Fisheries

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SEATTLE 2011

A Primer on Winter, Ice, and Fish: What Fisheries Biologists Should Know about Winter Ice Processes and Stream-dwelling Fish

Human Population Increase, Economic Growth, and Fish Conservation: Collision Course or Savvy Stewardship

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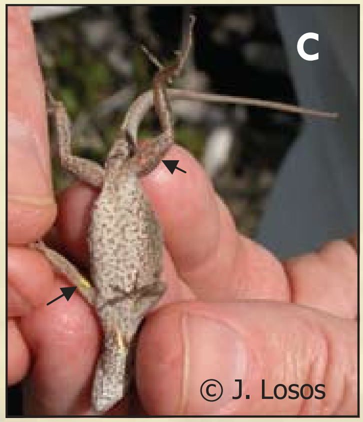

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301/897-8616 • fax 301/897-8096 • main@fisheries.org
The American Fisheries Society (AFS), founded in 1870, is the oldest and largest professional society representing fisheries scientists. The AFS promotes scientific research and enlightened management of aquatic resources for optimum use and enjoyment by the public. It also encourages comprehensive education of fisheries scientists and continuing on-the-job training.

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CREDIT: R. S. Brown.

COLUMN: PRESIDENT'S HOOK

Wayne Hubert
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New Frontiers in Fisheries Management and Ecology: Leadership in Collaboration and Coalition

The notion of working with others to achieve common goals, otherwise termed collaboration or coalition, has become widely accepted as means of enhancing the quality of scientific research and management of natural resources. The AFS is definitely a leader among professional societies in the implementation of collaboration and coalition.

Recall that the mission of the American Fisheries Society (AFS) is to advance sound science, promote professional development, and disseminate science-based fisheries information for the global protection, conservation, and sustainability of fishery resources and aquatic ecosystems. How can our relatively-small professional society of about 9,000 members enhance its ability to achieve the stated mission? A workable strategy is to align and partner with other professional societies having similar missions. Collaboration with societies focused on other aspects of natural resource management can create synergism and contribute to achievement of the long-term, broad-ranging goals of each society. With this in mind, the AFS joined in the development of the Coalition of Natural Resource Societies (CNRS) in 2009, largely through the efforts our Executive Director, Gus Rassam. The Coalition includes The Wildlife Society (TWS), the Society of Range Management (SRM), the Society of American Foresters (SAF), and the AFS. The four societies share in their visions of science, goals for professional development, and use of science-based information to attain conservation and sustainability of natural resources. The combined membership of the four societies is about 35,000 professionals. Think about what can be accomplished by this number of dedicated people!

The four societies share in their visions of science, goals for professional development, and use of science-based information to attain conservation and sustainability of natural resources. The combined membership of the four societies is about 35,000 professionals. Think about what can be accomplished by this number of dedicated people!

It is natural that these four societies came together in an alliance, as the societies have a history of common interests, concerns, and collaborations, especially at the levels of local chapters. Local chapters have frequently invited members of the other societies to present talks, sit on panels, and participate in a variety of ways at their meetings. Chapters from two or more of the societies have held joint meetings over the years to share scientific information, and they have formed partnerships when addressing local or regional environmental issues. It is not at all unusual for individual professionals to be members of two or more of these societies. The vast majority of members of these societies share educational backgrounds in biological sciences and natural resources management. The CNRS brings this sense of kinship and cooperation to the level of the parent societies, and contributes to a stronger community of natural resource professionals.

Several factors have come together to generate the formation of the CNRS. First, the recession has caused increasing limitations on the available resources supporting small professional societies. By working together and sharing resources, efficiency and economies of scale are enhanced for all member societies. Second, there is a strong need and trend toward interdisciplinary research and ecosystem-based studies. The fusion created by the CNRS is likely to facilitate large projects requiring cooperation among a wide array of academic disciplines and management entities. Third, when speaking out on environmental issues of common concern, the union of the broad natural resource community can provide strength that is greater than that which can be achieved by four independent societies. Consequently, it just makes sense that the four sister societies form a coalition.

All of the societies in the CNRS perform a similar suite of functions. They disseminate credible scientific information through publications and meetings. They provide continuing education and professional development for their members. They do public outreach and inform government on natural resource issues. By collaboration, the societies of the CNRS enhance their individual abilities to carry out these functions, and they have already begun to work together.

Here are three examples of how the CNRS is contributing to our joint interests:

1. The recent economic downturn in the U.S. has had drastic effect on state natural resource agencies resulting in furloughs, layoffs, hiring freezes, and travel limitations. The CNRS sent a letter to all governors in the U.S. pointing out the economic value that fish, wildlife, rangelands, forests, and other natural resources generate through angling, hunting, tourism, and other outdoor recreational activities, and urged the governors not to lose site of the long-term contributions to their states in the interest of short-term budgetary concerns.
2. Two of the societies within the CNRS, TWS and AFS, lead in the development of a special joint symposium, "Species Introductions and Re-introductions," on a topic of interest to members of all four societies. The symposium took place in April 2010 on the campus of Mississippi State University and was well attended. The proceedings were taped and a webcast is available (www.cfr.msstate.edu/wildlife/symposium/). This is a tremendous example of how collaboration can contribute to dissemination of science-based natural resource information of interest to members of

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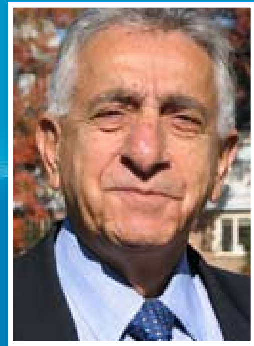
COLUMN:
DIRECTOR'S LINE

Gus Rassam
AFS Executive Director Rassam can be contacted at grassam@fisheries.org.



Plus ça change ….

While looking through an archive of *Science* recently, I noticed a description of an AFS meeting in New York City a hundred years ago. Having just concluded our 140th annual meeting in Pittsburgh, I thought it would be amusing to look back at the 40th annual meeting held on September 27-29, 1910.

The 40th AFS meeting took place at the New York Aquarium in Battery Park. The theme was "The Conservation of Our Rivers and Lakes," which was also the title of the plenary address by the chair of the meeting, Charles H. Townsend. Conservation of aquatic resources remains the central theme of society activities—as it was in Pittsburgh this last year —and as it will be in Seattle, and for many years to come.

After the plenary session, the 1910 meeting retired to a luncheon provided by the New York Zoological Society. The next day, the meeting moved from the aquarium to the American Museum of Natural History. All meetings commenced at 10 a.m., followed by an ample break for lunch (provided by the trustees of the museum) and then recommenced at 2 p.m. It appears that luncheons were the main social activities of that period. Today, it is evening receptions. Another change: programs nowadays extend over five days instead of three, and the days are essentially from 8 a.m. to 5 p.m., instead of the leisurely 10 a.m. to 12 p.m., then 2 p.m. to 5 p.m. But that is primarily due to the fact that now we have more attendees and more papers.

In planning society meetings, the Time and Place Committee, as well as the AFS staff, keep in mind appropriate accommodations and venues that provide reasonable rates and appropriate space for the presentation. This was the same in New York: the society headquarters for that meeting was in Hotel Navarre, where "special rates have been secured," since it was "four blocks from the Subway, five blocks from the Sixth and Ninth Avenue elevated stations, eight blocks from the Grand Central Station and six blocks from the new Pennsylvania Station," it provided a central location "in a district containing most of the theaters … and restaurants." As for activities, "No special entertainments have been arranged for the meeting… the committee being of the opinion that the visiting members will prefer the amusements afforded by the city." On the other hand, "The Fishmongers Association extends a cordial invitation to the members to visit the Fulton Fish Market, Pier 17, East River, foot of Fulton Street. The market should be visited in the morning—the earlier the better."

On the technical side of the arrangements, the New York hosts were just as concerned about presentations and technology as are today's program committees, the difference being mostly in the technology: "All papers requiring the use of the stereopticon will be presented on Wednesday, in order that advantage may be taken of the excellent facilities afforded by the Museum." What, no PowerPoint?

Looking at the geographic distribution of the presenters, it seems that AFS was already representative of the North American continent. While primarily East Coast, there were papers given by authors from Ottawa, Arkansas, Colorado, California, and Minnesota among others. Most were given by what we would call managers or administrators dealing with "International Regulations and what they mean," "The Education of the People in Fishery Matters," "Fish Cultural Possibilities of the Natural Preserves," "The Alaska Fisheries Service," "Moving Pictures with lecture on Conservation of Forest Life," and a paper by the president of the Russian Caviar Co., NYC, "On the Introduction of the European Sturgeon." Several other papers dealt with scientific issues: "The Natural History of the Weakfish," "Adaptive Change of Color among Fishes—illustrated," and "Animal Parasites and Parasitic Diseases of Fresh-water Fish in the United States."

Reflecting the origins of the society, a great majority of the papers dealt with fish culture of several species, including salmon, trout, and black bass. But what is truly astounding is the wide diversity of topics tackled by fisheries professionals one hundred years ago, and how that diversity has persisted over the years. It is reassuring in a sense that back in 1910 people were studying sunfish, lobsters, oysters, prevention of stream pollution, and sport fishing. It is also somewhat depressing to realize that fisheries and their habitats are under more stresses than ever before.

Looking at the 1910 program, I realize I must go back and read two papers in particular: one by Bashford Dean of Columbia University: "Announcement of Dr. Nishijikawa's Success in causing the Pearl Oyster to secrete Perfect and Spherical Pearls," and the other by William P. Seal, "The future of the American Fisheries Society." I'll report to you what I learn from the latter.

JOURNAL HIGHLIGHTS:

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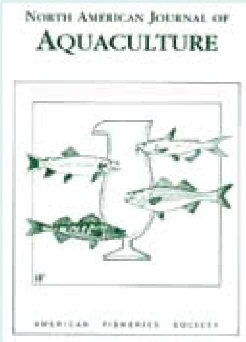

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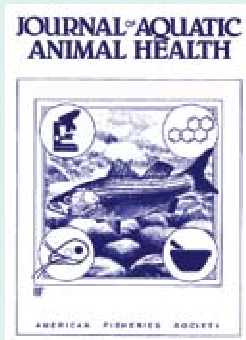

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UPDATE: LEGISLATION AND POLICY

Elden Hawkes, Jr.

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Remnants of Gulf Oil spill closes shrimp fishery

The discovery of tar balls in shrimp nets in late November has prompted the National Oceanic and Atmospheric Administration (NOAA) to close 4,200 square miles of the Gulf of Mexico waters. This closure directly affects the royal red shrimp fishery. As royal red shrimp are caught in Gulf waters deeper than 600 feet, and are the only species targeted with trawls at these depths, the closure will not affect the brown, white, and pink shrimp fisheries, as they are caught in waters less than 300 feet deep. The agency has received no reports of tar balls from fishermen that target other species in that area.

Asian carp legislation awaits presidential signature

The Asian Carp Prevention and Control Act (S. 1421) was passed by both houses of the US congress in early December. If signed into law, the Asian Carp Prevention and Control Act would amend the Lacey Act, listing the bighead carp as an injurious wildlife, and making it a federal crime to import or ship bighead carp for scientific, medical, educational, or zoological reason without the permission of the US Fish and Wildlife Service. President Obama is expected to sign the bill into law before the end of the year.

Shifting power in US House of representative sets stage for new committee leadership

As a result of the finish of the 2010 midterm election, the Republican Party gained a majority of 255 seats in the US House of Representatives. With this change in government, so comes a change in leadership. The House Republican Steering Committee has chosen Kentucky Representative Hal Rogers to lead the Appropriations Committee, e.g., the committee that writes the legislation that allocates federal funds to agencies, departments, and organizations. Representative Doc Hastings of Washington was selected to serve as the chairman of the House Natural Resources Committee.

Representative Ralph Hall of Texas has been chosen to be the House GOP leader to chair the Science and Technology Committee, which has jurisdiction over non-defense federal scientific research and development. Specifically, the committee has partial or complete jurisdiction over several federal agencies including: NASA, the Department of Energy, EPA, NOAA, and United States Geological Survey. Representative Fred Upton of Michigan was selected for the chairmanship of the Energy and Commerce Committee, which is responsible for legislative oversight of various topics including: quality and environmental health, and the supply and delivery of energy. This committee has jurisdiction over five Cabinet-level departments including: the Department of Energy, Health and Human Services, and the Food and Drug Administration.

All of these individuals will take their new leadership positions when the 112th Congress convenes in January of 2011.

50 percent cut in North Sea fishing proposed

With data indicating that there are no signs of recovery at current catch rates, the Belgium government has called for a 50 percent decrease in cod catch of the North Sea. In conjunction with this decrease, they have also called for a review of measures to ensure the future of the species. According to European Commission reports, North Sea cod took a hit in 2008 when a greater proportion of the stock was caught than in any year since 1999, while closures and cod-avoidance schemes had failed to protect it and had had little effect on fishing patterns.

FEATURE:

A Primer on Winter, Ice, and Fish: What Fisheries Biologists Should Know about Winter Ice Processes and Stream-dwelling Fish

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ABSTRACT: Stream-dwelling fish face highly-variable environmental conditions from fall to winter due to fluctuations in water temperatures, discharge, and ice conditions. We provide an in-depth description of the interactions between these complex environmental conditions and behaviors of stream-dwelling salmonids during winter. Fisheries managers should be aware of the conditions that fish confront during winter in order to make appropriate management decisions. Diverse habitats, including deep pools with low water velocities, coarse rock substrate, and abundant cover, as well as side channels and backwaters, aid in the survival of overwintering fish. The inflow of relatively warm groundwater into the water column can be an important factor affecting winter habitat. Considering the length of winter and the vulnerability of fish during winter, a broad understanding of winter ice process and their effects on stream dwelling fish can aid in the preservation and improvement of winter habitats.

Introducción a la relación entre el invierno, el hielo y los peces: qué deben saber los biólogos pesqueros acerca de los procesos del hielo y los peces de ríoh

RESUMEN: los peces demersales de río enfrentan condiciones ambientales altamente variables entre otoño e invierno debido a fluctuaciones en la temperatura del agua, descargas fluviales y las condiciones del hielo. En la presente contribución se ofrece una descripción detallada de las interacciones entre estas complejas condiciones ambientales y los comportamientos de los salmónidos en los ríos durante el invierno. Los administradores de pesquerías deben considerar las condiciones que confrontan los peces durante el invierno para tomar decisiones apropiadas de manejo. Diversos hábitats como las piscinas profundas con bajas velocidades de corriente, sustratos rocosos así como ríos tributarios y aguas estancadas, participan en la supervivencia de los peces hibernantes. El influjo de agua relativamente más cálida, proveniente del subsuelo, hacia la columna de agua puede ser un factor importante que afecta el hábitat invernal. Considerando que la duración del invierno y la vulnerabilidad de los peces durante esta estación, el entendimiento de los procesos fluvioglaciares y sus efectos en los peces demersales de río puede aportar información para la preservación y mejoramiento de los hábitats invernales.

Stream-dwelling fish face many challenges as a result of the highly variable environmental conditions from fall to winter to spring due to fluctuations in water temperatures, discharge, and ice conditions. Our purpose is to create a wider awareness of winter ice processes, habitat conditions, responses of fish to winter conditions, and the challenges that winter conditions pose in the management of many lotic fisheries. The relative role that groundwater plays in the formation of fish habitat can vary both temporally (i.e., changes among and within seasons) and spatially within a stream network. Thermal conditions and winter habitats for salmonids can be highly variable in some segments of streams and rivers, but relatively stable in others. Winter habitat for fish within a stream or river segment is affected by a complex array of factors includ-

Figure 1. Patchy anchor ice on the North Ram River, Alberta. Photo by R. S. Brown.

ing groundwater input, snowfall, elevation, latitude, channel type, and channel size. Anthropogenic influences, such as hydroelectric dams, groundwater extraction, and construction of instream structures to improve fish habitat are additional factors that affect winter habitat conditions in lotic systems. These complexities make it difficult to understand the winter habitat needs and behaviors of stream-dwelling fish, particularly their responses to river ice dynamics and interactions between groundwater and river ice. This review provides descriptions of the interactions among complex environmental conditions and behaviors of stream-dwelling fish during winter in order for fisheries managers to understand the conditions that salmonids confront. We attempt to link environmental conditions to management needs, describe when salmonid movements occur during winter and why, and examine the instream habitats that may be unstable during winter and why. Concurrently, we describe the instream habitats that are likely to be stable during winter and may be candidates of protective measures or habitat improvements. This review focuses on rivers and streams in temperate regions where it is cold enough for waters to have ice formations during winter. Within temperate regions, most winter research has been conducted on trout and salmon in rivers and streams. For this reason, the emphasis is on salmonids in flowing waters. This review synthesizes the endeavors of previous authors, such as Cunjak (1996), and complements those of others, such as Huusko et al. (2007), who focused primarily on juvenile salmonids.

Frazil ice crystals suspended in supercooled water have been called "active" because they are growing and have the ability to stick to any and all unheated underwater objects, including rocky substrate, vegetation, woody debris, or man-made structures (Ashton 1986).

For this review, Cunjak's (1996) definition of winter is used—"the period immediately following egg deposition by autumn-spawning salmonids (and coincident with a decline in water temperature) and extending until the loss of all surface ice (often accompanied by a major spate and snowmelt) and prior to any reproductive activity by spring-spawning, non-gadid fish." This definition is more appropriate than the astronomical definition of the period between the winter solstice (December 21) and the spring equinox (March 21) within the Northern Hemisphere, because freezing water temperatures and ice are often present in north-temperate streams well before December and last as long as frigid air temperatures and moderate water discharge persist.

RIVER ICE PROCESSES

In regions where average air temperatures drop below 0°C for periods of days or more, the heat loss from the water surface to the atmosphere causes the water temperature to decrease until it reaches 0°C. The rate of decrease depends on water depth, volume of flow, and exposure of the water surface. The fact that water has its maximum density at 4°C influences the vertical temperature distribution throughout its depth. As the water cools in the range of 4°C to 0°C during the winter season, it becomes less dense and the possibility of stratification arises. In streams and rivers with any appreciable current velocity, turbulent mixing generated by the river current is sufficient to overcome stratification, vertically mix the water column, and produce a uniform water temperature throughout. However, in lakes, ponds, and river reaches where the flow velocity is very low to non-existent, the water column becomes stratified with the coldest, least dense water at the surface. In these cases, ice production is limited to the water surface.

SUPERCOOLING, FRAZIL AND ANCHOR ICE FORMATION

Within vertically-mixed stream or river reaches, the entire water column can cool to below 0°C and become supercooled. Supercooling levels are small, typically less than 0.1°C. While it is not common to think of water being a liquid at temperatures below 0°C, it must be remembered that, as long as the air temperature is below 0°C, the only mechanism limiting the magnitude and duration of supercooling is the latent heat released when liquid water changes to solid ice. Water will remain supercooled until the latent heat warms the water column back to 0°C. However, there is a time lag before enough growing ice is present to overcome the heat loss to the atmosphere and warm the water back to near 0°C.

In practical terms, supercooling occurs when little or no surface ice is present, the air temperature is sub-freezing, and the water flow is sufficiently turbulent to overcome stratification. The genesis of the very first ice crystals is thought to result from seed crystals introduced at the water surface that become suspended in the water column by turbulence. Once introduced, these initial crystals lead to the creation of many new crystals that grow in size in the supercooled water (Daly 1984). This type of ice formation is referred to as frazil ice. Frazil ice crystals suspended in supercooled water have been called "active" because they are growing and have the ability to stick to any and all unheated underwater objects, including rocky substrate, vegetation, woody debris, or man-made structures (Ashton 1986).

Frazil ice deposited on the channel bottom is called anchor ice (Figure 1). Anchor ice in streams and rivers is typically composed of many small ice crystals and often has a milky appearance (Figure 2). In some cases, anchor ice includes sediment deposited along with the ice crystals and takes on a brownish appearance. The actual form of anchor ice is related to the flow conditions (Kerr et al. 2002; Kempema and Ettema 2009). In riffles with fast current, it can become quite thick and create anchor ice dams (Gerard 1989; Figure 3). These dams can temporarily block much or all of the water discharge in a stream or river leading to large fluctuations in water levels (Maciolek and Needham 1952; Daly 2005, Stickler et al. 2008a). For example, in a small Newfoundland stream, it was observed that anchor ice dams increased water depth by up to 0.7 m, decreased water velocity, and changed riffles to runs upstream from dams (Stickler et al. 2008a).

Anchor ice has been observed to lift from channel beds during early daylight hours following cold nights when frazil ice is formed. Anchor ice can transport large amounts of sediment, gravel, and aquatic invertebrates downstream (Martin et al. 2000; Kempema et al. 2002). It is common to see frazil slush on the surface of streams or rivers after a period of frazil ice production (Figure 4). Frazil slush is composed of anchor ice lifted from the bottom and frazil ice crystals, either singly or flocculated together. Since frazil slush is buoyant, it can consolidate on the water surface and pack or clump together into large floes. Freezing of interstitial water among consolidated ice crystals increases the strength and rigidity of floes.

In stream and river reaches with turbulent flows, frazil crystals at the surface may not consolidate and frazil ice may stay in the form of slush. In less turbulent reaches, circular, pancake floes may form with diameters of a meter or more (Figure 5). In reaches with low current velocities, very large floes can form and their effective diameter can be on the order of the channel width (Osterkamp and Gosink 1983).

ICE COVER FORMATION

Stationary ice cover can have a significant effect on both discharge and stage of streams and rivers (Ashton 1986). Ice moving at or near the velocity of the water surface has little impact on flow conditions. However, when the surface concentration and strength of floating ice increases to the point where significant shear stresses can be transmitted to the channel banks through the surface ice, it can begin to influence water flow. Shear stress causes the velocity of the floating ice to slow relative to the water in the rest of the channel. This slowing exerts resistance on the flowing water, decreasing the rate of discharge and increasing the stage of the river upstream, while decreasing these factors downstream.

The formation of stationary solid surface ice covers generally from where the moving ice motion is arrested by natural obstacles such as intact ice cover, river constrictions, or changes in channel slope. Ice motion can also be arrested by anthropogenic obstructions, such as bridge piers, dams, or ice control structures. Once ice motion is arrested, stationary ice cover can progress upstream with the leading edge of the ice cover advancing due to the arrival of ice floes from upstream (Figure 6).

The ice formation process depends on the form of ice (i.e., slush, pancake floes, or large floes) when it arrives at stationary ice cover, the hydraulic conditions at the leading upstream end of the ice cover, and the heat loss rate to the atmosphere. Initial ice cover, formed of individual ice floes, can thicken abruptly through shoving or consolidation events. These events start immediately after ice cover is formed and continue until ice cover is strong enough to resist the forces acting on it (Beltaos 2008; Hicks 2009). In addition, the strength and thickness of ice cover can increase through heat transfer to the atmosphere as the

Figure 2. An underwater photograph of anchor ice clinging to the bottom of Dutch Creek, Alberta. Photo by R. S. Brown.

interstitial water among the initial ice floes forming the ice cover freezes (Calkins 1979).

HANGING DAMS

The upstream progression of stationary ice cover may slow or stop altogether in reaches with fast-flowing water. Reaches that remain free of ice cover can produce substantial quantities of frazil ice that are transported downstream and deposited under ice cover (Figure 7). When this ice is deposited under ice cover in reaches with low water velocity—such as pools—a significant portion of the channel cross section can be blocked by deposited frazil ice. These depositions, sometimes referred to as hanging dams, can become quite large (e.g., extending across the channel of large rivers and up to a kilometer or more in length), restrict water flow, and increase current velocities through pools, transforming pools into areas with high current velocities (Gold and Williams 1963; Cunjak and Caissie 1994; Komadina-Douthwright et al. 1997; Brown et al. 2000).

Once stationary ice cover has formed on a stream or river reach, it can last throughout the winter as long as air temperatures remain cold and the discharge remains steady or declines. The amount of surface ice cover varies with both latitude and altitude. Streams and rivers in the Arctic may be covered in surface ice for more than half of the year, whereas streams and rivers at low latitudes or at low altitudes in the north temperate region may not have complete surface ice cover (Craig 1989).

ICE COVER BREAKUP AND ICE JAMS

Breakup of stationary ice cover transforms a completely ice-covered stream or river reach into an open system. Two examples illustrate the types of breakup commonly found in north temperate regions of North America (Daly 1995; Beltaos 2008). At one extreme is thermal meltout. During an ideal thermal meltout, ice cover deteriorates through warming and the absorption of solar radiation, and melts in place, with no increase in discharge and little or no movement of ice. At the other extreme is the more complex and less understood mechanical breakup. Mechanical breakup requires no deterioration of ice cover but results from an increase in discharge. The increase in discharge induces stresses in the ice cover, and the stresses cause cracks and fragment the ice cover into pieces that are transported by the current.

Breakups of stationary ice cover take place most often during warming periods when the strength of the ice cover deteriorates to some degree and the flow entering the stream or river reach increases because of snowmelt or precipitation. Therefore, most ice breakups actually fall somewhere between the extremes of thermal meltout and mechanical breakup. As a general rule, the closer a breakup is to being a mechanical breakup, the more dramatic it is because of the increase in flow and the large volume of fragmented ice produced (Daly 1995; Beltaos 2008).

Ice jams can occur at locations where the ice fragments stop moving with the current. Severe and sudden flooding can result upstream of ice jams or downstream of ice jams when they release. Surface ice cover can fill the entire channel with chunks of ice and create ice jams that flood large upstream segments of streams or rivers and leave downstream segments dewatered (Beltaos 1995).

FISH AND WINTER

Water temperature influences feeding, metabolism, and behavior

Water temperature has a substantial effect on fish because they are poikilothermic and their body temperatures vary with the external environment. At a given water temperature, the body temperature of freshwater fish is almost precisely the temperature of the water (Diana 1995). As body temperature changes, so do metabolic processes. When water temperature declines from fall into winter, metabolic processes slow down and the abilities of fish to swim, feed, avoid predators, and defend their locations decline (Beamish 1978; Parsons and Smiley 2003). At winter water temperatures (i.e., about 1°C or less under ice), most freshwater fish have little ability to respond to changes in their environment, such as changes in flow, or to avoid predators, such as mink (*Mustela vison*).

As water temperatures decrease in fall or early winter, defense of feeding positions becomes less important to fish while the search for suitable winter habitat becomes more important (Cunjak and Power 1986; Cunjak 1996; Lindstrom and Hubert 2004a). Adult trout may initiate movements, some of which may be very long distances, in search of suitable winter habitat (Bjornn 1971; Chisholm et al. 1987; Brown and MacKay 1995; Jakober et al. 1998; Lindstrom and Hubert 2004a). Such movements occur as the swimming abilities of fish decrease with declining water temperatures (Contor 1989; Sheppard and Johnson 1985; Simpkins et al. 2000a).

Many fish, such as salmonids, do not cease activity entirely, and feed throughout the winter (Needham and Jones 1959; Cunjak and Power 1987; Kolok 1991, Riehle and Griffith 1993; Pirhonen et al. 1997, Hebdon and Hubert 2001a; Simpkins et al. 2000b), even when water temperatures are less than 5°C (Lyons and Kanehl 2002, Dare and Hubert 2003). However, the ability of salmonids to acquire and assimilate food becomes more limited as water temperatures decline to near 0°C (Chapman and Bjornn 1969; Brett and Glass 1973; Metcalfe and Thorpe 1992). Concomitantly, growth may cease during winter (Cunjak and Power 1986; Metcalfe and Thorpe 1992).

During winter, the production of benthic invertebrates declines, and densities of drifting food items are low, so there can be little food available for sight-feeding insectivores such as trout (Simpkins et al. 2000b; Hebdon and Hubert 2001b). Cold water temperatures depress metabolic rates of fish during winter and prolong the duration that salmonids and other fish can survive with little or no food (Cunjak 1988; Connolly and Peterson 2003; Simpkins et al. 2003a). Thus, the combination of cold water temperatures and depressed metabolic rates during winter provides a survival mechanism for salmonids and other fish in streams.

Use of energy stores

Because of the physiological constraints on capture and consumption of food at low water temperatures and reduced availability of prey during winter, fish must utilize energy stored in their bodies (Cunjak 1988; Simpkins et al. 2000b, 2004a, 2004b). For example, salmonids are adapted to mobilize energy reserves and survive long periods without food (Toneys and Coble 1980; Navarro and Gatierrez 1995; Simpkins et al. 2003a). A complex three-stage physiological mechanism is involved in the mobilization of energy reserves and the defense of critical body organs (Castellini and Rea 1992; Hervant et al. 2001; Simpkins et al. 2003b). In short, during the first few days of food deprivation, glycogen reserves in the liver are used as an energy source. As starvation continues, the body switches to use of lipids as an energy source while preserving proteins. In later stages of starvation when lipids are depleted, the body begins to use proteins as a source of energy. The use of proteins compromises vital organ functions. Starvation and death occur after lipid reserves are depleted and protein degradation destroys the function of vital organs.

This starvation process has been widely observed among salmonids and has been related to declines in lipids through the course of winter among fish in both the wild (Beckman et al. 2000; Finstad et al. 2004a) and controlled experiments (Simpkins et al. 2003a, 2003b, 2004a, 2004b). Declines in

Figure 3. An ice dam on the Grand River, Ontario. The water level is elevated upstream of the dam. Photo by R. S. Brown.

body condition using indices of plumpness based on length and weight measurements have also indicated starvation processes among salmonids during winter (Simpkins et al. 2000b; Hebdon and Hubert 2001a), but body condition indices are not an accurate index of lipid reserves, or the extent of starvation experienced by fish (Simpkins et al. 2003a, 2003c). Starvation and associated mortality of fish during winter are related to the size of fish, with higher rates of starvation and mortality among smaller fish, especially age-0 fish in streams (Sogard 1997; Biro et al. 2004; Simpkins et al. 2004a; Borgstrom and Museth 2005). Size-selective mortality is a function of the fact that smaller fish have low levels of stored energy in their bodies (Shultz and Conover 1997; Finstad et al. 2004a) and higher mass-specific metabolic rates (Paloheimo and Dickie 1966; Miranda and Hubbard 1994).

The metabolic limitations that fish experience during winter have a variety of ecological consequences, resulting particularly in less ability to withstand the stresses of forced swimming events and predation by warm-blooded vertebrates (Marshall 1936; Sealander 1943; Gerell 1967; Jakober 1995; Simpkins 1997; Lindstrom and Hubert 2004b). When changes in environment or habitat occur, fish may be forced to swim from their winter refuges to find new refuges (Brown and Mackay 1995; Jakober et al. 1998; Simpkins et al. 2000a; McKinney et al. 2001; Annear et al. 2002; Dare et al. 2002). Forced swimming during winter enhances the rate of lipid depletion and generates size-selective mortality (Simpkins et al. 2003a, 2003b, 2003c, 2004a). If fasted fish are forced to swim to exhaustion, direct mortality may occur or they may be more vulnerable to predation (Simpkins et al. 2004b).

FISH BEHAVIOR AND ONSET OF WINTER

Habitat changes in fall

The slowing of the metabolism of fish with decreasing water temperatures during fall and early winter has implications on behavior and habitat use by fish in streams and rivers. Because their metabolism slows and they feed less, fish are less likely to defend feeding positions (Cunjak and Power 1986; Cunjak 1996). Also, because fish are feeding less, the habitats that were optimal during warmer parts of the year can become less favorable. Larger juvenile and adult fish may abandon feeding territories and aggregate (a type of schooling (i.e., shoaling) behavior) in areas where they can find winter refuges (Hartman 1965; Cunjak and Power 1986; Brown and Mackay 1995; Jakober et al. 1998). While this occurs for larger fish, smaller fish may become nocturnal, move short distances, and hide within interstitial spaces in channel substrate, preferring crevices among larger rock substrates (Hartman 1965; Griffith and Smith 1993; Linnansaari et al. 2008).

As water temperatures decrease in the fall, larger fish often make lesser use of shallow areas with higher water velocities, and greater use of deeper areas with slower water velocities. This behavior has been observed among riverine salmonids (Hartman 1965; Cunjak and Power 1986; Chisholm et al. 1987; Baltz et al. 1991; Heggenes et al. 1993; Brown and Mackay 1995; Jakober et al. 1998) and centrarchids (Lyons and Kanehl 2002). Because areas with these types of habitats are often limited in streams and rivers, it is common for fish to be found in large groups or aggregations within more optimal habitats.

The presence of stationary ice cover influences behavior and habitat use. For example, Atlantic salmon (*Salmo salar*) parr were observed to be nocturnal during winter, but their activity increased during daytime as stationary ice cover became thicker (Linnansaari et al. 2008). Although Atlantic salmon parr prefer larger substrates, they may use smaller substrate when stationary ice cover is present (Linnansaari et al. 2008, 2009).

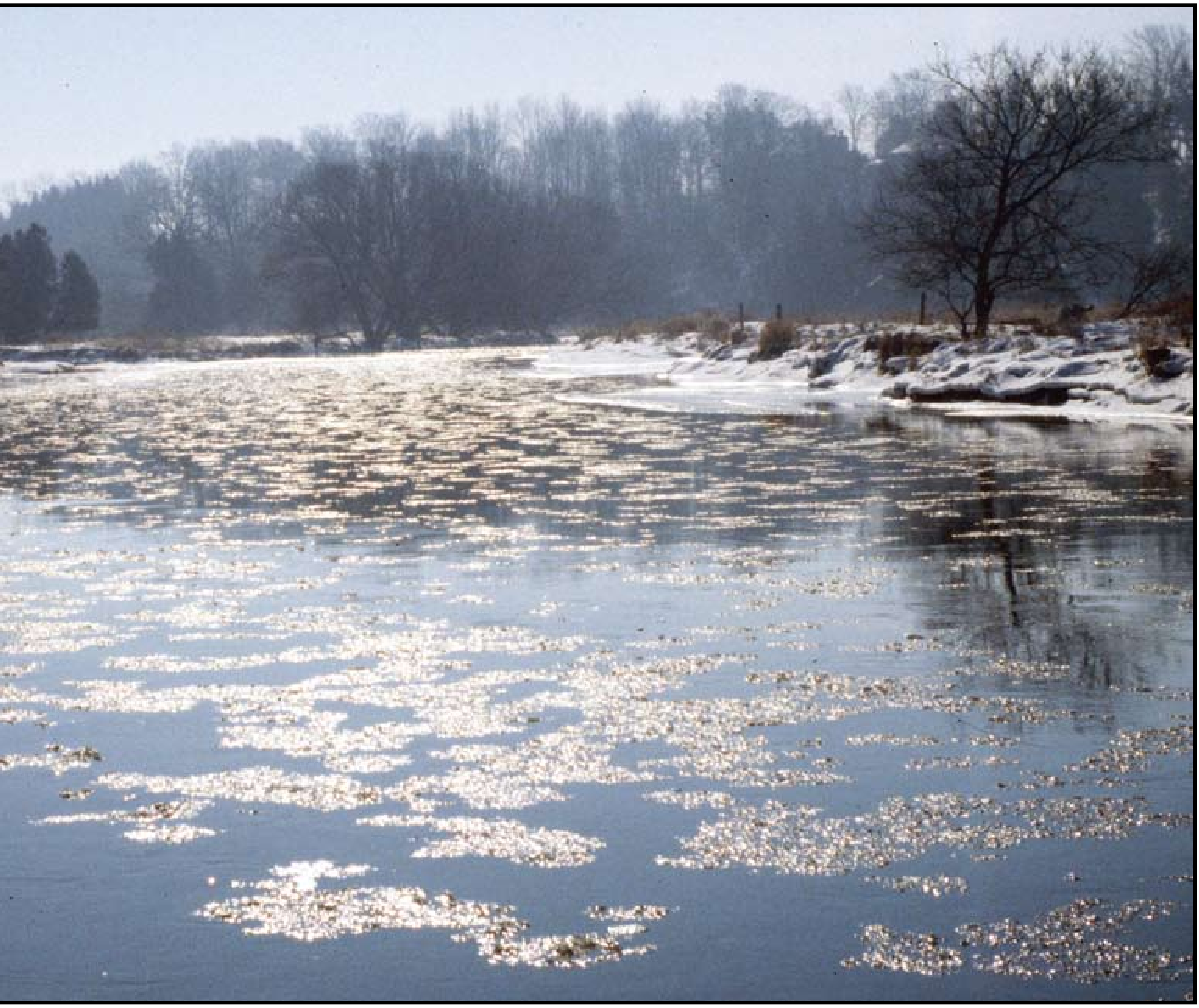
When anchor ice fills a pool, the water then flows through the ice in one or more high-velocity conduits, at water velocities that are often unsuitable for fish to maintain position

Aggregations

Aggregation may be a clumping or squeezing effect resulting from limited habitat availability (Cunjak and Power 1986). Habitat can be much more limited in winter than in other seasons due to low discharge and exclusion of previously suitable habitat by stationary ice (Chisholm et al. 1987; Brown et al. 1994; Brown and Mackay 1995; Jakober et al. 1998). Aggregation may also provide advantages to members of the group by decreasing predation risk (Neill and Cullen 1974; Milinski 1979; Tremblay and Fitzgerald 1979; Pitcher 1986).

Occurrence of winter aggregations of fish is linked to the general water temperature of the majority of the stream and the inflow of relatively-warm groundwater into the water column. The tendency of fish to form high-density winter aggregations increases with decreasing overall stream temperature (Cunjak and Power 1986; Brown 1999). Aggregations of cutthroat trout (*Oncorhynchus clarki*), brook trout, and brown trout (Cunjak and Power 1986; Brown 1999) have been observed in small areas of warm groundwater discharge. However, Brown and MacKay (1995) observed that fish aggregations were less common in long stream sections warmed by groundwater than in colder sections without groundwater inputs.

Figure 4. Frazil slush on the surface of the Grand River, Ontario. Photo by R. S. Brown.



NATURAL FACTORS AFFECTING FISH HABITAT AND BEHAVIOR DURING WINTER

Winter habitats of fish can range from very stable to almost consistent change due to variation in ice conditions and water temperatures. In some riverine environments, stationary ice cover forms early in the winter and seals fish under a stable sheet of ice. Deep snow can bridge small streams and also provide stable overwintering habitats (Chisholm et al. 1987; Hubert et al. 2000; Lindstrom and Hubert 2004a). However, among reaches of streams or rivers, habitats without complete surface ice or snow cover are likely to have dynamic ice conditions (Brown 1999; Lindstrom and Hubert 2004a; Barrineau et al. 2005).

From the start of freeze-up, ice can occlude fish habitat and influence fish behavior. Laboratory studies have shown that supercooled water temperatures and frazil ice can stress fish (Brown et al. 1999). In addition, stationary ice can form in habitat that was available during summer and be very dynamic, making otherwise suitable habitats unusable either temporarily or for most of the winter (Chisholm et al. 1987; Brown and Mackay 1995; Jakober et al. 1998; Brown 1999; Lindstrom and Hubert 2004a; Barrineau et al. 2005). As winter progresses, stationary ice cover can increase in thickness until it excludes large portions of habitats used by wintering fish in streams and rivers (Chisholm et al. 1987; Berg 1994; Scruton et al., 1997). An extreme example occurs in the Arctic where most streams and rivers freeze to the bottom of the channel because surface ice can grow to a thickness of more than 2 m (Mueller et al. 2006). Consequently, fish must reside in the deepest parts of rivers in pockets of unfrozen water or in areas influenced by groundwater (Craig 1989; West et al. 1992; Reynolds 1996; Brown et al. 2010).

THE EFFECTS OF FRAZIL AND ANCHOR ICE

When stationary ice cover forms and melts frequently during fall and winter, the resulting frazil ice and anchor ice events create harsh conditions that force fish movements and cause mortality (Maciolek and Needham 1952). Anchor ice can build up to the water surface and occlude fish from entire pools or reaches. When anchor ice fills a pool, the water then flows through the ice in one or more high-velocity conduits, at water velocities that are often unsuitable for fish to maintain position (Figure 8; Brown and Mackay 1995; Jakober et al. 1998; Brown 1999; Whalen et al. 1999). Several researchers have observed that fish are forced to make larger numbers of movements when influenced by frazil ice or anchor ice. Fish often shift habitats as the water temperatures decrease in the fall (Brown and Mackay 1995; Jakober et al. 1998) and may spend the entire winter at these new locations. However, if these new habitats are unstable due to the influences of ice, the fish may be forced to make multiple movements as ice occludes these habitats. One study found that cutthroat trout — in reaches influenced by anchor ice — made substantial movements 6 times more often during a winter, and moved 30 times farther than cutthroat trout in reaches free of anchor ice (Brown 1999). Other researchers have found that both bull trout (*Salvelinus confluentus*) and cutthroat trout moved more often in streams affected by anchor ice than in streams with stationary ice cover (Jakober et al. 1998). Cutthroat trout and brook trout overwintering in beaver ponds with stationary ice cover have been observed to move less than those in reaches of the same stream that were influenced by unstable ice conditions (Lindstrom and Hubert 2004a). Forced movements during frazil ice and anchor ice events can be energetically costly to fish and increase the probability of mortality. Because frazil ice and anchor ice form in stream sections that do not have stationary ice cover, fish in moderately cold climates may be forced to make more ice-related movements than fish in colder climates.

While larger juvenile and adult fish are forced from their habitats by anchor ice, small juvenile fish may not be influenced. One study found that although anchor ice completely blanketed a stream, Atlantic salmon (Salmo salar) parr were not forced to move (Roussel et al. 2004). Other researchers have found juvenile Atlantic salmon use anchor ice as cover (Stickler et al. 2008b), and redistribute daily as frazil ice and anchor ice form and melt (Whalen and Parrish 1999).

Recent research indicates that the distribution of anchor ice may influence whether stream reaches can be used by juvenile fish. Linnansaari et al. (2009) found that Atlantic salmon parr were able to remain in reaches with patchy, unconsolidated anchor ice. However, in reaches where dense growth of anchor ice extended from the substrate to the stream surface, the fish were not able remain, and did not re-enter over the course of the winter.

THE EFFECTS OF ICE DAMS AND HANGING DAMS

Thick deposits of anchor ice in riffles can create ice dams similar to ice jams (Gerard 1989; Beltaos 1995; Figure 3), causing a stage (i.e., water level) increase upstream from the ice dam, and decrease downstream from the ice dam (Maciolek and Needham 1952). In a high-elevation California stream, researchers found dead brown trout and rainbow trout (*Oncorhynchus mykiss*) stranded on damp rocks in dewatered pools downstream of an ice dam (Maciolek and Needham 1952) and concluded that this type of mortality was common, but others have found that ice dams may have little influence

Figure 5. Pans of frazil slush forming stationary surface ice in a small backwater area along the edge of the Grand River, Ontario. Photo by R. S. Brown.

on fish. For example, while habitats used by Atlantic salmon parr in a small Newfoundland stream upstream of an ice dam increased in water depth and decreased in water velocity the fish moved little if at all (Stickler et al. 2008a), but the ice dam was short lived, forming at night and disintegrating the next day.

Frazil ice can affect fish habitat by forming hanging dams. Hanging dams can form frequently in cool-temperate and colder climates (Komadina-Douthwright et al. 1997), forcing lotic fish to cope with resultant changes in habitat. Brown et al. (2000) observed that 80% of a pool in an Ontario river was filled by a hanging dam causing much higher water velocities in the pool (Brown et al. 2000). Others have observed more than 80% of the volume of pools filled by hanging dams in other systems (Cunjak and Caissie 1994; Caissie et al. 1997; Komadina-Douthwright et al. 1997).

Hanging dams can cause major difficulties for fish during winter, but they are often unnoted because they form under ice and are difficult to observe. Increased water velocities coupled with reduced pool volume can change pools from suitable to unsuitable overwintering habitat. This is indicated in studies where radio-tagged fish moved out of pools where hanging dams formed, but often returned to the same pools after the hanging dams were no longer present (Brown et al. 2000; Lindstrom and Hubert 2004a). Hanging dams can remain in place for days or from fall freeze-up to spring break-up (Beltaos and Dean 1981; Komadina-Douthwright et al. 1997; Brown et al. 2000; Barrineau et al. 2005).

THE INFLUENCE OF GROUNDWATER

The inflow of relatively warm groundwater into the water column can play a complex role affecting winter habitat for fish in streams and rivers. Groundwater input to flowing waters can provide stable overwintering habitats for fish and their eggs when they are near the source, but it can also contribute to unstable winter conditions further downstream. Many researchers have found fish dwelling within the main channel or side channels (often in large aggregations) where groundwater maintained ice-free habitat (Craig and Poulin 1975; Cunjak and Power 1986; Brown and Mackay 1995; Brown 1999; Harper and Farag 2004; Lindstrom and Hubert 2004a; Barrineau et al. 2005). However, as air temperatures decrease, or the distance downstream from groundwater sources increases, the thermal effects of groundwater input dissipate and the amount of ice-free habitat decreases. Reaches at the downstream end of groundwater-influenced stream segments are likely to have unstable ice conditions during winter (Brown 1999; Lindstrom and Hubert 2004a). In these reaches, frazil ice may form during colder weather and contribute to anchor ice and hanging dams farther downstream (Brown 1999; Lindstrom and Hubert 2004a; Barrineau et al. 2005). For example, Brown (1999) noted radio-tagged cutthroat trout were forced out of the lower reach of a groundwater-influenced stream segment by anchor ice during cold periods. The fish moved upstream toward the source of warmer groundwater during cold periods and later dispersed back into the lower reach of the groundwater section as air temperatures increased, allowing the length of the groundwater-influenced segment to expand. Lindstrom and Hubert (2004a) also noted that brook trout and cutthroat trout tended to avoid pools affected by groundwater that were greater than 250 m downstream of the sources of influx because winter habitat conditions in these pools were dynamic and unstable.

ICE BREAKUP AND FLOODING

Break-up of stationary ice cover can result in large changes in fish habitat and cause fish movements that commonly lead to mortalities. The occurrence of large volumes of ice moving with the current during break-up and associated flooding can result in remolding of river channels, moving of small islands, redistribution of alluvial gravel bars (Power et al. 1999), and crushing of riparian vegetation (Gatto 1994; Hicks 1994; Beltaos 1995). Under these conditions, fish may move long distances as their winter habitats are altered (Brown et al. 2001). As discharge increases during stationary ice break-up and flooding, water depth and velocities increase in the main channel. These changes can make main channel habitats more energetically demanding and less preferable for fish, so fish may move downstream, into backwaters, or to the edges of pools or runs. For example, Brown et al. (2001) found more than 10% of a group of radio-tagged white suckers (*Catostomus commersoni*) and common carp (*Cyprinus carpio*) stranded on a floodplain following stationary ice break-up and associated flooding, and concluded that such stranding may be a major cause of mortality.

Use of stream margins within runs or backwater areas has been found to be one mechanism through which fish avoid being swept downstream during stationary ice break-up and flooding. While many backwater habitats are shallow or dry during low-flow periods, they are commonly used as refuges by fish, too (Brown et al. 2001). Additionally, several species of centrarchids have been observed to move into backwater areas during winter (Knights et al. 1995; Raibley et al. 1997; Karchesky and Bennett 2004). Having backwater habitats

Figure 6. Frazil slush forming stationary surface ice on the North Ram River, Alberta. Photo by R. S. Brown.

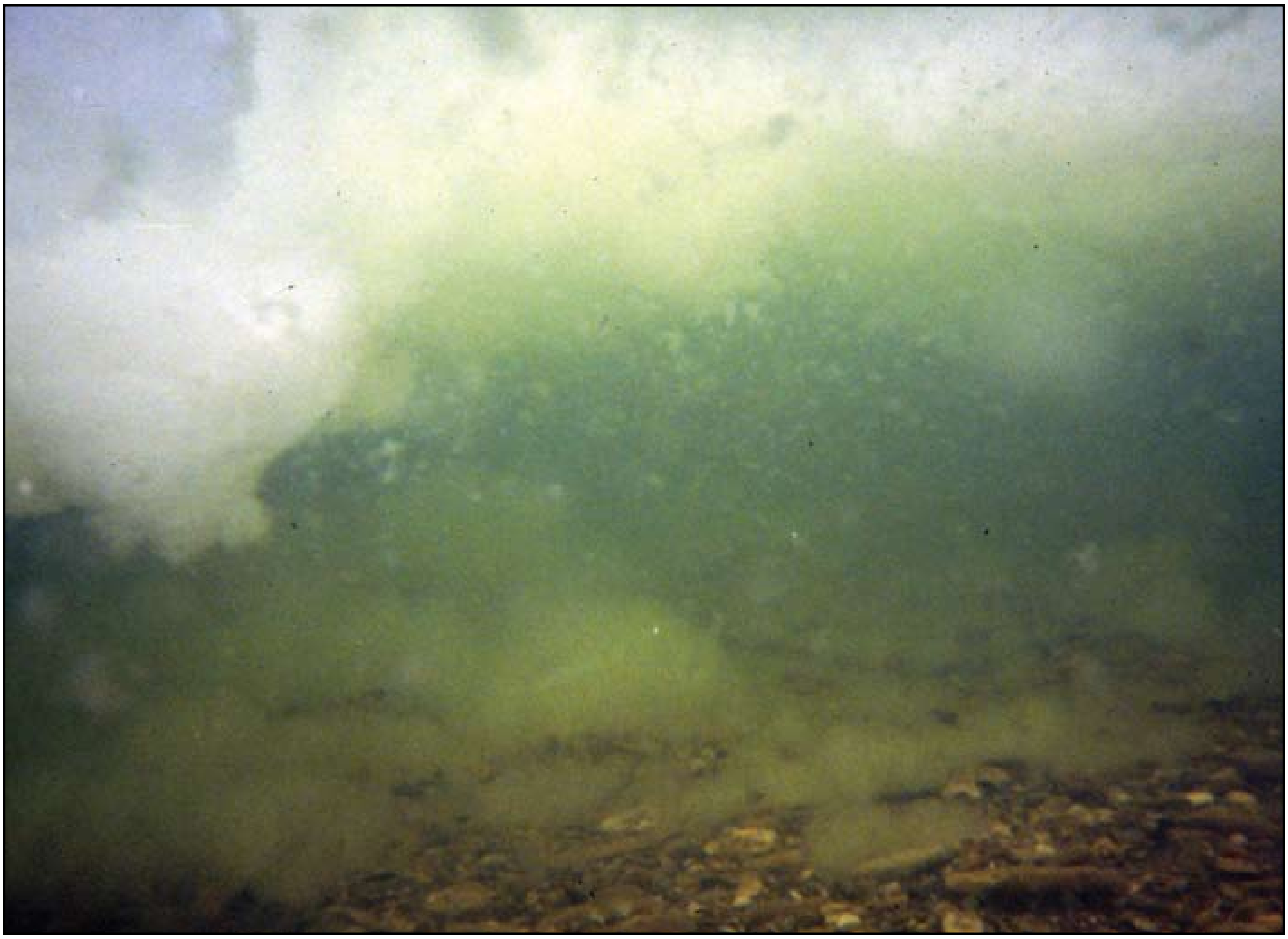
available in streams and rivers may decrease the numbers of fish that are caught in the current and forced to move downstream. Backwaters may also reduce the numbers of fish stranded on the flood plain where they can easily be taken by predators or die as waters recede.

Floods associated with stationary ice break-up can also influence the movements and behaviors of juvenile fish. For example, in an experimental stream, Atlantic salmon parr made more extensive movements during simulated floods, and the proportion of fish homing to their "home stone" after nocturnal movements was lower during these flood events (Linnansaari et al. 2008).

WINTER HABITATS

Suitable winter habitats for fish in streams and rivers are locations that allow fish to minimize energy expenditures while maximizing protection from environmental variation (Cunjak 1996; Bonneau and Scarnecchia 1998; Lindstrom and Hubert 2004a). Complex mixes of habitat features can provide suitable winter habitat for fish (Jakober et al. 1998; Harvey et al. 1999; Ford and Lonzarich 2000; Mitro and Zale 2002). Such habitats are generally the result of natural fluvial processes that maintain connections and create habitat diversity allowing full expression of life

Figure 7. This image shows three kinds of ice. Anchor ice can be seen on the bottom. In mid-column can be seen frazil slush or flocs of frazil ice. At the top of the image, a hanging dam can be seen forming under the stationary surface ice as frazil slush becomes buoyant and gathers under the surface ice. Photo by R. S. Brown.

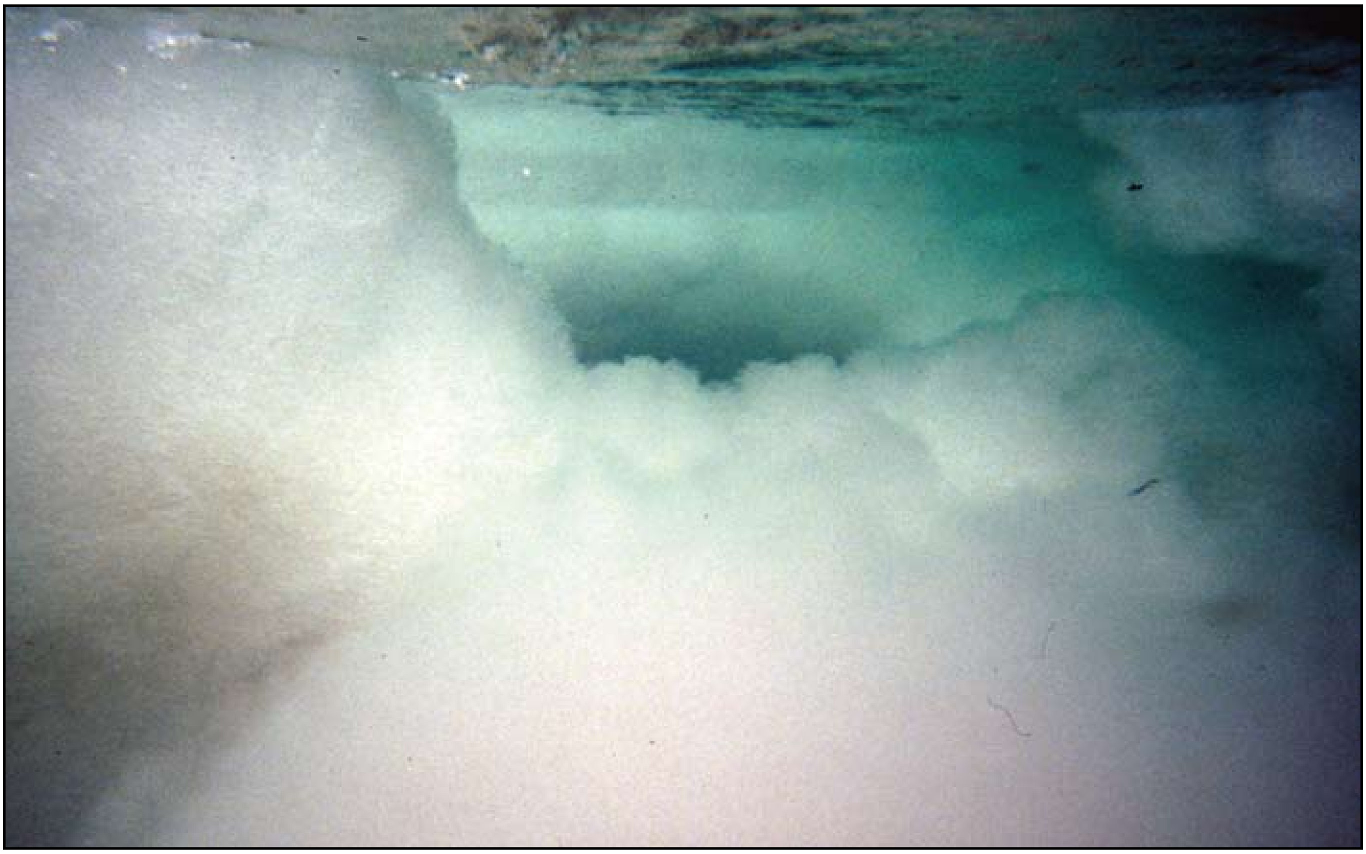


history traits and processes influencing dispersal and survival of fish (Muhlfeld and Marotz 2005). In general, microhabitat features needed by stream-dwelling fish include low-velocity water and protection from predation (Hiscock et al. 2002; Beechie et al. 2005; Gillette et al. 2006), but specific habitat needs within these general features can vary among species (Dare and Hubert 2003).

Deep pools often provide microhabitat features needed by fish during winter, and their quality as winter habitat for fish can be enhanced by the presence of crevices between rocks, large woody debris, or submergent vegetation (Mitro and Zale 2002; Muhlfeld et al. 2001). Deep pools have been widely described as habitat features needed by stream-dwelling fish during winter, but most of the literature characterizing this generality comes from salmonid studies (Bustard and Narver 1975; Cunjak and Power 1986; Heggenes et al. 1993; Bonneau and Scarnecchia 1998; Jakober et al. 1998; Simpkins et al. 2000a; Dare et al. 2002; Lindstrom and Hubert 2004a). Deep pools in small streams provide low-velocity waters and a stable environment when there is relatively large variation in discharge during ice events. However, in larger streams and rivers, additional habitat features are needed in pools for them to provide suitable winter habitat (Simpkins et al. 2000a). The additional features include unique elements, such as complex bank habitat with large rocks (Mitro and Zale 2002), off-channel pools with groundwater inputs that slightly raise water temperatures (Harper and Farag 2004), large woody debris, or submerged aquatic vegetation. Generally, when juvenile salmonids find pools with low current velocities and instream cover, they move infrequently from these pools during winter (Heggenes et al. 1991; Hilderbrand and Kerschner 2000; Simpkins et al. 2000a; Sanderson and Hubert 2009).

Water velocities suitable to fish during winter vary among species and life stages. Among juvenile salmonids, suitable water velocities during winter have been reported to be less than 1 body length per second (Simpkins et al. 2000a, 2004a; Beechie et al. 2005; Enders et al. 2007). Elements of habitat complexity in pools and runs that create specific locations with little or no current velocity during winter, include rocky substrate with crevices between rocks, large woody debris, and submerged aquatic vegetation. Numerous studies of salmonids have described fish concealing themselves in crevices among rocks during winter (Schrader and Griswold 1992; Griffith and Smith 1993; Riehle and Griffith 1993; Meyer and Gregory 2000, Muhlfeld et al. 2001; Riley et al. 2006). Other authors have described the use of small eddies downstream from large cobbles or boulders as habitat used by salmonids during winter (Simpkins et al. 2000a; Dare and Hubert 2003). Large woody

Figure 8. An underwater photo of a conduit through anchor ice in Dutch Creek Alberta. Most of the stream was covered in anchor ice leaving just a few of these high velocity conduits for water to pass through. Photo by R. S. Brown.



debris has been described as being used to provide protection from current and concealment for salmonids in many systems during winter (Meyer and Gregory 2000; Muhlfeld et al. 2001; Harper and Farag 2004; Beechie et al. 2005; Muhlfeld and Marotz 2005). Large woody debris and backwater habitats may be particularly important to salmonids during high-flow periods (Harvey et al. 1999, Brown et al. 2001). Many studies have described use of submerged aquatic vegetation as cover by salmonids during winter (Cunjak and Power 1986, 1987; Bendock and Bringham 1988; Heggenes et al. 1993; Griffith and Smith 1995; Mitro and Zale 2002). However, submerged aquatic macrophytes can deteriorate during winter, forcing fish to move and seek new habitat (Simpkins et al. 2000a). Instream cover in the form of rocks, large woody debris, and submerged aquatic vegetation have been shown to be an important winter habitat feature for several species of centrarchids as well (Carlson 1992; Cunjak 1996; Karchesky and Bennett 2004).

Habitats along stream and river banks can be important winter refuges for fish. Juvenile salmonids have been observed to use stream-bank habitats as refuges during anchor-ice events (Griffith and Smith 1993; Riehle and Griffith 1993; Heggenes et al. 1993). Atlantic salmon parr have been observed to be positioned closer to the stream banks during winter in comparison to summer and fall (Mäki-Petäys et al. 2004; Enders et al. 2008). Stream-bank habitats may provide cover from high current velocities and homoeothermic predators (Cunjak 1996; Mäki-Petäys et al. 2004).

Habitat stability during winter is important to fish (Dare et al. 2002). If habitat is stable, fish are not forced to move, seek new areas of residence, expend more energy, or experience greater predation risk (Brown and Mackay 1995; Brown et al. 2000; Lindstrom and Hubert 2004a). There is substantial natural variation in the stability of stream and river habitat during winter. For example, three classes of winter stream conditions have been described among streams of the Rocky Mountains, with differing extents of stability during winter (Chisholm et al. 1987; Hubert et al. 2000). First are small, high-elevation stream segments with low-to-moderate channel gradients that become entirely bridged by snow with no stationary ice cover during winter. Such streams maintain consistent flows and cold water temperatures during winter to provide stable habitats. Second, there are moderate-sized, mid-elevation stream segments with moderate channel slopes that do not snow bridge and have patches with and without stationary ice cover during winter. These streams experience variation in water temperatures and have dynamic ice conditions throughout winter providing unstable habitats for fish. Third are foothills stream segments that are larger and tend to have lower channel slopes with little snow cover but substantial stationary ice cover. Habitat conditions in these stream segments also tend to vary during winter, but not as severely as in mid-elevation stream segments.

One of the most stable habitats for fish during winter is beaver (*Castor canadensis*) ponds (Collen and Gibson 2001) with consistent water levels, very low current velocities, and stationary ice cover throughout winter. Numerous studies have shown that trout select beaver ponds during winter (Chisholm et al. 1987; Jakober et al. 1998; Lindstrom and Hubert 2004a).

ANTHROPOGENIC INFLUENCES ON WINTER HABITAT

A wide variety of anthropogenic activities can affect winter habitat for fish in streams and rivers. These include construction and operation of reservoirs, placement of barriers to fish movements, thermal effluents from electrical power production facilities and other industries, point sources of contaminants, nonpoint sources of sediments, and instream structures built to enhance habitat for fish.

EFFECTS OF DAMS AND RESERVOIRS

Widespread construction of reservoirs has had substantial effects on downstream fluvial habitats (i.e., tailwaters) during winter. Many reservoirs alter natural temperature regimes downstream due to hypolimnetic releases resulting in warmer-than-natural winter water temperatures. Warmer water temperatures within tailwaters can eliminate stationary ice cover, enhance the dynamics of ice processes, facilitate predation by homoeothermic predators, increase energy demands of fish during a period of low prey availability, and allow the persistence of angling during winter.

Warmer water temperatures in tailwaters can prevent formation of stationary ice cover across the channel for long segments downstream from dams (Simpkins et al. 2001a), and contribute to occurrences of anchor ice and frazil ice in these segments (Ward and Stanford 1979). Frazil ice and anchor ice can fill interstitial spaces among gravel and cobble substrates where juvenile fish have sought cover (Stickler et al. 2007a; Stickler et al. 2007b), remove submerged aquatic macrophytes that are important as sources of cover and protection from predation (Simpkins et al. 2000a; Johnson and Douglass 2009), and force fish to move from normal feeding and resting areas to refuges, such as the bottom of deep pools or under shelf ice in shallow water near shore (Griffith and Smith 1995; Simpkins et al. 2000a; Van Kirk and Martin 2000; Stickler et al. 2008a). The movements and lack of feeding opportunities in tailwaters caused by frazil ice episodes accentuate energy demands on fish, affect starvation processes, and perhaps force fish to move downstream out of managed reaches (Brown and Mackay 1995; Hebdon 1999), and enhance mortality of juvenile salmonids (Simpkins 1997; Simpkins et al. 2000a; Annear et al. 2002).

Diverse habitats, however, including deep pools with low water velocities, coarse rock substrate, and abundant cover, as well as side channels and backwaters, increase the probability of survival of overwintering fish.

Together, warmer water temperatures and lack of snow and stationary ice cover enable salmonids to feed throughout the winter in tailwaters (Simpkins and Hubert 2000b; Hebdon and Hubert 2001b). However, availability of prey is limited in tailwaters during winter, as most aquatic invertebrates have life cycles that make them unavailable or inactive during winter (Filbert and Hawkins 1995; Simpkins and Hubert 2000b; Hebdon and Hubert 2001b). Nonetheless, warmer water temperatures lead to higher metabolic rates, greater swimming ability, and more activity among salmonids in tailwaters, thereby generating a demand on stored energy reserves (Berg and Bemset 1998; Cunjak et al. 1998; Simpkins and Hubert 2000b; Hebdon and Hubert 2001a; Simpkins et al 2003a, 2004a; Finstad et al. 2004b). Loss of energy reserves can reduce the ability of fish to respond to variation in habitat or threats from predators, thereby enhancing mortality of small fish in tailwaters (Metcalfe and Thorpe 1992; Bull et al. 1996; Cunjak 1996; Finstad et al. 2004b). The lack of stationary ice cover associated with warmer winter water temperatures in tailwaters can enhance predation on fish by homoeothermic predators such as mink and river otter (*Lutra lutra* L.; Fraser et al. 1993; Valdimarsson and Metcalfe 1998).

Channels downstream from reservoirs often change and lose the complexity that existed prior to construction of the dam due to reductions in extremely-high flows and the lack of sediment released from dams (Ward and Stanford 1979). The result is often a loss of deep pools with low current velocities important to overwintering fish (Stickler et al. 2008b). Reservoirs also affect the occurrence of cobble substrate with interstitial spaces important to juvenile salmonids during winter (Rimmer et al. 1984; Heggenes 1996; Mäki-Petäys et al. 1997; Linnansaari et al. 2008; Stickler et al. 2008b). Highly-embedded, armored channels downstream from reservoirs generally lack cobbles with interstitial spaces.

Because dams regulate the flows of rivers for a variety of economic reasons, discharge regimes during winter are often quite different from relatively stable natural conditions. Variable discharges to meet hydropower, flood control, and water storage functions can lead to variable flows during winter, causing substantial variation in habitat at a time when fish need stable habitat (Dare et al. 2001; Lagarrigue et al. 2002; Enders et al. 2008). Variation in flows during winter downstream from reservoirs can strand fish (Saltveit et al. 2001; Berland et al. 2004; Stickler et al. 2007a; Stickler et al. 2007b; Enders et al. 2008), force fish to move from previously occupied habitats (Armstrong et al. 1998; Dare et al. 2002; Enders et al. 2008), accentuate mortality due to predation by vertebrates, and cause mortality due to the collapse of shelf ice along the shore onto fish below (Johnson 1994). Although rapid reductions in flows during winter can negatively affect fish, enhanced flows appear to have less of an effect, causing fish to shift in their habitat use but not stimulating long movements (Heggenes 1988; Simpkins et al. 2000c; Brown et al. 2001). Effects of hydropower peaking during winter on juvenile salmonids have been studied in artificial streams and rivers (Bradford et al. 1995; Saltveit et al. 2001; Scruton et al. 2005; Enders et al. 2008), but there is little information regarding the cumulative effects on incubating embryos or adult fish. In general, slow changes in discharge within the natural range of variation are needed to avoid negative impacts on juvenile salmonids (Bradford et al. 1995; Enders et al. 2008).

Dams, as well as culverts, dewatering of stream reaches, and alteration of stream channels, can also provide barriers to fish movements, impeding movements among habitats needed during winter or summer, or for spawning, or rearing of young across a watershed or riverscape (Northcote 1997; Fausch et al. 2002). For example, Sanderson and Hubert (2009) found that water diversion structures prevented adult cutthroat trout who wintered in the mainstem of the Salt River in Wyoming from accessing many tributary streams flowing from surrounding mountains with high-quality spawning and rearing habitat. Reductions in the area of available habitat due to anthropogenic fragmentation may lead to a loss of habitat complexity and decline in life history variations important to stream-dwelling fish (Rieman and McIntyre 1993; Schlosser and Angermeier 1995).

THERMAL DISCHARGE

Thermal discharges from electrical-generating plants and industrial and municipal sources can affect winter habitat in ways similar to reservoirs by preventing surface ice formation and providing opportunities for frazil ice episodes in downstream reaches. Additionally, thermal discharges during winter can cause fish to aggregate in the effluent plume where demands on energy reserves may be greater than in colder waters. The physiological effects of residence in thermally-enhanced areas during winter have not been widely studied, but at least one study suggests that reproduction may be negatively affected by such behavior (Cooke et al. 2004). Aggregation of fish in areas with point sources of both warmer water and contaminants can expose them to higher levels of contaminants than might otherwise be experienced.

SEDIMENTATION

Sedimentation, both from natural and anthropogenic sources, can lead to a decrease in both the quantity and the quality of fish habitat during winter (Cunjak 1996). Fine sediment can fill the interstitial spaces among rocks reducing the amount of habitat for small fish which hide in the substrate (Griffith and Smith 1993; Linnansaari et al. 2009). In addition, fine sedimentation can decrease water flow though redds during winter, reducing the survival of salmonid embryos (Chapman 1988; Levasseur et al. 2006).

INSTREAM IMPROVEMENT STRUCTURES

Instream structures have been widely used to improve or restore habitat for fluvial salmonids (Platts and Rinne 1985; White 1996). Instream structures are generally built to enhance pool habitat, but little is known about habitat associated with such structures during winter (Nickelson et al. 1992). Barrineau et al. (2005) assessed two types of instream structures (i.e., log-plunge and diagonal-boulder weir structures) constructed on a low-gradient reach of a mountain stream and found substantial differences in the quality of winter habitat formed by the two structures. Moreover, they observed that the habitat formed by instream structures in stream segments affected by groundwater sustained serious impacts from frazil ice and anchor ice during winter. Their research indicated that managers need to understand the thermal dynamics of a stream before constructing instream structures intended to benefit salmonids during winter. Groundwater areas may provide stable overwintering habitat in reaches near the source, but contribute to unstable ice conditions downstream and unsuitable overwintering habitat for fish in these reaches. If winter habitat is to be improved, reaches downstream from warm groundwater input need to be identified before such habitats are altered, and calculations or observations should be made to ensure that frazil ice and anchor ice during winter does not occlude habitat formed by instream structures.

SUMMARY

During winter, fish are vulnerable to numerous threats to their survival. Protecting or creating suitable winter habitat in temperate climates is critical because fish spend a large part of the year in these habitats. Both freeze-up and ice break-up are especially dynamic times when ice can cause riverine habitats needed by fish to be unstable and movement routes to be blocked. Diverse habitats, however, including deep pools with low water velocities, coarse rock substrate, and abundant cover, as well as side channels and backwaters, increase the probability of survival of overwintering fish. The inflow of relatively warm groundwater into the water column can be an important factor affecting winter habitat, and can either enhance or diminish winter habitat quality for stream-dwelling fish. Understanding the influences of groundwater, industrial or municipal effluents, or upstream reservoirs on winter water temperatures and ice dynamics in downstream reaches is critical to successful preservation or creation of suitable winter habitat. Research is needed on habitat needs of fish during winter to ensure preservation of these habitats and to ensure that suitable habitats are created when fisheries managers make habitat improvement efforts. To date, most habitat preservation and improvement efforts have focused on habitats used from spring through fall, with little consideration or understanding of the influence of winter on these habitats. Considering the length of winter and the vulnerability of fish during winter, a much broader effort to understand, preserve, and improve winter habitats is warranted.

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OPINION:

Human Population Increase, Economic Growth, and Fish Conservation: Collision Course or Savvy Stewardship?

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ABSTRACT: Globally, fishes and fisheries are in severe decline, driven in large part by economic and human population growth. Despite progress in environmental philosophies, legislation, and protection, conflicts between economic/human population growth and fish conservation remain and are intensifying at continental and global scales. The growth of the human enterprise ad infinitum is impossible because of dependence on finite resources; hence policies should leave a margin of error when dealing with the biophysical environment. We suggest a re-definition of Earth stewardship to serve as a conceptual bridge between ecology and economics, recognizing the hubris behind most economic models, which assume that the biosphere is a subset of the economy or else an externality, when in fact Homo sapiens is a species operating within the biosphere. Additional indicators that focus on a different suite of values (e.g., social justice, corporate responsibility, and ethics) would underscore the complexity of economic and human population growth effects on societies and ecosystems, and could help guide us away from unsustainable actions toward those that are "savvier" in terms of co-existence with the resources upon which we depend.

Incremento de la población humana, crecimiento económico y conservación de peces: rumbo de colisión o administración comprensiva

RESUMEN: a nivel global, los peces y las pesquerías se encuentran en franco deterioro, debido en gran parte al crecimiento económico y de la población humana. A pesar del progreso en las filosofías ambientales, legislación y protección, los conflictos entre economía/crecimiento poblacional y conservación de peces se mantienen e intensifican a escala continental y global. El crecimiento de los humanos ad infinitum es una condición imposible dada nuestra dependencia de una base finita de recursos; por lo tanto las políticas de manejo deben dejar un margen de error en lo concerniente al ambiente biofísico. Se sugiere una re-definición de la administración de los recursos del planeta para que sirva como puente conceptual entre la ecología y la economía, reconociendo la arrogancia detrás de la mayoría de los modelos económicos que asumen a la biósfera como una subdivisión de la economía o bien una externalidad, cuando en realidad el Homo sapiens es una especie que funciona dentro de la biósfera. Otros indicadores enfocados en un grupo diferente de valores (v.g. justicia social, responsabilidad corporativa y la ética) resaltarán la complejidad de los efectos que tiene el crecimiento humano y económico sobre las sociedades y ecosistemas y pueden ayudarnos a transitar de acciones no sostenibles hacia aquellas que sean más comprensivas en términos de coexistencia con los recursos de los cuales dependemos.

Over the past few years, a debate took place within the American Fisheries Society as to whether or not to adopt a policy statement on economic growth, fisheries, and a fundamental conflict of these activities with fish biodiversity and conservation. The debate was a healthy one, and included a series of articles (e.g., Czech et al. 2004; Miller Reed and Czech 2005; Bigford et al. 2006; Hyatt et al. 2007) that played out on the pages of this magazine for over two years. Ultimately, that policy was not adopted, the reason being that "…the draft document did not meet the rigorous requirements of a policy statement that would represent a position of the American Fisheries Society on the potential effects of economic activity on fish conservation" (Franzin 2009, p. 135). Franzin (2009) provides a full chronology of the debate.

As part of the vetting of the draft policy statement, three of us (KL, RH, DJ) were asked to develop a white paper, building upon the earlier work of a committee composed of members of the Water Quality Section and Resource Policy Committee. The intent of the white paper was to clarify points made in the draft, as well as to provide additional documentation of the need for such a policy. Here, we (together with BC) provide a condensed, updated version of the white paper and offer it as an opinion piece to the AFS readership. Our emphasis is on North American fisheries, but we recognize that the issue is a global one.

Globally, fisheries are in decline. Numerous studies indicate that wild fish and shellfish stocks are down virtually everywhere compared to several decades ago (Pauly and Palomares 2005, Myers and Worm 2003, SOFIA 2008), especially preferred stocks. Serial depletion of fish stocks by overfishing is a worldwide phenomenon (Pauly and Palomares 2005). Myers and Worm (2003) projected that 90% of large predatory fish are gone from global oceans. Diadromous species are in massive decline, many by > 95%, in the North Atlantic (Limburg and Waldman 2009) and elsewhere.

Unfortunately, in North America, examples abound (e.g. McEvoy 1986, Helfman 2007). North Atlantic cod (*Gadus morhua*), once a mainstay of the economy of northeastern North America, collapsed spectacularly in the early 1990s and is unrecoverable for the foreseeable future. Pacific salmon (*Onchorynchus* spp.) have gone from supporting major commercial fisheries to multiple listings as threatened or endangered. American shad (*Alosa sapidissima*), once the second most important U.S. fishery, is at historic population lows in its native range, with closures increasing. Within the Laurentian Great Lakes, a precipitous decline of valuable commercial species occurred in the late 1800s as a result of intensive commercial fishing, environmental degradation, and modification of land and hydrology. Impounded U.S. rivers have resulted in losses of high quality fisheries for native species, replacement with non-native fishes, and loss of native biodiversity. Precipitous declines in shellfish are exemplified by the loss of Eastern oyster (*Crassostrea virginica*), decimated up and down the Atlantic seaboard, with economic losses estimated in the millions of dollars from Chesapeake Bay alone, to say nothing of loss of ecosystem function.

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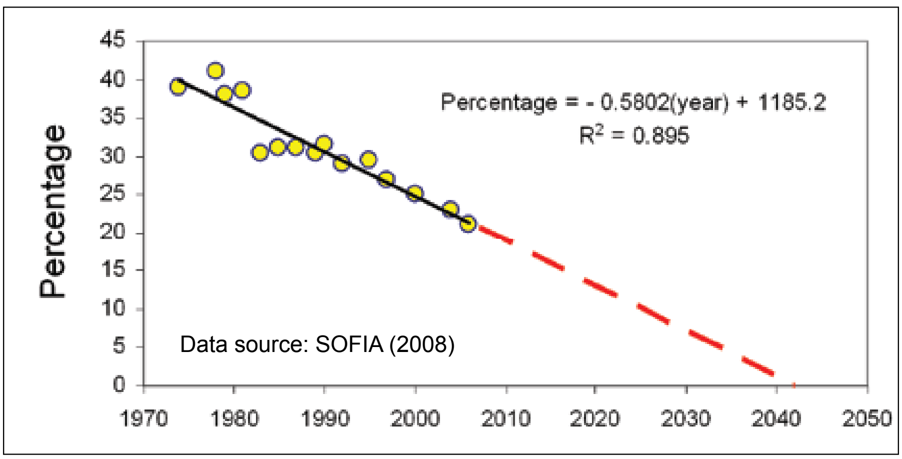
The generic drivers of these adverse changes are human population and economic growth. A growing human population demands more fish for food (76% of world fisheries production) and other purposes (24%), causing more and more effort to be applied to continually decreasing stocks. The latest State of World Fisheries and Aquaculture (SOFIA 2008) reported that 79% of world fished stocks are fully or over-exploited, or collapsed and recovering (compared to 60% in the mid-1970s). Worrisomely, the percentage of lightly exploited or moderately exploited fish populations has been declining almost linearly since 1974 (Figure 1); one can extrapolate that all fish populations will shift into the "fully exploited/depleted/recovering" category by 2042. This is similar to the conclusion drawn by Worm et al. (2006) that all then-currently exploited species would collapse by 2048.

From an economic perspective, overfishing is driven in part by overcapacity and subsidies (Sumaila and Pauly 2007). Furthermore, environmental change (e.g., global warming, land use, hydrological modification, and habitat alteration) and its attendant uncertainty result from human population and economic growth pressures. This sets the stage for increased incidence of unexpected events, tipping points, and sudden collapses. Increasingly, cultural eutrophication in a warming climate is tipping coastal ecosystems into hypoxic episodes that have direct and indirect impacts on fisheries. Low returns of Chinook salmon (*O. tshawytscha*) because of historical overexploitation and habitat change, coupled with poor ocean conditions, have predicated the closure of commercial and recreational fisheries for this species off the coasts of California and most of Oregon during the summers of 2008-2010 for the first time in history.

NATIVE SPECIES IN DECLINE

Within North America, recent studies document marked declines in fish species and fish assemblages at regional and continental scales. At least 700 North American freshwater fishes are endangered, threatened, or vulnerable (Jelks et al. 2008); at least 167 distinct population segments of marine North American fishes are so classified (Musick et al. 2000). At the fish assemblage level, only 57% of the

Figure 1. Trend (solid line) in percentage of world capture fisheries that are lightly or moderately exploited, with extrapolation (dashed line).



total stream and river length of the conterminous western USA supports least disturbed fish assemblages (Whittier et al. 2007) and 35% of that stream length was deemed impaired (Pont et al. 2009), while only 17% of mid-Atlantic Highland stream length contains least disturbed fish assemblages (McCormick et al. 2001). Only 28% of wadeable stream length in the conterminous USA supports least disturbed macroinvertebrate assemblages (Paulsen et al. 2008). Master (1991) estimated that 73% and 67% of mussel and crayfish species, respectively, are imperiled or rare.

Human population and economic growth are major drivers for these declines, incorporating all sectors of the economy. In the U.S. and Canada, the leading anthropogenic factors currently contributing to fish species listings under the U.S. federal Endangered Species Act (ESA) and the Canadian Species At Risk Act (SARA) are surface water diversion, agriculture, invasive species, urbanization, and pollution, often in combination (Miller-Reed and Czech 2005, Rose 2005). These drivers are indicators of economic activity and they are especially acute in coastal areas where more than half of U.S. citizens reside, and where most growth is projected. Additionally, high rates of species listings occur in some interior regions. For example, Nevada and Arizona, two of the fastest-growing states, have extensive water development projects that compromise aquatic ecosystems. These two states, together with California, Tennessee, and Alabama (also with extensive water projects), account for 87 of the 139 fish species presently listed. In a review of historical changes in large river fish assemblages, Hughes et al. (2005) concluded that flow and channel regulation plus alien species were key alterations, especially in the southwestern USA. Generally, it is such landscape and basin scale economic/land use disturbances that explain most of the variation in fish species or assemblages when viewed at state and national scales (Hughes et al. 2006).

Densely populated and rapidly expanding urban areas contribute significantly to aquatic habitat change and water pollution (Brown et al. 2005). Growth in impervious surface area has repeatedly been implicated in aquatic habitat degradation, affecting streams, rivers, lakes, and estuaries (e.g., Brown et al. 2005). For example, once the most productive estuary in North America, Chesapeake Bay has experienced extensive eutrophication, primarily from suburban and agricultural runoff, with periodic episodes of hypoxia and alteration in trophic structure.

Agricultural runoff has degraded and continues to degrade fish habitat. The United States Environmental Protection Agency (Paulsen et al. 2008) estimated excessive phosphorus, nitrogen, and fine sediment levels in 31%, 32%, and 25%, respectively, of wadeable U.S. streams, mostly from agricultural runoff. Impacts can be immediate or translocated over time and space. For example, a 20,000 square kilometer hypoxic region in the Gulf of Mexico developed through the increased inputs of nitrogen and phosphorus in the Mississippi River basin (Rabalais et al. 2002). On the East Coast, upland watersheds contribute substantially to coastal marine eutrophication (Boyer et al. 2002). Nationally, Dodds et al. (2009) estimated that eutrophication creates over $2 billion in damage costs per year, including an estimated $44 million/year paid out to mitigate or prevent biodiversity losses.

If these conflicts are not proactively addressed, we will lose fish, fisheries, and treasured traditions of interacting with them. But if the conflicts are addressed proactively, we might enter into an era of "savvy stewardship."

A variety of atmospheric stressors create both acute and diffuse problems. Airborne pollutants from fossil fuel combustion increase mercury contamination of fish tissue (Peterson et al. 2007), contribute to surface water acidification (Driscoll et al. 2001), inhibit the growth of algae, reduce hatching success, increase egg and larval mortality, and inhibit fish growth. Atmospheric nitrogen deposition further adds to both eutrophication and acidity problems (Driscoll et al. 2001; Bergström and Jansson 2006). Climate warming is projected markedly to reduce and fragment the ranges of both resident and anadromous salmonids in the U.S. (Bigford et al. 2009) and has already altered the ranges of many species globally (Parmesan and Yohe 2003).

Increased trade has also caused unprecedented transfers of non-native species (Fuller et al. 1999) which are associated with declines in native biodiversity and economic damages in the billions of dollars (Pimentel et al. 2005). Lomnicky et al. (2007) reported that over 50% of fish bearing stream length in the western U.S. contained non-native fish, and that non-natives dominated fish assemblages in 22% of western U.S. stream kilometers. Fifty-eight percent of the 6-digit hydrologic units in the conterminous USA contain over ten established alien fish species (Heinz 2008). Leprieur et al. (2008) found gross domestic product (GDP), human population density, and percent urban area to be better predictors of non-native species richness than altitude, basin area, net primary productivity, and number of native species.

Given the widespread evidence from the above examples, it is no surprise that tight correlations exist between U.S. GDP, population growth, and the mounting list of endangered species (Figure 2). Internationally, trends are more scattered, but all populated regions of the world show positive correlations between threatened fishes and the size of national economies (Clausen and York 2008b).

WHY WE CANNOT GROW (OR SHOP) OUR WAY OUT OF THIS PROBLEM

The U.S. comprises less than 5% of the world's population, but consumes over 30% of the resources used for economic growth (EarthTrends 2010). During the latter half of the 20th century, U.S. per capita resource use rose 45% overall (Suzuki 1998). The economy of the U.S. depends heavily on fossil fuel combustion, accounting in 2005-2007 for approximately 21% of annual consumption worldwide (EIA 2010). Much of this characterizes a "consumer society" in which discretionary spending is a mass phenomenon stimulated by government policies, not just practiced by the rich or the middle classes. Many scholars point to post-World War II as the time when consumption of goods and services began increasing sharply, both in absolute and per capita terms (e.g., Collins 2000). Rosenblatt (1999) estimated that approximately 90% of the U.S. workforce was employed in the production and sale of consumer goods.

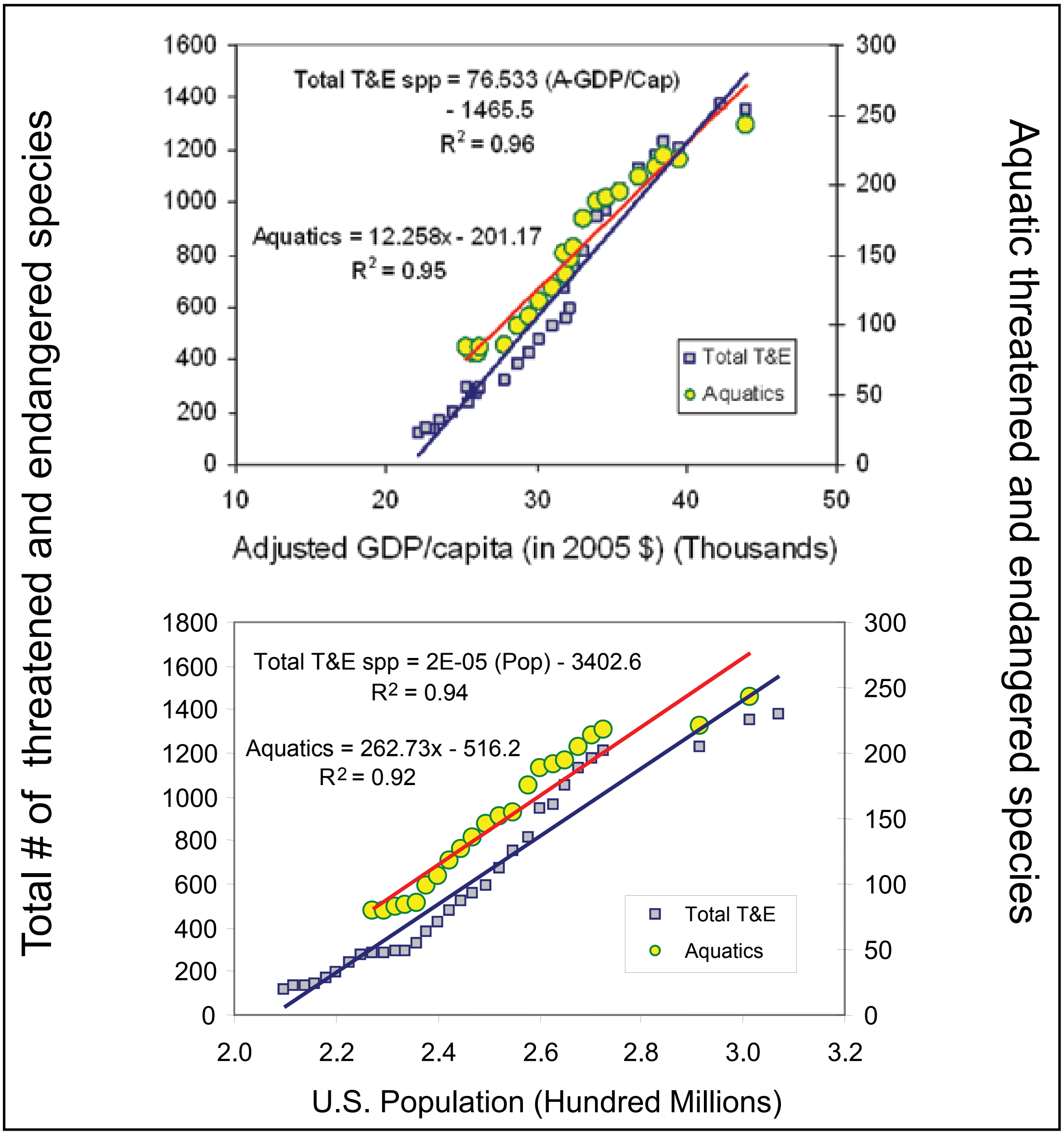
The typical measures of an economy's size are gross national product (GNP) and gross domestic product (GDP). GNP is defined as "the market value of final goods and services purchased by households, by government, and by foreigners (net of what we purchase from them), in the current year. Alternatively, it is the sum of all value added to raw materials by labor and capital at each stage of production, during the given year" (Daly and Farley 2003). GNP includes production by all nationals, whether at home or abroad. On the other hand, GDP accounts only for production within the bounds of the country in question, and includes both citizens and non-citizens. When adjusted for inflation, GNP and GDP reflect the size or scale of an economy. Changes over time reflect economic growth or recession. Indeed, economic growth, defined thus, has been the goal of the U.S. and other nations for much of the last 100 years (Collins 2000).

A common critique of GDP and GNP is that these are poor indicators of economic welfare, much less overall human welfare, yet they typically are assumed to be indicators of welfare by some economists and many policy makers. GDP and GNP reflect the amount of economic activity taking place. Concomitantly they reflect the amount of natural capital re-allocated from "the economy of nature" to the human economy (Czech 2008). That explains the tight connection of GDP and GNP growth with energy and material throughput (Daly and Farley 2003), and with environmental impacts such as biodiversity decline (Figure 2).

Economic growth (e.g., increasing GDP and GNP) entails increasing production and consumption of goods and services. Debating each other, Barry Commoner and Paul Ehrlich created the "IPAT" concept (Ehrlich and Holdren 1972) that states that ecological impact (I) of humanity is a product of human population (P), affluence (A), and technology (T), although technology was never really quantified and appears to serve as an error term (Dietz et al. 2007). Czech (2008), however, described why technological progress does not reconcile the fundamental conflict between economic growth and environmental protection, because research and development is closely linked with economic growth from pre-existing technology.

There are many who believe that economic growth and technological innovation can solve environmental problems and maximize human welfare, a "win-win" strategy. Evidence suggests that this is a naïve and ultimately risky perspective, as recently demonstrated in the Deepwater Horizon oil spill catastrophe in the Gulf of Mexico and the current debate over risking the world's largest sustainable sockeye salmon (*Oncorhynchus nerka*) fishery (Bristol Bay, Alaska) for a few decades of copper (Woody et al. 2010). It is also important to recognize that the major driver of impact in the wealthy nations (especially the U.S. and Western Europe) is over-consumption, whereas population growth is the driver in the Third World. As the Third World develops, those nations have an essential – and critical – opportunity to choose a more sustainable path. Similarly, we in the highly consumptive nations must reconfigure our economies to reduce our impact.

Figure 2. Threatened and endangered species (total and aquatic) in the United States plotted as a function of per capita Gross Domestic Product, adjusted to 2005 dollars (top panel) and U.S. population (bottom panel). Data sources: U.S. Fish and Wildlife Service, Endangered Species Program, U.S. Census Bureau, and U.S. Bureau of Economic Analysis. Abbreviations: T&E = threatened and endangered species; A-GDP/Cap = Adjusted Gross Domestic Product/Capita; Aquatics = Aquatic threatened and endangered species; Pop = U.S. population. Note that species are added to and removed from the endangered species list constantly; the numbers simply reflect the totals at the time.



RECOGNITION THAT HUMAN ACTIVITIES CAN BE USED TO MITIGATE THE CONFLICT BETWEEN ECONOMIC/POPULATION GROWTH AND FISH CONSERVATION

Proactive stewardship of natural resources has deep roots in human history. The original text of Genesis, when addressing humankind's relationship with the Earth, states that early humans were given dominion over the earth and directs humans to tend and keep the earth (Ravid 1987). The world's great religions, which serve as social ordering mechanisms, have all addressed this issue. This sense of respect for the earth and its resources in early civilizations was codified in the concept of shabbat or sabbatical (periodic rest and restoration for the land). It was recognized that there were limits to what the land could provide, that human relationships with the land had to operate within the framework of those limits; and when nurtured, land has the ability to restore itself. Over millennia, and in many civilizations and cultures, the concepts of responsibility, limits, and restoration regarding natural resources evolved. Where these concepts were inappropriate, misdirected or inadequate, the civilizations and cultures faded (Diamond 2005). In some arenas, the impacts to the land were so severe that landscapes have been refractory to rehabilitation.

In North America there have been champions for earth stewardship whose voices were (fortunately) heard "in the wilderness" of nation-building enterprise. Henry Thoreau, George Marsh, John Muir, Theodore Roosevelt, Aldo Leopold, Ding Darling, Rachel Carson, Annie Dillard, Al Gore, Winona LaDuke, and many others have, with time, advanced perspective that eventually helped redirect focus and changed mindsets regarding humankind's relationships to the Earth and its resources. Their legacy is appropriately a blend of the tangible and the intangible, reflecting the essence of the human experience. They forced us to look hard at our past and at the present, to project into the future, and to ask serious questions about ourselves in relation to our environment. The scope of their messages ranged from transcendentalism, to pragmatism, to threats to survival of life in its various forms (including human life), cultures, and civilizations as we now know them.

In response, much has been done to protect and restore landscapes. In the U.S., national legislation and regulatory agencies were created during periods of progressive thought to mitigate the effects of economic and population growth, either directly or indirectly. Following a period of economic intensification in the 1950s and 1960s, the National Environmental Policy Act of 1969 initiated a period in the 1970s of re-awakened concerns for the environment and associated impacts of socioeconomic activity. The 1973 Endangered Species Act (ESA) declared that "various species of fish, wildlife, and plants in the United States have been rendered extinct as a consequence of economic growth and development." The USEPA was formed in 1970 in part to administer the Clean Water Act (CWA) the objective of which "is to restore and maintain the physical, chemical, and biological integrity of the Nation's waters," and its second goal is to provide "for the protection and propagation of fish, shellfish, and wildlife." Further, the 1978 "God Squad" amendment to the ESA and the "use attainability" clause in Section 101 of the CWA both recognize that economic growth contradicts the objectives of the Acts. Yet both Acts represent remarkable foresight in environmental protection and served as models for similar legislation throughout the world. Chief examples are the Species at Risk Act (SARA of Canada), the CONABIO (National Commission for the Knowledge and Use of Biodiversity) in Mexico, and the Water Framework Directive of the European Union.

Earlier examples of mitigating legislation in the U.S. are the Antiquities Act (1906), the creation of the U.S. Forest Service in 1905, and the forming of the National Park Service in 1917, all of which facilitated protection of large tracts of land where nature protection from economic and population growth is the goal. Prior to these consolidating initiatives, ad hoc means were used throughout the continent to protect and conserve resources of special interest. Similarly, legislation creating national wildlife refuges and wilderness areas is dedicated to the proposition that economic development is contrary to nature protection. The Magnuson-Stevens Fisheries Conservation and Management Act limits fish exploitation along thousands of square miles of the U.S. coast and supports protection of essential fish habitat. Marine protected areas, established under various legislative authorities, provide refuges from economic exploitation for marine fish. The Coastal Zone Management Act, the Clean Air Act, the Wilderness Act, the National Wild and Scenic Rivers Act, the Toxic Substances Control Act, the Northwest Forest Plan, the Wetlands Reserve Program, and the Conservation Reserve Exclusion Program also limit economic activity and provide important protections for fish via protection of fish habitat.

There are many state analogs to federal environmental legislation. In New York the Adirondack Park, established in 1872 and a model for future national parks, protected New York City's drinking water through forest conservation. Oregon's Land Use Act of 1973 restricted commercial and residential development of private agricultural and forest lands. Mississippi's Scenic Streams Stewardship Act (1999) established a voluntary program to protect scenic waterways with unanimous-minus-one legislative support. Numerous county and city natural areas, greenways, and water supply watersheds offer local examples of protecting nature from economic development. However, extensive natural areas also attract residential and tourist developments.

Perhaps the best example of private national and international ecosystem rehabilitation is The Nature Conservancy, a non-governmental organization (NGO) that purchases lands and protects them through sustainable best management practices. Similar land trusts have been established by wealthy individuals and conservation groups with the sole purpose of protecting wildlife and fish from economic development in perpetuity.

All of the above mentioned endeavors are laudable and assist in establishing a foundation of awareness and action in the natural resources stewardship arenas. There are many educational success stories. Environmental curricula are widespread throughout educational institutions, NGOs, and professional organizations. Local, regional, and national media distribute news and programs addressing natural history, natural resources, and environmental issues. Many scientific societies are now actively engaged and effective in providing critical information to the media. In response to a growing public awareness of these issues, politicians and governments have had little choice but to incorporate them into platforms and agendas. Scientists have had a major role in providing technical information and perspective to legislative and administrative bodies at federal, state, provincial, and local levels.

However, the conflicts between human population and economic growth and fish conservation, while mitigated to some extent by the preceding initiatives, still remain and are intensifying at continental and global scales. Are we on a collision course with biodiversity and the Earth's restorative capabilities? If these conflicts are not proactively addressed, we will lose fish, fisheries, and treasured traditions of interacting with them. But if the conflicts are addressed proactively, we might enter into an era of "savvy stewardship."

A FRAMEWORK TO ASSIST SOCIETY AT LARGE IN RE-DIRECTING LIFESTYLES AND SATISFACTION AWAY FROM A CONSUMPTIVE PERSPECTIVE TOWARD A SUSTAINABLE PERSPECTIVE

There is a need for broad-reaching policy acknowledging that (1) economies and populations cannot grow ad infinitum, as they depend on finite resource bases (Meadows et al. 2004), (2) a margin of error should be left when dealing with the biophysical environment (the precautionary approach, Daly and Farley 2003), and (3) that fisheries management should be geared at protecting and fostering ecosystem services as much as for protection of single species of interest. For example, just as civilization at a global scale is approaching "peak oil" (Duncan 2006) and "peak food," it is apparent that we may have reached or have possibly surpassed "peak fish" (e.g., Pauly and Palomares 2005, Clausen and York 2008b).

Re-definition of Earth stewardship serves as a conceptual bridge between ecology and economics. But what are the appropriate relationships of humans to the planet? Stewardship and respect for the Earth are often-repeated mantras of the conservation community, but the actions of society at large demonstrate these attitudes only infrequently. Rather, the "tragedy of the commons" (Hardin 1968) plays out repeatedly. And sadly, fisheries declines and collapses and threats to or loss of fish species form a solid core of cases in point.

Key to re-defining Earth stewardship is to recognize the hubris behind most economic models of humanity, which assume that the biosphere is a subset of the economy or else an externality, when in fact *H. sapiens* is a species operating within and as part of the biosphere (Costanza et al. 1997, Daly and Farley 2003). The biosphere is indifferent to whether our species continues to exist or not. Nevertheless, humans are a dominant species on Earth, slowly yet execrably altering landscapes and riverscapes at global scales (Wolman 2002, Parmesan and Yohe 2003), appropriating much of global primary production and altering biogeochemical cycles (Vitousek et al. 1997), to say nothing of mining fossil fuels and other stored natural capital.

In a recent commentary, Bundy et al. (2008) proposed a new conceptual model for good governance of fisheries. Their vision reverses the conceptual model of humans as the apex of a resource pyramid, and instead views humans as destabilizing agents of abrupt changes in meta-stable ecosystems. The new model supports highly elevated levels of social justice, corporate responsibility, and ethics. Fish and fisheries management policies in line with this new vision include movement away from industrial fisheries toward smaller scale pursuits; removing direct and indirect subsidies for industrial fisheries (e.g., by nations and the World Trade Organization; Sumaila and Pauly 2007); and better accounting of marine discards, with the ultimate goal of elimination of this waste. Such a model includes ocean zoning (i.e., management districts or regions of ocean far larger than Marine Protected Areas) and developing similar approaches at smaller scales for inland waters (e.g., river reaches and lake sub-basins). Although many persons will have moral or social objections (Lakoff 2002, Graham et al. 2009, Kahan 2010), and because many scientists focus on short-term local changes versus long-term systematic changes (Parmesan and Yohe 2003), we offer our recommendations as a means to encourage dialogue.

We need to re-affirm an environmental ethic. Although not a new idea, it is one that gains increasing urgency and currency as the scale and quantity of human endeavor increases. Aided with greatly improved tools to observe and analyze the Earth at a macroscopic scale, we can assess our impacts now at local to global scales. Armed with this information, we have an ethical responsibility to care for the Earth, its ecosystems, and its biodiversity. For example, Nash (1989) argued for an expanded sense of ethics to include legal standing for ecosystems and species, and in the fall of 2008 Ecuador became the first nation to do so. Increasingly, the world's religious leaders are calling for a much more ethical relationship with Earth. For example, among his many other activities, the Greek ecumenical patriarch Bartholomew I called crime against the natural world a sin, and organized a meeting of 200 scientists, journalists, and politicians to discuss marine preservation and overfishing hazards.

As part of re-defining stewardship, we need to embrace a pluralistic suite of indices and paradigms of human and ecosystem welfare. Traditional indicators such as GDP and GNP are useful as indicators of the size of an economy, but are insufficient for assessing many human and ecological values and conditions (Daily 1997, Daly and Farley 2003). The use of alternative indicators causes us to focus on different values and to underscore the complexity of economic/population growth effects on society and ecosystems, and not just in economic terms. To better demonstrate the relationships between the alternative indicators, one may compare the temporal trends among various indicators (for examples of these, see Box 1).

Study of alternative indicators demonstrates a need to re-develop economies with incentives that serve to reduce consumption and population growth. Some of these incentives may by necessity be

Box 1. Examples of alternative or complementary economic, or ecological-economic, indicators.

- Monetary indicators include the Index of Sustainable Economic Welfare (ISEW), developed by Daly and Cobb (1994), which accounts for such things as the negative impacts of pollution to society, and the Genuine Progress Indicator (GPI, Venetoulis and Cobb 2004). The GPI estimates the value of unpaid and thus non-marketed services such as housework, caring for children and the elderly, and volunteerism. Tracking the ISEW and GPI suggests that, while GDP and GNP have continued growing over the past few decades, economic welfare has not, and ecological and economic sustainability have been declining (Daly and Farley 2003; Venetoulis and Cobb 2004).
- An example of a non-monetary indicator of social welfare is the Human Development Index (HDI). The HDI incorporates poverty, literacy, education, life expectancy, and other factors. Since 1993, the HDI has been used by the United Nations Development Programme in its annual report. Because HDI and other non-monetary indicators of welfare better represent the status of nations with regard to overall well-being, such indicators and their trends should be contrasted with those of GDP and GNP.
- Additionally, ecological indicators of biodiversity, sustainability, and resiliency must be better incorporated and appreciated within the suite of complementary stewardship indices. These include the ecological footprint (http://www.footprintnetwork.org), which is under consideration for adoption by the European Union; environmental accounting (Lange 2003), which incorporates some ecosystem goods and service values into national income accounts; ecosystem service valuation (e.g., Daily 1997), and the myriad indices of ecological condition or health (e.g., Roset et al 2007).

implemented through various means of command and control (e.g., taxation, regulation). Alternatively, incentives may take the form of payments for ecosystem services. Regardless, national monetary policy should be designed to stimulate conservation (vs. consumption) of natural capital.

Fundamental to this end are programs that address population growth and the IPAT problem. This can be accomplished through education, advancing economic opportunity for women and the poor, taxes, and subsidies (e.g., payments for family planning and health care). Concomitant with these programs would be allied initiatives that reduce society's environmental impact. This could be accomplished through re-configuring housing, transportation systems, zoning laws, and advancing green infrastructure and low intensity development ("wilding" our cities) through incorporating "scruffy places" (Kondolf 2006) that incorporate lakes, naturalized wetlands, and other aquatic ecosystems (even supporting wild fishes) into overall community designs. These and similar initiatives, with both functional and aesthetic dimensions, underscore linkages between Earth stewardship and economic efficiency—as long as increased efficiency is directed towards resource conservation and non-consumptive uses.

Efficiency perspectives then can move into industrial and energy sectors of societies. These perspectives could for example be expressed through development of durable goods with increased efficiencies and lifetimes (e.g., decreased energy consumption and removal of planned obsolescence and conspicuous consumption). Reduced energy demand would decrease needs for hydropower (and its negative impacts on migratory aquatic species), fossil fuels (and associated negative impacts via acidification of streams, mercury contamination of fish tissues, oil spills, and climate warming), and power plants situated on water bodies (that entrain fish and other aquatic life).

It is especially incumbent on the U.S., which exemplifies the highest population growth rate of the industrial democracies and is the poster child for conspicuous consumption, once again to lead the world in a different direction (Czech 2000). Our predecessors did exactly this with enlightened political discourse in the 1770s, the conservation movement of the late 19th century, and enlightened environmental protections in the 1970s.

In this vein, it has long been an obligation of professional societies as a group to support progressive policies for which some members, acting as individuals, might be threatened with scorn or firing. Such progressive policies provide essential political maneuvering space for managers, politicians, and citizens to freely discuss challenging issues and propositions that might otherwise appear radical or impossible. Therefore we, as members of professional scientific societies, call on the AFS, religious leaders, scientists, economists, journalists, and politicians, working in concert with fisheries and other natural resources professionals, to support a markedly reduced ecological footprint for much of North America by advocating and deliberately moving towards zero then negative population growth and economic growth, first in the U.S. and then throughout the North American continent.

We realize that this will not be easy, given current national and international policies and political perspectives. We also understand that the recommended actions should not occur so rapidly as to incur excessive social unrest (as witnessed by the current widespread recession). However, we (all North American nations) must move in this direction, because a Malthusian future in a massively degraded world with dysfunctional environmental services will be even more unpleasant than the prospects or even the manifestation of social unrest. There are multiple examples of societies and civilizations that have failed or faded into degraded landscapes (e.g., Diamond 2005), so there is no reason to believe that this is impossible for the U.S. and other high consuming nations. And because economies, resource demands, and environmental threats are global and interlinked, solutions ultimately must be global. But before the U.S. and other North American nations can take on the role of partnering with the global community and move towards a sustainable future, we must begin by doing so ourselves.

We, the authors of this essay, are scientists and managers trained to think broadly about ecosystems (including human dimensions of ecosystem functioning). We are concerned about the wellbeing of fish and fisheries. But our concerns really go much deeper. We are very concerned about the wellbeing of this planet and the wellbeing of people who live on it. In this regard, we recognize that (1) solutions to the challenges we have outlined in this essay must incorporate a focus on human behaviors, value systems, cultures and political enterprise, and (2) that success will depend on fisheries professionals like ourselves working in concert with professional social scientists, economists, journalists, political scientists and clergy adequately trained in the critical disciplines needed to address (or change) human components of ecosystem functioning. We need their help. We need *your* help. It is not something any of us can do alone. Success will depend on professional courage coupled with political will…from all of us.

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COLUMN:
STUDENTS' ANGLE

The Gulf Oil Spill:
What it means to the Gulf and the future of fisheries biology students

Figure 3. Expansive boom set to protect the barrier islands from oil.

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During the annual meeting of the Western Division AFS in Salt Lake City, Utah, American Fisheries Society President Don Jackson invited students from the division to see and experience firsthand the Pascagoula River. Several students were already committed to fieldwork, or their graduate projects, but two students were able to visit Mississippi. The Pascagoula River originates in east-central Mississippi, then flows south as an independent system, and eventually forms a large estuary prior to discharging into the Gulf of Mexico. It is regarded as a national treasure due to its uniqueness as the very last physically-unmodified large river system in the lower 48 states. Additionally, it is home to state and federally listed species, including the Gulf sturgeon.

On the morning of 20 April 2011, the BP Deepwater Horizon oilrig exploded off the coast of Louisiana. That evening in Salt Lake City, the invitation was made. However, unknown at the time was just how catastrophic this accident would become. Over the next weeks, as the disaster in the Gulf of Mexico evolved, our plans to visit the Pascagoula River shifted focus to witness the environmental and political aspects of the largest environmental disaster in American history. During this trip, which occurred 53 days after the accident, we were able to explore not only the Pascagoula River, but we also extended our activities into the estuary and further into the Gulf of Mexico around barrier islands off the coast of Mississippi. This enabled us to view the inland river habitat that was already of high conservation value, as well as the estuary and Gulf of Mexico, which were now at the forefront of a growing ecological problem.

While circumnavigating the islands, we observed sharks, blue crabs, sea turtles, horseshoe crabs, and schools of mullet. There was a conspicuous smell of oil in the air, and an oily, prismatic sheen on the water. On the south side of the islands, rust colored globs of oil, some as large as baseballs, and many with debris tangled up inside of them, floated on the waves and washed ashore.

On the Pascagoula River, houseboats floated, and a handmade cedar boat ferried a grandfather and grandson to their trotline—evidence that the river and the lives of people in this part of the country are deeply intertwined. We were provided opportunity to engage in recreational fishing, both freshwater (trotlines for catfishes) and estuarine (blue crabs and brackish-water finfish), in order to get a feel for the resources from the perspective of consumptive users (Figures 1 and 2). At the river mouth, the estuary was filled with boat traffic, including shrimp boats either heavy with the day's catch (prior to closure of the region's fisheries), or engaged in activities focused on intercepting the approaching oil slick. Because of a recently imposed ban on recreational fishing in marine waters, most of the activity that we encountered along the coast was associated with addressing the oil spill.

There are going to be numerous jobs available for persons with fisheries training. Due to the nature of the challenges associated with recovery from the oil spill, many of these opportunities could very likely establish the framework for entire careers.

The Mississippi Department of Marine Resources provided us with a boat and a driver to witness the oil coming onshore, and to see the subsequent preventive efforts on the barrier islands. The barrier islands were protected by expansive sets of orange and yellow booms designed and positioned to limit the amount of oil actually making it to shore (Figure 3). While circumnavigating the islands, we observed sharks, blue crabs, sea turtles, horseshoe crabs, and schools of mullet. There was a conspicuous smell of oil in the air, and an oily, prismatic sheen on the water. On the south side of the islands, rust colored globs of oil, some as large as baseballs, and many with debris tangled up inside of them, floated on the waves and washed ashore. Despite preventative efforts, the island beaches were littered with washed up oil globs, tar balls, and oily debris (Figure 4).

Figure 1. Blue crab from the Pascagoula estuary

Figure 2. Stingray sampled in the Pascagoula estuary.

Figure 4. Oil on a barrier island

It became clear to us during our trip to the Mississippi Gulf Coast, and upon reflection after our trip, that the oil spill is generating profound opportunities (and responsibilities) for the emerging cohort of new fisheries professionals in AFS. We will be needed to address contemporary and future needs of fisheries throughout the region. There are going to be numerous jobs available for persons with fisheries training. Due to the nature of the challenges associated with recovery from the oil spill, many of these opportunities could very likely establish the framework for entire careers. Our trip not only gave us firsthand experience in this emerging arena, but also insight into how we may be able to orient our academic programs and participation in AFS to better address the specific needs in the region.

Whether students are more inclined to conservation biology, fisheries science, or ecology, this situation requires diverse perspectives. The presence of threatened and endangered species, such as the Gulf sturgeon and brown pelican, warrants the need for people with a conservation biology concentration. These professionals will also be needed to effectively communicate with a concerned public. The economically valuable near-shore and offshore fisheries require skilled fisheries scientists to be able to explain the real and possible effects of this disaster to the various fin and shellfish markets. During the oil spill, recreational fishing was closed, and throughout the Gulf, boat captains were forced to adopt the role of protector in place of harvester. Subsistence and recreational resource users may be forced to adapt by utilizing freshwater systems. Like other marine subsidies, coastal fishing economies could be diverted inland as commercial and recreational fishermen focus on more pristine waters. With these issues, trained fisheries scientists can help expedite the region's recovery. Furthermore, the extent of the oil spill stretched from the deep-sea to the surface, and to every state that borders the Gulf. But unlike the beaches and near-shore habitats, the impacts to the deep-sea ecosystem will be difficult to assess. Likewise, any aquatic ecosystem in proximity to the Gulf, like the Pascagoula River and estuary complex, is at risk. Consequently, the vast scope of this disaster calls for ecologists to assist in determining the broad spatial scale that is affected and the likely changes we may see from the deep sea to the rivers that feed the Gulf. Professionals from these disciplines will be necessary to help others begin to comprehend the oil spill and its effects on the various ecosystems and organisms that are in the region's waters and lands.It may be difficult for the nation to comprehend the hardship faced by the Gulf, given the severity of the disasters faced recently. However, the risks and use of extractive methods to obtain natural resources are pervasive in the U.S., through nickel mines in the Great Lakes, gold mining in Alaska, coal bed methane in Wyoming, and offshore drilling in the Gulf. Implications of resource exploitation extend nationwide, and with continued use of extractive methods, fisheries professionals will remain responsible for creating best management practices of resources, and to be proactive if something goes wrong. The Deepwater Horizon accident is a tragedy, but the response from stakeholders (i.e., BP, residents, resource users, and the Government) necessitates objective science via skilled individuals. Objective science will be facilitated through state and federal agencies, academia, and private firms with the same purpose: to assess, mitigate, and manage the Gulf of Mexico's natural resources responsibly. The effect of the Deepwater Horizon spill will span generations, and this cohort of students can take advantage of the opportunities presented to young fishery scientists. Sometimes, just being involved can help you get there. Additionally, our trip underscored the importance of membership in AFS, and attendance and participation in AFS meetings. Had we not attended the 2011 Western Division Annual Meeting, there would have been no invitation, and we would not have been able to have the trip, nor gain the associated perspective regarding the oil spill. ♋

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INTERVIEW: FELIPE AMEZCUA

Felipe Amezcua, the President of the International Fisheries Section, as well as the President-Elect of the AFS Mexican Chapter, is seeking a major shift in the way AFS thinks about itself. In other words, he's going to put Latin America at the forefront of our minds. Says Amezcua, "Mexico should be considered more a brother to the U.S., rather than a distant cousin—the way that Canada is. One of our goals with the Mexican Chapter is to first increase the Mexican presence and participation. Then we'll work on Central America." The following is an interview with Dr. Amezcua.

Fisheries:
You certainly have a lot on your plate, and you carry some powerful titles. What are you most striving to accomplish in these leadership roles?
Amezcua:
One of the ideas is that not a lot of people from other countries go to the AFS meetings in the US or Canada. Most attendees are from US or Canada. But we want to have a large presence from Mexico and other Latin America countries. In fact, the Mexican Chapter was created because one of the goals of the AFS is to increase its presence in other countries, and part of that means increasing participation in other Latin American countries, in order to increase the participation and exchange of information.

Fisheries:
Why don't more Latin Americans come to US- or Canadian-based meetings?
***Amezcua*:**
Usually for us, the cost is quite high due to the exchange rate. One dollar is equivalent to thirteen Mexican pesos, which isn't that bad, but if you compare that to the exchange rate for Central Americans, well, it's almost impossible for them to attend the meetings. The benefits of these meetings are very high, because there is a lot of important social and academic activity taking place, but the problem is that for most Latin American countries, the price keeps people from attending. Researchers or scientists from undeveloped countries would participate more if we find a way for them to lower costs.

Fisheries:
That's a good point. What about your plans in your leadership roles?
Amezcua:
In general, science suffers when everyone is not participating. We are trying to form another AFS chapter for Central America that would include El Salvador, Panama, Nicaragua, Guatemala and Costa Rica. In those countries the fisheries science is extremely underdeveloped. They really need help. Usually they contact us to ask for help. There are a lot of areas in their countries where fisheries management is taking place, however there are no known studies. Why? Example—in El Salvador, there are two or three fisheries scientists in the whole country. The few scientists we do have are really interested in becoming more involved in the AFS, because they could benefit by making contact with scientists from US, Canada, and even with Mexico. If we can have those countries doing projects, regarding fisheries resources, they will then come to North America to talk about new, invaluable information.

Fisheries:
Is there any other reason why the Latin American countries shy away from AFS presence?
Amezcua:
From the point of view of Mexico and maybe other Latin American countries, one thing that prevents us from having a higher presence and participation in AFS, is that maybe we see this society as something very local in terms of US and Canada? One of the ideas we've discussed in the past was to have some courses offered that are more related to tropical or sub-tropical fisheries.

Fisheries:
What are we missing in terms of serving the Latin American community more?
Amezcua:
The AFS has already been very good. Last year, in Pittsburgh, one of the themes was to promote awareness of the International community more. We have the Mexican Chapter/Mexican Fisheries Society meeting coming up in May in Mazatlan. We anticipate a more pronounced presence of other Latin American scientists. We are inviting all members of the AFS to come and participate in our meeting, and partly we are able to do that because your magazine is helping to promote this.

Fisheries:
Perfect. Let's segue into giving our members a little more information on that meeting.
Amezcua:
We are organizing a symposium on climate change, working with people from Russia, England, Australia, New Zealand, and Japan. The idea is that there is going to be this large meeting in 2012 of the World Fisheries Congress. The World Council of

Fisheries Societies was looking for smaller inter-congress meetings in other parts of the world in order to serve the community on specific topics every two years or so. Our Mazatlan meeting follows up the symposium held this year in Belfast. That's why our main subject in Mazatlan is related to Climate Change and fisheries resources.

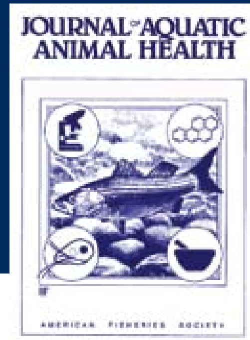
Fisheries:
What about the International Fisheries Section? What are your plans there?
Amezcua:
Well, we will continue doing what we have been doing well, such as our student membership exchange with Britain, and provide scholarships to attend AFS meetings. But we could do more: we could have membership exchanges with other fisheries societies in Australia, India, Pakistan, and Japan. We could continue supporting alternating symposia in Japan and North America. We could increase our attention to other languages by building on the program of having Spanish abstracts in Fisheries; have more submissions in our journals from non-North American authors; and have scientists from other countries on the journal editorial boards.

Fisheries:
Are you doing anything for students so they can attend the Mazatlan meeting?
Amezcua:
We don't have the funds to pay students to come here, but we already have a special student discount at our designated hotel. Each room costs $100 a room, and the hotel guarantees up to four students can stay in a room. That's a $25 room for a night for a student!"

Fisheries: Last question. Why Mazatlán?
Amezcua:
The weather is nice. We are located in the Sea of Cortes, and there is a lot of fishing. We are planning to do some fishing, go on sea-mammal watches, and take other ecological tours in connection with the symposium. Who wouldn't want to come to that?!

FISHERIES CURRENTS:

Understanding Fish Mortalities in the Potomac Drainage



By Vicki S. Blazer

Mortalities and associated skin lesions documented in the Potomac drainage since 2002 have raised the concerns of the public, state resource agencies, and the federal government about aquatic health within the watershed. The mortalities primarily affect mature smallmouth bass, redbreast sunfish, and some sucker species in the spring prior to and during spawning. Major kills have occurred in the South Branch Potomac, the Shenandoah, and the Monocacy Rivers, annually, with varying severity. The subsequent finding of a high prevalence of intersex (testicular oocytes) in male smallmouth bass from these same areas raised further unease regarding contaminants of emerging concern, particularly those with estrogenic activity. A recent synthesis in the *Journal of Aquatic Animal Health* showing eight years of survey information and research findings (by state biologists in West Virginia, Virginia, and Maryland, the U.S. Geological Survey, the U.S. Fish and Wildlife Service, and NGOs—such as the Riverkeepers Association, the Friend of the Shenandoah, and the Friends of the North Fork) documents the complexities of understanding chronic fish mortalities in wild populations. A variety of potential infectious agents were isolated or observed, including the bacterial pathogens *Flavobacterium columnare*, *Aeromonas salmonicida*, *A. hydrophila*, and other motile aeromonads, secondary oomycete infections, and Largemouth Bass Virus (LMBV). However, none were consistently found, i.e. *A. salmonicida*, *motile aeromonads* and LMBV are isolated from bass and sunfish in the Shenandoah, but A. salmonicida and LMBV have never been isolated from the affected South Branch fish. *Flavobacterium columnare* was isolated from affected fish in the South Branch and the Monocacy, but is not commonly isolated from affected fish in the Shenandoah. These fish also have high parasite loads including both digenetic trematodes and myxozoan parasites. Hence, the findings indicate stressed and immunosuppressed populations that eventually succumb to a variety opportunistic pathogens/parasites. The concurrent findings of a high prevalence of intersex and other pathological indicators of impaired water quality and chemical exposure—such as skin papillomas, oxidative damage in numerous organs, and gill lesions—provide further evidence for environmental stressors. The sources of the chemicals include wastewater treatment plant effluent, storm water runoff, industry, and agriculture.

The subsequent finding of a high prevalence of intersex (testicular oocytes) in male smallmouth bass from these same areas raised further unease regarding contaminants of emerging concern, particularly those with estrogenic activity.

The potential roles of individual chemicals—such as estrogens (natural and synthetic), arsenic, and atrazine— are discussed, as are complex mixtures and interactions of these mixtures with nutrient loads and climatic effects. The report documents the need for more coordinated, collaborative studies that include a variety of both biological and chemical (water quality, tissue analyses) indicators in order to better understand and manage these ecosystem level issues. ♋

Mortality of Centrarchid Fishes in the Potomac Drainage: Survey Results and Overview of Potential Contributing Factors, *by Vicki S. Blazer, Luke R. Iwanowicz, Cliff E. Starliper, Deborah D. Iwanowicz, Patricia Barbash, James D. Hedrick, Steve J. Reeser, John E. Mullican, Steve D. Zaugg, Mark R. Burkhardt and Jeff Kelble.* ***Journal of Aquatic Animal Health***

Blazer may be contacted at vblazer@usgs.gov

PRESIDENT'S HOOK CONTINUED FROM PAGE 4

all societies in the CNRS, as well as decision makers, legislators, and the general public.

3. The societies of CNRS are jointly concerned about the future of education of fisheries, wildlife, rangeland, and forest scientists and managers who can meet the needs of natural resource management agencies. Consequently, a special conference is being planned by the CNRS for 2011 to bring educators, practicing professionals, and administrators together to present their views and address concerns.

I am excited about the CNRS and its potential. I encourage AFS members, as well as the members of the sister societies in the coalition, to lead the way with their fellow professionals to enhance the synergism that is possible through this coalition. Help the CNRS to mature and facilitate the benefits that can be attained from the alliance. Do not hesitate to contact me or AFS Executive Director, Gus Rassam (grassam@fisheries.org), with your ideas regarding the CNRS and what the Coalition can do to foster natural resources management. ♋

CALENDAR: FISHERIES EVENTS

To submit upcoming events for inclusion on the AFS Web site Calendar, send event name, dates, city, state/province, web address, and contact information to sgilbertfox.org.

(If space is available, events will also be printed in *Fisheries* magazine.)

More events listed at www.fisheries.org.

Jan 13-16	AFS	Spring AFS Southern Division Meeting	Tampa, Florida	www.sdafs.org/meetings/meethome.htm
Jan 24-25		Fourth North American Workshop on Rainow Smelt	Portland, Maine	www.maine.gov/dmr/news/smelt.htm
Jan 26-28		Aquaculture Association 41st Annual Trade Show and Conference	Bay City, Texas	Cindy Schmiid, tinnyroo@aol.com
Jan 20-21	AFS	Fourth Annual Midwest Student Fisheries Colloquium	Brookings, South Dakota	http://dakotaafs.sdstate.org/SDSUAFS_webpage/index.htm
Feb 3-4		Acoustic Tag and Hydroacouostic Winter Short Courses	Seattle, Washington	www.htisonar.com/at short course.htm
Feb 10-11		Using Hydroacoustics for Fisheries Assessment	Seattle, Washington	www.htisonar.com/at short course.htm
Feb 13-18		American Society of Limnology and Oceanography Aquatic Sciences Meeting	San Juan, Puerto Rico	http://aslo.org/meetings/sanjuan2011
Feb 28-Mar3		Aquaculture America	New Orleans, Lousiana	www.was.org/WasMeetings/meetings/Default.aspx?code=AA2011
Mar 27-31		103rd Meeting of the National Shellfisheries Association	Baltimore, Maryland	http://shellfish.org/node/78817
Mar 14-18		Biologging4	Hobart Tasmania	www.cmar.csiro.au/biologing4
Mar 14-18		Fifth International Zooplankton Production Symposium: Population Connections, Community Dynamics, and Climate Variability	Pucon, Chile	www.pices.int/zooplankton2011.aspx
Apr 9-12		Kodiak Area Marine Science Symposium	Kodiak, Alaska	http://seagrant.uaf.edu/conferences/index.html#coming
Apr 19-21		31st Pakistan Congress of Zoology (Intrenational)	University of Azad Jammu and Kashmir, Muzaffarabad, Pakistan	
May	AFS	ASA-AFS Fisheries Acoustics Workshop	Seattle, Washington	
May 4-6		International Symposium on Circle Hooks	Miami, Florida	circlehooksymposium.org
May 14-18		Second International Marine Conservation Congress	Victoria, British Columbia, Canada	www2.cedarcrest.edu/imcc/index.html
Jun		First International Conference on Fish Telemetry	Sapporo, Japan	www.knt.co.jp/ec/s011/icft
Jun 7-9		Arctic Grayling Conference Symposium	Grande Prairie, Alberta, Canadad	http://tucanadaorg/TUC_AGSW2011.shtml
Jul 6-11		Joint Meeting of Ichthyologists and Herpetologists	Minneapolis, Minnesota	www.dce.ksu.edu/conf/jointmeeting/future.shtml
Aug 1-4		Sixth World Recreational Fishing Conference	Berlin, Germany	www.worldrecfish.org
Sep 4-8	AFS	American Fisheries Society 141st Annual Meeting	Seattle, Washington	www.fisheries.org

GUIDELINES:
Fisheries 2011 GUIDE FOR AUTHORS

Submit your manuscript at http://mc.manuscriptcentral.com/fisheries.

MISSION STATEMENT

Fisheries is the monthly peer-reviewed membership publication of the American Fisheries Society (AFS). Its goal is to provide timely, useful, and accurate information on fisheries science, management, and the fisheries profession for AFS members. Some types of articles which are suitable for *Fisheries* include fishery case histories, review or synthesis articles covering a specific issue, policy articles, perspective or opinion pieces, essays, teaching case studies, and current events or news features. We particularly encourage the submission of review articles on topics of current interest in fisheries science and management and will waive page charges for such topical review articles. Short research articles may be considered if the research has broad implications or applications and the article can be readily understood by professionals of a variety of backgrounds. We also encourage articles that will expose our members to new or different fields and recognize the varied interests of our readers. Because this is the mostly widely read fisheries science publication in the world, potential articles should appeal to a broad portion of fisheries professionals. Lengthy, specialized, or highly technical research articles should be submitted to one of the five AFS journals.

REVIEWED ARTICLES

Features, Perspectives, and Review Articles

We encourage submission of topical manuscripts of broad interest to our readership that address contemporary issues and problems in all aspects of fisheries science, management, and policy. Articles on fisheries management; aquatic resources; economics; educational/administrative concepts, controversies, techniques, philosophies, and developments; and other general interest, fisheries-oriented subjects will be considered. Policy and issue papers are welcome. Papers are judged on scientific and professional merit, relevance, and interest to fisheries professionals. Features and perspectives generally should not exceed 4,500 words (excluding references and tables) and should not cite more than 40 references.

Please consult the senior or managing editor PRIOR to submission for a length or reference limit exemption for review articles or articles of Society-wide significance. Please submit your manuscript online using our manuscript tracking website at http://fisheries.allentrack.net. If you cannot submit your manuscript online, please e-mail or phone the managing editor for instructions (sgilbertfox@fisheries.org or 301/897-8616 x220).

Essays

Essays are thought-provoking or opinion articles based upon sound science. Essays may cover a wide range of topics, including professional, conservation, research, AFS, political, management, and other issues. Essays may be submitted in conjunction with a full feature article on the same topic. Essays can be up to 1,500 words, may include photographs or illustrations, and should not cite more than eight references. However, essays should provide scientific documentation, unlike unreviewed opinion pieces (below). Essays are peer-reviewed based on the following criteria: contribution to the ongoing debate, logical opinion based on good science, persuasiveness, and clarity of writing. Reviewer agreement with the opinion of the views expressed is not a criterion. Essays do not have page charges or abstracts. Essays should be formatted and submitted online as above.

Fisheries Education

New this year, *Fisheries* will consider acceptance of teaching case studies and education-related topics. Teaching case studies are short topical articles comprehensible for undergraduate students that include a background of the case, discussion questions, teaching notes, and references. Peer review of teaching case studies and educational topics will be handled by a special committee of the AFS Education Section.

What to Submit

- Assemble manuscript in this order: title page, abstract page, text, references, tables, figure captions.
  Tables may included at the end of the article file or may be submitted as separate files. Figures should not be embedded in the article file and should be submitted separately.
- Authors are strongly encouraged to submit a word processing file in either Word, Word Perfect, or Text formats. Figures/images should be in TIF, JPG, EPS, or PDF formats and tables should be in Excel or Word formats.
- The cover letter should explain how your paper is innovative, provocative, timely, and of interest to a broad audience. It should also include a list of colleagues who have seen the manuscript in draft. The cover letter can also be used to provide further explanation if part of the information has been published or presented previously.

General Instructions

- Consult current issues for additional guidance on format.
- Manuscripts should be double-spaced, including tables, references, and figure captions.
- Leave at least a 1-in margin on all sides. Indent all paragraphs. Number pages sequentially.
- Please number lines for use as reference points by the reviewers.
- Use dictionary preference for hyphenation. Do not hyphenate a word at the end of a line. Use *Chicago Manual of Style, 14th edition,* to answer grammar or usage questions.
- The first mention of a common name should be followed by the scientific name in parentheses. Our standard is *Common and Scientific Names of Fishes from the United States, Canada, and Mexico, 6th edition.*
- Cite each figure and table in the text. Organize text so each is cited in numerical order.
- Use metric units of measure. Imperial equivalents may be given in parentheses.
- Define abbreviations the first time they are used in the text.
- Spell out one-digit numbers unless they are units of measure (e.g., four fishes, 3 mm, 35 sites). Use 1,000 instead of 1000; 0.13 instead of .13; % instead of percent.
- Use the name-and-year system for references in the text as follows:
  1. One author: Jones (1995) or (Jones 1995);
  2. Two authors: Jones and Jackson (1995) or (Jones and Jackson 1995);
  3. Several authors: Jones et al. (1995) or (Jones et al. 1995). But include author names in references.
  4. Manuscripts accepted for publication but not yet published: Jones and Smith (in press) or (Jones and Smith in press).
  5. Personal communications: (J. Jones, Institute for Aquatics, pers. comm.).
  6. Within parentheses, use a semicolon to separate different types of citations (Figure 4; Table 2), (Jones and Smith 1989; Felix and Anderson 1998). Arrange lists of citations chronologically (oldest first) in a text sentence.
- DO NOT cite more than three references for a specific point.
- For quotations include page number (Jones 1996:301).
- Institutional authors may be cited as acronyms in the text but must be defined in the reference list.

Title Page

- Type the title near the middle of the page, centered, in caps and lowercase.
- Keep the title short, preferably less than seven words; it should accurately reflect the paper's content. Use common names.
- Below title, include author(s) name(s), title(s), affilliations, city, and state. In multi-authored works, indicate which author is responsible for correspondence.

Abstract Page

- Type the abstract as one paragraph. You can copy and paste this into the online form.
- Do not cite references or use abbreviations in the abstract.
- Ensure that the abstract concisely states (150 words maximum) why you did the study, what you did, what you found, and what your results mean.

Text

- See "General Instructions."
- Set all type at left. Boldface primary subheads and italicize secondary subheads.
- Insert tabs—not spaces—for paragraph indents.
- Italicize any words that should appear in italics.

- Avoid footnotes by including the information in the text.

References

- Double-space between each reference entry but do not indent text. References will be formatted during the production process.
- Alphabetize entries first by the surnames of senior authors and the first word or acronym of corporate authors; second, by the initials of the senior authors with the same surname; and third, by the surnames of junior authors. References by a single author precede multi-authored works by the same senior author, regardless of date.
- List multiple works by the same author(s) chronologically, beginning with earliest date of publication.
- Distinguish papers by the same author(s) in the same year by putting lowercase letters after the date (1995a, 1995b).
- Use a long dash when the author(s) is/are the same as in the immediately preceding citation.
- "In press" citations must have been accepted for publication, and the name of the journal or publisher must be included.
- Insert a period and space after each initial of an author's name.
- Do not abbreviate journal names. Verify all entries against original sources, especially journal titles, accents, diacritical marks, and spelling in languages other than English.

Tables

- Tables may be included with the article or submitted as separate files.
- Double-space everything, including the table title and column headings.
- Use single horizontal lines to separate column heads and to indicate the end of the table—other horizontal lines are not needed. Never use vertical lines.
- Use sentence-style captions for tables, not fragments.
- Capitalize only the first letter of the first word in each column and row entry (except initial caps for proper nouns).
- Tab between column items— DO NOT "space" between columns.
- Type "NA" (not applicable) where no entry applies in the table body. Do not add filler dashes.
- Label footnotes with lowercase, superscript letters, starting from the beginning of the alphabet (a, b, c).
- Redefine, in the table's caption or in a footnote, any acronyms that are used in the table but are mentioned only infrequently in the text.

Illustrations

Illustrations are photographs, drawings, or figures. All illustrations will print in black-and-white unless an extra payment is made for color. Consult the editor about color costs if interested. Prepare illustrations using professional standards, and consult issues of *Fisheries* for examples.

- For review on the manuscript tracking system, we prefer digital photos (or scans). However, original film photos and slides can be used for final production. The managing editor or production editor will contact you after acceptance and let you know when to send original photos.
- Identify all people who appear in photographs, and identify photographer or agency responsible for photo. Caption must be in sentence, not fragment, form. Photos are not considered figures and do not need to be referenced in the text.
- Electronic photos should have good contrast, a size of at least 4 x 6 inches, at least 300 dots per inch (dpi) resolution, and be saved in EPS, TIF, or JPG formats. For black-and-white figures and graphs, please use a minimum resolution of 300 dpi. We cannot accept PowerPoint files. Hardcopy also must be submitted for production purposes after acceptance.

Page Proofs and Reprints

The corresponding author will receive page proofs of the laid-out article (usually sent as a PDF file via e-mail) approximately four to six weeks prior to publication. Check carefully for typographical errors and possible problems with the placement or captions of illustrations. Extensive revision is not allowed at this stage. Indicate any changes and return page proofs within 48 hours to Production Editor; AFS; 5410 Grosvenor Lane, Suite 110; Bethesda, MD 20814-2199; 301/897-8616; fax 301/897-8097. Reprint ordering instructions will be provided to the corresponding author with the page proofs.

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Papers are accepted for publication on the condition that they are submitted solely to *Fisheries* and that they will not be reprinted or translated without the publisher's permission. See "Dual Publication of Scientific Information," Transactions of the American Fisheries Society 110:573-574 (1981). AFS requires an assignment of copyright from all authors, except for articles written on government time or for the government that cannot be copyrighted. Authors must obtain written permission to reprint any copyrighted material that has been published elsewhere, including tables and figures. Copies of the permission letter must be enclosed with the manuscript and credit given to the source.

UNREVIEWED ARTICLES

Unit News and Other Departments

AFS members are encouraged to submit items for the Unit News, Member Happenings, Obituaries, Letters to the Editor, and Calendar departments. Dated material (calls for papers, meeting announcements, nominations for awards) should be submitted as early as possible, but at least eight weeks before the requested month of publication. AFS Unit News and Letters should be kept under 400 words and may be edited for length or content. Obituaries for former or current AFS members may be up to 600 words long and a photo of the subject is welcome. Do NOT use the online manuscript tracking system to submit these items—the text and 300 dpi digital photos for all departments except the Calendar should be e-mailed to the managing editor at sgilbertfox@fisheries.org or mailed to the address below. Calendar items should include the date, event title, location, and contact information, and should be sent to the Fisheries' production editor.

For information about submitting a Students' Angle column, please contact Student Subsection President Jesse Fischer, fischer@iastate.edu.

Fisheries News

Brief items for the Fisheries News section are encouraged. Typical items include conservation news, science news, new programs of significance, major policy or regulatory initiatives, and other items that would be of interest to *Fisheries* readers. News items for the section should be no more than a few paragraphs; please consult the managing editor about submitting longer news articles.

Fisheries Forum (formerly Guest Editorials)

Authors are encouraged to submit most opinion pieces about fisheries science or management as essays for peer review. Occasionally, editorials about professional or policy issues may be inherently unsuitable for a scientific review. Sometimes these pieces are submitted by a committee, agency, or organization. Editorials should be 750–1,500 words, may be edited for length or content, and referred for outside review or rebuttal if necessary. A disclaimer may accompany Fisheries Forum editorials stating that the opinion is that of the author and not the American Fisheries Society.

Book Reviews

Please contact Book Review Editor Francis Juanes at 413/545-2758, juanes@forwild.umass.edu, if you want to be added to the list of potential book reviewers. New books (preferably two copies) submitted for review should be sent to Francis Juanes, Department of Natural Resources Conservation, University of Massachusetts, Amherst, MA 01003-4210.

QUESTIONS?

Contact Managing Editor Sarah Gilbert Fox; AFS; 5410 Grosvenor Lane, Suite 110; Bethesda, MD 20814-2199; 301/897-8616, ext.220; sgilbertfox@fisheries.org.

Detailed instructions for using the online manuscript tracking system are available at:

http://mc.manuscriptcentral.com/fisheries

Also see the *Fisheries* "Guidelines for Reviewers" at: **www.fisheries.org/afs/docs/pub_authguide.pdf.**

Call for Award Nominations: 2011 American Fisheries Society Awards

The American Fisheries Society is seeking nominations and applications for several 2011 awards. Award recipients will be honored at the Annual Meeting in Seattle, Washington, September, 2011. Nominations typically require a candidate's name, full contact information, biographical information and/or history of service to the Society. Some awards require additional nomination materials. For more information on how to nominate an individual, or organization, see descriptions below or contact the award chair. You may also contact Gail Goldberg, AFS awards coordinator, at ggoldberg@fisheries.org, or 301-897-8616 X 201 for more information.

Award of Excellence
The Society's highest award for scientific achievement is presented to a living AFS member for original and/or outstanding contributions to fisheries and aquatic biology. Nomination materials can be sent via electronic, mail or fax. Materials should include a detailed letter of nomination to address award criteria, vitae of nominee, and additional supporting materials as needed. See the main awards page for criteria for selection and other important nomination information.
Nomination deadline: May 10, 2011
Contact: Christine Moffitt, Committee Chair
Department of Fish and Wildlife Resources
USGS-Idaho Cooperative Fish and Wildlife Research Unit
104C CNR, Sixth and Line Street
University of Idaho
Moscow, ID 83844-1141
Phone: 208-885-7047
Fax: 208-885-9080
Email: cmoffitt@uidaho.edu

Carl R. Sullivan Fishery Conservation Award
Presented to an individual or organization for outstanding contributions to the conservation of fishery resources. Eligibility is not restricted to AFS members, and accomplishments can include political, legal, educational, scientific, and managerial successes. Nominations should include a synopsis of fishery conservation contributions; a description of the influence of those contributions on improved understanding, management, or use of fishery resources; and at least one additional supporting letter. Nominations may be submitted electronically via email or as hard copy delivered by mail.
Nomination deadline: April 15, 2011
Contact: Bill Fisher, Committee Chair
New York Cooperative Fish and Wildlife Research Unit
Fernow Hall, room 206
Cornell University
Ithaca, NY 14853
Phone: (607) 255-2839
Email: wlf9@cornell.edu

Distinguished Service Award
Recognizes outstanding contributions of time and energy for special projects or activities by AFS members. The number of recipients may vary. A single member, a group of members, and AFS staff are eligible candidates. Nominations should include description of the outstanding contributions by the candidate(s) and may be submitted electronically via email or as hard copy delivered by mail.
Nomination deadline: January 31, 2011
Contact: Bill Fisher, Committee Chair
New York Cooperative Fish and Wildlife Research Unit
Fernow Hall, room 206
Cornell University
Ithaca, NY 14853
Phone: (607) 255-2839
Email: wlf9@cornell.edu

Excellence in Public Outreach
Presented to an AFS member who goes the "extra mile" in sharing the value of fisheries science/research with the general public through the popular media and other communication channels. Two or more individuals may act as nominators, but at least one nominator must be an AFS member. Entries must include a biographical sketch of the nominee (not to exceed 3 pages) and supporting evidence of communicating the value of fisheries issues/research to the general public through the media and other communication channels, plus any evidence of teaching others about communication with the public.
Nomination deadline: April 15, 2011
Contact: Walt Duffy, chair
CA Cooperative Research Unit
Humboldt State University
Arcata, CA 95521-8299
Phone: (707) 826-5644
Fax: (707) 826-3269
Email: wgd7001@humboldt.edu

Honorary Membership
Presented to individuals who have achieved outstanding professional accomplishments or have given outstanding service to the Society. Honorary Members must be nominated by at least 100 active members and elected by a 2/3 majority of active members online.
Nomination dateline: May 1, 2011
Contact: Gail Goldberg
American Fisheries Society
5410 Grosvenor Lane, Suite 110
Bethesda, MD 20815
ggoldberg@fisheries.org

Meritorious Service Award
Presented annually to an individual AFS member for loyalty, dedication, and meritorious service to the Society throughout the years; and for exceptional commitment to the programs, objectives, and long-term goals of the Society. Nominations should include the candidate's name, full contact information, biographical information and/or history of the nominee's service (not to exceed 3 pages) to the Society. Letters supporting the nomination are welcome. Nominations and any supporting letters may be sent electronically via email or as hard copy delivered by mail, or fax (email, in PDF format preferred).
Nomination deadline: May 20, 2011
Contact: Bob Curry, Committee Chair
NC Wildlife Resources Commission
Division of Inland Fisheries
1721 Mail Service Center
Raleigh, NC 27699-1721
Phone: (919) 707-0221
Fax: (919) 707-0028
robert.curry@ncwildlife.org

Outstanding Chapter Award
Recognizes outstanding professionalism, active resource protection, and enhancement programs, as well as a strong commitment to the mission of the Society. Three awards are given, one for small chapters, one for large chapters and one for a student subunit of a chapter. Chapters should submit an application to their division presidents to be considered. Division presidents must nominate two best chapters from their divisions, one with less than 100 members and another with 100 members or more by June 1, 2011

Applications can be obtained from the AFS website See the main awards page for more information –to be updated when available
Nomination deadline: June 1, 2011
Contact: Chair, Mark Porath,
Nebraska Game & Parks Commission
2200 N 33th St
Lincoln, NE 68503
Phone: (402) 471-5583
Fax: (402) 471-4992
Email: Mark.Porath@nebraska.gov

President's Fishery Conservation Award
Presented in two categories: (1) an AFS individual or unit, or (2) a non-AFS individual or entity, for singular accomplishments or long-term contributions that advance aquatic resource conservation at a regional or local level. The award is administered by the Past President's Advisory Council. A nomination package should include a strong and detailed letter describing the nominee's contribution and the evidence for accomplishment at a regional or local level. If the nomination is for an individual, include a CV if possible. Nominations may be supported by multiple individuals by signing one nomination letter, or by submitting supporting letters in addition to the main nomination letter. Include the nominee's title and full contact information (address, email, and phone).
Nomination deadline: May 10, 2011
Contact: Donald C. Jackson, Past President
Mississippi State University
Dept Wildlife & Fisheries
Box 9690
Mississippi State, MS 39762
TEL: (662) 325-7493
FAX: (662) 325-8726
Email: djackson@cfr.msstate.edu

William E. Ricker Resource Conservation Award
Presented to any entity (individual, group, agency, or company) for accomplishment or activity that advances aquatic resource conservation that is significant at a national or international level. The award is administered by the Past President's Advisory Council. A nomination package should include a strong and detailed letter describing the nominee's accomplishments and the evidence for being "significant at a national or international level". If the nomination is for an individual, include a CV if possible. Nominations may be supported by multiple individuals by signing one letter, or by submitting supporting letters in addition to the main nomination letter. Include the nominee's title and full contact information (address, email, phone).
Nomination deadline: May 10, 2011
Contact: Donald C. Jackson, Past President
Mississippi State University
Dept Wildlife & Fisheries
Box 9690
Mississippi State, MS 39762
TEL: (662) 325-7493
FAX: (662) 325-8726
Email: djackson@cfr.msstate.edu

Retired Members Travel Award for the AFS Annual Meeting
The American Fisheries Society has established this travel award to encourage and enable members of the Society to attend annual meetings, particularly those members who might play a more active role in the meeting. The Society recognizes that some retired members who desire to participate in the annual meeting might be inhibited for financial reasons. Retired members may not have funds for travel to meetings that were available to them while employed. Therefore, this award is meant for those members who truly have a need for financial assistance. The Society has neither means nor desire to verify financial need, so that your request for support is based on an honor system. However, you must be a dues-paying retired member of the American Fisheries Society to apply. A maximum of $1,500 may be awarded for reimbursable expenses. See the main awards page for the application form on the AFS website.
Please send applications to Don Jackson, Chair, Past President's Advisory Council.
Deadline: June 19, 2011
Contact: Donald C. Jackson, Past President
Mississippi State University
Dept Wildlife & Fisheries
Box 9690
Mississippi State, MS 39762
TEL: (662) 325-7493
FAX: (662) 325-8726
Email: djackson@cfr.msstate.edu

The Emmeline Moore Prize
The American Fisheries Society (AFS) has established a new career achievement award, named after the first female AFS president, Emmeline Moore (1927-1928), to recognize efforts of an individual member in the promotion of demographic diversity in the society. This award will be presented to an individual who demonstrates strong commitment and exemplary service to ensuring equal opportunity access to higher education in fisheries and/or professional development in the broad range of fisheries science disciplines. Qualified nominees must exhibit clear evidence of service and commitment to diversity initiatives, including a strong research or fisheries management leadership background, public understanding of diversity issues, technical and popular writing, and inspirational leadership. Candidates should also have enunciated principles that lead to greater involvement of under-represented groups in fisheries science, education, research or management. Nominees for the award are restricted to AFS members. A nomination package should include a detailed letter of support (maximum three pages) describing the nominee's accomplishments and including evidence of involvement in diversity initiatives given the criteria noted above. The main letter of nomination can be supported through several signatures or up to three additional letters of support can be submitted. Please include in the nomination letter, the nominee's title and full contact information (i.e. address, e-mail, phone etc.) to complete the package.
Nomination Deadline: May 31st 2011
For more information about the Emmeline Moore Prize, or to submit nominations (electronic format preferred),
Contact: Larry A. Alade, Chair
National Marine Fisheries Service
Northeast Fisheries Science Center
Woods Hole Laboratory/Population Dynamics
166 Water Street, Woods Hole, MA 02543
Phone: 508 495-2085
Fax: 508 495-2393
E-mail: larry.alade@noaa.gov

Student Writing Contest
Recognizes students for excellence in the communication of fisheries research to the general public. Undergraduate and graduate students are asked to submit a 500- to 700-word article explaining their own research or a research project in their lab or school. The article must be written in language understandable to the general public (i.e., journalistic style). The winning article will be published in Fisheries. Students may write about research that has been completed, is in progress, or is in the planning stages. The papers will be judged according to their quality and their ability to turn a scientific research topic into a paper for the general public and will be scored based upon a grading rubric. (check the AFS web site on the main awards page for the grading rubric)
(For examples of past winning papers, see Fisheries 32(12):608&609 and Fisheries 34(1):39)
Submission deadline: April 15, 2011
Contact: Walt Duffy
CA Cooperative Research Unit
Humboldt State University
Arcata, CA 95521-8299
Phone: (707) 826-5644
Fax: (707) 826-3269
Email: wgd7001@humboldt.edu

Awards Administered by Sections
Education Section
Excellence in Fisheries Education Award
The American Fisheries Society (AFS) Excellence in Fisheries Education Award was established in 1988. The award is administered by the Education Section and is presented to an

individual to recognize excellence in organized teaching and advising in some aspect of fisheries education. Nominees may be involved in extension or continuing education, as well as traditional college and university instruction. Nominees must be AFS members, have been actively engaged in fisheries education within the last five years, and have had at least 10 years of professional employment experience in fisheries education. Two or more people may act as nominators, but at least one nominator must be an AFS member. The nominator(s) is responsible for compiling supporting material and submitting the application. The suggested format for applications can be found on the Education Section web site. Application materials should be sent to Jason Vokoun (jason.vokoun@uconn.edu) in digital form. Nomination deadline is May 15, 2011.
Additional information can be obtained from:
Jason Vokoun
Chair, Excellence in Fisheries Education Committee
Dept. of Natural Resources and the Environment
University of Connecticut
Phone: (860) 486-0141
Email: jason.vokoun@uconn.edu

John E. Skinner Memorial Fund Award
The John E. Skinner Memorial Fund was established in memory of John Skinner, former California-Nevada Chapter and Western Division AFS President. The fund provides monetary travel awards (up to $800 per award) for deserving graduate students or exceptional undergraduate students to attend the AFS annual meeting. The 2011 meeting will be held in Seattle, Washington, September 4th through the 8th.
Any student who is active in fisheries or related aquatic disciplines is eligible to apply. Awardees are chosen by a committee of the AFS Education Section. Selection is based on academic qualifications, professional service, and reasons for attending the meeting. In addition to travel assistance to attend the AFS annual meeting, award winners will also receive a one-year paid membership to the American Fisheries Society.
Applications for 2011 will be available in January (see http://www.fisheries.org/afs/awards.html). Completed applications (for both students and faculty advisors) must be received no later than May 9th, 2011. Electronic submissions preferred.
For more information about the Skinner Award,
Contact: Dan J. Daugherty
Texas Parks and Wildlife Dept.
Heart of the Hills Fisheries Science Center
5103 Junction Hwy.
Mountain Home, TX 78058
Phone: (830) 866-3356 x 211
Fax: (830) 866-3549
Email: Dan.Daugherty@TPWD.state.TX.us

Equal Opportunities Section
J. Frances Allen Scholarship Award
The American Fisheries Society (AFS) is pleased to announce that applications are being accepted until March 11, 2011, for the J. Frances Allen Scholarship for a female doctoral fisheries student. The J. Frances Allen Scholarship was established in 1986 to honor Allen, who pioneered women's involvement in the AFS and in the field of fisheries. The scholarship fund was established with the intent of encouraging women to become fisheries professionals.
Eligibility: The qualified applicant must be a female PhD student who was an AFS member as of December 31, 2011. The applicant must be conducting aquatic research in line with AFS objectives, which include "all branches of fisheries science, including but not limited to aquatic biology, engineering, fish culture, limnology, oceanography, and sociology". Typically, this award is given to a student who has completed preliminary exams.
Application: To apply, submit items A through D:
A. Resume with information in the following format:
- Educational history: degrees, grade point average for each degree (overall and in major), relevant courses taken
- Professional experience: positions held, levels of position, years of experience at each level
- Publications: separated into refereed and other
- Presentations: "first author" implies you presented it, "second author" assumes you did not, specify if otherwise
- AFS participation: year joined, meeting attendance and participation, committee involvement, presentations at AFS meetings
B. Transcripts from all institutions of higher education: include enrollment in PhD program. Please include transcripts with your application, do not have them sent separately. You may scan an official transcript as long as it is of high quality.
C. Dissertation research proposal: do not exceed 4 single spaced pages (excluding title page, abstract, and references).
The proposal must be submitted in the following single-spaced format with headings:
- Title page: with project title, area of research (genetics, modeling, ecology, etc.), applicants name and affiliation
- Abstract: not to exceed one-half page, describing research proposed
- Introduction: Including project justification and background
- Specific objectives and hypotheses if appropriate
- Summary of procedures/methods: justification for choices including preliminary testing and references
- Expected and preliminary results
- Significance of research: include anticipated application of findings
- Literature cited: follow Transactions of the American Fisheries Society format
D. Three letters of recommendation: One must be from the applicant's major advisor and one must be from an AFS member. Each letter should address 1) the applicants promise as a fisheries scientist, 2) the potential of the applicant to complete their proposed work and 3) significance of the applicants proposed research to the advancement of fisheries science. If those writing letters prefer- they may email letters separately to the address below, but they must be received by the deadline and should contain the applicants name along with J.F. Allen Scholarship in the subject heading.
Please contact the Committee Chair if you have any questions. Send electronic applications and recommendations (preferably in one mailing), to be received by March 11, 2011 to:
Marie-Ange Gravel, Chair
EMAIL: magravel@connect.carleton.ca
Subject: J. Frances Allen Scholarship
PHONE: 613-520-2600 ext: 3573

An application will not be reviewed if any part is missing or it is received after the deadline.
Criteria for selection: Selection will be made by the J. Frances Allen Scholarship Committee of the AFS Equal Opportunity Section. Proposal reviews by scientists in appropriate fields will be solicited by the committee. Awardee will be selected on a competitive basis with an emphasis placed on research promise, scientific merit, and academic achievement. Submission of an application acknowledges the applicant's acceptance of the Committee's decision as final.
Public Announcement and Notification: Public announcement of the recipient will be made at the 2011 AFS Annual Meeting in Seattle, Washington. In addition a written announcement will appear in Fisheries and the recipient will receive an official letter of award. The recipient is encouraged to present the results of their research at an Annual Meeting of AFS. It is expected that the research findings will be published in an appropriate fisheries journal upon project completion, at which time the support from this scholarship and AFS will be acknowledged.

Marine Fisheries Section
The Steven Berkeley Marine Conservation Fellowship
This fellowship was created by AFS in 2007 to honor the memory of Steven Berkeley, a dedicated fisheries scientist with a passionate interest in integrating the fields of marine ecology, conservation biology, and fisheries science to improve fisheries management. Berkeley was a long-time member of AFS and a member of the first Board of Directors of the Fisheries Conservation Foundation. The fellowship comprises a competitively based $10,000 award to a graduate student actively engaged in thesis research relevant to marine conservation. Research topics may address any aspect of conservation; a focus on fisheries issues is not required.
For more information and application requirements see: http://fishweb.ifas.ufl.edu/mfs/index_files/Berkeley_Fellowship.htm
Send electronic applications and recommendations, to be received no later than
February 1, 2011 to: Howard Williams, hwilliams@fisheries.org

NEWS: UNITS

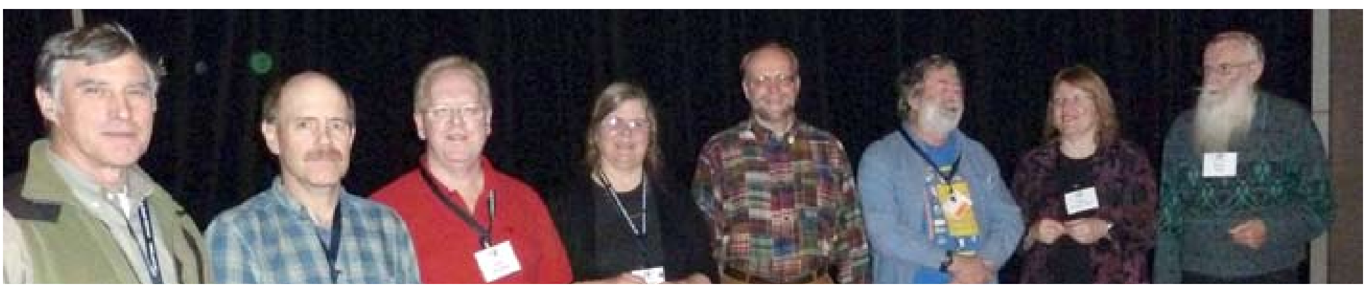
The 2010 Alaska Chapter Annual Meeting

Reported by Audra Brase AK Chapter President

The 2010 Alaska Chapter annual meeting was held November 3–5 in the capital city of Juneau. The meeting started off a bit rocky, when high winds forced several students to overnight in Anchorage, delaying the start of continuing education classes. But the winds died down by the start of the conference, itself, resulting the most well attended meeting in years. Gordon Kruse and Keith Criddle were the plenary speakers and did an excellent job kicking off the conference's theme of Alaskan Fisheries in a Changing World. Over 280 students and professionals attended the 3-day meeting, with 15 diverse sessions including a 30+ poster session luncheon.

Several awards were presented at the final evening's banquet, including: the Alaska Chapter Service Award (Gretchen Bishop); Almost Darwin Award (2009 Kwethluk SaRON field crew); and acknowledgment of attendees who had been members of the National AFS Chapter for 25 years or more. In addition, Gordon Kruse presented Jennifer Stahl with the American Institute of Fisheries Biologists W.F. Thompson Award for the best student paper published in 2008 (Spatial and temporal variability in size of maturity of walleye pollock in the eastern Bering Sea).

At the conclusion of the meeting, Jason Neuswanger won the best student paper award (The roles of territoriality and detritus in wild juvenile Chinook salmon drift-feeding behavior) and Jamie McKellar won the best student poster award (Population structure and reproductive status of razor clams, Siliqua patula, in eastern Cook Inlet). Both students attend the University of Alaska Fairbanks—School of Fisheries and Ocean Sciences.



CALENDAR: 2011 AFS CHAPTER AND DIVISION MEETINGS

MEMBERS:
Be sure to mark your calendars now, so you don't miss these important local events!

STATE	DATE	LOCATION	CONTACT
Alaska	Nov. 3-5, 2011	Juneau	www.fisheries.org/units/afs-ak/meetings/2011/meet2011.htm
Arizona-New Mexico Joint meeting with TWS	Feb 3-5	Pinetop, AZ	http://www.aznmfishsoup.org/
Arkansas	TBD		
California-Nevada	Mar 31 – Apr 2	Folsom, CA	saikifish@att.net
Colorado-Wyoming	Feb 23 – 26	Fort Collins, CO	awidmer@swca.com
Dakota	Feb 22 – 24	Bismarck, ND	jhendrickson@nd.gov
Florida	Jan 13 – 16	Tampa, FL	www.sdafs.org/meeting/meethome.htm
Georgia	Feb 3 – 4	Perry, GA	John.Kilpatrick@dnr.state.ga.us
Idaho	March 2-4	Boise, Idaho	http://www.idahoafs.org/meeting.php
Illinois	Mar 2 – 4	Peoria, IL	jeremiah.haas@exeloncorp.com
Indiana	Feb 22 – 23	Montgomery, IN	Debbie King, Dking@dnr.IN.gov
Iowa	Jan 20–21	Moravia, IA	http://www.fisheries.org/units/iowa/index.htm for more information.
Kansas	Jan 20	Wichita, KS	in conjunction with the Kansas Natural Resource Conference.
Louisiana	January 27-28	Lafayette	http://www.sdafs.org/laafs/Meetings.htm
Mexico	May 17 – 21	Mazatlán, Sinaloa, México	http://ola.icmyl.unam.mx/mazatlan2011/
Mid-Atlantic	Nov 18 – 19	Lewes, DE	
Mid-Canada	June 7-9		part of the Arctic Grayling symposium/workshop
Michigan	April 6-7	Petoskey, MI	http://www.fisheries.org/units/miafs/upcoming_meet.html
Minnesota	Dec 12 – 15, 2011	Minneapolis, MN	www.midwest2011.org
Mississippi	Feb 16-18	Starkville, MS	Mississippiafs.org; Tom Holman – tomh@mdwfp.state.ms.us
Missouri	Feb 3		www.moafs.org or www.mnrc.org
Montana	Feb 8-11	Great Falls, MT	craigb@cskt.org
Nebraska	TBD		
New York	TBD		
North Carolina	Feb 21-23	Drury Inn & Suites-Northlake	http://www.sdafs.org/ncafs/AnnualMtg.htm
North Central			
Division	Dec 12 – 15, 2011	Minneapolis, MN	www.midwest2011.org
Northeastern Division	April 17 - 19	Manchester, New Hampshire	http://neafwa.org/ with the 67th Annual Northeast Fish and Wildlife Conference
Ohio	Feb 4	Columbus, OH	http://www.biosci.ohio-state.edu/~ocafs/
Oklahoma	Feb 2-3	Western Hills Lodge "state park"	Jb_odwc@hughes.net
Ontario	March 3 – 5	Orillia, Ontario	Contact: scott.gibson2@ontario.ca
Oregon	Feb 23 – 25	Bend, OR	colleen.e.fagan@state.or.us.
Penn-			
sylvania	TBD		
South Carolina	TBD		
Southern Division	Jan 13 – 16	Tampa, FL	www.sdafs.org/meeting/meethome.htm
Southern			
New England	Jan 20	Woods Hole, MA	http://snec-fisheries.org/
Tennessee	TBD		
Texas	Feb 11 – 12		craig.bonds@tpwd.state.tx.us
Tidewater	TBD		
Utah	Mar 22 – 23	Salt Lake City, UT	craigwalker@utah.gov
Virginia	Feb 8-10	Berkeley Springs, WV	http://www.sdafs.org/wvafs/
Washington-British Columbia	Apr 19 – 23	Salt Lake City, UT	http://utahafs.org/wdafs2011/
West Virginia	Feb 8-10	Berkeley Springs, WV	http://www.sdafs.org/wvafs/
Western			
Division	Apr 19 – 23	Salt Lake City, UT	http://utahafs.org/wdafs2011/
Wisconsin	Jan 31- Feb 2	Stevens Point	http://www.wi-afs.org/

TIM THOMPSON

AFS 2011 SEATTLE: AN EXTRAORDINARY MEETING IN AN EXTRAORDINARY PLACE

by Amanda Cronin

If you haven't already heard, the AFS 141st annual meeting "New Frontiers in Fisheries Management and Ecology: Leading the Way in a Changing World" will be held in beautiful Seattle, Washington on September 4-8, 2011. We expect this to be one of the largest—if not the largest—national AFS meeting ever held. The program, expected to consist of 20 concurrent sessions, will include: symposia, contributed papers, and posters of cutting-edge science focused on diverse topics of regional, national, and global importance. In addition, there will be a full day on continuing education sessions aimed at a wide variety of professional interests.

September is an ideal time to explore Seattle, which offers a plethora of fun activities for the whole family. Within a short walk from the convention center is the world famous Pike Place Market with year-round farm fresh produce, flying fish, local artisans, and street musicians (across the street is the original Starbucks coffee shop!). Downtown Seattle boasts the Pacific Northwest's finest art museum, theaters, art galleries, shopping boutiques, and many restaurants serving Northwest cuisine. Just north of downtown is the Seattle Center with four other museums, eleven theaters, five gardens, six fountains, more than a dozen restaurants, a skate park, an events arena, and, of course, the Space Needle. And if you want to see something a bit more resource-oriented, perfect viewing spots of the Pink salmon runs (they'll be a their peak) will be found in several local rivers in and around Seattle.

Once you explore Seattle's attractions, you'll want to extend your trip to allow time for adventures in western Washington's three national parks, Puget Sound and the San Juan Islands. Day and overnight tours of Mount Rainer National Park are offered from downtown, and a scenic ferry boat ride will take you across to the Olympic Peninsula, where you can spend days exploring the wild Olympic Mountains, the Hoh Rainforest, and the wild Washington Coast. The trout fishing is top notch here, so charter a boat for salmon fishing. Yet another option is to hop on a ferry or float plane and head north to the gorgeous San Juan Islands for whale watching, bicycle touring, and a couple nights at one of the quaint bed and breakfasts. Or consider visiting Victoria and Vancouver, B.C. — an easy visit from Seattle.

So get ready to connect with colleagues at the AFS meeting, and have a great time making new memories.

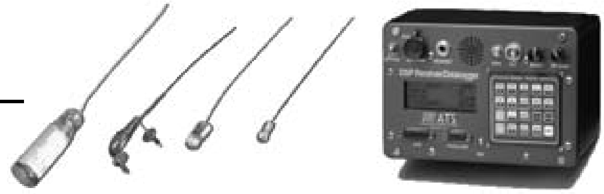
If you haven't already done so, please submit your Symposium proposals now. They must be submitted online through the meeting website (http://www.fisheries.org/AFS2011) by January 14, 2011. Contributed paper and poster abstracts are due by February 11, 2011.

TIM THOMPSON

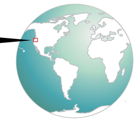
ANNOUNCEMENTS: JOB CENTER

EMPLOYERS: To list a job opening on the AFS Online Job Center submit a position description, job title, agency/company, city, state, responsibilities, qualifications, salary, closing date, and contact information (maximum 150 words) to jobs@fisheries.org. Online job announcements will be billed at $350 for 150 word increments. Please send billing information. Listings are free (150 words or less) for organizations with Associate, Official, and Sustaining memberships, and for Individual members, who are faculty members, hiring graduate assistants. If space is available, jobs may also be printed in *Fisheries* magazine, free of additional charge.

PhD Student Assistantship Biology, Ecology Track, Dept of Environmental Sciences, Univ of Toledo l phdSalary: Stipend range: $22,000-$30,000/year latter is for NSF GK-12 program , plus tuition, feeds, and medical insurance paid
Closing: 2/15
Responsibilities: Hard-working, innovative, outstanding Ph.D. student to conduct key research project in invasion genetics centered on the Great Lakes. Beautiful lab on Lake Erie, our students all have been graduating with 3-6 publications in top journals, including Molecular Ecology, Molecular Phylogenetics and Evolution, TAFS, JGLR, CJFAS, J. Fish. Biol., etc. Our students have been winning top honors, best paper awards, grants, and scholarships. Our graduates all have obtained jobs of their choice at universities or federal agencies e.g., NOAA, USFWS . Very reasonable cost of living, dynamic faculty, superior mentorship.
Qualifications: M.S. with publication and presentation record preferred.
Contact: Dr. Carol Stepien, University of Toledo Lake Erie Center, Great Lakes Genetics Lab, carol.stepien@utoledo.edu, 419-530-8362 apply to Dept. of Environmental Sciences at below link. Lab: http://www.utoledo.edu/as/lec/research/glgl/index.html
Contact Email Address: carol.stepien@utoledo.edu
Date Added: December-06-2010



Using Hydroacoustics to Evaluate Kokanee Population Size and Distribution in Lake Billy Chinook



Situated in sunny Central Oregon, Lake Billy Chinook (LBC) is a popular, year-round destination for fishing and outdoor recreation. Its 72 miles of shoreline and surface area of 4,000 acres offer habitat for a variety of fish. LBC was formed in 1964, after the construction of the Round Butte Dam. Since the dam's construction, a wild population of kokanee (*Oncorhynchus nerka*) became established, supporting the recreational fishery. In efforts to make more informed fisheries decisions, managers at Confederated Tribes of Warm Springs (CTWS) and Oregon Department of Fish and Wildlife (ODFW) periodically monitor the fish population using hydroacoustics.

In cooperation with Portland General Electric, CTWS conduct mobile hydroacoustic surveys in order to assess the magnitude and distribution of the kokanee population in the reservoir. Since 1996, hydroacoustic methods have been used following standardized survey transects. These mobile surveys provided time-series estimates of fish density per unit area, total population size, fish vertical distribution, and acoustic size distributions (which are related to fish length).

The primary objective of the study was to estimate the total population of kokanee present in the reservoir. Secondary objectives were to estimate kokanee populations in the three arms comprising the LBC reservoir, specifically the Crooked River, Metolius River, and Deschutes River arms. The estimates within each arm and for the reservoir as a whole were apportioned into estimated fish length groups based on the measured target strength of each sampled fish. HTI's *Model 241 Portable Split-Beam Echo Sounder* was used to achieve their objectives.

As the researchers of CTWS and ODFW continue to make significant strides in managing fisheries resources, HTI is proud to assist and support them in their work. To learn more about the tools used for this study, visit us at HTIsonar.com.

> "Hydroacoustics has proven to be a valuable tool for estimating kokanee population size and age structure in Lake Billy Chinook."
>
> - Patrick A. Nealson, Sr. Fisheries Biologist
> HTI Hydroacoustic Technology, Inc.


Aerial view of Lake Billy Chinook
Image Credit: Marc Litchfield


Aerial view of Lake Billy Chinook
Image Credit: Transect design, Steve Thiesfeld, WA DFW; aerial image, Google Earth


Kokanee migration.
Image Credit: Frank Lundburg at ECOSNAKE.COM

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