Research needs for fisheries and wildlife in Alberta

Mark S. Boyce and Mark Poesch
University of Alberta
Edmonton

Fisheries and wildlife management in North America is based on an extensive background of basic and applied research (Geist and McTaggart-Cowan 1995, Organ *et al*. 2010). Alberta has some of the finest hunting and fishing opportunities in the world with sustainably harvested populations of a diversity of fishes, birds, and mammals. However, because of aggressive industrial development, especially by the energy sector, future opportunities for hunting and fishing might be jeopardized unless habitats are managed carefully to ensure viable populations of fish and wildlife (Naugle 2011).

Our objective is to identify research that is required to ensure that resource managers have the information required to make sound management decisions in the future. To obtain this list of research topics we have surveyed fisheries and wildlife biologists and managers from the Alberta Department of Environment and Sustainable Resource Development (ESRD), and the Alberta Conservation Association (ACA). We held meetings with ESRD and ACA staff in Sherwood Park, Lethbridge, and Edmonton, Alberta and also received suggestions from others throughout the province by e-mail. Subsequently we conducted literature reviews to provide background information on the published research already conducted on each topic, and we summarize briefly what we believe to be feasible and timely research.

This report is an update of the original research-needs document prepared by Boyce (2000) that was updated for wildlife research in 2005 (Boyce 2005). We have used the Simple Multi-attribute Rating Techniques (SMART) process again to rank research projects according to a process developed by Ralls and Starfield (1995), which is detailed in the Appendix. These ranks identify the most-important research according to criteria identified by ACA and ESRD fish and wildlife biologists and managers. Academic ecologists likely would identify a different list of priorities (Cristescu and Boyce 2013), and input from practicing field biologists and managers will help to ensure that research can influence policy (Neff 2011). Projects in the top third are marked ***, middle third **, and lowest-ranked projects *.

We have organized this report a bit differently than previous reports, aggregating selected categories that span both fisheries and wildlife topics. We note that several of the listed topics are broad in scope and therefore might require several research projects to secure the desired information.

ANTHROPOGENIC ACTIVITIES

Industrial development and intensification of agriculture are rapidly changing Alberta's landscapes with large consequences for fisheries and wildlife. These changes are arguably the most urgent issues facing fisheries and wildlife in Alberta, calling for research that can ensure that development occurs in a way that has least consequences for the future of fish and wildlife.

1. *Effects of water extraction on stream form and function.* *** Water extraction, for irrigation and industrial activity, represents an uncharacterized form of hydrologic alteration (Gordon *et al.* 2007, Kennen *et al*. 2008). In Alberta, water is extracted at substantially high levels for use in agricultural irrigation and industry. For example, in southern Alberta irrigation accounts for 71% of water use, with some like the St. Mary's, Oldman and Bow Rivers oversubscribed by irrigation use (Schindler and Donahue 2006, Bjornlund *et al*. 2007). Likewise, in northern Alberta, industrial development of oil sands has reduced annual flows of streams and rivers (Squires *et al.* 2009, RSC 2010) and is likely to become more of an issue with the implementation of fracking techniques for oil recovery. Between 349-370 million cubic meters of water is extracted yearly from the lower Athabasca River for oil sands development (Griffiths 2006, CAPP 2009). Although the total allocations represent roughly 2.2% of the total annual average river flow (CAPP 2009), about 90% of that water is removed from the river for industrial use (Griffiths 2006, Schindler and Donahue 2006). Given current rates of consumption, future water extraction is expected to reduce the flow of the Athabasca River during critical low flow periods (September to April; Schindler and Donahue 2006). As such, there are concerns regarding the impact, and timing of water extraction (Krimmer *et al.* 2011, Paul 2012), and the cumulative impact on fish populations (RSC 2010). With increased future demand for water for agricultural and industrial use, the impacts of water extraction will produce or exacerbate water shortages around Alberta, and development might be limited by the availability of freshwater (Schindler and Donahue 2006, RSC 2010). Research is needed to ascertain the ecological impacts of water extraction and in particular whether different types of water extraction (e.g. agricultural versus industrial use) result in different impacts (e.g. duration, magnitude, frequency, seasonality), and timing (Krimmer *et al.* 2011, Paul 2012), and how such impacts can be mitigated. Landscape consequences also need to be documented, e.g., the influence of hydrological alterations on beaver (*Castor canadensis*) flowages in northern Alberta.

Beaver flowages such as this one near Bistcho Lake in northern Alberta could be altered substantially by proposed fracking operations in the area that will use vast quantities of water. These areas are hotspots for biodiversity in the boreal forest. M. S. Boyce photo.

2. *Sediment tolerances for fishes associated with logging and oil and gas development.* *** Sedimentation associated with road construction can be damaging to spawning areas as well as having direct effects on the fish. Although considerable research has been conducted on the effects of such sedimentation, an important issue relates to the timing of development activities. Sediments in spring, for example, may be removed or re-deposited during spring flushing flows in ways that do not have as much negative effects on the stream as later in the year. Sedimentation is a natural process, and may not be entirely bad. For example, gravels in the bottom of streams necessary for spawning by salmonids come from eroded alluvium (Boyce and Payne 1997). But the levels of sediment that can be input into streams associated with road construction and other industrial developments can exceed the sediments tolerated by fish (Ripley *et al*. 2005, Scrimgeour *et al*. 2008).

3. *Identification of thresholds for industrial development*. *** Rapid expansion of the energy sector, intensification of agriculture, and continued timber harvests are changing Alberta landscapes and altering wildlife habitats. Anticipating how this anthropogenic change is affecting biodiversity and wildlife populations is a continuing high priority for wildlife managers, as well as finding best management practices that can minimize the ecological consequences of this development (Northrup and Wittemyer 2013).

4. *Contaminants in fish*. *** Research in Alberta has shown that mercury in fish and other aquatic biota increases along a gradient from the mountains through agricultural areas (Brinkmann and Rasmussen 2012). Despite increased mercury emissions associated with oil sands development, no evidence of elevated mercury in the flesh of walleye (*Sander vitreus*), lake trout (*Salvelinus namaycush*), or northern pike (*Esox lucius*) has been documented in the Athabasca River or Lake Athabasca downstream from the oil sands (Evans and Talbot 2012). Biogeochemistry of heavy metals can influence toxicity, e.g., exposure to selenium results in high mortality in early life stages of trout in Alberta (Couillard *et al.* 2008). Guidelines for consumption of fish to avoid mercury have been developed for the USA (www.nrdc.org/health/effects/mercury/guide.asp). Such readily available information could inform anglers in Alberta about which species and localities are most likely to have significant levels of contaminants such as mercury and selenium that are known to influence human health.

5. *Bitumen effects on aquatic stream insects.* *** Transporting bitumen in pipelines has become immensely controversial because of the risk of a spill into streams or rivers. Bitumen sinks in water so that it will influence benthic organisms including larvae of aquatic insects that are important food for sport fish such as trout. The magnitude of effect of bitumen on aquatic stream insects is not known nor do we have adequate data on recovery of stream insects after such a spill. Tailings pond sediments have been

experimentally introduced into a stream resulting in substantial declines in benthic invertebrates (Barton and Wallace 1979), which will have lasting consequences for fish. Fine silt mixed with the sticky oils of the bitumen constitute one of the principal hazards to aquatic communities. Based on experience with the Enbridge spill in Michigan, dredging streams and rivers appears to be the only solution after a bitumen spill, with total alteration of fish habitats.

6. *Seasonal habitat selection by mule deer*. ** Proposed wind farms in SE Alberta are expected to displace mule deer from critical habitats. A radiotelemetry study could be used to compile seasonal location data and then to estimate resource selection functions and how they vary throughout the year. Response to disturbances versus infrastructure would be valuable information for anticipating possible mitigation.

7. *Breeding habitat for trumpeter swans*. * The trumpeter swan (*Cygnus buccinator*) is the largest species of waterfowl in the world. Populations have been recovering for 30 years with birds breeding in a number of localities in Alberta. Attributes of successful breeding habitats need study to develop predictive models such as resource selection functions (Manly *et al*. 2002) or occupancy models (MacKenzie *et al*. 2006) to identify breeding areas. RSFs could be mapped to facilitate opportunities to maintain and manage future breeding sites for population expansion, especially in context of industrial development. Studies in Alaska have found that trumpeter swans were sensitive to actively used infrastruction such as oil/gas roads, and that human disturbances might limit future expansion of the species (Schmidt *et al.* 2009).

In Alaska, permanent facilities, including roads, material sites, storage areas, powerlines, and aboveground pipelines may be prohibited within ¼-mile of known nesting sites and brood-rearing habitats of trumpeter swans because the species is sensitive to such anthropogenic features (Schmidt *et al*. 2009).

8. *Riparian management and buffers.* *** The riparian zone is a rich area for wildlife and has immediate relevance for fisheries. Although riparian zones occupy only 1% of North America's landscapes, they host over 80% of our species at risk (Boyce and Payne 1997). Fundamental to the diversity of riparian habitats is the maintenance of disturbance regimes including flooding, fire, erosion, and wildlife activity (e.g., beaver). This is a particular concern because changes in forest management might have long-term consequences for riparian habitats and wildlife. For example, the establishment of

timber-harvest buffers along streams to prevent soil erosion may inadvertently result in accelerated succession because beavers selectively remove hardwoods such as aspen (*Populus tremuloides*) and balsam poplar (*P. balsamifera*). This will lead to the loss of beavers from the system and consequently a structural alteration in the stream. Similarly, ensuring the perpetuation of flooding regimens can be essential to maintaining fish and wildlife habitats (Boyce and Payne 1997). West Fraser in Hinton has proposed a model of riparian zones that would better identify riparian habitats while permitting them to harvest large spruce trees that occur close to streams, yet Martell *et al.* (2006) present data to suggest that the riparian protection zone in Alberta is not sufficiently large. Research on the dynamics of riparian zones in various regions of the province will improve our ability to manage these areas effectively. An opportunity exists to design experiments in collaboration with industry to obtain the most reliable knowledge.

9. *Developing objective standards for habitat offsets.* ** Habitat compensation has been developed to offset habitats altered or destroyed by industrial activity. Compensation of 'like for like' habitat is typically favoured in areas close to those impacted by harmful activity. Changes to Canada's Fisheries Act have altered the legal landscape of how fish habitats are protected, enumerated and compensated. Does the purchase of undeveloped land truly offset the consequences of development if the undeveloped land was unlikely to be developed anyway? How do we know if the offset has achieved its objectives? Questions such as do compensation lakes mimic natural systems?; or how do we assess "no net loss" in situations where habitats differ (e.g. compensating a river for a lake)? remain important research questions (Marin *et al*. 2010).

INVASIVE SPECIES

The spread of non-native species into novel habitats can cause serious ecological impacts, including: homogenization of native fauna, genetic hybridization, and reductions in ecosystem services. For over 42% of species listed as threatened or endangered, non-native species have been identified as a primary factor. In addition, because invasive species can alter ecosystems, facilitative interactions can reduce ecosystem stability, thereby increasing the number of invasions, and causing additional damage. Such influences of invasive species are prominent in both terrestrial and aquatic ecosystems with important ramifications for both anglers and hunters.

10. *Climate change and northern spread of invasive species.* *** Global climate change is predicted to have a large impact for both terrestrial and aquatic ecosystems. Global air temperatures are predicted to increase between 1.4 and 5.8°C by the year 2100, with variability among estimates being due to different expectations about economic development. In regions closer to the poles, temperatures are predicted to increase at even faster rates (4-7°C). Therefore, fish species which typically rely on warm-water habitats may have access to additional favorable thermal habitat, shifting the northern limit of the

distribution of species further north and potentially negatively impacting native fish communities. The same is true for wildlife and we are already witnessing the effects of raccoon (*Procyon lotor*) invasion into southern Alberta—a species that is an efficient predator of ground-nesting birds. Species, such as zebra mussel (*Dreissena polymorpha*) and smallmouth bass (*Micropterus dolomieu*) are now within striking distance of Alberta's border. Climate change may also hasten the advancement of non-native species, such as brown trout and brook trout, which can impact native species. Broad-scale modelling is needed to identify candidate species, as well as species that might become susceptible (e.g., westslope cutthroat trout, *Oncorhynchus clarkii lewisi*), so to mitigate potential impacts.

Raccoons are highly effective nest predators on waterfowl. The species has been expanding its range further north associated with warmer temperatures.

11. *Impact of recently invading species.* *** Invasive species such as brown trout (*Salmo trutta*), brook trout (*Salvelinus fontinalis*), Prussian carp (*Carassius gibelio)*, rock snot (*Didymosphenia geminate*), and three-spine stickleback (*Gasterosteus aculeatus)* have been documented in Alberta waterways. The addition and/or expansion of these species into novel environments brings with it new interactions with native fauna. In some cases, such as the invasion and expansion of brown trout and brook trout, genetic introgression of native salmonids can occur. Research is needed to identify habitat suitability of invasive versus native species, physiological differences that might provide species-specific advantages; and options for control/recovery or maintenance of naturalized species.

Prussian carp (*Carassius gibelio*) have been recently documented in southern Alberta near Brooks. Photo Terry Clayton, ESRD.

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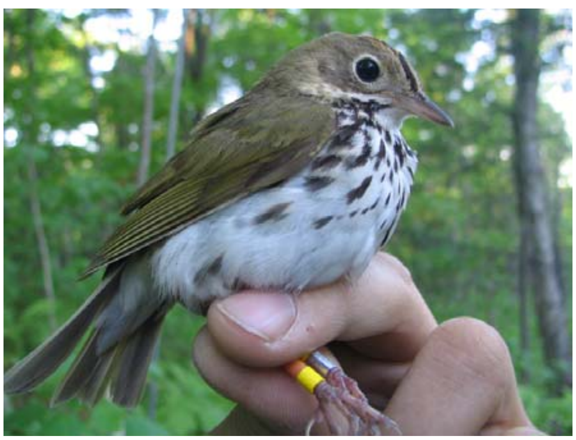
12. *Assessing cost-effective control programs for invasive species.* * Once invasive species become established, eradication is expensive and often unsuccessful. Whether or not such effort and cost is warranted requires careful evaluation, and could be evaluated using decision theory (Keeney and Raiffa 1993). If control of an invasive is expensive, how does this cost compare with alternative conservation programs that might be funded with the funds used for control or eradication? How to cope with the threat of exotics is a complex issue in economics with ramifications for trade policy (Olson and Roy 2010).

13. *Ecological consequences of expanding turkey populations in Alberta.* ** Merriam's turkey (*Meleagris gallopavo*) was introduced to the Porcupine Hills, Cypress Hills, Lees Lake, and Todd Creek areas of southern Alberta about 50 years ago. The species, exotic to Alberta, has become well established to the extent that for several years a limited hunting season has been available in southwestern Alberta. Although we presume that there are no management concerns associated with the release of turkeys (McGillivray and Semenchuk 1998), the consequences of turkeys on native fauna and flora have not been documented. Seedling recruitment among hardwood tree species is strongly influenced by the presence or absence of leaf litter, which can modify water, light, and nutrient availability. Wild turkeys scratch litter while foraging that results in heterogeneous forest litter and can alter germination for certain tree species (Rinkes 2004). Other effects such as influencing habitats for ovenbirds (*Seiurus aurocapillus*) and litter-dwelling shrews have not been studied.



Ovenbirds feed on the forest floor. The effect of wild turkeys disturbing the litter where ovenbirds forage has not been studied.

BIODIVERSITY

The conservation of biological diversity is fundamental for the preservation and stability of ecological communities, and the economies that rely on them. During the past few centuries, the rates at which species have declined have escalated. In particular, there has been a dramatic decline in freshwater fish biodiversity globally, and this is true for Alberta (Ehrlich and Wilson

1991, Ricciardi and Rasmussen 1999, Abbitt and Scott 2001, Ricciardi and Rasmussen 2001, Jelks *et al.* 2008, Hutchings and Festa-Bianchet 2009). Losses of freshwater fishes have important consequences to Albertans. Freshwater fish provide forage for other biota, drive ecosystem properties, and are indicators of aquatic ecosystem health (Poff and Allan 1995, Jackson *et al*. 2001, Olden *et al.* 2010). Freshwater fish also provide ~ 15% of animal protein to global diets, including an important component to Aboriginal peoples (FAO 2010). Fisheries provide an enormous economic value to Canada, including: $1.6 billion dollars in commercial value annually (landings alone); while 3.2 million Canadians bought recreational fishing licenses, representing $2.46 billion dollars invested annually (DFO 2010).

Research on how to mitigate impacts to biodiversity is urgently needed. This is especially true in Alberta, where climate change predictions suggest enhanced warming relative to more temperate climates, and where resource extraction is rapidly altering landscapes. For the sustainable management of biodiversity in Alberta, it is fundamentally important to measure, understand and predict the impacts of human-induced disturbances to biodiversity (composition, structure, and function), to monitor changes in ecosystems, and to develop and prioritize appropriate recovery and management actions.

Both terrestrial and aquatic biodiversity is altered by the landscape changes occurring in Alberta with some species being highly sensitive to habitat fragmentation, linear features that increase access, and altered predator-prey systems.

14. *Caching behaviour of Clark's nutcrackers*. ** Clark's nutcrackers (*Nucifraga columbiana*) are important dispersers of seeds of the endangered whitebark pine (*Pinus albicaulis*). Many questions need research to assist in developing conservation strategies for whitebark pine. What site characteristics are Clark's nutcrackers choosing when caching whitebark pine seeds? How does this relate to various disturbance processes (fire, harvesting, insect outbreaks)? How do mast and non-mast years of whitebark pine affect the distribution of seeds on the landscape through caching and how might this relate to health of whitebark stands now and under various climate change scenarios? This research would link to ongoing studies examining regeneration site characteristics for whitebark pine being carried out by Ellen Macdonald (University of Alberta), Joyce Gould (Alberta Parks and University of Alberta), and Diana Tomback (University of Colorado-Denver) in the Willmore Wilderness and other areas. Understanding nutcracker caching behaviour is an important component for ensuring the long-term survival of whitebark pine. The results of this work will have direct application to provincial and federal recovery strategies for whitebark pine. Drs. Macdonald, Gould and Tomback would be interested in being potential partners in Clark's nutcracker research.

Whitebark pine is an endangered species in Alberta. Seeds are cached by Clark's nutcrackers.

15. *Life history characteristics and population trends for data-deficient species*. *** Modelling species of conservation concern, such as those that are rare, declining, or have a conservation designation (e.g., endangered or threatened) is burdened by uncertainty (Ludwig 1999). Species that are of conservation concern often are found infrequently, in small sample sizes, and with spatially fragmented distributions, thereby making accurate enumeration difficult and traditional statistical approaches often invalid. One popular approach for managing organisms of conservation concern is the use of population viability analyses (Boyce 1992). Quantitative population viability analyses, such as age- or stage- based models are preferable for setting distribution or recovery targets. In most cases, habitat-based PVAs are most powerful. Globally, population viability analyses have been used almost exclusively for determining population and recovery based targets for species at risk.

    Information about movements, reproductive ecology, mortality patterns, food habits, and habitats often are needed for these models. Yet, many species that are of conservation concern are data deficient in regards to life history characteristics needed to build spatially explicit population viability analyses. Research is needed to determine life history characteristics and population trends on many species, such as mountain plover (*Charadrius montanus*), mountain sucker (*Catostomus platyrhynchus*), lake trout (*Salvelinus namaycush*), Rocky Mountain sculpin (*Cottus bairdii*), western silvery minnow (*Hybognathus argyritis*), pygmy whitefish (*Prosopium coulterii*), great plains toad (*Bufo cognatus*), Canadian toad (*B. hemioprys*), prairie rattlesnake (*Crotalus viridus*), Porsild's bryum (*Bryum porsildii*),Verna's flower moth (*Schinia verna)*, American badger (*Taxidea taxus*), and wolverine (*Gulo gulo*). For the current list of species of special concern and data-deficient species see the ESRD website: (http://srd.alberta.ca/fishwildlife/speciesatrisk/documents/SpeciesAssessed-EndangeredSpeciesConservationCommittee-ShortList-Nov06-2012.pdf)

16. *Bull trout metapopulations.* *** Bull trout (*Salvelinus confluentus*) is a perfect candidate for a population viability analysis (PVA; Boyce 1992a) and given the spatial structure of bull trout populations, a metapopulation structure would seem appropriate for such an

analysis. Brook trout tend to occupy reaches of streams previously occupied by bull trout and this may have isolated natural populations (Spruell *et al*. 1999). In addition, bridges and culverts constructed under road crossings associated with forestry or oil and gas development can be barriers to fish movement. The objective of a PVA should be to evaluate management alternatives and their ramifications for the probability of persistence of bull trout populations. Estimates of extinction risk carry enormous confidence intervals so little faith can be placed on the actual estimates (Ludwig 1999). But for comparative purposes we believe that PVA can be a useful tool for management and it can help to shape future research directions.

17. *Assess the use of bioenergetics models to assess habitat suitability for species at risk.* * Bioenergetics models are different from habitat suitability indices (HSIs) in that they use physiology to evaluate habitat quality. Unlike HSIs, bioenergetics models can be related to habitat quality and ideally the model allows estimates of fitness consequences in the form of fish tissue growth or net energy gain (Rosenfeld 2003, de Kerckhove *et al*. 2008). Other than directly estimating fitness consequences, bioenergetics incorporates food availability into the model. Food availability is a variable that drives many of the preferences seen in HSIs. However, if two streams were similar in velocity, depth, and substrate composition, yet one stream had a greater supply of macroinvertebrates for drift-feeding fish, then the stream with more macroinvertebrates will support more fish (Jones *et al*. 2003a). The HSI based on physical variables would not differentiate between streams, whereas the bioenergetics model would differentiate the streams based on food availability and estimated net energy intake or growth. Thus, bioenergetics models potentially can be better predictors of habitat suitability than HSI curves (Rosenfeld *et al*. 2005). Bioenergetics modelling requires vast amounts of data on metabolic and physiological relationships which can be limiting. Therefore, rare species are difficult to model because little information exists for them. Instead, bioenergetics models are typically restricted to well-studied species, particularly if of economic importance (e.g., drift-feeding salmonids, bobwhites, cottontail rabbits). Also, due to high information needs, bioenergetics models have been used mostly at microhabitat scales to determine habitat selection (e.g., Fausch 1984; Hughes and Dill 1990; Hughes 1992), while few bioenergetics models have been applied at larger scales (e.g., Hughes 1998; Rosenfeld and Boss 2001).

18. *Life history parameters for Arctic grayling.* *** Arctic grayling (*Thymallus arcticus)* are distributed widely in lakes and streams of the boreal region of Alberta, and only a few of these populations have seen study (e.g., Carl *et al.* 1992). Arctic grayling has been argued to be a model organism for bioenergetics study because of its sensitivity to contaminants, turbidity, temperature and flow changes, and requires unfragmented habitat to move between various habitat types (Stewart et al.2007). Arctic grayling is currently

listed as *sensitive* in *The General Status of Alberta Wild Species 2000* (Alberta Sustainable Resource Development 2001). Arctic grayling also was added to the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) 2010 Candidate List as a high-priority candidate species for assessment and status report production (YT, NT, NU, BC, AB, SK, MB). Fishing pressure, habitat fragmentation, contaminants, warm water temperatures, and droughts are considered to be key limiting factors for Arctic grayling populations (Scrimgeour *et al*. 2008). Information about movements, reproductive ecology, mortality patterns, food habits, and habitats can only enhance management for this species. This is especially important with the fragmentation of populations created by culverts associated with logging and oil/gas development (Scrimgeour *et al*. 2008). Isolated populations often may not be viable, especially if migration to spawning areas is a necessary part of the life history.

19. *Climate change and potential impacts to native species*. ** Climate change can alter the viability of native species. In particular changes in stream temperatures could potentially decrease the viability of cold water species such as Arctic Grayling. . Climate change also will influence snowpack levels, which has been shown to have downstream impacts on stream hydrology. Such changes can alter spawning habitats of sensitive species like westslope cutthroat trout. Likewise, we stand to lose extensive bighorn sheep range as forest and shrub habitats expand into higher elevations. Research is needed to identify the sensitivity of native species to the impacts of climate change, and to develop strategies to mitigate their impacts.

20. *Beavers as keystone species.* ** Fish communities can be structured by beaver (*Castor canadensis*) dams (Snodgrass and Meffe 1998, Hagglund and Sjoberg 1999, Schlosser and Kallemeyn 2000), and hydrology affected to a large degree (Meentemeyer and Butler 1999). The most common management performed on beavers involves shooting or trapping the beavers and blasting their dams. This may be short sighted, and often altering beaver populations may not be necessary. In xeric sites, beavers can greatly enhance stream characteristics and hydrology. But at other times beavers can alter habitats in ways that are detrimental to fish stocks or reproduction, and control may be the best option. Beaver dams can temporarily fragment fish populations which may be a concern for species at risk such as the bull trout (*Salvelinus confluentus*). Or beaver impoundments can provide habitats for Arctic grayling (*Thymallus arcticus*). A better set of criteria for managing beavers could enhance the management of fish as well as associated wildlife.

    Foraging by beaver can alter forest structure and composition (Donkor and Fryxell 1999) and can act as a keystone species, i.e., have ecological effects that are disproportionate to their abundance. Indeed, beaver can have a major influence on landscape (Broschart *et al.* 1989, Johnston and Naiman 1990) that generally is highly beneficial to wildlife. For example, bufflehead (*Bucephala albeola*), common merganser (*Mergus merganser*), moose (*Alces alces*), otters (*Lontra canadensis*), fisher (*Mustela pennanti*), mink (*Neovison vison*), and muskrats (*Ondatra zibethicus*) are commonly found associated with beaver impoundments. Hydrologic effects of beaver dams (Gurnell 1998) in xeric areas can enhance forage production for wildlife as well as livestock. Understanding how to manage beaver populations can have major consequences to the long-term capacity of a landscape to support a diversity of terrestrial and aquatic wildlife.

Restoration of greater prairie chickens. ** One of the only vertebrates to become extirpated in Alberta, the greater prairie chicken (*Tympanuchus cupido*) is now listed as extirpated from all of Canada. The species has been successfully reintroduced in eastern North Dakota and there might be opportunity to restore a population in southern Alberta, ideally in association with one of ACA's grassland conservation areas.

COSEWIC's (2009) review of the greater prairie chicken determined that the species has been extirpated from all of Canada. The species was abundant in Alberta 100 years ago.

Fisheries management

21. *Effects of triploidy on growth and longevity of trout in Alberta lakes.* ** Triploid fish look, swim, jump, and taste like normal fish, except for one important difference—they never develop normal eggs or sperm and are unable to reproduce (i.e., they are sterile). Researchers have shown that they could create triploid trout both by exposing trout eggs to pressure and by placing trout eggs in a warm water bath shortly after fertilization. Both processes inhibit a trout egg's ability to kick out that third set of chromosomes and triploid fish are hatched. Eggs treated in a hatchery can be hatched and triploid fish released without risk of hybridization with native trout. This might be particularly useful for stocking in areas with westslope cutthroat trout or Athabasca rainbow trout where protection of native gene pools is desired. Growth and survival of these triploid fish needs study to verify that they are indeed a viable option for hatchery stocking programs.

22. *Stream hydrology and life history characteristics of fishes.* * Understanding which species and what life-history characteristics are most vulnerable to changes in stream hydrology is a prerequisite for mitigating impacts and designing effective conservation strategies (Olden *et al.* 2010). Convergence of trait composition along hydrologic

gradients has been demonstrated for freshwater invertebrates (Konrad *et al*. 2008, Verberk *et al.* 2008) and freshwater fishes (Poff and Allan 1995, Lamouroux *et al.* 2002, Blanck *et al.* 2007, Logez *et al*. 2010, Mims *et al.* 2010), but empirical investigations that test predictions from life-history theory remain scant (but see (Reynolds *et al*. 2005, Mims and Olden 2012, Paul 2012)). Previous studies across the globe have found convergence of life-history characteristics of fishes in drainage basins along similar gradients of hydrologic variability, with an increasing prevalence of opportunistic strategists and a decreasing prevalence of periodic strategists concurrent with increasing hydrologic variability (Southwood 1988, Winemiller and Rose 1992, Kennard *et al*. 2010, Logez *et al*. 2010, Mims *et al*. 2010, Mims and Olden 2012). Together, these studies provide support for the response of fish life-histories to hydrologic conditions.

Hydrologic alterations such as this release of the Oldman dam after the floods of June 20, 2013 represent significant consequences to fish populations.

23. *Riparian logging and other land-use activities on thermal loading and large woody debris recruitment to foothills streams in Alberta.* *** Changes in freshet from climate/land-use (e.g. forestry) may differentially impact the viability of redds of *Onchornychus* spp. such as rainbow trout and westslope cutthroat trout.

24. *Ecological impacts of extreme events*. * Climate change predictions have suggested a change in the frequency, severity and magnitude of extreme events, such as large-scale flooding and droughts. Such extreme represent events have a low probability of occurrence, but likely have a large impact to population viability. We expect that the variance in vital rates of survival and fecundity will increase with concomitant effects on long-term population growth rates (Boyce *et al.* 2006).

Flooding in southern Alberta on June 20, 2013, in places such as Blairmore, was amongst the worst on record.

25. ** *Tradeoffs in relation to ecosystem-based fisheries management.* As the rate of species imperilment and habitat degradation continues to increase, meeting the challenges of species management and recovery has become increasingly difficult. One strategy to circumvent this trend has been to reduce the emphasis of species-specific management (which require more effort per species) and use ecosystem-based management, where several species can be managed across entire systems (Grumbine 1994). However the shift towards ecosystem-based management has come with related tradeoffs, including a decline in the rate of species recovery (Boersma *et al.* 2001; Clark and Harvey 2002). Evaluation of fish stocking and commercial fishing in this context would be good examples. Of the number of limitations addressed for shortcomings of ecosystem-based management, the lack of integration of ecologically relevant information is strongly correlated with species recovery (Clark and Harvey 2002). Research is needed to help determine the tradeoffs in relation to ecosystem management; including how ecological data may be used to enhance ecosystem management, and developing tools for determining when species-specific versus ecosystem-based management may be more appropriate (e.g. Poos *et al*. 2008).

26. *Human dimensions of anglers and fisheries management.* * Social and economic considerations for fisheries management have seen little study in Alberta. There are a number of questions that might be addressed to assist managers in meeting the expectations of anglers. For example, what do anglers prize most: fishing for native/non-native species or just catching fish? How can fisheries management align with fisher's interests? And what are the needs of multiple stakeholders and tradeoffs with fisheries management? How do anglers respond to the tag system for keeping walleye in Alberta?

27. *Fishing access effects on fisheries.* ** Industrial development in Alberta is resulting in enhanced access for anglers into formerly remote areas. This is especially relevant to stocks that are sensitive to angling pressure such as bull trout (*Salvelinus confluentus*)

and Arctic grayling (*Thymallus arcticus*). Documenting the effects of access is needed as well as systematic evaluations of alternative regulations attempting to limit the effects of increased access.

28. *Reasons for high mortality of trout in stocked lakes/ponds*. ** Research needs to assess habitat suitability of stocked locations. Survival analysis can be conducted with covariates representing attributes of the lake or pond including spatial patterns or attributes of the surrounding landscape (Johnson et al. 2004). Such models also might be used to propose new candidate locations for stocking.

Wildlife

29. *Movement and habitat use by male mule deer*. ** Male movements and survival are especially important for understanding the dynamics and prevalence of CWD in mule deer. Adult males have much higher prevalence of CWD, but we do not understand the mechanisms behind this strong pattern. Differential movements by young vs older males might be important to understand, as well as group dynamics. Sexual segregation between males and females outside of the breeding season has been the subject of a number of studies (Bowyer 2004), and may have implications for CWD transmission.

30. *Drones for wildlife monitoring*. *** Unmanned aerial vehicles or drones have many advantages over the use of fixed-wing airplanes or helicopters, including the exposure of wildlife biologists to risks associated with flights. Methods for estimating abundance using drones for sampling have been developed (Martin *et al*. 2012). In Alberta, drones for estimating abundance of woodland caribou, moose, pronghorn, and mule deer could be explored.

31. *Causes of bias in grizzly bear population estimation*. * Recent data on grizzly bear DNA using rub trees can yield very different population estimates than mark-recapture methods using DNA samples obtained from hair traps around a stinky bait (Sewaya *et al*. 2012). The actual reason for this is not understood but the ramifications for population estimation are substantial. For example, mark-recapture population estimates using rub trees in southwestern Alberta are at least 4× as high as those obtained using hair traps. Yet, behavioural differences between male and female bears result in a bias against detecting female bears at rub trees. One possibility is that the bears are avoiding the barbed wire that is placed around the stinky bait because bears might have encountered electrified wire on cattle ranches, causing them to avoid barbed wire. If the bias could be quantified, corrections to population estimates could be developed.

32. *Mechanisms of transmission for CWD.* *** Chronic wasting disease is caused by a prion which is a folded protein. How this is transmitted in the wild is not understood although it is known that it can be transmitted in the soil and in saliva. New biotelemetry

technology using proximity radiocollars might help to unravel the mechanism of transmission. At this time we do not have a reliable method for detecting CWD in the soil although DNA of various organisms can be detected in soil samples so finding the prion protein might be possible as well. This is high risk research given that finding the mechanism for transmission has proven elusive. Yet, CWD poses a high risk to the future of our Cervid populations and warrants high-risk research.

Despite extensive research, we still do not know many basic aspects of CWD, e.g., how CWD is transmitted among deer. M. Boyce photo.

33. *Reclamation of habitats for Greater Sage-Grouse*. ** Habitat for sage-grouse in Alberta is dominated by silver sagebrush (*Artemisia cana*) whereas throughout most of the species' range the dominant plant is big sagebrush (*A. tridentata*). Oil development throughout much of the species' range in Alberta has reduced habitat effectiveness. Developing methods for hastening the recovery of sagebrush vegetation could help to restore habitat for this critically endangered species (Connelly *et al.* 2011).

34. *Ecology and management of sharp-tailed grouse in Connor Creek Provincial Grazing Reserve.* ** Connor Creek Grazing Reserve 42 km northwest of Barrhead, Alberta is one of the largest grazing reserves in Alberta supporting over 10,000 head of cattle. Brush control and aggregate development on the Reserve may be negatively affecting sharp-tailed grouse (*Tympanuchus phasianellus*). Habitat selection, survival, and reproductive success of sharp-tailed grouse should be studied in landscape context.

35. *Competition between feral horses and wildlife*. *** Expanding populations of feral horses on Alberta's east slopes results in heavy use of forage resources on seasonal ranges,

clearly in competition with wildlife use of the same forage (Bork and Boyce 2013). Research to document the interference and exploitation competition between feral horses and native ungulates will provide a basis for sound management of the horse population.

36. *Grazing management for grasslands conservation*. *** Grassland birds are declining faster than any other group of birds in North America (Sauer and Link 2011). This is aggravated by the failure by the United States to renew the Farm Bill that funds Conservation Reserve Program (CRP) lands, thereby eliminating a major incentive for maintaining grasslands (Reynolds et al. 1994). Carbon capture and sequestration is highly effective in grasslands, storing the carbon in the soil where it is relatively safe from fire and other short-term perturbations (Slaski *et al*. 2006). Funds from industrial carbon offsets can be tapped for carbon capture and sequestration as in the Ducks Unlimited program in the USA (http://www.ducks.org/conservation/ecoassets/carbon-sequestration-program). But how to optimally manage grazing on these grasslands to maximize carbon sequestration is inadequately documented, and early research has found highly variable responses to grazing (Milchunas and Lauenroth 1993, Dormaar and Willms 1998). ACA has invested in the Wild Rose Conservation Area and is using rest-rotation grazing at low intensity because of benefits to grassland diversity and productivity (McNaughton 1985). The efficacy of alternative systems of grazing management for conservation values at the Wild Rose and other conservation areas (e.g., Southern Alberta Land Trust Society) needs research attention.

Once released from heavy grazing a profusion of forbs appeared on the Wild Rose Conservation Area. Rough fescue will gradually replace these forbs, efficiently sequestering carbon into the rich black Chernozem soils characteristic of the Milk River Ridge. B. Taylor photo.

37. *Harvest strategies for bighorns*. ** Alberta has been highly successful in managing bighorns but recently concerns have been expressed that harvest pressure is excessive in some areas. Several alternative harvest strategy changes have been considered recently including restrictions to full-curl only harvests, reducing the hunting season, and limiting harvest by quota. Designing a research program to document the consequences of alternative harvest policies should document horn size and growth, population size and composition, and hunter behaviour.

38. *Seasonal movement of bighorns*. ** Harvest of legal rams is often highest late in the season, i.e., late October. Some speculate that some of these rams are those that move out of the national parks onto Crown lands where they are available for hunters. Genetic mixing of bighorns from protected areas could swamp any consequence of size-selective harvesting by hunters (Tenhumberg *et al*. 2004). Insufficient data exist on the seasonal movement of bighorns, and such data could assist in managing the hunting season.

39. *Fire for management of bighorn habitats.* *** Encroachment of bighorn foraging areas by shrubs and trees can be controlled by fire. This might be especially important in the context of global change as the treeline moves higher (Elliott 2012). If fires are set on small scale, attraction to burned areas can concentrate foraging offsetting the benefits of burning (Spalinger and Hobbs 1992). And predators are thought to be attracted to burned landscapes where encounter rates are enhanced (Hebblewhite *et al*. 2005). How to optimally manage a system of prescribed burns in bighorn range warrants research attention and an evaluation of past burns in Alberta and how they are being used by bighorns.

40. *Post-harvest silviculture in Alberta's forests*. ** Current practice on Alberta's Forest Management Areas is to pile slash after clearcut timber harvest and to burn the piles. This greatly reduces the post-harvest value of the landscape for small mammals and other wildlife, and also releases large amounts of carbon into the atmosphere. Although current practice might be the fastest way to restore a productive forest (Lopushinski *et al.* 1992), other values might warrant consideration and evaluation. This is particularly true on lodgepole pine (*Pinus contorta*) forests where strategies need to anticipate future threats of pine bark beetle that is aggravated by planting large areas in single-aged stands of lodgepole pine.

41. *Harvest strategies for elk*. ** Many alternatives exist for managing elk harvests, both in the timing of the hunt and restrictions on the type of animal that can be taken. An experimental manipulation of alternative harvest regulations could help to achieve desired opportunities for hunters wanting trophy bulls, high abundance, and maintaining maximum yield of meat. In populations where mature bulls are too few, breeding may be done primarily by yearling bulls that often mature later resulting in cows being bred in their 2nd oestrus. This results in calves being born later in the season and not able to achieve adequate body mass to survive the next winter (Prothero *et al*. 1979). Therefore,

it might be crucial to ensure that sufficient branch-antlered bulls remain in the population to breed before being harvested.

42. *Declines in lesser scaup populations.* ** The lesser scaup (*Aýthya affinis*) is the most abundant and widely distributed diving duck in North America, but the species has continued on a population decline that began in the 1980s (Austin *et al*. 1999), with numbers down another 20% in 2013 from last year's estimates. Water conditions for waterfowl throughout the Prairie Pothole Region of Canada and the United States have been excellent since 1994, but only about 25% of lesser scaup nest in the Prairie Pothole Region. Instead, the largest number of scaup are produced in the Boreal Forest Region where waterfowl surveys are not as extensive as for the Prairie Pothole Region. The decline in breeding-season surveys appears to be most pronounced in the boreal forest region of western Canada, including Alberta, where it is correlated with climate change patterns and spring snow melt (Drever *et al*. 2012). Reasons for this decline have been postulated to relate to the trophic-mismatch hypothesis but are not understood and demand research. Especially useful would be documentation of the reproductive ecology and survival of lesser scaup throughout the boreal forest region of Alberta (Austin *et al*. 1999). Recent toxicology studies of contaminants such as selenium (Brady *et al*. 2013) and 23 other hepatic elements (Pillatzi *et al.* 2011) indicate that toxicity of these elements cannot explain the population decline. This research topic has been on both previous research needs documents and has been the subject of several research projects, but remains unresolved.

Lesser scaup (bluebill) populations have been in decline for nearly 30 years but the reasons for this decline are not understood.

43. *Status of the white-winged scoter in Alberta.* ** The white-winged scoter breeds throughout the prairies and parklands of Canada, into central Alberta. The species has undergone a decline in recent years and a reduction in breeding range, especially in the parklands and boreal forest region of Alberta (Krementz *et al*. 1997). A reduction in the ratio of harvested young per adult has occurred between 1961 and 1993 may be a consequence of heavy hunter harvest. Ecological reasons for the decline are correlated with climate change but the particular reasons for the reduction in breeding range in Alberta is not understood (Drever *et al*. 2012). Studies on the nesting ecology of white-winged scoters in Alberta may help to identify effective management alternatives to prevent continued decline in this sea duck.

44. *Wildlife responses to mountain pine beetles outbreaks.* *** Økland *et al*. (2011) review the complex community consequences of outbreaks of mountain pine beetles that have occurred in lodgepole pine forests of western Alberta in recent years. Most ungulates, with the exception of caribou, benefit from the open early-succession habitats that establish after pine beetle outbreaks. But indirect effects such as predator-prey interactions are known to vary geographically and are not easily generalized. Treatment effects, such as salvage logging and tree planting can alter outcomes. Site-specific prescriptions that benefit both wildlife and future timber yields are not incorporated in the current policy by the Alberta government and research is needed to guide sound forest-management practice.

45. *Distribution and status of bobcats*. * Typically associated with the southern tier of counties, in recent years bobcat (*Lynx rufus*) catch by trappers has occurred further north than in the past. Few data exist on this species in Alberta with which to base management. Strong pelt prices have increased interest in harvesting this species but we have insufficient data to ensure a sustainable harvest.

46. *Fisher habitat models.* * Fisher (*Martes pennanti*) populations appear to be decreasing in the Rocky Mountains of Alberta, but relatively little is known of their current distribution, abundance, and habitat requirements. Fishers have been successfully reintroduced east of Edmonton (Proulx and Genereux 2009). Marten (*M. americana*) appear to compete and the distribution of one species usually results in exclusion by the other (Fisher *et al.* 2013). A useful research program might be a radiotelemetry study of movements and the development of resource selection functions (Manly *et al*. 2002) to evaluate the potential habitats in the province. Coarse-scale RSF models have been developed for fishers in the Rocky Mountains but the models explained a small amount of the variance in distribution and as such did not reveal any conservation implications (Carrol *et al.* 2001).

47. *Silvicultural methods for restoring woodland caribou habitat*. *** Rapid declines in caribou (*Rangifer tarandus*) populations in Alberta are ultimately tied to habitat alterations associated with timber harvest and energy extraction. Recovery of caribou habitats is expected to take many decades, but silvicultural practices might be able to hasten recovery times allowing caribou populations to recover (Boan *et al*. 2011).

48. *Evaluation of the timing of disturbances on winter ranges.* *** In areas where industrial development, e.g., oil and gas, is occurring on big game winter ranges, a common restriction is to permit no surface occupancy during critical periods in winter. Indeed, winter ranges are often crucial areas for ensuring the persistence of wildlife populations,

and ungulates can be sensitive to human use and industrial activity (Sawyer *et al*. 2009). Yet, there are few studies on which to base such guidelines.

49. *Snowmobile management to reduce conflicts with wildlife*. ** Snowmobiles have been shown to disturb bears causing them to leave winter dens (Linnell *et al.* 2000). Also, snowmobile use on critical big game winter range can disturb elk (*Cervus elaphus*) and bighorns (*Ovis canadensis*) as well as other wildlife. Stress levels are elevated by snowmobile activity for both wolves (*Canis lupus*) and elk (Creel *et al*. 2002). Research on snowmobile effects on wildlife could directly influence policy for allowing snowmobiles in certain areas.

50. *Spring hunting and baiting of black bears in Alberta.* * Black bear hunting is an important component of the outfitting industry in Alberta, especially during spring when there are few alternatives for hunting in the province. In addition, black bears can cause considerable damage to apiaries (Gunson 1977), livestock, and crops (Jonker *et al*. 1998), so harvest of black bears is viewed to be important for controlling bear populations and reducing depredations. Likewise, baiting enhances hunter success, thereby increasing the effectiveness of black bear hunting as a management tool for controlling black bear populations. In Alberta, baiting and spring hunting of black bears are viewed to be important for wildlife management as well as providing recreational opportunity, supporting the outfitting industry, and attracting tourism revenues to the province. Demographic consequences of spring baited bear hunting has been studied (Czetwertynski *et al.* 2007), but we do not adequately understand the consequences of the baiting itself. One outfitter in northeastern Alberta reported placing 40 tonnes of bait during a spring hunt which surely has consequences for growth, nutrition, and survival of young during the critical spring period when bears can find it difficult to find food.

51. *Habitat limitations for mountain goats in Alberta.* ** Mountain goats (*Oreamnos americanus*) have been harvested at very low levels in Alberta for several years, and the herd has increased to approximately 2,000 animals with about 1,650 on provincial lands. Also, no attempt has been made to map goat habitat in detail. A radiotelemetry study and high-resolution remote sensing could be used to develop detailed habitat maps using resource selection functions (see Shafer *et al.* 2012). Such habitat maps could be used to evaluate the population potential for Alberta's mountain ranges and thereby develop long-term management plans for mountain goats.

52. *Expansion of timothy on elk winter ranges.* *** Timothy (*Phleum pratense*) has become naturalized throughout North America. This exotic grass spreads rapidly into grasslands that have been heavily grazed. Because ungulate winter ranges are typically heavily grazed, in recent years we have seen expansion of timothy into these areas at the expense

of native grasses. Winter forage value of timothy appears to be low relative to native species, but the extent of the problem and possible management treatments needs careful documentation. There are opportunities for experimental treatment of timothy on winter ranges to see if winter forage can be enhanced.

53. *Explanation for low moose density in NW Alberta.* * Biologists cannot explain the low density of moose in the NW portion of Alberta. Although habitats appear adequate and extensive, and harvests are low, the density of moose is remarkably lower in the vicinity of High Level, Alberta, than along the Peace River further south. Nutrition and predation are mechanisms that might merit attention, but no evidence exists at the moment to identify a cause. A broad-based study of the ecology of moose in NW Alberta, including nutrition, habitats, demography, predation, disease, and reproduction, may be necessary to develop management guidelines that could increase moose density in this region.

54. *Seasonal mortality of white-tailed deer.* * The white-tailed deer is an abundant and important game species in central Alberta. Sources of non-hunting mortality for this population are not understood, however. More complete information on the seasonal schedule of mortality could help to identify possible management approaches, and help to explain local variation in abundance. Such an investigation would necessarily entail radiotelemetry. New methods for survival analysis enhance our ability to draw strong inferences (Johnson *et al.* 2004).

55. *Evaluation of Moose App for monitoring moose populations.* * A major expense for the province and the ACA is the conduct of Aerial Ungulate Surveys, including those for moose (Boyce *et al*. 2012). These surveys require extensive air time, and impose danger for wildlife biologists recently amplified for us by the tragic death of Kristina Norstrom in a helicopter crash in northeastern Alberta. We have developed an App for iPhones and Android-based smart phones that allow hunters to report the moose that they see during hunting. Such counts have been shown to correlate strongly with moose abundance in Scandinavia (Ericsson and Wallin 1999, Solberg and Saether 1999) and need to be validated in Alberta. Such citizen science programs engage interested members of the public and offer highly cost-effective means for obtaining crucial monitoring data (Bonney *et al*. 2009; Devictor *et al*. 2012; Dickinson *et al*. 2012). If the Moose App is accepted and used by hunters it could save considerable funds from AUS and reduce risks for biologists.

56. *Otter harvest optimization in Alberta.* * As a top predator, the river otter (*Lontra canadensis*) almost certainly is a keystone species, and as such merit high priority for research attention (Soule and Kohm 1989). Otters prey on beaver (Reid 1984), fish, small mammals, mussels, and other invertebrates, and can cover extensive areas in the

foraging forays. Quotas are used to limit harvests per registered trapline, but it is not clear that these quotas are necessary or effective. Developing a harvest policy for this species should include consideration for the ecological consequences of the species as well as the potential for sustainable harvest.

57. *Methods for reducing livestock depredation*. ** Continued predation by wolves on cattle in SW Alberta results in compensation payments by ACA and animosity by ranchers toward wolves and other wildlife. Evaluation of alternative methods for reducing these livestock depredations warrants further research attention.

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Appendix

Table 1. Criteria for evaluating research projects compiled based on my meetings with Alberta Conservation Association and Alberta ESRD staff.

Criterion	**Explanation**
Mgmt significance	Whether or not a project was likely to have bearing on resource management.
Controversial/Issue	Does a study have potential to resolve a management issue—that may be controversial?
Threat to resource?	Is the resource under study threatened by development or current management?
Ecosystem mgmt	Will the study involve ecosystem management (see Boyce & Haney 1997)? Or is the project on a single species?
Habitat related	Does the study involve habitat issues? This criterion is based on the axiom that fundamental to fisheries/wildlife management is habitat management.
Good science	Does the research involve interesting ecological questions and/or elucidate ecological principles?
Species @ risk?	Does the project involve species at risk or species of special concern?
Keystone species	Is a keystone species involved, i.e., a species that has disproportionate influence on other organisms in the ecosystem?

Game/Fish spp.	Does the study involve species that are hunted or pursued by anglers?
Cost/Feasible	Is funding available for the project or likely to be available for the project?
Experimentation	Can sound study design be applied, ideally involving the experimental method?
Partnerships	Are multiple stakeholders involved in the project offering opportunities for partnerships in the research program?
Benefit hunter/angler	Is the project likely to offer benefits to hunters and/or anglers through improved management or enhanced appreciation for a resource?
Geographic scope	Does the project involve a broad geographic scope? Will the research involve resources that cross administrative boundaries?
Technology	Does the research involve new or sophisticated technology whereby involving university expertise could enhance the study?
Economics	Does the project have economic ramifications, either negative or positive?
Exotic species	Will the research assist in the management of exotic species or help to resolve issues related to exotics?
First Nations	Will people of First Nations be involved or affected by the research?

Table 2. Ranks of research evaluation criteria based on a 2013 survey of Alberta Conservation Association and Alberta Environment and Sustainable Resource Development staff where individual criteria were given ranks of 0-5. The mean, standardized means (score), and standard deviations (SD) are presented for comparison of the importance of these criteria to those sampled.

2013 Rank	Criterion	Mean	Score	SD
1	Controversial/Issue	4.4	1	0.699
2	Benefit hunter/angler	4.4	1	0.699
3	Mgmt significance	4.3	0.977	0.675
4	Game/Fish spp.	4.1	0.932	1.101
5	Threat to resource?	3.9	0.886	0.5
6	Species @ risk?	3.8	0.864	0.919
7	Habitat related	3.8	0.864	1.033
8	Ecosystem mgmt	3.6	0.818	1.174
9	Good science	3.5	0.795	1.179
10	Keystone species	3.4	0.773	0.699
11	Partnerships	3.1	0.705	0.994
12	Cost/Feasible	2.9	0.659	1.524
13	Experimentation	2.8	0.636	0.632
14	Geographic scope	2.8	0.636	1.033
15	Exotic species	2.7	0.614	0.823
16	First Nations	2.2	0.5	1.476
17	Economics	2.1	0.477	1.37
18	Technology	1.9	0.432	1.197

Caveats for Application of SMART

SMART offers the pretense of being an objective approach to ranking research projects. Yet, there remains considerable subjectivity (Game *et al*. 2013). The fact that the criteria were not independent means that some criteria are given higher influence in the total scores. Furthermore, the fact that a project ranks low in no way implies that the project is not a crucial one. For example, a research project on a new exotic species might become of urgent importance even though it might rank low on the project ranking. Nevertheless, I think that the projects that ranked highly are likely to be of keen interest for all of the reasons given in the criterion list.

Regional Priorities

Although not evaluated systematically, we were impressed that there existed regional variation in the urgency of fisheries and wildlife research needs. Although industrial development and associated effects are going on throughout the province, the extent of human modification of the landscape is greatest in the prairie and parkland regions. Furthermore, the majority of the species at risk occur in the prairies of SE Alberta. Water is managed intensively in the prairie region with dams, canals, and extensive irrigation systems creating unique challenges to fisheries management. In addition, 45% of the big game harvests occur in the prairie/parkland region. Yet, the prairie regions of ACA and ESRD host fewer ACA and ESRD staff biologists than any other ACA or ESRD region. Resource management in the prairies is particularly challenging because it requires working closely with landowners and ranchers. Research programs that can facilitate improved conservation in this region could be of great value to Alberta's fisheries and wildlife resources.

Biodiversity

The criteria for project evaluation (Tables 1-3) did not include biodiversity explicitly, although preservation of biodiversity is implicit in considerations for "species at risk" as well as "ecosystem management." Recent efforts in conservation have focused on a desire to preserve biological diversity. Justification for this priority includes the value that genetic information might have for developing new sources of drugs or medicines, industrial applications, or disease-resistant strains of domestic organisms. Also, evidence is accumulating that biological diversity has value for ensuring ecosystem functions including primary production, nutrient cycling, trophic interactions, decomposition, and sustaining water quality (Chapin *et al.* 2000, Packer *et al*. 2009). Beyond this is a strong sense that causing extinction is unethical (Tilman 2000). Convictions of the value of genetic diversity led to the Endangered Species Act in the United States of America, global guidelines by the International Union for the Conservation of Nature, and legislation in Canada such as the Species at Risk Act (SARA).

Strategies for preserving biodiversity usually involve protecting endangered species and their habitats. On a global scale, Myers *et al*. (2000) have advocated priority protection for diversity hot spots, i.e., areas of particularly high species richness. This clearly oversimplifies how conservation priorities should be established (Margules and Pressey 2000). Indeed, none of the global conservation hot spots identified by Myers *et al.* (2000) occur in Canada, yet, this does not imply that we should not be protecting biodiversity in Canada. Furthermore, the hot-spots approach overlooks other crucial considerations of conservation priority such as endemism, threat, viability, and ecological function of diversity (Mace 2000). And it is not clear that focusing priority on plant species diversity will reflect diversity in other groups (van Jaarsveld *et al*. 1998). Although floral diversity is relatively low in Canada, Alberta's Willmore Wilderness Area contains the highest native diversity of furbearing and large mammals of anywhere in the Western Hemisphere! The province of Alberta has recently expanded funding for the conservation of species at risk, partly in anticipation of federal programs supporting the proposed SARA legislation. Currently there is much duplication of programs focusing on biodiversity issues, both in Canada and globally. In Alberta there are non-governmental programs supported by Ducks Unlimited, the North American Waterfowl Management Plan, the Federation of Alberta Naturalists, World Wildlife Fund-Canada, the Canadian Nature Federation, the Canadian Wildlife Federation, Yellowstone-to-Yukon (Y2Y), The Nature Conservancy Canada, Canadian Parks and Wilderness Society, Canadian Wilderness Association, the Alberta Fish and Game Association, and the Alberta Conservation Association plus several others. At a global level, major players include Conservation International, World Wildlife Fund, BirdLife International, the International Union for the Conservation of Nature, World Resources Institute, Wildlife Conservation Society, and The Nature Conservancy. In addition to these organizations there are several government agencies with active conservation programs especially the Natural Resources Service of Alberta Environment, and the Canadian Wildlife Service at the federal level. This redundancy in programs has led to inefficiencies and occasionally competing interests. If we are to engage wide-spread public support for a unified conservation strategy we need to seek improved cooperation and consistency in data collection, analysis, and priority setting (Mace 2000).

Conservation decisions are typically made at local scales. Programs targeting global conservation priorities are not likely to engage the strength of support that can be found among people who will actively benefit from conservation actions. Collaborations, partnerships, co-management, and community-based conservation are the sorts of initiatives that are most likely to succeed in the long term (Freyfogle 1998). The fantastic success of the North American scheme of wildlife management has at its roots the fact that local publics are the beneficiaries of wildlife resources (Geist and McTaggart Cowan 1995).