Loss of Fish Habitat as a Consequence of Inappropriately Constructed Stream Crossings

ABSTRACT

In the light of declines in Atlantic salmon (*Salmo salar*) stocks, we sought to determine the extent to which stream crossings along a newly constructed section of the Trans Labrador Highway (TLH Phase II) in southern Labrador accorded with government regulations for fish habitat protection. We surveyed crossings of permanent streams over a 210 km road segment, containing 4 bridges and 47 culverts. Fifty-three percent of culverts posed problems to fish passage, due to poor design or poor installation. We conjecture that cost and inadequate environmental oversight in the field explain the weak compliance with the relevant fisheries guidelines. Our research has prompted the federal regulator to instigate remediation of problems with the Phase II part of the highway. In addition many of the planned stream crossings for Phase III of the TLH were re-designed, and a commitment to careful monitoring of the installations has been made by the federal regulator in cooperation with the indigenous inhabitants.

Trans Labrador Highway, Blue Hill Pond, upstream.

R. John Gibson
Richard L. Haedrich
C. Michael Wernerheim

The authors are all at the "Coasts Under Stress" Research Project, Memorial University of Newfoundland, St. John's. Gibson is a scientist emeritus in the Department of Fisheries and Oceans and an adjunct professor in the Biology Department; Haedrich is a university research professor in the Biology Department; and Wernerheim is an associate professor of economics. Gibson can be reached at rjgibson@nf.sympatico.ca.

Introduction

Although guidelines for stream crossings are explicit, remissness and priority of costs commonly has led to poor design and installation in a significant number of cases. The negative effects of culverts and poor construction practices at stream crossings have long been recorded (e.g., McClellan 1970; Dryden and Jessop 1974; Jones et al. 1974; Larson 1976). Culverts create more barriers to fish passage than other structures, but due to cost restraints corrugated metal pipe culverts are frequently installed instead of more environmentally benign bridges (Warren and Pardew 1998; Harper and Quigley 2000). A recent U.S. Congressional General Accounting Office report (26/III/02) noted that the U.S. Forest Service and the U.S. Bureau of Land Management estimated that over 10,000 culverts exist on fish-bearing streams in the states of Washington and Oregon. Although neither agency knows the total number that impede passage, their efforts have identified about 2,600 culverts that are barriers to migrating salmon, and they speculated that more than twice that number exist. Similarly, the Alaska Department of Fish and Game reported that 66% of the culverts in salmon streams in the Tongass National Forest may be inadequate for fish passage, and 85% of the culverts across trout streams may be likewise (Flanders and Cariello 2000). A briefing document by Trout Unlimited (J. Konigsberg, Trout Unlimited, Anchorage, Alaska, pers. comm.) reported that one of the more significant threats to Alaska's wild salmon was barriers created by culverts, causing loss of spawning and rearing habitats upstream.

In a recent study of 50 randomly-selected culverts in Nova Scotia, Langill and Zamora (2002) found that 58% were barriers to fish migration.

Similarly, Harper and Quigley (2000), in a survey of road crossings in British Columbia, found that round culverts or corrugated metal pipes (CMPs) resulted in greater habitat loss due to fragmentation than other crossing types. Chestnut (2002), in a survey of stream crossings in Kamloops, British Columbia, found that out of 31 culverts assessed, only one met Department of Fisheries and Oceans (DFO) objectives for juvenile fish passage and maintenance of fish habitat.

Similar problems occur in rivers of other countries. For example, Augerot (2004) reported that in the Russian Far East fish passage is not a central design feature for culverts in road construction. Many therefore become obstructions for anadromous fish. In Scotland considerable loss of salmonid spawning and rearing habitat was found due to elevated culverts (Glen 2002). Thus the study we present for one particular area of eastern Canada exemplifies a common and widespread problem.

Improperly designed or installed culverts have damaged many small streams on the island of Newfoundland, preventing salmonid access to spawning and rearing areas, and sometimes resulting in elimination of anadromous or resident salmonid populations. In 1987 the Salmonid Association of Eastern Newfoundland (SAEN) examined 843 culverts on streams of the Avalon Peninsula, the southeastern part of the island of Newfoundland. They found that 27% were direct barriers to fish passage and an additional 33.5% were so poorly placed that it could not be determined if they allowed fish passage (Briffett et al. 1987).

In southwestern Newfoundland, the Harry's River watershed has more stream crossings than any other salmon river studied in the province. Half of the crossings are cylindrical culverts. The salmon stocks are well below predicted levels, which is probably due to loss of access to minor brooks for rearing of juvenile salmon because of culvert deficiencies (Gibson 2002).

Stream crossings can be designed to allow safe fish passage of all species and size ranges. Salmonid body size, water temperature, time of year, dissolved oxygen, and previous exertion significantly influence the swimming performance of fish. While Gosse et al. (1998), describing DFO guidelines for protecting of freshwater fish habitat, stated that "appropriate water velocities for the fish species and size of fish at the site/area should be provided in culvert installations," the authors did not quantify the actual velocity requirements. A summary of DFO requirements for installations is presented in Table 1, in which suitable water velocities for passage of salmonids were taken from published material referred to below.

Adequate passage must be allowed during all seasons (McDonald et al. 1998; Scruton et al. 1998; Crisp 2000). For example, with young (mean length 13.6 cm) sockeye salmon (*Oncorhynchus nerka*) acclimated to 15°C, a 4% reduction in swimming speeds at 10°C and 20°C was observed (Brett 1967). Adult salmon and large trout (*Oncorhynchus* sp.) are known to have travelled up to 30.5 m against water velocities of 0.82 m/s; however, to ensure fish passage, water velocities should be less than the sustained swimming speed of upstreaming fish, which for salmonid under-yearlings is less than 30 cm/s and nearer 15 cm/s (Wightman and Taylor 1976). Powers et al. (1997) recommended culvert design velocities for fry (≤ 60 mm) and fingerlings (> 60 mm) as 33.5–34.0 cm/s. Since safe passage of fish includes juveniles, the recommended maximum water velocity in embedded culverts is 0.3–0.6 m/s provided a coarse substrate is present to allow slower flows near the bottom for fry migration (Poulin and Argent 1997; Scruton et al. 1998).

Gosse et al. (1998) emphasized that "natural bottom substrate and hydraulic capacity of watercourses are best maintained using open bottom/bottomless arch culverts; these are the preferred type of culvert crossings." Where cylindrical culverts are used, the DFO guidelines stipulate that the culverts be countersunk to a depth of 300 mm below the stream bed elevation, or 15% of the diameter of culverts having a diameter exceeding 2,000 mm. Cylindrical culverts need to be embedded with the natural stream substrate to retain invertebrate producing capacity of the stream. Rubble or boulders should be present to stabilize the substrate, to facilitate migration of fish and to

Table 1. Biological criteria used in the present study for installations at road crossings in southern Labrador to allow passage of fish of all sizes, based on the DFO guidelines (Gosse et al. 1998).

Guideline	Requirement
Span of water course	≥ channel bed width.
Stream bed	Natural watercourse bottom and hydraulic condition preferred (e.g. bridges, bottomless arch culverts). 30 cm depth of substrate in round culverts up to 200 cm in diameter; countersunk a minimum of 15% of the culvert diameter with culverts > 200 cm diameter.
Water depth	A minimum of 20 cm water depth throughout the culvert length. With simulated streambeds depths approximate those of the natural channel.
Water velocity	≤ 60 cm/s if a coarse substrate is present; ≤ 34 cm/s if a coarse substrate is not present.
Baffles	Drops between adjacent baffles should be a maximum of 20 cm. The elevation of the outlet pool should back water up to the entrance baffle.

provide protection from predation by larger fish. When an embedded culvert is properly installed the pipe should have the same cross-section and slope as the natural channel, and have a substrate simulating natural conditions. Non-embedded culverts rarely meet fish passage requirements and can only be used with a gradient of less than 0.5%, i.e., essentially on flat grades with very low flow (Dryden and Stein 1975; Langill and Zamora 2002).

Since streams under road crossings should simulate natural conditions, a bridge length or a culvert width should be selected to fully span the active channel. Bates et al. (2003) recommended that to allow stream channels to develop within a culvert, the minimum width of the bed in the culvert ($W_{culvert}$ bed) should be determined by the formula, $W_{culvert}$ bed = $1.2W_{ch}$ + 0.6 m), where W_{ch} is the width of the channel bed, measured across the channel between ordinary high water marks.

Culverts are often placed in riffles, covering the natural stream bed (e.g., Photo 1). Riffles are important for spawning and rearing areas and are the most valuable areas for invertebrate production (Williams and Feltmate 1992). DFO guidelines state that crossings should be located away from, and preferably downstream of the riffle area.

Poor stream crossings destroy habitat, fragment and isolate fish populations, and increase vulnerability to disturbance and extirpation. Delayed or concentrated migrating fish are vulnerable to avian, mammalian, and piscine predators. For example smolt predators were found to concentrate at a bridge that constricted the waterway (Jepsen et al. 1998).

R. J. GIBSON

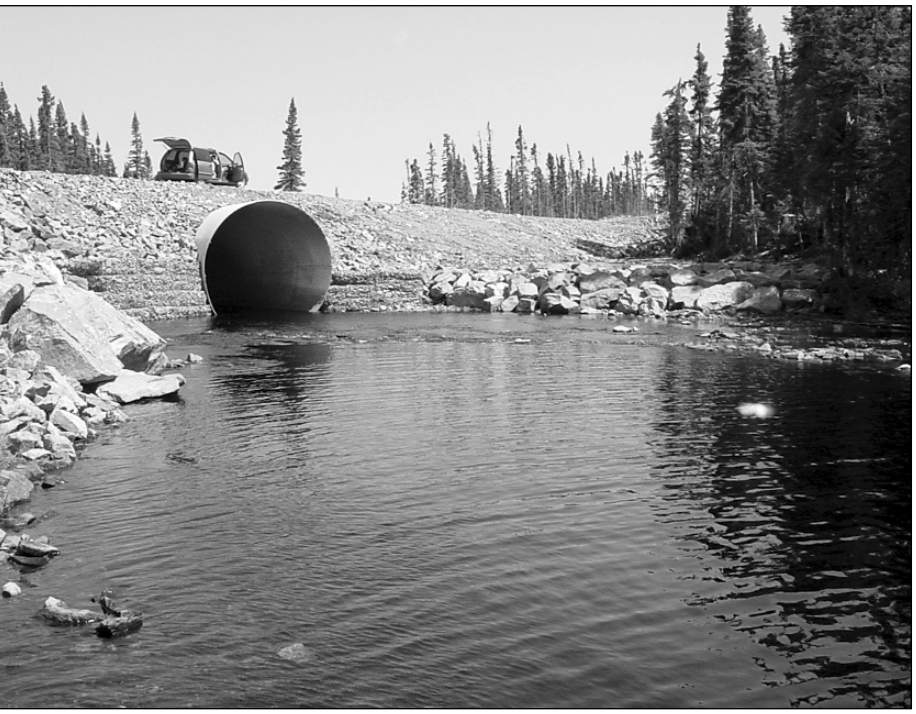


Photo 1. Inlet of the cylindrical culvert at Shinney's Waters, Trans Labrador Highway. The culvert, not properly sized, constricts the stream, and creates a velocity barrier for upstream migration of small fish. The crossing was built on a riffle area and was not embedded. Spawning and rearing habitat (442.6 m^2) and riparian vegetation have been lost.

In addition to some adult fish migrating up small streams at spawning time, juvenile salmon and trout migrate up small tributaries for rearing, sometimes several kilometers up first order streams (Huntsman 1945; Curry et al. 1993, 1997; Erkinaro and Gibson 1997; Erkinaro et al. 1998). Small streams are more productive per unit area for invertebrate food items than larger streams (Hynes 1970). Moreover, growth rates of young salmon are higher in smaller tributaries than in the main stem river (Erkinaro and Niemelä 1995). In the River Teno in Finland, at least half the adult salmon stocks were reared from the smaller tributaries (Erkinaro et al. 1997).

Elsewhere juvenile salmon have been shown to migrate considerable distances to suitable overwintering habitats. Such habitat could be fragmented by improperly installed culverts (Robertson et al. 2003). In Scottish streams salmon parr will colonize streams very quickly after removal of impeding culverts, often travelling significant distances upstream (Glen 2002). Since salmon parr are known to migrate into river estuaries over the feeding season, returning to the river to overwinter (Cunjak 1992; Cunjak et al. 1989), migration barriers for small fish near an estuary could have negative effects on anadromous fish (e.g., Photo 2). Dispersal of some invertebrates, especially molluscs and crustaceans, may be impaired by culverts (Vaughan 2002).

Our study area was located in a section of what is known locally as the Phase II part of the Trans Labrador Highway (TLH). The TLH (Phase II) is a two-lane, gravel-surfaced road constructed during 1999–2002. It stretches from Red Bay north to Cartwright, (325.5 km), in southern Labrador, with access roads to St. Lewis/Fox Harbour (30 km) and Charlottetown (28 km). During construction 20 different watersheds with 166 watercourses were crossed (Jacques Whitford Environment Limited 1998). The fish species of primary interest to anglers in these watersheds are brook trout (*Salvelinus fontinalis*), Atlantic salmon (*Salmo salar*), and Arctic char (*Salvelinus alpinus*) (Anderson 1985). In addition to the value of recreational fisheries, these species are an important part of the Labrador Métis diet and have very high cultural value (Corey Morris, Labrador Métis Nation, pers. comm.). It has been argued that since wild Atlantic salmon in general are severely depleted throughout much of the species' range, all possible conservation measures should be implemented (Parrish et al. 1998).

Our objectives were to: (1) ascertain if fish movements or habitat may have been changed by the new section of the TLH, and (2) to assess com-

pliance with Section 35 of the Canadian Fisheries Act, which stipulates that there be "no net loss of the productive fish habitat resulting from any project developments or activities that have potential negative impact on fish habitat."

This study was undertaken in cooperation with the Labrador Métis Nation (LMN). We hypothesised that all stream crossings would be designed and executed according to government guidelines, because the LMN had earlier expressed concerns about possible environmental impacts of constructing the new highway on fishes important to their culture. Moreover, a federal and provincial environmental impact study had been conducted that presumably had taken due account of fish habitat considerations.

Methods

Between 28 June and 8 July 8 2002, we examined crossings of permanent waterways for effective fish passage and effects on the aquatic habitat along the 210 km section of highway from Mary's Harbour to Charlottetown intersection, including the new access roads to St. Lewis and to Charlottetown (Figure 1). We measured variables based on DFO guidelines for installations at stream crossings (Gosse et al. 1998), summarized in Table 1.

We recorded the locations of crossings with a Global Positioning System. The type of culvert and level of embeddedness for cylindrical culverts also were recorded. We measured culvert lengths and widths, and mean water depths and velocities. Water velocities were measured with a 201D Marsh McBirney current meter at 0.6 depth. Mean wet widths of streams were measured by two or three measurements above and below the culvert, beyond physical evidence of construction impact. All data including photographs are available at: www.coastsunderstress.ca/arm1/pubs/gibson_trans_labrador_road_jun_2004_v6.pdf)

Results

The bridges sampled include those on the St. Mary's, St. Lewis, Port Hope Simpson Brook and Alexis rivers. Only 2 out of the 47 culverts examined were open-bottomed arches. Culvert diameters varied from 1.2 m to 5 m (mean = 2.5 m). Lengths of culverts averaged 25.3 m (range 17.1–40.5 m). No cylindrical culverts were embedded with the minimum 30 cm of natural substrate required by DFO. We estimate that the failure to embed these structures resulted in loss of 3,001 m^2 of benthic stream habitat from the culverts themselves.

Twenty-two culverts probably allowed fish passage for all size classes, and 25 (53%) presented barriers. The following variables, singly or in combination, created problems at the obstructed culverts. The major problem was insufficient depth, with 13 culverts (36.1%) ranging from 0.15 m to 0.01 m deep (mean = 0.06 m, standard deviation = 0.05). Five culverts (13.9%) were dry, with water flowing under or around the culvert. Six culverts (16.7%) had a drop at the outlet, with a mean drop of 0.26 m (standard deviation = 0.16). Three crossings (8.3%) had rocky barriers at the outlet. Nine culverts (25.0%) had velocities high enough to prevent passage, ranging from 0.38 m/s to 1.0 m/s, with mean of 0.64 m/s (standard deviation = 0.30). One baffled culvert on a high gradient stream was rated as having unsatisfactory velocity. It is unlikely that small fish could have migrated through the high velocity drops and turbulence. Bates et al. (2003) emphasized that "baffles within the culvert are not a desired solution to meeting velocity criteria and are not appropriate for new culvert installations." Baffles may block juvenile fish passage by creating large turbulence relative to the size of the fish, and therefore they are not recommended as a solution when juvenile passage is required (Powers et al. 1997).

Photo 2. A corrugated pipe culvert constricting the river at the mouth of Port Marnham River (also known as Black Hill Pond River) on the St. Lewis access road, Trans Labrador Highway. The culvert (5 m wide, length 25.1 m) was installed in an 85 m causeway built across the river. It was not embedded. Velocity in the culvert was 0.9 m/s at high tide, and faster at low tide (not measured). The culvert creates a velocity barrier at all stages of tide for upstream migration of small fish, such as Atlantic salmon parr (which are known to migrate to estuaries over the feeding season [Cunjak 1992]), and smaller anadromous arctic char and brook trout, which must return upriver for overwintering.

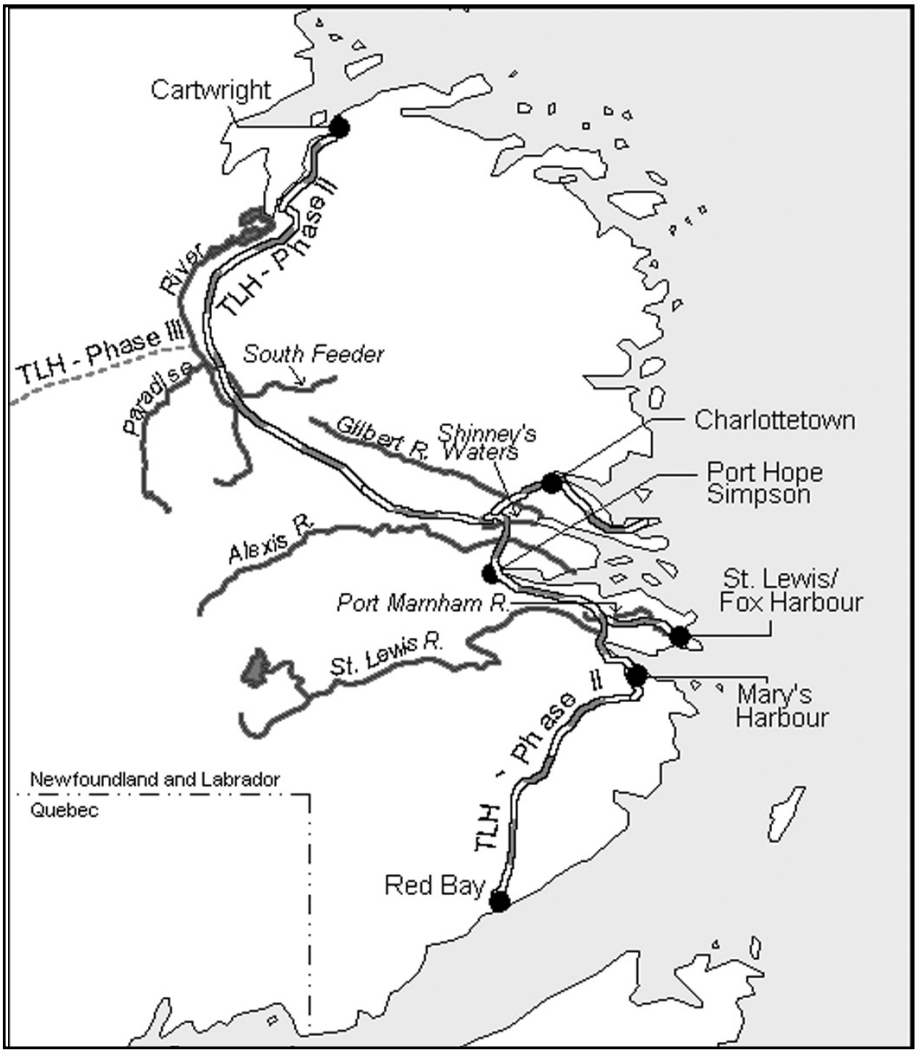


Figure 1. The Trans Labrador Highway (Phase II) between Red Bay and Cartwright. The study area was between St. Mary's Harbour and the Charlottetown access road, including the access roads to St. Lewis and to Charlottetown.

Discussion

Our hypothesis that all culverts would be installed according to DFO guidelines proved to be incorrect. Since our survey was conducted during a relatively short period, it is possible that at other times of the year some of the culverts that we classified as barriers may have been passable. We also allow that some that presented velocity barriers for migration of juvenile fish at all flows might have allowed migration of large fish at some velocities. However, it is unlikely that these would be satisfactory for all sizes of fish during 90% of the passage season, as recommended by Bates et al. (2003). We found loss of stream habitat due to poor installation of the culverts themselves (about 3,000 m^2), and probable consequent loss of upstream rearing habitats. This leads us to conclude that these crossings were not in compliance with Section 35 of the Fisheries Act.

Velocity barriers prevent upstream movement of small fish, and fish held up can be exposed to greater predation from avian and mammalian predators, as previously noted. Anadromous fish species are known to contribute nutrients from marine sources to upstream freshwater areas from their eggs and corpses, and the excretory products from predators (e.g., Jonsson and Jonsson 2003). For example, smelts (adults and juveniles) are important prey for large trout and avian and mammalian species. During spawning the eggs are major food items for salmon parr and trout (Thonney and Gibson 1989). DFO guidelines (Gosse et al. 1998) instruct developers to "design causeways and associated culverts to permit fish passage over the full range of natural flows. Causeway openings should have sufficient clearance to handle peak flows without interference to fish movement." These guidelines were disregarded at two sites (a 185 m causeway with two 3 m cylindrical culverts on the south side of an island at St. Lewis River Inlet, where fast currents and turbulence could be seen, and also an 85 m causeway with a 5 m culvert on the Port Marnham River—Photo 2). At the St. Lewis River Inlet seals and gulls were attracted downstream of the culverts, probably preying on migrating fish. Smelt (*Osmerus mordax*) were seen to be taken by gulls. This had not been observed in

previous years; a negative impact on fish production upstream is therefore likely.

Habitat loss and fragmentation of small streams should be considered as seriously as other perceived negative factors, such as fisheries overexploitation, and some forestry and aquaculture practices, yet these problems seem to be given relatively little consideration compared with engineering hydraulic concerns.

The failure to properly design some culverts is probably related to the very large number of potential sites, each one requiring a decision by the Provincial Government Department of Transportation and Works (T&W) regarding the trade-off between cost considerations and environmental priority. Given the significant costs involved it is perhaps not surprising that all crossings do not receive the attention that due consideration to fish habitat warrants. It stands to reason that the outcome may be compromised if construction companies (that are responsible for installation rather than design) are unaware of the importance of small streams for spawning and rearing of salmonids, and adequate environmental oversight in the field is lacking.

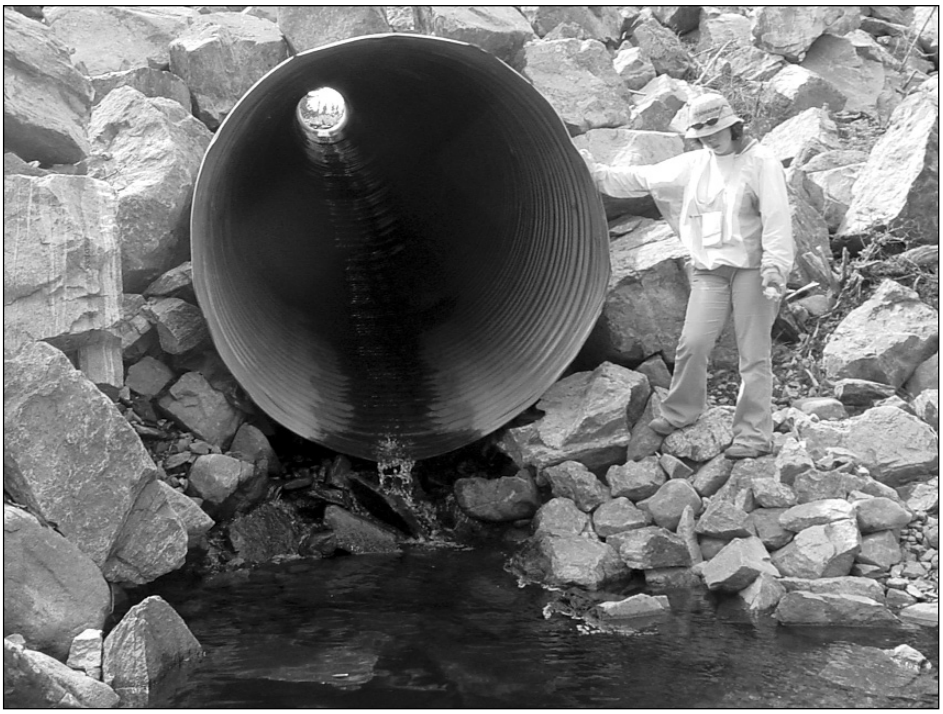
Round pipe is stronger than any other pipe and the most cost effective. Round pipe can also easily be adapted with fish baffles. Arched pipe with a flat bottom can be an alternative to round pipe if the ground is level. This type of structure reduces fill cost but it is not as strong as round pipe. Rock normally will have to be placed inside the structure to guard against collapse. This design needs a bedrock stream and concrete footings. A major problem here is that the footings are subject to scouring. Installation is very costly, and it requires blasting. These circumstances add at least CDN $100,000 to the cost of the next best alternative structure.

Some examples from the TLH help put the economical choice of bridges and bottomless structures in perspective. The most common structure, round 800–900 mm pipe, costs about CDN $200 per meter (about CDN $4,000 for the average stream crossing). The construction cost increases exponentially as the water widens. For example, 20-meter single-span arch structures cost about CDN $800,000 each. The 30-meter span at South Feeder and the 35-meter span on Gilbert River each cost CDN $1.2 million. The bridges at St. Lewis, Alexis River, and Mary's Harbour cost CDN $8 million, CDN $5 million, and CDN $1.2 million respectively. These projects were funded entirely by the provincial government. For reasons of cost alone bottomless structures are used only at DFO's insistence (T. McCarthy, T&W, pers. comm.).

A number of authors (Gibson et al. 1987; Harper and Quigley 2000; Chestnut 2002) recommended that since cylindrical culverts were frequently installed without reference to fish habitat, clear span, open bottom structures should be used on all fish bearing streams. We concur with these recommendations, and suggest that environmental damage be minimized by legislating that clear-spanning, bottomless structures be installed on all fish-bearing streams, and that cylindrical culverts be restricted to drainage ditches with temporary flows.

Despite numerous studies over many years describing the loss of habitat and fragmentation of small streams due to poorly installed culverts, disappointingly little attention is given to this continuing problem, which can have serious deleterious effects on fisheries and ecosystem health. Propagation of the importance of small streams and how to treat them accordingly is probably best undertaken by informed stakeholders. A recent report of the European Inland Fisheries Advisory Commission (FAO 2002) suggested such local stewardship. It recommended that all stakeholders be included in the consultative and decision-making process for management and conservation of inland fisheries resources, and that integrated management of the ecosystem emphasize the need to develop new participatory approaches. The present study is an example of how this might work. Due to the high profile of the LMN, meetings were held between DFO and the LMN, and the LMN were asked to provide input (B. Wood, LMN, pers. comm.). Thus it seems clear that concern and awareness must exist at a very local level in government if legislation is to be at all effective.

R. J. GIBSON



Charlottetown Brook, on the Charlottetown Access Road, Trans Labrador Highway. Depth < 1 cm, with a drop of 35 cm on to rocks. About ¾ of the flow was under the culvert.

As a result of the research conducted for this study, careful measurements of installed stream crossings have been made by DFO in co-operation with the LMN, and poorly constructed stream crossings will be improved (five culverts were remedied in 2003). The fish habitat component of the EIS for Phase III was reviewed and considered unsatisfactory. Many of the previously planned stream crossings for Phase III of the TLH were not approved. Better stream crossings designs have since been developed, and careful monitoring of the installations will be made by DFO and the LMN. The local Innu also are involved in implementing the improvements in Phase III. Thus it takes more than good academic science to raise awareness.

We believe that this study component of the Coasts Under Stress project, in collaboration with the LMN, highlights the problem of small stream habitat loss associated with highway construction in North America and elsewhere, and hope will lead to a more competent treatment of sensitive and crucial waterways in the future.

Conclusion

More than half of the stream crossings in our sample had substantially deleterious effects on salmonid migration and habitat. The culverts were inappropriately designed or not installed properly and in accordance with DFO guidelines. When we allow for the significant variation in stream crossing construction costs, it seems clear that cost considerations play a major role in design choices, particularly when considering that the department of the provincial government responsible for construction uses cost effectiveness as the criterion in selecting the design on a given stream. That is, the department is mandated to minimize the cost of the installation subject to certain constraints such as the guidelines for habitat protection issued by DFO. Our study leads us to conclude that environmental (habitat) concerns are nevertheless frequently ignored or neglected. We conjecture that the reason for this is that cost factors in conjunction with a lack of awareness of the role played by small streams, and in some cases large river crossings, by both levels of government combine to jeopardize salmonid habitat to a far greater extent than commonly believed. The importance of local stewardship in implementing conservation is demonstrated by the results of our study and the consequential informed pressures from the LMN.

Acknowledgements

We acknowledge the support from the "Coasts Under Stress" Project, and wish to thank the Social Sciences and Humanities Research Council of Canada (SSHRC), and the Natural Sciences and Engineering Research Council of Canada (NSERC) which have provided the major funds for the "Coasts Under Stress" Project through the SSHRC Major Collaborative Research Initiatives (MCRI) program. The cooperation of the Labrador Métis Nation is appreciated, and especially of Rebecca J. Luther, fishery guardian, LMN, who guided us to all locations and assisted with all measurements.

References

Anderson, T. C. 1985. The rivers of Labrador. Canadian Special Publication of Fisheries and Aquatic Sciences 81.

Augerot, X. 2004. Salmon stocks and habitat in the Russian Far East. Pages 77-88 *in* P. Gallaugher and L. Wood, eds. Proceedings of the World Summit on Salmon, June 10-13, 2003. Simon Fraser University, Burnaby, British Columbia, Canada.

Bates, K. M, R. J. Barnard, B. Heiner, J. P. Klavas, and **P. D. Powers.** 2003. Design of road culverts for fish passage. Washington Department of Fish and Wildlife, Olympia.

Brett, J. R. 1967. Swimming performance of sockeye salmon (*Oncorhynchus nerka*) in relation to fatigue time and temperature. Journal of the Fisheries Research Board of Canada. 24:1731-1740.

Briffett, D., W. Camp, J. Jones, and **P. King.** 1987. A study of culvert obstructions on the Avalon Peninsula. Report for the Salmon Association of Eastern Newfoundland, St. John's.

Chestnut, T. J. 2002. A review of closed bottom stream crossing structures (culverts) on fish-bearing streams in the Kamloops Forest District, June 2001. Canadian Manuscript Report of Fisheries and Aquatic Sciences 2602.

Crisp, D. T. 2000. Trout and salmon: ecology, conservation and rehabilitation. Fishing News Books, Blackwell Science Ltd., Oxford, U.K.

Cunjak, R. A. 1992. Comparative feeding, growth and movements of Atlantic salmon (*Salmo salar*) parr from riverine and estuarine environments. Ecology of Freshwater Fish 1:26-34.

Cunjak, R. A., E. M. P. Chadwick, and **M. Shears.** 1989. Downstream movements and estuarine residence by Atlantic salmon parr (*Salmo salar*). Canadian Journal of Fisheries and Aquatic Sciences. 46:1466-1471.

Curry, R. A., S. Allen, M. G. Fox, and **G. E. Morgan.** 1993. Growth and food of young-of-the-year brook charr, *Salvelinus fontinalis*, in lake and creek environments. Environmental Biology of Fishes 37:131-138.

Curry, R. A., C. Brady, D. L. G. Noakes, and **R. G. Danzmann.** 1997. Use of small streams by young brook trout spawned in a lake. Transactions of the American Fisheries Society 126:77-83.

Dryden, R. L., and **C. S. Jessop.** 1974. Impact analysis of the Dempster Highway

culvert on the physical environment and fish resources of Frog Creek. Environment Canada, Technical Report Series CEN/T-74-5.

Dryden, R. L., and **J. N. Stein.** 1975. Guidelines for the protection of the fish resources of the Northwest Territories during highway construction and operation. Environment Canada, Technical Report Series CEN/T-75-1.

Erkinaro, J., and **R. J. Gibson.** 1997. Interhabitat migration of juvenile Atlantic salmon in a Newfoundland river system, Canada. Journal of Fish Biology 51:373-388.

Erkinaro, J., M. Julkunen, and **E. Niemelä.** 1998. Migration of juvenile Atlantic salmon *Salmo salar* in small tributaries of the subarctic River Teno, northern Finland. Aquaculture 168:105-119.

Erkinaro, J., and **E. Niemelä.** 1995. Growth differences between the Atlantic salmon parr, *Salmo salar*, of nursery brooks and natal rivers in the River Teno watercourse in northern Finland. Environmental Biology of Fishes 42:277-287.

Erkinaro, J., J. B. Dempson, M. Julkunen, and **E. Niemelä.** 1997. Importance of ontogenetic habitat shifts to juvenile output and life history of Atlantic salmon in a large subarctic river: an approach based on analysis of scale characteristics. Journal of Fish Biology 51:1174-1185.

FAO (Food and Agriculture Organization of the United Nations, European Inland Fisheries Advisory Commission). 2002. Report of the Symposium on Inland Fisheries Management and the Aquatic Environment. FAO Fisheries Report 681, Suppl.

Flanders, L. S., J. Cariello. 2000. Tongass road condition survey report. Alaska Department of Fish and Game Technical Report 00-7.

Gibson, R. J. 2002. The effects of fluvial processes and habitat heterogeneity on distribution, growth and densities of juvenile Atlantic salmon (*Salmo salar* L.), with consequences on abundance of the adult fish. Ecology of Freshwater Fish 11:207-222.

Gibson, R. J., T. R. Porter, and **K. G. Hillier.** 1987. Juvenile salmonid production in the Highlands River, St. George's Bay, Newfoundland. Canadian Technical Report of Fisheries and Aquatic Sciences 1538.

Glen, D. J. 2002. Recovery of salmon and trout following habitat enhancement works: review of case studies 1995-2002. Pages 93-112 *in* Proceedings of the 13th International Salmonid Habitat Enhancement Workshop, Westport, Co. Mayo, Ireland. Irish Freshwater Fisheries Ecology and Management Series, Central Fisheries Board, Dublin, Ireland.

Gosse, M. M., A. S. Power, D. E. Hyslop, and **S. L. Pierce.** 1998. Guidelines for protection of freshwater fish habitat in Newfoundland and Labrador. Fisheries and Oceans, St. John's, NF.

Harper, D. J., and **J. T. Quigley.** 2000. No net loss of fish habitat: an audit of forest road crossings of fish-bearing streams in British Columbia, 1996-1999. Canadian Technical Report of Fisheries and Aquatic Sciences 2319.

Huntsman, A. G. 1945. Migration of salmon parr. Journal of the Fisheries Research Board of Canada 6:399-402.

Hynes, H. B. N. 1970. The ecology of running waters. University of Toronto Press, Toronto.

Jacques Whitford Environment Limited. 1998. Trans Labrador Highway (Red Bay to Cartwright) Environmental Assessment. JWEL Project No. 1152. St. John's, Newfoundland and Labrador.

Jepsen, N., K. Aarestrip, F. Okland, and **G. Rasmussen.** 1998. Survival of radio-tagged Atlantic salmon (*Salmo salar* L.) and trout (*Salmo trutta* L.) smolts passing a reservoir during seaward migration. Hydrobiologia 371/372:347-353.

Jones, D. R., J. W. Kiceniuk, and **O. S. Bumford.** 1974. Evaluation of the swimming performance of several fish species from the MacKenzie River. Journal of the Fisheries Research Board of Canada 31:1641-1647.

Jonsson, B., and **N. Jonsson.** 2003. Migratory Atlantic salmon as vectors for the transfer of energy and nutrients between freshwater and marine environments. Freshwater Biology 48: 21-27.

Langill, D. A., and **P. J. Zamora.** 2002. An audit of small culvert installations in Nova Scotia: habitat loss and habitat fragmentation. Canadian Technical Report of Fisheries and Aquatic Sciences 2422.

Larson, D. J. 1976. Stream habitat and forest harvesting. Fisheries Technical Report 76-3. Saskatchewan Fisheries Laboratory, Department of Tourism and Renewable Resources, Saskatoon.

McClellan, T. J. 1970. Fish passage through highway culverts; a field evaluation. Fed. Highway Administration, Region 8 and Oregon State Game Commission, Portland, Oregon.

McDonald, D. G., W. J. McFarlane, and **C. L. Milligan.** 1998. Anaerobic capacity and swim performance of juvenile salmonids. Canadian Journal of Fisheries and Aquatic Sciences 55:1198-1207.

Parrish, D. L., R. J. Behnke, S. R. Gephard, S. D. McCormick, and **G. H. Reeves.** 1998. Why aren't there more Atlantic salmon (*Salmo salar*)? Canadian Journal of Fisheries and Aquatic Sciences. 55 (Suppl. 1): 281-287.

Poulin, V. A., and **H. W. Argent.** 1997. Stream crossing guidebook for fish streams. V. A. Poulin and Associates, Vancouver, B.C.

Powers, P. D., K. Bates, T. Burns, B. Gowen, and **R. Whitney.** 1997. Culvert hydraulics related to upstream juvenile salmon passage. Washington Department of Fish and Wildlife, Olympia.

Robertson, M. J., K. D. Scruton, and **J. A. Brown.** 2003. Interhabitat and instream movements of large Atlantic salmon parr in a Newfoundland watershed in winter. Journal of Fish Biology 63:1208-1218.

Scruton, D. A., R. S. McKinley, R. K. Booth, S. J. Peake, and **R. F. Goosney.** 1998. Evaluation of swimming capability and potential velocity barrier problems for fish. Part A: Swimming performance of selected warm and cold water fish species relative to fish passage and fishway design. CEA Project No. 9236 G 1014, Montreal, Quebec.

Thonney, J. P., and **R. J. Gibson.** 1989. Feeding strategies of brook trout (*Salvelinus fontinalis*), and juvenile Atlantic salmon (*Salmo salar*), in a Newfoundland river. Canadian Field Naturalist 103:48-56.

Vaughan, D. M. 2002. Potential impact of road-stream crossings (culverts) on the upstream passage of aquatic macroinvertebrates. U.S. Forest Service Report, San Dimas, California.

Warren, M. L., and **M. G. Pardew.** 1998. Road crossings as barriers to small-stream fish movement. Transactions of the American Fisheries Society 127:637-644.

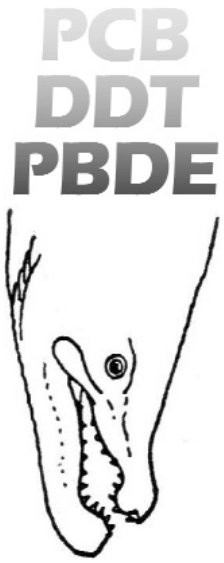
Wightman, J. C., and **G. D. Taylor.** 1976. Salmonid swimming performance in relation to passage through culverts. Victoria, British Columbia: Fish Habitat Improvement Section, Fish and Wildlife Branch, Ministry of Recreation and Conservation: 1-53.

Williams, D. D., and **B. W. Feltmate.** 1992. Aquatic insects. C.A.B. International, Wallingford, U.K.

Salmon Carcass Deployment: A Potential Pathway for PCB Contamination

Brian Missildine

Missildine is a fish and wildlife biologist at the U.S. Fish and Wildlife Service in Lacey, Washington and a graduate student at The Evergreen State College. He can be reached at cohophysh@yahoo.com.



The views of the author do not necessarily reflect the views of his agency.

Salmon carcass planting throughout the Pacific Northwest has become an important component in salmonid habitat restoration that is supported by local, state, and federal agencies. Several authors have shown the benefits of decaying salmon carcasses to the stream environment (Bilby et al. 1996; Cederholm et al. 1999; Cederholm et al. unpublished data; Helfield and Naiman 2001). Cederholm et al. (1999) stated salmonids are a major source of marine-derived nutrients to the aquatic and terrestrial landscape. Bilby et al. (1996) found that many aquatic invertebrates and streamside plants were enriched with marine-derived nutrients from coho salmon (*Oncorhynchus kisutch*) carcasses. However, none of the authors discuss the potential of recontamination of the environment with polychlorinated blphenyls (PCBs) or other persistent organic pollutants such as polybrominated diphenyl ether (PBDE; fire retardants) and dichlorodiphenyltrichloroethane (DDT) from planting salmon carcasses.

I could not find any published reports which evaluate the influence of salmon carcass deployment on pollutant reintroduction to stream ecosystems. However, PCB concentrations in the water column (O'Toole; Trent University, Peterborough, Ontario, unpublished data), and in the sediment (Krummel et al. 2003) have increased following natural spawning. O'Toole (unpublished data) found an increase in PCB concentrations in the water column of the Credit River from post-spawned Chinook salmon (*O. tshawytscha*). Krummel et al. (2003) found that PCBs concentrations in the sediment of Alaskan lakes increased seven-fold upon the return of adult sockeye salmon (*O. nerka*). Puget Sound Ambient Monitoring Program (PSAMP 2000) data show that coho and Chinook salmon in the Pacific Northwest are contaminated with PCBs. These data suggest that PCB concentrations in rivers and streams in the Pacific Northwest may increase following carcass deployment.

Carcass deployment also may distribute PCBs to the terrestrial ecosystem. Decaying salmon carcasses are an important component of the terrestrial food web. Willson and Halupka (1995) indicate that over 20 mammalian and avian species combined are direct consumers of salmonid carcasses. The consumption of salmon carcasses contaminated with PCBs may be impacting survival rates of species that feed on salmon carcasses. Bowerman et al. (1995) indicated that bald eagles (*Haliaeetus leucocephalus*) birth rates and adult mortality in the Great Lakes region still may be impacted by consuming post-spawned salmon carcasses contaminated with PCBs. Buck et al. (1999) indicated that bald eagles from the lower Columbia River also were experiencing lower birth rates than bald eagles in other Northwest locations in association with PCB-contaminated prey sources. It is important to note in the two studies mentioned above, other environmental contaminants, may also contribute to the lower birth rates of bald eagles.

The carcass distribution program could be reintroducing PCBs and other persistent organic pollutants back into the environment at unknown levels. Currently, fish in the carcass distribution program are tested for disease and viruses but not contaminants. No research to date is occurring to determine if the PCBs in salmon carcasses are having an impact on other Pacific Northwest fish and wildlife species that feed on these carcasses. Testing thousands of carcasses that are planted into streams and rivers each year would be cost prohibitive and time consuming. However, I believe it is worth the time and effort to at least sample a sub-set of carcasses. Other alternatives such as organic pellets or seeding the streams and rivers could be an effective means of delivering marine-derived nutrients to the ecosystem, but may not be as efficient as carcass deployment and may pose other unknown risks. Some may argue that naturally-spawning fish are already contaminated, so what difference does it make whether we plant contaminated carcasses or not? I would argue that many of the salmon deployment projects are located in streams with very few returning salmon and therefore would potentially have extremely low concentrations of PCBs and other persistent organic pollutants.

Managers and scientists need to determine whether the benefits of marine-derived nutrients outweigh the detrimental impacts associated with PCBs. Planting carcasses will most likely result in the introduction of PCBs (or the increase of PCBs, for streams that already have naturally-spawning salmon), along with other toxic chemicals, into the environment where they might not currently be found. Although contamination would still occur by the die-off of natural spawners if the carcass deployment programs were discontinued, natural spawners also would still provide marine-derived nutrients to the ecosystem, albeit not at historic levels. Technological

advances may be able to duplicate the marine-derived nutrients without the increased risk of contamination, or less contaminated stocks such as those from the coast of Washington (Missildine, in press) could be used for carcass deployment.

This is a very serious question that I believe has been overlooked and needs immediate attention. I recommend that we, as scientists and managers, start a dialogue to determine where we go from here, especially with the recent discovery of PBDEs (fire retardants) in salmon from the Puget Sound (O'Neill, Washington Department of Fish and Wildlife, Olympia, pers. comm.).

Literature Cited

Bilby, R. E., B. R. Fransen, and **P. A. Bisson.** 1996. Incorporation of nitrogen and carbon from spawning coho salmon into the trophic system of small streams: evidence from stable isotopes. Canadian Journal of Fisheries and Aquatic Sciences 53:164-173.

Bowerman, W. W., J. P. Giesy, D. A. Best, and **V. J. Kramer.** 1995. A review of factors affecting productivity of bald eagles in the Great Lakes region: implications for recovery. Environmental Health Perspectives 103(S4).

Buck, J., R. G. Anthony, and **F. B. Issacs.** 1999. Changes in productivity and environmental contaminants in bald eagles nesting along the lower Columbia River. Miscellaneous report. U.S. Fish and Wildlife Service, Portland, Oregon.

Cederholm, C. J., M. D. Kunze, T. Murota, and **A. Sibatani.** 1999. Pacific salmon carcasses: essential contributions of nutrients and energy for aquatic and terrestrial ecosystems. Fisheries 24(10):6-15.

Helfield, J. M., and **R. J. Naiman.** 2001. Effects of salmon-derived nitrogen on riparian forest growth and implications for stream productivity. Ecology 82(9):2403-2409.

Krummel, E. M., R. W. MacDonald, L. E. Kimpe, I. Gregory-Eves, M. J. Eaves, M. J. Demers, J. P. Smol, B. Finney, and **J. M. Blais.** 2003. Aquatic ecology: delivery of pollutants by spawning salmon. Nature 425:255-256.

Missildine, B. R. In press. PCB concentrations in adult Chinook salmon returning to coastal and Puget Sound hatcheries. Masters thesis, The Evergreen State College, Olympia, WA.

PSAMP (Puget Sound Ambient Monitoring Program). 2000. 2000 Puget Sound update: Seventh report of the Puget Sound Ambient Monitoring Program. Puget Sound Water Quality Action Team, Olympia, WA.

Willson, M. F., and **K. C. Halupka.** 1995. Anadromous fish as keystone species in vertebrate communities. Conservation Biology 9(3):489-497.

Fish and Watershed Program Review: USDA Forest Service

Introduction

In the public's trust, the U.S. Department of Agriculture's (USDA) Forest Service manages 155 National Forests across the country, making up nearly 200 million acres of lands and waters. This national legacy includes 220,000 miles of streams, over 2 million acres of lakes, and 15,000 miles of coastline—some of the more significant and valuable fisheries and aquatic resources in the nation.

These fisheries and aquatic resources on National Forests contribute substantially to our local and national economies, help conserve our country's aquatic biodiversity assets, and provide ready accessibility to some of the best sport fishing in the United States.

Rivers, streams, and lakes on National Forests contain viable—and in some cases, the only extant populations of endangered aquatic species. Additionally, National Forests provide important aquatic biodiversity reserves. For example, National Forests in the Tennessee-Cumberland River Basins and the Mobile basins contain 35% of all vulnerable and imperiled fish and mussel species in the nation, 70% of which occur nowhere else in the world.

In 1996, there were nearly 47 million user-days dedicated to sportfishing on National Forests, generating $8.5 billion in local economic impact. As access to private land becomes increasingly restricted, especially near ever-expanding urban areas, National Forests play a significantly increased role in providing the public sportfishing access and opportunity.

Background

In 1987, the Forest Service launched the Rise to the Future initiative that resulted in more effectively managed fisheries and other aquatic resources, and better promotion of sportfishing. With strong support from Congress, the agency dramatically increased its fisheries and aquatic staffing, program funding, and effectiveness. Peak staffing and funding occurred in the mid- to late-1990s. Since then, the Forest Service's emphasis on fisheries and aquatic programs has weakened with subsequent declines in staffing and funding.

Since the initiation of the 1987 Rise to the Future initiative, there have been significant advances in fisheries and aquatic resource science, and increased complexity in resource management. These changes prompted organizational realignments within the agency, such as the 2001 transition to combine the Washington Office's fisheries and watershed staffs.

Responsibilities of field fisheries and watershed professionals also have changed dramatically. For example, the primary focus used to be resource protection and tactical mitigation for aquatic resources. Today fieldwork requires extensive consultation with regulatory agencies, and development and implementation of strategies for the protection and restoration of watershed processes and native aquatic species. At the time of the original Rise to the Future initiative, there were few fish species listed as threatened or endangered. Today, many salmon stocks in the West, most native fishes in the Southwest, and large numbers of native aquatic fauna in the Southeast, including fishes, mussels, and crayfishes, are listed under the Endangered Species Act.

For much of the 1980s and early 1990s, the focus of the Forest Service's aquatic habitat management was local in nature: erosion control structures, fish habitat structures, and fish passage solutions were high on the list of accomplishments. Today, the focus of fisheries and aquatic resource management is to implement tactical treatments on a strategic basis. Maintaining the long-term natural watershed processes that create and maintain in-stream and in-lake habitat at the appropriate scale and time frame is a primary concern. The move from localized projects to understanding and integrating ecological processes into land management prescriptions at the watershed scale is a complex challenge. Integrating a number of staff skills from watershed, soils, hydrology, and fisheries is essential to effectively meet current and future management challenges that reach beyond forest boundaries. In addition, interest in sportfishing and other recreation on National Forests continues to increase and challenge Forest Service staff.

Because many aquatic species of concern spend a portion of their lives off National Forest lands, efforts to conserve native fish communities and their habitats must include collaborative efforts with private landowners and managers. This necessitates the formation of basin-wide partnerships with land managers representing state, tribal, private, and conservation organizations. Today, partnerships are no longer just opportunities; they are

Virgil Moore
Fred Harris
David Cross

Moore is chief of fisheries, Idaho Department of Fish and Game, Boise, and he can be reached at vmoore@idfg.state.id.us. Harris is deputy director of the North Carolina Wildlife Resources Commission, Raleigh. Cross is national fisheries program leader at the USDA Forest Service, Washington D.C.

This article is adapted from the Official USDA Forest Service Report, 2004, Report to the Chief—USDA Forest Service, Rise to the Future Task Force 2003. Fisheries and Watershed Program, FS-802.

Hutton scholar Erin Grinde and Forest Service mentor Mary Faurot sample fish in Idaho. The Hutton Scholarship program is assisting the Forest Service to insure a diverse pool of candidates for future positions.

necessary to define strategic vision and to implement effective fisheries and watershed resource management.

In 2002, representatives of FishNet, an affiliation of more than 20 fishery organizations, including AFS, met with Forest Service Chief Dale Bosworth and suggested a Task Force evaluation of the Rise to the Future Initiative to help guide revitalization of the agency's fisheries and aquatic resource programs. Chief Bosworth concurred with the formation of a task force and asked that the findings and recommendations be reported back to him and the National Leadership Team of the Forest Service. The team conducted field reviews and staff interviews in Region 2 (Colorado and Wyoming), Region 6 (Oregon and Washington), and Region 8 (Southeast United States).

The recommendations in this report address programmatic and strategic objectives, accountability, and staffing and institutional investments needed to ensure the USDA Forest Service can fulfill its stewardship responsibilities and reach its full potential to lead fisheries and aquatic resource management and continue to provide exceptional outdoor recreational opportunities.

Task Force Findings and Recommendations

The 2003 Task Force interacted with Forest Service and community leaders, fisheries and watershed program managers, scientists, and partners across the country. Forest Service staff exhibited extraordinary dedication, pride, commitment, and creativity in implementing their complex fisheries and watershed resource program responsibilities. The team also found that obligations far exceeded staffing capacities, which have resulted in staff frustration at missed opportunities and procedural burdens.

Strategic Planning and Accountability

The fisheries and watershed program budgets have been declining in effective dollars since the mid-1990s. The tie between national and regional strategic goals and the budget is weak. Partners and agency managers cannot readily track budget allocations, expenditures, and accomplishments. Partner contributions are not included within the measure of accomplishments.

A key to the success of the agency's fish and watershed programs is developing strategic goals with accountability systems linked to performance and budget. Past efforts to establish integrated strategic goals and objectives for these resource programs have not resulted in an agency-supported strategy. Currently the lack of strategic objectives and performance accountability systems is resulting in the implementation of projects in a random and somewhat opportunistic basis with little linkage to the agency's or partners' highest priorities.

Outcome: Clear and integrated strategic objectives for fisheries and watershed management are essential components of the agency's strategic plan. Agency employees and partners are knowledgeable and engaged in the implementation and measurement of progress on these objectives.

Recommendations:

Strategic Objectives

1. Develop a Federal Advisory Committee Act (FACA) chartered Sportfishing and Aquatic Resource Council to assist in strengthening strategic objectives, priorities, and performance measures at multiple levels within the Forest Service, and to provide advice to the Chief of the Forest Service and the Secretary of Agriculture. This council, consisting of major partners, will provide advice on strengthening partnerships and marketing opportunities for the agency's fisheries and watershed programs.
2. Clearly articulate national fisheries and watershed program priorities to ensure field-level efforts are focused on addressing issues of national scope and importance, including the provision of sportfishing opportunities.

Rise to the Future Task Force members observe the release of native darters, part of a supplementation effort by the Forest Service, FWS, and Conservation Fisheries, Inc., in Tennessee.

Budget

1. Increase the accountability of the fisheries and watershed budgets and their resource accomplishments by providing strong national program oversight. Combine the fisheries and watershed budget line items to provide program accountability and strengthen support from partners. Provide adequate funding to the national program and regional leaders for program oversight and consistent implementation of selected national priorities at national, regional, and forest levels.
2. Improve the coordination of budget development and allocation with national and regional program leaders and field units to ensure a focus on priorities. The budget process needs to be adjusted to reflect national and regional priorities.
3. Display funding levels and outputs for out-year budgets for the national fisheries and aquatics program. National and regional program leaders should be able to clearly delineate outputs to stakeholder groups to allow for greater leverage in long-term projects, programs, and partnerships.

Accountability

1. Include measures of success for strategic objectives for all fisheries and watershed program work.
2. Prepare an annual "stockholder" report that highlights program accomplishments, and provides an assessment of progress toward the goals. Ensure this information is shared appropriately with partners and at all agency levels.
3. Invite FishNet to continue conducting annual regional assessments of the fisheries and watershed programs to complement this national assessment. A comprehensive review of the programs by agency and FishNet representatives should be conducted at 5-year intervals.

Program Leadership

Effective leadership and advocacy of the fisheries and watershed programs by the Forest Service top leadership (chief, national leadership team, director, and national program directors and leaders) is essential to program success. Identifying and developing future leaders with fisheries and watershed knowledge and experience will allow sustained program success. Fiscal constraints, low levels of new hiring, and declining training programs are jeopardizing the agency's ability to develop such leaders for the future. Sportfishing and clean water to support recreation are among the most important economic engines of National Forests, yet the profile of agency leaders on these issues is relatively low.

Outcome: Agency leaders are recognized as advocates of the fisheries and watershed programs. Potential program leaders with fisheries and watershed knowledge and experience are identified and provided with development opportunities to ensure effective future leadership.

Recommendations:

1. Develop a strategy for agency leaders' involvement in national fishery events such as the American Fisheries Society's Annual Meeting, International Association of Fish and Wildlife Agencies annual conference, Trout Unlimited's annual meeting, North American Wildlife and Natural Resources annual conference, and the American Sportfishing Association's Sportfishing Summit.
2. Convene an aquatics leadership forum in partnership with the fisheries community to identify opportunities for advancing fisheries and watershed health on National Forests.

Sportfishing on the National Forest System

National Forests lands provide more fishable waters than lands managed by any other federal resource management agency. Each year, sportfishing on Forest Service lands conservatively contributes more than $8.5 billion to the nation's economy and provides 47 million days of angler recreation. The Forest Service is positioned to be even more of a national leader in providing quality sportfishing.

The President's Executive Order on Recreational Fishing emphasizes the importance of federal agencies' role in providing sportfishing opportunities. While sportfishing use has markedly increased on National Forests, the agency's public use and economic data are outdated and significantly underestimate visitation and participation. Inadequate investments in sportfishing continue to result in low emphasis on increasing sportfishing opportunities. In addition, limited staffing, limited funding, and increased Endangered Species Act-related work are decreasing the agency's ability to promote important sportfishing opportunities. The integration of sportfishing and other aquatic resource needs into the agency's strategic planning has been weak.

On issues related to recreation, fisheries, and aquatic resources, program managers often operate independently. This uncoordinated approach limits the ability to integrate sportfishing projects with other projects. Program efforts should focus on maximizing the efficiencies and benefits from a team approach.

The use of Sikes Act funding agreements with states for conservation and rehabilitation programs was observed to be highly variable across the country. In addition, many opportunities to strengthen the working relationship with states through cooperative agreements designed to improve sportfishing, stream habitat, stream access, and facilities have not been maximized.

Outcome: The Forest Service is recognized as an outstanding provider of sportfishing opportunities. Information on sportfishing opportunities is readily available in multiple media formats and sportfishing facilities are provided to meet the demands of anglers.

The Forest Service annually participates with our partners in National Fishing and Boating Week with hundreds of events around the country to introduce youngsters to the wonders of fishing and boating. Fishing ethics and aquatic conservation are important messages that youngsters receive at these annual events.

Recommendations:

1. Use sportfishing opportunities to build local coalitions to accomplish broader aquatic resource management objectives.
2. Revise the current RecFish web site (www.fs.fed.us/fishing/) to present sportfishing information in a manner that is easily understood and is directly accessible from a single web address and from the Forest Service home page.
3. Develop stronger cooperative relationships with state fish and wildlife agencies for the management of sportfishing on National Forests. Cooperatively work with the American Sportfishing Association and the International Association of Fish and Wildlife Agencies to increase the participation of states in Sikes Act programs. In coordination with state fish and wildlife agencies, ensure the Forest Service's strategic and operational plans (National Forest Plan revisions) include strong linkages to sportfishing opportunities on National Forests.
4. Develop educational materials to promote public understanding of aquatic resource conservation and the connection to sportfishing. Leaders for recreation and fisheries programs should jointly develop with partners shared performance expectations for improving sportfishing and providing conservation information, facilities, and fishing opportunities on the National Forest System.
5. Work with partners such as the Recreational Boating and Fishing Foundation and state fish and wildlife agencies to develop and implement a marketing strategy for sportfishing opportunities on National Forests.

Staffing and Professional Development

Fisheries staffing has declined by 20 full-time employees (FTEs) since 1996, reversing a staff-building trend that began with implementation of Rise to the Future in 1987. Considerable progress was achieved since the initiative began, but the decline in fisheries and watershed staffs in key areas threatens the maintenance of critical mass. Meanwhile, workloads are increasing in volume and complexity, training and professional development are low, distribution of skills is inconsistent, and the advancement track is unclear.

Outcome: Agency staffing is of sufficient size and distribution to address current and projected workloads for fisheries and aquatic resources management, creating an environment with a high premium on professional development and leadership advancement for a skilled and motivated workforce.

Recommendations:

1. Complete a needs assessment for fisheries management and aquatic research. This assessment should identify current staff capacity as well as project future staffing needs. The needs assessment would determine and recommend technical and leadership skill levels for effective fisheries and watershed management on public lands in the future.
2. Conduct an analysis for the appropriate use of the Cooperative Education Program to meet current and projected needs.
3. Implement a comprehensive training program to provide staff with skills required for competency in core work performance areas. Include mentoring as a component of this training program.
4. Ensure that the fish and watershed program needs assessment includes adequate staff time for the collection and management of information.
5. Based on the needs assessment, develop a strategy for funding and staffing of the fisheries and watershed programs, including a response to declining trust funds and use of alternative funding streams.

Development and Use of Aquatic Information

Science-based decision making is critical to successful accomplishment of the agency's mission. To strengthen the agency's decision-making process, comprehensive, high quality data and scientific assessments are essential. Currently an inventory of aquatic systems lacks sufficient frameworks and standards to identify appropriate sampling priorities, consistency, and comprehensiveness. This undermines the ability of agency decision makers to base their conclusions on sound science. Much of the data gathered on aquatic habitats and biota are not available in an electronic format that partners can access. This results in inadequate and incomplete information being available on forest resources and duplication of data collections performed by partners. This is a chronic problem across many agencies in the United States but is compounded in the Forest Service from the lack of consistent annual reporting. The Forest Service Natural Resource Information System (NRIS) is designed to remedy this issue but there is skepticism in the field that resources will be available for completion and maintenance of the database

Watershed analysis provides foundational information for better project design and implementation. Currently watershed analysis is variable across the agency in quality, cost, products, and expectations. Completions of basin-wide assessments are critical to long-term agency success.

The aquatics, watershed, and air research programs in the Forest Service have achieved national renown. The linkage between National Forest managers and Forest Service researchers to prioritize, develop, and use aquatic science within the agency is variable but generally low. Large-scale research of environmental issues, a Forest Service strength, is particularly valuable because of the difficulty for universities and private research institutions to fund and sustain research of that magnitude. Support for this type of research is declining, yet it is essential for land managers.

Outcome: Agency managers and partners are using consistent, comprehensive, high quality aquatic data. Watershed analysis is an integral tool for informing project managers of the comprehensive array of actions from which to develop projects. The aquatics and watershed research programs are fully supported, and appropriate methodologies are applied in the agency's management of aquatic resources.

Recommendations:

Information management

1. Develop and implement a strategy to comprehensively inventory aquatic systems on National Forests.
2. Ensure the completion of the aquatics portions of NRIS as the corporate database for the agency. Improve field staffs' understanding and commitment to update and use the NRIS databases.
3. Complete reviews at the national and regional levels to assure consistency of inventory data and management of information resources.

4. Develop and issue national and regional direction on the use of watershed analysis as an essential tool in project development. Provide adequate flexibility in implementation to ensure the level of analysis is commensurate with the scale of the project being implemented.
5. Develop standards and sampling methods for inventory and data management.

Research

1. Develop a regular briefing schedule for line managers and field staff summarizing major research products, and highlighting successful implementation and impacts to resource management.
2. Include partners, agency line officers, and fisheries and watershed program leaders in the identification and implementation of priority research needs.
3. Create an advisory panel of selected partners from fisheries, biodiversity conservation, resource management, and research institutes that will evaluate fisheries and aquatic staffing and training needs, and implementation of research products to help refine the agency's research agenda. The committee may be a prototype that would be evaluated for expansion into a broader science advisory committee for the agency.

Partnerships

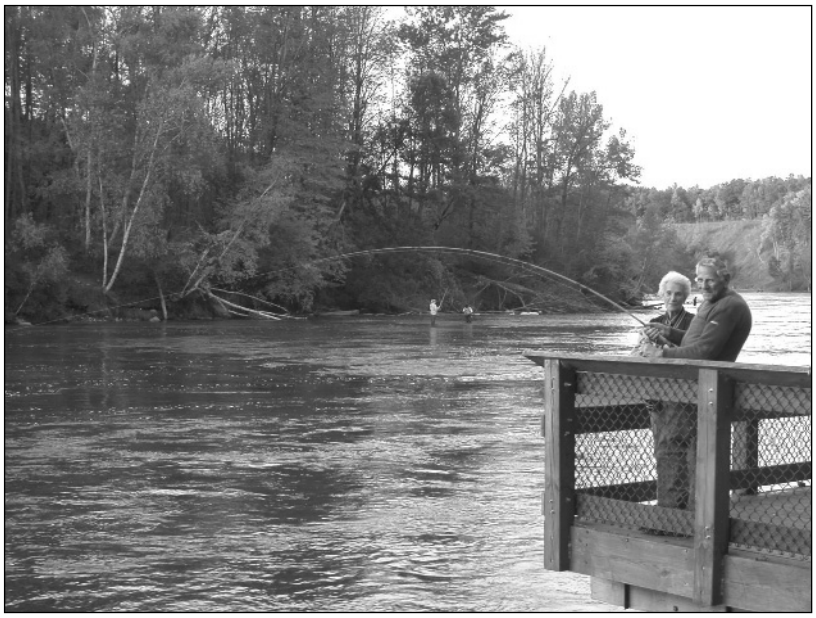
Partnerships have become an essential tool for the Forest Service to accomplish its fisheries and watershed program objectives. The number of partnerships has expanded greatly, but there are inconsistencies in the interpretation and application of policies to develop and maintain them. Partners are critical to accomplish work on National Forests, and especially for collaboration on private lands that will benefit forest habitat, fisheries, and endangered species.

In many areas of the West Forest Service funding, under the Wyden amendment authority, is used extensively to complete work in important mixed ownership watersheds containing both public and private lands. In other areas, the ability to complete similar work is limited by a lack of understanding of this authority and the flexibility it provides to work outside the traditional Forest Service boundaries.In many areas there is concern by partners and Forest Service employees about the agency's ability to sustain its partnership commitments and adequately involve partners in setting priorities for projects. Some partnerships no longer supplement a program but have become programs in themselves.

Outcome: Excellent relationships with fisheries, conservation, and aquatic resource management partners exist through expanded cooperative efforts. Agency employees and partners view partnerships as efficient and effective with minimal procedural burdens.

Recommendations:

1. Work with the Washington Office legislative affairs staff to develop language and justification for making Wyden Amendment authority permanent.
2. Continue the cooperative relationship with FishNet to improve the fisheries and watershed programs within the agency.
3. As a part of the needs assessment staffing analysis, ensure that partnership coordination and development are included as a part of the essential workload.
4. Complete and distribute the "National Partnership Guide" to improve the understanding and consistent application of the full range of relevant authorities.
5. Provide an accurate way to include partner contributions in the annual report of progress and accomplishments.
6. Further develop partnerships to address the public/private land and water matrix issues that are critical to fisheries and watershed resource management objectives.
7. Nationally recognize a partner each year for outstanding contributions to the Forest Service's fisheries program.



A barrier-free access point on the Manistee River in the the Huron-Manistee National Forests. One aspect of the Task Force review focused on recreational fishing access.

Endangered Species Act and Clean Water Act

Fifteen years ago, few aquatic species were listed as threatened or endangered under the Endangered Species Act. Today, many salmon stocks in the West, native fishes in the Southwest, and a significant percentage of native aquatic fauna, including fishes, crayfishes and mussels, in the Southeast are listed. The workload and complexity associated with the

conservation of listed aquatic species, and consultations with the regulatory agencies having oversight responsibilities, are overwhelming Forest Service fisheries and aquatics resources staff in some areas of the country, especially the West. The scope and scale of this impact is predicted to grow significantly.

The increasing number of listed aquatic species is a reflection of habitat fragmentation and the poor condition of many native aquatic species populations. Restoring populations of listed species and their habitats must be a high priority, often requiring coordinated work on Forest Service and private lands. Additionally, the Forest Service must ensure that Endangered Species Act and Clean Water Act tasks are carried out efficiently so that staff can accomplish other priorities, including the substantial watershed restoration work that must be done to recover listed species.

The Forest Service has developed and implemented policies designed to improve the resource conditions for fish and other aquatic species. Policies such as the aquatics portion of the Northwest Forest Plan, InFish, PACFish, and 4E authorities (Federal Power Act) have provided substantial habitat improvement and protection. During the upcoming Forest Plan revisions, similar or strengthened program policies will be needed to sustain those gains.

Agency fishery staff is effective in the management and recovery of aquatic endangered species. The Forest Service is actively implementing the Endangered Species Act; however, there is a concern by field biologists over increasing costs relative to benefits of the consultation processes. There is particular concern about aquatic restoration projects with potential short-term negative effects and long-term beneficial effects.

For example, consultation in the southern region of the Forest Service is working well, but there is concern that future issues, such as Section 7 consultations, may increase dramatically without associated increases in staff and other resources. In the Pacific Northwest, programmatic consultations are working well in some areas, such as culvert removals.

Outcome: High quality aquatic habitats on Forest Service lands support sensitive, threatened, and endangered species sufficient to ensure their recovery, and in the case of sportfish, to a level commensurate with state recreational management needs. Strong relationships with fishery management and regulatory agencies have resulted in streamlined methods that effectively implement the Endangered Species and Clean Water Acts.

The 2003 Rise to the Future Task Force included the following members:
Gordon Robertson, vice president, American Sportfishing Association
Jim Sedell, former director, Fish Wildlife and Watershed Research, USDA Forest Service
Sharon Heywood, forest supervisor, Shasta-Trinity National Forest
Chris Knopp, National Hydrology and Water Quality Program leader, USDA Forest Service (ex officio)
Dave Cross, National Fisheries Program leader, USDA Forest Service (ex officio)
Jim Gladen, former director, Fish Wildlife Watershed, Air and Rare Plants, USDA Forest Service
Brad Powell, former Region 1 regional forester
Fred Harris, deputy director, NC Wildlife Resources Commission
Steve Moyer, vice president for governmental affairs, Trout Unlimited
Not pictured:
Jonathan Higgins, senior ecologist, The Nature Conservancy
Dave Holland, director for recreation, USDA Forest Service
Virgil Moore, fisheries chief, Idaho Department of Fisheries and Game

Recommendations:

1. Explore, develop, and employ mechanisms (e.g., programmatic consultations) to improve efficiency of Endangered Species Act consultations, allowing faster coordination between Forest Service fisheries staff and their U.S. Fish and Wildlife Service and NOAA Fisheries counterparts.
2. Develop strong working relationships between Forest Service leadership and their counterparts in regulatory agencies, to facilitate consultation interactions between agency personnel.
3. Coordinate closely with conservation partners to develop and implement strategies to protect and restore threatened and endangered species on public and private lands.
4. Develop a strong relationship with state fish and wildlife agencies to meet sportfishing objectives for native fishes.

Summary

The watersheds and waters managed by the Forest Service address critical societal values such as the maintenance of aquatic communities, conservation of aquatic biodiversity, and provision of water-based outdoor recreational opportunities, which are important to local and national economies. National Forests are the source of about 80% of the nation's freshwater resources, providing high quality water to local communities throughout the country. For these reasons and others, the effective management of these national aquatic resources is of interest to us all.

The recommendations of the Task Force form a basis for the Forest Service to develop and implement a strategy that will improve its effectiveness in conserving our national aquatic legacy. We were impressed with the extraordinary dedication, pride, commitment, and creativity exhibited by the Forest Service staff in implementing the complex fisheries and watershed program responsibilities of the Forest Service. We suggest that an annual review of the agency's response to the Task Force recommendations by the American Fisheries Society would be beneficial, creating na adaptive management feedback mechanism to identifying successes and challenges to implementation.

Economic Growth, Fish Conservation, and the American Fisheries Society:

Introduction to a Special Series

We are pleased to introduce the special series, "Economic Growth, Fish Conservation, and the American Fisheries Society." The series stems from a symposium of the same title held at the 2004 American Fisheries Society (AFS) conference in Madison, Wisconsin. The symposium was well-attended and generated substantial discussion, prompting organizers and presenters to author the forthcoming articles. As with the symposium, this series will demonstrate the fundamental conflict between economic growth and fish conservation and provide suggestions for addressing that conflict.

Economic growth is an increase in the production and consumption of goods and services. It occurs when the product of population times per capita consumption is increasing. It is generally gauged by measures of national income such as gross domestic product (GDP) and gross national product (GNP). It is the most prominent policy goal in the domestic policy arenas of the United States, Canada, Mexico, and many other countries.

Brian Czech
Phil Pister

Czech is an adjunct professor, Virginia Polytechnic Institute and State University, Northern Virginia Center, Alexandria, and he can be reached at brianczech@juno.com. Pister is president of the Desert Fishes Council, Bishop, CA, and can be reached at phildesfish@besmug.org.

In recent years, natural resource professionals have developed a keen interest in the process, policies, and politics of economic growth. They recognize the desirable effects of economic growth, but their training in ecology and other natural sciences leads them to conclude that the production and consumption of human goods and services cannot increase without a simultaneous decrease in fish and wildlife populations. This conflict between human and nonhuman species is described by the ecological principle of competitive exclusion.

On the other hand, fish and wildlife biologists have been reticent to engage the public and polity on the issue of economic growth. Typically this reticence stems from the opinion that economic issues should be left to economists. We disagree with that opinion, partly because ecologists are the "economists of nature," dealing with the processes of production and consumption like "regular" economists, albeit with different species, foci, and jargon.

More importantly, most economists do not have the background in ecology and other natural sciences to accurately address the relationship of economic growth to fish and wildlife conservation. In fact, a large and burgeoning movement in academia called "ecological economics" has developed partly to address this shortcoming in conventional, or "neoclassical," economics.

Economics is a sweeping field in academia, business, and government. The vast majority of professional economists deal with microeconomic issues such as production trends, demand, and prices affecting a business, market, or sector. The small number of macroeconomists tend to be employed in private-sector investment firms or in the public sector as policy advisors. Very few have a focus on environmental protection, much less the more specific task of fish and wildlife conservation, nor would their conventional training suffice for a sophisticated assessment of the relationship of economic growth to fish and wildlife conservation. Neoclassical economists, micro and macro, typically opine that there is no practical limit to economic growth and, as a corollary, no inevitable conflict between economic growth and environmental protection (including fish and wildlife conservation).

Meanwhile, in the political community economic growth is a primary, perennial, and bipartisan goal. Corporations and other businesses have a vested interest in strong pro-growth policies because such policies maximize short-term profits and shareholder returns. Corporations and other businesses have a tremendous amount of influence in American policy-making because they control much of the national wealth and finance the major political campaigns. These business interests and their political affiliates are very influential in both fiscal policy (including budgets and tax codes) and monetary policy (including interest rates and banking regulations).

As a result of the political influence on economic policy as related to the environment, growth interests have gone further than simply denying a conflict between economic growth and the environment. Economists, politicians, and corporations argue that economic growth is actually necessary for environmental protection, including fish and wildlife conservation. This argument is based on a conceptual model called the "environmental Kuznets curve," which we and others addressed in a previous *Fisheries* column (Czech et al. 2004). The environmental Kuznets curve has a spurious reputation in microeconomics, but the natural sciences render it utterly fallacious in macroeconomics.

It is not within the scope of this introduction to elaborate upon the weaknesses of neoclassical economics, the tendencies of politicians to err on the side of economic growth, or the corporate involvement in

political economy. Nor will these weaknesses, tendencies, and involvements be within the scope of this series to a significant degree. A tremendous amount of literature is available on these and closely related topics, with the textbook on ecological economics by Daly and Farley (2003) providing a good summary. It bears repeating that this series will simply demonstrate the fundamental conflict between economic growth and fish conservation and provide suggestions for addressing that conflict.

We believe the fisheries profession can no longer remain silent on the topic of economic growth if it expects to succeed with the goal of fish conservation. We harbor no illusion that the AFS will replace the Council of Economic Advisors upon the completion of this series or that the American propensity to consume will significantly decline. However, for American democracy to work as applied to fish conservation, citizens will need to understand the trade-off between economic growth and fish conservation. They are not learning about this trade-off from neoclassical economists, politicians, or business interests, and in fact are led by these parties to believe there is no trade-off. Only with a basic understanding of the conflict between economic growth and fish conservation will they be empowered to make personal and political decisions conducive to an optimal amount of economic growth and, conversely, an optimal amount of fish conservation.

Fish biologists cannot lead the American public or its policy makers to face the trade-off between economic growth and fish conservation unless they themselves have a thorough understanding of the conflict. They will also need to develop the ability and confidence to communicate their understanding of the conflict in the vernacular (for the public) and, when necessary, by using keywords and phrases commonly used in the economic policy arena. We hope this series is helpful for these purposes.

We have begun the series by providing an ecologically macroeconomic perspective on the relationship of economic growth to fish conservation, and we can summarize that perspective in one sentence: Due to the tremendous breadth of the human niche, which expands via technological progress, the human economy grows at the competitive exclusion of fish and wildlife in the aggregate. For detailed information we refer readers to The Wildlife Society's technical review 03-1, *The Relationship of Economic Growth to Wildlife Conservation,* or, for an intermediate level of detail, the positions on economic growth taken by the North American Section of the Society for Conservation Biology, the U.S. Society for Ecological Economics, and The Wildlife Society.

None of this is to say, however, that microeconomics is irrelevant to fish conservation. Economists focusing on specific fisheries, products, and markets have made important contributions to fish conservation and fisheries management. An ecologically macroeconomic perspective serves as the essential paradigm from which to approach the issue of economic growth, but the toolkit we bring must include the nuts and bolts, wrenches, and pliers of microeconomics. Even in microeconomics, however, the neoclassical tradition lacks important ecological considerations. We need to upgrade our tools, and next month we hear from Lisi Krall on "The Ecological Microeconomics of Fisheries Conservation: a Response to Economic Orthodoxy."

With the theoretical foundations of ecological economics laid from macro and micro perspectives, the series will proceed with empirical evidence for the conflict between economic growth and fish conservation. Some of the most compelling evidence is found in the causes of fish species endangerment. "Economic Causes of Fish Endangerment in the United States" by Kelly Miller and Brian Czech will present these causes as an unmistakable "Who's Who" of the American economy.

At first glance, however, not all causes of fish endangerment are so obviously linked to economic growth. Invasive species, for example, are a major and growing threat. "The Economic Roots of Aquatic Species Invasions" by Jenny Ericson will demonstrate how species invasions are a function of international trade and interstate commerce, proliferating with the growth of national and global economies.

A special case of species invasions stems from the trade in live bait. The sheer volume of such trade may surprise readers and qualifies live bait as a distinct economic sector. Julie Thompson and Shawn Alam will report on this sector and its implications for fish conservation in "Live Bait Trade as a Vector for Aquatic Nuisance Species Introductions."

Another prominent economic sector with a direct impact on fish conservation is the production of animal protein for the table, fertilizer, and livestock feed. Christine Moffitt, a past president of AFS, has analyzed the development of this sector and her penetrating insights will be found in "Economic and Environmental Aspects of Animal Protein Production."

Another approach to analyzing the threats to fish conservation is to hone in on particular taxa or ecosystems. Phil Pister has long been a leader in desert fish ecology and conservation. His article, "Economic Sectors in Conflict with Desert Fishes," will highlight the distinct economic threats to desert species.

Another author to privilege our series is Robert Lackey, best known for documenting the causes of the long-term decline of wild salmon in western North America, along with offering straightforward assessments of policies that will determine the future of salmon. True to form in "Salmon Recovery: Reconciling Economic Growth and Conservation," he presents a no-nonsense analysis of society's choices for maintaining significant, sustainable runs of wild salmon in the Pacific Northwest. The heart of his message is that the trajectory of economic growth (including population growth) will have to change if wild salmon are to have much of a future.

There are similarly tough choices to be made if North American societies truly want to maintain significant populations of many fish species, and our series turns next toward future choices. Paul Angermeier is one of the rare fish biologists with outstanding academic credentials who has dared to adopt an advocatory stride toward the future. We find that refreshing and hopeful, and we think AFS readers will too in "Fisheries Biologists as Catalysts for Ecological and Economic Sustainability."

In addressing the issue of economic growth, the AFS will surely want to know what other professional societies have done or may do to help. As the executive director of the Society for Conservation Biology, Alan Thornhill is uniquely qualified to provide a look in "The Role of Professional Societies in Economic Growth Policy."

The Wildlife Society is a sister society to AFS and may be of particular interest to AFS members. The Wildlife Society has published a technical review on economic growth, taken a position on economic growth, and chartered a Working Group for the Steady State Economy. Ken Stromborg will report on these developments in "Recent Attempts by The Wildlife Society to Address the Issue of Economic Growth."

In many circles, the subject of economic growth invokes strong feelings and even heated debate. We hope the latter, at least, will not be the case with AFS, but at the outset we realize that some may not be inclined to accept the portent of our introduction. We ask only that readers keep an open mind, watch our series unfold, and draw conclusions (technical, philosophical, or political) after digesting the articles.

Surely our series will fall short of perfection, but we repeat our belief that there is a fundamental conflict between economic growth and fish conservation, and we think this belief will be widely shared by natural resources professionals in due time. We also believe AFS has a crucial, leading role to play in verifying and addressing this conflict, and we hope our series will assist AFS in these efforts. Much is at stake, not the least of which are fish and the fisheries profession.

References

Czech, B., P. Angermeier, H. Daly, P. Pister, and **R. Hughes.** 2004. Fish conservation, sustainable fisheries, and economic growth: no more fish stories. Fisheries Forum article. Fisheries 29(8):36-37.

Daly, H., and **J. Farley.** 2003. Ecological Economics Textbook: Principles and Applications. Island Press, Washington, DC.