losses) of 0.947 acres as compensatory mitigation that would be appropriate for every acre of M-S habitat affected by the project.

Summary and Status

Habitat Equivalency Analysis is still a relatively new tool in the analysts' tool box, but shows promise in being able to help solve some of the more intractable issues. In this project, HEA was used to provide a framework for discussion so that all parties could come to the table with their issues in a 'common currency'. This allowed for some of the more qualitative elements of ecological services to be resolved.

HEA still requires negotiation. Choosing indicator species and metrics for recovery requires all parties do due diligence before they come to the table. But it does help remove some of the value judgments and inject more science-based arguments into the decision-making process.

The original model worked well for the initial calculations, but changes by agencies dictated additional modeling to refine the functional form of the production function. This highlights the fact that the "devil is in the detail". Agency changes (part of the negotiation process since more cards are on the table) became a reoccurring theme. The models, though static, are easily changed in their spreadsheet form and are more easily understood by agency personnel.

In the end, project developers, and state and federal government agencies were able to come together and approve the project. The fact that the PCGP goes through some of the most contentious habitat zones in the country (northern spotted owl and old-growth timber) and is still the only LNG project so far approved on the US West Coast, proves that HEA is a viable contribution.

Table 3. Areas of LSOG Forested Habitat Impacted (Acres)

Late-Successional - Old Growth Habitat

	LSOG Area 1 Impacted (Acres)	LSOG Area 2 Impacted (Acres)	LSOG Total Impacted (Acres)	LSOG Compensation Mitigation (Acres)
Late Successional Reserves	41.83	104.90	146.73	157.66
Riparian Reserves	6.00	17.85	23.85	25.60
Northern Spotted Owl	117.96	351.90	469.86	504.48
Marbled Murrelet	0.00	0.00	0.00	0.00
SO/NCC Coho Salmon	0.00	0.00	0.00	0.00
OC Coho Salmon	0.00	0.00	0.00	0.00
Total LSOG	**165.79**	**474.65**	**640.44**	**687.74**
In-kind replacement ratio	1.09	1.07		1.074

Mid-Seral Habitat

	M-S Area 1 Impacted (Acres)	M-S Area 2 Impacted (Acres)	M-S Total Impacted (Acres)	M-S Compensation Mitigation (Acres)
Late Successional Reserves	7.81	18.01	25.82	23.98
Riparian Reserves	4.72	17.30	22.02	19.99
Northern Spotted Owl	164.29	185.71	350.00	338.84
Marbled Murrelet	30.31	96.22	126.53	115.67
SO/NCC Coho Salmon	3.15	15.19	18.34	16.47
OC Coho Salmon	1.16	10.82	11.98	10.55
Total Mid-Seral	**211.44**	**343.25**	**554.69**	**525.50**
In-kind replacement ratio	1.09	0.86		0.947

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