ADAPTIVE MANAGEMENT OF WATER RESOURCES
AWRA SUMMER SPECIALTY CONFERENCE
Missoula, Montana
June 26-28, 2006

ADAPTIVE MANAGEMENT OF AN ENDANGERED WHITE STURGEON POPULATION: THE "KITCHEN SINK" APPROACH

J.C. Laufle[1], P.J. Anders[2], G. Barton[3], S.W. Bettin[4], R. Hallock[5],
G.C. Hoffman[6], C. Holderman[7], S.C. Ireland[7], and E.R. Lewis[8]

ABSTRACT: The Kootenai River, in British Columbia (Kootenay in Canada), Montana and Idaho, is home to the endangered Kootenai River white sturgeon (*Acipenser transmontanus*). Although a recovery plan has been finalized and partially implemented, the wild population has suffered from recruitment failure since at least the 1950s, due to various causes. Population abundance is declining at an estimated rate of 9% per year, from 5,000-6,000 adults in the 1980s to an estimated 500 adults in 2005. Consequently, the International Kootenai Ecosystem Restoration Team (IKERT), which includes members of Kootenai River White Sturgeon Recovery Team, adopted what may be viewed as a reversed adaptive management process in 2004. This strategy, coined the "kitchen sink" approach at the 2004 IKERT meeting, consists of simultaneously implementing all supportable (scientifically, financially, logistically, and legally) restoration actions as soon as possible. This contrasts with a classic scientific adaptive management approach, which implements and evaluates individual management actions successively, one at a time. Actions taken to date by several involved entities include flow augmentation from Libby Dam in Montana, investigation of physical and legal mechanisms to enhance flow augmentation, transport of spawners upriver to areas thought more suitable for egg incubation than current spawning locations, outplanting of embryos in areas thought more suitable than current spawning locations, planning for spawning habitat enhancement, and planning for channel modification to induce migration of spawners to better habitat. Meanwhile , a conservation aquaculture program at the Kootenai Tribal hatchery at Bonners Ferry, Idaho, supports the population by release of hatchery-reared juveniles of captively-spawned wild fish. The hatchery program also supports experimental evaluations through release of embryos, larvae and juveniles. These actions have been adaptively managed individually. This paper discusses the suite of actions and their places in an adaptive management framework for endangered Kootenai River white sturgeon.
KEY TERMS: white sturgeon; Kootenai; adaptive management; recruitment

INTRODUCTION AND BACKGROUND

The Kootenai River white sturgeon (sturgeon—*Acipenser transmontanus*) in Idaho, U.S.A., and British Columbia, Canada, is a population in decline. It consists of older individuals, and its lack of recruitment and of young individuals in the population structure has been well-documented (Duke et al. 1999; Paragamian et al. 2005; Paragamian and Beamesderfer 2003). Despite management and recovery efforts since the early 1990s, the population is currently estimated at about 500 adults, down from an estimated 5000-6000 adults in the 1980s (USFWS 2006a). It is believed to be declining at a rate of about 9% per year. The last significant year class is believed to have been from approximately 1974, a high-flow year that occurred soon after operation of Libby Dam began on the Kootenai River in Montana. KTI (2005) asserts that the population is likely to be functionally extinct in 20-30 years.

The reasons for general recruitment failure, beginning in the 1950's, of the sturgeon are unclear, though causes may include damming, channel constriction, over-fishing, contaminated sediments, undocumented spill of toxic chemicals, increased predation, and loss of primary productivity. Construction and operation of Libby Dam, upriver in Montana, for

[1] U.S. Army Corps of Engineers, PO Box 3755, Seattle, WA 98124-375, Phone: 206-764-6578 Fax: 206-764-4470, E-mail jeffrey.c.laufle@usace.army.mil
[2] S.P. Cramer and Associates and the University of Idaho, 121 Sweet Ave., Suite 124, Moscow, ID 83843
[3] U.S. Geological Survey, 1201 Pacific Avenue—Suite 600, Tacoma, WA 98402
[4] Bonneville Power Administration, P.O. Box 3621-EWI, Portland, OR 97208
[5] U.S. Fish and Wildlife Service, 11103 E. Montgomery Dr., #2, Spokane, WA 99206
[6] U.S. Army Corps of Engineers, Libby Dam, Libby Dam Project Office, 17115 Highway #37, Libby, MT 59923
[7] Kootenai Tribe of Idaho, Fish and Wildlife Department, PO Box 1269, Bonners Ferry, ID 83805
[8] U.S. Army Corps of Engineers, PO Box 3755, Seattle, WA 98124-3755

flood control and other project purposes has curtailed peak flows (Fig. 1) in the Kootenai River during the spring freshet, altering river characteristics such as turbulence, velocity, turbidity, temperature, and peak and base flows which affected the sturgeon's habitat. Winter flows are higher for power production and flood control, and spring flows are less than the pre-dam average. The sturgeon spawn over fine sediment, where their eggs are believed to be coated or buried and do not hatch, even though there is substrate that is believed suitable for egg incubation and hatching within a few miles upstream.

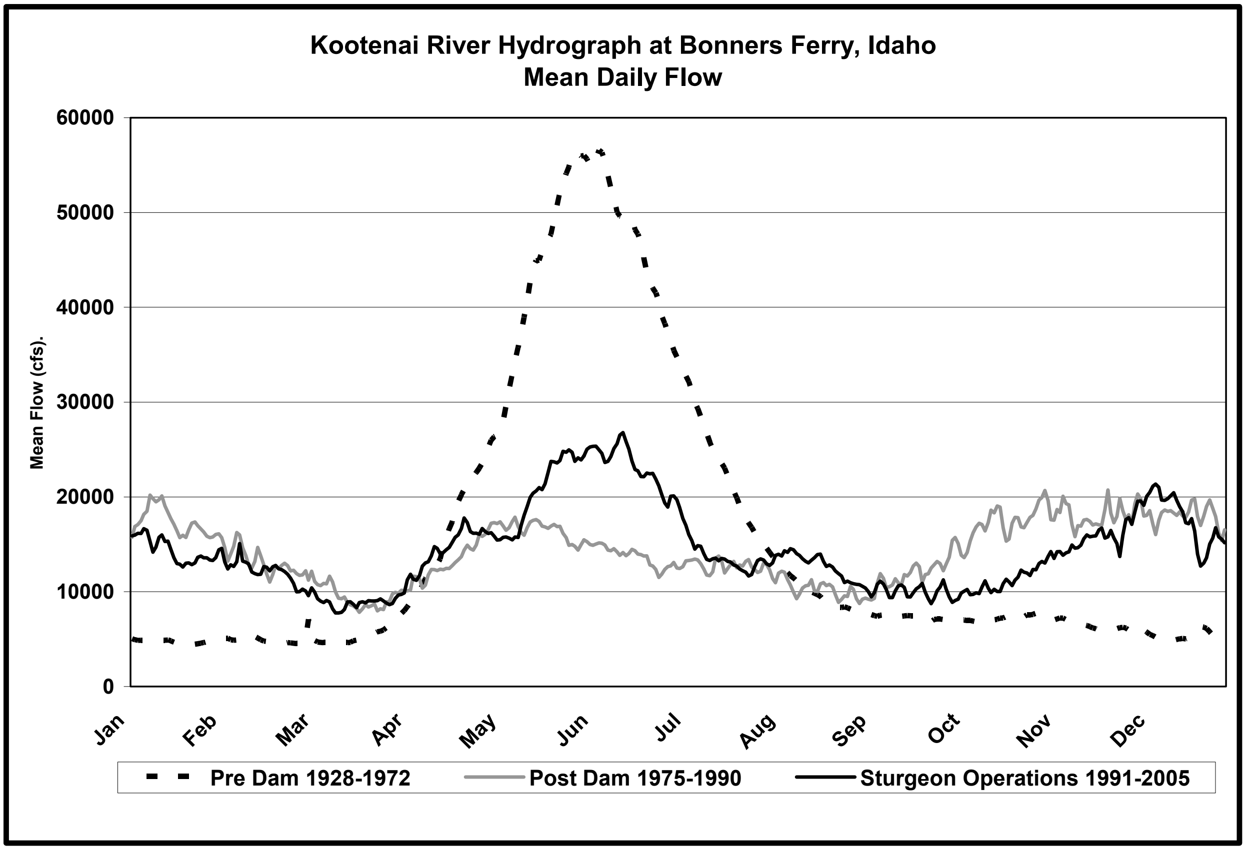

Figure 1. Comparison of historic, post-dam, and post-sturgeon-operation daily average flows at Bonners Ferry, Idaho, downriver from Libby Dam.

The lack of recruitment led the U.S. Fish and Wildlife Service (USFWS) to list the Kootenai River white sturgeon as endangered in 1994 (USFWS 1994). A recovery plan (Duke et al 1999) was developed in 1999.

The U.S. Army Corps of Engineers (USACE) and the Bonneville Power Administration (BPA) operate Libby Dam for hydropower and flood control, as well as for fish and wildlife and recreation purposes.

The 2006 USFWS Biological Opinion (BiOp—USFWS 2006a) for Libby Dam operations requires the Corps and BPA to implement Reasonable and Prudent Alternative actions (RPA) in order to avoid jeopardizing sturgeon and adversely modifying its critical habitat, which includes 18.8 miles of river upstream from Shorty's Island (USFWS 2006b).

The USFWS provided performance-based RPAs which require the Corps and BPA to achieve certain specific habitat attributes to foster successful sturgeon spawning, and egg and larvae survival, such as velocity (at least one meter per second to reduce the effectiveness of predators), depth (23 feet or more for inducement of use by the negatively phototactic spawners), turbidity, and temperature. Under this approach the Corps and BPA have retained the flexibility to select how they will achieve the specific habitat attributes, but four major categories of actions—habitat improvements; conservation aquaculture; river flows; and further research, monitoring, and evaluation—have been emphasized. The sturgeon's habitat attributes may receive subsequent alteration or adjustment in accordance with the federal agencies' use of the best available scientific information as to the species' needs.

Since the early 1990s, a number of U.S. and Canadian public agencies and a Native American tribe have been engaged in a cooperative effort to recover this population. These entities have been represented on the Kootenai River White Sturgeon Recovery Team (KRWSRT), convened by the USFWS. Its members are employed by the USFWS; the Kootenai Tribe of Idaho (KTOI); Montana Fish, Wildlife & Parks (MFWP); Idaho Fish and Game (IDFG); BPA; USACE; the British Columbia Ministry of Environment (BCME); and the Canada Dept. of Fisheries and Oceans; as well as a consultant (S.P. Cramer and Associates). An interagency technical committee, the International Kootenai Ecosystem Restoration Team (IKERT), led by the KTI, has served as an informal coordination and steering forum for much of the effort to address ecosystem impacts in the Kootenai basin. The IKERT comprises most of the members of the KRWSRT, as well as a number of others.

ADAPTIVE MANAGEMENT IN THE KOOTENAI ECOSYSTEM

Adaptive management of resources has developed over time to a set of actions that have been well described in literature (Holling 1978; Walters 1986). Lee (1993) specifically viewed management actions as experiments that should be designed based on hypotheses, and from which new information should be acquired. A standard approach is an iterative cycle of Plan, Act, Monitor and Evaluate (Forest Ecosystem Management Assessment Team 1993; Interagency Ecosystem Management Task Force 1995). Based on a hypothesis or hypotheses about the resource issue at hand, a management action is planned in an experimental manner to test the hypothesis. It is then implemented, and its results are monitored. Scientific evaluation is applied, and a determination is made whether the hypothesis is supported. If not, new action is planned and implemented as part of a new cycle. It is possible that a new hypothesis may be developed, or a new goal for the management actions will be developed based on knowledge attained. This stepwise approach accommodates experimental design and the scientific method.

Such an approach may work if the resource being acted on is not in trouble, or if research is the primary goal. In a situation where ecosystem functions are impaired in multiple ways, and the resource is in clear danger, a different approach may be justified. That is the case with the the Kootenai River ecosystem in general, and Kootenai River white sturgeon in particular.

As documented by Walters et al (2005), an Adaptive Environmental Assessment (Walters, 1986, 1997; Walters and Gunderson, 1994; Walters et al, 1992) was undertaken in cooperation with ecosystem interests. It consisted of construction of an ecosystem function model through a series of workshops among specialists in a number of disciplines pertinent to Kootenai ecosystem functions. The model was not intended to be predictive. Rather, it employed the best understanding of various ecosystem functions, and was intended as a tool for assessing the state of knowledge about the Kootenai ecosystem, and thus could be used to help guide further actions. The ecosystem facets were revisited in an IKERT meeting in 2004 (Walters et al 2005), which led to a "kitchen sink" approach to ecosystem recovery actions, whereby multiple actions might be taken in the shortest time possible. Although sturgeon were a focal point, the intent was to address several ecosystem attributes (Anders et al, this proceeding).

This multipronged effort is counter to the classic adaptive management approach. It consists of taking as many actions as possible in the immediate and short term, and monitoring responses of the ecosystem and the sturgeon. If desired responses are detected, then further analysis can be applied, if necessary, to determine the proximal causes. Sturgeon recovery interests are aware of the possible masking effects among actions, and will take steps to evaluate those.

Recovery Approaches for Kootenai River White Sturgeon

This evaluation focuses on recovery of Kootenai River white sturgeon as part of the Kootenai ecosystem. It must be stated clearly that this effort is not being done outside the context of other ecosystem recovery efforts. However, as a subset of those efforts, actions aimed specifically at sturgeon habitat and behavior are underway or planned, and themselves constitute a considerable undertaking. Table 1 is a summary of actions to date, as well as some being planned, for direct application to sturgeon.

Table 1. Management actions for sturgeon recovery in the Kootenai River.

Project	Planning	Action	Monitoring	Evaluation
Flow provisions for spawning and recruitment *(USACE, BPA)*	Based on last significant year class appearing to be from high-flow year, hypothesis is that (normative) high spring flows provide conditions needed for reproduction.	Augment flows from Libby Dam to powerhouse capacity of ~25 kcfs; ongoing since 1992; dam release temperatures as warm as possible. Volume tiers keyed to water supply forecast.	(*IFG,KTI, BCMWLAP*) Adult spawner movement; presence of eggs, larvae and juveniles. Spawning observed, but little hatching success or offspring presence	Flow capability up to 10 kcfs above powerhouse capacity has been sought as part of USFWS RPA; other means needed to provide this.
Greater flow provisions for spawning and recruitment *(USACE, BPA)*	Based on lack of recruitment of juveniles from previous flow provisions, USACE and BPA have been working toward providing higher flows.	Interagency collaborative effort underway to provide flow protocol for up to 10 kcfs above Libby powerhouse capacity. Only capability thus far is spill. Working with Montana on inherent dissolved gas issue.	(*IFG, KTI, MFWP*) Adult spawner movement; presence of eggs, larvae and juveniles; dissolved gas effects on resident fish below dam.	Action not implemented yet.

Project	Planning	Action	Monitoring	Evaluation
"Set and Jet" Spawner Transport *(IFG, KTI)*	Spawners do not upstream to areas of clean gravel and rock substrate, so intent was to see whether transporting spawners to good substrate might result in successful spawning and hatching of eggs.	In 2003 and 2004, spawners were captured downstream of Bonners Ferry and released upriver in canyon reach in Idaho, where clean rock and good velocities are present.	Spawner activity was monitored after transport of spawners to canyon. A few eggs resulted in 2004 from one documented spawning event, but could not be evaluated for fertilization.	Judged not successful due to apparent reluctance of spawners to remain on site, as well as lack of clear reproductive results. Discontinued after two years in favor of embryo outplants.
Embryo Outplants *(KTI, IFG)*	Spawners did not respond as hoped when transplanted; next idea is to bypass that stage to see if successful egg hatching and embryo survival can occur on clean substrate	In 2005, embryos were planted in upstream canyon reach and in braided reach by onsite mixing of eggs and sperm from hatchery-held wild spawners.	Canyon too dangerous for boat sampling Monitoring for larvae took place in the braided reach. No larvae collected.	Further discussion is necessary. No clear reason yet to cease this project.
Habitat Restoration Projects: Pilot *(USACE, KTI, IFG, BPA, USGS, BCME)*	Since sturgeon are spawning over unsuitable substrate (fines), placement of rock there may aid hatching success.	Pilot project underway in 2005-2006 to construct small-scale rock substrate placement project near Shorty's Island by spawning season in 2006 if possible. Main objective is physical integrity.	Placed rock will be monitored for tendency to sink into the substrate or to silt in (alternative to expensive foundation studies). Local hydraulics, as well as sturgeon spawner response, will be monitored.	Action has not occurred yet. Results will be used to inform larger scale projects at Shorty's Island and Ambush Rock.
Habitat Restoration Projects: Shorty's Island and Ambush Rock *(USACE, KTI, IFG, BPA)*	Larger-scale projects where sturgeon now spawn over fines will be based on results from above pilot project .	Rock substrate will be placed, when funding is available, to enhance spawning and egg incubation. Will not extend far enough downstream for full shelter of migrating larvae.	Physical variables and spawner response will be monitored, as will egg deposition and hatching success.	Results will inform further actions based on physical or biological responses.
Habitat Restoration Projects: Braided Reach Access Restoration *(USACE or BPA, unknown sponsor)*	Spawners approach the tailout of the braided reach of the Kootenai above Bonners Ferry, but do not generally enter it. A project is planned to induce migration and spawning in braided reach.	Channel deepening in the braided reach is planned, to concentrate low flows and provide sufficient depth to induce the negatively phototactic sturgeon to enter and perhaps find the cleaner gravels there.	Velocity and depth will be monitored in the project area. Behavior of tagged spawners will be monitored. Sampling for eggs and larvae will also occur if spawning appears to have taken place.	Physical results will help determine the need for maintenance of the channel. Biological results will be evaluated for desirability of continuing the project.
Conservation Aquaculture Program *(KTI) (KTI, 2006)*	Lack of recruitment prompted a hatchery rearing program in early 1990s.	Underway at Kootenai Tribal sturgeon hatchery at Bonners Ferry. Conservation Aquaculture Program provides "safety net" and addresses demographic and genetic problems.	Juvenile numbers in river and lake are monitored; larvae are sought after their release.	Hatchery-reared juveniles are dominant among young in river; larvae are elusive, if they are surviving.

Other Ecosystem Recovery Actions

Because Libby Dam acts as a nutrient sink, the river below it is nutrient-poor. This, of course, has effects at all trophic levels. The British Columbia Ministry of Water, Land and Air Protection has been conducting a successful (in terms of biological response, notably kokanee) fertilization in the North Arm of Kootenay Lake, and is expanding it into the South Arm.

The Kootenai Tribe of Idaho and BPA have initiated a river fertilization experiment, whereby nutrients (phosphate) were dripped from tanks placed on shore in Idaho, just downstream of the Montana state line, from July through September 2005. Monitoring showed spiraling effects as far downstream as Bonners Ferry. The action and the monitoring will continue annually for at least the short term. Releases in 2006 will likely include nitrates as well.

The Kootenai Tribe of Idaho and Idaho Fish and Game are exploring feasibility of floodplain reconnections along the lower Kootenai River, along with restoration of riparian habitat function and wetland creation.

DISCUSSION

Sturgeon restoration efforts are part of a multifaceted ecosystem restoration program that includes other aquatic restoration measures, as well as riparian and terrestrial measures. Adaptive management of all aspects is part of the intent. Monitoring and evaluation requirements specific to each action have been developed or are being developed.

The Kootenai white sturgeon has not always shown predictable responses to environmental variables, although Perrin et al (2003) indicated, based on observations in the Fraser River in British Columbia, that the range of spawning variables for white sturgeon may be wider than had been reported previously. For example, in the Kootenai, spawning activity has begun at temperatures as low as 7-8^o C, such as in 1995 (Duke et al 1999), in contrast to spawning activity at 13-19^o C in the Fraser (Perrin et al 2003) and 10-18^o C in the Columbia (Parsley et al 1993). Spawning has taken place consistently over what is understood (Kock 2004) to be unsuitable fine substrate. Cues that might induce the sturgeon to spawn upstream over better substrate are poorly understood.

Responses to flow manipulations to date have not been encouraging in terms of recruitment, due to apparent egg hatching failure. Successful larval releases by the KTI hatchery have not been easily documented through recaptures. The several approaches we discuss for improving sturgeon reproductive success are intended to address habitat needs in the long term, and (through the conservation aquaculture program) to maintain to preserve genetic diversity and a viable population in the short term.

Each action is intended to be adaptively managed. By implementing scientifically sound efforts as quickly as the means are available, while recognizing that outcomes are not certain, it is hoped that reproductive success for sturgeon in the wild will result. As previously indicated, specific reasons for successful outcomes in a multiple-action scenario may not be obvious, and hypotheses will need to be developed for further testing based on observed results. But even if combined actions yield successful results without full understanding of individual effects, a main goal will have been met.

CONCLUSION

The foregoing describes an unconventional application of adaptive management. However, the level of concern over the Kootenai River white sturgeon population, and its ecosystem, has risen sharply in recent years. The use of this “kitchen sink” approach received much discussion at the 1994 IKERT meeting, facilitated by experts in adaptive management. All acknowledged the tradeoff in emphasizing the application of all available tools as soon as possible to effect a benefit to sturgeon reproduction, over a classic controlled experimental approach. The main hurdles are related to funding and process to put actions in place. Nevertheless, all deliberate steps will be taken, and the results monitored, documented and evaluated for what they may reveal, and the adaptive process will continue.

REFERENCES

Anders, P.J., J. Korman, C. Holderman, S. Ireland, and S. Soults. (this proceeding). An adaptive management program to rehabilitate a post-development large river-floodplain ecosystem.

Duke, S., P. Anders, G. Ennis, R. Hallock, J. Hammond, S. Ireland, J. Laufle, L. Lockard, B. Marotz, V.L. Paragamian, and S. Bettin. 1999. Recovery plan for the white sturgeon (*Acipenser transmontanus)* Kootenai River population. U.S. Fish and Wildlife Service, Region 1. Portland, OR.

Forest Ecosystem Management Assessment Team. 1993. Forest ecosystem management: an ecological economic, and social assessment. U.S. Dept. of Agriculture.

Holling, C.S. 1978. Adaptive environmental assessment and management. John Wiley and Sons Ltd. 398pp.

Interagency Ecosystem Management Task Force. 1995. The ecosystem approach: healthy ecosystems and sustainable economies. Vol. 1—Overview. Council on Environmental Quality. 55 pp.

KTI (Kootenai Tribe of Idaho). 2006. Kootenai River White Sturgeon Conservation Aquaculture Program, 1990-2005. Bonners Ferry, Idaho. Report edited by R. Beamesderfer and P. Anders, S.P. Cramer and Associates. 70 pp.

Kock, T.J. 2004. Effects of sedimentation and water velocity on white sturgeon (*Acipenser transmontanus*) embryo survival. MS Thesis, University of Idaho, Moscow. 66 pp.

Lee, K.N. 1993. Compass and gyroscope: integrating science and politics for the environment. Island Press, Washington, DC. 243 pp.

Paragamian, V.L., and R.C.P. Beamesderfer. 2003. Growth estimates from tagged white sturgeon suggest that ages from fin rays underestimate true age in the Kootenai River. Trans. Amer. Fish. Soc. 132:895-903.

Paragamian V.L., R.C.P. Beamesderfer, and S.C. Ireland. 2005. Status, population dynamics, and future prospects of the endangered Kootenai River white sturgeon population with and without hatchery intervention. Trans. Amer. Fish. Soc. 134:518-532.

Parsley, M.J., L.G. Beckman, and G.T. McCabe, Jr. 1993. Spawning and rearing habitat use by white sturgeons in the Columbia River downstream from McNary Dam. Trans. Amer. Fish. Soc. 122:217-227.

Perrin, C.J., L.L. Rempel, and M.L. Rosenau. 2003. White sturgeon spawning habitat in an unregulated river: Fraser River, Canada. Trans. Amer. Fish. Soc. 132:154-165.

USFWS (U.S. Fish and Wildlife Service). 1994. Endangered and threatened wildlife and plants; determination of endangered status for the Kootenai River population of white sturgeon. Federal Register 59(171):45989-46002.

USFWS (U.S. Fish and Wildlife Service). 2006a. Fish and Wildlife Service Biological Opinion regarding the effects of Libby Dam operations on the Kootenai River white sturgeon bull trout and Kootenai sturgeon critical habitat (1-9-01-F-0279R). Pacific Region, Portland, Oregon. Feb 18, 2006.

USFWS (U.S. Fish and Wildlife Service). 2006b. Endangered and threatened wildlife and plants; critical habitat designation for the Kootenai River population of the white sturgeon. Federal Register 71(26):6383-6396.

Walters, C. 1986. Adaptive management of renewable resources. MacMillan, New York, NY. 374 pp.

Walters, C. 1997. Challenges in adaptive management of riparian and coastal ecosystems. Conservation Ecology [online] 1(2):1. URL: http://www.ecologyandsociety.org/vol1/iss2/

Walters, C., and L.H. Gunderson. 1994. A screening of water policy alternatives for ecological restoration in the Everglades. pp. 757-767 *in* Davis, S.M. and J.C. Ogden, editors. Everglades the ecosystem and its restoration. St. Lucie Press, Delray Beach, FL. 826 pp.

Walters, C., L.H. Gunderson, and C.S. Holling. 1992. Experimental policies for water management in the Everglades. Ecol. Appl. 2(2):189-202.

Walters, C., J. Korman, P. Anders, C. Holderman, and S. Ireland. 2005. Draft Kootenai River Adaptive Management Plan. Report prepared for the Kootenai Tribe of Idaho. 11 pp.