Discovery, response, and assessment of the Bullseye Snakehead *Channa marulius* in Florida

KELLY B. GESTRING, PAUL L. SHAFLAND, AND MURRAY S. STANFORD

Nonnative Fish and Wildlife Program
Florida Fish and Wildlife Conservation Commission,
Boynton Beach, FL 33431, USA
Kelly.gestring@myfwc.com

Oral presentation

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Abstract—The Bullseye Snakehead *Channa marulius* is an air-breathing, large-bodied freshwater fish native to Southeast Asia. All *Channa* species are listed as prohibited (no live possession) in Florida and are high priority for Early Detection Rapid Response (EDRR). This species was illegally introduced to southeast Florida waters and first reported in 2000. Bullseye Snakehead are now abundant in six major canal systems and are slowly spreading into interconnected canals. The laboratory derived lower lethal temperature of $\leq 10^{o}$C indicates the potential range of Bullseye Snakehead is limited to peninsular Florida. Bullseye Snakehead opportunistically feed on a wide variety of organisms but primarily consume small fishes, crustaceans, and insects. No measurable negative effects on native fishes in urban canals have been associated with the presence of Bullseye Snakehead to date. The Florida Fish and Wildlife Conservation Commission (FWC) is concerned these successful invaders may spread into natural areas including Everglades National Park where their potential adverse impacts are unknown. The FWC conducts standardized electrofishing, promotes consumptive use at outreach events, and conducts EDRR as management strategies for Bullseye Snakehead. The illegal presence of Bullseye Snakehead in Florida is undesirable and less problematic to native fish communities in urban canals than anticipated, but their potential impact in natural areas is unclear.

Management implications from a stock-recruit model for Northern Snakehead in Virginia portions of the tidal Potomac River

MICHAEL HOFF[1] AND JOHN ODENKIRK[2]

[1]*USFWS (retired)*
81922 State Hwy. 13
Washburn, WI 54891
michaelhhoff@comcast.net

[2]*VA Dept. Game & Inland Fisheries*
1320 Belman Road
Fredericksburg, VA 22401
John.odenkirk@dgif.virginia.gov

Oral presentation

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Abstract -- The U.S. Congress directed the U.S. Fish and Wildlife Service (USFWS) to identify, contain, and eradicate Northern Snakehead *Channa argus* in the United States. Later, the Mississippi River Basin Panel on Aquatic Nuisance Species requested that the Aquatic Nuisance Species Task Force develop a management plan to include additional snakehead species (Channidae) that are, or have the potential to become, invasive in United States waters. Objectives of the snakehead management and control plan, which was developed by USFWS and collaborators, include developing long-term adaptive management and control methods. We developed a Ricker stock-recruit model using Northern Snakehead population data collected in four northern Virginia tidal tributaries during 2009-2015 to inform management and control efforts. The resulting model functional relationship explained 93% of recruitment variability using adult stock size (mean electrofishing catch/h [CPUE] of adults) and mean river flow during May. Recruitment was quantified using boat electrofishing CPUE of age-2 fish lagged for two years, because age-0 and even age-1 fish did not appear to be fully recruited to the gear. Seventy-six percent of recruitment variation was explained by adult abundance, while an additional 17% was explained by mean river flow during May (inverse relationship). Model predictions indicated management efforts to reduce adult stock size, from the optimum of 2-4 fish/h to < 0.5 fish/h, should be the most effective tool to reduce recruitment and resulting adult abundance over the long term. That level of adult abundance (approximately 12% of the mean during 2009-2015) should be the target maximum for Northern Snakehead control efforts in the study areas.

A history and distribution of Northern Snakehead *Channa argus* in Arkansas

JIMMY BARNETT

Arkansas Game and Fish Commission
Benton, AR
Jimmy.barnett@agfc.ar.gov

Oral presentation

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Abstract - Northern Snakeheads were imported to fish farmers in the state of Arkansas for use in the food fish market before being banned in 2002. Farmers were advised to destroy their specimens in 2002 when importation and interstate trade was banned under the Lacey Act. These farmers reportedly attempted this action. On April 14, 2008 a wild Northern Snakehead was captured by an area row crop farmer and confirmed by AGFC Fisheries Biologist. An eradication effort was formulated for the fall of 2008 involving several agencies and universities. The state experienced several late summer storm systems that had the area at flood conditions during this time. The eradication was named Operation Mongoose, and it was rescheduled for March 2009. Operation Mongoose involved application of the fish toxicant rotenone using helicopters, marsh masters, boats and ground teams to cover approximately 700 km of creeks, ditches and backwater areas within the 20,250 ha Piney Creek watershed. The effort reduced the Northern Snakehead in the drainage but did not eradicate them. This area is flooded almost annually each year which has allowed for range expansion of the fish. The AGFC tracks this dispersal through reporting from the angling public. During 2017, we had the first confirmed range expansion outside of Arkansas into the state of Mississippi.

Fishing for an invasive: Applying old concepts to a new problem

JOSEPH W. LOVE AND PAUL GENOVESE

Maryland Department of Natural Resources
580 Taylor Avenue B-2
Annapolis, MD 21401
Joseph.love@maryland.gov

Oral presentation

Publish

Abstract - Consistent efforts to raise awareness and limit ecological impacts of Northern Snakehead *Channa argus* led by the Maryland Department of Natural Resources began in 2010. While using press releases and videos to raise awareness and encourage harvest of the invasive species, the department hosted promotional raffles that encouraged a harvest fishery and ultimately led to 659 reports of euthanized snakeheads to the department's Angler's Log between 2010 and 2017. As popularity grew, the department worked with a snakehead bow hunter in 2011 to organize the first snakehead tournament on Potomac River waters. Between 2011 and 2015, tournament participants removed 5943 pounds of snakeheads. Snakehead tournaments now occur on Potomac River, Patuxent River, and eastern shore rivers of Maryland. In 2014, the department created a new invasive species state record program that requires euthanization. Set in 2014, the record has been broken 4 times and currently is 18.42 pounds. The department engaged the commercial sector with seafood marketing campaigns beginning 2011 and created an inexpensive commercial license for bow hunters in 2016. In 2016 and 2017, licensed bow hunters reportedly sold 8,809 pounds of snakeheads. Since the department began requiring commercial harvesters to report landings in 2011, commercial harvest has increased every year to a sum total of 17,151 pounds (2011-2017) from Potomac River. Partly owed to effective law enforcement, applying age-old harvest incentives to control an invasive species has not resulted in stocking for commercial purposes but has instead resulted in an informed public and on-going harvest that has noticeably increased fishing mortality.

Impacts of Northern Snakehead on freshwater fish communities

JOSEPH W. LOVE[1] AND JOSHUA J. NEWHARD[2]

[2]*Maryland Department of Natural Resources*
580 Taylor Avenue B-2
Annapolis, MD 21401
Joseph.love@maryland.gov

[2]*U.S. Fish & Wildlife Service*
177 Admiral Cochrane Drive
Annapolis, MD 21401
Joshua.newhard@fws.gov

Poster presentation

Abstract - Northern snakehead *Channa argus* was illegally introduced into storm water ponds of Maryland in 2002. Later discovered in tidal freshwater of Potomac River, the species has spread throughout much of the tidally influenced Chesapeake Bay watershed. Its establishment, demonstrated by significant increases in relative abundance and distribution, led to concern about its negative impacts to existing freshwater species. The predatory aspects of snakeheads have been well-studied and suggest Northern Snakehead is a piscivorus, top predator like Largemouth Bass *Micropterus salmoides*. Therefore, we hypothesized its impacts were similar to those of Largemouth Bass. Using a series of pond experiments we observed consumption levels that indicated a population of Northern Snakehead would impact prey species similar to that as a population of Largemouth Bass. This, in addition to the ability of the species to thrive across different microhabitats in tidal freshwater, may warrant control efforts to limit its impact in the Chesapeake Bay watershed.

Effective terrestrial locomotion by the invasive Northern Snakehead, *Channa argus*

NOAH R. BRESSMAN[1], MIRIAM A. ASHLEY-ROSS[1], TYLER KING[1], CAROLINE HORNE[1], & JOSEPH W. LOVE[2]

[1]*Wake Forest University*
Department of Biology
1834 Gulley Drive
Winston-Salem, NC 27109
Bresnr16@wfu.edu

[2]*Maryland Department of Natural Resources*
580 Taylor Avenue B-2
Annapolis, MD 21401
Joseph.love@maryland.gov

Oral Presentation

Abstract – Native to Southeast Asia, the Northern Snakehead *Channa argus* is potentially an ecologically harmful invasive species to the United States. These fish are known for extreme hypoxia tolerance and air-breathing capabilities, while some snakehead species have exhibited amphibious behaviors. However, previous descriptions of *C. argus* terrestrial behaviors are inconsistent and lack important details. The goals of the present study are to quantify terrestrial locomotion of the Northern Snakehead, compare their terrestrial locomotor behaviors to other amphibious fishes, and to assess the potential of this species to spread overland into additional bodies of water. We quantified kinematics from videos of Northern Snakeheads moving on multiple terrestrial substrates and recorded electromyograms from axial and appendicular muscles as *C. argus* moved over a substrate of artificial turf. Northern Snakeheads over a wide size range (approximately 25 cm - 70 cm) used their pectoral fins and body for effective axial-appendage-based terrestrial locomotion, with similar kinematics to walking catfishes *Clarias* spp. and the Tidepool Sculpin *Oligocottus maculosus*. They simultaneously activated ipslateral hypaxial and epaxial muscles, alternating with the contralateral side to complete a stride. Additionally, *C. argus* coordinated pectoral fin abductor and adductor muscles with the cyclical motion of the axial body to generate effective terrestrial locomotion. This behavior allowed them to move several body lengths in bursts lasting several seconds. Their effective terrestrial locomotor behavior combined with their efficient air-breathing capabilities suggests that in a moist environment, Northern Snakeheads may be capable of abbreviated temporary overland movements.

Using eDNA to estimate dispersal of non-native Bullseye Snakehead *Channa marulius* in south Florida

PAM SCHOFIELD, MARGARET HUNTER, GAIA MEIGS-FRIEND, AND MARY BROWN

U. S. Geological Survey
Gainesville, FL
pschofield@usgs.gov

Oral presentation

Publish

Abstract – Bullseye Snakehead *Channa marulius* was first found in south Florida in 2000 and has been rapidly expanding its geographic range. It is a large predatory fish from southeastern Asia that could impact native and naturalized species via predation and competition. There is concern that it will use the interconnected system of canals to disperse to natural conservation areas such as Everglades National Park, Big Cypress National Preserve and state-held Water Conservation Areas. The goal of this project is to develop a protocol for using environmental DNA (eDNA) to estimate occupancy and dispersal of non-native Bullseye Snakehead. This includes developing species-specific eDNA assays, estimating occurrence and dispersal by analyzing water samples, and ground-truthing geographic range occupancy revealed by eDNA testing.

Fishing impacts on Northern Snakehead populations in the Potomac River

JOSHUA NEWHARD[1], JOHN ODENKIRK[2] AND LUKE LYON[3]

[1]U. S. Fish and Wildlife Service
177 Admiral Cochrane Drive
Annapolis, MD 21404
Joshua_newhard@fws.gov

[2]VA Dept. of Game & Inland Fisheries
1320 Belman Road
Fredericksburg, VA 22401
John.odenkirk@dgif.virginia.gov

[3]D.C. Dept. of Energy and Environment
1900 Anacostia Drive SE
Washington, D.C. 20020
Luke.lyon@dc.gov

Oral presentation

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Abstract – Northern Snakehead, a species native to Asia, became established in the Potomac River drainage prior to 2004. Removals by agencies appeared to do little to control abundance or limit spread into new waterways. As such, Northern Snakehead has become widespread throughout much of the Potomac River drainage in addition to many other river systems throughout the Chesapeake Bay watershed. As abundance increased within the Potomac watershed, new recreational and commercial fisheries were organically born aided by encouragement of state and federal agencies to increase harvest. A mark-recapture program to examine growth and movement of Northern Snakehead began in 2009, as population density appeared to be increasing. In 2013, tagging methods changed to allow population size of Northern Snakehead to be estimated within selected tributaries (Little Hunting Creek (LHC) and Upper Anacostia (UA)). Using mark-recapture angler returns and agency sampling data, we were able to view population size in context with changes in fishing mortality over time. The UA population linearly declined with increasing fishing mortality, while the LHC population changed very little in response to fishing mortality except for 2016 which had the lowest population estimate and highest fishing mortality. We are cautiously optimistic that exploitation may help control population growth, but recreational fishing alone is unlikely to cause significant declines in Northern Snakehead populations. Furthermore, well-established populations are likely to require high (>25%) exploitation rates to be effective.

The history of snakeheads in Hawaii

ANNETTE TAGAWA

Division of Aquatic Resources
Hawaii
annette.w.tagawa@hawaii.gov

Oral presentation

Abstract – The snakehead, locally known as pongee, was one of the species brought to Hawaii by Asian immigrants during the plantation days in the 1800's. In Hawaii, the snakehead was known to inhabit reservoirs on the island of Oahu. Originally thought to be *Channa striata* brought in to Hawaii by Asian immigrants, it turned out *C. maculata* was the species introduced into ponds and irrigation ditches, while *C. striata* was later imported in 1994 for commercial culture and is presently only found in one aquaculture facility on Oahu. More recently, the snakehead was only found on the island of Oahu until October 2017 when a specimen of an unidentified species was caught in a stream on Kauai. Thus, to date there are now possibly three species of snakeheads in Hawaii. On Oahu, the snakehead was at one time very abundant. However, within the last two decades, their numbers have declined to the point of being nearly nonexistent. Wahiawa Reservoir Public Fishing Area on the island of Oahu used to be one place where snakeheads were known to be fairly abundant. Among freshwater fishermen, the snakehead is considered to be one of the best eating fish. Recent creel surveys suggest no snakeheads have been caught at the reservoir recently. The last known snakehead caught was in 2000. Compared to areas across the country where snakeheads are perceived to be pests, the complete opposite seems to be the case in Hawaii.

Bioenergetics of the snakehead *Channa argus*

JIASHOU LIU

Institute of Hydrobiology
Chinese Academy of Sciences
Wuhan 430072 China
jsliu@ihb.ac.cn

Oral presentation

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Abstract – The bioenergetics of the snakehead *Channa argus* (Cantor) were studied in the laboratory. The combined relationship between rate of standard metabolism (R_s, mg O_2/h), body weight (W, kg) and temperature (T, ^oC) could be described by the multiple regression equations: $\ln R_s = -2.328 + 0.801\ln W + 2.104\ln T$. No significant interaction of body weight and temperature on R_s was found. The proportion of food energy channeled to specific dynamic action was 8.73%. Specific growth rates in wet weight, dry weight, protein and energy increased linearly with increased ration level. The growth efficiency increased curvilinearly with increasing ration level. Fecal production and nitrogenous excretion increased with increasing ration level. The energy budget at maximum ration level was: $100C = 7.01F + 4.76U + 40.13R + 48.10G$, where C, F, U, R, and G were food consumption, fecal production, nitrogenous excretion, metabolism and growth, respectively. The bioenergetics model included sub models of food consumption, fecal production, nitrogenous excretion, standard metabolism, activity metabolism, SDA and energy. The model prediction was most sensitive to the parameters of the sub model for standard metabolism and was not sensitive to the parameters of the sub models for fecal production, nitrogenous excretion and SDA. The predicted growth from the bioenergetics models agreed well with observed growth.

Some population and diet traits of Northern Snakehead in Pomonkey and Mattawoman Creeks

TIM GROVES, JOSEPH LOVE, AND MARY GROVES

Maryland Department of Natural Resources
RR4, Box 106E
Brandywine, MD 20613
Tim.groves@maryland.gov

Poster presentation

Abstract - Maryland's Potomac River became home to a small population of Northern Snakehead (*Channa argus*) in 2004. Since that time, the population has expanded to most major tributaries of Maryland's portion of the Chesapeake Bay. Northern Snakehead is native to China, Russia and Korea. Their quick expansion has fishery managers concerned about adverse effects towards Maryland's natural resources. We examined some population aspects of Northern Snakehead from two tributaries to the Potomac River: Pomonkey and Mattawoman creeks, and then compared those aspects to other populations of the Potomac River drainage. Aspects included demographics, growth and diet. Relative abundance of Northern Snakehead (> 400mm) from boat electrofishing surveys averaged 3.9 fish per sampling hour (SD=1.6). Twenty-two snakehead were sexed in Pomonkey creek, and 50% were male. A total of 57 snakeheads were sampled in Pomonkey and Mattawoman Creeks for a diet study. Twenty-nine snakeheads (51%) contained fish, and fourteen (25%) had eaten invertebrates. One snakehead had eaten frogs. Growth rates and habitats were similar to those described for other populations of the Potomac River. To help minimize potential adverse effects, the Maryland Department of Natural Resources offers an invasive species state record and awards for some anglers participating in a harvest program.

Snakehead Fishes in the United States

AMY J. BENSON

U.S. Geological Survey
Wetland and Aquatic Research Center
7920 NW 71st Street
Gainesville, FL
abenson@usgs.gov

Oral presentation

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Abstract – The United States has a long history of non-native fish introductions whether intentional or unintentional dating back to the earliest European settlers. The introduction of snakeheads is relatively new to the contiguous U.S. A recent genetic study of the Channidae family of snakeheads recognized 38 species in two genera in the world native to Asia and Africa. As many as eight species of snakeheads are aquacultured around the world for human food and, to a lesser degree, the aquarium trade. There have been five species of snakeheads introduced in the U.S. of which four have been collected in open waters. Of those four, three have successfully established reproducing populations. The most widespread is a temperate species, Northern Snakehead *Channa argus* primarily found in the Mid-Atlantic region. Other snakehead species have established populations: Bullseye Snakehead *Channa marulius* in Florida and Blotched Snakehead *Channa maculata* in Hawaii.

Assessing the risk of snakehead in Ohio through environmental DNA and traditional sampling

JOHN NAVARRO

Ohio Department of Natural Resources
2045 Morse Road
Columbus, OH 43229
John.navarro@dnr.state.oh.us

Oral presentation

Abstract –Snakehead *Channa sp. and Parachanna sp.* are a potentially highly invasive group of fish that have become established in many Mid-Atlantic States. All species of snakehead are listed as injurious in Ohio, and possession of live fish is illegal. The discovery of Silver Carp *Hypophthalmichthys molitrix* in the Ohio River near Cincinnati in 2012 prompted Ohio to develop a plan of action to deal with this threat. This included the testing of water for the presence of environmental DNA (eDNA). Such sampling on the Muskingum River, a direct link from the Ohio River to two hydraulic connections to Lake Erie, tested positive for Bighead Carp *Mylopharyngodon piceus* in 2013. A planned action in 2013 using electrofishing gear did not discover live Bighead Carp. The archived water samples were later tested for a suit of fish species, and one sample in the upper Muskingum River tested positive for snakehead. This prompted a planned action in July, 2015 where ODNR Division of Wildlife expended 155 minutes of electrofishing time over 5.5 miles of Killbuck Creek, but no live snakeheads were collected. We will continue to monitor the Muskingum River for snakeheads, Bighead, and Silver Carp using both eDNA and traditional sampling gears.

Fish community response to a Northern Snakehead introduction in New York

MELISSA K. COHEN

New York State Department of Environmental Conservation
47-40 21st Street
Long Island City, NY 11101
melissa.cohen@dec.ny.gov

Poster presentation

Abstract –A population of Northern Snakehead *Channa argus* was discovered in the Meadow/Willow lakes system in Queens, NY, in 2005 and monitored annually by electrofishing through 2016. Despite existence of suitable habitat and availability of forage species, the Meadow/Willow Lakes Snakehead electrofishing catch rate has remained relatively low and has not changed significantly for approximately ten years. Catch rates of forage species did not follow a clear positive or negative trend. Potential causal factors in this lack of (or delay in) snakehead population increase include water quality, presence of other fish species, and angling pressure; although exact reasons for slow population growth are unknown.

Modeling expansion of Northern Snakehead in the southeastern U.S.

SHANNON C.F. SMITH[1], JUSTIN M. HOMAN[2], MICAH D. TINDALL[2], AND STEVE E. LOCHMANN[1]

[1]University of Arkansas at Pine Bluff
Aquaculture/Fisheries Center
1200 N. University, Box4912
Pine Bluff, AR 71601
smithscf@uapb.edu

[2]Arkansas Game & Fish Commission
1201 N. Main Street
Brinkley, AR 72021

Oral presentation

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Abstract –Northern Snakehead have been expanding within Arkansas during the past decade and have recently crossed the Mississippi River into Mississippi. To better understand their expansion trends in this region, we analyzed expansion directionality from 2008 to 2017 and calculated estimates of occupied area using standard deviational ellipses in a GIS. From 2008 to 2017, expansion occurred in a predominantly north-south direction rather than east-west which was likely attributable to snakeheads utilizing river drainages as main movement corridors. Estimates of occupied area remained low for the first few years indicating a slow rate of expansion. However, from 2014 to 2017; annual estimates of occupied area increased exponentially. To investigate the likelihood of movement into new regions, we developed maximum entropy models (Maxent v3.4.0) to predict the probability of snakehead presence in multiple southeastern states. Models evaluated habitat suitability based on presence-only location data and environmental constraints. We used a GIS to visualize model output by generating maps showing low to high probability of snakehead presence. Although these models are not yet fully comprehensive, they have the potential to highlight areas that may be particularly susceptible to snakehead colonization. Used in conjunction with informed knowledge of a specific region, these models offer insight on where the forefront of invasion is likely to occur and could provide managers and researchers with the ability to identify especially vulnerable regions.

Opening Pandora's Box: Socrates and the Northern Snakehead

DONALD J. ORTH

Department of Fish and Wildlife Conservation
Virginia Polytechnic Institute and State University
Blacksburg, VA 24061
Don_orth@vt.edu

Oral presentation

Publish

Abstract –Invasion biology studies the origin, spread, impact, and control of invasive species, and risks of invasion are increasing on a global scale. The distribution, abundance, and spread of Northern Snakehead *Channa argus* in the Potomac River has been studied. Although management of alien species is increasingly contested in social arenas where such species are valued differently by stakeholders, few investigations have focused on social or ethical dimensions of the snakehead invasion. Management actions for Northern Snakehead are limited to regulating possession, educating anglers, and encouraging harvest. In this paper, I analyze the discourse surrounding Northern Snakehead introduction and controversies and consider potential ethical frameworks for Northern Snakehead introductions and management. I contrast foundationalist and pragmatic ethical frameworks to guide future decision making. Because invasive and potentially invasive species, such as Northern Snakehead, are not inherently "bad" or "good," our attitudes toward and management of members of such species should examine conflicts on a case by-case basis. To confront or avoid differences in value systems among stakeholders, I recommend integrating the plurality of environmental values into Northern Snakehead discourse. Participatory approaches that are inclusive and transparent will improve trust among stakeholders, scientists, and managers. Proactive approaches are needed to effectively confront the ethical and social dimensions and conflicts inherent in the Northern Snakehead invasions. Understanding stakeholders' plural views and values of the Northern Snakehead is a key for developing and maintaining workable management strategies and to minimize conflict.

Integrated pest management: lessons learned from Sea Lamprey control

NICHOLAS SCHLOESSER, RICHARD ERICKSON, AND JOEL PUTNAM

U.S. Geological Survey
Upper Midwest Environmental Sciences Center
nschloesser@usgs.gov

Poster presentation

Abstract –Invasive Sea Lamprey *Petromyzon marinus* entered the Great Lakes around 1920 following improvements to the Welland Canal. Sea Lamprey established spawning populations in all of the Great Lakes by 1947 and devastated commercial and recreational fisheries. In response to the threat posed by the Sea Lamprey, the United States and Canadian governments formed the Great Lakes Fishery Commission (GLFC) in 1954 to "eradicate or minimize Sea Lamprey populations" in the Great Lakes. Great Lakes Sea Lamprey are still managed by the GLFC using an Integrated Pest Management (IPM) program. The techniques used in the IPM program include chemical control using lampricides, trapping spawning adults, sterile male release, physical and electric barriers to prevent upstream migration, and use of pheromones as an attractant or deterrent. Many variables must be factored into an IPM program including population assessments of both adult and larval Sea Lamprey, ranking streams for treatment in order to best utilize available resources, and looking at non-target effects and environmental fate of lampricides. New techniques might assist with the IPM program such as the use of eDNA to estimate Sea Lamprey populations in a stream. There is also a current push within the GLFC to explore "next-generation" lampricides that might prove more efficacious and selective in targeting Great Lakes Sea Lamprey. Lessons learned from decades of Sea Lamprey management could inform development of an invasive Northern Snakehead *Channa argus* IPM program.

Diel feeding and movement activity of Northern Snakehead *Channa argus*

NICOLAS W. R. LAPOINTE[1], RYAN K. SAYLOR[2], AND PAUL L. ANGERMEIER[3]

[1]*Canadian Wildlife Federation*
350 promenade Michael Cowpland Drive
Kanata, ON K2M 2W1
nlapointe@cwf-fcf.org

[2]*Oak Ridge National Laboratory*
rsaylorr@ornl.gov

[3]*U. S. Geological Survey*
VA Cooperative Fish & Wildlife Research Unit
VA Tech
Blacksburg, VA 24060
biota@vt.edu

Oral presentation

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Abstract –Understanding the diel activity of a species can shed light on potential interactions with other species and inform management practices. To understand the diel activity of Northern Snakehead *Channa argus*, movement and feeding patterns were observed. The movement of fish implanted with radio transmitters was monitored every 1.5 hours for 24 hours in March and July 2007. Movement rates were compared between seasons and by time of day. Additionally, 272 Northern Snakehead were captured by boat electofishing in May and June of 2007 and 2008, and their gut contents were extracted and preserved. The level of digestion of each prey item was estimated in the lab from fresh (1) to >50% digested (4) or empty (5). Random forests were used to predict feeding activity based on time of day, tide, date, length, and sex. Fish moved greater distances during spawning season than during winter. In winter, fish moved greater distances during morning than at night ($P < 0.01$). A similar but non-significant ($P > 0.05$) pattern was observed during spawning season. Independent variables predicted only 6% of variation in feeding activity; however, feeding patterns were apparent. No fresh gut content items were observed between 12:30 and 7:30 am, and the proportion of empty stomachs increased at the end of May indicating the onset of spawning season. Tide did not appear to affect feeding. Movement and feeding data indicated higher activity during daylight suggesting Northern Snakehead is a diurnal species.

Eradication of Northern Snakehead from the Catlin Creek watershed in southeastern New York: a success story?

MICHAEL J. FLAHERTY

New York State Department of Environmental Conservation
21 S. Putt Corners Road
New Paltz, NY 12561
Michael.flaherty@dec.ny.gov

Oral presentation

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Abstract –In late May 2008, a private pond owner notified New York State's Department of Environmental Conservation (DEC) of the capture of two Northern Snakehead (NSH) from Catlin Creek, a headwater stream in the Hudson River watershed located in southeastern New York. Within three months, DEC confirmed the presence of a reproducing population of NSH in this watershed and conducted an eradication effort that included a 2-mile section of Catlin Creek, four small ponds, a 49 acre wetland and Ridgebury Lake (28 acres). Rotenone was used for this eradication effort, and a total of 227 dead NSH were collected along with over 8 tons of other fish species. In October 2009, a follow-up rotenone treatment was conducted over a portion of the original treatment area using Marshmaster vehicles to more efficiently treat some of the most difficult terrain. The relatively quick response time to conduct this eradication effort was facilitated by New York State declaring this NSH introduction an environmental emergency which helped to prioritize environmental review and free up funding during an era of tight fiscal restraints and little discretionary staff time. Follow-up surveys using electrofishing and water sampling for eDNA analysis have resulted in no evidence of NSH within the area treated with rotenone. DEC is cautiously optimistic that the eradication of NSH was complete, however, an ecological shift in Ridgebury Lake resulting in nuisance levels of aquatic macrophytes remains a blemish on claiming this effort as a total success within the local community.

How are introduced snakeheads doing in Japan?

KATSUKI NAKAI

Lake Biwa Museum, Shiga Prefecture, Japan
nakaikatsuki@gmail.com

Oral presentation

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Abstract –Channid snakeheads are originally distributed in East and Southeast Asia where many species are regarded as important food resources. This importance has stimulated active intention to introduce these fish outside their native ranges including Japan and the United States. In Japan, the Northern Snakehead *Channa argus* was introduced from Korea around the 1930s with expectation for a new fishery resource followed by another southern species *Channa maculata* from Taiwan. However, they were predatory fish not native to Japan, and the fisheries authorities started to prohibit their intentional introductions. But, it was too late to prevent nationwide distribution of Northern Snakehead from Hokkaido to Okinawa before World War II and relatively limited distribution of *C. maculata* within Japan. Numerous Japanese ichthyologists commonly observed snakeheads coexisting with abundant small-sized cyprinid fish in irrigation ponds and canals in floodplains. In spite of scarcity of ecological studies on naturalized snakeheads in Japan, it is plausible their invasiveness was not intense enough to expel coexisting small fish as has been tragically realized by the invasion cases of New World predators Largemouth Bass and Bluegill. This contrary outcome of aquatic invasions may be explained by the historical coexistence of predator-and-prey through evolutionary time scale. After enacting Invasive Alien Species Act in Japan in 2005, Largemouth Bass and Bluegill were selected as Invasive Alien Species which should be strictly controlled, while snakeheads were included in a tentative list of invasive species which require special attention. However; in a renewed National Invasive Species List (2015), all mention of snakeheads disappeared.

Designing snakehead outreach and messaging for behavior change and impact

TIM CAMPBELL AND SARAH FOX

University of Wisconsin
445 Henry Mall
Madison, WI 53506
Tim.campbell@wisc.edu

Poster presentation

Abstract –Public outreach programs have been effective at raising awareness and inspiring water users to take action to stop the spread of aquatic invasive species. Consistent branding combined with community-based social marketing principles has helped drive this efficacy in outreach. In order to ensure that outreach related to Northern Snakehead is having a similar effect, we completed an audit of snakehead outreach items that were designed for public consumption. We classified each item by purpose and message frame to better understand previous outreach strategies. Through this process, we hope to recommend future directions for public outreach relating to Northern Snakehead.

Evaluation of Northern Snakehead diets in Virginia tidal rivers and lakes

MIKE W. ISEL AND JOHN S. ODENKIRK

Virginia Department of Game and Inland Fisheries
1320 Belman Rd., Fredericksburg, VA 22401
Mike.Isel@dgif.virginia.gov

Oral Presentation

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Abstract - The non-native Northern Snakehead *Channa argus* was first documented in the Potomac River system in 2004. Since then, range in Virginia has expanded to include other rivers and numerous impoundments as a result of migration and illegal introductions. Most reservoir populations were discovered after 2012. Through 2017, almost 4,000 Northern Snakehead had been collected via VDGIF electrofishing surveys resulting in a robust dataset. This has provided an opportunity to investigate food habits of Northern Snakehead in both lotic and lentic systems which may assist with management and better understanding of potential community impacts. Incidence of occurrence (n = 677) of identifiable prey items was evaluated since 2004, however wetted weights (n = 370) were not recorded until 2014. A total of 30 different prey items were identified from Northern Snakehead stomachs taken from rivers, while 7 different items were identified from lakes. Top three food items (in order) based on frequency of occurrence in rivers were Banded Killifish, Bluegill, and crayfish, while Bluegill, frogs, and Yellow Perch were most consumed in lakes. Most important food items (in order) based on % wetted weight in rivers were Bluegill, Gizzard Shad, and Banded Killifish, while Bluegill, Yellow Perch, and frogs contributed the most mass in lakes.

Students engaging the environment: an eDNA outreach survey for the presence of aquatic invasive species

JAMES W CASEY, RODMAN GETCHELL AND DONNA CASSIDY-HANLEY

Department of Microbiology and Immunology
College of Veterinary Medicine
Cornell University
Ithaca, NY 14853
Jwc3@cornell.edu

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Abstract - This project develops a joint school/research eDNA approach for assessing presence of aquatic invasive species and providing a collaborative research model that allows middle and high school students to determine invasive species levels in local waterways. New York students and Cornell researchers working together have generated significant data regarding levels of invasive species in lakes, streams, and rivers throughout New York. In three years since the program's inception, over 72 schools and 1200 students throughout New York have helped to monitor invasive fish species. Students access results through the FishTracker web page that also provides an avenue to further explore ecological consequences of invasive species and DNA biochemistry. The program engages students from a broad spectrum of society, ranging from students at small rural schools to underrepresented inner city minorities. To date, water samples from 232 sites have been assayed for the presence of seven invasive fish species: Round Goby *Neogobius melanostomus*, four Asian carp species (*Ctenopharyngodon idella, Hypophthalmichthys molitrix, Hypophthalmichthys nobilis, Mylopharyngodon piceus*), Northern Snakehead *Channa argus*, White Perch *Morone Americana*. Project results are summarized on our web site (https://fishtracker.vet.cornell.edu/) and updated regularly. We will present methodology developed for targeting eDNA from specific fish species and will show current results for snakehead surveys in New York waters.

Defining electrical settings to increase sampling efficiency and precision for Northern Snakehead *Channa argus*

ALAN J. TEMPLE[1] AND JOSHUA NEWHARD[2]

[1]*U.S. Fish & Wildlife Service*
National Conservation Training Center
Alan_Temple@fws.gov

[2]*U. S. Fish and Wildlife Service*
177 Admiral Cochrane Drive
Annapolis, MD 21404

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Abstract - The goal was to identify electrical outputs that improve capture efficiency and precision of electrofishing for Northern Snakehead. The lab portion determined 1) electrical waveform characteristics causing capture-prone responses (e.g., attraction to anode, immobilization), and 2) capture-prone response thresholds (voltage gradients). Taxis was consistently observed with direct current (DC) and 30 pps, 24% duty cycle pulsed direct current (PDC). For immobilization using PDC, 60 and 120 pps frequency and 20 – 40% duty cycle waveforms had the lowest electrical thresholds (most efficient). Low duty cycle symmetrical and asymmetrical alternating current (AC) waveforms caused immobilization at higher thresholds compared to PDC but had the advantage of reduced electrical loading. Snakehead effective conductivity (C_f) was 81 µS/cm. The field portion consisted of mapping the electric field of a 2-boom electrofishing boat powered by a 7.5 GPP and subjectively evaluating success of three waveforms: 120 pps PDC, 30 pps PDC, and AC. When electrofishing was deemed effective in 207 µS/cm ambient water conductivity, threshold settings were 278 V_{peak} and 23 $Amps_{peak}$ (PDC 30 pps, 13%) and 230 V_{peak} and 19 $Amps_{peak}$ (AC 60 Hz, 44%). Immobilization thresholds for 300-350 mm snakeheads occurred 164 cm distant (30 pps PDC) and 121 cm distant from anode center (AC). The taxis threshold was located 209 cm distant (30 pps PDC). PDC 120 pps and AC waveforms appeared to be more effective in shallower, narrower and less vegetated waters. PDC 30 pps had higher catch rates in deeper, vegetated systems. Example output standardization tables were developed for typical 2-boom electrofishing boats.

Mycobacteriosis among Northern Snakehead *Channa argus* from Potomac River tributaries

CHRISTINE DENSMORE, ANNE HENDERSON, DEBORAH IWANOWICZ, LUKE IWANOWICZ

U.S. Geological Survey, Leetown Science Center
11649 Leetown Road
Kearneysville, WV 25430
cdensmore@usgs.gov

Poster Presentation

Abstract - Piscine mycobacteriosis, caused by infection with several species of mycobacteria, is a chronic disease of fishes that occurs worldwide. Effects on fishes range from subclinical to fulminant epizootics with concurrent mortality. Some species of *Mycobacteria* that infect fishes also have zoonotic potential and associated human health implications. Mycobacteriosis has been reported among cultured snakehead species in Asia, and in 2014, it was identified in a Northern Snakehead collected from Pohick Bay in the Potomac River system. In 2015 and 2017, Northern Snakehead collected from Potomac River tributaries were screened for health parameters including the presence of mycobacteriosis. None of the fish collected displayed gross external or internal evidence of disease associated with mycobacteriosis. A subset of the health-screened snakehead was assessed for presence of *Mycobacterium* sp. and associated lesions through histopathological analysis and *Mycobacterium*-specific microbial culture methodology. In 2015 and 2017, approximately 60% of Northern Snakehead examined had chronic granulomatous inflammation within internal organs (predominantly kidney or spleen) consistent with chronic mycobacterial associated lesions. Presumptive *Mycobacterium* sp. (acid fast-positive organisms grown on media selective for *Mycobacterium*) were recovered from kidney/spleen tissues from approximately 33% of fish collected and analyzed in 2015 and 2017. Nucleic acid sequence analysis to determine species of *Mycobacterium* isolates is underway. Further investigation into Northern Snakehead mycobacteriosis in the Potomac River system and throughout the region will help to ascertain prevalence and potential impacts of the disease among these fish and other aquatic wildlife.

Clinical conundrum: An unusual case of coelomic distension associated with fluid accumulation in a captive Northern Snakehead

ANNE HENDERSON AND CHRISTINE DENSMORE

U.S. Geological Survey, Leetown Science Center
11649 Leetown Road
Kearneysville, WV 25430
ahenderson@usgs.gov

Poster Presentation

Abstract - A group of several Northern Snakehead *Channa argus* are maintained at the USGS Leetown Science Center (Kearneysville, WV) for display and educational purposes. One of these fish, a male approximately three years of age, 445 mm total length, and 1 kg body weight, developed a gradual coelomic distension over the course of a few months with no other apparent clinical signs. The fish was anesthetized for diagnostic evaluation, but the fish died within a day after the procedure. On necropsy, approximately 200 ml of an amber transudate fluid was removed from a fibrous cystic structure that appeared to be associated with spleen tissue in the coelomic cavity. Culture of the fluid on BHIA bacterial agar media yielded no microbial growth in 72 hr. No other abnormalities were noted on necropsy with the exception of some compression of other coelomic organs, particularly the swim bladder. The fish appeared to be in good body condition overall. As no other organs were associated with the cystic structure and no additional splenic tissue was observed apart from that within the walls of the cyst, a splenic cyst is the most likely diagnosis. Histological evaluation is underway to further describe any tissue or cellular changes in the spleen and other coelomic organs and to help elucidate the etiology. To our knowledge, this is the first report of this condition in this species.

Northern Snakehead distribution in Virginia

AARON BUNCH[1], JOHN ODENKIRK[2], MIKE ISEL[2], AND SCOTT HERRMANN[1]

[1]*Virginia Department of Game and Inland Fisheries*
3801 John Tyler Memorial Highway
Charles City, VA 23030
Aaron.bunch@dgif.virginia.gov

[2]*Virginia Department of Game and Inland Fisheries*
1320 Belman Road
Fredericksburg, VA 22401

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Abstract - Northern Snakehead *Channa argus* were first discovered in the Potomac River system in 2004 and have spread into nearly the entire tidal Potomac system and several additional coastal tributaries in Virginia. Ecosystem-level impacts of this non-native species are uncertain. A centralized statewide database containing all Northern Snakehead observations was used to develop distribution maps. Most fish were collected during standard electrofishing surveys, while other data sources included verified reports from anglers and commercial fishers. The species has been collected in every major drainage in Virginia with the most recent being the James River watershed. Anglers have illegally introduced the fish into numerous impoundments. Northern Snakehead have shown a propensity to survive relatively high salinities during migration**,** as river mouths entering the Chesapeake Bay have elevated salinity relative to upper river sections and tributaries. Movement likely occurs downstream during seasonal freshets and other periods of high freshwater inflow to the Bay system, and upstream during spring pre-spawn dispersal**.** Continued monitoring is needed to document future spread and distribution.

Marginal increment analysis of Northern Snakehead otoliths

QUINTON PHELPS[1], HAE KIM[1], AND CATHERINE LIM[2]

[1]*West Virginia University*
Morgantown, WV
quinton.phelps@mail.wvu.edu

[2]*Virginia Department of Game and Inland Fisheries*
12104 South Washington Highway
Ashland, VA 23005

Oral Presentation

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Abstract - The Northern Snakehead *Channa argus* population in the Potomac River has been the subject of considerable study and sampling effort since its discovery in 2004 including the collection of otoliths harvested annually from March through October. Age and growth information obtained has indicated length at age is highly variable with rapid growth in the first three years. Some individuals attained up to 381 mm total length by the end of the first year (age 0) and 559 mm as an age-1. Although snakehead otoliths viewed in the transverse plane appear to have distinct, narrow bands interpreted as annuli; it is important to have validation confirming the periodicity of the putative annuli especially given the high variability in growth rates. Marginal increment analysis is one method that has traditionally been employed to confirm this assumption. Although not all otoliths previously collected for age determination will be suitable to use for precise measurements, there are otoliths from snakeheads of many sizes (130mm -895mm) and ages (0 -10 years) to complete this task.

Fishing social network to track snakehead angler catches and distribution

DUSTIN R. MARTIN

ReelSonar, Inc.
dustin@reelsonar.com

Poster Presentation

Abstract - Invasive fish species such as Northern Snakehead *Channa argus*, have potential negative consequences on their environments, and it is important to track their distributions. However, traditional surveys to capture distribution data are often cost and time prohibitive. Angler catch records, by anglers self-supplying locations of catches, are often used to examine range expansions of invasive species. However, these data are sparse, difficult to obtain, and nearly impossible to verify. One potential method to gather this information is to use online fishing social networks that already operate on a larger spatial scale. Users may provide information on species, location, length, as well as a photo of the catch that can be used to verify species. We used the NetFish mobile application and social platform to examine user's catches and location data and how that information can be used to examine distributions and timing of range expansion. Even though snakehead, *Chana* spp. are fairly rare, the NetFish app users' have recorded 22 catches since July 2017. The majority of these catches were in the Mid-Atlantic region, however there were a few recorded outside of this region that may represent range expansions. We must acknowledge the caveat that this is angler-provided data, and although photos and locations were provided, we cannot guarantee the accuracy of the data and must take precautions to help ensure validity.

Contaminant levels of polychlorinated biphenyls (PCBs) in edible fillets of Northern Snakehead *Channa argus* from Virginia Potomac River tributaries

GABRIEL DARKWAH AND RICK BROWDER

VA Department of Environmental Quality
Gabriel.darkwah@deq.virginia.gov

Poster Presentation

Abstract - Northern Snakehead *Channa argus* was relatively recently introduced to the Potomac River drainage and have become an important recreational and commercial fish species. Several Virginia Potomac River tributaries have fish consumption advisories established by the Virginia Department of Health (VDH) for some fish species due to Polychlorinated Biphenyls (PCBs), however, data regarding contaminant load of PCBs in Northern Snakehead was lacking. To address this concern, from 2014 to 2016, VADEQ tested 19 composite samples of edible filets of Northern Snakehead for total PCBs at six Potomac River tributary sites provided by the Virginia Department of Game and Inland Fisheries. Composite samples consisted of edible filets of 2-5 individuals of similar size (i.e. the smallest fish in each composite was within 75% of the length of the largest fish). Length and weight ranges were 540 to 868 mm and 1487 to 6200 g. Tissue lipid content ranged from 3.62 to 12.34%, and total PCBs ranged from 5.16 to 105.30ug/kg-wet weight with mean equal to 32.51ug/kg-wet weight among all composite samples. The mean concentration of total PCBs in edible filets was below the VDH consumption advisory trigger value of 100ug/kg-wet weight. [1] Based on these data, which are the most current at this time, VDH does not see a need to add Northern Snakehead to the fish consumption advisory for Potomac River tributaries. Information gained from this monitoring may be helpful to anglers desiring to harvest Northern Snakeheads and may aid fisheries managers.

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1 State Board of Health. 12/31/2012. Advisory Guidelines for Fish with PCBs. Virginia Regulatory Town Hall

Movement of Northern Snakehead within the White River, Arkansas System

MICAH D. TINDALL[1], STEVE E. LOCHMANN[2], JUSTIN M. HOMAN[1]

[1]*Arkansas Game and Fish Commission*
1201 N. Main Street
Brinkley, Arkansas 72021
Micah.tindall@agfc.ar.gov

[2]*University of Arkansas at Pine Bluff, Aquaculture/Fisheries Center*
1200 N. University, Box 4912
Pine Bluff, Arkansas 71601

Poster Presentation

Abstract - Northern Snakehead *Channa argus* were first discovered in Arkansas in 2008. Little effort has been expended understanding their movements among the many interconnected waterways of the White River system. To characterize these movements, Northern Snakehead were implanted with ATS radio transmitters and released into three tributaries of the White River: the Cache River, Wattensaw Bayou, and Bayou Des Arc. Using stationary receivers, movements made by these individuals were monitored. In particular, we observed choices individuals made at the intersection of a tributary and the main stem of the White River. Behaviors included movement within the tributary and along the White River. These patterns have been analyzed across two seasons: winter (Jan-Mar) and spring (April-June). Additionally, attempts were made to locate fish every two weeks using a mobile receiver. Confirmed locations during mobile tracking were marked with a GPS. Mobile tracking allowed us to further examine Northern Snakehead movements on shorter time scales.

Age and growth of Northern Snakehead in eastern Arkansas

JUSTIN M. HOMAN AND MICAH D. TINDALL

Arkansas Game and Fish Commission
1201 N. Main Street
Brinkley, Arkansas 72021
Justin.homin@agfc.ar.gov

Poster Presentation

Abstract - Northern Snakehead *Channa argus* were first documented in the Piney Creek basin of Eastern Arkansas in 2008. Age and growth of this species from populations within this introduction area have not been reported. To assess age and growth of Northern Snakehead in the Piney Creek basin, otoliths were removed from 51 individuals collected during spring 2008. Mean length at age and a von Bertalanffy growth curve will be presented from this sample. Also, fish collected during May 2018 will be aged, and growth data will be presented. These data will be used to assess potential changes in growth patterns since introduction. Age and growth data will be compared to data from other populations around the world. This study will add to information available about the age and growth of Northern Snakehead within non-native habitats.

Proposed standard-weight (*Ws*) equation and size structure indices for Northern Snakehead

HAE H. KIM[1], JASON A. EMMEL[2], AND QUINTON E. PHELPS[1]

[1]*West Virginia University, Morgantown, WV*
Hhk0003@mix.wvu.edu

[2]*Solitude Lake Management, Charlottesville, VA*

Poster Presentation

Abstract - Northern Snakehead relative weight and size structure indices are useful tools for fish biologists to characterize fish condition and size structure. However, these indices do not currently exist for Northern Snakehead *Channa argus*. We complied length-weight data from four established populations of Northern Snakehead in North America across five states and four drainages (*N=2,338*). We used the regression-line-percentile (RLP) method to develop a standard-weight equation for Northern Snakehead. The RLP method uses the 75th percentile as a benchmark for standard weight. Based on this approach, we propose a metric standard-weight equation as $\log_{10}(Ws)=-5.138+3.041*\log_{10}(TL)$ with a minimum length of 200mm; W_s is weight in grams, and TL is total length in millimeters. For calculating proportional size distribution (PSD), we proposed the following length categories: stock=19 cm; quality=34 cm; preferred=42 cm; memorable=56 cm; and trophy=70 cm. Population level indices developed in this study should help provide fish biologists another set of tools to describe invasive Northern Snakehead populations in North America.