

# Mid Columbia Ecosystem Enhancement Project Catalogue

## Annotated Bibliography – August 2016

This catalogue project aims to enhance access to information about ecosystems impacted by hydropower construction and operations in the Mid-Columbia area from Shelter Bay to Mica Dam, and about potential ecosystem enhancement projects in the area to mitigate these impacts.

Over 80 publicly available reports completed in the last 25 years were identified. Project resources did not allow for review of earlier literature. The list of documents reviewed is available from the Project Lead.

The project team scanned a short list of these documents, including original research, project reports and strategic action plans to identify potential projects for the catalogue. This Annotated Bibliography compiles information from these documents. These reports can be accessed by Googling each title.

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***Arndt, S. 2009. Footprint impacts of BC Hydro dams on Kokanee populations in the Columbia River basin, British Columbia. Prepared for Fish and Wildlife Compensation Program - Columbia. 77 pp.***

Kokanee (*Oncorhynchus nerka*) are a primary prey for Rainbow Trout (*O. mykiss*) and Bull Trout (*Salvelinus confluentus*), as well as prey of terrestrial animals, including humans. Kokanee may have benefited from the increase in in lentic (still) water after reservoir creation. However, the quantity and quality of spawning habitat was reduced; impacts on populations are generally unknown.

Compensation options including adding nutrients to lakes, creating spawning channels, stream restoration, and changes to dam operations are discussed and tabulated including estimated cost and possible performance measures.

No specific projects were identified.

***Arndt, S. 2009. Footprint impacts of BC Hydro dams on Rainbow Trout in the Columbia River basin, British Columbia. Prepared for Fish and Wildlife Compensation Program - Columbia. 113 pp.***

Two ecoytpes of Rainbow Trout (*Oncorhynchus mykiss*) suffered from the loss of river and stream habitats associated with reservoir creation, with impacts including general habitat loss, the extirpation of a 'yellowfin' trout in the Arrow Lakes, and loss of connectivity due to dams blocking interactions and migrations. Research is recommended to determine if existing spawning and rearing habitat are currently limiting factors. Proposed compensation actions include creating spawning channels, gravel additions, hatchery propagation, creation of fishways in dams, prey population management, and operational changes at dams, while enhancement of stream habitats could include habitat restoration (such as adding large woody debris, boulder clusters, or weirs) and reconnection, nutrient additions, or stocking of fish. Options are tabulated including estimated costs and performance measures.

No specific projects were identified.

**Arndt, S. and J. Baxter. 2006. Status of Burbot (*Lota lota*) in Arrow Lakes Reservoir. Prepared for Columbia Basin Fish and Wildlife Compensation Program. 35pp.**

Burbot in the Arrow Lakes, including Revelstoke Reach, were widely distributed and relatively large, with high growth rates. Recommendations include research into the habitats and growth of young burbot.

No area-specific projects were identified.

**Bird, C. and H. van Oort. 2015. Marsh bird productivity and conservation in Revelstoke Reach. Prepared for Fish and Wildlife Compensation Program. 38pp.**

Eight wetlands in Revelstoke Reach were surveyed for marsh birds. Airport Marsh was the prime nesting ground for many species. Reservoir operations and nest flooding were the main cause of nest failure.

*Potential projects* – Stabilizing water levels in Airport Marsh

**Bird, C., R. Clarke, D. Lewis, and R. Serrouya. 2010. Cougar ecology, predation, and caribou in the Columbia Mountains of British Columbia. Prepared for Fish and Wildlife Compensation Program – Columbia Basin. 45pp.**

The distribution of cougar, their overlap with caribou, and their prey selection and kill rates were investigated. Deer, moose, elk and beaver were the primary prey of cougar. Caribou comprised a small proportion of their diet, yet this predation could impact small caribou populations. Further monitoring of cougar populations was recommended in general.

No site-specific projects were identified.

**Bray, K. 2003. Lake Revelstoke Reservoir Bull Trout radio telemetry – Progress report 2003-2004, Year 3. Columbia Basin Fish and Wildlife Compensation Program. 8 pp.**

Bull trout in Lake Revelstoke were radio-tagged to determine spawning and migratory movements and timing. Locations were classified as sensitive and not identified in the report.

No potential projects were identified.

**Clarke, A. and K. Telmer. 2008. Arrow reservoir bull trout: Microchemical analysis of otoliths to determine stock structure, migration timing, and location of spawning and rearing habitats. Prepared for Fish and Wildlife Compensation Program. 36pp.**

Otoliths from bull trout showed that the trout moved among smaller tributaries during rearing, and entered the reservoir at 3 or older.

Recommendations were given for several projects outside of the Mid-Columbia.

**Cope, S. 2008. Footprint impacts of BC Hydro dams on Burbot Populations in the Columbia River Basin, British Columbia. Prepared for Fish and Wildlife Compensation Program - Columbia. 88 pp.**

Burbot (*Lota lota*) populations before and after dam construction were compared for 12 dam units across the FWCP area. Burbot populations have likely decreased in 5 dam units, and increased in 1 dam unit, with the impacts in other units unknown. Research into life history and habitat use of burbot is recommended prior to enhancement work. Potential compensation projects include whole lake and/or localized fertilization/ nutrient restoration, operational changes, hatchery and stocking, and habitat restoration and enhancement.

Potential projects – Research on life history types and population dynamics of Burbot in Arrow Lakes, assessment of adult numbers and recruitment in Arrow Lakes using standardized methodology, and compilation of existing data on life history and catch-per-unit effort.

**Crossman, J.A. and L.R. Hildebrand. 2012. Evaluation of spawning substrate enhancement for white sturgeon in a regulated river: effects on larval retention and dispersal. River Research and Applications. DOI: 10.1002/rra.2620**

Large and small angular rocks were added to a section of the Columbia River in the only known White Sturgeon (*Acipenser transmontanus*) spawning area in the Mid-Columbia. Sturgeon larvae were released at the treated and control sites; more larvae hid and stayed longer in the rocky substrate. Work is needed to determine if adult sturgeon will spawn on the new substrate.

Potential projects – research impacts/benefits of substrate enhancement on other life stages of White Sturgeon

**Decker, S. and J. Hagan. 2007. Distribution of adfluvial bull trout production in tributaries of the Arrow Lakes reservoir and the feasibility of monitoring juvenile and adult abundance. Prepared for Columbia Basin Fish and Wildlife Compensation Program and BC Hydro. 131 pp.**

The distribution and abundance of bull trout and rainbow trout were identified using snorkeler counts and red surveys in tributaries of Arrow Lakes, to identify the relative contribution of tributaries to fish production. The Illecilliwaet River was the most important bull trout rearing and spawning stream. The past removal of barriers to fish passage has resulted in use of upstream habitat in both the Illecillewaet and Halfway Rivers. Spawning habitat for bull trout in tributaries are threatened by channel instability, migration barriers, water temperatures, and competition from rainbow trout.

No specific enhancement projects were identified.

**Dulisse, J. and D. Hausleitner. 2010. 2009 amphibian survey - Columbia Forest District. Prepared for Prepared for Fish and Wildlife Compensation Program. 35pp.**

Forty-three wetlands were sampled. Breeding-site encounter rate for western toads (*Bufo boreas*) suggested that the area was an important breeding region. Amphibian species richness was low, while presence of Bd (*Batrachochytrium dendrobatidis*, chytrid fungus) was much higher than in adjoining forest districts.

Further chytrid sampling, from more species of amphibians, was recommended. General conservation actions were discussed, including captive breeding, habitat protection, mitigation at road crossings, and habitat enhancement or restoration, but no specific projects were identified.

**FWCP. 2012a. Columbia Basin Large Lakes Action Plan.**

Creation of reservoirs impacted, altered, and created large lakes (greater than 1000 ha) in the Columbia region, notably Kootenay Lake and Duncan, Arrow Lakes, Revelstoke, and Kinbasket Reservoirs. Priorities for fisheries conservation and mitigation vary across lakes, and have included spawning channels and hatcheries, dam removal on the Illecillewaet, and fertilization of Kootenay and Arrow Lakes. Inventory of bull trout spawning and rearing habitat has been completed for Arrow Lakes but not other priority large lakes.

Actions to address priority issues were developed. Proposed actions are broad, general prescriptions to be applied at the reservoir level (e.g. develop and implement invasive species monitoring and response plan – priority 2 for Kootenay and Arrow Lakes). No site-specific actions were identified.

**FWCP. 2012b. Columbia Basin Plan Draft. 45 pp.**

The Basin plan contains information about dams, summary footprint impacts, completed compensation projects, and future priorities. Action plans are outlined.

No specific projects were identified.

**FWCP. 2012c. Columbia Basin Small Lakes Action Plan.**

Creation of reservoirs inundated or otherwise impacted productive small lakes (smaller than 1000 ha) in the Columbia region, affecting many of the fish and wildlife species associated with small lakes.

Actions to address priority issues and species were developed for six small lakes, none of which occur in the Mid-Columbia region.

***FWCP. 2012d. Species of Interest Action Plan. 39pp.***

Habitat loss and alteration from dam construction and/or reservoir creation has impacted many terrestrial and aquatic species. Species of interest were categorized into Recovery, Focal, and inventory Species. Priority actions were identified for each Species of Interest. Actions were categorized as Research and Information Acquisition (inventory, assessment, integrated habitat planning), Species-based Actions (translocate-reintroduce, manage alternate predator-prey, other), Habitat-based Actions (habitat creation, restoration, restore connectivity), Land Securement (habitat acquisition, stewardship), and Monitoring and Evaluation.

Potential projects - specific projects were identified for mountain caribou and white sturgeon.

***FWCP. 2012e. Streams Action Plan. 16pp.***

Creation of reservoirs permanently destroyed many stream and riparian habitats across the Columbia Basin. Habitat improvement/enhancement opportunities exist for streams outside of the impacted area. Fifteen streams and priority species of concern were identified for initial compensation actions. In the mid-Columbia region, the Alkolkolex River and its westslope cutthroat trout were identified.

Potential projects for the Akolkolex River/westslope cutthroat trout – Develop a regional stream plan and implement habitat-based actions, enhancement through habitat complexing.

***FWCP. 2012f. Upland/Dryland Action Plan. 23pp.***

Approximately 20% of the habitat flooded during reservoir creation was terrestrial habitats. Priority habitats for compensation/enhancement/conservation include fire-maintained ecosystems, exceptional old-growth forests, deciduous forests, and ungulate winter range.

Potential compensation actions include securement of important conservation areas and treatment of invasive plants.

***FWCP. 2014. Riparian and Wetlands Action Plan. 101 pp.***

Low-elevation wetlands along major rivers have been impacted by reservoir creation in the Basin. Six priority wetland areas were identified for compensation or enhancement, and action plans created for all focal areas. One of these areas, the Revelstoke Reach area south to Shelter Bay, is in the Mid-Columbia region.

Potential projects – monitor and treat aquatic invasive species in wetland and riparian areas, restore or create wetland and riparian habitats, partner to conserve and enhance wetland and riparian areas, compile, and assess the effectiveness of completed wetland and riparian restoration projects.

**Gilles, C. and J. Boulanger. 2001. The LaForme Creek lichen enhancement project: preliminary results to-date. Prepared for Columbia Basin Fish and Wildlife Compensation Program. 25 pp.**

Girdling trees may increase the amount of lichen present on trees and as litterfall. Recommendations to improve this project were made.

No specific future projects were discussed.

**Golder Associates Ltd. 1998. Examination of fish passage problems on an unnamed tributary of Bigmouth Creek. Prepared for FWCP-Columbia. 177 pp.**

Fish sampling at the unnamed tributary suggested that it provided spawning and rearing habitat for bull trout. However, there were various barriers for fish in the unnamed tributary including debris piles and dense vegetation, high water velocities in a culvert, and a steep channel gradient. There was limited habitat above the proposed enhancement area. Enhancement work would be better focussed on lower-gradient tributaries or tributaries with higher capacity for fish production (eg Big Fish Creek).

No specific projects were identified.

**Golder Associates. 1998. An evaluation of fish passage problems on Goldstream Creek. Prepared for CBFWCP. 29 pp.**

Barriers to fish passage were identified at three culverts at road crossings, at Hwy 23, Goldstream Mine Rd, and Devil's Garden Rd. Fish inventory and habitat mapping was done for the lower goldstream, which documented rainbow trout and potential spawning and rearing habitat for fluvial and adfluvial fish.

Potential projects – Enhancement of fish passage through the Hwy 23 culvert, habitat enhancement of lower Goldstream creek to provide habitat for adfluvial rainbow and bull trout

**Golder Associates. 1998. Improvement of Fish Passage for Adfluvial Trout in Birch Creek.**

Birch Creek, near Mica Dam, was assessed for fish habitat and barriers to fish passage. Six barriers to fish passage (logs with accumulated gravel or debris jams) were removed, enabling bull trout to access spawning and rearing habitat up the creek. Monitoring fish and habitats in the creek and maintaining fish passage is recommended.

Potential projects – re-assessing barriers to fish passage in Birch Creek; maintaining passage; monitoring fish populations.

**Hagen, J. 2008. Impacts of dam construction in the upper Columbia Basin, British Columbia, on bull trout (*Salvelinus confluentus*) production, fisheries, and conservation status. Prepared for FWCP-Columbia. 78pp.**

Bull trout spawn at higher elevations than most reservoirs, so spawning habitat was likely not impacted by dam construction, with the exception stream losses around Kinbasket and Lake Revelstoke. Instead, impacts included loss of rearing habitat in inundated creeks, plus loss of genetic diversity in adults due to the homogenous nature of large reservoirs. Most populations are secure, although several specific populations outside of the Mid-Columbia area are of concern. Possible compensation actions must focus on off-site compensation, and could include reservoir (particularly Lake Revelstoke) and stream fertilization, improving fish access to spawning areas, side channel development, riparian restoration to shade streams and prevent increasing water temperatures, and preservation of existing rearing reaches.

Potential projects – Fertilization of Lake Revelstoke or tributaries, removal of instream barriers to increase access to spawning habitat in Nagel, Downie, Hoskins, and Park Creeks, side channel development in Carnes Creek, feasibility of monitoring adult abundance in tributaries of Revelstoke Reservoir.

**Haney, A., M. Sarell, and J. Runciman. 2002. Revelstoke Community Forest Corporation, TFL 56 Northern Long-eared bat inventory.**

Northern long-eared bats (*Myotis septentrionalis*), Little Brown Bats (*M. lucifugus*), Long-legged Myotis (*M. volans*), Big Brown Bats (*Eptesicus fuscus*), Hoary Bat (*Lasiurus cinereus*) and Silver-haired bat (*Lasionycteris noctivagans*) were captured or detected in the Downie and Goldstream drainages. Little Brown myotis was the most common species captured.

No specific compensation projects were presented.

**Hawes K. and D. Drieschner, 2012. Arrow Lakes Tributary Fish Migration Access. Year 5. 2012. Fish Migration Passage Monitoring Summary Report. Program No. CLBMON-32 / Q8-8004. Ecoscape Environmental Consultants Ltd. Kelowna, BC. 106pp**

The impacts of reservoir elevation and stream flows on fish access to tributaries to Arrow Lakes were assessed. Key species of interest were Kokanee (*Oncorhynchus nerka*), Bull Trout (*Salvelinus confluentus*), and Rainbow Trout (*O. mykiss*). Accessibility was generally not impacted by reservoir operations; however, several tributaries with impeded access were identified. Observations of non-impeded natural creeks provided the basis for recommendations to improve impeded tributaries.

Potential projects – Enhancement of fish passage at Drimmie Creek. Note – this site was visited during the field trip for this project and it was agreed that this was not needed now.

**Keefer Ecological Services. 2010. CLBWORKS-2 Arrow Lakes reservoir revegetation program physical works report (Phase 2). Prepared for BC Hydro Generation, Water Licence Requirements. 143 pp.**

Live sedges (*Carex* spp) and Black Cottonwood (*Populus balsamifera* ssp. *trichocarpa*) were planted in three key sites (McKay Creek, 9 Mile, and 12 Mile) in Revelstoke Reach. These planting led to conclusions about preferable planting sites (non-mobile soils for sedge plantings, sites assessed as 'good revegetation potential' for cottonwood stakes) and concluded that application of fertilizer was not beneficial for plant growth in the drawdown habitats.

Potential projects : Trial planting of Sitka willow (*Salix sitchensis*), trial of planting methods comparing hand and machine planting in Revelstoke Reach

**Kellner, M. 2015. Revelstoke Reach Riparian Restoration Project W-F15-01. Prepared for Fish and Wildlife Compensation Program. 26pp.**

Shrubs and locally-harvested live stakes were planted in higher-elevation areas of the drawdown zone near Revelstoke, and hand-planting of both types of stock was deemed useful for restoration of areas covered by reed canarygrass.

No specific projects were identified.

**Krebs, J. and D. Lewis. 1999. Wolverine ecology and habitat use in the Columbia Mountains. Columbia Basin Fish and Wildlife Compensation Program. 27pp. in: L. M. Darling, editor. 2000. Proceedings of a Conference on the Biology and Management of Species and Habitats at Risk, Kamloops, B.C., 15 - 19 Feb.,1999. Volume Two. B.C. Ministry of Environment, Lands and Parks, Victoria, B.C. and University College of the Cariboo, Kamloops, B.C. 520pp.**

Wolverine density, reproductive rate, and home ranges were investigated. Wolverine activity focussed on National Parks and unroaded wilderness areas. Human-caused mortality from trapping and roadkill was significant.

No specific projects were identified.

**Ladell, J., J.McPhail, and J.Baxter. BC Hydro dam impact footprint review – whitefish, westslope cutthroat trout, Cottids, Cyprinids and Catostomids. Prepared for FWCP-Columbia. 70pp.**

There are many relatively-unstudied fish species in the Columbia Basin, and very little is known about these species may have been impacted by dam construction. Long-nosed dace and suckers suffered from habitat loss in Revelstoke Reservoir. Studying the distribution, abundance, and life history of these little-known species may be the most effective action at present, to support future compensation projects. Additionally, preventing introductions of fish to reservoirs and tributaries should be stopped, to protect genetically pure populations.

Potential projects - Determine current distribution of adult whitefish, sculpins, minnows, and suckers with presence/ absence surveys, study biology of fluvial pygmy whitefish, survey of reservoir nearshore areas for minnow spawning habitat, to determine if reservoir drawdowns may impact its habitat



**Lister, D. and J. Wood. 1994. Overview of fish habitat enhancement options at Standard Creek. Prepared for Mica Fisheries Compensation Program. 30 pp.**

The lower 1.2 km of Standard Creek were assessed for enhancement options. In-stream enhancement was no feasible, but a side channel was proposed and plans drawn up.

Potential projects – Removal of partial barriers to fish passage (log jams), feasibility study for enhancement work and installation of an artificial spawning and rearing channel for kokanee and trout.

**Machmer, M. 2004. Small wetland literature review and mapping. Prepared for Columbia Basin Fish and Wildlife Compensation Program. 94 pp.**

Wetlands in the Columbia Basin were inventoried and classified, and their functional significance reviewed. The current legislation protecting wetlands was also reviewed, with the conclusion that the majority of wetlands are not legally protected, in spite of their ecological importance. Conservation and protection of wetlands in the Basin should be a high priority, and may be essential for protection of listed species of wildlife.

No are-specific projects were identified.

**Mackillop, D. and G. Utzig. 2005. Primary production in the flooded terrestrial ecosystems of the Columbia Basin. Prepared for Columbia Fish and Wildlife Compensation Program. 28 pp.**

Modelling was used to conduct a retrospective analysis of losses of Net Primary Productive (NPP) and Net Ecosystem Productivity (NEP) due to the loss of terrestrial ecosystems during reservoir creation. Productivity estimates for forested and non-forested site types were developed and presented.

No potential enhancement projects were identified.

**Mackillop, D., J. Krebs, I. Manley, and A. Waterhouse. 2008. Impact of BC Hydro dams on terrestrial and wetland habitat in the Canadian portion of the Columbia Basin: assessing the significance of ecosystem change. Prepared for FWCP-Columbia. 177 pp.**

Impacts from dam creation were assessed across dam units, using ecosystem mapping and knowledge of the pre-dam ecosystem distribution to determine the areas of each lost ecosystem and the proportions of ecosystems lost. The most highly-impacted Ecosystem Types (groupings of site series) were forested wetlands, wetlands, gravel bars, cottonwood forests, shallow open water, and wet forests – generally ecosystems found in valley bottoms. Impacts and compensation possibilities varied with dam unit.

Compensation options were tabulated by dam unit, with the Revelstoke and Arrow Units candidates for gravel bar creation, habitat purchases, private land stewardship efforts and covenants, restoration of flood regimes that encourage cottonwood establishment, dispersion of fish carcasses to enrich riparian vegetation, creation of wildlife trees, restoration of coarse woody debris, and shrub restoration with fencing/planting. The Arrow Unit was also a candidate for invasive plant control, pasture seeding, habitat creation (wetlands and islands), erosion control with fencing, restoration of shallow open water,

shoreline revegetation, restoring water to wetlands, and cottonwood planting.

No area-specific projects were identified.

***Maltby, F. 2000. Painted turtle nest site enhancement and monitoring, Red Devil Hill nest site at Revelstoke, BC. Prepared for Columbia Basin Fish and Wildlife Compensation Program. 18 pp.***

Nests of painted turtles (*Chrysemys picta*) were located and monitored. Vegetation encroachment was identified as a detriment to hatching success.

Potential projects – Vegetation management at Red Devil Hill

***Manley, I. 2008. Common nighthawks in the Columbia Basin – a summary of sightings submitted by the public. Fish and Wildlife Compensation Program – Columbia. 8 pp.***

A web-based reporting program was used to collect public sightings of Common Nighthawks (*Chordeiles minor*) in the Basin. Efforts focussed on the lower Columbia, however, one sighting was reported from McBride. More work is needed to promote the project in Revelstoke, Valemount and Nakusp areas.

Potential projects – Collect reports of common nighthawk sightings in the Mid-Columbia.

***Manley, I. and J. Krebs. 2011. Wildlife impacts due to BC Hydro dams in the Columbia Basin. Prepared for FWCP-Columbia. 107pp.***

Species lists and pre-inundation habitat models were used to assess the impact of dam creation on terrestrial and aquatic wildlife in the Columbia Basin. This list was combine with provincial and regional conservation priorities to identify 64 ‘priority 1’ and 48 ‘priority 2’ species. Compensation actions were identified, with inventory and monitoring being the most pressing action, to supply the necessary information to guide other compensation actions. Habitat acquisition, stewardship, planning, restoration, and creation, as well as predator management, translocation and re-introduction, and restoration of connectivity are also recommended.

Detailed example activities are provided including supporting habitat restoration and education work, inventory and identification of nest sites for Western Screech Owl and Great Blue Heron, inventories of waterfowl, bats, predators, and prey, identify and protect or restore key Mountain Caribou habitat, initiate a nest box program for cavity nesting birds, create wetlands for Painted Turtle, Yellow Warbler, and Western Toads, revegetate the drawdown zone to create habitat for various species, controlling the spread of invasive species, manage wetlands, captive rearing and re-introduction of the Northern Leopard Frog, and maternity penning of Mountain Caribou. Potential activities are tabulated, and the costs and proposed performance measures detailed. No area-specific projects were identified.

**Moody, A., P. Slaney, and J. Stockner. 2007. Footprint impact of BC Hydro Dams on aquatic and wetland primary productivity in the Columbia Basin. Prepared for CBFWCP.**

Historical mapping and pre-dam information was compared to current, post-dam conditions of aquatic and wetland ecosystems to assess the amount, location, and significance of dam impacts on these ecosystems. Surface area of large lakes has approximately doubled in the basin, while the area of rivers, streams, wetlands, and floodplain habitats decreased, with associated changes in productivity. The project aimed to provide the necessary background information for CBFWCP to initiate and monitor aquatic and wetland primary productivity mitigation and compensation efforts, and compensation suggestions for each habitat type are proposed.

Potential projects – Pelagic, shoal, or stream fertilization around Revelstoke Reservoir, instream habitat rehabilitation with large woody debris, habitat enhancement with wetland or riparian plantings.

**Nupqu Development Corp. 2013. Monitoring of impacts on Nagle Creek wetland from Mica Units 5 and 6. Study period 2012. CLBMON59.**

The Nagle Creek wetland and riparian habitats were monitored for impacts from changing flow regimes Mica 5 and 6 as part of the Columbia River Water Use Plan. Primary potential impacts include changes to the hydrological regime, amount and timing of wetted land, and ultimately, associated changes in habitat over time. This study examined only changes in wetted area, to determine if further assessment was needed. Deeper water for longer periods of inundation, and associated changes in plant communities, were predicted.

No specific potential enhancement projects were identified.

**Porto, L. 2008. White sturgeon populations in the BC Hydro dam footprint impacts area. Prepared for Fish and Wildlife Compensation Program – Columbia Basin. 54 pp.**

Dam creation has isolated and impacted eight sub-populations of white sturgeon, which now suffer from declining productivity and population sizes. Impacts include sediment and water quality changes during construction, habitat loss, change in nutrients/contaminants due to altered flows, reduction in turbidity from decreased sediment transport, fragmentation and loss of habitat connectivity, and fish entrainment and death. Compensation options relevant to the Mid-Columbia area include transport of adults or juveniles upstream of the Hugh L Keenleyside (HLK) dam, building fish passage at HLK dam, and addition of hatchery-reared juveniles to the Arrow Lakes.

No site-specific compensation projects are presented.

**Schindler, E., D. Sebastian, T. Weir, H. Andrusak, G. Andrusak, M. Bassett and K. Ashley. 2013. Arrow Lakes nutrient restoration program, years 11 and 12 (2009 and 2010) report. Fisheries project report No. RD 137. 177pp.**

The nutrient-addition program is believed to have benefitted all trophic level sin the Arrow Lakes. Recommendations for future work include research into the effect of reservoir flows, study of trophic interactions, the effects of spawning channels, the relationship between kokanee fry and adult abundance, and investigation into the role of predation on kokanee.

No area-specific projects in the mid-Columbia were identified.

**Sebastian, D. and T. Weir. 2014. CLBMON-2 Kinbasket and Revelstoke Reservoirs Kokanee Population Monitoring – Year 6 (2013). Prepared for BC Hydro Water Licence Requirements. 49pp.**

Water temperatures, kokanee distribution, and kokanee size were monitored in Kinbasket and Revelstoke Reservoirs.

No specific projects were identified.

**Thorley, J. 2008. Aquatic habitat losses and gains due to BC Hydro dams in the Columbia Basin. Prepared for FWCP-Columbia. 125 pp.**

Reservoir creation resulted in losses of highly productive stream, small lake, and medium lake habitats, and an increase in the area of less-productive large lakes habitat (reservoirs). Lakes and streams can not be re-created; compensation must occur by maintaining or increasing productivity of existing large lakes. Compensation options presented included habitat acquisition and protection, reconnection of isolated habitats (barrier removal), bank stabilization and riparian restoration, addition of large woody debris or boulders, modifying water flows, stabilizing logging roads to reduce sedimentation, fertilization, creation of spawning channels, hatchery programs, and removal of exotic species. Costs for options were compared.

No area-specific projects were identified.

**Triton Environmental Consultants. 1991. A preliminary report outlining some enhancement opportunities for tributaries flowing into Revelstoke Lake. Prepared for BC Hydro. 35pp.**

Twenty-three tributaries were surveyed to determine which streams provided or could provide habitat for fish resident in Lake Revelstoke, how much habitat was available, if any fish were currently present, and any enhancement opportunities in these creeks. Various enhancement tactics were reviewed.

Potential projects - Nagel and Park Creek were identified as candidates for enhancement work through removal of barriers. Horne, Pat, Soards, Laforme, and Goldstream (including Brewster, Old Camp, and McCullogh) were identified as having resident fish populations and potential for enhancement of recreational fisheries.

***Triton Environmental Consultants. 1992. Biophysical surveys and evaluations of enhancement opportunities for streams tributary to Lake Revelstoke. Prepared for Mica Fisheries Technical Committee. 325pp.***

Based on the work begun in 1991, data on fish presence, habitat quality, and habitat availability were reviewed. Nine primary streams were identified as potential enhancement sites. Seven streams (Bigmouth, Scrip, Kirbyville, Ruddock, Carnes, Downie, and LaForme) provide habitat for adfluvial (lake) fish and could be enhanced. One stream, Nagle, could provide habitat if a barrier were removed. The Goldstream River is not accessible to adfluvial fish but has indigenous trout. Trial enhancement projects are recommended, before proceeding. Fourteen other tributaries were also reviewed and potential projects listed.

Potential projects: various enhancement opportunities at each of the creeks were presented.

***Utzig, G. and D. Schmidt. 2011. Dam footprint impact summary – BC Hydro dams in the Columbia Basin. Prepared for Fish and Wildlife Compensation Program – Columbia. 49pp.***

Thirteen reports, addressing impacts on different ecosystem components, were summarized to describe the impacts of dam and reservoir creation and assess compensation options. General compensation options were explored and the benefits assessed.

No specific projects were identified.

***Utzig, G. and R. Holt. 2008. Terrestrial productivity in the flooded terrestrial ecosystems of the Columbia Basin: impacts, mitigation, and monitoring. Prepared for Columbia Fish and Wildlife Compensation Program. 38 pp.***

Productivity losses due to flooding were developed based on the models from MacKillop and Utzig 2005.

Mitigation options were presented and reviewed in a general sense, including pros and cons of each approach. Options included historic ecosystem restoration, alternative ecosystem restoration, habitat element restoration, reclamation within footprint, floating islands, habitat stewardship, habitat acquisition, and control of invasive species. No specific projects were identified.

***van Oort, H. and J. Cooper. 2015. CLBMON-36: Kinbasket and Arrow Lakes Reservoirs: nest mortality of migratory birds due to reservoir operations - Year 7, 2014. Prepared for BC Hydro Ware Licence Requirements. 55pp.***

Flooding of nests by reservoir operations was investigated during a multi-year study in Revelstoke Reach, Canoe Reach, and Bush Arm. Nests of multiple species suffered from inundation. Much of the nest flooding in Revelstoke Reach could be prevented by stabilizing water levels at the very productive Airport Marsh.

Potential projects – A major physical works project is proposed, to protect Airport Marsh from inundation.

**van Oort, H. and J. Cooper. 2015. CLBMON-40: Arrow Lakes Reservoir shorebird and waterbird monitoring program. Annual report – Year 7, 2014. Prepared for BC Hydro Generation, Water Licence Requirements. 48 pp.**

Waterbirds and shorebirds were impacted by the loss of wetlands during dam creation. Reservoir operations continue to impact these birds. Bald eagle and osprey productivity were monitored, and observations of raptors nesting in the drawdown zone were documented.

No specific projects were identified.

**Wood, C.M. and V. C. Hawkes. Okanagan Nation Alliance and LGL Limited. 2015. Revelstoke Reach painted turtle monitoring program. Wildlife effectiveness monitoring of revegetation and wildlife physical works in the Arrow Lakes Reservoir. CLBMON-11B3 Year 5.**

CLBMON-11B3 is a 10-year study (initiated in 2010) to look at the effects of reservoir levels on the Western Painted Turtle (*Chrysemys picta belli*), in Revelstoke Reach, Upper Arrow Reservoirs. This report summarizes results from Year 5, 2014. Focus was on overwintering site locations, characteristics, and movements between sites. Montana Slough and Airport Marsh were identified as key overwintering areas. Project outcomes should include the identification of physical works that benefit turtles.

Potential projects – Floating islands in Montana Slough and Airport Marsh to mitigate habitat loss during inundation, enhancement and management of known upland painted turtle nesting sites, including Red Devil Hill.