Black Bear Den Enhancement and Creation in the Jordan River

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Introduction

American black bears (*Ursus americanus*) require suitable winter den sites to provide security and cover to successfully survive the critical winter denning period. Female bears may utilize dens for up to 6 months and have additional energy costs associated with gestation, whelping, and nursing of cubs during this period (Lentz et al. 1983). Dens are reused intermittently over decades, if not longer, and are often used by successive bears (Davis et al. 2012). On Vancouver Island, winter dens used by black bears have only been found in or beneath large diameter (mean = 143 cm) trees or wooden structures derived from trees (i.e., logs, root boles and stumps; Davis 1996). It is likely that black bears do not use structures other than wooden ones in coastal BC because of the cool and wet climate during the denning period, unlike other parts of North America where they may dig dens in the soil (Beecham et al. 1983) or den in nests on the ground (Martorello and Pelton 2003).

Current and historic land management activities in coastal forests have affected the supply of these critical element-level features. Most prominently, forest harvesting has removed many large trees that are needed to form den structures. Furthermore, the new crop of trees is not allowed to grow to sufficient size for replacement dens to develop in future forest rotations. Further negative impacts come from harvesting of second growth, which may remove or destroy the few residual structures remaining from old growth harvesting. Additionally, flooding of forested land for hydro-electric development removes trees from the potential den supply. Despite the knowledge that these habitat features are critical to the over-winter survival of black bears, the BC government has not provided any regulatory protection for these critical structures. A reduction in the supply of suitable den sites may impact bear populations through predation on denned bears (Davis and Harestad 1996) and loss of condition of bears utilizing unsuitable dens. The net effect of this reduction in supply is that suitable den sites may become a factor that limits black bear populations.

Figure 1. A typical coastal black bear den tree (photo by D. Wellwood).

The objectives of this project are two-fold. First, this project aims to mitigate losses of denning opportunities in the Jordan River Watershed by creating potential dens in existing old growth trees or large legacy stumps. Second, this project will install and evaluate the efficacy of artificial den structures for black bears. The augmentation techniques that we develop may be useful for other areas in which forest harvesting and hydroelectric development have diminished the supply of dens for black bears.

Study Area

The study area is within the Jordan River Watershed (Figure 2) on southwestern Vancouver Island, 30 km north of Sooke, BC. It covers 159 km² and lies in the Coast and Mountain Ecoprovince, Western Vancouver Island Ecoregion and the Windward Island Mountains Ecosection (Demarchi 1996). The watershed is comprised of 4 different subzones and variants of the Coastal Western Hemlock (CWH) biogeoclimatic zone and one of the Mountain Hemlock (MH) zone (Green and Klinka 1994). The CWH mm1 (Submontane Moist Maritime) and mm2 (Montane Moist Maritime) are found in the valley bottoms and above (respectively) in the eastern half of the watershed whereas the CWH vm1 (Submontane Very Wet Maritime) and vm2 (Montane Very Wet Maritime) are found at the valley bottoms and above in the western half of the watershed. The MH mm1 (Windward Moist Maritime) is at the highest elevations in the western portion of the watershed above the CWH vm2. Elevations within the Jordan River basin range from zero to 1000 m. At lower elevations, the climatic conditions are typified by moist, mild winters and cool but relatively dry summers (Green and Klinka 1994). Upper elevations experience cooler temperatures, greater snowfall, and a shorter growing season. Heavy precipitation occurs between October and April with an average of 500 mm in November (Fish and Wildlife Compensation Program 2011).

Forests of the CWHmm1 are dominated by western hemlock (*Tsuga heterophylla*), amabilis (balsam) fir (*Abies amabilis*), and Douglas-fir (*Pseudotsuga menziesii*, Green and Klinka 1994). Shrub layers commonly include red huckleberry (*Vaccinium parvifolium*), Alaskan blueberry (*V. alaskaense*), and, to a lesser extent, salal (*Gaultheria shallon*) and dull Oregon-grape (*Mahonia nervosa*). Forests of the CWHmm2 contain more yellow-cedar (*Chamaecyparis nootkatensis*) and mountain hemlock (*Tsuga mertensiana*) and those in the CWHvm1 are dominated by western hemlock and amabilis fir but with a western redcedar (*Thuja plicata*) component rather than Douglas-fir. The understory generally features a well-developed shrub layer also dominated by red huckleberry and Alaskan blueberry. At higher elevations, the CWHvm2 is similar to that of the CWHmm2, with greater amounts of yellow-cedar and mountain hemlock and less Douglas-fir.

The watershed has experienced extensive industrial development since the late 1800's: forest harvesting, mining and flooding for hydroelectricity has occurred. Industrial development continues today with the ongoing harvest of second-growth forests, a copper mine on the east side of the Jordan River (in production 1919-1977; currently for sale), and hydro-electric power generated from 3 reservoirs. These reservoirs flooded the richest soils with the highest forest productivity in the valley bottom and thus some of the largest trees in the watershed were likely within the inundation zone. BC Hydro owned-land that was not flooded was logged (Figure 3), which has led to further reductions in den supply in the watershed.

In addition to the direct habitat effects of logging and reservoir development, the industrial history of the Jordan River Watershed has also led to further impacts on local black bear populations through the disappearance of spawning salmon (*Oncorhynchus* spp.) as a food source during the critical weight-gain period prior to winter denning. The Jordan River once supported extensive spawning but contamination of the lower reaches by copper from the mine has led to spawning salmon being almost non-existent (last known to occur in 1970; Burt 2014) but there is some efforts being made to restore spawning habitat and recreate a sustainable run.

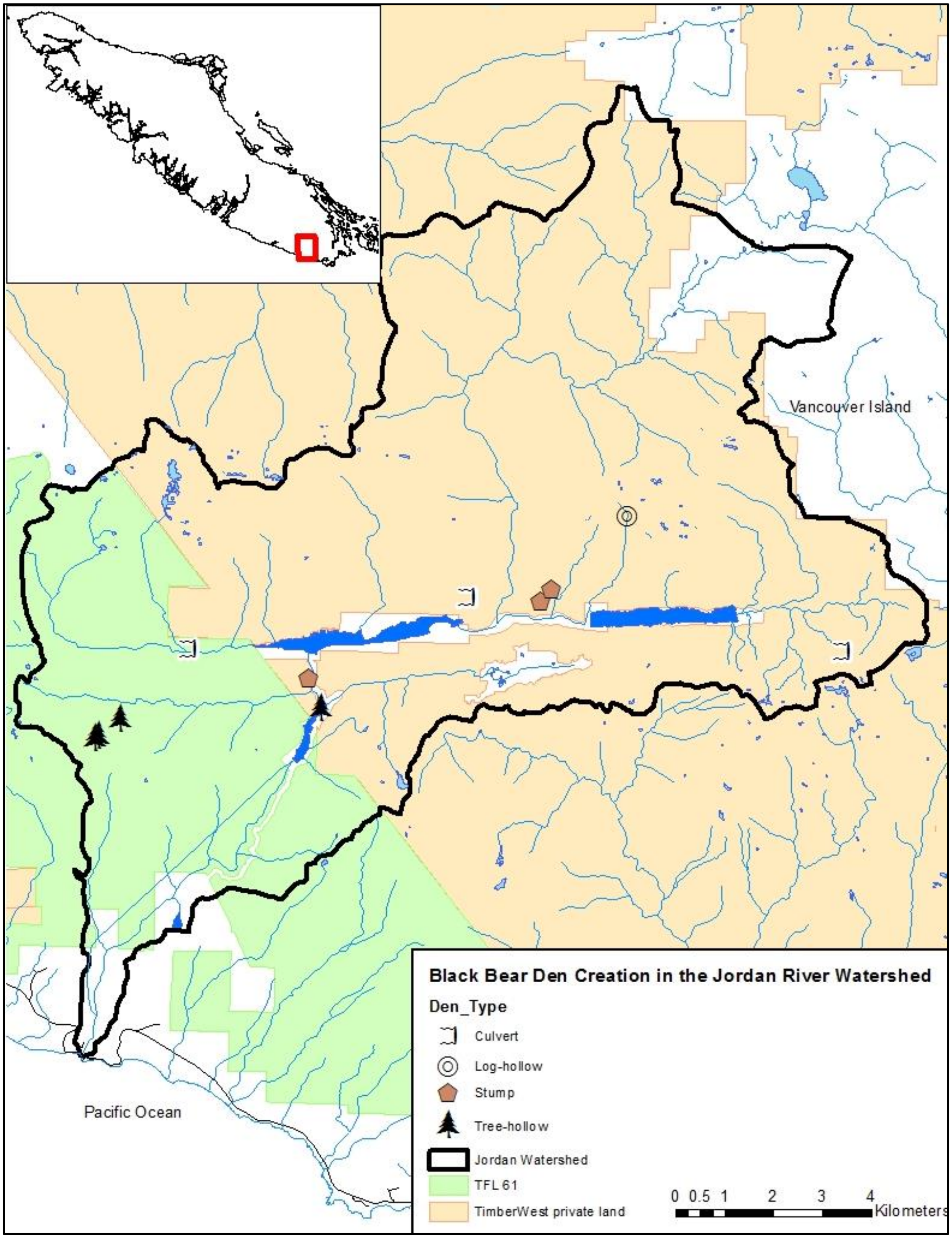

Figure 2. The Jordan River Watershed showing land ownership and locations of enhanced natural dens (log-hollow, stumps, trees-hollow) and artificial dens (culverts) installed in 2014.

Figure 3. Two large logs and a stump next to the Diversion Reservoir (Jordan River Watershed), left behind from harvesting of old growth and then second growth forests.

Methods

In highly modified landscapes, several options exist to create new denning opportunities for bears on a small element-level scale. First, existing natural structures not currently suitable for denning could be enhanced to create new winter dens. Second, entirely new denning structures that meet the need for thermal and security cover could be engineered and distributed on the landscape for adoption by bears as winter dens. Use of artificial structures for dens by black bears has been documented in the past; dry road culverts have been used (Wyoming, Barnes and Bray 1966; Minnesota, Noyce and Dirks 2012). However, to our knowledge, no one has attempted to create artificial dens for black bears. We applied both techniques using an adaptive management approach to mitigate the reduction in den supply resulting from past hydroelectric and forest harvesting.

Our project is intended as an interim method of addressing shortages of dens at a very fine spatial scale (i.e., element scale) and does not address the larger landscape-scale issue of den supply. Enhanced natural structures and artificial den structures may provide a stop-gap supply of dens that could bridge the period between current and historic forest management (i.e., little or no voluntary retention of suitable structures) and future element, stand and landscape management that takes den supply into account.

Activity 1: Enhancement of Natural Structures

We used a variety of spatial data to identify stands within the watershed that may supply either functioning den trees or those that are precursors to den trees. The first step in the project was compiling existing information on den supply to guide field work. We gathered information on known den sites from TimberWest Forest Corp and Pacheedaht Andersen Timber Holdings Ltd. (PATH) and GIS data was compiled from PATH to identify forest stands with large western redcedar or yellow-cedar trees that may be suitable candidates for enhancement.

We created a query of spatial vegetation data to identify stands with the greatest likelihood of containing potential dens based upon structural attributes. Where data was available, the query identified stands with the following attributes:

- Site series 01, 03, 06 (zonal and one drier and one wetter than zonal)
- Seral stages 6 and 7
- Age >300 years
- Height >30 m
- Crown closure >50
- western redcedar or yellow-cedar as the leading, secondary or tertiary species (less than half the time cedar is leading in stands used for denning)
- Basal area >63 m^2/ha

We targeted stands with western redcedar and yellow-cedar trees because they are the most likely to have hollow centres, unlike amabilis fir, Douglas-fir, western hemlock or mountain hemlock which do not have decay patterns that produce large hollow basal cavities.

Based on the results of our GIS analysis, we conducted ground searches (Figure 4) for large western redcedar or yellow-cedar trees or large, high-cut stumps that had internal heart rot but no entrance to the centre. These were enhanced by creating suitably sized openings into the centre with a chainsaw and removing decayed wood when necessary. Entrance sizes were based on those found in natural den trees on northern Vancouver Island (Davis 1996) and by structural limitations of the tree or stump being enhanced. We sealed stumps that had an open top and hollow centre with a "roof" of ¾" plywood affixed by lag bolts. See Appendix I for photos and descriptions of each den.

ACTIVITY 2: ARTIFICIAL DEN STRUCTURES

In this, year 1, we created artificial dens out of large plastic culverts. The size and shape of these dens closely resemble natural dens in hollow logs (Figure 5, Davis 1996) and were situated in several areas within the Jordan River watershed. Artificial culvert dens were manufactured by Armtec (Nanaimo, BC) from their HDPE Boss 2000 drainage pipes (culverts). Culverts were available in either 600 mm or 750 mm diameters, based on the size of dens in logs in the Nimpkish Valley (i.e., 2 log dens had an average diameter of 78 cm; Davis 1996) and the diameter of road culverts used as dens in Wyoming and Minnesota (>60 cm, Barnes and Bray 1966; >65 cm, Noyce and Dirks 2012), we used 750 mm diameter culverts. Culverts were made of double-walled plastic with a smooth inner wall and a corrugated outer wall. Culverts came in 20 foot lengths; these were cut in half to create two 3-m long dens. The supplier welded a ¾" HDPE plate to each end of the pipe and secured it with 4 lag bolts for extra strength. Based upon entrances of dens utilized by adult females in the Nimpkish Valley (Davis 1996), an oval entrance was cut into one of the end plates that was 35 cm wide and 45 cm high. We attempted to have an entrance size that was accessible to adult females while excluding adult males to reduce the possibility of predatory attacks by other carnivores and male bears (Davis and Harestad 1996). Entrance dimensions were also similar to that found for hollow tree dens in Idaho (mean height 39 cm ± SD=15, mean width = 36 cm ± SD=7, n= 13; Beecham et al. 1983). Final net weight of the artificial dens was approximately 90 kg.

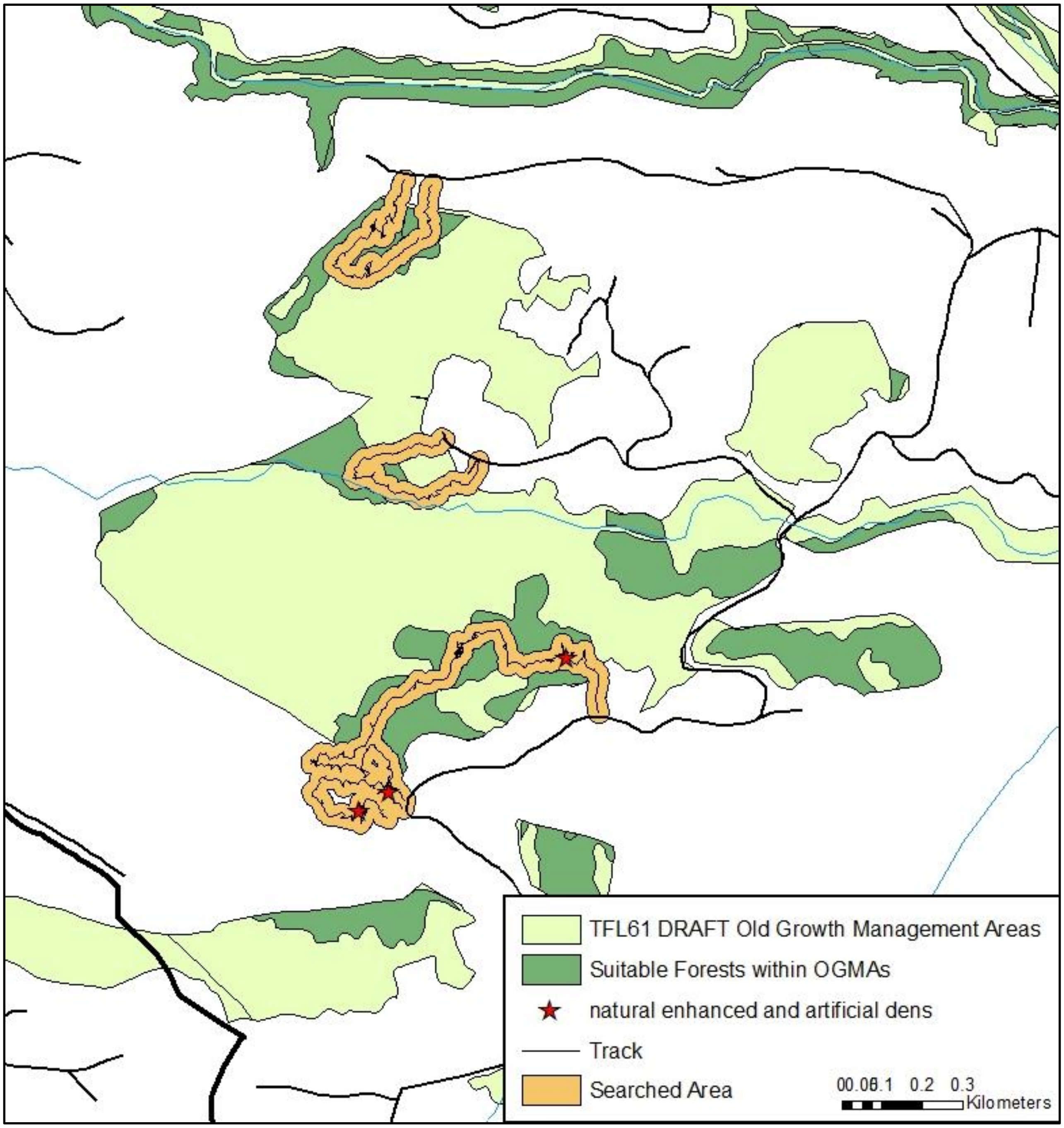

Figure 4. Example of areas searched for natural structures suitable for enhancement. In this case, searches were concentrated in suitable polygons identified by GIS that overlapped proposed Old Growth Management Areas (OGMAs). Tracks reflect one person's walking path, the searched area reflects two people searching a swath 25 m wide. Jordan River Watershed, 2014.

Figure 5. Inside a hollow log used as a den by a black bear in the Nimpkish Valley. The log has an internal diameter of 80 cm, notice the large amount of bedding (western hemlock boughs) on the far side of the person.

MONITORING OF ENHANCED AND ARTIFICIAL DENS

We deployed 4 remote-sensing cameras (Bushnell Trophy Cam HD Max) at several enhanced and artificial dens to monitor wildlife activity. We established cameras at 3 artificial dens; one was configured to record 10-second video clips while the other 2 took still photographs. A 4th camera was installed at a natural enhanced (stump) den.

Because the thermal properties of the artificial dens is unknown relative to those of natural structures, we deployed temperature data loggers (Hobo Pendant Temperature/Light Data Logger MAN-UA-002) at one natural, two enhanced, and three artificial dens in the watershed. At each potential den, we paired one data logger inside the den chamber with one affixed in a nearby tree, which will allow us to compare the temperature within the cavity to the ambient temperature outside the cavity. Data loggers were configured to collect temperature readings 4 times per day beginning on 1 November 2014.

Results and Discussion

We achieved our objectives in year 1 by creating potential black bear dens in 7 natural structures (3 in hollow trees, 3 in stumps, 1 in a log) and 3 in artificial structures constructed from plastic culverts.

ENHANCEMENT OF NATURAL STRUCTURES

Natural structures suitable for enhancement were rare in the Jordan watershed and finding trees to enhance proved to be very challenging. Forest harvesting in the Jordan watershed has been extensive and the remaining old growth stands were often of low quality to forest companies because the trees are short or small diameter. We documented very few trees large enough to house dens on private forest lands. Additionally, burning after clear-cutting was extensive and thorough; stumps that remained from harvesting were often too burned out to have enough structural integrity to house a den that would protect bears from winter weather conditions.

During 9 field days with 2 people searching, we searched approximated 98 ha of forests and clearcuts with a high probability of potential den structures (identified by GIS queries), during which we found 1 hollow tree (Den 1) that appeared to have been used as a den and 3 hollow trees and 3 stumps suitable for enhancement.

We applied enhancement techniques to either stumps left over from previous old-growth harvesting or trees that had existing cavities but which were currently not suitable for use as dens due to a lack of a large enough entrance into the cavity. We added "caps" to all 3 old-growth stumps which became reasonable good quality potential dens. Only 1 of the 3 enhanced hollow trees were immediately suitable; the other 2 may become suitable in the future (i.e., one needs to grow and the other needs to decay more). See Appendix I for details of enhancement techniques applied at each site.

ARTIFICIAL DEN STRUCTURES

A crew of 4 carried the 3 artificial dens into the forest (approximately 50 m in each case) at selected sites in the watershed in July 2014. We had originally planned on placing artificial dens in clearcuts so they could be embedded in the ground but we decided to place them in forested stands instead to provide greater security cover (i.e., climbable trees) and thermal cover. Each artificial den had holes drilled in the bottom for drainage, "wildlife tree" signs and flagging tape were hung, woody debris was piled around the sides and bedding was added (i.e., ferns, salal, hemlock or balsam fir boughs). Trapping lure (anise oil, pulverized beaver castor, commercial fisher lure, skunk oil and glycerin) that attracts Mustelids (weasels) was placed around the site to create interest by bears without providing a food reward.

We installed the artificial dens in areas of extensive second growth forests. Two artificial dens were placed within mature second growth stands, another was placed in an unharvested patch within a clearcut. Upon inspection of the entrances to the artificial dens, we decided the entrances were too large and thus 2 of the artificial dens had a piece of plywood screwed over part of the entrance to reduce the entrance size. If more artificial dens are created from culverts in the future, we will change the design by decreasing the entrance size and either angling the cut to the entrance (see Appendix II) or putting a 45^o elbow in the culvert. This will achieve better weather protection of the entrance, better separation of the entrance from the chamber, and allow the creation of 3 dens from a single 20 foot culvert rather than 2 dens. We will also explore options for creating more insulation around artificial dens, whether through using soil and vegetation or insulative products that can be applied after installation of the artificial dens – finding a product that bears will not eat, chew, or claw will be difficult. However, so far, bears have not damaged any of the artificial dens.

In future, we hope to construct dens of more insulative materials and of a design more appealing to black bears than plastic culverts. We hired an industrial designer to develop options for materials, construction methods, den designs and costs (see Appendix II). Dimensions for the new den designs will be based on dens excavated by bears in other areas of North America (Tietje and Ruff 1980, Beecham et al. 1983; Table 1) because we assume that these dimensions better reflect the cavity size that bears would choose (since they dig the excavations) than those of den cavities in trees (where bears have little influence on the internal chamber size). Based on these papers, the proposed dimensions for artificial den designs could be: entrance height 45 cm, entrance width 50 cm, tunnel height 45 cm, tunnel width 65 cm, chamber height 70 cm, chamber width/length: 110 cm. However, the entrance sizes found in these studies were larger than that used for the entrances to culvert dens in 2014. It may be that entrances to naturally excavated dens are larger than necessary because they cannot be constructed smaller by bears when they are digging, and passing through dirt tunnels may cause some erosion of them, thereby increasing the size. We will decide on exact dimensions during model construction and after input from other bear researchers. Dens also need to be accessible to researchers to be able to check them for signs of use. Therefore, either entrance sizes will need to be large enough for a person to climb in or dens will need to be able to be taken apart to get inside. Design will also be strongly influenced by the limitations of transport of structures to suitable denning areas.

Table 1. Mean dimensions (in cm) of excavated dens in west-central Idaho (Beecham et al. 1983) and Cold Lake, Alberta (Tietje and Ruff 1980).

	Entrance			Tunnel				Cavity/Chamber				
	N	Height	Width	*N*	Height	Width	Length	*N*	Height	Width	Length	Approx. volume (m^3)
West-central Idaho (from Beecham et al. 1983)												
Adult males	7	54 ± 11[1]	71 ± 19[1]	3	46 ± 4	69 ± 2	49 ± 13	7	69 ± 8	103 ± 28	119 ± 32	
Adult females	28	44 ± 11	51 ± 19	13	41 ± 10	63 ± 18	67 ± 35	27	78 ± 17	107 ±27	108 ± 21	
Cold Lake, Alberta (from Tietje and Ruff 1980)												
Adult males	12	53	51	12	52	65	85	12	78	114	124	1.17
Adult females	16	45	49	16	45	72	74	16	70	99	116	0.80

[1] entrance height and width differed significanlty ($P < 0.05$) between adult males and females

MONITORING OF NATURAL AND ARTIFICIAL DENS

Remote-sensing cameras were operational for 282 days between 11 July and 29 October 2014 at the 3 artificial dens (Table 2). We photographed 3 different bears and one family group visiting one of the dens and 6 separate visits by bears (≥3 individuals) at another. Bears investigated the dens (i.e., sniffing the culverts and looking inside), but no bears were photographed climbing inside. We only had one technical problem with the cameras; a shrub grew up in front of a camera, blocking its view of the animals triggering the camera. Because we scented the sites with a lure for trapping Mustelids, it is not surprising we captured photos of Pacific martens (*Martes caurina*). Other species detected included squirrels and a crow.

Table 2. Remote camera effort and number of photo sequences at artificial dens deployed in the Jordan River Watershed, 2014.

				Number of photo sequences					
Den #	Start date (dd/mm/yyyy)	Last date downloaded	# days operational	Bears	Deer	Marten	Other	Unknown	Total
10	11/07/2014	29/10/2014	67[1]	3	2	0	0	3	8
11	11/07/2014	29/10/2014	110	4	8	5	4	7	28
12	11/07/2014	24/10/2014	105	6	5	1	0	4	16

[1] Camera was unable to capture images from 16/09/2014 to 29/10/2014 due to vegetation.

A fourth camera was set up at an enhanced natural structure (stump) at the end of October; the camera has not been downloaded since installation. All 4 cameras will be operational over winter 2014-15 and will be downloaded in spring 2015.

The remote-sensing cameras provided invaluable information about the artificial dens and the animals that investigated them. There were no obvious signs of investigation by bears at any of the dens; if the structures are not used by bears in the future we would not have known if this was because bears chose not to use them or if they simply had not detected the structures.

Extension and Communications

Interest about the project was unexpectedly extensive. The FWCP-Coastal sent out media releases announcing funding decisions from the program which led to initial interest by the Sooke Mirror (21 May 2014: http://www.sookenewsmirror.com/news/259978321.html) and Times Colonist newspapers. We sent out a project-specific media release after installing the culvert dens, which garnered additional media interest. This media release was reviewed and approved by TimberWest Forest Corp, PATH, Pacheedaht First Nation and BC Hydro. Subsequently, stories about our project were printed in:

- The Victoria Times Colonist (26 July 2014: http://www.timescolonist.com/news/local/artificial-dens-could-lure-black-bears-to-jordan-river-watershed-1.1262971),
- Sooke Mirror (13 August 2014: http://www.sookenewsmirror.com/community/270922551.html),
- NationTalk (28 July 2014: http://nationtalk.ca/story/timberwest-provides-lands-for-bear-den-project/)
- College of Applied Biology newsletter (August 2014 "College Matters"),
- The Private Forest Landowners Association newsletter (http://www.pfla.bc.ca/stewardship/timberwest-land-provides-home-for-bear-den-enhancement-project/), and,
- The FWCP newsletter.

Additionally, a TimberWest spokesperson did an interview about the project on CBC Radio on 28 July 2014. Renewed interest occurred in late November and resulted in 2 more newspaper articles (Times Colonist and The Province Newspaper: http://www.theprovince.com/technology/Black+bears+flirting+with+hibernation+made+dens+Vancouver+Island/10423914/story.html). Both CBC Radio and Shaw TV would like to do a piece on the project; this has been delayed until 2015 when we will have more results to discuss. A presentation to the Victoria Natural History Society is scheduled for fall 2015.

We had good involvement and interest from our project partners and there is interest in taking results of the project and applying it to other watersheds by TimberWest and other land managers (Capital Regional District-Parks, BC Timber Sales). Extension products are being developed for use in contractor training by TimberWest in 2015.

Incidental Wildlife Observations

We recorded wildlife species observed during field work (other than deer) including:

- One Common Garter Snake (*Thamnophis sirtalis*) near the north side of the Diversion Reservoir, possibly foraging on Pacific chorus frog tadpoles.
- Band-tailed Pigeons (*Patagioenas fasciata;* Special Concern*)* on numerous occasions along the road at the west end of the south side of the Diversion Reservoir and along the north side of the Diversion reservoir. They appeared to be feeding on red elderberries (*Sambucus racemosa*).

We investigated the wetlands created on the north side of the Diversion Reservoir (an FWCP-funded project; Tuttle 2013) for pond-breeding amphibians on 18 July 2014. At this time, the reservoir was over the top of the berms, the ponds fully inundated and the edges inaccessible for sampling. We were able to make our way out to the middle berm to conduct some amphibian sampling. We were only able to find 8 chorus frog (*Pseudacris regilla*) tadpoles, 5 of which were dead. In addition, we collected some insects that have been submitted to the Royal BC Museum (Table 3). Further work should be conducted on the efficacy of the wetland design.

Table 3. Insect species collected by Lea Gelling (BC Conservation Data Centre) on 18 July 2014 at the wetlands created on the north side of the Diversion Reservoir, Jordan River watershed.

Species	Common Name	Location of specimen
Syrphid fly	N/A	sent to J.Heron for identification
Libellula forensis	Eight-spotted Skimmer	identified in-hand; not collected
Sympetrum illotum	Cardinal Meadowhawk	collected; specimens to RBCM
Ischnura cervula	Pacific Forktail	collected; specimens to RBCM
Enallagma annexum	Northern Bluet	collected in tandem; specimens to RBCM
Dragonfly larvae	undetermined	collected; specimens to RBCM

Partner Contributions

- TimberWest Forest Corps provided us with gate keys to access their private lands, GIS spatial data, and GIS model outputs to define areas for potential den tree searches. One biologist and a summer student joined us for a day in the field at the start of the project and both company biologists (Dave Lindsay and Molly Hudson) joined us to assess the culvert dens installed on TimberWest land and an enhanced stump den created on their land.
- Pacheedaht Andersen Timber Holdings Ltd. provided gate keys to access their TFL lands and GIS spatial data to identify habitats of interest.
- I hired an assistant through the Pacheedaht First Nation; Michael "Bear" Charlie assisted me on 9 field days, and 3 other members of the Pacheedaht Forestry crew assisted with artificial den installation.
- BC Ministry of Environment employees assisted me on 4 days: Richard Weir climbed one above-ground den and assisted in enhancing a stump den as well as install culvert dens. Lea Gelling (Conservation Data Centre) and Keegan Meyers (CDC co-op student) joined me on separate field days.

Future Work

As a result of our first year of study, we created potential dens for black bears in 7 enhanced natural structures (i.e., trees, stumps and logs) and 3 in modified culverts. In May 2015, we will examine all of the natural enhanced and artificial den structures to determine if they were used in the 2014-15 winter. We will retrieve temperature data loggers and download remote-sensing cameras. We have applied to FWCP-Coastal to continue to create more structures in the Jordan River Watershed in 2015 and to deploy them in the Campbell River drainages on Crown land in 2015 (in response to a request by BC Timber Sales) and on TimberWest's private land in 2016. We hope to have a total of ≥15 artificial structures by 2016 that can be monitored over time to assess adoption of the structures by coastal black bears.

We will be implementing an extension program in 2015 to transfer information to forest companies and forest workers about the need for adequate denning habitat and den structures for coastal black bears. We will be providing TimberWest with materials for inclusion in their training course for contractors and to BC Timber Sales as well as looking for other venues at which to present our results. At the conclusion of the project, we will publish our results in a peer-reviewed scientific journal.

Acknowledgements

This Project is funded by the Fish and Wildlife Compensation Program on behalf of its program partners BC Hydro, the Province of B.C., Fisheries and Oceans Canada, First Nations and the public, who work together to conserve and enhance fish and wildlife impacted by the construction of BC Hydro dams.

I was assisted by Michael "Bear" Charlie who made the project a lot of fun whether we were hiking through horrendous brush, up steep slopes or cutting entrances into potential den trees. The tough work of carrying culvert dens into the bush was done by Stephan McClurg, Richard Jack and Bob Mackin. The project was supported by Helen Jones and Tom Jones (Pacheedaht First Nation).

Molly Hudson (TimberWest) provided a great deal of logistical and GIS support to the project, as well as field time. Dave Lindsay (TimberWest) also assisted in timely review of press releases and provided field time.

Pacheedaht and Andersen Timber Holdings LP provided access to lands and GIS data that was very helpful in refining the GIS models. Angus Hope and Loren Perraton provided guidance and support.

Richard Weir (MOE) provided moral support, advice, helped out in the field and reviewed the final report. Lea Gelling and Keegan Meyers from the Conservation Data Centre volunteered for a field day each.

Karen Noyce (Minnesota Department of Natural Resources and International Bear Association president) and Lana Ciarniello (Aklak Wildlife Consulting) provided advice on den designs.

Dr. Patrick Gregory helped with snake identification.

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Appendix I. Natural, enhanced and artificial den catalogue

Structure #1: Natural den

Diameter: 170 cm dbh
Species: yellow-cedar (splits into 2 boles about 2 m above ground)
Entrance: 95 cm (h) x 22 cm (w)
Habitat: old growth forest, CWHvm2
Modifications: none.
Notes: The only natural den found in 98 ha of searching high-probability stands. Heavily chewed and clawed by bears (around entrance, photo below), but no bedding present. Unsure if it has been used or not. Temperature data loggers installed. Located in a proposed OGMA.

Structure #3: Enhanced natural structure (stump)

Diameter: 255 cm dbh
Species: western redcedar
Entrance: 82 cm (h) x 39 cm (w)
Habitat: second growth forest, CWHmm1
Modifications: entrance already existed, top capped with plywood
Notes: Stump had large hole in top (photo below) and was very wet inside. Inside of stump had dried out considerably by October after capping in June 2014 (much quicker than anticipated). Entrance is a bit large but overall a very nice den. Temperature data loggers and remote sensing camera installed.

Structure #4: Enhanced natural structure (tree)


Diameter: 137 cm dbh

Species: western redcedar

Entrance: Before (photo above left): 75 cm (h) x 18 cm (w), after (photo above right): 75 cm (h) x 24 cm (w)

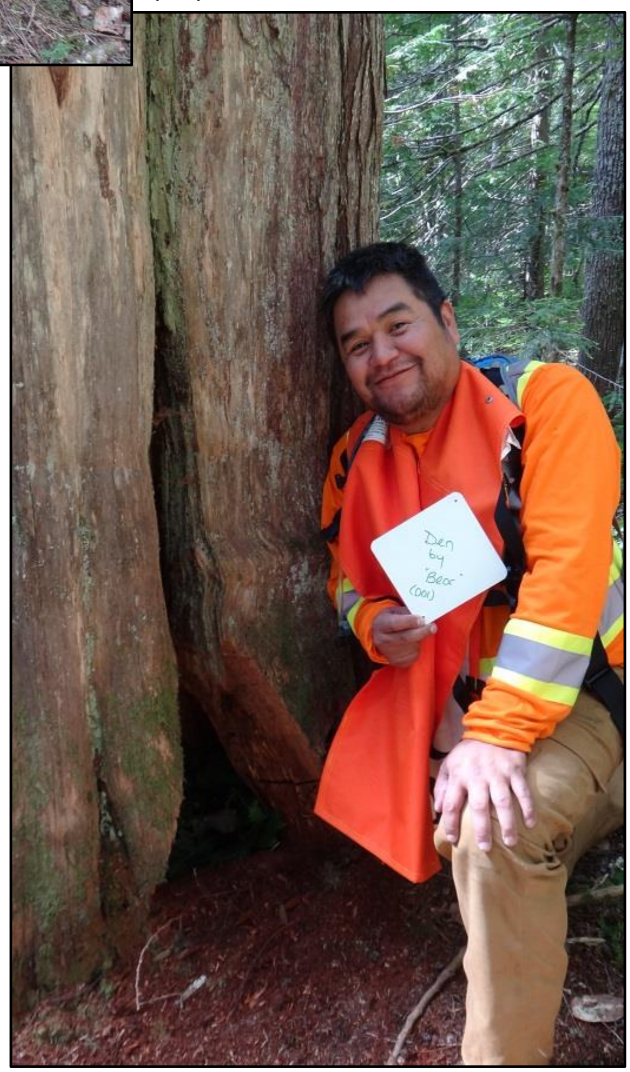
Habitat: old growth forest, CWHvm1

Modifications: entrance widened with chainsaw. Decayed wood inside excavated to create chamber. Bedding added.

Notes: This hollow tree worked out the best of the ones we tried. The chamber is tucked in around to the left of the entrance. Temperature data loggers installed. Located in a proposed OGMA.

Structure #5: Enhanced natural structure (tree)

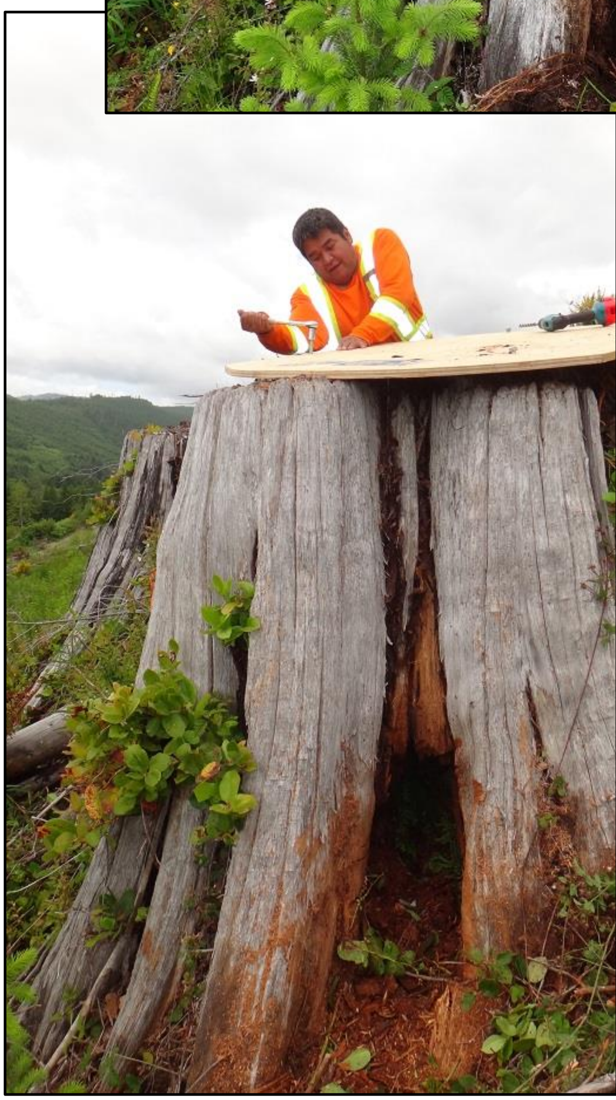
Diameter: 90 cm dbh
Species: western redcedar
Entrance: Before (photo left:) 45 cm (h) x 10 cm (w), after (photo below): 45 cm (h) x 35 cm (w)
Habitat: old growth forest, CWHvm2
Modifications: entrance widened with chainsaw. Internal decayed wood removed to increase chamber size. Bedding added.
Notes: Resulting effort was not a very high quality potential den, the tree was a bit too small, the chamber ended up being too close to the entrance. Near edge of proposed OGMA.



Structure #6: Enhanced natural structure (log)

Diameter: 103 cm diameter
Species: mountain hemlock
Entrance: 57 cm diameter tube, about 5 m long
Habitat: Clearcut, CWHmm2
Modifications: End of log capped with plywood, no other modifications. Debris piled against plywood to hide it (much more than in lower picture).
Notes: Closing off the end of the log creates a good quality den that is more likely to be used once trees grow up around it.

Structure #7: Enhanced natural structure (stump)



<u>Diameter</u>: 140 cm dbh
<u>Species</u>: western redcedar
<u>Entrance</u>: 40 cm (h) x 24 cm (w)
<u>Habitat</u>: Clearcut, CWHmm1
<u>Modifications</u>: Entrance cut into base, top cut off and covered with plywood, lots of inside wood cut out. Bedding added.
<u>Notes</u>: Before (above), after (below). The entrance is nice and small, perfect for a female bear. Suitability will increase once regenerating trees grow up around it.

Structure #8: Enhanced natural structure (tree)

Diameter: 122 cm dbh
Species: western redcedar
Entrance: 60 cm (h) x 20 cm (w)
Habitat: small old growth patch on edge of Jordan River, CWHmm1
Modifications: Entrance cut into tree at split, large amount of decayed wood removed from inside.
Notes: Before on left, after on right photo. Cutting this entrance did not work very well. The thickness of solid wood was too wide to create a nice entrance into the cavity. In 2015 we hope to do some more cutting to improve the entrance. It will be interesting to see the progression of decay in this structure.

Structure #9: Enhanced natural structure (stump)

Diameter: 182 cm dbh
Species: western redcedar
Entrance: 50 cm (h) x 25 cm (w)
Habitat: Clearcut, CWHmm1
Modifications: Top cut off, covered with plywood. Stump burned so much that there were openings in various places, one large one was filled with debris and covered with plywood. Entrance cut into opening already present on side. Bedding added.
Notes: Before (left), during (middle), after (below). The entrance is a bit large, it was already present except for some cutting away of a piece covering the entranceway. Will likely be more suitable once trees grow up around it.

Structure #10: artificial den (culvert)

<u>Diameter</u>: 75 cm dbh

<u>Species</u>: corrugated black plastic culvert

<u>Entrance</u>: 30 cm (h) x 35 cm (w)

<u>Habitat</u>: unharvested, poor-nutrient dry site of the CWHmm2

<u>Modifications</u>: bedding added, remote camera installed, temperature data loggers installed (see bottom left of lower photo). Entrance was reduced in size by the addition of a piece of plywood in Oct. 2014.

<u>Notes</u>: Visited by bears 3 times (top photo), can't tell if they were the same individual or different bears.

Structure #11: artificial den (culvert)

Diameter: 75 cm dbh
Species: corrugated black plastic culvert
Entrance: 30 cm (h) x 35 cm (w)
Habitat: second growth, CWHmm1
Modifications: Bedding added, remote camera installed, temperature data loggers installed. Entrance was reduced in size by the addition of a piece of plywood in Oct. 2014.
Notes: Den was investigated by at least 3 different individual black bears and this female and cubs (above).

Structure #12: artificial den (culvert)

Diameter: 75 cm dbh
Species: corrugated black plastic culvert
Entrance: 45 cm (h) x 35 cm (w)
Habitat: second growth, CWHvm1
Modifications: bedding added, remote camera installed, temperature data loggers installed.
Notes: Investigated 6 times by bears (up to 4 different bears).

Appendix II. Artificial den design options

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Molded Den Options

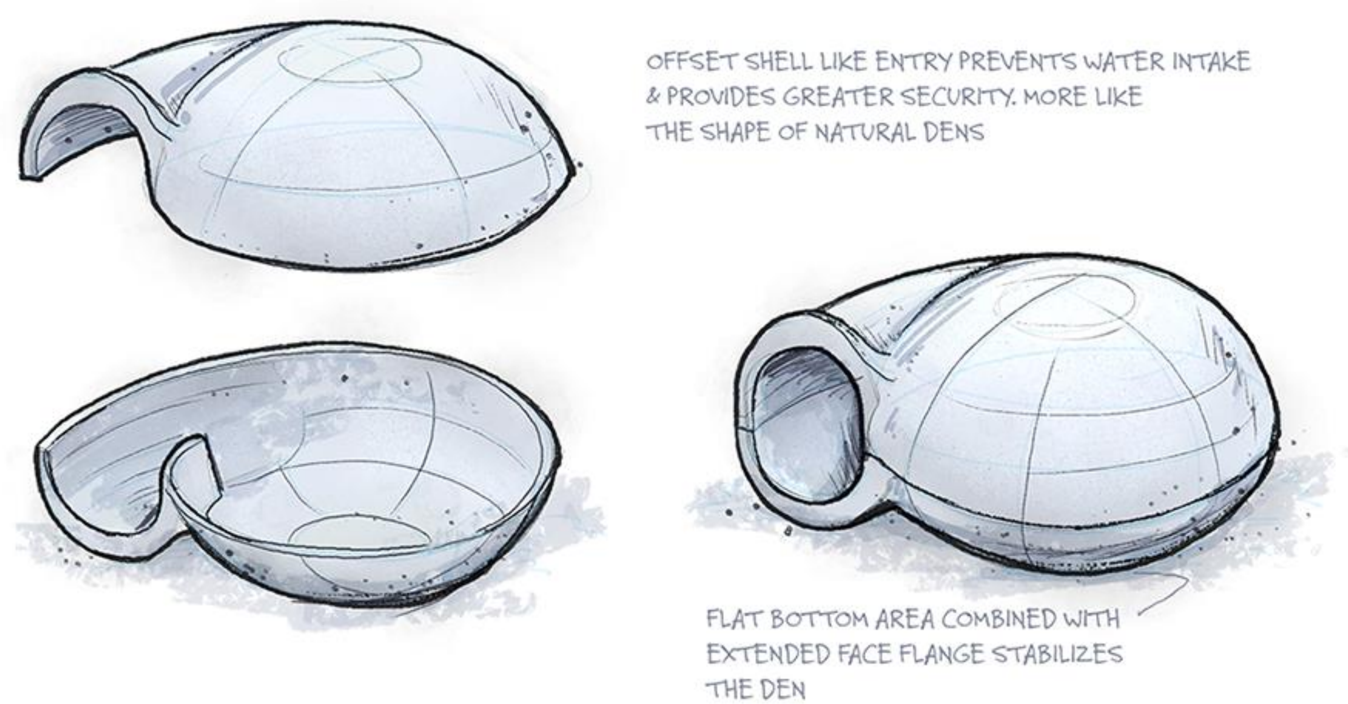


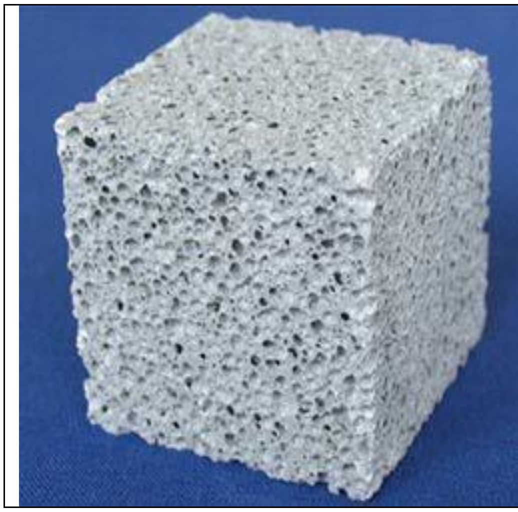
Figure 1. A possible molded den design.

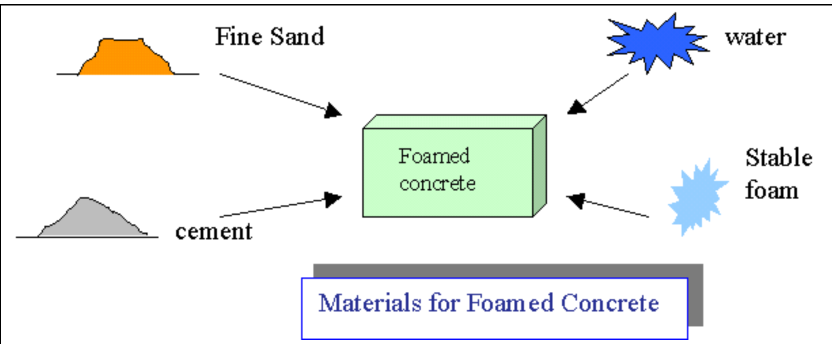
What is molding? Molding is the process of shaping liquid or pliable material using a rigid frame called a mold. A mold is a hollowed-out block that is filled with a pliable material like plastic, metal, or other raw materials. The liquid hardens or sets inside the mold, adopting its shape. **Casting** is a version of molding where the material is poured into a mold. This usually requires materials that cure like concrete or are cold setting like molten metal. **Injection molding** is more complicated and involves injecting the material at high temperature and high pressure.

Benefits of a molded or cast den: Casting or injection molding the den would combine multiple components and design elements into a single, seamless product. Casting the parts in two halves could be symmetrical with a single mold or asymmetrical with two molds needed. A two piece design could make installation and transportation to the den site more efficient since the parts would be easier to handle and lighter than a completed den structure. A more specific form can be created through molding, which could aid in the success of the adoption by bears. Materials that are thermally Insulating could be chosen and molded right into the den parts. Textures and colours can be molded in. The following are technologies that could be used to mold or cast the den structure.

POTENTIAL MATERIALS FOR MOLDED DENS

1. **Pre cast, foamed, cellular concrete**





Benefits: This process produces a rigid well-bonded body (i.e., very strong and durable). It is a high-strength, low density material that is light relative to its strength. The lightest foamed concrete has a density of 300-600 kg/m^3 vs regular concrete which has a density of 2400 kg/m^3 (i.e., 1/8 the weight of regular concrete). More exploration would be needed to define the exact density required for a den design. For further comparison, PVC plastic has a density of 1330 kg/m^3. A foamed concrete part would need much thicker wall thickness than a plastic part but this would mean that it would incorporate thermal insulating properties. However, because of its lower density, the overall weight could be similar to plastic construction. The parts would be pre-cast in halves for easier and more efficient transporting to the installation site. Concrete casting fabricators should be readily available. This material has thermally insulating properties, low water absorption and sound insulating properties. It is also long lasting in the elements. The production of foamed concrete on a small scale is a fairly easy process which does not involve any expensive or heavy machinery and in most cases uses equipment that is already available for normal concrete/mortar production. Concrete casting is available with many local and regional fabricators. Medium tooling cost.

Risks: Material cost is unknown. Although much lighter than regular concrete the finished part may still be heavy.

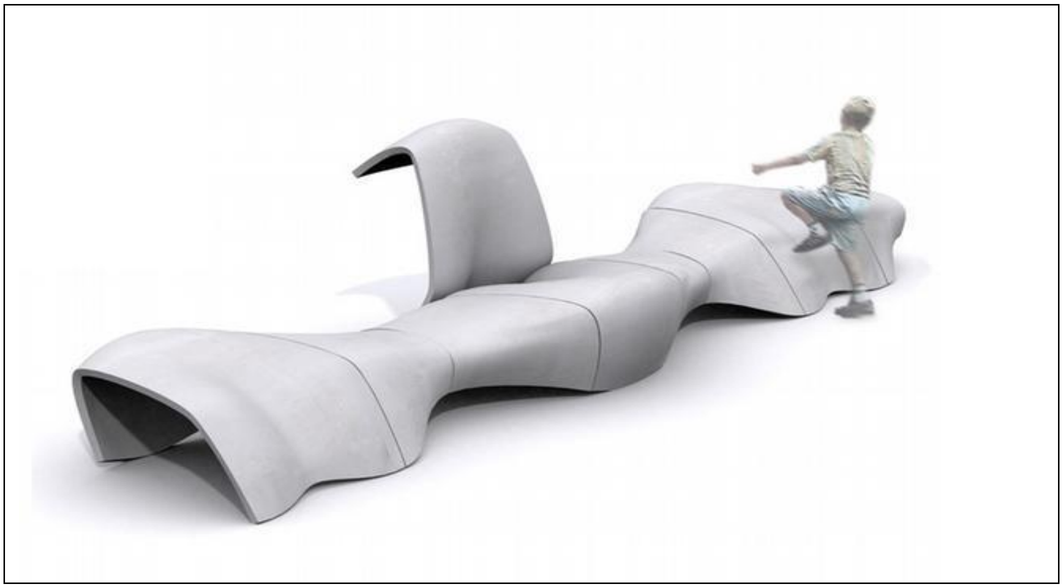
Notes: Pre cast would make the most sense but it's possible the den parts could be cast on site. Possibly as a single top part? Was not able to find a fabricator that works with cellular concrete that could provide pricing.

References:

http://www.hbp.usm.my/norizal/FoamConcrete/production.htm

http://www.szolyd.com/services/

2. **Pre-cast, Ductal concrete**



Benefits Ductal® is an ultra-high performance, fiber reinforced concrete-like material that provides superior strength, durability and aesthetic design flexibility. Molded shapes are thinner, lighter and more graceful compared to conventional concrete. Ductal elements provide superior impermeability against water corrosion, abrasion and impact. The finished molded structure would have extremely low maintenance requirements and have an exceptionally long useable lifespan. Ductal molded parts can be recycled and reused. This also makes it an excellent eco-efficient choice. A local Victoria, BC firm specializes in casting this material. Medium tooling cost. High material cost.

Disadvantages: High material cost.

Risks: Material cost is expensive. For two halves that would create a bear den at ¾" thick walls just the material cost would be approximately $1100. Finished parts could still be heavy to manipulate into place. Calculated weight would be 172 kg or 380 lbs per half of the den.

Notes: This process and material could facilitate a single part mold where the Ductal material is sprayed against the mold and set. This would simplify to fabrication process and reduce mold costs.

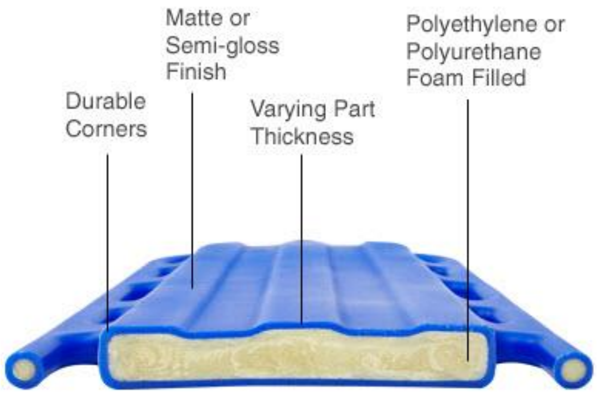
Cost Estimate: Molds: $5,000-$10,000 Parts: $1,200 – 1,800 for both parts that make a complete den.

References:

http://www.ductal-lafarge.com/wps/portal/ductal/1-About_Ductal

http://www.szolyd.com/services/

3. **Foam filled Roto-molding**



Benefits: A very high level of detail can be molded in (camera and sensor mounting, threaded inserts etc.). Insulating properties are obvious if foam filled. It could produce a water tight, very durable and long lasting den structure. The parts should be fairly light weight. This process could also facilitate molding the den in a single part. This process might have the lowest part cost and easiest assembly.

Disadvantages: High mold cost

Risks: Mold cost will require a minimum quantity. At present the cost is $1500 per den for the culvert pipe fabricated version (not including labour to place it). We would need to investigate mold costs with design drawings for accurate numbers. The tooling would pay for itself if a minimum of 50 were to be deployed. Because tooling cost is high changing the design is expensive.

Notes: This might be the best option for high volume deployment after a design is proven.

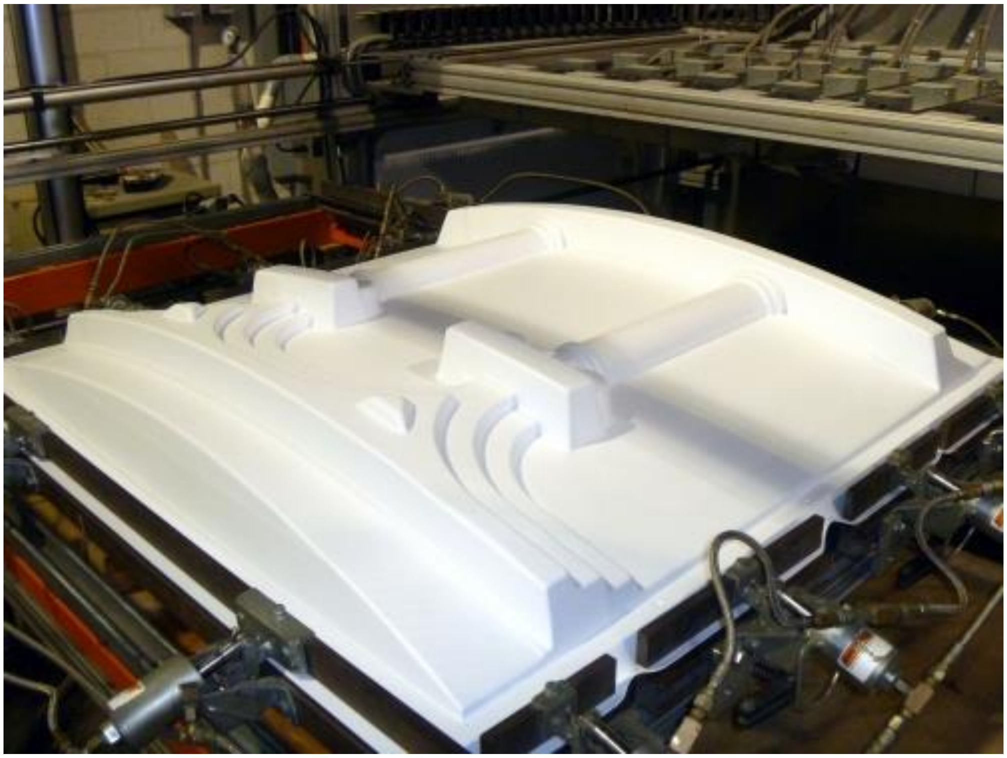
Cost Estimate: Molds: $45,000-$75,000 Parts: $100 – $200 for both parts that make a complete den.

References:

http://newwavedocks.com/residential/dock-floats

http://www.centuryplastics.ca/

4. Vacuum formed Thermo Plastic



Benefits: Water tight, durable and long lasting materials can be chosen with this process. The parts are light and multiple parts that can nest together could facilitate more efficient transport. Insulation could be sheet material or foam added after an inner and outer shell is assembled. It might also be possible to vacuum form the insulation material. Tooling costs are medium to low but this technology would require more tools since more parts would need to be molded. This might be the lightest weight option since the outer shell, insulation and inner shell could all be transported as individual elements to the site and assembled there. Design changes are easier to make vs other molding options. Lighter weight than fiberglass. Thermoformed plastic and the manufacturing process is environmentally safe, its material is recyclable, and most raw thermoplastic materials are VOC free.

Disadvantages: More parts and assembly needed than other molding options.

Risks: Tooling cost and part cost is unknown since at least two tools are needed to produce an inner and outer shell. If insulation is required to be vac formed then that's another tool needed. There might be limited fabricators who could produce large parts. This could introduce higher shipping costs.

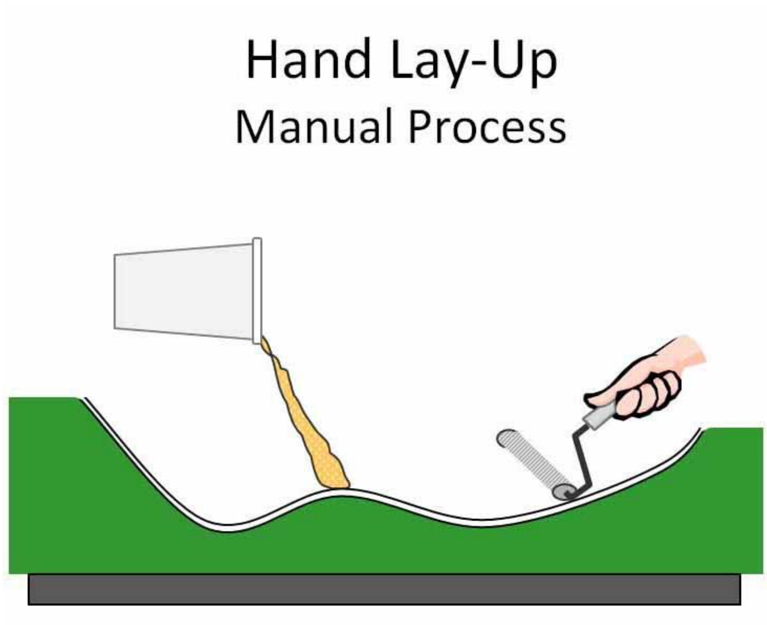
Notes: This might be a good option to test a design before committing to a Roto-molded product. TPO material is durable, UV and crack resistant.

Cost Estimate: Molds: $10,000, parts: $485 - $530 for both parts that make a complete den. An option to fabricate a double wall den to provide insulation might cost $5000 more in molds and another $300 to the part cost.

References:

http://www.rayplastics.com/contact-us/

5. **Fiberglass Open molding**



Benefits: The simplest of the molded fabrication processes, good for low-volume production of large products. (note, this is the process to make the concrete forms), great shape complexity. Pigmented gel coats can be used to produce a smooth, colorful surface. Water tight, durable. Tooling cost are low. Because tooling costs are low, design changes are easier.

Disadvantages: Labour intensive and would require multiple parts and assembly to integrate an insulating layer (unless an insulating layer could be bonded into the layup process). There is little advantage of this process over vacuum forming. Can chip and crack and deteriorate in the elements. Heavier than other options. The fiberglass process produces large amounts of environmentally hazardous styrene and is non-recyclable.

Risks: Part cost could be high. Unsure if insulation layer can be applied to hand layup process effectively.

Notes: Vacuum forming would appear to be the better option.

Cost Estimate: Molds: $9,500 Parts: $1500 for both parts that make a complete den.

References:

http://marineplastics.ca/services

6. **Hard Coated CNC foam.**

Benefits: Can create a very specific form and design, seamless product. Details can be built in. A detailed and specific form can be produced, water tight and durable if hard coated. It could possibly be a very light weight part even when built as a complete den. Highly insulating. No tooling costs. Very easy to try new designs since there is no tooling involved.

Disadvantages: Labour intensive and possibly a high part cost.

Risks: Part cost could be very high, might not be durable enough if bear breaks the hard coat surface.

Notes: This might be a good option for making a female layup tool for open molding or even a tool for vacuum forming. This is most likely the best option for a prototype of any molded option.

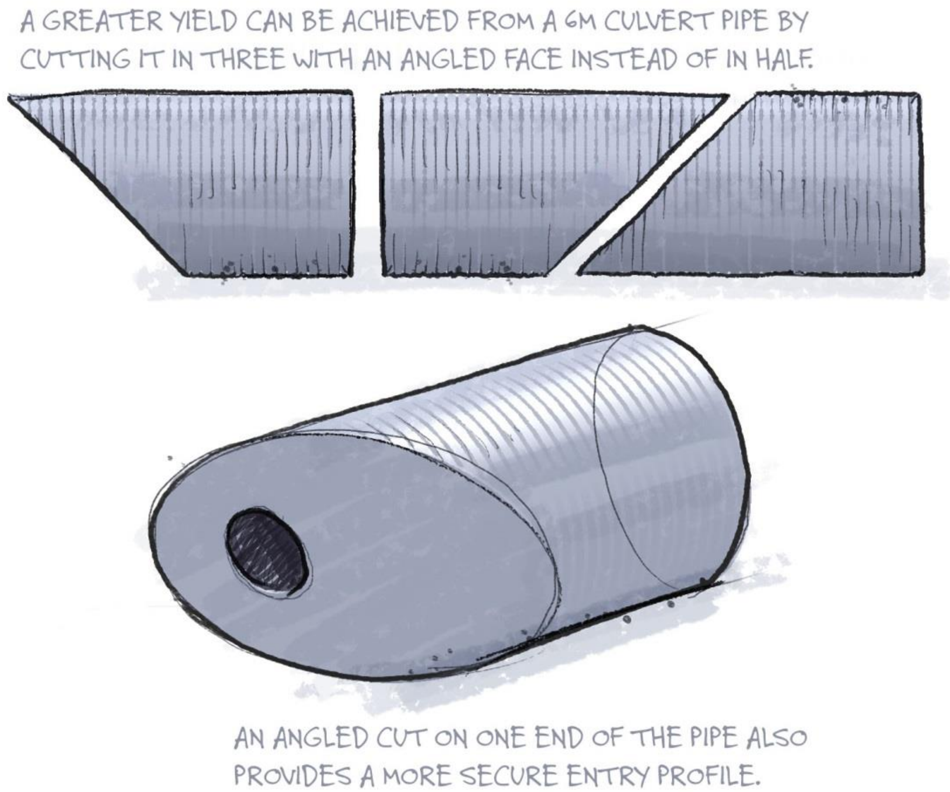
Cost Estimate: Molds: $0.00 Parts: $5,500 for both parts that make a complete den (minimum order quantities of 20).

References:

http://www.3dcustomfoam.com/addressmap.php

Non-molded Option

Fabricating from culvert tubing and sheet material



Benefits: Little to no tooling cost. Best solution for very low build quantity. Lower cost to experiment with design variations since no tooling is involved. Existing design based on large culvert is in place already and being tested. Greater yield and other possible gains could be had from simply re-examining the den design using the same materials (see the sketch above).

Disadvantages: High part and labour cost. Less detail can be built into the den. Limited form and design possibilities. Cumbersome to place in location. Difficult to incorporate thermal insulation.

Risks: If greater quantity is needed, costs will grow. Less specific design might limit its adoption by the bears.

Cost Estimate: Molds: $0.00 Parts: $1200-1800 for a complete den.

References:

http://www.armtec.com/en-ca/products-and-services/drainage-solutions-and-water-treatment/hdpe-pipe.aspx

Other Notes

The Bear Den could also be constructed by combining parts from different fabrication methods. For instance a top could be cast from concrete and a base could be vacuum formed or fabricated from sheet material.

GREEN ROOF

A green roof could be incorporated into the bear den structure. This could act as a thermal insulation layer to provide a better habitat that is more similar to the bears existing habitats. It might also provide a better visual integration into the environment which might also increase adoption by bears and disguise the structure from unwanted human investigation. A green roof could be created by incorporating vegetation that is harvested from the immediate area of the installation.

http://sunmarkenvironmental.com/envirolok/

DESIGN AND ENGINEERING COSTS

Future design and engineering costs will depend on the approach to the chosen direction to develop the next generation of artificial bear dens. The following lists shows estimates based on possible directions. These numbers are for labour only and do not include travel or prototype fabrication costs.

1. Assist in designing and producing documentation to assist in the fabrication of a pipe based bear den: $3000.
2. Design and develop a molded bear den base on a single specific molding technology such as vacuum forming. $6,000 - 10,000.