Maine Department of

Inland Fisheries & Wildlife

Report back to Legislature

On Resolve Chapter 18

Resolve, To Require the Department of Inland Fisheries and Wildlife To Conduct a Study on the Use of Rubber lures and Nondegradable Fishing hooks and Lures

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EXECUTIVE SUMMARY

The development of this report is a result of a legislative resolve passed in 2013 (LD 42) titled "Resolve, To Require the Department of Inland Fisheries and Wildlife (Department) to Conduct a Study on the Use of Rubber Lures and Nondegradable Fishing Hooks and Lures."
To meet the reporting requirements outlined in LD 42, this report:

1) summarizes published literature and/or other forms of relevant information regarding the effects of soft plastic lures (SPLs) and non-degradable hooks on freshwater fish;
2) presents field and observational data collected by the Department in 2013;
3) reviews information obtained from the fishing tackle manufacturing industry; and
4) presents recommendations regarding angler education and outreach, enforcement, and Department initiatives.

- Soft plastic lures are popular tackle among many sport fisheries in North America. Discarded SPLs have been documented in many Maine lakes by the Department and others; the ingestion of these SPLs by salmonids is a growing concern expressed by anglers and fisheries managers.
- The Department has extensively searched for relevant data or other information on the effects of SPLs on freshwater fish, fish health, and on the environment.
- To the Department's knowledge, there is currently one peer-reviewed manuscript specific to the effects SPLs have on freshwater fish health in Maine.
- The Department was not able to identify literature on the effects of non-degradable hooks on freshwater fish. Steel hooks typically oxidize and degrade in freshwater. pH and the oxygen concentration of water are main factors affecting the oxidization and degradation of steel hooks.
- The Department summarized plastic toxicity and the effects various plastic products have on aquatic organisms.
    - Plasticizers, such as phthalates, are a major chemical constituents of plastics. Phthalates are frequently used in soft plastics and are used to render SPLs flexible and can comprise a substantial proportion of SPL weight.
    - Phthalates have been documented to negatively affect aquatic life and may concentrate in some organisms.
    - The constituents of biodegradable SPLs are not fully advertised and there are no established standards for what constitutes a biodegradable SPL.
    - There is no, or very limited, information on the time period for SPLs to biodegrade.
    - Manufacturers are not currently required to list the ingredients of SPLs which makes evaluating the effects of discarded SPLs on aquatic biota difficult to determine.
- The Department conducted a cursory field assessment and data review to determine if discarded SPLs in Maine's freshwater lakes and ponds could be quantified. The Department also evaluated the degradation of a biodegradable SPL in freshwater.
    - Soft plastic lures were documented at higher occurrences in Region A waters than in any other regional water surveyed (Regions A, B, and C).

- Multiple piles of discarded SPLs (e.g., one pile = 10-20 individual SPLs) were observed at the toe of public boat ramps. This was indicative of anglers purposely dumping used SPLs after fishing and prior to trailering their boat out of the water.
- The majority of SPLs observed in all regional waters surveyed were of the following variety: worms, twirl tail grubs, and lizards.
- Some coated hooks were still present in degraded SPLs; these hooks appeared and felt new in comparison to the SPLs that appeared to be very old. In Region C waters, non-coated hooks were observed in few SPLs, but had mostly degraded (i.e. rusted).
- During the Department's Fish Stomach Content Database search, SPLs were documented in 5.2% of lake trout (togue) surveyed from Sebago Lake, Region A between 1994 – 2003 and 3.2% of lake trout surveyed from Sebec Lake, Region E between 1985 – 2008. Only 2 ingested SPLs from lake trout caught by gill netting (0.4%) were documented in Region C's database from 2005 - 2013.
- The Department documented SPL ingestion by other salmonids and largemouth bass between 2004 – 2012 in 22 southern Maine waters. Brook trout and lake trout had the highest occurrences of ingested SPLs.
- Bass tournament organizers volunteered to submit SPL discard and recycling information to the Department. The results indicated that out of approximately 500 participating boats, approximately 310 pieces of SPLs were lost during fishing. There was active participation by anglers to collect and recycle SPLs and over 12 pounds of used/discarded SPLs were submitted for recycling in 2013.
- During a SPL water exposure study, after 1 week, 1 month, and 8 months post-treatment, a popular sinking minnow SPL advertised as 100% biodegradable showed no signs of degradation. The SPL retained the same observable physical characteristics and elasticity of a new, identical SPL. Signs of degradation or swelling of the SPL were anticipated after 8 months, however results are not surprising since the manufacturer advertises that despite the SPL being 100% biodegradable, the SPL will not dissolve "off the hook."

* The Department contacted several companies that produce or sell SPLs including Pure Fishing, Inc. and Big Bite Bates, Inc. The Department also received a response letter from the American Sportfishing Association (ASA). Most companies did not return calls and/or did not provide any data or other information regarding the "effects of disposal and ingestion of soft baits made of rubber and soft plastic and longevity of nondegradable hooks for fishing, and the performance and durability of biodegradable alternatives."
* Pure Fishing, Inc. (the parent company to Berkley®, Gulp!® and many other rod, reel and lure companies), said that Pure Fishing, Inc. is still testing the rate at which their products break down and what their products break down into.
* In a letter from the ASA to the Department dated November 26, 2013, the ASA indicated that "The amount of these products [phthalates] in soft baits is small and not a health hazard to fish or humans," however in the same letter the ASA later stated that plasticizers, such as phthalates, "probably account for roughly 75% of all plasticizers used for PVC."
* Despite the ASA claiming that "phthalates have no adverse effects in low dosages and are excreted from organisms quickly", The Agency for Toxic Substances and Disease

Registry documents that some phthalates have been found at high levels in fatty foods such as dairy products, fish, and seafood which are most likely to absorb phthalates

- The Maine Bass Anglers Sportsmen's Society (B.A.S.S.) Nation provides plastic Re-Baits® bags to all B.A.S.S. members for use in collecting used SPLs during fishing tournaments. Re-Baits® re-cycling canisters are located at several boat launches in Maine to make the public aware of the recycling effort. The SPLs collected are melted down, remolded, and provided to children involved in youth fishing clubs at no charge.

RECOMMENDATIONS

Education

- Actively support and participate in the development of public information and education materials to provide for increased public awareness of the potential impacts of SPLs on freshwater environments and fish species.
- The Department could establish a process for public education and outreach regarding the effects of discarded SPLs and the process by which anglers should discard or recycle used SPLs. Education and outreach materials could be in the forms of permanent signage at boat launches, SPL collection boxes at boat launches for recycling, newspaper and television advertisements, and printed material in the fishing law books and on the Department's website. For example, in the 2014 fishing lawbook, the Department discusses the effects of discarded SPLs, how to properly dispose of used SPLs, and how to rig SPLs for maximum hook retention.
    - The Department could encourage the general angling public to participate in SPL recycling programs such as the B.A.S.S. Re-Baits® SPL recycling program. This could include providing SPL collection bags with each purchase of a Maine fishing license and/or advertising the Re-Baits® program in print on the Maine fishing license. Additionally, Re-Baits® collection canisters should be installed at more boat launches, including the lakes and ponds surveyed in this study.
- The Department could encourage retailers and anglers in Maine to consider selling and buying only advertised biodegradable SPL products and encourage manufacturers to develop new alternatives that are made of 100% biological material (gelatin, fish/plant/mineral oils, etc.).
- The Department could encourage local (state) manufacturers of recycled SPLs to advertise their products more widely, for example in the Department's fishing lawbook as part of continued angler education and product promotions.
- The Department could encourage retailers, fishing clubs, and tournament organizers to promote and educate anglers on improved approaches to retain SPLs on hooks. For example, a small o-ring or zip tie can be placed in the middle of the SPL, and the hook placed under the o-ring/zip tie. If the hook is pulled through the SPL, the o-ring/zip tie retains the SPL on the hook. SPL retention kits are available from retailers, however improved angler education may be needed to better promote this SPL retention strategy.

Enforcement

- Support and encourage rigorous enforcement of state and local laws and regulations pertaining to littering of SPLs in freshwater environments.
  - The Fisheries Division could work with the Warden Service to raise awareness of litter issues caused by discarded SPLs in Maine's lakes and ponds.

Department Initiatives

- The Department could consider the addition of a new tournament permit requirement that would necessitate an SPL collection and recycling effort during each permitted tournament.
- The Department has an established, standardized process to document the occurrences of ingested SPLs by salmonids. This is in the form of regional databases that document fish stomach contents during biological and creel surveys. The Department will continue to collect fish stomach content data from various waters throughout the State.

Other

- The tackle industry could be encouraged to continue to develop the advancement of SPL hook retention and SPLs that are less likely to be pulled off by fish after repeated use.
- The MDIFW is currently working with the Department of Environmental Protection's (MDEP) Surface Water Ambient Toxins program to develop a laboratory study focused on determining the chemical constituency of biodegradable and non-biodegradable SPLs and study the effects of SPL leachate (i.e. phthalates) accumulation in fish tissue. The MDEP has issued a Request for Proposals and received cost estimates from several labs capable of performing these chemical analyses.

RECOMMENDED LEGISLATION

Requiring the sale and use of only biodegradable SPLs is currently not a solution. There is currently no standard national or international definition for what constitutes "biodegradable plastic" and SPLs specifically. Based on the information presented in this report, the Department does not recommend any legislation at this time.

INTRODUCTION

The development of this report is a result of a legislative resolve passed in 2013 (LD 42) titled "Resolve, To Require the Department of Inland Fisheries and Wildlife to Conduct a Study on the Use of Rubber Lures and Nondegradable Fishing Hooks and Lures," that reads in part:

Sec. 1. Department of Inland Fisheries and Wildlife to study effects of artificial fishing lures made of rubber and soft plastic and nondegradable hooks for fishing. Resolved: That the Department of Inland Fisheries and Wildlife, referred to in this resolve as "the department," shall study the effects of artificial fishing lures made of rubber and soft plastic and nondegradable hooks for fishing on fish and wildlife species in the State, other states and countries. The department shall review and analyze the existing literature on the effects of artificial fishing lures made of rubber and soft plastic and the longevity of nondegradable hooks for fishing, including field and laboratory studies, and conduct direct observation of multiple species of fish in waters of the State or in waters that contain chemical characteristics that are similar to waters of the State. As part of its study, the department may seek and include in its report information obtained from fishing tackle manufacturers or fishing tackle manufacturers' associations regarding the effects of disposal and ingestion of soft baits made of rubber and soft plastic and longevity of nondegradable hooks for fishing, and the performance and durability of biodegradable alternatives.

To meet the reporting requirements outlined in LD 42, this report: 1) summarizes published literature and/or other forms of relevant information regarding the effects of soft plastic lures (SPLs) and non-degradable hooks on freshwater fish; 2) presents field and observational data collected by the Maine Department of Inland Fisheries and Wildlife (Department) in 2013; 3) reviews information obtained from the fishing tackle manufacturing industry; and 4) presents recommendations and recommended legislation regarding SPL usage in Maine.

BACKGROUND

Soft plastic lures are popular tackle among many sport fisheries in North America. In Maine, SPLs are used frequently in the bass fishery and are often lost to the aquatic environment when lines accidentally break, SPLs become hooked on underwater structures (e.g., rocks, logs, submerged vegetation), or when old or heavily used SPLs disengage from the line during casting. Discarded SPLs have been documented extensively in many Maine lakes by the Department (F. Brautigam and J. Seiders, pers. comm.) and others, and the ingestion of these SPLs by salmonids is a growing concern expressed by anglers and fisheries managers (Danner et al. 2009).

LITERATURE REVIEW

The Department has extensively searched for relevant data or other information on the effects of SPLs on fish, fish health, and on the freshwater environment. To the Department's knowledge, there is currently only one peer-reviewed manuscript specific to the effects SPLs have on freshwater fish health in Maine (Danner et al. 2009). Several other studies were found, and though not specific to Maine or New England, we summarize them briefly below.

The abstract for Danner et al. 2009 is provided below and the full manuscript is provided in Appendix A.

Danner, G.R., J. Chacko, and F. Brautigam. 2009. Voluntary Ingestion of Soft Plastic Lures Affects Brook Trout Growth in the Laboratory. North American Journal of Fisheries Management, 29: 352-360.

Thirty-eight brook trout *Salvelinus fontinalis* were fed a commercial trout diet mixed with a free-choice assortment of soft plastic lures (SPLs) over a 90-d period. Fish growth was recorded and compared with that of a control group. The brook trout readily ate the SPLs from the water's surface as well as from the tank bottom. At the conclusion of the study, SPLs were recovered from the stomachs of 63% of the test fish. Several fish stomachs contained multiple lures. Twelve percent of the fish voluntarily ingested more than 10% of their body mass in SPLs. These fish lost a significant amount of weight during the study, had a significant decrease in body condition factor, and began displaying anorexic behaviors. For these reasons, anglers should be discouraged from discarding used SPLs in trout waters.

An unpublished field and laboratory study was recently conducted in Ontario, Canada on the effect of discarded SPLs on fish and the environment (Cooke Lab, Carleton University, Unpublished Data, *In Review*). Unpublished results from field surveys indicate that the deposition rate of SPLs was about 50 per mile of shoreline per year in one lake. Despite SPLs varying in composition, SPL decomposition was not readily observed in 10 brands evaluated (including various products marketed as "biodegradable") during a 2-year water exposure laboratory study. However, most SPLs swelled and remained in that state throughout the study. In cold water treatments, SPLs increased an average of 61% in weight and 19% in length, while in warm water treatments SPLs increased an average of 205% in weight and 39% in length. The two biodegradable SPLs evaluated experienced the least change in weight and length during the study in comparison to the other 8 SPL brands. A summer creel survey revealed that 17.9% of anglers reported finding at least one ingested SPL when cleaning lake trout. However, results from gill net surveys for lake trout and angling surveys for smallmouth bass indicated lower SPL ingestion rates (2.2% and 3.4% respectively) than ingestion rates reported by anglers. The most common SPL found in lake trout gastrointestinal tracts were stick baits. Of the lake trout with ingested soft plastics, 9 out of 12 fish contained at least one stick bait.

The Maryland Department of Natural Resources (MD DNR) summarized bass fishing and the effects of soft plastic lures in The Maryland Natural Resources Magazine (Love and Sewell, Summer 2012 Issue). The MD DNR reported that discarded SPLs were ingested by largemouth bass, but they did not document SPL discard rates from Maryland waters. The MD DNR also noted that SPL recycling programs exist and that the MD DNR works with the Maryland Bass Federation Nation and the Bass Anglers Sportsmen's Society regarding public outreach and education regarding recycling SPLs. The 2012 MD DNR summary on bass and the effects of soft plastic lures is provided in Appendix B.

In a related study, the effects of chemical attractant lures on smallmouth bass hooking injury and mortality was evaluated (Dunmall et al. 2011). The type of bait used to hook fish had no significant effect on hook penetration depth or location of hooking on the fish. The authors suggested that chemical attractant lures do not affect fish injury rates or survival of smallmouth bass.

Dunmall, K.M. S. J. Cooke, J. F. Schreer & R. S. McKinley 2011. The Effect of Scented Lures on the Hooking Injury and Mortality of Smallmouth Bass Caught by Novice and Experienced Anglers. North American Journal of Fisheries Management, 21 (1): 242-248.

Although regulations prohibiting the use of natural baits are relatively common, new regulations specifically targeting the use of chemical attractants have recently been implemented. While no citeable evidence for these new regulations exists, they may have been promulgated due to a perceived increase in the risk of fish mortality from scented lures compared with unscented lures. The present study investigated the hooking injury and short-term mortality of 238 adult smallmouth bass *Micropterus dolomieu* captured on Lake Erie by both experienced (fished > 100 d/year) and novice (fished < 10 d/year) anglers on actively fished jigs similarly threaded with minnows, nonscented plastic grubs, or grubs scented with chemical attractants. The depth of hook ingestion, the anatomical hooking location, the presence of bleeding at the hook wound, and the total amount of time taken to remove the hook were noted on all captured fish. The fish were then transferred to a retention cage, and their survival was monitored for 72 h before release. None of the fish captured suffered any immediate (<1 h) or short-term (<72 h) mortality. The type of bait used to capture the fish had no significant effect on the depth of hook penetration or the anatomical hooking location. More experienced anglers, however, hooked the fish significantly deeper in the mouth than the novice anglers. These results suggest that the use of the chemical attractants tested in the present study do not deleteriously affect the injury rates or survival of captured smallmouth bass. Therefore, regulations prohibiting the use of chemical attractants on actively fished single-hook jigs for smallmouth bass appear unjustified if the intent was to reduce hooking injury and mortality.

An extensive number of studies have been conducted to evaluate the effects of plastics, discarded fishing lures, lines, and other plastic materials on marine finfish, mammals, birds, and sea turtles. A sub-set of existing literature is summarized below including study abstracts. Based on the ubiquity of plastics in marine waters, and the documented effects plastics have on marine organisms and habitat, the American Fisheries Society (AFS) has developed policy regarding Plastic Debris in Marine Environments (Appendix C).

Andrady, A.L, J. E. Pegram, Y. Song. 1993. Studies on enhanced degradable plastics. II. Weathering of enhanced photodegradable polyethylenes under marine and freshwater floating exposure. Journal of environmental polymer degradation, Volume 1 (2): 117-126.

The weatherability of three types of enhanced photodegradable polyethylene films and corresponding control films were studied under outdoor and marine floating conditions at two exposure sites. Progress of weathering was monitored using tensile elongation at break. In general, both the enhanced-degradable plastics and the corresponding controls degraded slower in marine exposure than in outdoor exposure. This is attributed to the lower sample temperatures (compared to samples exposed outdoors) and to shielding from light afforded by surface fouling in samples exposed floating in sea water. Enhanced-photodegradable polyethylenes disintegrated faster than the control samples in the case of both outdoor and marine exposures. The improvement obtained in marine exposures was greater than that for outdoor exposure of corresponding sample types. This is due to the extremely slow rates of disintegration of control films under marine floating conditions.

Boerger, C.M., G. L. Lattin, S. L. Moore, C. J. Moore. 2010. Plastic ingestion by planktivorous fishes in the North Pacific Central Gyre. Marine Pollution Bulletin 60, 2275–2278.

A significant amount of marine debris has accumulated in the North Pacific Central Gyre (NPCG). The effects on larger marine organisms have been documented through cases of entanglement and ingestion; however, little is known about the effects on lower trophic level marine organisms. This study is the first to document ingestion and quantify the amount of plastic found in the gut of common planktivorous fish in the NPCG. From February 11 to 14, 2008, 11 neuston samples were collected by manta trawl in the NPCG. Plastic from each trawl and fish stomach was counted and weighed and categorized by type, size class and color. Approximately 35% of the fish studied had ingested plastic, averaging 2.1 pieces per fish. Additional studies are needed to determine the residence time of ingested plastics and their effects on fish health and the food chain implications.

Gregory, M.R. 2009. Environmental implications of plastic debris in marine settings—entanglement, ingestion, smothering, hangers-on, hitch-hiking and alien invasions. Phil. Trans. R. Soc. B. 364, 2013–2025.

Over the past five or six decades, contamination and pollution of the world's enclosed seas, coastal waters and the wider open oceans by plastics and other synthetic, non-biodegradable materials (generally known as 'marine debris') has been an ever-increasing phenomenon. The sources of these polluting materials are both land- and marine-based, their origins may be local or distant, and the environmental consequences are many and varied. The more widely recognized problems are typically associated with entanglement, ingestion, suffocation and general debilitation, and are often related to stranding events and public perception. Among the less frequently recognized and recorded problems are global hazards to shipping, fisheries and other maritime activities. Today, there are rapidly developing research interests in the biota attracted to freely floating (i.e. pelagic) marine debris, commonly known as 'hangers-on and hitch-hikers' as well as material sinking to the sea floor despite being buoyant. Dispersal of aggressive alien and invasive species by these mechanisms leads one to reflect on the possibilities that ensuing invasions could endanger sensitive, or at-risk coastal environments (both marine and terrestrial) far from their native habitats.

Laist, D.W. 1987. Overview of the biological effects of lost and discarded plastic debris in the marine environment. Marine Pollution Bulletin 18 (6), Supplement B, 319–326.

In the past thirty years, the use of plastics and other synthetic materials has expanded at a rapid pace. As new uses for these materials have been developed, applied, and made available to more people, the quantity of plastic debris entering the marine environment has undergone a corresponding increase. Many of these products degrade very slowly. Those that are buoyant remain suspended at the sea surface for a long time, and those that are not, sink and remain on the bottom for years or even decades. The accumulating debris poses increasingly significant threats to marine mammals, seabirds, turtles, fish, and crustaceans. The threats are straightforward and primarily mechanical. Individual animals may become entangled in loops or openings of floating or submerged debris or they may ingest plastic materials. Animals that become entangled may drown, have their ability to catch food or avoid predators impaired, or incur wounds from abrasive or cutting action of attached debris. Ingested plastics may block digestive tracts, damage stomach linings, or lessen feeding drives. The deceptively simple nature of the threat, the perceived abundance of marine life, and the size of the oceans have, until recently, caused resource managers to overlook or dismiss the proliferation of potentially harmful plastic debris as being insignificant. However, developing information suggests that the mechanical effects of these materials affect many marine species in many ocean areas, and that these effects justify recognition of persistent plastic debris as a major form of ocean pollution.

Lynch, AM. J., S.G. Sutton, and C.A. Simpfendorfer. 2009. Implications of recreational fishing for elasmobranch conservation in the Great Barrier Reef Marine Park. Aquatic Conservation: Marine and Freshwater Ecosystems 20(3), 312-318.

309 Great Barrier Reef Marine Park recreational fishers were surveyed to examine recreational catch and harvest of elasmobranchs and to explore recreational fishers' handling behaviour and attitudes. Elasmobranchs represented 6% of fishers' total catch of all fish (including released individuals), and 0.8% of fishers' total harvest (i.e. retained individuals) across all survey days. The majority of elasmobranchs caught by fishers were released, primarily because they were perceived as being inedible. Recreational fishers' self-reported handling and release behaviour for elasmobranchs is largely consistent with 'best practice' guidelines except that fishers had low use of circle hooks and barbless hooks, and a significant proportion (33%) reported using stainless steel hooks. Most fishers had positive attitudes towards elasmobranchs, placing high importance on releasing sharks and rays in good condition (86%), high value on their existence (84%), and low value on catching them (63%). Results indicate that post-release mortality is probably the largest source of recreational fishing mortality of elasmobranchs in the Great Barrier Reef. Future research should be targeted at obtaining better estimates of species-specific post-release mortality levels, understanding how post-release survival can be increased by changing fishing

techniques or fisher behaviour, and developing more effective methods of engaging fishers in elasmobranch conservation.

As noted earlier, the Department was not able to identify a large amount of data or published reports regarding the effect SPLs have on freshwater fish or "waters of the State or from waters that contain chemical characteristics that are similar to waters of the State." Additionally, the Department was not able to identify literature on the effects of non-degradable hooks on freshwater fish. However, the Department conducted a literature review summarizing plastic toxicity and the effects various plastic products have on aquatic organisms because this information is highly relevant to the evaluation of SPL effects to aquatic organisms in Maine's lakes and ponds.

Summary of Plastic Toxicity in Aquatic Environments

SPLs are produced by many manufacturers and are widely distributed among retailers. SPLs are highly variable in size, color, shape, scent, elasticity, and chemical constituency. Whereas the effects of ingested SPLs on brook trout (*Salvelinus fontinalis;* BKT) growth and condition factor has been documented (Danner et al. 2009), the bioaccumulation of chemicals leached from ingested SPLs has not. To our knowledge, no data on the effects of chemicals leached from ingested SPLs were found from literature searches using search terms "fish health", "plastic lure leachates", "plastic lure toxicity" and "plastic lure leachates".

Plasticizers, such as phthalates, or phthalate esters, are low-molecular weight polymers; Di-*n*-butyl phthalate (DBP) and di-(2-ethylhexyl)-phthalate (DEHP) are the major chemical constituents of plastics (Metcalf et al. 1973; Stalling et al. 1973; Chandra et al. 2012). Phthalates are used in virtually every major product category including construction, automotive, household products, apparel, toys, packaging and medical products (DeFoe et al. 1990). Phthalates represent 69% of plasticizer use in the United States, 92% in Western Europe, and 81% in Japan (Johnson et al. 2010). The widespread use of phthalate products globally has, within a few decades, resulted in the global contamination by this class of compounds (Bell, 1982). Phthalates are frequently used in soft plastics and are used to render SPLs flexible (Danner et al. 2009; Johnson et al. 2009; Chandra et al. 2012). Phthalates may comprise 10-40% of the total weight of consumer products (Metcalf et al. 1973l; Johnson et al. 2010), and likely comprise a substantial proportion of SPL weight based on the requirement of an SPL to be extremely flexible and "life like".

Recently, fiber-reinforced and biodegradable SPLs have been developed to reduce the potential of SPL loss and spread of harmful chemicals into aquatic environments. The constituents of biodegradable SPLs are not fully advertised and are likely proprietary and vary between manufacturers. Additionally, there are no established standards for what constitutes a biodegradable SPL and likely there is no, or very limited, information on the time period for SPLs to biodegrade. Some producers claim their product is 100% biodegradable and made from all natural ingredients. However, a review of one product quotes the manufacturer as saying that the SPL is a blend of plastic (i.e. 15% polyvinyl-chloride [PVC]) and natural ingredients (i.e. 85% fish and vegetable oils; DeWitt, 2008). In a letter from the American Sportfishing Association (ASA; Appendix D) to the Department dated November 26, 2013, the ASA indicated that "The amount of these products [phthalates] in soft baits is small and not a health hazard to fish or humans," however in the same letter the ASA later stated that plasticizers, such as phthalates, "probably account for roughly 75% of all plasticizers used for PVC."

Even small percentages of PVC in SPLs are of concern; DEHP is the most common plasticizer in PVC formulation for many consumer products (Metcalf et al. 1973; Carnevali et al. 2010). The harmful effects of phthalate esters on the environment and human health are well documented (Metcalf et al. 1973; Blount et al. 2000; Ghorpade et al. 2002; Duty et al. 2003; Lee et al. 2005; (Norman et al. 2005; Lithner, et al. 2009; Oehlmann et al. 2009).

Manufacturers are not currently required to list the ingredients of SPLs which makes evaluating the effects of discarded SPLs on aquatic biota difficult to determine. The negative effects of phthalates on both terrestrial and aquatic organisms have been documented in many studies, however. For example, DEHP has been shown to have diverse biochemical effects in rats, rabbits and pigs, such as inhibition of cholesterologenesis in liver, testes, and adrenal gland, decreased plasma cholesterol levels, and increased fatty acid oxidation in liver mitochondria (Bell, 1982). In the aquatic environment, DEHP can bioaccumulate in a variety of plants and animals (Oehlmann et al. 2009). DEHP degrades very slowly in algae, *Daphnia* spp., mosquito larvae, snails, and clams; it closely resembles Dichloro-Diphenyl-Trichloroethane (DDT) in rate of uptake and storage in the lipids of plants and animals and is concentrated through food chains (Metcalf et al. 1973). Channel catfish (*Ictalurus punctatus*) exposed to 1 µg/l of DEHP for 24 hrs. resulted in tissue residues of 2.6 µg/g (Stalling et al. 1973). Exposure of early life-stages of Atlantic salmon (*Salmo salar*) to DEHP has been shown to interfere with gonad differentiation and cause intersex (ovo-testis) individuals (Norman et al. 2005). In recent studies, plastic leachates have caused acute toxic effects for *Daphnia magna*; of 15 different plastic types tested, PVC was one of two plastics that displayed toxicity in *D. magna* (Lithner et al. 2009). Environmentally relevant doses have also been shown to affect vitellogenesis in zebrafish (*Danio rerio*) in the laboratory (Carnevali et al. 2010).

Phthalates are widespread in aquatic environments worldwide and fish are exposed to phthalates via water, food, and/or sediments, depending on their ecological niche (Oehlmann et al. 2009). In samples from freshwater Canadian lakes and rivers, the level of DEHP was 104 ppb, and DBP was detected in some of the samples (Williams 1973), indicating contamination of the lakes and rivers by phthalates due to widespread use of consumer products containing phthalates. In wild fish in the Netherlands, median [DEHP] ranged from 1.7 µg kg^{-1} to 141 µg kg^{-1} (wet wt.). However, biotransformation of DEHP in fish appeared to be relatively fast (Peijnenburg and Struijs, 2006).

Some biodegradable SPL manufacturers may have eliminated, or greatly reduced, phthalate use in their products, but some proportion of plastics like PVC, or more importantly phthalate esters found in plastics, may still be used in the production of SPLs which could continue to leach phthalates into the aquatic environment. Throughout the United States, fish consumption advisories are listed for various freshwater and marine fish species that contain chemicals that could cause human health risks, such as mercury, polychlorinated biphenyls (PCBs), and dioxins (USEPA 2012). Despite the ASA claiming that "phthalates have no adverse effects in low dosages and are excreted from organisms quickly" (Appendix D), some phthalates have been found at high levels in fatty foods such as dairy products, fish, and seafood which are most likely to absorb phthalates (ATSDR, 2002). The Department has not found fish consumption advisories listed for phthalates.

MDIFW DATA REVIEW

The Department conducted a cursory field assessment to determine if discarded SPLs in Maine's freshwater lakes and ponds could be quantified. A preliminary methodology was developed with guidance and recommendations from Fisheries Division biological staff. The results of this study are preliminary and are unpublished. The Department also searched relevant regional fish stomach content databases for occurrences of ingested SPLs. Finally, the Department evaluated the degradation of a biodegradable SPL in freshwater.

Methodology

Field Study

Between August and October, 2013, the MDIFW conducted underwater surveys via SCUBA equipment to document the occurrence of SPLs in several waters with popular black bass (smallmouth and largemouth bass) fisheries in Fisheries Management Regions A, B, and C (Figure 1). Surveyed waters were chosen based on the following criteria: water clarity (minimal tannins and/or submerged aquatic vegetation), size (100 – 400 acres), similar substrate composition (e.g. hard bottom; sand/gravel/cobble), and presence of largemouth and/or smallmouth bass fisheries. Popular waters on which bass tournaments occur were not specifically targeted for survey mainly because they did not meet the above water clarity or substrate criteria which were anticipated to hinder SPL documentation.

Survey waters chosen were as follows: Region A – Tricky (311 acres) and Coffee (137 acres) ponds; Region B – Minnehonk Lake (99 acres) and Flying Pond (360 acres); Region C – Big Lake (10,305 acres), Lily Pond (32 acres), Georges Pond (380 acres). Big Lake (Region C) was an outlier because it exceeded the acreage criteria. It was initially chosen because it supported a popular bass fishery and had good water clarity conditions for surveys. It was the first water surveyed, and based on initial field results, the decision was made to survey waters between 100 – 400 acres.

Surveyed shoreline segments were chosen based on substrate composition viewed from the boat prior to diver deployment. Shorelines were also chosen based on where anglers have historically been observed to angle for bass. Shoreline surveys were conducted by a SCUBA diver towed behind a 16-foot boat on a planer board and followed standardized MDIFW procedures. The planer board was fitted with a clicker counter to aid in tracking numbers of observed SPLs. One SCUBA diver was towed approximately 100 feet behind a boat at a slow trolling speed to facilitate SPL observation and sample collections when possible. Water depths surveyed ranged between 2 and 19 feet (average 5 – 10 feet depth). Along the survey route, the diver counted SPLs between 6 – 10 feet to both the right and left side of the diver. This distance varied between waters and was limited by water clarity and visibility. Start and stop locations were marked with a hand-held Global Positions System (GPS) unit. At the end of each dive, the SCUBA diver would note the dominant substrate compositions for each shoreline section surveyed, the number and types of SPLs counted, and minimum, maximum and average depths for each dive. Start and end GPS points were used to approximate shoreline distance surveyed. Data were recorded on field forms then later entered electronically.

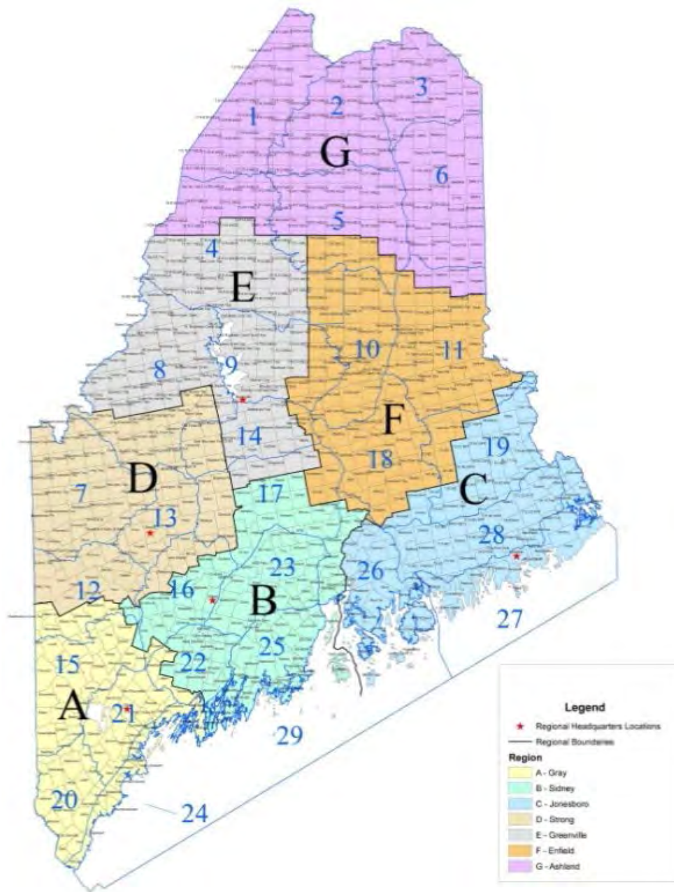

Figure 1. Maine Department of Fisheries and Wildlife Management Regions.

Database Review

In October 2013, the Fisheries Division accessed its Fish Stomach Content Database (SAS v. 9.2) to summarize occurrences of SPLs in fish stomach content data. Database results were summarized in tabular format only.

In addition, the Department's public Bass Working group recommended the Department collaborate with bass tournament organizers to collect information on SPL discard rates and SPL recycling efforts. This information reporting was completely voluntary. The Department received bass tournament forms that reported numbers of SPLs lost during the 2013 tournament season and the results are summarized. The forms noted the boat number, the number of lost SPLs and whether SPLs were recycled or not. When possible, tournament organizers wet weighed submitted SPLs for recycling.

Biodegradable SPL Degradation Evaluation

On March 5, 2013, one commercially popular, and common, sinking minnow SPL marketed as "100% biodegradable" was placed into a 1/2 liter glass jar filled with freshwater obtained from the Kennebec River in Augusta. The jar and SPL were placed on an office windowsill exposed to ambient sunlight and kept at room temperature (~68°F). The biodegradable SPL was removed from the water and inspected for signs of degradation at 1 week, 1 month, and 8 months. Evidence of degradation was recorded as any change in SPL appearance, color, size, shape, feel, and/or elasticity.

Results and Discussion

Field Study

Substrate composition (Figure 2) was similar between all survey waters, except large woody debris (LWD) was not documented in Big Lake (Region C) and was not prevalent in Lily and Georges ponds (Region C). Water clarity was excellent in the Region A waters surveyed but very limited in the Region B waters surveyed.

Soft plastic lures were documented at higher occurrences in Region A waters (Tricky and Coffee ponds) than in any other regional water surveyed (Figure 2). Many discarded SPLs were readily observed visually from the boat prior to the diver survey. Hundreds of additional discarded SPLs were observed at Tricky Pond but were uncounted outside the initial survey area due to time limitations. In addition, multiple piles of discarded SPLs (e.g., one pile = 10-20 individual SPLs) were observed at the toe of the Tricky Pond public boat ramp. This was indicative of anglers purposely dumping used SPLs after fishing and prior to trailering their boat out of the water. In Tricky Pond, one ~10" smallmouth bass attempted to pull a discarded worm from the diver's hand during the survey.

Despite popular bass fisheries on Minnehonk Lake and Flying Pond in Region B, few SPLs were observed. Region B's waters had lower water clarity in comparison to Regions A and C. In addition, Flying Pond had extremely steep sided shorelines which may have contributed to the difficulty documenting discarded SPLs. In Lily Pond, Region C, one ~15" smallmouth bass was observed to pick at, ingest, and regurgitate one SPL (worm) during the survey.

Estimated numbers of discarded SPLs per mile were highest in Region A waters. Lily Pond in Region C had high numbers of SPLs despite small acreage and total shoreline distance (1.04 miles; Figure 3). Few SPLs were calculated for Big Lake in Region C; this was notable because excellent bass habitat was documented. In addition, the survey of Big Lake occurred directly after a bass tournament. The relatively low estimated numbers of SPLs per mile are likely influenced by the size of Big Lake (10,305 acres) relative to the small amount of shoreline surveyed during this study (4.12 miles). These estimates assume uniform shoreline habitat in each water and that bass anglers would evenly fish the entire shoreline and discard/lose SPLs equally along the shoreline.

The majority of SPLs observed were of the following variety: worms, twirl tail grubs, and lizards. Worms and grubs were the only documented SPLs in Region B waters. A higher percentage of lizard SPLs were documented in Region A waters. In Coffee and Tricky Ponds (Region A), some coated hooks were still present in degraded SPLs; these hooks appeared and felt new in comparison to the SPLs that appeared to be very old. In Region C waters, non-coated hooks were observed in few SPLs, and these had mostly degraded (i.e. rusted). This discrepancy in hook degradation may be related to differences in water quality, but is likely more attributable to the hook coatings which led to their preservation in water.

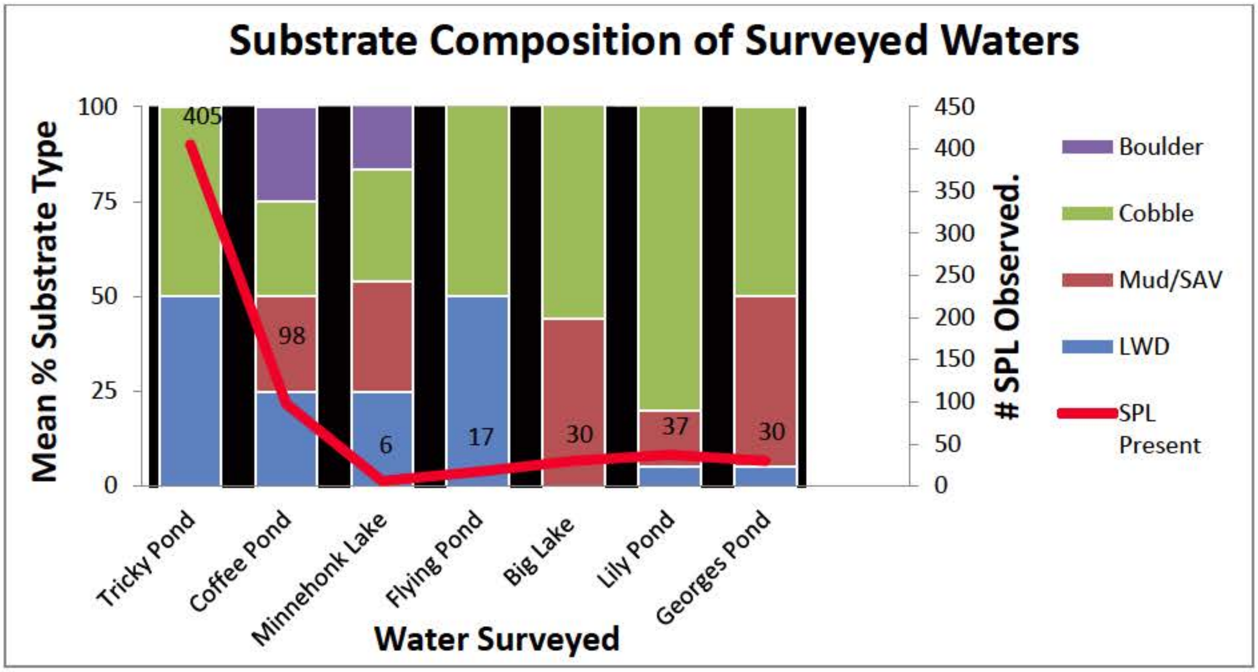

Figure 2. Dominant substrate compositions for surveyed waters in Region A (Tricky and Coffee ponds), Region B (Minnehonk Lake and Flying Pond), and Region C (Big Lake, Lily and Georges ponds). Total numbers of soft plastic lures (SPLs) counted for surveyed portions of each water are indicated by a red line and numbered. Cobble substrates were predominant type in all waters. Large woody debris (LWD) was also documented in most study waters except Big Lake.

Database Review

In October 2013, the Department accessed its Fish Stomach Content Database and searched for occurrences of ingested SPLs. Soft plastic lures (coded "RUB" for rubber or "LUR" for lure) were documented in 5.2% of lake trout (togue) surveyed from Sebago Lake, Region A between 1994 – 2003 and 3.2% of lake trout surveyed from Sebec Lake, Region E between 1985 – 2008. Only 2 ingested SPLs from lake trout caught by gill netting (0.4%) were documented in Region C's database from 2005 - 2013. The percent occurrence of ingested SPLs by lake trout in Sebago and Sebec lakes is similar to other lake trout SPL ingestion data (2.2%; Cooke Lab, Carleton University, Unpublished Data, *In Review*). In addition, the Department documented SPL ingestion by other salmonids and largemouth bass between 2004 – 2012 in 22 southern Maine waters that support black bass fisheries (Table 1). Brook trout and lake trout had the highest occurrences of ingested SPLs.

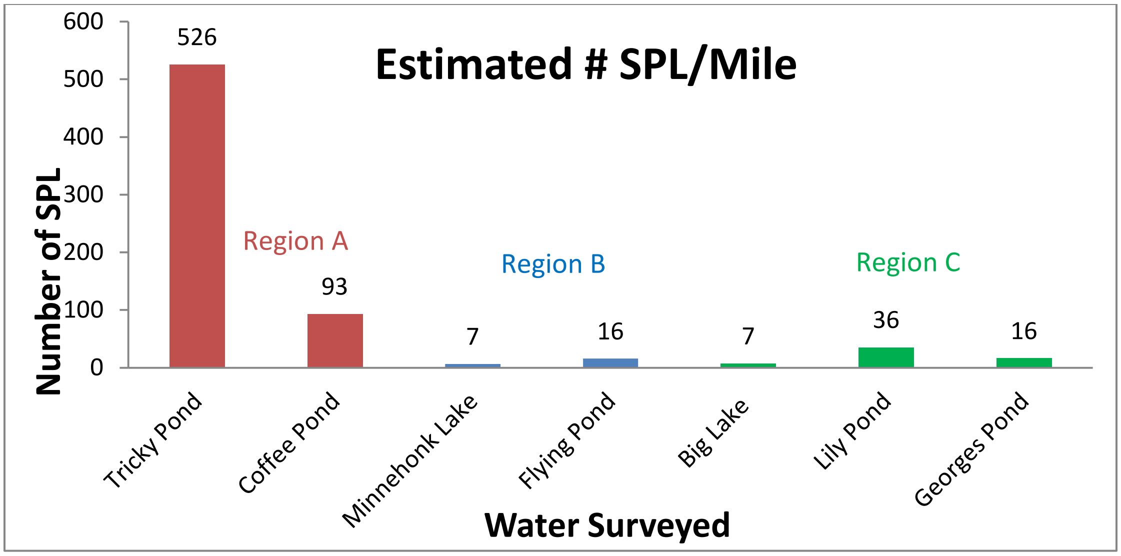

Figure 3. Estimated numbers of soft plastic lures (SPLs) per mile of shoreline for surveyed waters in Region A (Tricky and Coffee ponds), Region B (Minnehonk Lake and Flying Pond), and Region C (Big Lake, Lily and Georges ponds). These estimates assume uniform shoreline habitat for each water and that bass anglers would evenly fish the entire shoreline and discard/lose SPLs equally along the shoreline.

WATER	WAT CODE	YEAR	SPECIES	# OF FISH WITH SPL	# OF FISH SAMPLED	% OF SAMPLED FISH WITH SPL
Kezar Lake	0097	2004	Lake Trout	9	64	14.06
Indian Pond	3480	2004	Splake	1	31	3.23
Bickford Pond	3158	2005	Brown Trout	2	14	14.29
Broken Bridge Pond	3264	2005	Brook Trout	1	33	3.03
Thomas Pond	3392	2005	Largemouth Bass	2	221	0.90
Middle Range Pond	3762	2005	Lake Trout	1	5	20.00
Middle Range Pond	3762	2005	Brown Trout	1	3	33.33
Middle Range Pond	3762	2005	Rainbow Trout	1	7	14.29
Beaver Park Pond #1	3809	2005	Brook Trout	3	81	3.70
Deer Pond	5016	2005	Brook Trout	2	29	6.90
Burnt Meadow Pond	5572	2005	Brook Trout	3	12	25.00
Kezar Lake	0097	2006	Lake Trout	3	38	7.89
Hancock Pond	3132	2007	Brown Trout	1	12	8.33
Stearns Pond	3234	2008	Brown Trout	1	11	9.09
Kennebunk Pond	3998	2008	Brook Trout	2	3	66.67
Upper Range Pond	3688	2009	Rainbow Trout	1	21	4.76
Middle Range Pond	3762	2009	Rainbow Trout	4	44	9.09
Worthley Pond	3764	2009	Brook Trout	1	14	7.14
Highland Lake	3734	2010	Brown Trout	1	17	5.88
Wilson Lake	3920	2010	Brown Trout	1	16	6.25
Tripp Pond	3758	2011	Brown Trout	1	22	4.55
Isinglass Pond	5010	2012	Brook Trout	5	26	19.23

Table 1. Occurrences of soft plastic lure (SPL) ingestion by bass and salmonid species in 22 southern Maine waters that support black bass (largemouth and smallmouth) fisheries. Of the species surveyed, brook trout and lake trout had the highest occurrences of ingested SPLs.

The Department, in partnership with the public Bass Working Group and bass tournament organizers, obtained bass tournament forms that noted voluntary information regarding the numbers of SPLs lost by each participating boat during the 2013 tournament season. To date, the Department received forms from 17 tournaments held between May and September. Reports came from various clubs, the Junior Bassmasters clubs, the Maine Special Olympics, the Maine County Bassmasters Club, and the Governor's Cup. Combined, over 500 boats participated in these tournaments and also voluntarily submitted SPL discard information. A total of 310 SPLs were voluntarily reported as "lost". Many boats participated in recycling lost SPLs and made efforts to recover lost SPLs when possible. Combined, over 12 pounds (wet weight) of SPLs were submitted for recycling from all tournaments.

Biodegradable SPL Degradation Evaluation

After 1 week, 1 month, and 8 months post-treatment, the biodegradable sinking minnow SPL showed no signs of degradation (Figure 4). The SPL retained the same observable physical characteristics and elasticity of a new, identical SPL. Signs of degradation or swelling of the SPL was anticipated after 8 months, however results may not be surprising since the manufacturer advertises that despite the SPL being 100% biodegradable, the SPL will not dissolve "off the hook."

The manufacturer advertises their biodegradable minnow SPL as:

> "…ideal for drifting or jigging. With over 20 years invested in its production…it can actually outperform live bait. The water-based formula disperses over 400 times the amount of scent that soft plastics can offer. Plus, it is 100% biodegradable. But just because it breaks down in water, doesn't mean it will dissolve off the hook. Lures made with this new compound will last just as long as any soft-plastic on the market."

These results are very similar to other unpublished data that indicated two SPL products from the same manufacturer (one of which was the identical sinking minnow used in the Department's study) experienced little change in weight and length during a 2 year water exposure and degradation study in comparison to other SPL brands (Cooke Lab, Carleton University, Unpublished Data, *In Review*).

Figure 4. An advertised 100% biodegradable Berkley® Gulp!® sinking minnow SPL was placed in Kennebec River water to evaluate degradation over time (Left). The SPL was checked at 1 week, 1 month, and 8 month intervals. No signs of degradation were documented during this cursory study (Right).

FISHING INDUSTRY INFORMATION

The Department contacted several companies that produce or sell SPLs including Pure Fishing, Inc. and Big Bite Baits, Inc. The Department also provided the ASA with a questionnaire pertaining to SPL information and data (Appendix D). Most companies did not return calls and/or did not provide any data or other information regarding the "effects of disposal and ingestion of soft baits made of rubber and soft plastic and longevity of nondegradable hooks for fishing, and the performance and durability of biodegradable alternatives."

Dr. Keith Jones, of Pure Fishing, Inc. (the parent company to Berkley®, Gulp!® and many other rod, reel and lure companies), said that Pure Fishing, Inc. is still testing the rate at which their products break down and what their products break down into. Products made with animal products on average should break down in 6 months in the environment (Dr. Jones' best personal guess). The Gulp!® products (which Dr. Jones would not disclose what the components/ingredient are) break down at rates longer than 2 years. In an email from Pure Fishing, Inc. (Appendix E), Dr. Jones provided a link to a study that was conducted on the longevity of ECOGEARAQUA SPLs. The site information indicated that ECOGEARAQUA SPLs are made from biodegradable and water soluble polymers. The SPLs in the ECOGEARAQUA study experienced a 50% reduction in weight after 18 months exposed to lake water. Dr. Jones wrote in an email that Berkley® Gulp!® products would show similar degradation curves to that presented by ECOGEARAQUA (Appendix E).

Big Bite Baits, Inc., report that their product, Biobait©, is 100% biodegradable and made from "all natural ingredients." A review of Biobait© quotes the manufacturer as saying that the SPL is a blend of plastic (i.e. 15% polyvinyl-chloride [PVC]) and natural plasticizers (i.e. 85% fish and vegetable oils; DeWitt, 2008). The company did not clarify this information at the Department's request.

The Department contacted Richard Gaudreau, Maine Bass Anglers Sportsmen's Society (B.A.S.S.) Nation Conservation Director regarding a recycling program for used or discarded SPLs. The Re-Baits® Program was started by Eamon Bolten, Florida B.A.S.S. Nation Conservation Director. This program was initiated to collect SPLs from waters throughout the United States. To date, Mr. Gaudreau indicates the Re-Baits® program has been a great success with many bass clubs participating. Plastic Re-Baits® bags are passed out to all B.A.S.S. members for use in collecting used SPLs during fishing tournaments. Some members have also placed Re-Baits® re-cycling canisters at boat launches to make the public aware of the recycling effort. The SPLs collected from these canisters are sent to Mr. Gaudreau who submits them for recycling. A B.A.S.S. member receives the used/discarded SPLs, melts them down, and uses his own molds to make recycled SPLs. These recycled SPLs are provided to children involved in youth fishing clubs at no charge.

In Maine, Re-Baits® collection canisters are located at: Maranacook Lake (both the Readfield and Winthrop boat launches), Annabessacook Lake, (Annabessacook Road launch), Androscoggin Lake state boat launch, Wilson Pond state boat launch, and the Androscoggin River (Center Bridge launch, Turner; recently stolen). Mr. Gaudreau noted that individual bass clubs monitor the collection canisters and submit the SPLs to him for recycling.

RECOMMENDATIONS

Education

- Actively support and participate in the development of public information and education materials to provide for increased public awareness of the potential impacts of SPLs on freshwater environments and fish species.
- The Department could establish a process for public education and outreach regarding the effects of discarded SPLs and the process by which anglers should discard or recycle used SPLs. Education and outreach materials could be in the forms of permanent signage at boat launches, SPL collection boxes at boat launches for recycling, newspaper and television advertisements, and printed material in the fishing law books and on the Department's website. For example, in the 2014 fishing lawbook, the Department discusses the effects of discarded SPLs, how to properly dispose of used SPLs, and how to rig SPLs for maximum hook retention.
    - The Department could encourage the general angling public to participate in SPL recycling programs such as the B.A.S.S. Re-Baits® SPL recycling program. This could include providing SPL collection bags with each purchase of a Maine fishing license and/or advertising the Re-Baits® program in print on the Maine fishing license. Additionally, Re-Baits® collection canisters should be installed at more boat launches, including the lakes and ponds surveyed in this study.
- The Department could encourage retailers and anglers in Maine to consider selling and buying only advertised biodegradable SPL products and encourage manufacturers to develop new alternatives that are made of 100% biological material (gelatin, fish/plant/mineral oils, etc.).
- The Department could encourage local (state) manufacturers of recycled SPLs to advertise their products more widely, for example in the Department's fishing lawbook as part of continued angler education and product promotions.
- The Department could encourage retailers, fishing clubs, and tournament organizers to promote and educate anglers on improved approaches to retain SPLs on hooks. For example, a small o-ring or zip tie can be placed in the middle of the SPL, and the hook placed under the o-ring/zip tie. If the hook is pulled through the SPL, the o-ring/zip tie retains the SPL on the hook. SPL retention kits are available from retailers, however improved angler education may be needed to better promote this SPL retention strategy.

Enforcement

- Support and encourage rigorous enforcement of state and local laws and regulations pertaining to littering of SPLs in freshwater environments.
    - The Fisheries Division could work with the Warden Service to raise awareness of litter issues caused by discarded SPLs in Maine's lakes and ponds.

Department Initiatives

- The Department could consider the addition of a new tournament permit requirement that would necessitate an SPL collection and recycling effort during each permitted tournament.

- The Department has an established, standardized process to document the occurrences of ingested SPLs by salmonids. This is in the form of regional databases that document fish stomach contents during biological and creel surveys. The Department will continue to collect fish stomach content data from various waters throughout the State.

Other

- The tackle industry could be encouraged to continue to develop the advancement of SPL hook retention and SPLs that are less likely to be pulled off by fish after repeated use.
- The MDIFW is currently working with the Department of Environmental Protection's (MDEP) Surface Water Ambient Toxins program to develop a laboratory study focused on determining the chemical constituency of biodegradable and non-biodegradable SPLs and study the effects of SPL leachate (i.e. phthalates) accumulation in fish tissue. The MDEP has issued a Request for Proposals and received cost estimates from several labs capable of performing these chemical analyses.

RECOMMENDED LEGISLATION

Requiring the sale and use of only biodegradable SPLs is currently not a solution. There is currently no standard national or international definition for what constitutes "biodegradable plastic" and SPLs specifically. Based on the information presented in this report, the Department does not recommend any legislation at this time.

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Appendix A

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North American Journal of Fisheries Management 29:352–360, 2009

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[Management Brief]

Voluntary Ingestion of Soft Plastic Fishing Lures Affects Brook Trout Growth in the Laboratory

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Abstract. Thirty eight brook trout *Salvelinus fontinalis* were fed a commercial trout diet mixed with a free choice assortment of soft plastic lures (SPLs) over a 90 d period. Fish growth was recorded and compared with that of a control group. The brook trout readily ate the SPLs from the water's surface as well as from the tank bottom. At the conclusion of the study, SPLs were recovered from the stomachs of 63% of the test fish. Several fish stomachs contained multiple lures. Twelve percent of the fish voluntarily ingested more than 10% of their body mass in SPLs. These fish lost a significant amount of weight during the study, had a significant decrease in body condition factor, and began displaying anorexic behaviors. For these reasons, anglers should be discouraged from discarding used SPLs in trout waters.

Soft plastic lures (SPLs) are very popular among many angler groups, including those targeting black basses (Centrachidae), freshwater perches (Percidae), and salmonids (Salmonidae). Available in a variety of sizes, colors, shapes, scents, and degrees of biodegrad ability, SPLs are readily observed littering the bottoms of Maine's lakes and ponds, particularly those waters supporting bass fisheries. The voluntary ingestion of SPLs has become an increasing fisheries management concern for brook trout *Salvelinus fontinalis*, brown trout *Salmo trutta*, landlocked Atlantic salmon *Salmo salar sebago*, and lake trout *Salvelinus namaycush* in Maine because undigested aggregates of SPLs have been found in the stomachs of these species by anglers and fisheries managers. In January 2003, the stomachs of 56 lake trout harvested during an ice fishing derby on Sebago Lake (Naples, Maine) were examined for ingesta. Twenty five percent contained SPLs (F. Brautigam, unpublished data). The SPLs, used primar ily during summertime bass angling on the lake, accumulate in lake trout stomachs as a result of voluntary ingestion and form gastric bezoars. Gastric bezoars are masses or concretions of food and foreign material (e.g., hair, stones, plastic, etc.) found accu mulating in the stomach (Figure 1). Bezoars have been found and studied in many vertebrate species, and they are usually associated with postprandial fullness and malaise. When undiagnosed and untreated, gastric bezoars result in gastric ulceration, bleeding and perforation, intussusceptions, small bowel obstruction, anorexia, decreased fecal output, weight loss, and depression. Derraik (2002) demonstrated that when seabirds voluntarily ingested plastic litter, they subse quently ate less and lost weight.

No data on the effects of voluntary SPL ingestion were found for any fish, nor were any data found on the prevalence of voluntary SPL ingestion in fish from literature searches in Pub Med and Aquatic Sciences and Fisheries Abstracts using the search terms "lure consumption," "lure ingestion," "bezoar," "fish pearls," "Mustika pearls," or "gastric foreign bodies." Radomski et al. (2006) estimated the tackle loss for five Minnesota waters to be 0.0127 lure pieces/h; 80% of boat anglers interviewed reported tackle loss. Without an estimate quantifying voluntary SPL consumption and ingestion's injurious effects, it is impossible to determine the extent to which SPL litter puts fish populations at risk.

In addition to the negative health implications of SPLs from physical irritation of the gastric area, the chemical composition of these lures makes them dangerous pollutants to the environment and potential health hazards to humans, fish, and wildlife. Plasticiz ers render SPLs resilient and flexible. Phthalates are a family of chemical plasticizers known to cause health problems (Staples et al. 1997). A study conducted on the effects of phthalates on freshwater fish showed that exposure to such chemicals altered the activity of liver

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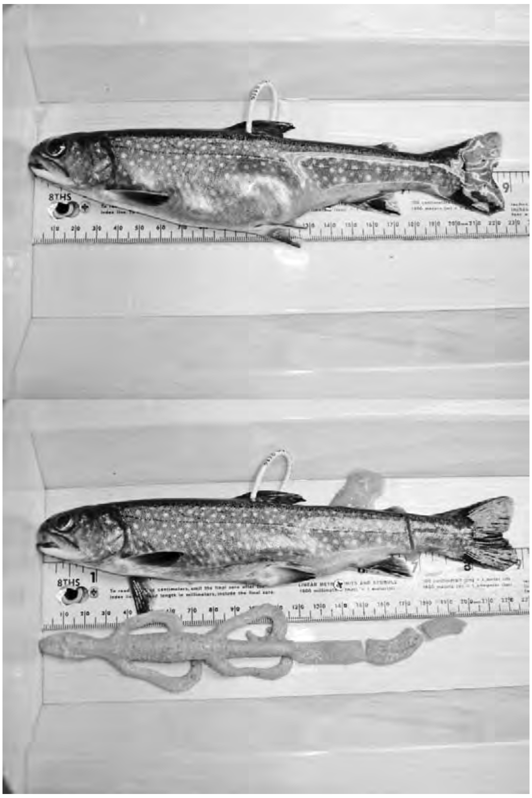

FIGURE 1. Visibly distended coelom of a brook trout fed a commercial diet supplemented with a choice of SPLs (top) and lure removed from the stomach of a brook trout at the conclusion of the study (bottom). Undigested lures may form bezoars and lead to chronic health problems, including ulcers, anorexia, and weight loss. Plastic lures may remain in the aquatic environment for decades.

and certain muscle enzymes, which could have more harmful effects on fish from prolonged exposure (Ghorpade et al. 2002). Phthalate exposure has also been linked to tumors in rats (Vossa et al. 2005), underdevelopment of the testes and reduced sperm count in male rats exposed prenatally (Gray et al. 2005), the global decline of amphibians (Lee et al. 2005), chemical imbalances in several tissues and organs, including the liver (Bell 1982; Hinton et al. 1986), and deleterious effects on human reproductive health (Lovekamp Swan and Davis 2003). Sha et al. (2007) demonstrated that plastics also have the ability to absorb inorganic substances from sediments. Overall, they are dangerous to the aquatic environment because of both their solid waste and their chemical composition.

Thus, this study was designed to measure voluntary ingestion rates of SPLs by catchable brook trout, to assess the ingestion volumes of these soft plastic bezoars, and to measure the associations between voluntary SPL ingestion and brook trout growth and health.

Methods

Fish. Juvenile brook trout (234 ± 20 mm [mean ± SD]) were obtained from the Maine Department of Inland Fisheries and Wildlife (MDIFW), Palermo Fish Rearing Facility, Palermo. The Palermo facility obtained the fish as fry from MDIFW's Governor Hill Fish Hatchery, Augusta, one of the department's broodfish hatcheries. The fish were transported to Unity College, Unity, Maine, for the study. The two strains of brook trout that were used comprised 38 Kennebago Lake strain brook trout, representing a heterogeneous population, and 38 Maine hatchery strain brook trout, representing a fast growing but very homogenous population (Bonney 2005). An equal number of each strain was assigned to the control and the study tank.

Feeds and feeding. Fish were fed a 3 mm sinking pelleted Vigor salmonid feed (50% protein, 20% fat; Corey Feeds, Fredericktown, New Brunswick). Beginning in March 2007, the fish were fed 0.5% of their combined body weight per day. Each week a different type of soft plastic lure was offered to the fish during a single feeding. Fish were kept in two 1 m × 1 m × 0.75 m fiberglass tanks, each receiving 100 L/min of recirculated filtered and ultraviolet light sterilized water kept at 9 ± 1°C. A 1 cm^2 mesh net was placed over each tank after the first day because seven fish jumped out of the tank and were found dead on the floor. Data from these fish were removed from subsequent statistical analyses. The photoperiod was 12 h light : 12 h dark, and lights were turned on at 0700 hours. Water quality in the aquaculture facility was monitored and recorded. All temperature, dissolved oxygen, and pH data were unremarkable.

Study design. This observational epidemiological study was designed to scrutinize the occurrence of morbidity and mortality in cohort groups relative to exposure to SPLs. This was an observational cohort study without strict experimental research methodology (Thrusfield 2005). The study's design, variables, statistical analysis, assumptions, and power are listed in Table 1. This study proposes probable inference from a specific case where brook trout are fed trout feed mixed with or without SPLs. The starting point is healthy individuals that are followed for 3 months, during which time they are exposed to the putative agent (i.e., SPLs) and compared with a control group that is not exposed. Table 2 provides the chronology of SPL exposure and SPL recovery from the study tank or a fish's gastrointestinal tract (GI). Some lures were

TABLE 1. Hypotheses tested in a study of the ingestion of soft plastic lures by brook trout. Two strains of brook trout were studied, a Maine hatchery strain (n 38) and the Kennebago strain (n 38). The Shapiro Wilk W test was used to evaluate the normality of the data. The Mann Whitney U test was used to test the statistical hypotheses, the Wilcoxon signed rank test to test the post hoc hypotheses. The level of significance was set at 0.05.

Study design, variables, statistics, assumptions, and power	
Scientific hypothesis	Ingestion of indigestible soft plastic lures by trout may be influencing their growth in Maine waters.
Study design	Observational cohort study
Subjects	Brook trout ($n = 76$)
Strains	Maine hatchery strain ($n = 38$); Kennebago strain ($n = 38$)
Groups	Treatment (α_1): fed diet of fish food and soft plastic lures. Replicates = 0 Control: (α_2): fed diet of fish food only. Replicate = 0.
Statistical hypotheses	H_{0_1}: TMα_1 TM$\alpha_2 = 0$. Body mass of the treatment group is not be significantly different than the mass of the control group at any time period (day 0, 30, 60, or 90). H_{α_1}: Not H_{0_1}. H_{0_2}: TLα_1 TL$\alpha_2 = 0$. Total body length of the treatment group is not significantly different than the length of the control group at any time period (day 0, 30, 60, or 90). H_{α_2}: Not H_{0_2}. H_{0_3}: Kα_1 K$\alpha_2 = 0$. Condition factor of the treatment group is not significantly different than condition factor of the control group at any time period (day 0, 30, 60, or 90). H_{α_3}: Not H_{0_3}. H_{0_4}: HCTα_1 HCT$\alpha_2 = 0$. Hematocrit of the treatment group is not significantly different than the hematocrit of the control group at study's conclusion (day 90). H_{α_4}: Not H_{0_4}. H_{0_5}: TPα_1 TP$\alpha_2 = 0$. Plasma protein level of the treatment group is not significantly different than the plasma protein level of the control group at the study's conclusion (day 90). H_{α_5}: Not H_{0_5}. H_{0_6}: GLUα_1 GLU$\alpha_2 = 0$. Blood glucose level of the treatment group is not significantly different than the blood glucose level of the control group at the study's conclusion (day 90). H_{α_6}: Not H_{0_6}.
Independent variable	Diet
Dependent variable	Total body length (TL), total body mass (TM), condition factor (K), lure mass (LM), hematocrit (HCT), total plasma protein (TP), blood glucose (GLU)
Normality test	Shapiro–Wilk (W)
Statistica test	Mann–Whitney U-statistic
Statistical assumptions	Two independent samples collected from similarly shaped distributions measured on an ordinal or continuous scale
Significance level	$P < 0.05$
Decision rules	Reject H_0 when $P < 0.05$ with df = 1
Computations	Indepentently evaluated
Post hoc hypotheses	H_{0_7}: TLα_1 (day 0) TLα_1 (day 90) = 0. Total body length of the treatment group at commencement (day 0) is not significantly different than the total body length at the study's conclusion (day 90). H_{α_7}: Not H_{0_7}. H_{0_8}: TLα_2 (day 0) TLα_2 (day 90) = 0. Total body length of the treatment group at commencement (day 0) is not significantly different than the total body length at the study's conclusion (day 90). H_{α_8}: Not H_{0_8}.
Post hoc analysis	Wilcoxon signed ranks statistic (paired data)

TABLE 2. Number of soft plastic lures fed and number recovered in a study of the ingestion of such lures by brook trout, by week and lure type. The column headed GI shows the number of lures collected from the stomachs of fish. The color or shape of the lures was varied each week. Some lures were never recovered owing to digestion, data error, or loss inside the recirculating system. Week 13 has been omitted because no lures were fed that week.

Week of study	Lure type	Week of study													
		1	2	3	4	5	6	7	8	9	10	11	12	14	GI
1	Zoom green lizard	7/2	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0
2	Zoom brown lizard		6/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0
3	Berkley brown worm			6/2	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0
4	Kinami worm				8/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	6
5	Kinami lobster					2/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	1
6	Gulp red worm						5/0	0/0	0/5	0/0	0/0	0/0	0/0	0/0	0
7	Zoom purple lizard							2/0	0/0	0/0	0/0	0/0	0/0	0/0	1
8	Zoom green lizard								2/0	0/0	0/0	0/0	0/0	0/0	0
9	Zoom brown lizard									2/0	0/0	0/0	0/0	0/0	0
10	Gulp red worm										2/0	0/0	0/0	0/0	5
11	Zoom brown lizard											2/0	0/0	0/0	2
12	Zoom green lizard												2/0	0/0	4
14	Berkley brown worm													2/0	10

TABLE 3. Median values and 95% confidence intervals of the variables examined in a study of the ingestion of soft plastic lures by brook trout. A check in the N column indicates that the data were normally distributed. Since so many dependent variables did not meet the normality assumption, it was decided to report the results with the more conservative nonparametric statistics.

				Lure diet		Control	
Variable	Units	Day	N	*n*	Median (95% CI)	*n*	Median (95% CI)
Total length	mm	0	✓	38	236 (225–243)	38	232 (227–239)
		30	✓	38	227 (224–240)	31	240 (230–245)
		60	✓	37	237 (230–247)	31	240 (233–248)
		90		38	237 (227–248)	31	247 (240–251)
Total mass	g	0		38	127 (118–150)	38	125 (118–152)
		30		38	138 (114–152)	31	134 (118–150)
		60		38	120 (104–140)	31	138 (127–150)
		90		38	121 (104–132)	31	156 (140–178)
Condition factor	g/mm^3	0	✓	38	1.030 (0.929–1.147)	38	1.073 (0.923–1.167)
		30		38	1.042 (0.945–1.158)	31	1.013 (0.929–1.114)
		60		38	0.951 (0.873–0.998)	31	1.007 (0.917–1.071)
		90	✓	38	0.947 (0.902–0.997)	31	1.056 (0.987–1.135)
Hematocrit	% red blood cells	90		33	27 (23–31)	27	35 (32–38)
Total protein	mg/dL	90	✓	30	3.0 (2.6–3.4)	26	3.1 (2.7–3.9)
Glucose	mg/dL	90		37	91 (85–111)	31	295 (113–327)

immediately eaten, while other lures remained in the tank available to the fish for the remainder of the week. Uneaten SPLs were removed from the tank before the next type of SPL was fed to the fish. This study design cannot control for extraneous factors that may distort the results (e.g., tank effect) but does provide a useful measure of association upon which subsequent exper iments can be designed.

Animal care and use. A peer review group composed of fisheries biologists, hatchery personnel, and academics reviewed this study prior to initiation and served as the Animal Care and Use Committee (ACUC) during the study. The study was designed and carried out within the published guidelines for the use of fish in research (Nickum et al. 2004). Sixty fish from each brook trout strain were tested and found to be negative for pathogens of regulatory concern in Maine prior to commencing the study according to fish health inspection procedures (USFWS and AFS FHS 2004).

Anesthesia. To facilitate growth measurements, fish were anesthetized with tricaine methanesulfonate (MS 222; Finquel, Argent Chemical Co., Redman, Washington) following manufacturer suggested dosing for salmonid fishes, and the level of anesthesia was monitored according to the scalar stages of anesthesia in fishes (Brown 1993). Fish were anesthetized to stage II, plane 1.

Surgical procedures. After anesthesia to stage II, plane 2, a looping tag with a specific number was inserted laterally and transecting the supracarnalis muscles caudal to the dorsal fin using an initially sterilized trochar needle as directed by the manufac turer (Hallprint Tags, Australia). The fish were randomly assigned to either the control or treatment group and visually monitored during recovery from anesthesia. The fish were allowed to acclimate to the new environment for 1 week.

Growth measurement. Fish were individually weighed for total mass (TM; ES6R Ohaus Corp., Pine Brook, New Jersey), and measured for total length before the study and then monthly. Condition factor (K) was calculated as

$$K = (\mathrm{TM}/\mathrm{TL}^3) \times 10^{-5}.$$

Euthanasia. At the conclusion of the study, fish were euthanatized with an overdose of MS 222 and placed on wet ice for immediate necropsy (AAZV 2007; AVMA 2001; Hartman 2007).

Necropsy. All fish were dissected immediately after euthanasia, and the ingested masses of the SPLs in the GIs were counted and weighed. A whole blood sample was collected directly from the caudal vein into a microhematocrit tube, filling the tube approximately two thirds full. The tube was sealed on one end with clay and centrifuged (5,000 × gravity for 5 min at 20°C). The percentage of packed cells to total volume (HCT) was determined by direct measurement (Stos kopf 1993). Total protein was measured using a handheld refractometer. Blood glucose was measured by placing a single drop of whole blood on a test strip for an Accu Chek Glucose Meter (Roche, Basel, Switzerland). Soft plastic lures were removed from the GI and placed in Whirlpak plastic bags (Nasco, Ft. Atkinson, Wisconsin). The bags were individually weighed.

Data analysis. Data from each dependent variable were tested for normality by means of a Shapiro Wilk

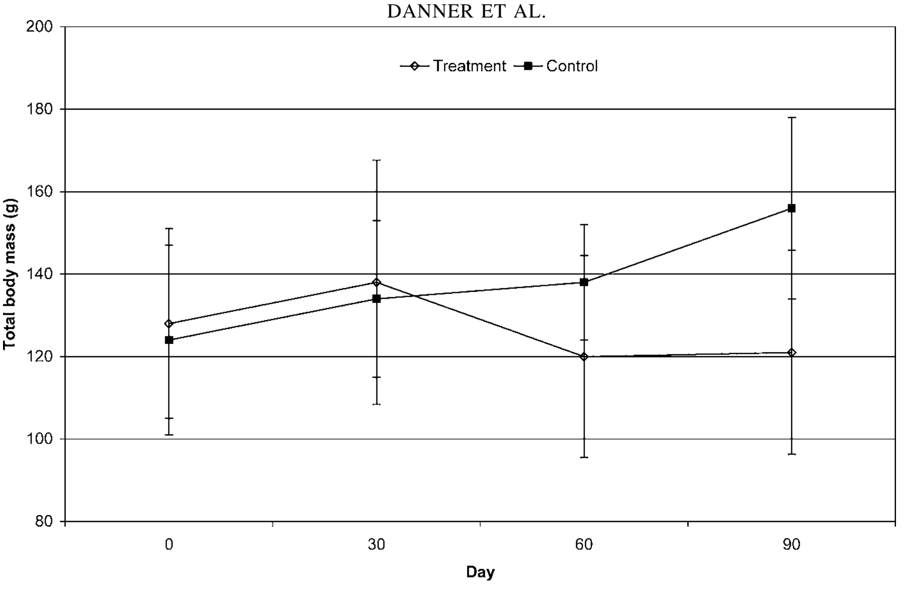

FIGURE 2. Median body mass of brook trout fed a diet that included soft plastic lures (the treatment group) vis à vis that of the control group at 0, 30, 60, and 90 d. Both groups grew initially, but after about 30 d the fish fed the diet with lures began to loose weight while the control group continued to gain weight. The error bars indicate interquartile ranges.

test (Analyze it Software, Leeds, UK). Histograms of the data were visually assessed along with calculated values for skewness and kurtosis to evaluate if the distributions deviated grossly from a bell shaped Gaussian distribution. A column in Table 3 indicates which dependent variables met the strict normality assumptions. Many of the dependent variables did not meet Normality assumptions; therefore, the data were analyzed with more conservative nonparametric statis tics. After reviewing the data, decisions about when to use parametric versus nonparametric statistics were made about the entire data set rather than mix and match statistical analyses within this same data set. Figures correspondingly illustrate nonparametric val ues as well.

Results

Ingestion of SPLs

Overall, 24 of 38 (63%) fish in the treatment group voluntarily ingested at least one SPL. Eighteen fish (47%) ingested a single SPL, five fish (13%) voluntarily ingested two SPLs, and one fish (3%) ingested more than three SPLs. Only one fish (3%) had a lure extending caudally into its small intestine. In all the other fish, the SPLs were retained within the gastric fundus. One fish (3%) in the study group died during the study with a single SPL in its stomach. The median mass of the SPLs recovered from the fish stomachs was 1.1 g. Three fish (13%) voluntarily ingested more than 10 g of SPLs, accounting for more than 10% of their TM. Overall, SPL mass accounted for 1% of the affected fish TM. In the more "wild" or heterogeneous Kennebago strain, 15 of 18 fish (83%) voluntarily ingested at least one SPL, while only 9 of 18 domesticated Maine hatchery strain brook trout (50%) voluntarily ingested the SPLs.

Growth and Health Assessment Variables

Mann Whitney *U* tests were used to formally test for differences between the medians (Table 2). At the commencement of this study, there were no differences in TL (U = 700.0; df = 1; P = 0.8351) between Kennebago and Maine hatchery strain brook trout; however, as expected Maine hatchery strain brook trout had greater TM (U = 1,015.5; df = 1; P = 0.0021) and K (U = 1,290.0; df = 1; P = 0.0001) than the wild Kennebago strain. After randomly allocating individual fish from each strain to either the study or control group, there was no group difference in TL (U = 623.5; df = 1; P = 0.3082), TM (U = 687.0; df = 1; P = 0.7198), or K (U = 763.0; df = 1; P = 0.6663). After 30 d and exposure to four different types of SPLs, there was no group difference in TL (U = 679.0; df = 1; P = 0.2770), TM (U = 569.5; df = 1; P = 0.8140), or K (U = 505.5; df = 1; P = 0.3138). After 60 d and exposure to additional types of SPLs, there was no group difference in TL (U = 597.0; df = 1; P = 0.9230), TM (U = 678.0; df = 1; P = 0.2828), or K (U = 718.0; df = 1; P = 0.1197). The TM measurement for day 30 and day 60 evaluations included the mass of any SPL retained within the GI potentially masking weight loss associ ated with SPL ingestion. The final evaluation (day 90)

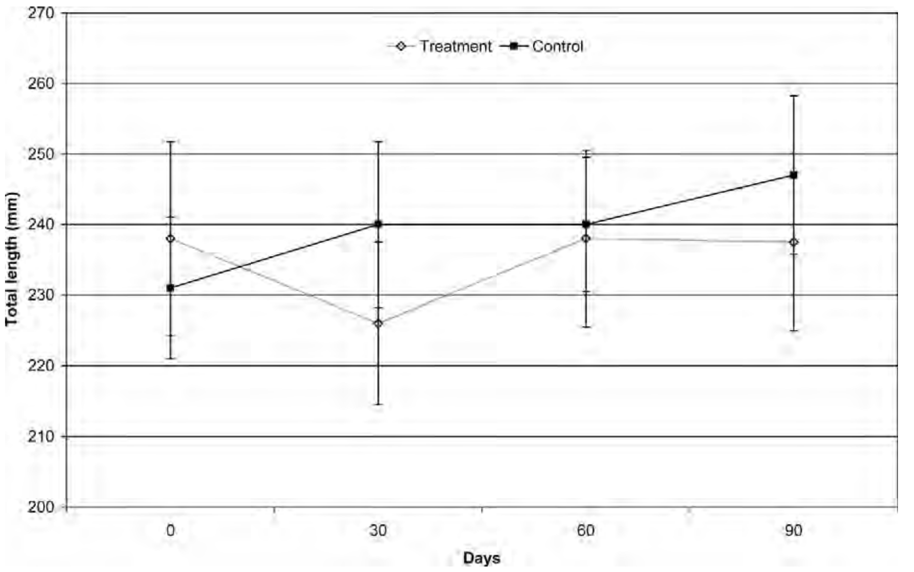

FIGURE 3. Median total body length of brook trout fed a diet that included soft plastic lures (the treatment group) vis à vis that of the control group at 0, 30, 60, and 90 d. The control group grew throughout the study, while the treatment group showed no significant growth. The error bars indicate interquartile ranges.

included both a gross TM and net TM after the SPLs were removed and weighed. There was a significant difference at day 90 in gross TM ($U = 753.5$; df = 1; $P = 0.0472$), net TM ($U = 770.0$; df = 1; $P = 0.0290$), and K ($U = 752.5$; df = 1; $P = 0.0486$), but not in TL ($U = 710.0$; df = 1; $P = 0.1438$). Post hoc analysis of TL data demonstrated that there was significant TL growth within the control group ($W = 64.5$; df = 1; $P = 0.0003$) but not the treatment group ($W = 319.0$; df = 1; $P = 0.9477$). Changes in median TM in each group during the study may have begun to appear as early as 30 d (Figure 2). Changes in TL were not as apparent as changes in TM, requiring post hoc analysis of within group differences to demonstrate that SPLs were retarding the growth of the study group (Figure 3).

Glucose was significantly higher in the control group ($U = 851.5$; df = 1; $P = 0.0006$) than in the treatment group. Hematocrit was significantly higher in the control group ($U = 649.5$; df = 1; $P = 0.0024$) than in the treatment group; however, there was no difference in TP ($U = 466.5$; df = 1; $P = 0.2088$). There were no differences in TL ($U = 130.0$; df = 1; $P = 0.2494$), TM ($U = 144.5$; df = 1; $P = 0.4768$), K ($U = 182.0$; df = 1; $P = 0.6718$), GLU ($U = 129.5$; df = 1; $P = 0.3236$), TP ($U = 131$; df = 1; $P = 0.3297$), or HCT ($U = 157.5$; df = 1; $P = 0.3101$) between the 63% of fish in the treatment group with at least one lure in their stomach on day 90 and the 37% of fish in that group that did not have a lure in their stomach.

Discussion

Fishing with SPLs has become increasingly popular among anglers; however, the use of these lures may have deleterious effects on fish and hence presents some serious concerns for fisheries managers. Soft plastic lures are manufactured into sizes, shapes, and colors useful for catching a variety of species and fishes of different sizes. Their use is more socially acceptable than impaling a live nematode, crustacean, or small fish on a barbed hook. The lures are disposable and can be disinfected to minimize the spread of aquatic invasive species and pathogens of aquatic organisms. Several types of SPLs claim to be biodegradable, and some may be digestible. Unfortu nately, indigestible and unbiodegradable SPLs are contributing to aquatic benthic litter and gastric bezoars in salmonids.

An initial literature search for articles examining the effects of consuming SPLs on the growth of fish was unsuccessful; thus, this study was designed and executed to measure any association between voluntary SPL ingestion and subsequent effects on brook trout growth or health.

Voluntary SPL Ingestion Rates

The results of this short term observational investi gation suggest that SPLs are readily ingested by "catchable" brook trout without momentous effort. Simply by distributing SPLs in the tank simultaneously with fish pellets, we got more than one half of the brook trout to voluntarily ingest them; 83% of the Kennebago strain fish did so. The voluntary lure ingestion rates observed in this study are greater than anecdotal field observations by MDIFW fishery biologists. This may indicate that field observations underestimate the prevalence of SPL gastric bezoars in brook trout. The observation that wild brook trout voluntarily ingested SPLs more readily (3:2 [Kenne bago : Maine hatchery strains]) than domesticated brook trout also forewarns of the impact of plastic litter on wild brook trout populations. Fish in this study were fed a balanced diet at a rate that should promote growth and satiation. Nevertheless, voluntary lure ingestion rates exceeded 50%.

We attempted to measure the brook trout's ability to voluntarily regurgitate the lures by using different colors and types of lures throughout the study. Presumably, brook trout have the ability to regurgitate these lures, but data on the recovery of lures indicate that they are not regularly regurgitated (Table 2). Some lures were never recovered during the study; this could indicate digestibility, although it is also possible that they remain trapped someplace within the tank's recirculation system.

Voluntary SPL Ingestion Affects Growth

In this study, the relative risk of weight loss was seven times as great in brook trout that voluntarily ingested SPLs than in controls. The treatment group lost a median of 6 g during the study, while the controls gained 31 g. During the 90 d of this study, there was no TL or TM growth within the treatment group. Even fish in the treatment group necropsied and found to be without an SPL in their stomach did not grow as well as controls. This may indicate that digesting or regurgitating lures has a prolonged effect on growth or that the competitive dynamic of a shoal's feeding behavior is affected by individuals carrying masses of SPLs. Video of the study group's feeding behavior taken about a month into the study showed a marked lethargy in comparison to the feeding behavior of the controls. If SPL ingestion can be linked to changes in feeding behavior, then the effects of SPL gastric bezoars will directly impact brook trout fishing and management. Presumably, brook trout ingesting SPLs will have reduced growth rates, be more vulnerable to predation, and have lower catch rates than unaffected brook trout.

Voluntary SPL Ingestion Affects Health

Soft plastic lure ingestion does not appear to be acutely lethal to brook trout. Only a single fish died during the study (mortality rate = 3%) with an ingested lure. However, there were significant decreases in the GLU and HCT of brook trout that ingested SPLs. While GLU levels are transient indicators of food consumption and metabolic state, HCT is a good indicator of general health. Neither group's GLU level indicated hypo or hyperglycemia, but the control group's GLU was significantly higher than that of the study group's under the same study conditions. Likewise, the HCT of both groups was within the normal range; overall, however, the treatment group's HCT was significantly lower than that of the control group, and in this instance four fish with large SPL bezoars had HCTs below 20%. If SPL ingestion were to be linked with chronic anemia, its implications for fisheries management would be significant. From this study, it is not possible to determine if the decreased HCT is a direct result of malnutrition from postprandial fullness or discomfort, or whether the SPL's chemical composition is affecting the HCT.

Since plastics have been implicated in a variety of toxicities in other vertebrates, we hypothesized that the ingestion of SPLs may be associated with toxicities in fish. Where brook trout and other salmonids occur either naturally or are stocked, and are managed for growth and survival to older age, study results suggest that plastic ingestion may impede attainment of growth and size expectations in the development of desirable sport fisheries. Where "legal size" trout are stocked to provide seasonal put and take fisheries of short duration, foraging on SPLs by newly stocked trout poses fewer potential adverse management implica tions. These legal size trout are immediately vulnerable to harvest and experience fewer opportunities to forage prior to harvest. However, if ingestion occurs soon after stocking and causes behavioral changes (such as increased lethargy and reduced frequency and duration of feeding), these changes could diminish angler catch rates associated with these fisheries.

Field observations by anglers and biologists of SPLs in salmonid stomachs are generally associated with fish much larger than those tested in this investigation. Large, old age fish have greater opportunity (exposure time) to accumulate SPLs and experience any associ ated adverse impacts over an extended period of time. One large lake trout harvested from on Mousam Lake (Acton, Maine) during the winter of 2002 (Brautigam, personal communication) was found to contain 18 SPLs. Also, these older individuals may represent important adult broodfish in self sustaining wild populations. Any diminishment in health and body condition could negatively influence fecundity and desired recruitment important to the maintenance of the fishery. The chronic retention of an SPL may have additional influences on a fish's overall health and well being.

Several studies concerning plastics have shown harmful effects from exposure to improperly disposed of plastics (Staples et al. 1997). These harmful effects range from the esthetic deterioration of aquatic environments to acute and chronic health effects on terrestrial wildlife due to the potential ingestion of pieces of SPLs or exposure to the harmful chemicals within the plastics (Bell 1982; Cashman et al. 1992; Derraik 2002; Islam and Tanaka 2004; Radomski et al. 2006; Barse et al. 2007). Plastics continue to be one of the most abundant sources of environmental pollution worldwide, particularly in aquatic ecosystems (Islam and Tanaka 2004). These plastic remains are indestructible for decades, and many of them will eventually settle in the sediments of aquatic ecosystems.

Future investigations are warranted to more fully assess the management implications associated with fishing with SPLs. A subsequent investigation should examine the effect of SPL ingestion on larger fall yearling stocked salmonids, and should monitor the effects over a much longer period of time with stricter experimental research methodologies. Larger salmonids are routinely stocked in southern and coastal Maine because larger fish appear to withstand higher levels of interspecific competition and predation. The use of SPLs is very common in bass, perch, crappie, and salmonid fisheries in the aforementioned region of Maine. Gonad development should be included as a monitoring parameter, as should an assessment of behavioral changes that could affect fish catchability by sport anglers. A comparison of biodegradable plastic products and those not labeled as such should be investigated to determine if the rates of biodegradation in fish stomachs are different and whether the rate of decomposition associated with the biodegradable product reduces the apparent negative influence on fish growth and condition. Available product information should be obtained from the manufacturers of biodegradable SPLs to identify any completed research to assess environmental fate. Input should be solicited from key angler organizations regarding the scope of a subsequent study to cultivate a vested interest in the study outcome, which may not reflect favorably on the continued use of some popular SPLs commonly used by anglers. Meanwhile, anglers should be discouraged from disposing of SPLs in the water.

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Appendix B

Bass & Stewardship, The Effects of Soft Plastic Lures

The Maryland Natural Resources Magazine (Love and Sewell, Summer 2012 Issue)

Bass & Stewardship

The Effects of Soft Plastic Lures

By Joseph W. Love, Ph.D. and Scott Sewell

Last year, Joe Ford from Lake Amistad, Florida, landed a 10-pound bass with 12 large, soft plastic lures in its belly: only lures, no hooks. Two years earlier, biologists from the Maine Department of Inland Fisheries and Wildlife reported that a brook trout that had eaten soft plastic lures had lost weight and displayed signs of anorexia.

Fears are that this could happen to largemouth bass as well. But what *are* soft plastic lures and are they really a problem in the Chesapeake Bay watershed?

Luring them in

Since soft plastic lures were introduced to the market, sales have skyrocketed and the range of products has exploded to include soft plastic worms and critter baits such as crayfish, lizards and frogs. The essential advantage of soft plastic lures is that they are somewhat buoyant, which increases their drop time in the water, or the amount of time it takes to descend to the bottom. The plastic lure descends in the strike time zone, which is the area where a bass will actually pursue its prey.

Joseph W. Love

A tournament catch

Mike Schenck

Two bass caught with soft plastic lures

Joseph W. Love

Black bass tournaments are routinely held at Smallwood State Park and bring together hundreds of anglers each year.

According to a review submitted to the U.S. Patent Office in 1986, about 95 percent of all bass strikes occur during this drop time. Consequently, for anglers and the lure manufacturers who depend on them, a long drop time is preferable. The other five percent are the fish that possibly got away.

Some lures are designed to float because they are filled with air pockets. Other plastic worms have a curly-tail feature to create movement during descent. Scents have also been mixed in to entice bass; although in 2001, scientists from Lake Erie surmised that scenting might not make a difference.

It's no surprise that bass eat soft plastic lures. For the past few years, Department of Natural Resources (DNR) biologists have found soft plastics in the stomachs of several largemouth bass. Unfortunately, the amount of soft plastics that are discarded by anglers is not documented or known in Maryland.

On the Potomac River, Ken Penrod of *Lifetime Outdoors, Inc.* reports catching a bass that had "plastics sticking out of her vent." With more than 40 years of experience on the Potomac, he notes, "discarded plastics and monofilament are big problems… and growing."

Recycling bait

The soft plastics problem was originally brought to nationwide attention by *BASS Times* author, Robert Montgomery, who advocated soft plastic bait recycling. Silicon rubber, the material used in many soft lures, can be recycled. BASS National Conservation Director Noreen Clough says the program to recycle has "gone viral." At the 2012 Bass Pro Shops Southern Open, Florida Bass Federation Nation Conservation Director Eamon Bolten recycled 17 pounds of soft plastics from this event.

Anglers will continue to use soft plastics as lures because they are very effective at catching fish. DNR encourages anglers to store their unwanted or damaged soft plastics in bags throughout the fishing day for recycling back at the dock. Anglers may visit *mdrecycles.org* or *mde.maryland.gov* to confirm that their neighborhood curb side recycling handles silicone.

Educating anglers

The Maryland Bass Federation Nation and Bass Anglers Sportsman Society (B.A.S.S.) support the efforts of *ReBaits*®, a private company that is working to increase public awareness of this growing problem. The goals of the *ReBaits*® program are to educate anglers of the reasons to keep these baits out of our waters, provide a means for anglers to properly dispose of them, and engage youth and adult anglers in conservation. More information about this and other conservation programs supported by the Maryland Bass Federation Nation is available at *mdbass.com*. ■

Eamon Bolten

Bolton shows seventeen pounds of recycled soft plastic lures that will not be getting into the waterways, landfills or bellies of bass.

Corey Charity

Charity displays his 45.5 inch catch.

Joseph W. Love, Ph.D. is the DNR Fisheries Service Manager.

Scott Sewell is Conservation Director of the Maryland Bass Federation Nation.

Appendix C

American Fisheries Society (AFS) Policy Statement #20

Plastic Debris in Marine Environments

AFS Policy Statement #20:

Plastic Debris in Marine Environments

(Full Statement)

A. Issue Definition

The use of synthetic materials, especially plastics, has greatly increased over the past 35 years. Because of plastic's versatility, its use has moved rapidly into all aspects of our everyday life. This plastic proliferation has resulted in more and more "floatable trash." Many plastics degrade at such a slow e that the debris may remain in the natural environment for years or decades. There is increasing evidence that synthetic debris is more detrimental to aquatic life - fish**,** seabirds, marine mammals**,** and crustaceans-then previously believed by scientists.

Until recently, there was little information available about the impact of plastic debris on natural living resources. Published information primarily documented ducks and geese entwined in six-pack rings or gulls caught in monofilament fishing fine.
A ban on the dumping of any plastic materials in the ocean was put into effect by the United States in January 1989. This legislation and rising public awareness have provided an opportunity to move effectively toward reducing the amount of plastics discarded in aquatic environments.

B. Impacts of Marine Debris

Biologists began to encounter plastic material in the stomachs of fish, birds, turtles, and mammals with increasing regularity; however, there was no formal or broad ranging exchange of information on this subject. The first international "Workshop on the Fate and Impact of Marine Debris" was held in Honolulu, Hawaii, in November 1984. Oceanographers, marine mammal specialists, and fishery scientists shared findings about the effects of plastic debris on marine living resources. Papers focused on animals becoming entangled in discarded plastic lines or net fragments, injury from chaffing, impaired ability to escape predators or pursue food, and drowning.

The workshop concluded that the plastic problem was of such a magnitude as to be a contributing factor in the decline of many populations of fish, marine mammals, and turtles. In a May 1988 report of the Interagency Task Force on Persistent Marine Debris, it was stated: "Scientists regularly report 'scars' and bruises on marine mammals as evidence of entanglement. They point out that it is difficult, if not impossible, to know if the scar is from active or discarded fishing gear. There are no reliable estimates of the fate of marine animals which entangle in debris while at sea or ingest plastic products, because these animals either sink, are eaten, or go unnoticed by human observers due to the vastness of the ocean."

The general public has become increasingly aware of the debris problem through beach cleanup efforts and the increased attention to plastic debris in the national press. The first coastwide cleanup was held in Oregon in 1984 and each year additional coastal states have joined in the cleanups. In the fall of 1988 nil coastal states, Costa MCA, and Puerto Rico participated in this annual event. Providing the public with "hands-on" involvement during the cleanups has given volunteers a better understanding of marine debris and products which become a threat to marine animals when discarded in the natural environment. Quantification of debris collected has allowed understanding of the problems and provided insight to the source of the materials. For example, the Center for Marine Conservation indicates that the beaches of Texas, Mississippi, and Louisiana are among the dirtiest in the nation, each averaging over 2,000 pounds of trash per mile of coastline.

The commercial fishing industry has played a leadership role in addressing ways to reduce the materials accidentally or deliberately discarded into the marine environment. Fishermen are taking a hard look at how ships are provisioned and seeking ways to reduce the amount of garbage generated by food packaging and supplies. Since storage space on most ships is at a premium, some fishermen have installed compactors to accommodate storage of trash on board. Fishermen have a keen interest in solving the entanglement problem because ropes and net fragments wrapped around propellers or plastic bags sucked into engine intake systems result in breakdown. Safety at sea is the major concern, but time and money spent in repairs is an additional concern as is lost fishing time.

The plastics industry has taken an active part in seeking solutions to the debris problem. They initiated research to further develop photodegradable and biodegradable plastics for specific applications. Recycling and scrap industries are interested in the collection of plastic materials because of new domestic and overseas markets.

In December 1987 the United Stiles adopted Annex V of the MARPOL Convention. Annex V bans the dumping of any plastic material into the ocean by any source within the United States 200-mile Exclusive Economic Zone (EEZ) and mandates that all port facilities, including processing plants, marinas, and the smallest commercial ports provide acceptable disposal facilities for plastic from vessels. Effective January 1989, Annex V requires the maritime and plastics industries and several federal agencies to work on an accelerated schedule to develop economically and environmentally acceptable strategies and facilities to dispose of shipboard plastic garbage.

Because the American Fisheries Society is committed to the protection and conservation of aquatic animals and their environment, it is the policy of the Society to address the important issue of marine debris.

C. Needed Actions

The American Fisheries Society and its members realize the environmental image caused by debris in aquatic systems and support its reduction and ultimate elimination through the following actions:

1. Actively support and participate in the development of public information and education materials to provide for increased public awareness of the impacts of marine debris on aquatic species. Further, it should facilitate the effective transfer to users of new and innovative information and techniques regarding plastic recycling, packaging, alternative materials, and ways to effect change in Individual disposal habits.
2. Support and encourage rigorous enforcement of federal, state, provincial, and local laws, regulations, and standards pertaining to marine debris.
3. Support and encourage programs to identify, inventory, and document sensitive habitats and species impacted by plastic debris, and utilize this information to devise corrective actions.
4. Encourage studies designed to determine and apply the most effective means of increasing the recycling of plastic and other synthetic materials.
5. Emphasize the need for further research on biodegradability, and the development of new, more environmentally sound packaging technology.
6. Lobby for sensible legislation which aims to control the disposal and recycling of non-degradable debris.

Additional information needs to be collected. The American Fisheries Society encourages its members to:

1. Publish articles on marine debris in professional journals and nontechnical outlets. Become informed on entanglement and ingestion of plastic by aquatic animals and use this information in presentations to school, civic, and sporting organizations.

2. Document by photography and other appropriate ways, evidence of aquatic animal mortality caused by entanglement or ingestion of plastic materials.

3. Actively and visibly participate in and/or sponsor beach cleanups to help document the amount and source of debris in their local area.

Appendix D

Letter Response from the

American Sportfishing Association (ASA) to

The Maine Department of Inland Fisheries and Wildlife

Regarding an Information Request on Soft Plastic Lures

November 26, 2013

Mr. Michael Brown
Fisheries Division Director
Inland Fisheries and Wildlife
284 State Street
Augusta, Maine 04333

Dear Michael,

Thank you for the continuing dialog about soft bait use for recreational fishing in Maine. On October 3, 2013 you sent me nine questions to answer that would assist the Department in preparing its report to the legislature per "H.P. 37 - L.D. 42 Resolve, To Require the Department of Inland Fisheries and Wildlife To Conduct a Study on the Use of Rubber Lures and Nondegradable Fishing Hooks and Lures."

Sportfishing in Maine is important to the State's economy, generating $614,401,405 in economic impact annually and supporting 6,723 Maine jobs each year. Certainly, the American Sportfishing Association (ASA) and the sportfishing industry overall want anglers in Maine to have the best sportfishing opportunities possible. We also believe that decisions made relative to sport fish management and angler management should be determined by scientific facts as opposed to emotional rhetoric. ASA and the Department need to work together to assure those tenets as we address this issue. We also see the opportunity to engage anglers in an educational effort that minimizes the loss of soft baits and are confident that such an effort can substantially diminish the current loss rate.

We have attempted to answer these questions as completely as possible. Because there are many varying factors related to soft baits and hooks and their breakdown in the environment it is not possible to assign time or life spans to these products. In addition, we note the following points:

- Biodegradable is a term used to denote that a product breaks down because of the presence of microorganisms or bacteria.
- Hooks do not biodegrade but degrade due to oxidation or rusting.
- Material data safety sheets (MSDS) for soft baits show they are not harmful or toxic to humans in any ways. Human consumption of soft baits has been known to occur and in these situations humans will pass these baits out of their bodies without harm. Similarly industry studies have shown that fish also pass or regurgitate soft baits without harm as our answers indicate.
- Two common chemical compounds may be used in some soft baits that have been the subject of numerous popular media reports: Phthalates and Bisphenol A, commonly known as BPA. According to the U.S. FDA, BPA has no adverse

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effects in small dosages and according to the CDC phthalates have no adverse effects in low dosages and are excreted from organisms quickly and are highly prevalent in the environment and a vast array of products. Both of these compounds are used in a wide variety of food packaging and health care products. The amount of these products used in soft baits is small and not a health hazard to fish or humans.

- Soft baits do offer positive attributes that are important to fisheries and the environment. They offer a commonly accepted bait alternative to live baits. The use of live baits does increase the opportunity for the introduction of aquatic invasive species. In general, the use of soft baits reduces hooking mortality for species released.

1) *Is there any effort/desire to standardize the definition of biodegradable (rubber lures/hooks) - is it valuable as a marketing tool?* Response: According to the Federal Trade Commission (FTC) biodegradable products are products that “break down and decompose into elements found in nature within a reasonably short amount of time when they are exposed to air, moisture and bacteria or other organisms”. However the FTC also acknowledges that a product that is labeled biodegradable may not easily breakdown as they are intended to because of environmental factors. To our knowledge there is no definition of “biodegradable” for any product in statute or rule. This is because of the wide variability of environmental conditions and many factors that impact the rate at which breakdown occurs. It would be extremely difficult to apply the definition to any product, except in the most specific conditions. In the sportfishing industry we have found that labeling products “biodegradable” is of limited marketing value. Anglers seek products that they believe attract fish and will not trade bait effectiveness for degradable products.

2) *Do you or the manufacturing companies have any research on the effects of plastic baits on salmonids- you mentioned some studies?* Response: Much of the research done by the industry has been on species of bass, various pan fish and salmonids, primarily rainbow trout. This research has not produced mortality or ill effects on fish species tested. Tests consistently demonstrate that fish regurgitate or pass soft baits without harm.

3) *Do you or the manufacturing companies have any research on the time it takes hooks to deteriorate (New England waters if possible)?* Response: There is no specific research for Maine or New England waters. All tests are done in a laboratory. While the finish on the hook is a determining factor in its longevity, in general steel hooks rust quickly. While many factors such as pH,

contribute to the rate of oxidation, the major determining factor for the rate of hook deterioration is the oxygen level of the water the hook is in. Hooks oxidize, rust and break down into various iron oxide components.

4) *Technical advances that are available or planned to prevent/reduce the loss of plastic lures?* Response: Currently, some soft baits have fibers in them to provide strength and some have parts that are made of different density or hardness, but there is no standard for preventing loss. Loss rates are highly variable and the best way to minimize loss rates is through angler education. Anglers will not trade bait effectiveness for construction they perceive negatively impacts performance.

5) *A timeline of technological advances that have lead up to the current biodegradable bait now being used?* Response: The first soft baits were produced in the early 1950s, the addition of PVC to soft baits to give the industry more variability and options quickly became the industry standard for soft baits. The first biodegradable baits were made in the late 1980s to the mid-1990s. At most 10% of soft baits on the market are labeled biodegradable.

6) Is *there a list of standard chemicals that are used to create some of these lures – I know we discussed 2-3 of the major components?* Response: While soft bait formulas are highly variable the main components are polyvinylchloride, polyvinylalcohol and various protein materials. Stabilizers, mineral oils and hardening agents are added to create varying levels of pliability. Common PVC plasticizers are diisononyl phthalate (DINP), diisodecyl phthalate (DIPP), and di-2-ethylhexyl phthalate (DEHP, aka DOP). These plasticizers probably account for roughly 75% of all plasticizers used for PVC. Additionally, other kinds of plasticizers are used to meet specific requirements, including adipates for low temperature resistance and trimmelliates for heat resistance. Mineral seal oil is often used as a secondary plasticizer. Most company's formula's for soft baits are proprietary information and is unavailable.

7) *Any mitigation/recycling/ programs sponsored by the manufacturing companies. Who and how can we increase participation?* Response: Companies encourage anglers to use soft baits responsibly and encourage state agencies and fishing organizations to promote angler education for proper use of soft baits. We are not aware of any mitigation programs or scientific findings of harm that would merit a mitigation program. B.A.S.S. has a program entitled "ReBaits®" that educates anglers to be good stewards of

clean water and to collect their used soft baits instead of throwing them into the water. This program is used by B.A.S.S. Nation chapters, including Maine's own chapter. The Maine chapters of B.A.S.S. Nation have plastic lure collection containers available for on-site collection and also collects used soft baits by mail. Collecting and mixing soft baits in a recycle program is challenging for most companies because you cannot control the contents of the collections and produce a quality recycled product.

8) *Funding for educational efforts – is there money available to address this issue?* Response: The industry does not have funds for this but would provide Maine technical assistance in expanding your current angler education program to include artificial baits. In addition, ASA would consider working with the recreational fishing community in Maine and beyond to design and implement a volunteer educational program covering both fishing technique and proper disposal of used soft baits.

9) *Is there a way to determine the manufacture of a given series of bait from the chemical makeup?* Response: To determine the age of a lure lost on bottom? Response: No, the formula varies for each style of bait made per company and also between companies. There is no reliable method to determine the age of found baits.

Mike, I hope these answers assist with your report. It is important that we continue to discuss this issue and work towards solutions that maintain angling opportunity in Maine and a commonsense approach that does not lend to emotional and unnecessary legislation or rules that are not based on science. Our offer to visit with the Department and others in Maine to discuss this report still stands.

Sincerely,

Gordon C. Robertson

Gordon C. Robertson
Vice President

Appendix E

Email Correspondence from

Dr. Keith Jones, Pure Fishing, Inc.

LD 42 reads: “As part of its study, the department may seek and include in its report information obtained from fishing tackle manufacturers or fishing tackle manufacturers' associations regarding the effects of disposal and ingestion of soft baits made of rubber and soft plastic and longevity of nondegradable hooks for fishing, and the performance and durability of biodegradable alternatives.”

To fulfill this part of LD 42’s requirements, the Department contacted Dr. Keith Jones at Pure Fishing, Inc. The email below provided a website link to a Japanese study conducted by ECOGEARAQUA. There is little discernible information provided on this website. No other information or data was provided by Pure Fishing, Inc.

--- On **Mon, 2/18/13, Jones, Keith <*kajones@purefishing.com*>** wrote:

From: Jones, Keith <kajones@purefishing.com>
Subject: Design for Fisherman - ECOGEARAQUA
To: jcamusowalker@yahoo.com
Date: Monday, February 18, 2013, 3:30 PM

http://www.ecogear.jp/game_fishing/environment/ecogearaqua.html

Judy -- Here is the link to the Ecogear study. Berkley Gulp! would show a very similar degradation curve. I have no information whatsoever on Rapala Trigger-X.

Lure / bait

Ecogearaqua concept " **lure / bait**"

Fusion perturbation bait of comparable to lure a factor of action, form, color and raw food, exactly what is the attraction of the following bait.

A revolutionary and pursued the three themes, to develop a new material ecogearaqua.

1-Extraordinary attraction,
-Environment-friendly biodegradable
-For angler safety

1, Extraordinary attraction

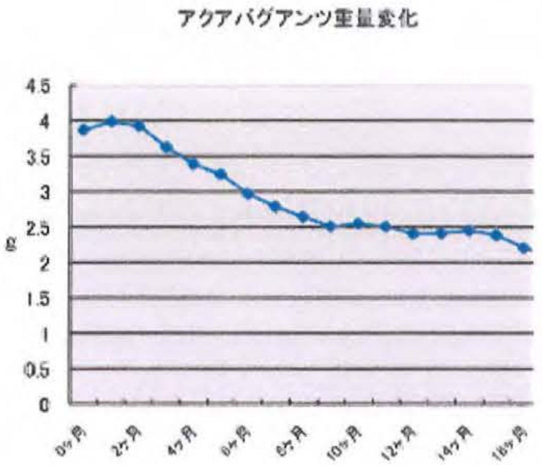
Attractive effect derived by the collective research staff who knows the game fish, and over the years research and testing of high amino acid incorporated into mass in the ecogearaqua. And the combination of each amino acid composition according to the target, cost-effective, dissolution rate also to the exquisite control. Stimulates the appetite of widely scattered target attracts and delivers explosive power further to the moment the bytes.

In repeated field testing beyond imagination byte rush. Completely overrule common sense ever perfect. What will we do once you experience its bytes can no doubt.

Environment-friendly bio-degradable

Ecogearaqua is made of completely biodegradable and water soluble polymer. In addition to examine low impact on the environment using natural materials to the lame.

Experiments in the Lake by approximately 50% weight reduction in 18 months.



0 Months 18 Months

Currently, in joint research with Tokyo University of marine, has been in more detail about the solution of.

You see compared to start immediately (photo left), 9 months (right) at the big crack that degradation is happening in surface observations.

Scanning electron microscope photographs. Offers: Tokyo Ocean University

High safety against angler

Ecogearaqua with water soluble polymer non-primary raw materials, high safety stuff.
To save fees ranging from ecogearaqua body-only solution, using extremely harmless to fish and all those things. No use whatsoever is harmful to the human body, such as formalin. What is used as a cosmetic to dye used.