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Piscicides and Invertebrates: After 70 Years, Does Anyone Really Know?

Atlantic Sturgeon Vessel-Strike Mortalities in the Delaware Estuary

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Contents

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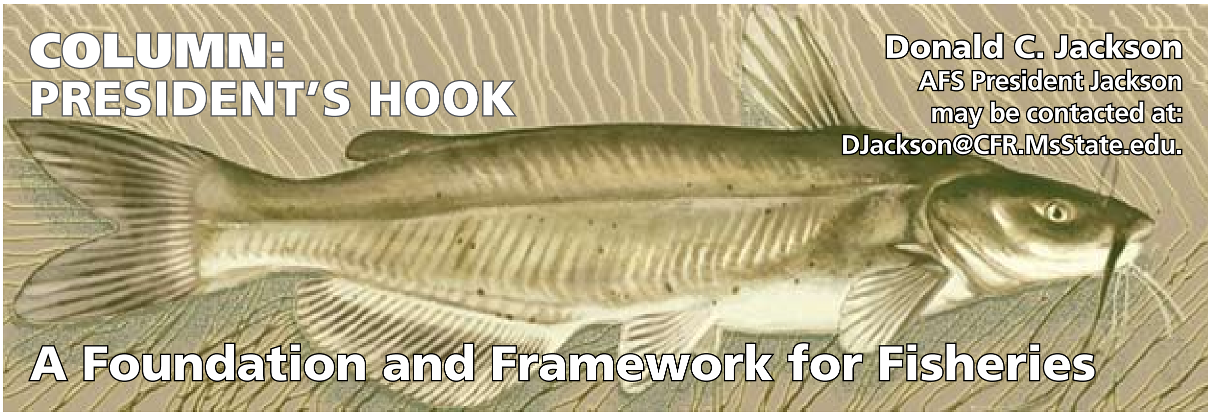

COLUMN: PRESIDENT'S HOOK

Donald C. Jackson
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A Foundation and Framework for Fisheries

One late fall afternoon I was working with my elderly uncle in a tractor shed over in northeast Arkansas, helping him replace spindles on his cotton picker. During one of our breaks (and there were many), he asked me a question that cut to the core of my work as a university professor and my identity as a fisheries biologist: "What are the two most important things that you teach over there at Mississippi State University?"

Now what are you supposed to do with a question like that? Academic programs and professions in fisheries are incredibly complex, intellectually challenging, science-based endeavors that engage cutting-edge technology and sophisticated analyses and modeling to address natural resources issues. They promote and require a dynamic interface of many disciplines. How can you possibly boil it down to two things?

So, at first I thought he just wanted to harass his college-educated nephew a little. He's been known to do that. But then I saw the look on his face and realized that he was serious. I knew that I couldn't hide behind professional jargon. He didn't want a lecture. He just wanted to know the two most important things I taught—not one, not three—two. I sat there silently for about a minute and then he said, "Take your time. We have all afternoon. Hand me that wrench."

About 30 minutes later, I gave him my answer: "Habitat and faith. If fish, and people who catch fish, don't have a place, or if that place isn't working well, their future is doubtful. Habitat is the foundation. We also must have faith… faith that we were taught the right stuff, faith in science and technology, faith that most people want to do the right thing (and hopefully know what 'the right thing' is), faith in ourselves as persons, faith in our professional abilities, faith in political process, and most importantly, faith in the future. *Faith is the framework.*"

"Hummh," he replied with a soft snort, giving a spindle one more good crank with his wrench to be sure it was well seated. "I guess that should do it."

I wasn't sure if he was referring to the repairs on the cotton picker or to my answer. It was probably both. He's a practical, thrifty sort of man.

The American Fisheries Society (AFS) is currently engaged in initiatives that address both habitat and faith. We have recently established a new AFS Fish Habitat Section. We have faith in its mission, its leadership, and its future. The Fish Habitat Section will become a driving force within AFS as we move into evolving arenas of fish habitat issues during this new decade. Additionally, AFS has official representation on the National Fish Habitat Board, and with the board is working with state and federal agencies and allied professional, conservation, and industry groups to advance the National Fish Habitat Action Plan (NFHAP). We have faith that this plan, if adopted, will take the United States into a new realm of environmental and natural resources stewardship.

The NFHAP calls for a status report on all inland and coastal/near-shore fish habitats within the United States during 2010 and every five years thereafter (National Fish Habitat Board 2009). The NFHAP is a non-regulatory, trans-jurisdictional, science-based program designed to work with and enhance existing fisheries programs at regional and national levels. Although emphasis will be the lower 48 states, some parts of Hawaii and Alaska also will be assessed. Oceanic areas will not be assessed in detail in 2010, but will be included in planned future revisions of the assessment. The NFHAP calls for setting conservation (protection, restoration, and enhancement) priorities and establishment of Fish Habitat Partnerships targeting priority habitats. Along with habitat assessments, the plan takes into account economic and sociologic factors for use as prioritization tools. It is action oriented. Its purpose is to make things happen.

Congressional support and action is needed for the NFHAP to move forward. During 2009, the National Fish Habitat Conservation Act (S.1214) was introduced by Senators Lieberman (I-CT), Casey (D-PA), Bond (R-MO), Stabenow (D-MI), Cardin (D-MD), Sanders (I-VT), Whitehorse (D-RI) and Crapo (R-ID). This bill would, if passed, codify the NFHAP. It is receiving bipartisan support from both houses of Congress.

AFS has taken the lead in organizing a briefing session on Capitol Hill (10 February 2010) to help congressional personnel become more familiar with the importance of habitat and with NFHAP, and to encourage Congress to continue supporting not only the plan but also to fund it. The congressional briefing session was organized and

Continued on page 90

National Saltwater Angler Registry Opens

NOAA's new National Saltwater Angler Registry opened for registrations on 1 January 2010. The registry will be used as the basis for conducting surveys of saltwater recreational fishermen to find out how often they fish. It will eventually replace the use of random-digit dialing to coastal households, a system NOAA has had in place since the 1970s. The goal is to improve survey efficiency and reduce bias by making calls only to homes where people fish, and reaching saltwater anglers who live outside coastal counties. The surveys will be used by NOAA scientists to assess the health of fish stocks and to estimate the economic contributions of anglers. Many saltwater recreational fishermen will be required to register before fishing in 2010, but those who have a state saltwater fishing license may already be part of the registry. National Saltwater Angler registration is free in 2010. To register, anglers can visit NOAA's Marine Recreational Information Program (www.countmyfish.noaa.gov) and click on the Angler Registry link, or call the toll-free registration line at 1-888/MRIP411 (1-888/674-7411).

Asian carp DNA found in Lake Michigan harbor

Federal officials said two DNA samples taken beyond the final electrical carp barriers between Chicago-area waterways and Lake Michigan had tested positive for invasive Asian carp—including one in the lake's Calumet Harbor. They insisted it was far from certain that carp have actually reached the lake, however, saying no live or dead specimens had been spotted there or anywhere past the electrical barrier.

The U.S. Supreme Court refused to order the immediate closure of shipping structures near Chicago to contain the Asian carp. The court rejected Michigan's request for a preliminary injunction to shut the locks and gates temporarily while officials and interest groups debate a long-term strategy.

Authorities consider DNA testing "an early warning device where Asian carp may be present," Gen. John Peabody of the U.S. Army Corps of Engineers said. Agencies will use netting and electrical stunning to search for live or dead fish while continuing to process hundreds more DNA samples taken last fall. The Corps' view is that the locks and gates on the Chicago Sanitary and Ship Canal and other waterways should remain in operation. Closing them would be "totally inadequate to the task" of blocking the carp, Peabody said. "The locks are leaky, and there are alternate pathways around them."

JOURNAL HIGHLIGHTS: NORTH AMERICAN JOURNAL OF FISHERIES MANAGEMENT

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FISHERIES CURRENTS: SCIENCE NEWS FROM AFS

Are intensive bass regulations still needed?

With the growth of catch-and-release bass fishing, are length-based harvest limits still a useful management tool? The answer is yes, according to a recent article by two Minnesota researchers in the *North American Journal of Fisheries Management.* They compared the response of bass populations in three lakes with a 305-mm (12-inch) maximum length limit to six lakes with mandatory catch-and-release and nine lakes with the statewide regulations in place (seasonal closures and bag limits). The size structure of the populations in some lakes with the length limits did improve, resulting in more large bass, while the catch-and-release lakes showed lesser effects and the reference lakes had no significant changes. The results suggest that angler exploitation is still an important factor even with the growing trend of catch-and-release bass fishing in Minnesota, and that stringent harvest regulations may be used to improve the size structure of bass populations. **Mandatory Catch and Release and Maximum Length Limits for Largemouth Bass in Minnesota: Is Exploitation Still a Relevant Concern?,** by *Andrew J. Carlson and Daniel A. Isermann. North American Journal of Fisheries Management* 30:209-220. Carlson may be contacted at andrew.carlson@state.mn.us.

Managing fisheries with little data

Calls for better fisheries management are often seen as difficult to answer in fisheries where there are little data. In an article in a special section on data-poor fisheries in the open-access journal *Marine and Coastal Fisheries,* two New Zealand authors compare different paradigms for management decision making: the "assessment" paradigm versus the "procedural" paradigm. As the name implies, the assessment paradigm is built on constant estimates of the status of the fishery, but the process only works effectively for those few high-value fisheries that are data rich. In contrast, the procedural paradigm is based on evaluating alternative candidate management procedures and their expected performance in reaching management objectives. The authors use the metaphor of a tourist on a southward drive—under the assessment paradigm, he would get out of the car at each intersection and use a compass and the immediate view of the landscape to determine which way to go next, but under the procedural paradigm he would use a map and other information beforehand to evaluate alternative routes. Some

Continued on page 90

UPDATE: LEGISLATION AND POLICY

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AFS congressional briefing on National Fish Habitat Conservation Act

On 10 February 2010, the American Fisheries Society (AFS) will hold a briefing on H.R. 2565, "The National Fish Habitat Conservation Act," and the National Fish Habitat Action Plan. AFS is presenting the briefing in partnership with various organizations including the Association of Fish and Wildlife Agencies, U.S. Fish and Wildlife Service, and the National Fish Habitat Action Plan board. The briefing will emphasize the importance of the bill and to showcase how vital U.S. fish habitats are to the stability of our ecosystem and our country as a whole. The briefing will be held in room 122 of the Cannon House Office Building at 10:00 a.m.

EU cuts key fishing quotas in the Atlantic and North Sea

The European Union has reduced fishing quotas for haddock and other key catches in 2010. The cuts cover stocks in waters of the Atlantic, the North Sea, and the channel between France and England. Cuts of between 15% and 35% for cod in different areas, with the exception of west Scotland and the Celtic Sea (between Cornwall and Brittany), have also been called for. The EU also cut Norway lobster quotas in Porcupine Bank by 9%, those for southern anglerfish by 15%, and whiting off Scotland and in the Irish Sea 10%.

Conservation plan agreement for Yellow Sea

The People's Republic of China and Republic of Korea reached agreement on the environmental management needed to revitalize the Yellow Sea, as detailed in the Strategic Action Programme (SAP) developed under the United Nations Development Programme Global Environment Facility (UNDP/GEF) Yellow Sea Large Marine Ecosystem Project (YSLME). According to the United Nations "Large Marine Ecosystem Report" in 2009, more than 60% of Yellow Sea fish stocks are either overexploited or collapsing. The World Wildlife Fund reports more than 40% of intertidal wetlands have been reclaimed, and the YSLME project's environmental status reports suggested that the major pollutants including inorganic nitrogen, heavy metals, and oils are degrading coastal environments, impacting fisheries production and damaging the ecosystem.

To combat these growing threats, the YSLME project has worked with scientists and governments from both countries to agree on the management measures needed to sustain the sea and help its recovery; these include a 30% reduction in fishing effort (cutting both numbers of fishing boats and engine size), a 10% cut in point-source pollution every 5 years, and strict control of new reclamation. The goal of the SAP is to protect the "ecosystem carrying capacity" of the Yellow Sea so that ecosystem services, such as provision of food, nutrient absorption, and carbon sequestration, continue to support the vibrant coastal communities. The governments have already shown their commitment to implement major management actions, with several hundred million U.S. dollars being spent every year to tackle environmental problems.

Fisheries advisory panel recommendations on CITES proposals

An advisory panel of independent experts convened by the United Nations Food and Agriculture Organization (FAO) has issued recommendations regarding six proposals to limit international trade in a number of commercially exploited aquatic animals under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). The proposals, submitted by various CITES parties, request that the convention control international trade in certain shark and coral species and ban international trade in Atlantic bluefin tuna. They will be considered for listing at the 15th Conference of CITES parties (Doha, Qatar, 13-25 March 2010).

The advisory panel consisted of 22 international fishery experts from 15 different countries. It was convened to evaluate the proposals according to criteria established by CITES and to give independent and impartial recommendations based on the experts' knowledge and on the scientific evidence presented in each proposal. This follows a formal process through which the FAO channels advice from external fishery scientists to CITES. The CITES Conference of Parties will make the final decision regarding listing of proposed species.

After a six-day review, the panel determined that sufficient evidence existed to place the following species on CITES Appendix II: oceanic whitetip shark, porbeagle, and scalloped hammerhead shark. The panel did not reach consensus regarding the proposed listing under CITES Appendix I of Atlantic bluefin tuna; however, there was consensus that the evidence available supports the inclusion of Atlantic bluefin tuna on Appendix II.

The panel assessed that spiny dogfish and all species of the coral family Coralliidae did not meet the criteria required by CITES for listing on Appendix II. The panel did note that there was a cause for concern with these species, and that inadequate management in many areas of distribution of these species needs to be addressed in order to prevent rates of exploitation for these animals from exceeding acceptable levels.

Piscicides and Invertebrates: After 70 Years, Does Anyone Really Know?

Mark R. Vinson, Eric C. Dinger, and Deanna K. Vinson

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ABSTRACT: The piscicides rotenone and antimycin have been used for more than 70 years to manage fish populations by eliminating undesirable fish species. The effects of piscicides on aquatic invertebrate assemblages are considered negligible by some and significant by others. This difference of opinion has created contentious situations and delayed native fish restoration projects. We review the scientific evidence and report that short-term (< 3 months) impacts of piscicides to invertebrate assemblages varied from minor to substantial and long-term (> 1 year) impacts are largely unknown. Recovery of invertebrate assemblages following treatments ranged from a few months for abundances of common taxa to several years for rarer taxa. Variation in reported effects was primarily due to natural variation among species and habitats and a lack of adequate pre- and post-treatment sampling which prevents determining the true impacts to invertebrate assemblages. The factors most likely to influence impacts and recovery of aquatic invertebrate assemblages following piscicide treatments are: (1) concentration, duration, and breadth of the piscicide treatment; (2) invertebrate morphology and life history characteristics, including surface area to volume ratios, type of respiration organs, generation time, and propensity to disperse; (3) refugia presence; and (4) distance from colonization sources.

Piscicidas e invertebrados: después de 70 años ¿Realmente alguien sabe?

RESUMEN: Los piscicidas rotenona y antimicina han sido utilizados por más de 70 años para manejar poblaciones de peces, eliminando especies indeseables. Para algunos autores los efectos de los piscicidas en las asociaciones de invertebrados acuáticos son considerados como insignificantes sin embargo, para otros, son importantes. La diferencia entre las opiniones ha creado una situación tirante, retrasando así los proyectos de restauración de peces nativos. Revisando la evidencia científica, se encontró que en el corto plazo (<3 meses) los impactos de los piscicidas en las asociaciones de invertebrados varió de menor a sustancial, y en el largo plazo (>1 año) los impactos son básicamente desconocidos. Tras recibir los tratamientos, la recuperación de dichas asociaciones fue de pocos meses para los taxa más abundante hasta varios años para los taxa más raros. La variación en los efectos reportados se debió principalmente a la variación natural entre especies y hábitats y a la falta de un adecuado muestreo pre y post-tratamiento. Los factores que más probablemente determinen el impacto y recuperación de las asociaciones de invertebrados después del tratamiento con piscicidas son: (1) concentración, duración y espectro del tratamiento de piscicida; (2) la morfología de los invertebrados así como las características de su historia de vida, incluyendo la razón superficie-volumen, tipo de órganos respiratorios, tiempo generacional y propensión a la dispersión; (3) presencia de refugios; y (4) distancia hacia las áreas de colonización.

INTRODUCTION

The piscicides rotenone and antimycin A (hereafter antimycin) have been used for more than 70 years to manage fish populations by eliminating undesirable fish species (McClay 2000). While piscicides are intended to control and eradicate fish, they can also be toxic to non-target aquatic biota, such as invertebrates and amphibians. Impacts on aquatic invertebrates are a concern because of their role in ecosystem processes and their importance as food sources for fish. A popular belief among fisheries professionals has generally been that impacts to invertebrates are minimal and short-term. This view is frequently repeated in both professional society publications (e.g., Finlayson et al. 2005), sportsmen-oriented publications (e.g., Williams 2002, 2007), and in piscicide project planning documents. Alternatively, others, such as the Center for Biological Diversity (2003), have claimed that piscicides cause irrevocable damage. This difference of opinion has led to litigation and caused delays in native fish restoration projects (Finlayson et al. 2005). We suggest that the true impacts of rotenone and antimycin on invertebrate populations are not well known. The objective of this article is to review published studies on the effects of rotenone and antimycin on invertebrate assemblages. Lastly, we provide some recommendations on sampling schemes to allow for more robust analyses of piscicide effects.

HOW PISCICIDES WORK

Antimycin and rotenone belong to a class of chemicals known as oxidative phosphorylation inhibitors or uncouplers. These affect toxicity through disrupting cellular respiration (energy generation) in the mitochondria, but at slightly different sites in the respiratory chain. Rotenone is a naturally occurring compound found in many plants within the family Leguminosae. Rotenone concentrations of 25 parts per billion (ppb or µg/L) or higher can be toxic to most fish and some invertebrates (Ling 2003). Rotenone may be detected by fish and fish avoidance may occur. Antimycin is an antibiotic produced by several species of *Streptomyces* bacteria (Harada and Tanaka 1956). Most fishes can be killed by antimycin concentrations of 20 parts per billion or less and fish are unable to detect antimycin. Antimycin has been reported to be effective in small streams, shallow ponds and alpine lakes, whereas rotenone is reported to be effective in most situations including large rivers and deep lakes (Finlayson et al. 2000).

There are three commonly available commercial forms of rotenone: two liquids containing either 5% active ingredient or 2.5% active ingredient with a 2.5% synergist, and a powder containing 5% rotenone. These products are generally applied at a treatment rate of 1–5 mg/L (ppm) which yields active rotenone concentration of 0.025–0.25 mg/L (25–250 ppb or µg/L). In the literature, values are generally reported as treatment rate concentrations of 2.5 or 5% rotenone products. In this review, we attempted to standardize rotenone concentrations to ppb of active rotenone, e.g., 5 mg/L of 5% rotenone solution = 250 ppb active rotenone. Currently, only one form of antimycin is commercially available, Fintrol® (11% active ingredient) and application rates are reported in ppb or equivalent µg/L active antimycin.

OREGON DEPARTMENT OF FISH AND WILDLIFE

A barge loaded with rotenone and manpower heads out into Diamond Lake, Oregon, 21 September 1954. The 1,200 surface hectare lake was treated with 90,718 kilograms, plus 1,041 liters of liquid rotenone for treatment of tributary streams and for aerial spraying of a marsh area.

KIRK PATTEN

A rotenone drip station used by New Mexico Department of Game and Fish on Costilla Creek in September 2008. CFT legumine (5% rotenone) was applied at a constant rate for four hours to obtain an initial concentration of 50 ppb active rotenone. The project was part of a Rio Grande cutthroat trout (*Oncorhynchus clarki virginalis*) restoration project.

ROTENONE EFFECTS TO INVERTEBRATES

Laboratory results were summarized from Engstom-Heg et al. (1978). Twenty-two field studies were reviewed to assess the effects of rotenone on aquatic invertebrate assemblages. Thirteen of these studies were conducted in lentic systems (Table 2) and nine studies were conducted in lotic systems (Table 3). Rotenone concentration and treatment duration varied widely among studies. Lower concentrations were < 50 ppb (10 studies) and higher concentrations were > 100 ppb (7 studies), but not all studies provided information on the concentration of rotenone used and only one study (Trumbo et al. 2000) reported that actual concentrations were verified by field or laboratory analyses.

Rotenone: Laboratory Studies

Aquatic invertebrates have a wide range of sensitivity to rotenone, with 96 h 50% lethal concentration (LC50) values ranging down to 2 ppb (Pesticide Management Education

Program 1993). A review of published laboratory toxicity tests (Table 1, also see Ling 2003) showed several general results: (1) there has been little rotenone toxicity work on lotic aquatic invertebrates; (2) there is a wide range of sensitivity within and among taxonomic groups; (3) benthic invertebrates appear less sensitive than planktonic invertebrates; (4) smaller invertebrates appear more sensitive than larger invertebrates; (5) aquatic invertebrates that use gills to extract aqueous oxygen appear more sensitive than invertebrates that acquire aqueous oxygen cutaneously through lamellae or spiracles, use respiratory pigments, or that can breathe atmospheric oxygen; and (6) mortality was typically near 100% for rotenone concentrations of 50 to 75 ppb for lotic invertebrates and > 150 ppb for many lentic taxa depending on the exposure time. Effects appear not only related to concentration and duration, but also seem largely influenced by animal surface-area-volume ratios, with small animals like zooplankton being more susceptible than thick-bodied benthic invertebrates.

Rotenone: Lentic Studies

Rotenone effects on invertebrates in lentic habitats have been studied since the 1940s (Table 2). The results of these studies have been highly variable, with much of this variation likely related to rotenone dosage (concentration x duration) differences. Considerable variation in reported effects also appears related to the intensity, or lack thereof, of pre- and post-treatment sampling. Pre-treatment invertebrate sampling varied from a single survey to more than a year of pre-treatment sampling. Post-treatment invertebrate sampling varied from a single post-treatment sample to up to four years of post-treatment sampling. Reported impacts were generally less for studies that conducted less sampling.

More lentic studies reported greater rotenone effects on zooplankton than on benthic organisms, with most of these studies concluding that zooplankton assemblages were significantly reduced in both numbers and diversity (Table 2). More studies reported on changes in abundance than changes in species composition. Studies that have evaluated effects on benthic organisms (e.g., Cushing and Olive 1957; Houf and Campbell 1977; Koksvik and Aagaard 1984; Melaas et al. 2001) reported small differences in total benthic invertebrate abundance or biomass between pre- and post-treatment samples, with effects on Chironomidae, likely the most dominant organism, being greatest.

Recovery of zooplankton following rotenone treatments was most often reported in terms of organism abundance. Recovery to pre-treatment abundances ranged from 1 month to 3 years. Rotifer and Copepoda assemblages appeared to recover quicker than Cladoceran assemeblages (Brown and Ball 1943; Anderson 1970; Beal and Anderson 1993). Kiser et al. (1963) reported that 42 species extirpated immediately following treatment returned within 5 months. The three studies that evaluated benthic invertebrate assemblage recovery reported similar assemblages to control ponds (Houf and Campbell 1977); within 6 months (Blakely et al. 2005) and no differences between pre- and post-treatment samples within 1 year of treatment (Melaas et al. 2001).

Rotenone: Lotic studies

Study of rotenone impacts on aquatic invertebrates in rivers started in the 1960s. The majority of early studies were of short duration with little or no pre-treatment sampling and a year or less of post-treatment sampling (Table 3). Among the river studies we reviewed, three studies collected no pre-treatment data, five studies collected samples immediately before treatment, and a single study collected samples a year before treatment. Post-treatment sampling was similarly variable, with few studies collecting samples for more than a year post-treatment. Exceptions to this were Mangum and Madrigal (1999), Whelan (2002), and Hamilton et al. (2009), who collected several years of post-rotenone treatment data.

Table 1. Summary of laboratory derived rotenone tolerances (ppb hour = ppb of rotenone • duration [hour]) of selected aquatic invertebrate taxa. Summarized from Engstom-Heg et al. (1978) and Finlayson et al. (2010)*.

Low Tolerance (1,000–6,000 ppb hour)	**Intermediate tolerance (6,000–16,000 ppb hour)**	**High tolerance (1,600–24,000 ppb hour)**
Diptera	Diptera	Coleoptera
Simuliidae	Chironomidae	Elmidae
	Tipulidae: *Antocha*	Ephemeroptera
Ephemeroptera	Ephemeroptera	Leptophlebiidae: *Paraleptophlebia*
Baetidae: *Baetis tricaudatus**	Ephemerellidae: *Ephemerella*	
Heptageniidae *Rhithrogena morrisoni**	Heptageniidae	
Plecoptera	Plecoptera	Plecoptera
Perlidae *Claassenia sabulosa**	Chloroperlidae	Pteronarcyidae: *Pteronarcys*
Perlodidae *Oroperla barbara**		Megaloptera
		Corydalidae
Trichoptera	Trichoptera	Trichoptera
Psychomyiidae: *Psychomyia*	Limnephilidae	Glossosomatidae: *Glossosoma*
Hydropsychidae: *Arctopsyche grandis** *Hydropsyche**	Philopotamidae	Hydropsychidae: *Hydropsyche* *Cheumatopsyche*
Rhyacophilidae: *Rhyacophila*		Odontoceridae

Table 2. Field studies on the effects of rotenone on lentic invertebrates.

Location	Study year	Rotenone treatment	Pre-treatment sampling	Post-treatment sampling	Observed change in aquatic invertebrate assemblages	Citation
Third Sister Lake, MI	1943	5 mg/L unknown solution		Bimonthly	Zooplankton, leeches, and Odonata greatly reduced	Brown and Ball 1943
Reservoir 4 and Smith Lake, CO	1954	1 mg/L 5% rotenone solution = 50 ppb	4 Ekman dredge samples, 2 weeks prior	Biweekly Ekman dredge samples for 1 yr	Few negative effects to Chironomidae	Cushing and Olive 1957
Salbo and Holm lakes, Sweden	1958 1956	0.5–0.6 mg/L 5% rotenone solution = 25–30 ppb	Immediately prior	Immediately after	Most zooplankton and benthic fauna were killed	Almquist 1959
Fern Lake, WA	1960	0.5 mg/L 5% rotenone solution = 25 ppb	Biweekly for 2 yrs prior	Frequently for 6 mos after	Complete zooplankton assemblage kill 2 days after; all 42 species found before treatment found within 5 mos	Kiser et al. 1963
Patricia and Celestine lakes, Alberta, Canada	1966	0.75 mg/L 5% rotenone solution = 37.5 ppb	1 sample 2 mos prior	3 yrs after	Near complete recovery in 3 yrs	Anderson 1970
Experimental ponds, Columbia, MO	1971	0.5 and 2 mg/L 5% rotenone = 25 and 100 ppb	Biweekly for 2 mos prior, and then 14, 7, 3, 2, and 1 day pre-treatment	1, 2, 3, 7, and 14 days post-treatment and then biweekly 1 yr after	No immediate or long-term decreases in abundance or taxa observed	Houf and Campbell 1977
Lake Haugatjern, Norway	1980	0.5 mg/L 5% rotenone solution = 25 ppb	7 samples 1 yr prior	3 yrs and 4 yrs after	Small effect on zooplankton species composition and biomass	Reinertsen et al. 1990
Lake Haugatjern, Norway	1980	0.5 mg/L 5% rotenone solution = 25 ppb	Monthly, 6 mos prior	Seasonal, 2 yrs	Little change to overall benthic assemblages, except to Chironomidae fauna, *Chironomus* in particular	Koksvik and Aagaard 1984
Lake Christina, MN	1987	3 mg/L 5% rotenone solution = 150 ppb	Seasonal 2 yrs prior	Seasonal 3 yrs	Large change in zooplankton assemblages. Observed changes attributed to change in fish assemblage	Hanson and Butler 1994
Golf Course Ponds, IL	1991	0.6 mg/L 2.5% rotenone solution = 15 ppb	15 min. prior	6 mos	Full recovery in 6–8 mos	Beal and Anderson 1993
Unnamed pond, MN	1998	3 mg/L 5% rotenone solution = 150 ppb	2 samples 6 mos prior	1 yr	Large short-term effect on zooplankton, no effect after 1 yr	Melaas et al. 2001
Lake Davis, CA	2006	Estimated to be 2 mg/L 5% rotenone solution = 100 ppb	3 mos and 18 days prior	1 week, 9 mos, and 22 mos after	57% decrease in total zooplankton abundance immediately after treatment and was 58% and 61% lower after 1 and 2 yrs. Taxa richness unchanged	CA Fish and Game 2006
Orchard Ponds, New Zealand	2004	Not specified	None, design compared control and treatment ponds that were treated, 1 mo, 1 yr, and 3 yrs previously	1 sampling date– zooplankton, sweep net, and Ekman dredge samples	Zooplankton—no difference in abundance or taxa richness among treatments Benthic assemblages–no difference in taxa richness among treatments	Blakely et al. 2005

The immediate and short-term responses of aquatic invertebrates to rotenone treatments in streams have been large reductions in invertebrate abundance and taxa richness (Table 3). Aquatic insects appeared more sensitive than non-insects, and the insect groups Ephemeroptera, Plecoptera, and Trichoptera appeared more sensitive than Coleoptera and Diptera.

Aquatic invertebrate assemblage recovery following rotenone treatment varied from months to years depending on the severity of impact and often on how recovery was measured and study length. Overall invertebrate abundances generally returned to pre-treatment levels quicker than biodiversity and taxonomic composition measures. Overall assemblage abundances typically returned to pre-application levels within a few months to a year (Table 3). Recovery times for taxonomic richness and community composition measures exceeded two years in some studies (Binns 1967; Whelan 2002) and more than five years for individual species (Mangum and Madrigal 1999). Unfortunately, longer-term (two or more years of post-treatment sampling) studies of aquatic invertebrate assemblage recovery following rotenone treatments are limited (Table 3).

ANTIMYCIN EFFECTS TO INVERTEBRATES

Published studies on antimycin effects on invertebrates appear scarce compared to the occurrence of antimycin treatments. Most available literature is limited to theses and government reports, with much of it 30 to 40 years old. Of the 15 studies we located, 4 were journal publications (Kawatski 1973; Morrison 1979; Minckley and Mihalick 1981; Dinger and Marks 2007). Three were laboratory studies (Table 4), four were conducted in lentic systems (Table 5), and eight were conducted in lotic systems (Table 6).

Table 3. Field studies on the effects of rotenone on lotic invertebrates.

Location	Study year	Rotenone treatment	Pre-treatment sampling	Post-treatment sampling	Observed change in aquatic invertebrate assemblages	Citation
Robinson Creek, CA	1963	5% rotenone active, unknown concentration	None, treated/ untreated comparison	8 mos	10–50% reduction in abundance	Cook and Moore 1969
Green River, UT	1963	2.5–9.4 mg/L 5% rotenone solution = 125–470 ppb for 7 h	2 weeks prior	2 yrs after	Immediate reduction in abundance of nearly all species. Hydrosychidae (Trichoptera) recovered after 2 yrs, burrowing mayflies extirpated	Binns 1967
Strawberry River, UT	1990	3 mg/L 5% rotenone solution = 150 ppb for 48 h	1 week prior	Annually 5 yrs	54% decrease in taxa richness after 1 yr, 21% decrease in taxa richness after 5 yrs	Mangum and Madrigal 1999
Steams, Papua, New Guinea	1990	Unknown	Immediately prior	Immediately after and then up to 2 hrs	Significant declines in Dixidae and Hydropsychidae, no change in Leptophlebiide or in total abundance	Dudgeon 1990
Silver King Creek, CA	1964–1996	Treatments in 1964, 1976, 1977, 1991, and 1993. Unknown concentrations to 20 ppb for 18–24 hr in 1991 and 1993	None	Multiple times 1984 – 2006	Slight reduction in total, Ephemeroptera, Plecoptera, and Trichoptera taxa richness and change in percent dominant taxa	Trumbo et al. 2000
Manning Creek, UT	1995	0.5–1.5 mg/L 5% rotenone solution = 25–75 ppb for 12–18 hrs	1 mo prior	1 yr and 3 yrs	13% decrease in taxa richness after 3 yrs	Whelan 2002
River Ogna, Norway	2001	Unknown	Just prior	2 mos	Rapid recolonization of common taxa, a few taxa disappeared	Kjaerstad and Arnekleiv 2003
Strawberry Creek, Great Basin NP	2000	5 mg/L 5% rotenone solution = 250 ppb for 1 h and 2 mg/L 5% rotenone solution = 100 ppb for 7 hr	1 yr and 1 day prior	1 mo, 9 mo, and 1 yr after	89% reduction in total taxa richness at 1 month, 22% reduction at 1 year, 4 taxa missing at 1 year, 2 taxa missing at 3 years. 95% reduction in total abundance at 1 month, 47% reduction at 1 year	Hamilton et al. 2009
Virgin River, UT	2001–2005	11 treatments between 1988 and 2005, unknown concentrations prior to 2004. In 2004 and 2005, 3 ppm of unknown rotenone solution for 3–8 hr.	None	1 yr	Little to no change following 2004 and 2005 treatments, study complicated by lack of pre-data and > 20 yrs of rotenone treatment	Vinson and Dinger 2006

Antimycin: Laboratory studies

A summary of several laboratory studies suggests invertebrates have a wide range of sensitivity to antimycin (Table 4). Sensitivity increases with increasing water temperatures (Walker et al. 1964) and decreases at pH > 8.5 (Marking 1975). Water hardness appears to have little effect on antimycin toxicity (Lee et al. 1971). Kotila (1978) tested 18 stream invertebrate taxa to various concentrations, exposure times, and water chemisty and documented a range of tolerances with some taxa surviving 1,000 ppb over 48 hours and others suffering 50% mortality at concentrations as low as 16.9 ppb over 8 hours (Table 4).

Antimycin: Lentic habitats

Few studies of antimycin effects on invertebrates in lakes and ponds have been published in peer-reviewed journals. Initial response to antimycin appears greater for zooplankton than benthic invertebrates, where the reported impacts on assemblages have been slight (Table 5). The few reports on recovery following treatment suggest little short or long-term effects of antimycin on lentic macroinvertebrate assemblages (Snow 1974, sampling 6 years after treatment; Houf and Campbell 1977).

Antimycin: Lotic habitats

Antimycin has been used in streams since the 1970s. The extent of pre-treatment sampling varied widely across studies from none to seasonal sampling for two years prior to treatment (Dinger and Marks 2007), with the majority of studies sampling just prior to treatment (Table 6). Post-treatment sampling was similarly variable, with some studies only sampling immediately following treatment and two studies collecting samples for more than a year after treatment.

Treatment concentrations in rivers varied from < 10–100 ppb (Table 6). In general, measured effects on abundances appeared related to concentration, with significant reductions in invertebrate assemblage abundance observed at concentrations > 10–20 ppb. Similar to that observed with rotenone, zooplankton appear more sensitive than larger benthic invertebrates, small lentic invertebrates and aquatic insects appeared more sensitive than non-insects, and the insect groups Ephemeroptera, Plecoptera, and Trichoptera appeared more sensitive than Coleoptera and Diptera (Jacobi and Degan

Table 4. Summary of laboratory derived tolerances of selected aquatic invertebrate taxa to antimycin. Summarized from Kotila (1978), except for Odonata: Coenagrionidae: *Ischnura* and Cladocera (Walker et al. 1964) and Ostracoda (Kawatski 1973).

Low tolerance (0–20 ppb)	**Intermediate tolerance (20–100 ppb)**	**High tolerance (> 100 pb)**
Diplostraca Cladocera Daphniidae	Trichoptera	Trichoptera
Ostracoda	Brachycentridae: *Micrasema rusticum*	Hydropsychidae: *Diplectrona modesta*
Trichoptera	Helicopsychidae: *Helicopsyche borealis*	Lepidostomatidae: *Lepidostoma griseum*
Brachycentridae: *Brachycentrus amercanus*	Limnephilidae: *Pycnopsyche guttifer*	Plecoptera
Brachycentridae: *Brachycentrus occidentalis*	Plecoptera	Perlidae: *Perlesta placida*
Hydropsychidae: *Hydropsyche bifida*	Capniidae: *Paracapnia angulata*	Ephemeroptera
Uenoidae: *Neophylax concinnus*	Nemouridae: *Nemoura trispinosa*	Ephemerellidae: *Ephemerella*
Plecoptera	Perlidae: *Agentina capitata*	Coleoptera
Perlodidae: *Isoperla signata*	Perlidae: *Paragnetina media*	Dryopidae: *Helichus striatus*
Perlodidae: *Isoperla slossonae*	Perlodidae: *Isoperla clio*	Dytiscidae: *Agabus seriatus*
	Pteronarcyidae: *Pteronarcys pictetii*	Elmidae: *Optioservus fastiditu*s
	Taeniopterygidae: *Taeniopteryx nivalis*	Elmidae: *Stenelmis crenata*
	Ephemeroptera	Psephenidae: *Psephenus herricki*
	Baetiscidae: *Baetisca lacustris*	Odonata
	Ephemerellidae: *Ephemerella invaria*	Coenagrionidae: *Argia apicalis*
	Ephemeridae: *Hexagenia limbata*	Coenagrionidae: *Ischnura* sp.
	Heptageniidae: *Leucrocuta hebe*	Corduliidae: *Neurocordulia molesta*
	Heptageniidae: *Maccafertium vicarium*	Gomphidae: *Gomphus vastus*
	Leptophlebiidae: *Leptophlebia cupida*	Megaloptera
	Potamanthidae: *Anthopotamus myops*	Corydalidae: *Nigronia serricornis*
		Diptera
		Athericidae: *Atherix variegate*
		Tipulidae: *Tipula*

Table 5. Field studies on the effects of antimycin on lentic invertebrates.

Location	**Study year**	**Antimycin treatment**	**Pre-treatment sampling**	**Post-treatment sampling**	**Observed change in aquatic invertebrate assemblages**	**Citation**
2 hatchery ponds, Delafield, WI	1963	10 ppb	Not specified	Not specified	Invertebrates were more abundant post-treatment	Walker et al. 1964
8 various ponds/ lakes, WI, WY, NE, AR, NY, and NH	1964–1966	3.12–12 ppb	Not specified	Not specified	Mortalities in 7 of 15 taxa examined, as high as 99%	Gilderhus et al. 1969
Rush Lake, WI	1967	0.5–0.75 ppb	None	Once, 6 yrs after	No gross effects 6 yrs later	Snow 1974
9 Experimental ponds, Columbia, MO	1971	20–40 ppb	Biweekly for 2 mos prior and then 14, 7, 3, 2, and 1 day pretreatment	1, 2, 3, 7, and 14 days post-treatment and then biweekly 1 yr after	No short or long term declines in abundance in 6 representative taxa observed. No change in taxa diversity.	Houf and Campbell 1977

1977; Morrison 1979; Minckley and Mihalick 1981; Moore et al. 2005; Dinger and Marks 2007; Hamilton et al. 2009).

Studies of aquatic invertebrate assemblage recovery following antimycin treatment generally reported recovery within one year (Table 6). As with rotenone treatments, invertebrate assemblage abundances returned to pre-treatment levels quicker than biodiversity and taxonomic composition measures. Longer-term studies of recovery (one or more years of post-treatment sampling) were limited to Dinger and Marks (2007) and Hamilton et al. (2009). Dinger and Marks (2007) observed shifts in species composition towards more tolerant species, but after 24 months, they concluded that there was no discernable pattern in why certain species were eradicated and others were not. Hamilton et al. (2009) reported all pre-treatment taxa were collected within 1 year post-treatment.

Table 6. Field studies on the effects of antimycin on lotic invertebrates.

Location	Study Year	Antimycin treatment	Pre-treatment sampling	Post-treatment sampling	Observed change in aquatic invertebrate assemblages	Citation
Seas Branch Creek, WI	1972	17–44 ppb	Monthly, 6 mos prior	Immediately, monthly, and bi-monthly for 2 yrs after	50–100% decrease in biomass immediately after, recovery in ~1 yr	Jacobi and Degan 1977
Ashippun River, WI	1974	7–42 ppb	None	Artificial samplers, 2 days and 5 days after	Decreases in benthic abundances observed	Kotila 1978
Ord Creek, AZ	1977	10 ppb	Immediately prior	Immediately after and 3 yrs after	Decrease in standing crop (5X numerically, 70X biomass); recovery 3 yrs later	Minckley and Mihalick 1981
Allt a' Mhuilinn, Scotland	1977	10–20 ppb	Once, 5 days prior	Once, 2 weeks after	No significant decreases	Morrison 1979
Sams Creek, TN	2001	8 ppb	Occasionally 5 yrs prior, and mo prior	Immediately after and seasonally 1 yr after	18–25% reduction in total taxa richness, recovery 1 yr after	Walker 2003, Moore et al. 2005
Snake Creek, NV	2002	8 ppb	1 yr and 1 day prior	1 mo, 9 mo, and 1 yr after	23% reduction in total taxa richness at 1 month, 10% reduction at 1 year, no taxa missing at 1 year. 10% reduction in total abundance at 1 month and 1 year	Hamilton et al. 2009
LaBarge Creek watershed, WY	2002 to 2003	10 ppb	not specified	not specified	No measurable effects	Cerreto 2004
Fossil Creek, AZ	2004	54–100 ppb	Seasonally 2 yrs prior	Seasonally 2 yrs after	Decreases in invertebrates immediately after, recovery 5 mos after	Dinger and Marks 2007

SUMMARY OF EFFECTS

For both piscicides, interpretation of the effects on invertebrate assemblages were often contradictory, with some studies reporting few treatment effects on invertebrates (e.g., rotenone—M'Gonigle and Smith 1938; Brown and Ball 1943; Ball and Hayne 1952; Zilliox and Pfeiffer 1960; Cook and Moore 1969; Houf and Campbell 1977; Finlayson et al. 2010; antimycin—Walker et al. 1964; Houf and Campbell 1977; Walker 2003; Moore et al. 2005; Hamilton et al. 2009) and other studies reporting substantial treatment impacts to invertebrates (e.g., rotenone—Davidson 1930; Cutkomp 1943; Zischkale 1952; Das and McIntosh 1961; Binns 1967; Hamilton et al. 2009; antimycin—Jacobi and Deagan 1977; Minckley and Mihalick 1981; Dinger and Marks 2007). The causes of these differences are intriguing and not entirely clear, but to us they appeared due to three factors: (1) piscicide concentration, duration, and treatment breadth; (2) aquatic invertebrate study objectives and sampling intensity; and (3) natural variation in toxicity among species and species groups.

Effects were nearly always greater at higher concentration levels. Finlayson et al. (2010) suggest a mean rotenone concentration of 25–50 ppb for < 8 h should result in complete mortality to salmonids and limited mortality to invertebrates in streams. This rotenone dosage is less than that commonly used in fish removal projects (Table 3). They also found that rotenone formulations containing secondary chemicals, such as the synergist piperonyl butoxide, contributed to toxicity to invertebrates, but not to salmonids. Additional research on the effects of secondary chemicals and refinement of minimum exposure rates is needed for more fish species so that treatment application rates are sufficient to meet project objectives, but also lessen impacts to non-target organisms.

Morphological differences among invertebrates occupying different habitats also appear to strongly influence the impact of piscicides on invertebrates. Benthic invertebrates appear less sensitive than planktonic invertebrates, smaller invertebrates appear more sensitive than larger invertebrates, and aquatic invertebrates that use gills appear more sensitive than those that acquire oxygen cutaneously, through lamellae, use respiratory pigments, or breathe atmospheric oxygen. These generalizations are similar to those described by Ling (2003) and suggest that impacts of piscicides in lotic environments may be greatest in mountain trout streams. These habitats are characterized by cold water and high oxygen levels, and are often dominated by small gilled invertebrates, namely Ephemeroptera, Plecoptera, and Trichoptera (EPT). Indeed, piscicide studies in mountain streams generally showed EPT taxa to be more susceptible than other taxonomic groups (Binns 1967; Minckley and Mihalick 1981; Mangum and Madrigal 1999; Trumbo et al. 2000; Whelan 2002; Dinger and Marks 2007; Hamilton et al. 2009). However, a rigorous evaluation among habitat types, such as high-elevation mountain streams versus low-elevation rivers has not been conducted.

Studies that tended to evaluate the effects on aquatic invertebrates as fish food availability (invertebrate assem-

PISCICIDE IMPACT STUDY DESIGN CONSIDERATIONS

Study designs to detect piscicide impacts on invertebrates will take many forms depending on the level and type of impact needing detection. While the overall question may simply be, "What is the effect of a piscicide on aquatic invertebrates?" the specifics of this question need to be addressed to develop a robust study design. Principally, will "before-after" comparisons be done based on assemblage-level measures only, such as total abundance and taxa richness; or will community composition and individual species or genera occurrences be evaluated as well?

Changes in community-level attributes are best evaluated using a BACI (Before-After-Control-Impact) study design (Underwood 1994). In BACI study designs, data are collected at control and treatment sites, both before and after the treatment. Equal numbers of control and treatment sites should be sampled for equal periods of time before and after treatment. Replication in both sites and sampling dates will increase statistical power and the ability to detect differences. For this type of study design, quantitative sampling where data are summarized as the number of individuals or taxa per a consistent sampling area is desired. The number of locations and the period of pre- and post-treatment sampling will be dependent on the heterogeneity of the system, the diversity of invertebrate assemblages, and budgets. However, we suggest that a reasonable sampling design to detect changes in community-level attributes should include four control and four treatment sites, sampled seasonally, a minimum of two years before and three years after a treatment. Statistical analysis should then follow the BACI design, using the ANOVA (Analysis of Variance) models of Underwood (1994), and insuring that the appropriate F-ratio is used to assess the impacts. For general guidance on BACI and other alternative designs (e.g., BACIPS—Before-After-Control-Impact-Paried-Series) an excellent resource is Schmitt and Osenberg (1996). Field and laboratory protocols for the collection and processing of stream invertebrate samples should follow that described in Vinson and Dinger (2008) or the Environmental Protection Agency Rapid Bioassessment of Creeks and Small Rivers single habitat (quantitative) and multi-habitat (qualitative) survey protocols (Barbour et al. 1999). Field sampling in lakes might involve collecting both zooplankton and benthic invertebrate samples. We recommend identifying invertebrates to the genus level. While species-level identifications are required to evaluate species occurrences and extirpations, this usually requires the collection of short-lived terrestrial adult stages. The effort to collect and identify adult specimens needs to be weighed against other project objectives, but in general we feel this level of detail is beyond the scope of most agencies conducting piscicide treatment assessments. Based on this design, we suggest that analysis of impacts should focus on assemblage level measures such as total abundance and taxa richness and diversity measures, and avoid assessing impacts to individual invertebrate taxa. The presence of threatened or endangered invertebrate species will obviously require different protocols for these species.

blage abundances or biomass) generally found quick recovery (e.g., M'Gonigle and Smith 1938; Brown and Ball 1943; Ball and Hayne 1952; Zilliox and Pfeiffer 1960; Walker et al. 1964; Cook and Moore 1969; Snow 1974; Houf and Campbell 1977; Trumbo et al. 2000; Moore et al. 2005); whereas studies looking at effects on invertebrate biodiversity as either in terms of individual species or species groups generally found more lingering effects (e.g., Minckley and Mihalick 1981; Koksvik and Aagaard 1984; Reinertsen et al. 1990; Beal and Anderson 1993; Mangum and Madrigal 1999; Melaas et al. 2001; Whelan 2002; Dinger and Marks 2007; Hamilton et al. 2009). These somewhat contradictory results appear due to natural variation in colonization rates among species and the amount of pre- and post-treatment sampling. In a review of 150 case studies of aquatic ecosystem recovery from disturbance, (15 of which were rotenone treatments), Niemi et al. (1990) found that recovery times of total macroinvertebrate assemblage abundances to 85% of pre-disturbance densities generally occurred in less than 18 months, whereas recovery of abundances for different taxonomic orders of insects varied widely. Recovery of Diptera abundances occurred to near 80% within 1 year, Ephemeroptera abundances to near 70% after 1 year, and Trichoptera and Plecoptera abundances recovered to only about 60% after 2 years. They found that recovery rates were influenced most by: (1) impact persistence, including changes in system productivity, habitat integrity, and persistence of the stressor; (2) organism life history, including generation time, and propensity to disperse; (3) time of year the disturbance occurred; (4) refugia presence; and (5) distance of colonization sources. They did not mention pre-disturbance densities, but the relative rarity of taxa would also likely influence their ability to repopulate an area or the ability to collect these taxa. They felt that downstream drift from unimpacted upstream areas was the critical factor in determining recovery times.

We found in general that sampling conducted a year post-treatment appeared adequate to detect impacts to assemblage measures, such as total abundance or taxa richness, but not for detecting impacts to individual taxa. The three longest duration studies to date (Mangum and Madrigal 1999; Whelan 2002; Hamilton et al. 2009) all reported the loss of several taxa, i.e., taxa found prior to treatment were not collected one year post-treatment, however many, but not all, of these taxa were found 2 to 3 years post-treatment. These studies also reported collecting a number of taxa post-treatment that were not collected pre-treatment. These results suggest two things; (1) pre- and perhaps post-treatment sampling was insufficient to adequately characterize the local fauna and (2) aquatic invertebrate assemblages are highly diverse and dynamic. Both of these factors prevent us and the authors of the original studies from conducting more rigorous analyses to determine if differences in taxa occurrences between pre- and post treatment samples were due to natural variation, sampling variation, or piscicides. No studies appear to us to have done an adequate job of describing pre-treatment assemblages with respect to the occurrence of individual taxa.

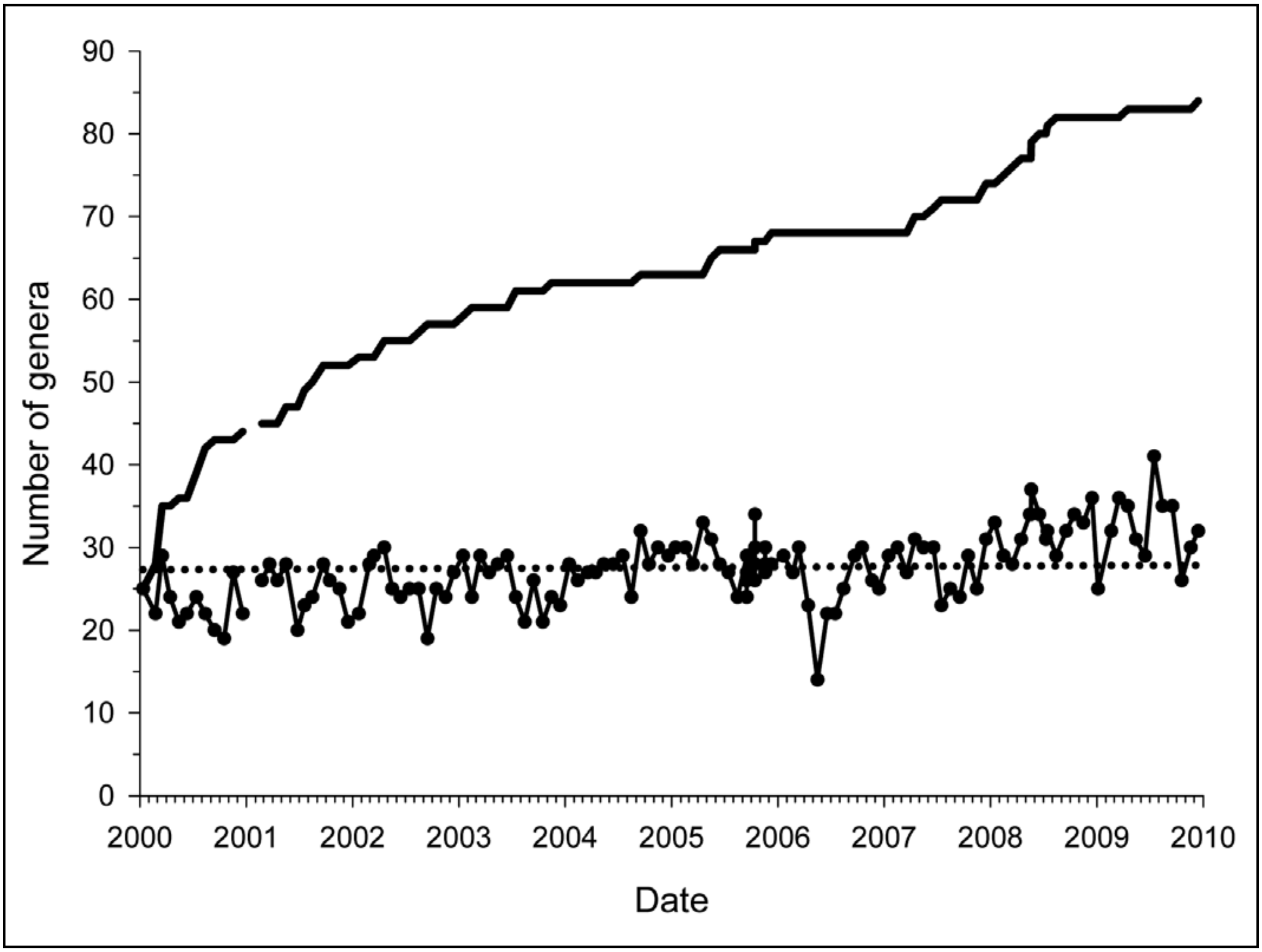
The amount of sampling necessary to provide accurate and precise measures of individual genera or species occurrences both before and after a treatment can be extensive. For stream invertebrates, the presence of large numbers of rare taxa is a common phenomenon. There have been no complete inventories of invertebrates of any body of freshwater, but several studies to date have documented that local stream reach (ca. 1 km) faunas contain hundreds to thousands of species. A total of 1,122 species have been reported from the Danube River, Austria, and 1,044 species from the Breitenbach River, Germany (Strayer 2006). In comparison, most published studies with seasonal sampling for 1 to 2 years of length seldom collect 100 genera/species and 50 to 60 genera/species is more common in a 1 km stream reach (Vinson and Hawkins 2003, M. Vinson unpublished data).

M. Vinson (unpublished data) sampled the same location on the Logan River, Cache County, Utah, monthly for 10 years. Samples were collected following standard protocols commonly used in piscicide assessment projects (field sampling methods described in Vinson and Dinger [2008] and laboratory procedures described in Vinson and Hawkins [1996]). The results of this study have shown little variation in the number of genera collected each month, but the occurrences of individual genera varies widely. To date, 84 genera have been collected at the site, but the number of individual genera collected each month averages 27.5, roughly 33% of the total genera collected in the stream reach over 10 years. On average, a new genera has been collected about every 2 months (Figure 1) and the genera accumulation curve shows little inclination for flattening out and would likely even be steeper for species-level identifications. These results, similar to that reported by Needham and Usinger (1956) and Resh (1979), led Resh (1979) to suggest that variation in aquatic invertebrate populations within a stream reach is so high that collecting data on the abundances of all but the most common taxa or the assemblage as a whole is likely beyond the scope of most assessment projects.

CONCLUSIONS

Overall, there have been too few published studies with little comparability with respect to treatment methods and invertebrate sampling efforts to allow for any sweeping statements on the overall effects of rotenone and antimycin on aquatic invertebrates in general and stream invertebrates in particular. Thus, scientists and managers must consider effects on invertebrates and the consequences on a case-by-case basis. However, recent work suggests that impacts to invertebrate assemblages can be reduced and mortality to target fish species maintained at lower concentrations than have generally been used in the past (Finlayson et al. 2010). To further reduce impacts and enhance recolonization, we recommend the following actions: (1) chemical treatments of larger drainages should stage treatments with intermediate barriers and allow time between treatments for dispersal and recolonization of invertebrates to avoid potential for cumulative impacts; (2) headwater and tributary fishless stream reaches should not be treated so they can serve as refuges for invertebrates; and (3) piscicides should be neutralized downstream of the project area to protect downstream colonization sources. We also see a need for additional laboratory toxicity tests, field studies that measure actual rotenone concentrations for the duration of the treatment so actual exposure conditions can be quantified, and longer-term (3-year pre-treatment and > 5-year post-treatment), more rigorous field evaluations of invertebrate assemblages to improve our ability to predict piscicide effects on invertebrates.

Figure 1. Monthly collections and genera accumulation curves for benthic aquatic invertebrates collected from the Logan River, Cache County, Utah between January 2000 and December 2009. Solid lines are individual monthly values (bottom) and cumulative collection (top) of unique genera. The dotted line is the long-term mean and median of 27.5 genera per sample. Five samples were collected per month in September–December 2005, three samples were collected in May 2008, and two in July 2008. No sample was collected in January 2001.



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FEATURE:
ENDANGERED SPECIES

Atlantic Sturgeon Vessel-Strike Mortalities in the Delaware Estuary

ABSTRACT: The Atlantic Sturgeon Status Review Team has recommended that the Secretary of Commerce list the New York Bight distinct population segment of Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*), which includes the Delaware River and Hudson River populations, as threatened under the federal Endangered Species Act. Between 2005 and 2008, a total of 28 Atlantic sturgeon mortalities were reported in the Delaware Estuary. Sixty-one percent of the mortalities reported were of adult size and 50% of the mortalities resulted from apparent vessel strikes. The remainder of the mortalities were too decomposed to ascertain the cause of death, but the majority were likely the result of vessel strikes. For small remnant populations of Atlantic sturgeon, such as that in the Delaware River, the loss of just a few individuals per year due to anthropogenic sources of mortality, such as vessel strikes, may continue to hamper restoration efforts. An egg-per-recruit analysis demonstrated that vessel-strike mortalities could be detrimental to the population if more than 2.5% of the female sturgeon are killed annually. We report on our observations of vessel-strike mortalities in the Delaware Estuary, discuss the possible implications for the Delaware River population, and recommend further research.

Mortalidad del esturión del Atlántico en el estuario Delaware por colisión con embarcaciones

RESUMEN: El grupo de trabajo que revisa el estado del esturión del Atlántico recomendó que la Secretaría de Comercio enliste al segmento distintivo de la población de esturión del Atlántico (*Acipenser oxyrinchus oxyrinchus*) que habita en la Bahía de Nueva York, la cual incluye a las poblaciones de los ríos Delaware y Hudson, como especie amenazada dentro del Acta Federal de Especies en Peligro. Entre 2005 y 2008, se reportó un total de 28 esturiónes muertos en el estuario Delaware. Sesenta y un porciento de dichos animales eran de talla adulta y 50% de las mortalidades parecen haber sido resultado de colisiones con embarcaciones. El resto de los individuos muertos se encontraban en un estado de descomposición tan avanzado que no fue posible determinar la causa de muerte, sin embargo la mayoría de ellos muy probablemente perecieron como resultado de una colisión. Para las pocas poblaciones remanentes del esturión del Atlántico, como aquellas que habitan el río Delaware, la pérdida anual de algunos pocos individuos por mortalidad antropogénica, como la provocada por las colisiones con embarcaciones, pueden entorpecer los esfuerzos de restauración. Mediante un análisis de huevos por recluta se demostró que las mortalidades causadas por impacto con embarcaciones pueden ir en detrimento de la población, si perecen más de 2.5 por ciento de las hembras por año. En la presente contribución reportamos nuestras observaciones sobre la mortalidad de esturiones el estuario Delaware causadas por colisión con embarcaciones, se discuten las posibles implicaciones para la población del río Delaware y se recomiendan futuras líneas de investigación.

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INTRODUCTION

The Atlantic Sturgeon Status Review Team (ASSRT), a group comprised of federal agency biologists, recently reviewed the status of Atlantic sturgeon (*Acipenser oxyrinchus*) populations in the United States and recommended that several distinct population segments (DPS) be listed as threatened under the federal Endangered Species Act. The ASSRT concluded that the Delaware River population had a moderately high risk (> 50% chance) of becoming endangered in the next 20 years (ASSRT 2007). The ASSRT grouped the Delaware River and Hudson River populations into a single New York Bight DPS and made a recommendation to the Secretary of Commerce that this DPS be listed as threatened under the Endangered Species Act. The states of Delaware and Pennsylvania, which border sections of the Delaware Estuary, have already placed Atlantic sturgeon on their respective state endangered species lists, and New Jersey lists this species as a “species of special concern” and its Endangered and Nongame Species Advisory Committee recommended an endangered status listing.

Given the long generation time and slow rate of population growth of Atlantic sturgeon, any anthropogenic sources of mortality may continue to hamper restoration efforts (Boreman

1997; Secor and Waldman 1999; Gross et al. 2002). Many factors including historical overfishing, habitat degradation, and the construction of dams have been implicated in the decline of Atlantic sturgeon populations. Due to the decline of populations along the Atlantic Coast, the Atlantic States Marine Fisheries Commission instituted a coastwide moratorium on the harvest of Atlantic sturgeon in 1998, which is designed to remain in effect until there are at least 20 protected year classes in each spawning stock. Collins et al. (1996) and Stein et al. (2004) detailed the impact of bycatch mortality on Atlantic sturgeon. We report here on another anthropogenic source of mortality that has not been widely considered—mortality from vessel strikes, and examine how these vessel strikes may be affecting the population of Atlantic sturgeon in the Delaware River. We use the term "vessel strike" to indicate mortality caused by entrainment through the propellers of vessels and direct collisions with vessel hulls.

The Atlantic sturgeon is one of nine species/subspecies within the family Acipenseridae present in North American waters (Cech and Doroshov 2004). Although intensely studied since the 1970s, many aspects of Atlantic sturgeon life history remain unknown (Murawski and Pacheco 1977; Bain 1997; Bemis and Kynard 1997; Smith and Clugston 1997; Kynard and Horgan 2002; ASSRT 2007). Specific life history characteristics vary latitudinally along the Atlantic Coast, but the Atlantic sturgeon is generally characterized as a long-lived, late-maturing, estuarine-dependent, anadromous species (ASSRT 2007). Anadromous species are those that spend the majority of their life cycle in marine environments but reproduce in freshwater habitats. The historic range of Atlantic sturgeon included major estuarine and riverine systems spanning from the Saint Johns River, Florida, to Hamilton Inlet on the coast of Labrador (Murawski and Pacheco 1977; Smith and Clugston 1997; ASSRT 2007), with the Delaware River historically supporting the largest population along the Atlantic Coast (Secor and Waldman 1999; ASSRT 2007).

Atlantic sturgeon are slow maturing, with females typically reaching sexual maturity at 16 years or older and males at least 12 years in mid-Atlantic systems (Van Eenennaam et al. 1996). Spawning is not believed to occur every year, with spawning intervals ranging from 2 to 5 years for females (Vladykov and Greeley 1963; Van Eenennaam et al. 1996; Stevenson and Secor 1999; ASSRT 2007). Fecundity has been correlated with age and body size and typically ranges between 400,000 and 8 million eggs per female (Smith et al. 1982; VanEenennaam and Doroshov 1998; Dadswell 2006; ASSRT 2007).

Spawning adults are generally thought to migrate upriver in their natal systems during April and May in mid-Atlantic systems (Murawski and Pacheco 1977; ASSRT 2007), with recent studies suggesting that spawning may occur as late as mid to late June in the Delaware River (Simpson and Fox 2007). Spawning is believed to occur in flowing water between the salt wedge and fall line of large tidal rivers, where optimal flows are between 46 and 76 cm/s and depths are between 11 and 27 m (Borodin 1925; Crance 1987; Bain et al. 2000; ASSRT 2007). The highly adhesive eggs are deposited on hard-bottom substrates and fertilized externally (Smith et al. 1980; Gilbert 1989; Smith and Clugston 1997; ASSRT 2007).

Spawning locations in the Delaware Estuary were historically reported between river kilometer (rkm) 75 and rkm 130, with locations such as Pea Patch Island near Delaware City, Delaware, and Penn's Grove, New Jersey (rkm 85–110), noted as likely spawning areas. However, these conclusions were based primarily on fishery dependent information from the caviar fishery (Ryder 1890; Cobb 1900; Borodin 1925). Recent information from the movements of telemetered adult Atlantic sturgeon coupled with substrate and water quality information suggests that present day spawning may occur between north Philadelphia, Pennsylvania (rkm 176), and Trenton, New Jersey (rkm 211), in the Delaware River (Simpson and Fox 2007). However, the area between Marcus Hook, Pennsylvania (rkm 125), and Trenton could be considered potential spawning habitat based on substrate and water quality information (Simpson and Fox 2007). The majority of hard-bottom substrates, particularly coarse-grained substrates, occurring at depths suitable for Atlantic sturgeon spawning between Marcus Hook and Tinicum Island (rkm 136) either neighbor or are located within the shipping channel (Sommerfield and Madsen 2003).

After hatching, juvenile sturgeon move downstream into brackish waters, and eventually become residents in estuarine waters for months or years (Smith and Clugston 1997; ASSRT 2007). Upon reaching sizes of approximately 76 to 92 cm, the juveniles may emigrate to coastal waters (Murawski and Pacheco 1977; Smith 1985; ASSRT 2007), where they may travel widely, undertaking long range migrations and wandering among coastal and estuarine habitats (Dovel and Berggren 1983; Bain 1997; ASSRT 2007). Studies on the movements of telemetered juvenile and adult Atlantic sturgeon tracked manually in the Delaware Estuary indicate that sturgeon commonly utilize the shipping channel for upriver and downriver movements. These studies also identified three riverine concentration areas for juveniles during the summer months located at Artificial Island (rkm 89), Cherry Island Flats (rkm 110), and the Marcus Hook Anchorage (Shirey et al. 1999; Simpson and Fox 2007). Genetic studies and tagging programs indicate that a large percentage of the juveniles utilizing these concentration areas originated in other systems, mainly the Hudson River (King et al. 2001; ASSRT 2007; Wirgin et al. 2007).

Although the Delaware River once supported the largest population of Atlantic sturgeon along the Atlantic Coast (Secor and Waldman 1999; ASSRT 2007), overfishing, beginning in the 1880s and continuing throughout the early 1900s, led to recruitment failure and stock collapse. Habitat degradation and continued fishing prevented the population from recovering, and thus the population has apparently maintained itself at a very low level since the early 1900s. Currently, it is believed that Atlantic sturgeon are still reproducing in the Delaware River based on the capture of sexually mature adults during the historic spawning season (Simpson and Fox 2007). Genetic analyses from nuclear (King et al. 2001) and mitochondrial DNA (Wirgin et al. 2007) indicate that the Delaware River population is distinct from others on the Atlantic Coast. However, the ASSRT found that the Delaware River population was not sufficiently distinct to stand as its own DPS, and was grouped together with the Hudson River population as part of the New York Bight DPS.

The ASSRT speculated that the current population size of the Delaware River population is probably less than 300 spawning adults (ASSRT 2007). Although the ASSRT did not provide any empirical data to justify this population size, their rationale for using this figure was that the river systems for which adult population size estimates were available, the Hudson and the Altamaha, had approximate population sizes of 860 and 350 spawning adults, respectively. They speculated that these two populations are the largest populations in the United States and assumed that the other U.S. populations would be smaller than these two systems, hence the 300 spawning adults figure (ASSRT 2007). Rigorous estimates of the size of the Delaware River population are not available due to the difficulties associated with capturing a sufficient number of fish for study, particularly adults, the vast size of the Delaware Estuary, and the long-range migrations and coastal wandering behavior of juveniles and adults.

STUDY AREA

The Delaware Estuary, the tidal portion of the Delaware River, stretches from Trenton, New Jersey, and Morrisville, Pennsylvania (rkm 217), south to Cape May, New Jersey, and Cape Henlopen, Delaware, and includes all of Delaware Bay (Figure 1). It encompasses approximately 17,600 km^2 and is bordered by the states of New Jersey, Delaware, and Pennsylvania. The estuary is highly industrialized and hosts one of the largest petrochemical port complexes in the United States. Many large commercial vessels transit the estuary to reach these ports in the Wilmington, Delaware; Camden, New Jersey; and Philadelphia, Pennsylvania areas. The Maritime Administration of the U.S. Department of Transportation groups 17 ports in the Philadelphia, Pennsylvania, area together as Philadelphia/Delaware River Ports. These ports stretch from Salem, New Jersey, and Delaware City, Delaware, at rkm 97 to the ports of southern Bucks County, Pennsylvania, at rkm 203. In 2007, a total of 3,148 ocean-going vessels greater than 10,000 deadweight tons (DWT) visited the Philadelphia/Delaware River Port Complex, making it the fifth busiest port complex in the United States, following Houston, Los Angeles/Long Beach, New York, New Orleans, and San Francisco (USDOT 2008). Within the port complex, the Port of Philadelphia at rkm 159 handles the greatest volume of cargo (USACOE 2006).

Vessels transit the estuary through a shipping channel, the depth of which is maintained by the U.S. Army Corps of Engineers. The lower portion of the shipping channel, which extends 203 rkm from the mouth of Delaware Bay to the south of Bordentown, New Jersey (approximately 24 rkm upriver of the northern boundary of the city of Philadelphia), is currently maintained at a depth of 12.2 m (40 ft). The width of the channel varies from 122 m to 305 m, with the channel being wider in the lower estuary and narrower upriver. North of Bordentown to the southern boundary of Trenton, a distance of 8.6 km, the channel depth is maintained at 7.6 m (25 feet). Through the city of Trenton, a distance of 2 km where there is a small port, the channel depth is maintained at a depth of 3.7 m (12 feet). The Delaware River is non-navigable by large vessels above Trenton. The relatively long distance vessels need to travel from the sea through the estuary to reach their ports is unusual; most of the other major Atlantic Coast ports such as New York and Norfolk, Virginia, are located close to the sea. The long distance that vessels transit through the Delaware Estuary allows for a greater chance of interaction with sturgeon. In addition to commercial vessels, many recreational and commercial fishing vessels also traverse the Delaware Estuary.

METHODS

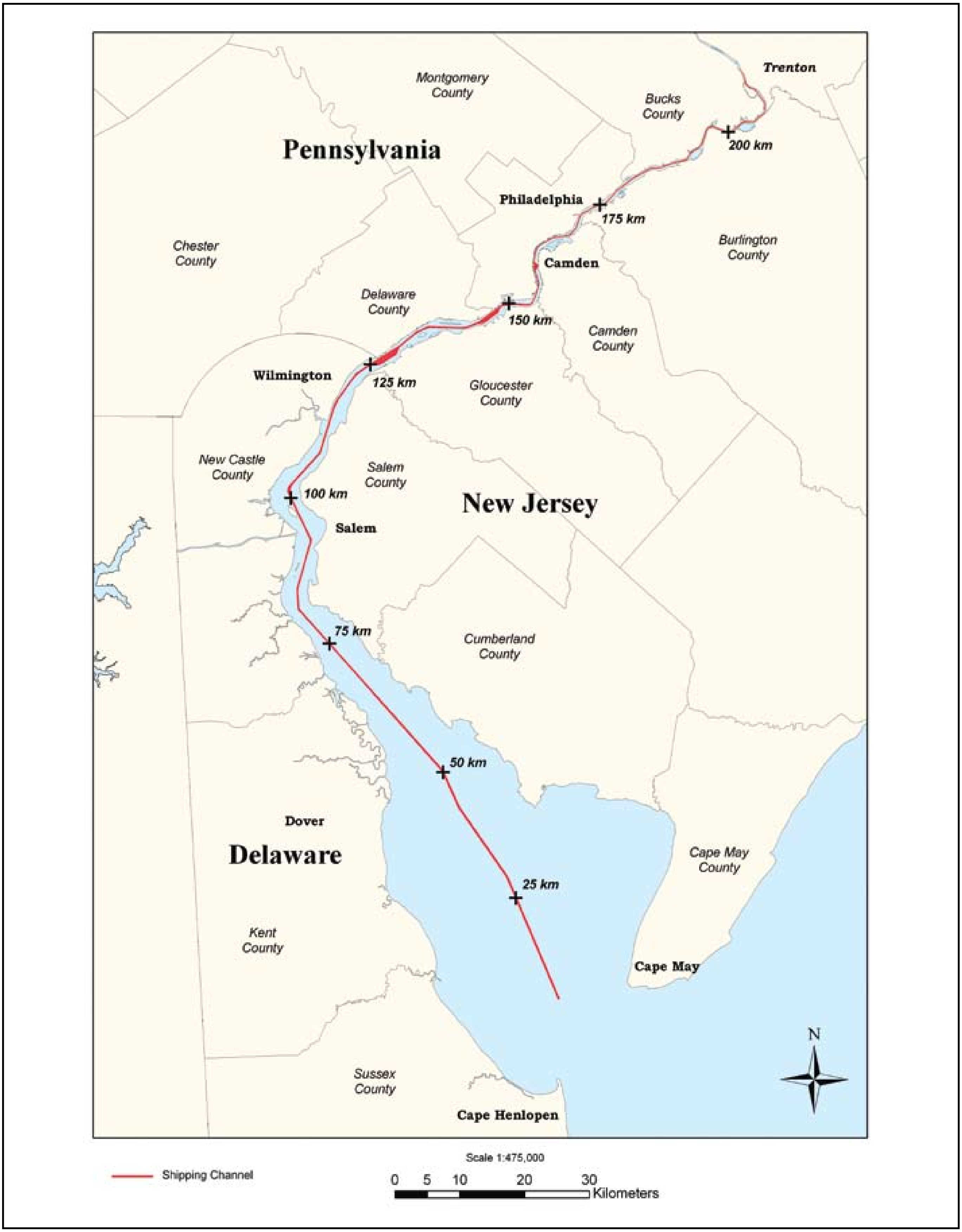
To evaluate the occurrence of Atlantic sturgeon vessel-strike mortalities in the Delaware Estuary, the Delaware Division of Fish and Wildlife (DEDFW) began tracking reports of sturgeon mortalities in 2005. The DEDFW received several reports of Atlantic sturgeon mortalities annually prior to 2005 but the reports were not formally documented. All of the sturgeon mortalities were reported by interested citizens or directly by agency biologists who encountered the carcasses while conducting surveys on other species. A dedicated survey program has not been implemented by DEDFW. However, the DEDFW Natural Heritage and Endangered Species Program has integrated logbooks and contact information into their shorebird monitoring program training guide. The shorebird monitoring program surveys a large portion of the beaches along Delaware Bay during spring and typically accounts for several of the sturgeon mortality reports annually. The majority of sturgeon reported were measured for total length (or length of portion found), scanned for internal and external tags, sexed when practical, examined for injuries, photo documented, and marked prior to being buried to eliminate double reporting. Tissue samples were taken and archived for future genetic stock analysis and a subset for contaminant analysis depending on the stage of decomposition.

To explore the effect of vessel-strike mortalities on the Delaware River Atlantic sturgeon population, we conducted an egg-per-recruit (EPR) analysis (Boreman 1997) to examine the impact on lifetime fecundity. The equation of the EPR is:

$$EPR = \sum_{i=2}^{n} \lambda_i \varphi_i \prod_{t=1}^{i-1} e^{-(VS_t + M)}$$

where n is the oldest spawning age, λ is the proportion of females that are mature at age i, ϕ_i is the mean fecundity of a female at age I, VS is the instantaneous rate of vessel-strike mortality during the period t, and M is the instantaneous natural mortality rate. All maturity and fecundity schedules were taken from Kahnle et al. (2007). We evaluated a range of VS values from 0 to 0.25 at intervals of 0.01. We assumed a maximum age of 60 years, a constant M equal to 0.07 over all ages, fishing and bycatch mortality rates equal to zero, and that sturgeon become fully vulnerable to vessel strikes starting at age 3 (assuming knife-edge recruitment). We assumed that sturgeon become vulnerable to vessel strikes at age 3 because this age corresponds approximately to the length of the smaller sturgeon carcasses that were observed (Stevenson and Secor 1999). Vessel-strike mortality rates that result in EPRs of 50% or more of the EPR from an unexploited population were considered sustainable based on Kahnle et al. (2007).

Figure 1. Map of the Delaware Estuary, the tidal portion of the Delaware River, which stretches from Trenton, New Jersey, and Morrisville, Pennsylvania, south to Cape May, New Jersey, and Cape Henlopen, Delaware, and includes all of Delaware Bay. The estuary encompasses approximately 17,600 km^2 and is bordered by the states of New Jersey, Delaware, and Pennsylvania. The shipping channel is shown and rkm points are indicated.



RESULTS

A total of 28 Atlantic sturgeon mortalities were reported in the Delaware Estuary between 2005 and 2008 (Table 1). The locations of reports ranged from Little Tinicum Island on the Delaware River near Chester, Pennsylvania, to Cape Henlopen near the mouth of Delaware Bay (Figure 2). Sixty-one percent of the sturgeon reported were of adult size, which was defined as sturgeon exceeding or likely to exceed 150 cm total length if not severed, with the majority (71%) of mortalities reported in spring during the months of May and June. Only one carcass was reported from the New Jersey side of the estuary.

Fifty percent of the sturgeon reported had injuries consistent with being struck by a vessel, while the remaining sturgeon reported were too decomposed to definitively determine the cause of death. Of the carcasses that had injuries consistent with being struck by a vessel, 71% were severed through the torso or head region (Figures 3 and 4), which is consistent with being entrained through the propeller of a large vessel. A few sturgeon had injuries that were consistent with a strike from the propeller of a small vessel, such as a recreational or commercial fishing vessel (Figure 5). Field observations indicate that it is unlikely that the injuries are occurring post-mortem. For instance, a DEDFW marine patrol officer encountered an adult Atlantic sturgeon that surfaced in the wash of a large vessel navigating upstream in the Delaware River in May 2005. The sturgeon was bleeding and moribund from a laceration near the dorsal fin described as a propeller strike (T. Penuel, DEDFW, pers. comm.). In addition, a Delaware commercial crabber reported hitting an adult-size Atlantic sturgeon with his outboard motor during late spring while moving through a shallow section of the lower Delaware River (C. Shirey, DEDFW, pers. comm.).

Results from the EPR analysis are shown graphically in Figure 6. We plotted the percentage of female sturgeon killed annually by vessel strikes versus the percent reduction in maximum EPR. Eggs per recruit declined rapidly from the maximum of 7.1 million eggs, if the only source of mortality was natural mortality, to less than 10% of this amount if the annual percentage of female sturgeon mortalities exceeded 9% of the population. The $VS_{50\%}$, or the vessel-strike mortality rate that results in a 50% reduction of the maximum EPR, occurs when

Table 1. Summary of Atlantic sturgeon carcasses reported in the Delaware Estuary between 2005 and 2008. Adults were defined as sturgeon exceeding or likely to exceed 150 cm total length if not severed. The dates and locations reported are the dates and locations where the carcasses were found and are not necessarily the dates and locations where the vessel strikes occurred.

Date reported	Location found	Life stage	Apparent cause of death	Injuries noted
5/7/2005	Artificial Island, NJ	Adult	Vessel strike	Severed at anal fins, blunt force trauma to head
5/17/2005	Woodland Beach, DE	Adult	Vessel strike	Severed through torso, crushed scutes, anterior section only
5/18/2005	Woodland Beach, DE	Adult	Vessel strike	Laceration through mid torso
5/19/2005	Slaughter Beach, DE	Adult	Unknown	Badly decomposed, head region missing,
5/23/2005	Conch Bar, DE	Adult	Unknown	Badly decomposed, head region missing
7/5/2005	Woodland Beach, DE	Juvenile	Vessel strike	Laceration near caudal peduncle
5/2/2006	Augustine Beach, DE	Adult female	Vessel strike	Severed through lower torso at anal fins, anterior section only
5/9/2006	South Bowers Beach, DE	Juvenile	Unknown	Badly decomposed, head region missing
5/15/2006	Port Mahon, DE	Juvenile	Unknown	Badly decomposed, head region missing
5/16/2006	Brockonbridge Gut, DE	Adult	Unknown	Badly decomposed, severed through lower torso at anal fins, anterior section only
5/17/2006	Kitts Hummock, DE	Adult	Unknown	Badly decomposed
5/17/2006	Little Tinicum Island, PA	Adult	Vessel strike	Severed through lower torso at anal fins, anterior section only
6/1/2006	Bay View Beach, DE	Juvenile	Vessel strike	Severed through mid torso region, anterior section only
8/15/2006	New Castle, DE	Adult	Unknown	Badly decomposed
8/17/2006	Augustine Beach, DE	Juvenile	Vessel strike	Laceration to head region
5/11/2007	Collins Beach, DE	Adult	Vessel strike	Severed through torso, posterior section only
5/13/2007	Pea Patch Island, DE	Adult	Unknown	Unreported
5/14/2007	Pickering Beach, DE	Juvenile	Vessel strike	Severed through torso, posterior section only
5/25/2007	Pea Patch Island, DE	Juvenile	Vessel strike	Severed through torso, posterior section only
6/11/2007	Bay View Beach, DE	Adult	Unknown	Badly decomposed
5/29/2008	Cape Henlopen, DE	Juvenile	Unknown	Badly decomposed, head region missing
6/23/2008	Marcus Hook, PA	Adult	Vessel strike	Severed head and crushed scutes
6/29/2008	Augustine Beach, DE	Juvenile	Vessel strike	Laceration posterior to head region and side of torso
7/10/2008	Port Mahon, DE	Juvenile	Unknown	Badly decomposed
7/12/2008	South Bowers Beach, DE	Adult	Unknown	Badly decomposed
10/21/2008	Ship John Shoal, DE Bay	Adult	Vessel strike	Head region severed
10/27/2008	Cape Henlopen, DE	Juvenile	Unknown	None observed
11/3/2008	Woodland Beach, DE	Adult	Unknown	None observed

Figure 2. Locations of Atlantic sturgeon carcasses reported in the Delaware Estuary between 2005 and 2008. The locations shown are where the carcasses were found and are not necessarily the locations where the vessel strikes occurred.

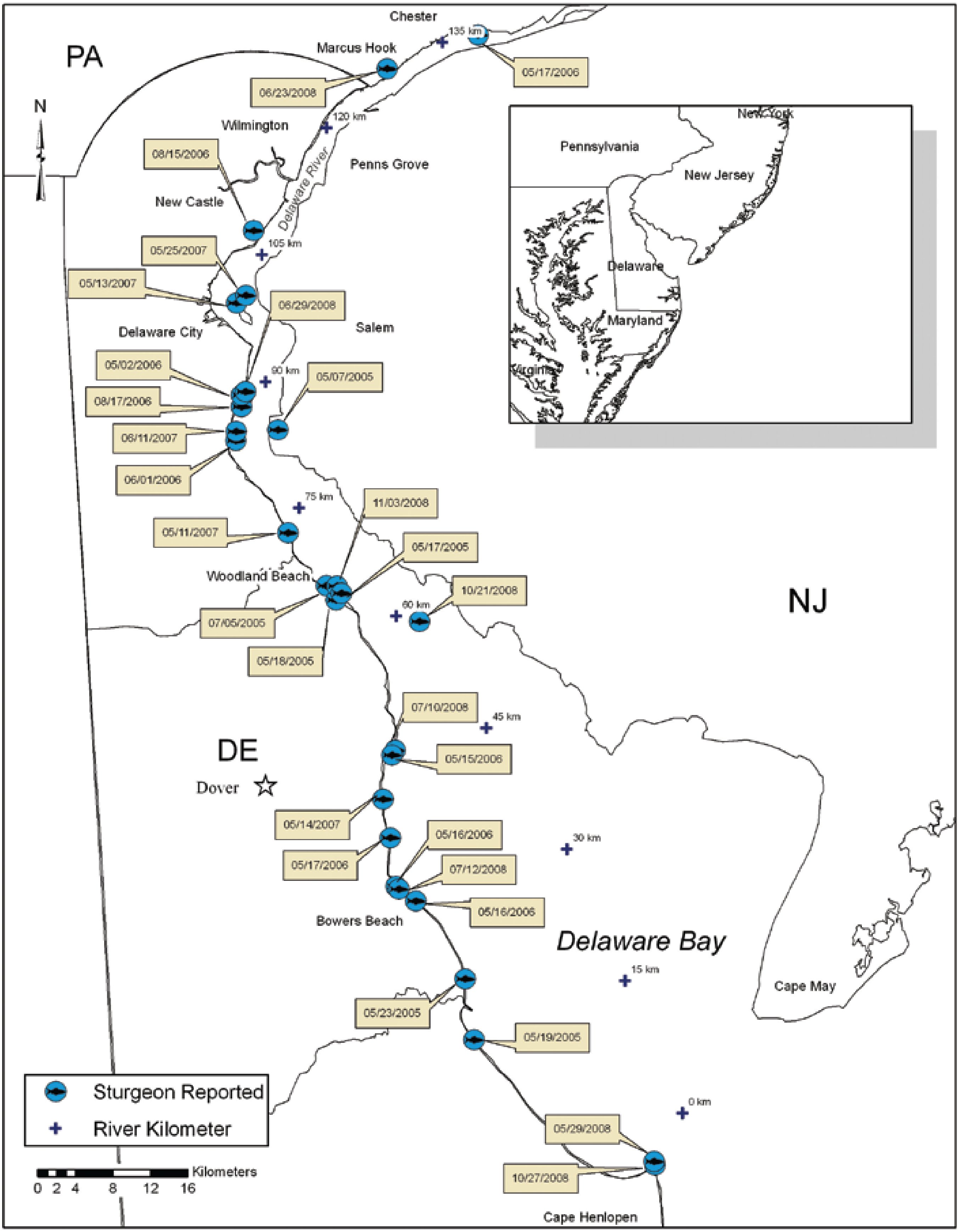


Figure 3. Gravid female Atlantic sturgeon found at Augustine Beach, Delaware, on 2 May 2006. This sturgeon appeared to have been struck by the propeller of a large vessel and was severed through the torso region near the anal fins. The anterior portion found measured 145 cm in length.

JARED JACOBINI, DEDFW

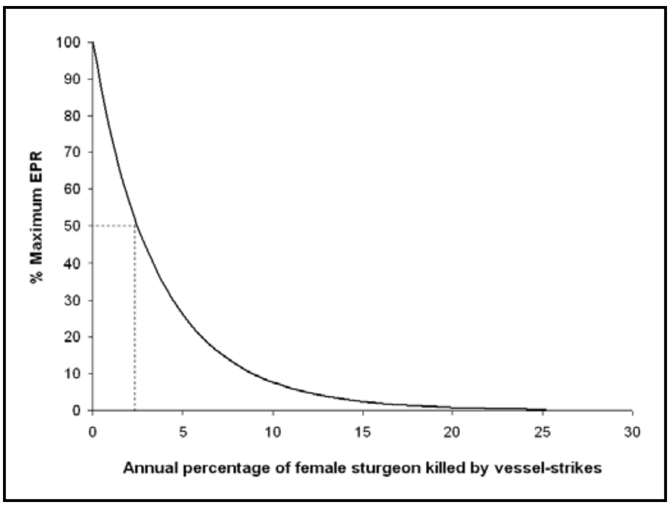
Figure 4. Large adult Atlantic sturgeon found at Woodland Beach on 17 May 2005. This sturgeon appeared to have been severed by the propeller of a large vessel. Greg Murphy of URS Corporation shown in photo examining the carcass.

JARED JACOBINI, DEDFW

Figure 5. Juvenile Atlantic sturgeon found at Augustine Beach, Delaware on 29 June 2008. The injuries were consistent with a strike from the propeller of a small vessel. This sturgeon measured 75 cm total length.

GREG MURPHY, URS CORPORATION

Figure 6. The percent of maximum eggs per recruit (EPR) versus the annual percentage of female Atlantic sturgeon in the Delaware River population killed by vessel strikes.



approximately 2.5% of the female Atlantic sturgeon in the Delaware River population are struck by vessels and killed annually.

DISCUSSION

The presence of gravid Atlantic sturgeon in the Delaware River during the historical spawning season is strong evidence that a remnant population continues to persist. However, the number of sturgeon being killed by vessel strikes may be detrimental to the long-term viability of the population. Because juvenile sturgeon inhabiting the Delaware Estuary are composed of mixed stocks, predominantly fish of Hudson River origin foraging in the Delaware River (King 2001; ASSRT 2007; Wirgin et al. 2007), the vessel strikes occurring in the estuary may be adversely affecting sturgeon populations from other systems as well. The impact of these mortalities on the viability of the Delaware River population would be better understood if population estimates were available. Therefore, it may be useful to assess estimates of adult spawning populations from other Atlantic Coast systems. Peterson et al. (2008) estimated the size of the spawning run population in the Altamaha River, which is thought to be one of the largest populations in the United States, to be about 350 fish. Kahnle et al. (2007) estimated that the size of the Hudson River population, purportedly the largest population on the Atlantic Coast, is approximately 860 adults. Neither of these studies estimated the total Atlantic sturgeon population (all age classes) for these rivers. Relative abundance estimates from gillnet surveys conducted by DEDFW indicate that the current Delaware River sturgeon population is much smaller by comparison than that of the Hudson or Altamaha rivers (Shirey et al. 1999).

Some studies have recommended harvest strategies using $F_{40\%}$ as the basis for formulating risk-adverse harvest strategies (Clark 1993; Mace 1994), that is, the harvest strategy that consists of fishing at a rate that reduces spawning biomass per recruit (equivalent to lifetime egg production per recruit) to 40% of the unfished value. However, other studies have indicated that using $F_{50\%}$, may be more prudent for long-lived stocks with low resiliency and for those stocks targeted for rebuilding (Boreman 1997; Clark 2002; Kahnle et al. 2007). Based upon the vulnerability schedule assumed in the EPR, a small increase in annual mortality due to vessel strikes can have a large impact on the lifetime fecundity of sturgeon. Our EPR analysis showed that the $VS_{50\%}$ (analogous to $F_{50\%}$) occurred at a vessel-strike mortality rate of approximately 2.5% per year. For example, if the Atlantic sturgeon population in the Delaware River is 100 female fish, then probably not more than 2 females could be struck and killed annually without having an adverse effect on the population. Similarly, if the Atlantic sturgeon population is 1,000 females, then probably not more than 25 females could be killed annually without negatively impacting the population.

There are very few beaches or access areas along the length of the Delaware Bay. Much of the shoreline consists of dense marsh vegetation limiting public access and reducing the likelihood that a carcass would be encountered and reported. Thus, only some fraction of the total vessel-strike mortalities that have occurred probably are reported. Another reason to suspect that the data reported here underestimate the total number of vessel-strike mortalities is that the data are derived primarily from reports received by DEDFW, and not from any agencies on the New Jersey side of the estuary. The New Jersey Division of Fish and Wildlife (NJDFW) does not have a program that tracks sturgeon mortalities in the Delaware Estuary and their biologists have not found carcasses on the New Jersey side of the estuary (R. Allen, NJDFW, pers. comm.).

Aside from the fact that the data reported here were primarily collected by DEDFW, physical oceanographic processes are probably responsible for the fact that most sturgeon carcasses were found on the Delaware side of the estuary. In the Delaware Estuary, dense, high salinity water flows into the estuary via the deep channel and the light low salinity water flows out along the surface of the Delaware and New Jersey shores. However, because the Coriolis force deflects the light, low salinity water flowing out of the estuary against the Delaware shore, the buoyant outflow is much stronger along the Delaware shore than the New Jersey shore (Wong and Munchow 1995).

In 2006, nine sturgeon mortalities were found in the Delaware Estuary. In the unlikely scenario that these mortalities represented 100% of the total sturgeon mortalities in the Delaware Estuary (and were all female), then the sturgeon population would need to exceed 360 female fish to avoid adverse population impacts. In the more likely scenario that the nine mortalities that were reported represented only 10 or 50% of the total sturgeon vessel-strike mortalities (and were all female), then the sturgeon population would need to be larger than 3,600 or 720 female fish, respectively, to avoid adverse impacts. Gutreuter et al. (2003) noted that entrainment kills are rarely observed even in abundant species, but that if vessel traffic is large, even low kill rates that are extremely difficult to detect have the potential to adversely affect the production of certain species.

Fifty percent of the sturgeon carcasses found were too decomposed to definitively ascribe the cause of death to vessel-strikes. It is possible that these sturgeon were killed in gillnets, partially preyed upon by large predators, or died from disease. However, because these sturgeon were found in the same general area as the less decomposed carcasses and 36% were missing their head region, it is not unreasonable to assume that the majority of these sturgeon were also vessel-strike mortalities. We are unaware of any large predators such as large sharks that would move up the Delaware Estuary and consume only a portion of a sturgeon. Seals are occasional visitors to the Delaware Estuary, but they tend to visit in the late fall and winter and for the most part are localized in the lower Delaware Bay (www.ocean.udel.edu/oilspill/wildlifeimpacts.html). Similarly, we are unaware of any epizootics targeting sturgeon. There is a gillnet fishery for American shad (*Alosa sapidissima*) and striped bass (*Morone saxatilis*) in the lower Delaware Estuary, which is mostly prosecuted on the Delaware side of the estuary (New Jersey prohibits the commercial harvest of striped bass and Delaware's jurisdiction extends to the New Jersey shoreline of the Delaware River north of Delaware Bay). None of the carcasses found showed any indication of being entangled in gillnet mesh, i.e., none of the carcasses were enmeshed in netting, and none showed any indications of gillnet scars. Additionally, many of the commercial fishermen in the gillnet fishery report releasing the vast majority of the sturgeon they catch alive in good condition, which has been substantiated by tag returns months after being caught as bycatch in Delaware Bay (C. Shirey, DEDFW, pers. comm.). Similarly, many of the sturgeon carcasses reported here were found upriver of the northern limit of the anchored gillnet fishery (Liston Point, Delaware, rkm 77). Because of the nature of the currents in the estuary, it is unlikely that these carcasses drifted upriver. Finally, the striped bass gillnet fishery in Delaware, which is the primary gillnet fishery in the estuary, is open only from 15 February to 31 May and then, depending on the amount of quota harvested in the spring, can be opened again from 15 November to 31 December. Yet 50 % of the carcasses were found from 1 June to 14 November, outside of the striped bass gillnet season window.

The Philadelphia/Delaware River port complex differs from most of the other major ports in the United States in that the port facilities are located far up in the estuary. This poses an additional liability for sturgeon. The port's distant location from the Atlantic Ocean requires that vessels navigate through most of the estuary into potential Atlantic sturgeon habitat, thereby increasing the possibility of interactions with sturgeon. Additionally, above the Salem, New Jersey, and Delaware City, Delaware area, the estuary narrows significantly. Therefore, there is less habitat outside of the shipping channel for sturgeon to inhabit, and consequently sturgeon may be more likely to be struck by a vessel in the upper estuary.

Currently, the U.S. Army Corps of Engineers is planning to deepen the main channel of the Delaware River by 1.5 m (5 feet), from 12.2 m (40 feet) to 13.7 m (45 feet), from the Philadelphia Harbor, Pennsylvania, and Beckett Street

Terminal, New Jersey, to the mouth of the Delaware Bay, a distance of 165 km, to allow larger vessels to enter the river (www.nap.usace.army.mil/cenap-pl/drmcdp/overview.html). Both the dredging to deepen the channel and the subsequent increase in large vessel traffic may further hamper the recovery of the Delaware River Atlantic sturgeon population.

The majority of vessel strikes appeared to result from interactions with large vessels, such as tankers, with a lower percentage likely resulting from interactions with small recreational or commercial fishing vessels equipped with outboard or inboard/outboard (stern drive) engines. Atlantic sturgeon are demersal fishes and thus if the sturgeon are spending most of their time at the bottom of the water column, then they are most likely being impacted by larger vessels. Large vessels that transit the shipping channel typically draft close to the bottom of the channel, thereby posing a threat to sturgeon positioned close to the bottom of the channel. Other species of sturgeon, such as the white sturgeon (*A. transmontanus*) are primarily found in the lower portion of the water column. Paragamian and Duehr (2005) tagged white sturgeon with depth-sensitive radio transmitters during prespawn and spawning periods in the Kootenai River, Idaho, located in the upper Columbia River basin, and found the sturgeon in the bottom one-third of the water column during 75% of the relocations. Fisher and Jacobini (2007) reported that Atlantic sturgeon surgically implanted with depth-sensing acoustic transmitters in the Delaware River were recorded at depths of 6.1 to 15.5 m and averaged 9.0 m in depth during manual relocations. Additional data on movements in the water column are still being collected and analyzed (Fisher and Jacobini 2007). Similarly, some of the sturgeon carcasses reported appeared to be too large to be severed by a small outboard propeller. Alternatively, sturgeon are known to frequently jump out of the water (Sulak et al. 2002). During jumping episodes, when sturgeon are located at or near the surface of the water, they may be more vulnerable to strikes from smaller vessels powered by outboards.

The problem of vessels striking and killing Atlantic sturgeon may be common in other estuaries and rivers as well. For example, five Atlantic sturgeon were reported to have been struck and killed by vessels in the James River, Virginia, in 2005, three in 2006, seven in 2007, and eight mortalities were reported in 2008. Most of the carcasses were found in a small area upstream of Hopewell, Virginia, where there is a significant narrowing of the shipping channel (A. Spells, U.S. Fish and Wildlife Service, pers. comm.). The James River is similar to the Delaware River in that commercial vessels transit long distances upriver to reach the ports. In the James River, vessels need to transit over 140 km to reach ports in Richmond, Virginia (www.nao.usace.army.mil/Partnerships/James%20 River/homepage.asp).

Vessel-strike mortalities have also been noted in other sturgeon species. Gutreuter et al. (2003) examined mortality rates in adult fish entrained through the propellers of river towboats on the Upper Mississippi River and Illinois Waterway and found that a variety of fish were killed by towboat propellers, including shovelnose sturgeon (*Scaphirhynchus platorynchus*). They estimated that an average of 0.53 shovelnose sturgeon were killed per km of towboat travel. Partially or completely severed adult lake sturgeon (*A. fulvescens*) have also been recovered from the Upper Mississippi River (S. Gutreuter, U.S. Geological Survey, pers. comm.).

The only reports we were able to find of marine fish mortalities related to vessel strikes were for whale sharks (*Rhincodon typus*; Gudger 1938a, 1938b, 1940). The whale shark mortalities reported by Gudger were all rammings by the bow of vessels. There have been reports of marine mammals such as whales (Laist et al. 2001; Kraus et al. 2005; Panigada et al. 2006), dolphins (Wells and Scott 1997) and manatees (Marmontel et al. 1997; Laist and Shaw 2006) being struck by vessels. Additionally, there have been reports of sea turtle vessel strikes, e.g., from 1994–1999, 30% of the 109 sea turtles found dead in the Delaware Estuary were victims of vessel strikes (Stetzar 2002). To our knowledge, this represents the first reported account of Atlantic sturgeon being struck and killed by vessels.

Finally, vessel strikes in conjunction with other anthropogenic impacts may further impede the recovery of Atlantic sturgeon populations. Factors such as poor water quality, low dissolved oxygen levels (although dissolved oxygen levels in the Delaware Estuary have improved dramatically over the past 50 years; Sutton et al. 1996), habitat modification, and bycatch mortality may be affecting the Atlantic sturgeon populations. For example, under scenarios of low recruitment in the Hudson River, it was estimated that bycatch mortality of Atlantic sturgeon would exceed levels that would result in stable or growing populations, and it was noted that populations smaller than that of the Hudson River, such as the Delaware River population, would be expected to be disproportionately affected by bycatch as proportional removals have larger negative effects on less productive populations (ASMFC 2007).

RECOMMENDATIONS

Further research to quantify the extent of vessel-strike mortalities in the Delaware Estuary could include directed ground or aerial surveys, and a public outreach campaign to request public assistance in reporting Atlantic sturgeon carcasses to the relevant agency. The 2009 Delaware Fishing Guide, which lists the fishing regulations of the DEDFW, added a section which requests the public's assistance in reporting dead sturgeon to the agency (www.fw.delaware.gov/Fisheries/Documents/2009fishingguideweb.pdf). This approach could be adopted by other states. Creation of a centralized database to allow scientists to report vessel strikes on a coastwide basis would aide in gaining an understanding of the magnitude of the problem along the Atlantic coast. In an effort to evaluate the depth and area in the water column that Atlantic sturgeon utilize, DEDFW is currently tagging sturgeon in the Delaware River with depth-sensing ultrasonic transmitters, which will provide valuable information related to vessel strikes, perhaps identifying the depths at which sturgeon are being struck by propellers. Additionally, more sophisticated approaches to quantify sturgeon mortality could be considered, such as trawling behind vessels (Gutreuter et al. 2003).

Possible mitigation measures could include recommending reduced vessel speed during the Atlantic sturgeon spawning season for vessels transiting through known concentration or spawning areas in the Delaware Estuary or other rivers with Atlantic sturgeon populations. This strategy has proven effective for marine mammals (Laist and Shaw 2006). For marine mammals, it is thought that slower vessel speeds reduce vessel-strike mortalities by reducing the force of collision impacts and by allowing animals more time to detect and avoid oncoming vessels (Laist and Shaw 2006). Although reducing vessel speed to reduce mortalities from the force of collision may be important for large whales (Vanderlaan and Taggart 2007), which can survive collisions due their large body size, we expect that the primary benefit of reduced vessel speeds would be to allow sturgeon additional time to detect and avoid approaching vessels.

Alternatively, it may be useful to investigate the possibility of using underwater sound, light, or odor to divert sturgeon from the shipping channel and/or attract them to areas outside of the shipping channel. Ultrasound has been found to be effective in controlling the behavior of clupeid species (Gibson and Myers 2002; Plachta and Popper 2003; Popper et al. 2004) but findings from studies on other species using a variety of frequencies have been ambiguous (Popper and Carlson 1998). Studies to date have not shown any indication that sturgeon would be capable of detecting ultrasound (Lovell et al. 2005; Popper 2005). Similarly, studies on using light to divert fish have demonstrated that mercury and strobe lights can be used to attract some species and divert others (Popper and Carlson 1998). Other research has demonstrated that scent is used to attract sturgeon for feeding (Bardi Jr. et al. 1986) and for reproduction (Kynard and Horgan 2002), and therefore it may be worthwhile to investigate using odors to divert sturgeon from areas with heavy vessel traffic. However, if sturgeon require the channel habitat to spawn, then continually diverting them from the channel may be problematic.

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COLUMN:
GUEST DIRECTOR'S LINE

UNsustainable Global Fisheries Need a UNified Call for a UN Conference



William W. Taylor, Abigail J. Lynch, and Michael G. Schechter

Taylor is an AFS past president and University Distinguished Professor in Global Fisheries Systems at Michigan State University. He can be contacted at taylorw@msu.edu. Lynch is a University Distinguished Fellow and doctoral student in the Department of Fisheries and Wildlife at Michigan State University. Schechter is a professor of international relations, James Madison College at Michigan State University.

At the most recent AFS Annual Meeting, the Past Presidents' Council unanimously passed a motion that calls for the Society's past presidents and current Governing Board to work towards the establishment of a global conference that will establish a framework agreement for global fisheries sustainability. This resolution, passed on September 3rd at the Past Presidents' Luncheon, was prepared based on a symposium on the sustainability of the world's fisheries. This symposium brought together experts in the field of fisheries science and governance, including representatives from the United Nations Food and Agriculture Organization (FAO) and the World Bank. Based on the science presented at the symposium and subsequent workshop, the Past Presidents' Council determined that we should work with member governments of the United Nations to request a meeting on global fisheries sustainability.

Currently, about 19% of stocks are considered to be overexploited, 8% depleted, 1% recovering from depletion, 52% fully exploited, and only 20% are estimated to be moderately exploited or underexploited (FAO 2007). While the causes that relate to unsustainable fisheries have been made effectively to most fisheries professionals, actions that would result in corrective behaviors have been largely absent or inadequate. The ecological sciences are generally well established; what is lacking is appropriate governance structures for sustaining global fisheries populations and their habitats. The sustainability of our fishery resources needs to be elevated to a priority position for policy makers and the public. The problems need to be reframed to emphasize the importance of fish as an essential and often only source of protein and essential fatty acids to many communities. Additionally, governments need to be informed in a more structured way of employment possibilities and economic opportunities that healthy, sustainable fish populations provide via a vibrant and robust fisheries supply chain. Lastly, policy makers need to understand the cost in terms of human and environmental health that results from the demise of wild fish populations and the growth of unregulated aquaculture operations that the world is currently experiencing. To adequately address sustainability, policy makers and the public must be re-educated to understand that relying on "the market" to sustain fish or lead to technological fixes will not prevent the exhaustion of capture fisheries and that climate change, invasive species, and habitat destruction, issues heretofore largely absent from environmental treaties, have significant effects on the ecological and economic health of fisheries, their ecosystems, and the human populations that depend on their continuing presence for their sustenance and livelihoods.

To remedy this situation, we have proposed the convening of a diplomatic conference on sustainable global fisheries. Working at a global policy scale is particularly important because fish, and sometimes fishers, recognize no political boundaries. Globalization has had a significant influence on the sustainable use of fisheries resources through consumption and use far removed from the source populations. As a result, the ecological consequences of fishing are compounded by socioeconomic ones far from the locales where fish are harvested. Small-scale management regimes are no longer sufficient to address inter-jurisdictional issues; higher levels of governance systems are necessary for the survival and sustainability of the world's fisheries. This is particularly true for fishes that are transboundary in nature and for those that inhabit international waters. Also, fish populations are often jeopardized in areas where the fishing rights in coastal waters are sold to fishing fleets that belong to individuals and nations distant from the local communities, increasingly becoming a major source of fisheries insecurity.

With its global reach, the UN system is uniquely positioned to raise awareness of fisheries issues at an international scale. The proposed conference will be designed to draw media and policy maker attention to key global fisheries problems that have heretofore never received sustained global attention and are not adequately addressed by existing governance structures. To be successful at producing workable policies, a UN sustainable fisheries conference must prepare policy makers to make decisions and compromises so that fish can live and thrive. This is not, by any means, an easy task but it is a necessary one for future fisheries sustainability. And it is one where the FAO secretariat and fishery experts from around the world, like those of you reading this article, will play a vital role. The goal is policy-relevant, scientifically sound, feasible proposals that will make sustainable fisheries an achievable goal.

With direction from the sustainable fisheries symposium and past presidents' resolution, we are finalizing *Sustainable Fisheries: Multilevel Approaches to a Global Problem,* an AFS publication, which provides a comprehensive overview and will serve as a key support document to inform the appropriate audiences of the need for a UN conference. The next step in this process is to persuade UN member governments that sustainable fisheries, with their essential nutritional value, high economic potential, and ecological significance, can best be achieved by convening a UN global conference, like those convened to address issues of food sustainability, human rights, the environment, and development. In calling for an UN conference that focuses on sustainable fisheries, we are calling for a mechanism to augment and accelerate ongoing policy processes and revise and perhaps replace some of the current polices being pursued and institutions being relied upon with better management, leading to healthier fisheries resources in the future. We are working with member state representatives to assist in the call for a global conference that we hope will ensure vibrant fisheries ecosystems and their supply chain for future generations to enjoy. We hope that you will join us in calling for such a conference and ensuring healthy fisheries for future generations.

We welcome any suggestions and recommendations that you may have in support of this project. Please contact us at: Bill W. Taylor (taylorw@msu.edu), Abigail J. Lynch (lynchabi@msu.edu), or Michael G. Schechter (schechte@msu.edu).

COLUMN:
STUDENT'S ANGLE

The Fish Culture Section of AFS— Encouraging, Recognizing, and Rewarding Student Involvement

Heidi A. Lewis

Lewis is a Ph.D. candidate at Southern Illinois University and can be contacted at hal7e7@siu.edu.

PROFESSIONALISM AND RESEARCH EXCELLENCE... LEADERSHIP SKILLS...A NETWORK OF PROFESSIONAL CONTACTS AND COLLEAGUES....

These are the ingredients of a successful career. As members of the American Fisheries Society (AFS), students have the opportunity to promote aquatic stewardship while developing communication, conservation, and networking skills on local, state, regional, and global levels. Meanwhile, AFS benefits from the youthful enthusiasm of its 1,500+ student members. The Fish Culture Section (FCS), one of the 22 Sections of AFS, encourages its student members to be actively involved in Section activities, and also recognizes and rewards these students for their participation.

The FCS is an association of over 440 members from 10 countries "…concerned with advancing cultivation technology of aquatic organisms for food, recreation (sport and ornamentals), habitat enhancement, and conservation. The Section disseminates information about fish culture to professionals and the lay public; it strives to support and enhance fish culture programs of private, governmental, and international entities" (www.fishculturesection.org). Students represent about 10% of the FCS membership, with the remainder largely representing governmental hatchery professionals and academics from the United States and Canada. Student involvement is strongly encouraged by the FCS, and the benefits of being a student member are staggering:

- Like other FCS members, students can request page charge waivers for publication in the *North American Journal of Aquaculture.*
- Travel awards are awarded annually to students giving fish culture-oriented presentations at AFS Annual Meeting and Aquaculture America.
- Student members of both AFS and the U.S. Aquaculture Society are eligible for more travel support—a $500 Best Abstract Travel Award to Aquaculture 2010 has just been announced!
- Although not limited to just student members, the FCS Continuing Education Committee is developing a number of electronic media-based modules to provide continuing education credits for use towards achieving AFS Fisheries Professional Certification.

These aforementioned benefits and many more, combined with low membership fees ($20 for annual student AFS membership and $2 Section dues), have improved membership growth over the last few years.

An ad-hoc Student Committee was formed in 2006 which coordinates student activities for the Section. This committee also enhances the level students can become involved within the FCS. Involvement with the Student Committee has resulted in current and former members continuing their professional service as members of the FCS Executive Committee. This is just another example of the level of encouragement the FCS has towards fostering students to build professional relationships through participation within the American Fisheries Society.

AQUACULTURE-THEMED QUIZ BOWL

New student member recruitment has greatly improved due to FCS-sponsorship of a Quiz Bowl held during Aquaculture America student receptions. The annual quiz bowl is a collaborative effort between the FCS Student Committee and the U.S. Aquaculture Society Student Activities Committee. Each year, questions are gathered from aquaculture professionals across the country to test students' knowledge of popular cultured species: health, nutrition, physiology, spawning techniques, water quality, etc. Questions are then assembled into two 10-question rounds per match. Students volunteer to compete and are randomly assigned to a team which encourages interaction between different labs, universities, and the two societies. Interaction is also encouraged between team members as they discuss answers prior to ringing in during the event. The team that wins the most matches at the end of the tournament is awarded prizes from various donors. Members of the winning team also receive a one-year paid membership to AFS and the FCS. This event has resulted in increased student FCS membership, not only through free memberships, but also due to its enthusiastic reception by everyone during Aquaculture America. During the 2009 meeting, over 50 students signed up for the event and 8 free student memberships were awarded. Not only do students enjoy the event, professors and Society officers have also been caught looking around their tables to see if anyone knows the correct answer to a particularly challenging question.

LOGO CONTEST AND T-SHIRT DISTRIBUTION

Other activities coordinated by the Student Committee include an FCS logo contest and T-shirt design. In 2007, FCS requested designs for a new section logo to be submitted by students. That year the committee developed T-shirts which were distributed free of charge to all student members. This contest is still open and any student FCS member can submit a potential design which may be used to represent the Section.

OTHER FCS BENEFITS NOT LIMITED TO JUST STUDENTS

The FCS Newsletter—An informative online publication is available to FCS members that features up-to-date news and notes from all fields of fish culture. Published quarterly, the newsletter includes the traditional communiqués of Section business as well as aquaculture program overviews, meeting and position announcements, occasional editorials on hot topics in aquaculture, and tips and tricks for better fish husbandry (see Aquaculture Application Notes below)—if it matters to fish culturists, it's in our newsletter. Many culturists consider the newsletter (available at www.fishculturesection.org) to be the number one benefit of membership in the FCS.

Aquaculture Application Notes—Are you looking for a more efficient way to culture fish or have you developed an innovative technique or piece of equipment that makes culturing fish faster and easier? Aquaculture Application Notes (first introduced in April 2009) are a regular feature published in the FCS Newsletter—available via www.fishculturesection.org—that details new techniques or equipment modifications to assist fish culturists. Feed training young fish can be difficult, and the first two Application Notes provided novel techniques used by the Rathbun Fish Hatchery and Fish Culture Research Facility and the Florida Bass Conservation Center at the Richloam Fish Hatchery to accomplish this tremendous feat. As an FCS member, you can easily access these revolutionary methods or share your own inventive ideas.

Continuing Education Opportunities—The FCS's first electronic-media continuing education module is currently in development. This year, President Elect Jim Bowker taught a module entitled "Use of Drugs in Aquaculture – What Every Fish Culturist Should Know" in the Coldwater Fish Culture Course held at the U.S. Fish and Wildlife Service National Conservation Training Center. This 4-hour course included information from the service's Aquatic Animal Drug Approval Partnership Program detailing legal use of aquaculture drugs, an overview of the investigational new animal drug (INAD) program, and calculations to determine how to administer aquaculture therapeutants. This information is currently being developed into a multi-media package that will include an instructional video, reference materials, and self-tests. This package can be delivered to the membership and used to earn formal continuing education credits which count towards obtaining or maintaining "Fisheries Professional" certifications by AFS. This multi-media package should be available in spring 2010.

Fish Culture Hall of Fame—The only Fish Culture Hall of Fame (located in Spearfish, South Dakota) was established and is maintained by the FCS. Individuals who have made significant scientific and professional contributions advancing fish culture are recognized here. Members of FCS can nominate and vote for potential inductees who are honored inside the replica of the original 1899 Hatchery Ice House housing the Hall of Fame.

NOW THAT YOU'VE DECIDED TO BECOME A STUDENT FCS MEMBER…

Just check the FCS box when you are renewing your AFS membership each year. You will be eligible for all the amazing opportunities discussed in this article as well as plenty more. As you can see, it's the best $2 you'll spend all year!

ACKNOWLEDGMENTS

I would like to thank Jesse Trushenski and Curry Woods, FCS president and immediate past president, respectively, for their contributions and comments on early drafts of this article.

It's a nail-biter as teams deliberate the answer to another question asked by emcee Charlie Brown during the Aquaculture Quiz Bowl held during Aquaculture America 2009's Student Reception.

NEWS: AFS UNITS

Western Division President Scott Bonar presents appreciation gifts to meeting organizers Julie Meka Carter (Arizona Game and Fish Department), Colleen Caldwell (New Mexico State University/U.S. Geological Survey), Pam Sponholtz (U.S. Fish and Wildlife Service), and Amy Unthank (U.S. Forest Service).

Western Division

Meets in Albuquerque, New Mexico

The Arizona-New Mexico Chapter hosted the annual meeting of the Western Division of the American Fisheries Society in Albuquerque, New Mexico, 3–7 May 2009. Attendance was much lower than expected due to the current economic climate and last-minute concerns about a viral pandemic. Nonetheless, we had a successful meeting featuring 143 oral presentations in 3-4 concurrent sessions and 44 posters. This year's theme "Evolution of the Western Landscape: Balancing Habitat, Land, and Water Management" was the focus for a diverse panel of water policy experts in a plenary session. Five guest plenary speakers addressed water law and politics, including Zuni Tribal Hydrologist Kirk Bemis, who shared the tribe's efforts to maintain water in streams supporting tribal lands and the endangered Zuni bluehead sucker. Eight symposia covered topics ranging from aquatic invasive species, climate change, and fish barriers, to habitat management and Pecos River fishes.

The Best Student Poster award went to **Eric Andersen** of Oregon State University for his poster summarizing work on Bayesian networks for prioritizing stream connectivity projects. The Best Student Oral Presentation Award went to **Jonathan Gerken** of the University of Alaska-Fairbanks. There were four Ph.D. and four master's applicants for the graduate student scholarships. The Eugene Maughan Scholarship for a master's student went to **Gerard C. Carmona** of the University of California Davis and the Ph.D. student recipient was **Joseph H. Anderson** of the University of Washington. The Sustainable Fisheries Foundation William Trachtenberg Scholarship went to **Matthew P. Corel** of the University of Montana.

The Western Division's Award of Excellence this year honored Emeritus

Scientist **Bruce Rieman** of the Forest Service Rocky Mountain Research Station and his exemplary career contributions to fisheries science. The Conservation Achievement Award was given to the **Devil's Hole Pupfish Incident Command Team and Associates** for their continued efforts at preventing the extinction of this species. The Chapter of the Year award was given to the **Oregon Chapter.** The **Palouse Unit** (Idaho Chapter) was recognized with the Student Subunit of the Year Award for a second year in a row. Recipients of the Riparian Challenge Awards included the **Bureau of Land Management's Coos Bay District** for the North Coquille River Restoration Project and the **U.S. Forest Service's** West Fork Clear Creek Streambank Restoration Project led by Bill Janowsky on the Arapaho-Roosevelt National Forests and Pawnee National Grasslands. **Leanne Roulson** and **Jim Tilmant** were also recognized for their years of service in the development of the Western Native Fishes Database. Congratulations to all of this year's award winners.

The Spawning Run was a hit with 26 participants. **Justin Mapula**, a graduate student at the University of Arizona, and **Pam Sponholtz,** of the U.S. Fish and Wildlife Service Flagstaff Office, were the fastest male and female. The average time for the run was 28 minutes and 57 seconds and **Chuck Korson** and **Anna Senecal** were the most average male and female, including the walkers that made for a speedy less than 10 minute-mile! The banquet was held at the city of Albuquerque's aquarium, which was a great hit with excellent food and lots of exhibits to see featuring the aquatic life of the Rio Grande River from its headwaters to the Gulf of Mexico.

At the WDAFS annual business meeting, a resolution was unanimously passed recommending a formal independent scientific review of potential environmental and socioeconomic consequences of large-scale mineral extraction in the Bristol Bay watershed of Alaska. Support was also given for developing a letter opposing withdrawal of 250,000 acre feet of water from the Green River and Colorado River for transfer to the Front Range of Colorado.

Bill Franzin, then president of the parent Society, attended the meeting and made an extra effort to talk to folks about the support of AFS and areas important to the Chapters to emphasize. We invite everyone to the next Western Division annual meeting in Salt Lake City, Utah, 19-23 April 2010. The meeting will be held in the downtown Radisson Hotel and the adjacent Salt Palace Convention Center. The theme will be "The Future of Aquatic Resources in the West: Science, Management, and Politics." For the latest developments on that meeting, see the meeting website at www.utahafs.org.

—*Amy Unthank*

Oregon Chapter President Neil Ward accepts the Chapter of the Year Award from WDAFS Past President Eric Wagner.

COLUMN: PRESIDENT'S HOOK

Continued from page 56

coordinated by the AFS External Affairs Committee and the AFS Resource Policy Committee, with assistance from the AFS policy development director, the U.S. Fish and Wildlife Service, the National Oceanic and Atmospheric Administration, and the National Fish Habitat Board.

A fundamental purpose of AFS is to generate and disseminate credible, science-based information regarding fisheries. In the context of NFHAP initiatives, AFS has faith that Congress sincerely desires and will use effectively the best information available when rendering decisions affecting the nation's fisheries. Congress has faith that AFS will provide the science-based information needed for the decision making process and associated actions.

Bidirectional faith like this can be a very powerful force. When applied to the issue of habitat for fish and fisheries, well, let me just say that when I consider the possibilities, my heart is strangely warmed.

Habitat and faith…"I guess that should do it."

REFERENCE

National Fish Habitat Board. 2009. Purpose and use of the National Fish Habitat Assessment and the NFHAP Decision Support System. Available at: www.fishhabitat.org/images/documents/assessment_09assess_and_dss.pdf.

FISHERIES CURRENTS: SCIENCE NEWS FROM AFS

Continued from page 59

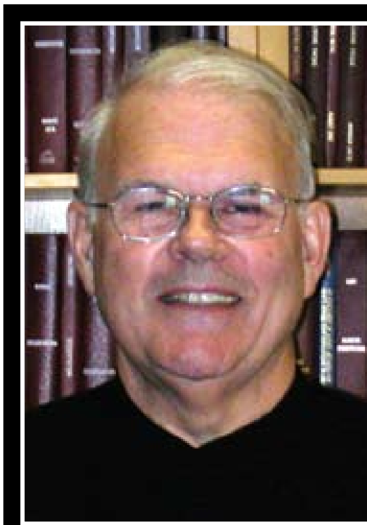
of the authors' recommendations for implementing a procedural paradigm in data-poor fisheries include finding simpler ways to measure performance in fisheries management, separating fisheries management into science and the application of the science in engineering solutions, evaluating the costs and benefits of monitoring programs, and considering whether generic management procedures may be applied when designing a custom management plan is impractical. **Contrasting Paradigms for Fisheries Management Decision Making: How Well Do They Serve Data-Poor Fisheries?,** by *Nokome Bentley and Kevin Stokes. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science* 1:391-401. Bentley may be contacted at nbentley@trophia.com.

Home is where the genes are

The U.S. Endangered Species Act works on the basis of "evolutionary significant units" or "distinct population segments" (DPS). Based on physical attributes, genetics, and ecological data, these groups within the larger population form the basis for conservation activities under the act. In the case of western species of trout, which have been moved around into various waters all over the West for angling purposes and more recently to provide satellite "refuge" populations, deciding which populations belong in which DPS can be problematic. Often these isolated groups of fish are so small that they possibly may have drifted away genetically from their source population. In a recent article in *Transactions of the American Fisheries Society,* scientists from the University of Nevada and the Oregon Department of Wildlife tackled a thorny question: under what DPS do translocated populations of Lahontan cutthroat trout belong? The researchers clipped the fins of dozens of cutthroat trout in the Steens Mountain Alvord Lake basin in eastern Oregon, where they had been established in the 1970s and 1980s using stock from the nearby Willow-Whitehorse drainage in the Coyote Lake basin. They then analyzed the genetic variation against previously taken fin clips from trout in the Willow-Whitehorse drainage. The scientists determined that the genetic variation in the translocated Steens Mountain populations still matches that of the Willow-Whitehorse source population and they should be included in the same DPS. Given the continuing losses of isolated Lahontan cutthroat populations, the authors suggest managing and conserving genetic diversity across all of the populations in the DPS. **The Evolutionary Significant Unit Concept and the Role of Translocated Populations in Preserving the Genetic Legacy of Lahontan Cutthroat Trout,** by *Mary M. Peacock, Morgan L. Robinson, Timothy Walters, Heather A. Mathewson, and Ray Perkins. Transactions of the American Fisheries Society.* Peacock may be contacted at mpeacock@unr.nevada.edu.

OBITUARY: ROBERT B. DITTON

Leader in Human Dimensions Research



Robert B. Ditton, 66, of College Station, Texas, and long-time member of the American Fisheries Society, passed away peacefully on 30 October 2009 after a two-year long courageous battle with cancer. As a youth, Ditton was an Eagle Scout and lover of the outdoors. He earned his bachelor's of science from the State University of New York at Cortland in recreation education in 1964, and his masters and doctorate in recreation and park administration from the University of Illinois in 1966 and 1969, respectively.

Upon graduation, Ditton accepted a faculty position at the University of Wisconsin—Green Bay (UW—GB) in 1969 in Leisure Sciences/Regional Analysis, and remained there until 1974. In 1974, Ditton accepted a faculty position at Texas A&M University (TAMU) in the Department of Recreation and Parks and started the Marine Recreation Lab. In 1988, he joined the faculty in the Department of Wildlife and Fisheries Sciences as their first human dimensions professor and started the Human Dimensions of Fisheries Research Lab. He remained as graduate faculty in the Department of Recreation, Park, and Tourism Sciences and retired in September 2007 as professor emeritus in both departments. Ditton also was honored with a graduate faculty appointment in the Department of Public and Environmental Affairs at UW—GB in 2003, and served as adjunct professor in the Ph.D. program of the Department of Coastal Resources Management at East Carolina University in Greenville, North Carolina.

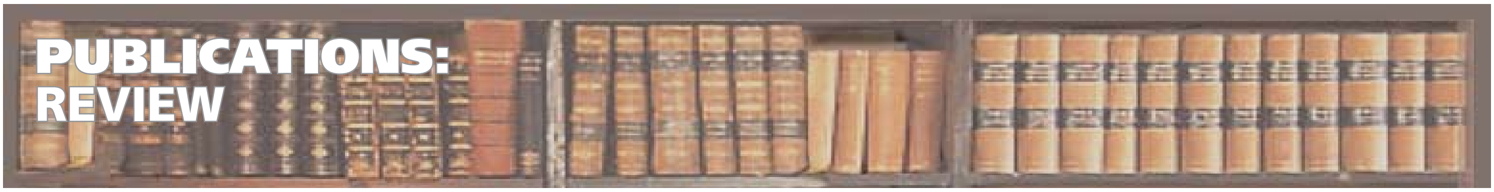
During his long and successful career, Ditton taught a number of classes at the graduate level focusing on the human dimensions of fisheries and outdoor recreation management. He advised a large number of graduate students, who went on to careers as university human dimensions faculty, state fisheries research directors, and an executive director of a state fisheries agency, among others. Ditton and his graduate students' human dimensions research on recreationists and anglers transcended national boundaries and included research in Norway, Mexico, Canada, Australia, Italy, Hungary, Jordan, Guatemala, Finland, Ireland, Dominican Republic, Portugal, Korea, Galapagos Islands, Ecuador, Puerto Rico, and Costa Rica.

Ditton served in many editorial positions for numerous scientific journal publications, including *Fisheries, North American Journal of Fisheries Management, Human Dimensions of Wildlife, Society and Natural Resources, Leisure Sciences,* and the *Coastal Zone Management Journal*. He co-wrote three books and hundreds of journal articles and papers in his field of expertise. Ditton was affiliated with a number of professional organizations including the American Fisheries Society (member since 1982), Texas Chapter of the American Fisheries Society, National Recreation and Park Association, Society for Park and Recreation Education, and he started the AFS Committee on the Human Dimensions of Recreational Fisheries within the Fisheries Management Section. The HDRFISH listserv that he started in 1995 kept human dimensions researchers around the world connected to one another.

Ditton was honored with numerous awards throughout his career, including the Benton H. Box Award from the Department of Recreation, Parks, and Tourism Management at Clemson University, Distinguished Service Award from the National Association of Recreation Resource Planners, Distinguished Achievement Award in Teaching from the Texas A&M Association of Former Students, TAMU Vice Chancellor's Award for Graduate Teaching, Outstanding Educator Award from the Texas Chapter of the American Fisheries Society, Group Scientific Achievement Award (Human Dimensions Lab) from The Billfish Foundation, and the Distinguished Alumni award from SUNY—Cortland. He was also the recipient of the Theodore and Franklin Roosevelt Award for Excellence in Recreation and Parks Research, presented by the Board of Trustees of the National Recreation and Park Association.

Ditton is survived by his wife of 43 years, Penelope; his daughters Allison and Megan; his brothers John and Franciscus; and countless former students, colleagues, and friends who will all miss his candor and friendship. Before his passing, Ditton set up the Robert B. Ditton Scholarship Fund at Cortland College to underwrite expenses for low-income students to attend the Raquette Lake Outdoor Recreation Program. If interested in helping, send donations to: Cortland College Foundation, P.O. Box 2000, Cortland, NY 13045. Please make checks payable to: Cortland College Foundation—Ditton.

—*Kevin Hunt*



Fish Behavior

EDITED BY C. MAGNHAGEN, V. A. BRAITHWAITE, E. FORSGREN AND B.G. KAPOOR. SCIENCE PUBLISHERS, ENFIELD, NH. 2008. 648 PAGES. $137.50 (CLOTH).

Every 11 years, much like periodical cicadas, a new multi-authored book on fish behavior appears. The current volume is a worthy successor to earlier ones edited by Pitcher (1986) and Godin (1997) but differs from them in many ways, reflecting changes in the field in the intervening decade and a bit. The present book, co-authored by 37 experts (the majority from Europe) is organized into three main sections: "The Basis" (4 chapters on senses, cognition, hormones and social behavior, and genetics), "Essentials of Life" (7 chapters on migration, foraging, predation risk assessment, and various aspects of reproduction), and "Coping with a Complex World" (6 chapters on cooperative behavior, social networks, decision-making and trade-offs, parasites, cleaning symbiosis, and farmed fish welfare). In the editors' words, these are intended to consider "firstly how basic behaviors are generated; secondly, how behavior is influenced and shaped by the natural environment; and finally, how behavior allows fish to generate complex and integrated responses to the world around them." These sections are not clearly distinct from one another, but there are many cross-references throughout the book drawing the connections back-and-forth. As expected, this volume contains up-to-date summaries of work in various areas of fish behavior, and by comparison with its predecessors, highlights interdisciplinary approaches (especially in the hormones and genetics chapters) and such new areas of research interest as cognition and behavioral syndromes. In many chapters, new methodological (e.g., molecular) and theoretical approaches are apparent (e.g., network analysis, market theory applied to symbiosis, and new theory laid out in the chapter on parental care). Another excellent feature of many of the chapters is that they present suggestions for future studies, something that should be of great value to beginning investigators. Some of the chapters are rather limited in scope. For example, that on migration and habitat choice deals only with marine species and pays virtually no attention to predation avoidance as a driving factor, and that on social networks deals almost exclusively with guppies and is very method-based. Nowhere in the book is there much attention given to aggression and territoriality, schooling behavior, or anti-predatory tactics, though these were important topics in the earlier volumes; this simply reflects a shift in research emphasis within the field itself. Yet one shift in emphasis—the realization that behavior matters if we want to understand processes at the population and community levels, and thus is critical to conservation—is scarcely mentioned. Conservation is considered briefly in the chapters on sexual selection and mate choice, but I'd have liked to have seen an entire chapter (or section) on this topic, rather than a concluding piece on aquaculture, dealing (by necessity) almost exclusively with salmonids. It seems to me that there are far more important applied issues where greater knowledge of, and attention to, fish behavior would be useful. The book is attractively produced and well edited (with the exception of the last chapter which could have done with some closer proofreading and contains some unnecessary—and unnecessarily colored—figures). And Chapter 5 misspells one of my co-author's names (it's Hugie) and claims we worked on bluegill sunfish, which we did not (there may be more egregious errors in the book, but they're easiest to detect in my own citations!). Despite this I highly recommend this book—it should be in every university and agency library, and on the shelf of most scientists who work with fish. The past 11 years have brought some interesting developments; I'm looking forward to 2019, to see what's exciting and new in the world of fish behavior by then.

—Lawrence M. Dill
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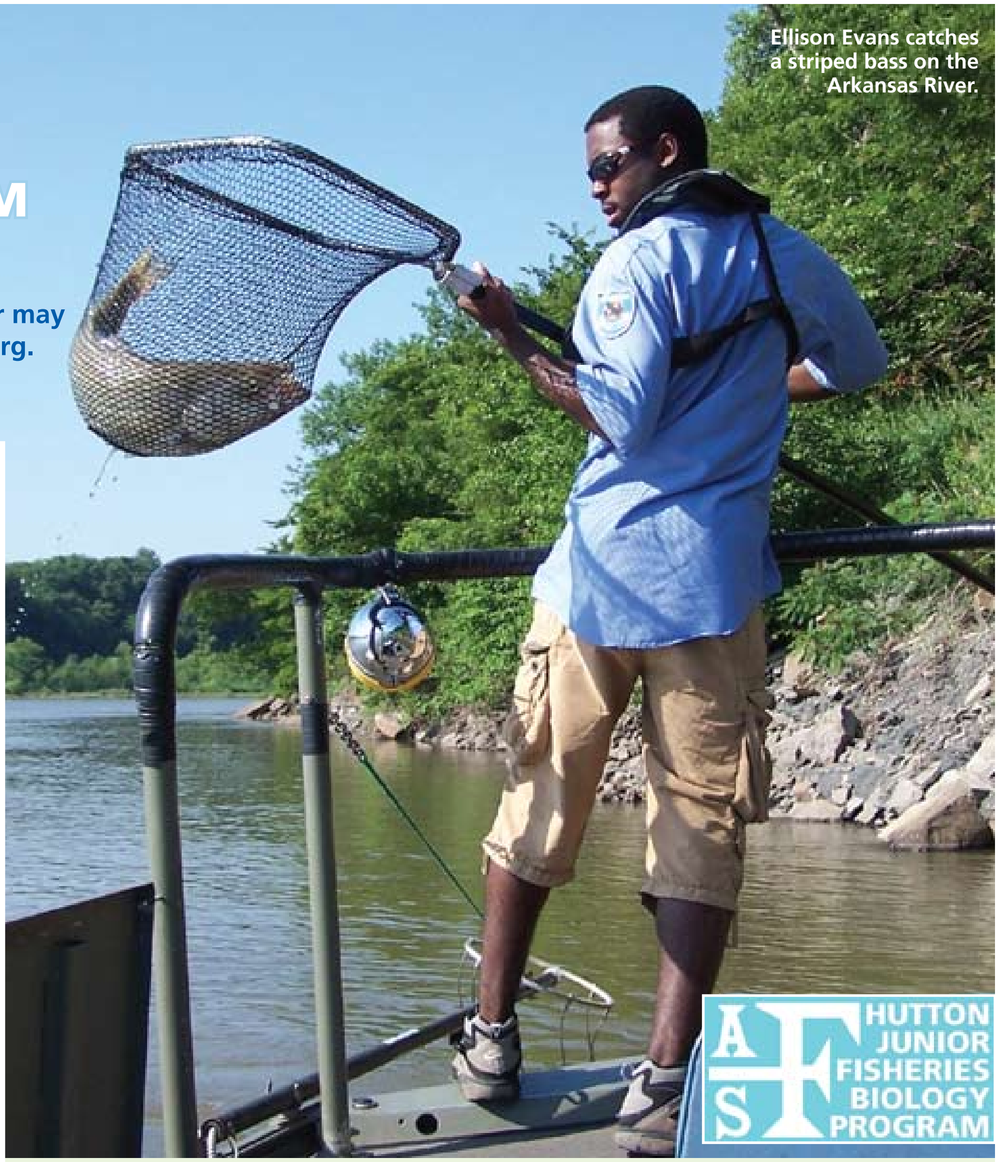
Godin, J.-G. J. (editor). 1997. Behavioural ecology of teleost fishes. Oxford University Press, Oxford, UK.
Pitcher, T. J. (editor). 1986. The behaviour of teleost fishes. Croom Helm, London.

Feb 11-12		Using Hydroacoustics for Fisheries Assessment Class	Seattle, Washington	www.htisonar.com/at_short_course.htm
Feb 11-15		69th Annual Miami International Boat Show and Strictly Sail Miami	Miami, Florida	www.miamiboatshow.com,Twitter@ MiamiBoatShow
Feb 15-17		Societal Applications in Fisheries and Aquaculture Using Remote Sensing: Remote Sensing and Fisheries	Kochi, India	www.geosafari.org/kochi
Feb 22-26		ASLO Ocean Sciences Meeting: From Observation to Prediction in the 21st Century	Portland, Oregon	www.agu.org/meetings/os10
Feb 25-28		Southern Division	Ashville, North Carolina	www.sdafs.org/meetings/2010/default.htm
Feb 26-28		University of Florida Thermal Imaging Seminar	Gainesville, Florida	www.conference.ifas.ufl.edu/tis
Mar 1-5		Aquaculture 2010 Conference	San Diego, California	www.was.org
Mar 25-27		Eighth Biennial Conference on University Education in Natural Resources	Blacksburg, Virginia	www.cpe.vt.edu/cuenr/index.html
Apr 8-9		AFS-The Wildlife Society Species Introductions and Re-introductions Symposium	Starkville, Mississippi	www.cfr.msstate.edu/wildlife/symposium
Apr 10		Oregon Council for the Social Studies Spring Conference: Journey on the Columbia River: Past, Present, and Future	Rainier, Oregon	http://www.oregonsocialstudies.org
Apr 22-23		Electrofishing Class	Vancouver, Washington	www.smith-root.com
Apr 25-27		Northeastern Division, joint with Northeast Fish and Wildlife Conference	Newton, Massachusetts	www.neafwa.org
Apr 26-30		16th Western Groundfish Conference	Juneau, Alaska	https://tundra.iphc.washington.edu
May 4-8		State of the Salmon: Ecological Interactions between Wild and Hatchery Salmon	Portland, Oregon	www.stateofthesalmon.org/
May 5-6		17th Annual Conference on the Great Lakes / St. Lawrence River Ecosystem: Protecting and Restoring Aquatic Ecosystems through Government and Community Action	Cornwall, Ontario, Canada	http://riverinstitute.ca/mailman/listinfo/ conferencenews_riverinstitute.ca
May 23-26		Australasian Aquaculture International Conference and Trade Show	Hobart, Tasmania	www.australian-aquacultureportal.com
May 30-Jun 3		AFS Early Life History Section's 34th Annual Larval Fish Conference	Santa Fe, New Mexico	www.larvalfishcon.org
Jun 16-18		Offshore Mariculture Conference	Dubrovnik, Croatia	www.mercatormedia.com
Jun 20-22		Second International Catfish Symposium sponsored by AFS North Central and Southern Divisions	St. Louis, Missouri	www.catfish2010.org
Jun 21-24		International Symposium on Genetic Biocontrol of Invasive Fish	Minneapolis, Minnesota	www.seagrant.umn.edu/ais/biocontrol

Jul 7-12		Joint Meeting of Ichthyologists and Herpetologists	Providence, Rhode Island	www.dce.ksu.edu/conf/jointmeeting
Jul 25-30		Fisheries Society of the British Isles Conference: Climate Change and Fish	Belfast, Northern Ireland	www.fsbi.org.uk/events.htm.
Aug 1-6		95th Annual Meeting of the Ecological Society of America	Pittsburgh, Pennsylvania	www.esa.org/pittsburgh
Aug 15-20		Second International Conference on the Effects of Noise on Aquatic Animals	Cork, Ireland	www.aquaticnoise.org
Sep 8-11		Fish Sampling with Active Methods Meeting	Ceske Budejovice, Czech Republic	www.fsam2010.wz.cz
Sep 12-16		American Fisheries Society 140th Annual Meeting	Pittsburgh, Pennsylvania	www.wildtroutsymposium.com
Sep 22		World Ocean Council:Sustainable Ocean Summit	Honolulu, Hawaii	www.oceancouncil.org
Sep 22-23		Electrofishing Class	Vancouver, Washington	www.smith-root.com
Sep 27-28		Fourth International Natural Channel Systems Conference: Stream Corridors: Restoring Our Natural Infastructure	Mississauga, Ontario, Canada	www.naturalchannels.ca
Sep 28-30		Wild Trout Symposium	West Yellowstone, Montana	www.wildtroutsymposium.com
Oct 3-8		Aquatic Resources Education Association Biennial Conference	Omaha, Nebraska	www.areanet.org
Nov 8-11		Alaska Sea Grant Meeting: Ecosystems 2010 Lowell Wakefield Fisheries Symposium:Global Progess on Ecosystem-based Fisheries Management	Anchorage, Alaska	http://seagrant.uaf.edu/conferences/2010/wakefield-ecosystemb/index.php
Dec 12- 15		North Central Division, joint with Midwest Fish and Wildlife Conference	Minneapolis	www.midwest2010.org
2011				
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

REPORT: AFS HUTTON JUNIOR FISHERIES BIOLOGY PROGRAM

Kathryn Winkler
Hutton Program Coordinator Winkler may be contacted at kwinkler@fisheries.org.



Ellison Evans catches a striped bass on the Arkansas River.

PROGRAM DESCRIPTION

The Hutton Junior Fisheries Biology Program is a summer mentoring program for high school students sponsored by the American Fisheries Society (AFS). The principal goal of the program is to stimulate interest in careers in fisheries science and management among groups underrepresented in the fisheries professions, including minorities and women. Application to the program is open to all current 11th and 12th grade high school students, regardless of race, creed, or gender. Because the program seeks to increase diversity within the fisheries professions, qualified female and minority students are strongly encouraged to apply. Students selected for the program are matched with mentor professionals and enjoy an eight-week, hands-on fisheries science experience in a marine and/or freshwater setting. Assignments are made with participating organizations within reasonable commuting distance from the students. Each student receives a $3,000 scholarship and a complimentary student membership in AFS.

2009 PROGRAM

Selection to the program has become very competitive. From 148 eligible student applications, the Hutton Evaluation Panel selected 35 students for the Class of 2009. The students were matched with professional mentors in state and federal agencies, at universities, tribal facilities, and private organizations throughout 21 states. Minorities made up 57% of the class, and 65% of all selected students were female.

At the end of the summer, students and mentors submit a final report to AFS evaluating their experience, their mentor or student, and the program. The students respond to questions about their future education and career plans. The immediate success of the program is defined by the number of students who make a positive statement in their final reports about their experience and whether or not they plan to study or are considering studying fisheries or a related field when they enter college. Of the 35 students in the Class of 2009:

15 are currently enrolled in college, and of those students:

- 4 are studying fisheries;
- 3 are studying biology;
- 2 are studying environmental science;
- 2 are studying other sciences;
- 1 is studying an unrelated field; and
- 3 are undecided about a major, but are considering fisheries as an option.

20 are planning to attend college, and of those students:

- 7 plan to study fisheries;
- 4 plan to study biology; and
- 9 are undecided on a major, but are considering fisheries as an option.

These reports verified that participation in the Hutton Junior Fisheries Biology Program significantly benefits students in many ways. All of the students had the experience of working in a professional setting and learning what is required to be successful in the field. They learned about fisheries issues in their local area and the importance of conservation and education to the future of the fisheries resource.

SOME MAJOR ACHIEVEMENTS BY STUDENTS FROM THE CLASS OF 2009

Myranda Clark of Nixa, Missouri, has been hired by her Hutton mentor's host agency, the National Park Service, to work part-time while attending Missouri State University.

Georgia Downey of Mill City, Oregon, has plans to return to her Hutton mentor's host agency, the USDA Forest Service, Willamette National Forest, Detroit Ranger District, as a seasonal employee. In addition, she is applying for the Forest Service Student Career Experience Program (SCEP) award to facilitate her goal of employment with the Forest Service starting as a GS-9.

Ellison Evans of McLoud, Oklahoma, is planning to major in aquaculture/fisheries and has been offered a full scholarship to attend the University of Arkansas at Pine Bluff School of Agriculture, Fisheries, and Human Sciences.

Diane Perry of Franklin, Tennessee, is attending the University of Washington in Seattle. Perry received a scholarship from the School of Oceanography to study aquatic and fisheries sciences.

Sunflower Wilson of Manistee, Michigan, has decided to continue working for the Little River Band of Ottawa Indians (LRBOI) Inland Fisheries and Water Quality Department, helping to educate people in her community about Nmé (sturgeon) and the importance of water quality. Wilson participated in the LRBOI Nmé Release Ceremony on 19 September 2009 by setting up a Hutton Junior Fisheries Biology Program booth and sharing her experiences as a Hutton scholar.


A contract officer with Georgia Downey.

SURVEYS

AFS surveys the parents of the current class for their evaluation of the program and suggestions for improvement. A survey of the parents of the Class of 2009 received a good response with 21 completed surveys received to date. All of the responses were very positive with respect to evaluation of the program and benefit to the students. The most commonly repeated suggestion for improvement was to make the program more widely known by increasing promotion. Other suggestions for improvement included extending the internship to last the entire summer, providing more information/literature about post-secondary fisheries programs and career opportunities, and increasing student networking opportunities.

The long-term results of the program will continue to be monitored by the Annual Hutton Alumni Survey to determine how the Hutton experience affects the educational plans and career choices of Hutton alumni. Ultimately, the success of the program will be measured by the number of minority and female Hutton alumni who choose a career in fisheries science or natural resource management. AFS staff spent several months conducting the Annual Hutton Alumni Survey of students in classes 2001–2009. It was completed in January 2010, with 196 responses, generating a 61% response rate.

According to the survey results:

108 (55%) are studying or considering studying fisheries, biology, or environmental science;

9 (4%) are studying related non-sciences;

11 (5%) are studying other sciences;

26 (13%) are studying, planning to study, or working in an unrelated field.

14 (7%) are working in fisheries or biology;

1 (1%) is working in environmental science;

39 (20%) have undergraduate degrees in fisheries or biology, and of those students:

23 (59%) are pursuing advanced degrees in fisheries or biology;

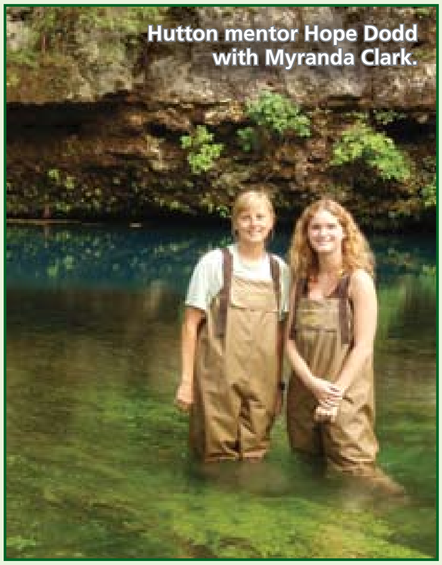
OVERSIGHT AND EVALUATION

The Hutton Oversight Committee oversees and evaluates the Hutton Junior Fisheries Biology Program. This is a special AFS committee composed of AFS members appointed by the Society's president.


Diane Perry with Hutton mentor Kimberly Elkin.

PARTNERS

The 2009 Hutton Program would not have been possible without the generous financial support from NOAA Fisheries Service, USDA Forest Service, U.S. Fish and Wildlife Service, Wisconsin Department of Natural Resources, Northwest Marine Technology, Inc., AFS Education Section, Michigan Chapter AFS, Minnesota Chapter AFS, Washington-British Columbia Chapter AFS, Wisconsin Chapter AFS, and many individual AFS members.


Hutton mentor Hope Dodd with Myranda Clark.

LOOKING FORWARD

AFS plans to encourage the growth of the Robert F. Hutton Endowment Fund to approximately $150,000 before any money from this account is used. After that, about 70% of the interest should provide approximately enough money to fund one Hutton Scholar each year. For every unit of about $150,000 that we can accrue to the fund, we should be able to fund another student.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AMERICAN FISHERIES SOCIETY 140TH ANNUAL MEETING

BEING GREEN IS EASY!

CREDIT: DAVID L. LAWRENCE CONVENTION CENTER

PHOTOS BY PENNSYLVANIA FISH AND BOAT COMMISSION

For the AFS 2010 Annual Meeting, our "Green Meeting Committee" is guiding our planning efforts in many ways, with the purpose of making the AFS 2010 meeting the "greenest" AFS meeting to date. This effort starts with the David L. Lawrence Convention Center (DLCC): the largest convention center awarded Gold LEED® Certification by the U.S. Green Building Council. From its green roof to its own grey water reclamation facility, from its operation to its dedicated staff, the DLCC is leading the way in implementing the 3 R's of conservation (*reduce, reuse, recycle*). After a brief overview we believe you will be pleased with the work of our AFS 2010 Green Committee, this world-class facility, and the environmental renaissance of Pittsburgh.

The DLCC is located in downtown Pittsburgh, within walking distance of many fine restaurants, shops, and entertainment options. However, if you do need to take a vehicle, public transportation is available and the Port Authority of Allegheny County now has hybrid electric buses as part of its fleet. The DLCC was built with conservation as a priority—over 75% of the DLCC receives natural light. The facility and gracious staff are fully dedicated to "green first" by reducing waste and recycling in every aspect of operation and administration of the building.

Specifically for the AFS 2010 Annual Meeting, we are pursuing a variety of conservation efforts. We have developed a system to reuse our sign boards which is expected to reduce the number of signs that will need to be printed. For registration, we will be using items made from recycled materials.

All socials and breaks at the DLCC will emphasize recycling and reducing waste. Here are few highlights:

- **The Welcome Social will be held in the concourses overlooking the Allegheny River, providing natural light to this event.**
- **All socials and breaks at the DLCC will emphasize recycling and reducing waste. The DLCC caterer, Levy Restaurants, is dedicated to purchasing locally grown food, when such options are available and feasible. This reduces transportation costs and use of fuel. The DLCC even grows herbs on its green roof.**
- **Participants will be encouraged to use the water cambros to reduce consumption of bottled water.**
- **Leftover food is donated to charity and waste food is composted.**
- **China and cloth are used whenever possible, but if disposable flatware and plates are used, they are biodegradable.**

12–16 SEPT. WWW.FISHERIES.ORG

PITTSBURGH AFS 2010 MERGING OUR DEEPER CURRENTS

The AFS Trade Show is another major event being hosted at the DLCC and there are many environmentally friendly features and options for vendors to consider.

- **The entire exhibit hall receives natural light through skylights and glass walls.**
- **Large blue recycle dumpsters will be available for gathering recyclable cardboard, paper, and plastic.**
- **The DLCC provides recommendations to vendors on how they can reduce waste and use environmentally friendly materials in their booths. For suggestions see: www.greenfirst.us/exhibitor.html.**

"Certainly, the David Lawrence Convention Center is a highlight of Pittsburgh's green building initiative and is one representation of the 'Steel City's' transformation from a historically polluted metropolis to a cleaner and environmentally friendly urban area," said Douglas J. Austen, executive director of the Pennsylvania Fish and Boat Commission (PFBC). "The water quality of the Three Rivers also has improved dramatically from mid-twentieth century conditions. In fact, areas nearly devoid of fish just 30–40 years ago now provide angling opportunities for major fishing tournaments such as the Bassmaster Classic in 2005 and the Forrest L. Wood Cup in 2009."

Pittsburgh has a lot to offer, from great restaurants, world-class entertainment, professional sports, and diverse outdoor recreation opportunities to shopping and cultural events. You can find more details at: www.visitpittsburgh.com. To learn more about the DLCC and Pittsburgh's "green story," visit www.greenfirst.us and www.pittsburghgreenstory.org.

CREDIT: DAVID L. LAWRENCE CONVENTION CENTER

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.

Ph.D. Research Assistantship, Pennsylvania Cooperative Fish and Wildlife Research Unit, Pennsylvania State University, State College.
Salary: To be determined.
Closing: Until filled.
Responsibilities: Integrate data from downscaled atmosphere-ocean general circulation models and land use change projections to identify how climate and land use change will impact fish habitat in the northeast U.S. and to determine the biological response of brook trout to projected habitat changes.
Qualifications: Minimum M.S. degree in fisheries, ecology, or a related field; a GPA of 3.0 or greater; and competitive GRE scores. Knowledge of ArcGIS and programming in *R* is desirable.
Contact: E-mail a cover letter describing research experience and interests, CV, transcripts, GRE scores, and contact information of three references to Tyler Wagner, txw19@psu.edu, and Paola Ferreri, cpf3@psu.edu. For information about individual positions, contact primary investigators. For information about the project in total, contact Doug Beard, dbeard@usgs.gov; Craig Paukert, cpaukert@ksu.edu; or Jeff Kershner, jkershner@usgs.gov

Postdoctoral Fellow, University of Minnesota—Duluth.
Salary: To be determined.
Closing: Until filled.
Responsibilities: Participate in an effort to predict specific changes in thermal habitat in coldwater lakes, along with corresponding changes in water quality and fish assemblages resulting from altered climate and land use. Develop and apply analytical approaches including both empirical and mechanistic models. Possibly, model ways in which changes in climate and land use may affect changes in habitat in coldwater lakes, quantifying responses of fish assemblages and water quality to changes in environmental conditions, and work with other members of the project team to develop an approach for rating the potential vulnerability of the glacial lakes of Michigan, Minnesota, and Wisconsin to climate and land use changes. Interact with other researchers who are developing individual-lake models that predict temperature and oxygen in coldwater lakes.
Qualifications: Ph.D. in aquatic or fisheries ecology, or related field a strong quantitative background experience with geographic information systems, preferably ARCGIS, and excellent written and verbal English.
Contact: Position supervisor, Lucinda Johnson, ljohnson@d.umn.edu.

Postdoctoral Research Associates (2 positions) and Doctoral Research Student Assistant (1 position), Michigan State University.
Salary: To be determined.
Closing: Until filled.
Responsibilities: Post docs will classify river reaches into thermal and hydrologic types. Model ways in which changes in climate and land use may affect changes in habitat of fluvial systems. Quantify responses of fish assemblages to changes in environmental conditions. Develop an approach for rating the potential vulnerability of the nation's fluvial systems to climate and land use changes. Lead the effort to quantify the vulnerability of streams to changes in climate and land use and to predict changes in distributions of fishes that may result at a national scale. Focus on the Midwestern Glacial Lakes Partnership region and will lead the effort to predict specific changes in thermal and hydrologic regimes along with corresponding changes in fish assemblages from altered climate and land use. Develop and apply analytical approaches for making research determinations.

Doctoral student will develop a project to evaluate the response of fluvial fishes to physical and biological changes in stream systems that may result from changes in climate and land use, with special emphasis on considering mechanisms by which landscape-scale controls affect fishes. Potential focus areas include considering altered physical habitat characteristics and/or response of assemblages to changes in species membership. Assist with data management, analysis, literature reviews, and other duties.
Qualifications: Ph.D. in aquatic or fisheries ecology, landscape ecology, or related field; a strong quantitative background; and experience with geographic information systems, preferably ARCGIS.

M.S. in aquatic or fisheries ecology, landscape ecology, or related field is required. Experience with geographic information systems, preferably ARCGIS, strong quantitative interests, and excellent written and verbal communication skills.
Contact: Dana Infante, Michigan State University, and Lizhu Wang, Michigan Department of Natural Resources. See www.msu.edu/~infanted.

Postdoctoral Research Associate, University of Missouri.
Salary: To be determined.
Closing: Until filled.
Responsibilities: Lead the effort to quantify population-level effects to fishes as a result of changes in climate and land use. Contribute to a team that will lead the effort to predict specific changes in thermal and hydrologic regimes in the Lower Colorado River Basin along with corresponding changes in fish assemblages from altered climate and land use. Develop and apply analytical approaches for making these determinations. Possibly evaluate how changes in thermal habitat will affect growth and consumption of fishes, class river reaches into therma and hydrologic types, model ways in which changes in climate and land use may affect changes in habitat of fluvial systems, and quantify responses of fish assemblages to changes in environmental conditions.
Qualifications: Ph.D. in aquatic or fisheries ecology or related field a strong quantitative background and experience or interest in applied fisheries conservation and management, bioenergetics, and geographic information systems preferably ARCGIS.
Contact: Position supervisors Craig Paukert,cpaukert@ksu.edu, and Joanna Whittier, and collaborator Julian Olden, (University of Washington). See www.k-state.edu/fisheries.

Postdoctoral (3-4 positions) and Ph.D. Students (1-2 positions), U.S. Geological Survey and university consortium—University of Missouri, Michigan Department of Natural Resources, Minnesota Department of Natural Resources, Michigan State University, Pennsylvania State University, University of Minnesota—Duluth, and University of Washington.
Salary: $40,000–50,000 per year, depending on experience and location. Funded for a 2-3 year minimum. Pay rates determined by the university at which these positions appear.
Closing: Until filled.
Starting: As soon as possible.
Responsibilities: Develop methods to integrate climate change and land use forecasts into assessment and management of the nation's fish habitat. Help develop a multi-scale assessment of the current and future status of fish habitat and predicted biological responses under scenarios of projected climate and land-use changes on national, regional, and local scales. Work closely with all members of the project, regardless of where home institution resides.
Contact: Send a letter of inquiry and a current CV to Doug Beard, dbeard@usgs.gov and/or the principle investigator for the institution of interested. Response to letter of inquiry will include additional details.

Seasonal Field Technician (temporary), Utah Division of Wildlife Resources.
Salary: $10.99–13.65/hr.
Closing: 19 February 2010.
Responsibilities: Assist with field projects involving native fish populations of the upper Colorado River Basin. Monitor native and nonnative fishes using a variety of electrofishing techniques, seining, and PIT-technology. Survey high elevation amphibians.
Qualifications: Bachelors degree or degree-seeking in biological sciences. Preference may be given to applicants with electrofishing experience, boating/rafting experience, and demonstrated ability to work well independently and with others. Strenuous physical activity, long hours of operation, backpacking, rafting, and overnight camping in remote locations is common.
Contact: Send resume, transcripts, and letter of interest with qualifications and dates of availability to Matthew J. Breen, Native Aquatics Biologist, Utah

Department of Natural Resources, 152 East 100, North Vernal, Utah 84078; 435/781-5317; fax 435/789-8343; mattbreen@utah.gov.

Fisheries Naturalist Aide (temporary), Indiana Department of Natural Resources.
Salary: $9.89 hour. Subject to change.
Closing: 28 February 2010. Application information will be accepted until all positions are filled.
Responsibilities: Assist fish hatchery managers, district fish management or research biologists in conducting field and laboratory investigations. Includes lake and stream fish population surveys, creel surveys, fish population estimates, water quality analysis, public relations, aquatic weed control, fish population control, fish habitat improvement, and fish culture activities.
Qualifications: Preferences to upper class college students or recent graduates enrolled in a fisheries curriculum and having completed courses in ecology, fisheries, limnology, and aquatic sciences.
Contact: E-mail resume and transcript to Robin Longenbaugh at rlongenbaugh@dnr.IN.gov. Please indicate a preference for fish management or fish culture when submitting a resume for consideration.

Using Acoustic Tags to Monitor Movement and Habitat Use of Chinook Salmon Smolts, Northern Pikeminnow & Smallmouth Bass

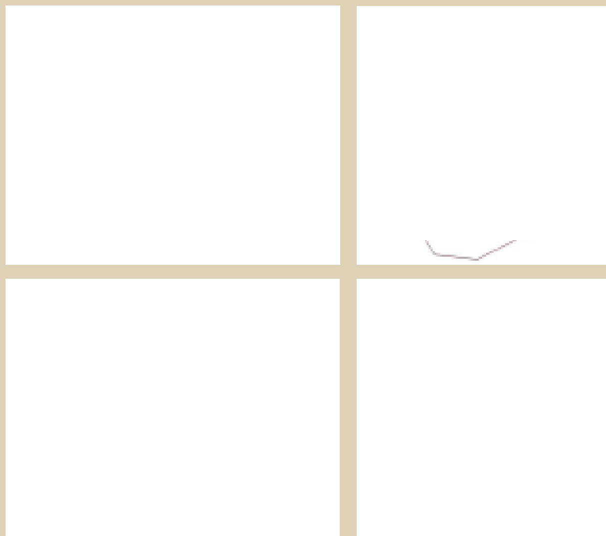
Located east of Seattle, Lake Washington supports the world's longest floating bridge at 7,578 ft (2,310 m), commonly referred to as the “520 Bridge” (State Route 520). The 520 Bridge connects Seattle with Eastside communities and is a high priority with the Washington State Dept. of Transportation (WSDOT) as they move forward with replacing the aging bridge.

When WSDOT began the SR 520 Program, they set out to better understand fish behavior with the help of the U.S. Fish and Wildlife Service (USFWS). It's known that structures, such as bridges in and near waterways, can influence the ecological dynamics of the aquatic environment. Such influences can affect behavior, habitat use, and survival. For example, many naturally-reared Chinook salmon smolts (*Oncoryhnchus tshawytscha*) in Lake Washington must pass beneath the 520 Bridge as they migrate toward Puget Sound. The goal of the study was to evaluate movement and habitat use of the salmon smolts and two predators - northern pikeminnow (*Ptychocheilus oregonensis*) and smallmouth bass (*Micropterus dolomieu*) near the bridge..

Researchers employed HTI's fine-scale acoustic tracking system to track fish in a 17.2 ha area along a 1,838 ft (560 m) stretch of the bridge from late May through early August. The study site was on the west end of the bridge, and was believed to lie within a major migratory corridor for salmon smolts. Naturally-reared smolts moving from south Lake Washington travel north along the western shore of the lake and encounter the bridge before moving toward the entrance to the Lake Washington Ship Canal en route to Puget Sound. Hatchery-reared smolts occur throughout the lake and many move along the southwestern shore of the lake and encounter the bridge. Tagged smolts were released 2,625 ft (800 m) south (upstream) of the study site to observe behaviors as they volitionally entered the study site and encountered the bridge. Most predators were captured on-site, tagged, and released near the place of capture.

Though differences in timing of migrational cues (e.g., moon apogee), physiological smolt status, water temperature, and prey availability may have contributed to differences in behaviors observed between release groups, the ultimate questions remain. How does the current bridge affect fitness and survival of Chinook salmon, and how should the new bridge be designed and sited to minimize impacts to Chinook salmon?

HTI is proud to provide the tools needed for WSDOT and USFWS to observe fish behavior, and for the opportunity to be involved as they continue their commitment to environmental stewardship. To learn more about acoustic technology used in this study, visit us at HTIsonar.com.



Day and night density plots of northern pikeminnow #4667 at State Route 520 Bridge study site, summer 2007.