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Predicting ecological outcomes of stream creation using fish community attributes

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Abstract

We demonstrated an approach for predicting a new stream environment, and the fishes it can support in terms of species composition, population density, and biomass. The challenge was to depict the future of a flowing stream in a setting where no present stream existed. The habitat of the Peconic River was field surveyed and digitally mapped for three water level conditions: run, glide and pool. Biomass estimates, in g/m^2, were calculated for species historically found in the river, and species percent biomass was used to determine the number of each species likely to occur in each habitat type. The total biomass for all sites in each habitat type was averaged to predict biomass per unit area by habitat type. Biomass was then linked to habitat type to enable an estimate of where each fish species would be located and in what proportions. Biomass was predicted to increase with the amount of water in the Peconic River system. Pools are expected to exist with greater frequency at low and mid water and runs are expected to be more prevalent at high water. Glides are only expected when water levels are low. The total predicted biomass for the Peconic River study section in low water is expected to be 7 kg for glides, 13 kg for runs and 11 kg for pools. In mid water, 34 kg of biomass is expected for runs and 88 kg for pools. In high water, 370 kg of biomass is expected for runs and 62 kg for pools. Chain pickerel (*Esox niger*) is expected to comprise the highest biomass in all habitat types at all water levels. The results from this study are important to decision makers seeking a solution to an environmental problem through creation of a waterway in a heavily populated and altered environmental setting.

Keywords: species composition; habitat classification; water level; population density; fish biomass; stream reconstruction

1 Introduction

Increasingly ecologists and engineers are faced with the need to create new habitats and ecosystems that cannot be guided by pristine or natural reference conditions. Some examples of such places are mined lands, brownfields, urban waterways, and soil depleted areas (Gattie et al. 2003). Changes emerging in climate, flora and fauna, community structure, and ecosystem processes are further expanding the need for newly reconstructed ecosystems. Also, addressing the desires and needs of people increasingly requires us to rethink how ecological reconstruction should be aimed (Cairns 2000). Ecosystem reconstruction, which integrates people and nature (domesticated nature, Kareiva et al. 2007), leads to the development of novel habitats and ecosystems. This challenge is not new and has been practiced since the 1960s under different labels such as ecological engineering, ecotechnology, artificial ecology, ecosystem rehabilitation, and nature engineering (Mitsch and Jørgensen 2003; Shields et al. 2003).

The most common approach for creating novel ecosystems is to alter the physical characteristics and allow a natural system to emerge in the new environment. Novel ecosystems have species compositions, ecological properties, and ecosystem processes that have not previously existed at a given location (Hobbs et al. 2006). Palmer et al. (2004) promote the concept of designer ecosystems based on ecological principles to serve human needs and sustain biodiversity. For example, they describe a designed urban waterway that provides benefits for recreation, water quality, and streamside vegetated habitats. We believe much can be accomplished by engineering new environments that support biodiversity and ecosystem processes in places where none currently exist.

Ecologists and engineers need to do more than create a physical setting to make a persuasive case for ecological engineering of new environments. Sizable and costly environmental rehabilitation requires a method for assessing accomplishment and measuring performance. Here we demonstrate an approach for predicting a new stream environment, and the fishes it can support in terms of species composition, population density, and biomass. The challenge was to depict the future of a flowing stream in a setting where no present stream existed. Though not verified, the resulting fish fauna was important to decision makers seeking a solution to an environmental problem through creation of a waterway in a heavily populated and altered environmental setting.

2 Materials and methods

Brookhaven National Laboratory (BNL) is a United States Department of Energy research facility located on Long Island, New York. Wastewaters from BNL are treated at an onsite sewage treatment plant (STP) and are discharged to the headwaters of the Peconic River. Water flow in the headwaters are controlled by the water table elevation and STP discharge. However, contamination issues involving mercury, organics including PCBs, and radionuclides have restricted wastewater handling. Thus, the Peconic River in this area flows intermittently and has experienced extended dry periods over the last 30 years (Sullivan 2003). An environmental restoration program was initiated in the early 2000s to include contamination cleanup, wetlands restoration, and additional water releases to the headwaters of the Peconic River. Our study assists the environmental restoration program by providing a prediction of Peconic River fish abundance and species under a variety of future water levels for use in public discussion and permitting.

More specifically, the aim of this study was to determine the approximate fish biomass that the Peconic River can support in the section from the STP to Wading River/Schultz Road for low water, mid water, and high water scenarios (Figures 1-3). Two tasks were necessary to approximate fish biomass in the Peconic River: 1) habitat mapping and 2) biomass data assembly. The aquatic habitat in the Peconic River was surveyed from October 24-25, 2002 by walking 4.5 km upstream from Wading River/Schultz Road to the STP on BNL property. While walking in the streambed, changes in potential aquatic habitat (i.e. run, pool, glide), vegetation and substrate were noted. At each transition point, the distance (m) from the last change was determined, as were bankfull width and wetted width, using a tape measure. A geographic positioning system (GPS) was used to pinpoint the exact location at each change. Missing GPS coordinates, due to dense tree cover in some areas, were approximated using coordinates from well locations and previous survey markers noted during the survey.

We used the wetted width measurements and the distance along the streambed to determine the outline of the wetted area at low water in ArcView 3.2 (ESRI 1999). Values of pool, run or glide were assigned to habitat areas based on observations and measurements at the study site. The high water map was developed in the same way except using bankfull width measurements instead of wetted width. The water outlines were then verified and augmented with information from digital orthoimagery provided by BNL Environmental Information Management System (EIMS) for Suffolk County (2001) which indicated inundated areas. Habitat characterizations were assigned based on the following rule: habitat is considered a run at high water unless the stream goes around a bend or into a side channel, in which case refuge areas (pools) of slower moving water would occur (Dunne and Leopold 1978). The mid water map was created using a digital map of water outlines supplied by BNL EIMS. These outlines fell between those already created for low and high water. Most maps we produced inferred water levels and habitats without direct observation so this information must be taken as an approximation of the conditions found under each of the water levels.

Biomass estimates for the Peconic River were computed by first collecting data from fish surveys previously completed in the Peconic River by the New York Department of Environmental Conservation (NYDEC, Region 1) between 1988 and 2001. These data were supplemented with data from the Ipswich River obtained from the Massachusetts Division of Fisheries and Wildlife (MA DFW), and from Hunts Brook, Folwix Brook, and Cold Spring Brook obtained from the Connecticut Department of Environmental Protection (CTDEP). Like the Peconic River, these supplemental waterbodies are also in the northeast US with sandy, coastal, low gradient channels. The Ipswich River also experiences heavy human water use and periodic flow reductions (Armstrong et al. 2001). Thus, these rivers were deemed suitable analogues. The following information was obtained for all datasets: species collected, length, weight, equipment used, length and width surveyed, and habitat type. Only surveys by electrofishing gear were used in our analysis.

Biomass values were calculated for the Peconic and Ipswich River datasets; values were included with the Connecticut data. Length-weight regression formulas (Carlander 1969; Carlander 1977; Carlander 1997; Froese and Pauly 2002) were applied for all individuals for whom length but not weight data were available. For species with missing length data, average lengths of same species fish at that site were computed.

Next, the number of individuals per site was tallied and used in the following formula to adjust for electrofishing gear inefficiency (Ontario Ministry of Natural Resources 2001):

$$Y = 2.18(X^{1.02})$$

where X is the number of fish caught in a single pass and Y is the population estimate. While electrofishing gear is viewed as the most effective method for fish sampling in streams (Bagenal 1978; Plafkin et al. 1989), it is reported to be size selective, with large fish more susceptible to capture than small fish (Wiley and Tsai 1983).

All biomass estimates were next divided by the length and width of the surveyed region to obtain biomass (g/m^2). The Peconic River, Ipswich River and Connecticut streams were then classified by habitat type. Only pool, run and glide were used in this analysis in order to reflect habitats expected in the Peconic River at low, mid and high water levels. Biomass for each species at all sites in each habitat type was then averaged to obtain the average biomass per square meter of each species and the percent biomass of each species. Zeros were used in places where the species was expected but not caught and blanks were used in places where the fish were not expected and not caught.

The biomass estimates of fish not expected in the Peconic River study area were merged with the biomass estimates of fish with similar characteristics previously recorded in the region. This was done to present a more realistic representation of the likely recolonization scenario upon rewetting of the study area. Therefore, the biomass estimates of yellow bullhead (*Ameiurus natalis*) were merged with those of brown bullhead (*A. nebulosus*), redfin pickerel (*Esox americanus americanus*) with chain pickerel (*E. niger*), green sunfish (*Lepomis cyanellus*) and redbreast sunfish (*L. auritus*) with bluegill (*L. macrochirus*), yellow perch (*Perca flavescens*) with pumpkinseed (*L.*

gibbosus), and swamp darter (*Etheostoma fusiforme*) with creek chubsucker (*E. oblongus*). American eel (*Anguilla rostrata*), sea lamprey (*Petromyzon marinus*) and white sucker (*Catostomus commersoni*) do not have closely related analogues therefore, the biomass estimates of these species were spread among all previously recorded species in percentages which correspond to the that species' overall representation at that water level and habitat type. These final species' percent biomass figures were used to determine the number of fish of each species likely to occur in each habitat type. Finally, the total biomass for all sites in each habitat type was averaged to obtain the predicted biomass per unit area for each habitat type.

Finally, we linked the biomass approximations to the habitat types in the Peconic River to enable an estimate of the locations and proportions of each species. Biomass approximations were calculated for each square meter so that they could be applied to any size area. For each habitat type at each water level, the area was calculated and multiplied by the predicted biomass per unit area to obtain total biomass in grams. The number of individuals of each species was then predicted for each habitat type at each water level by multiplying the percent species biomass by the total biomass and then dividing that figure by the median fish size values. The median fish size in grams of each species was determined from Peconic River data with Ipswich data substitutions for species not commonly occurring in the Peconic River data set.

3 Results

Habitat characterizations for the Peconic River at low, mid and high water levels indicate that the river is primarily shallow and narrow near both ends of the study area with large pools in the middle sections (Figures 1-3). Bankfull width measurements at high water ranged from 2 - 52 m with a mean of 9 m and wetted width measurements at low water ranged from 0 - 30 m with a mean of 4 m. The Peconic River at low water is expected to be 13% glide, 39% run and 48% pool habitats. We expect 79% pool and 21% run at mid water and the inverse, 80% run and 20% pool, at high water (Table 1).

Depending on the volume of water used to maintain the upper Peconic River, we project 9,475 to 133,276 m^2 created aquatic habitat supporting eight fish species and from 464 to 7,361 individuals. The eight expected species are: banded sunfish (*Enneacanthus obesus*), bluegill, brown bullhead, chain pickerel, creek chubsucker, golden shiner (*Notemigonus crysoleucas*), largemouth bass (*Micropterus salmoides*), and pumpkinseed.

Data from all reference sites were used to estimate biomass as a function of river habitat. The Peconic River had eight sites classified as run and five as pool. The Ipswich River had eleven sites with data from glides and two from runs. Three sites in the Connecticut dataset qualified as pool habitats. Using data from all sources, the predicted biomass in glides is expected to be 5.69 g/m^2, in runs 3.48 g/m^2 and in pools 2.32 g/m^2.

The predicted biomass by habitat type was combined with area measurements from the habitat surveys to yield an expected total biomass of approximately 7 kg for glides in low water, 13 kg for runs and 11 kg for pools (Table 1). For mid water, approximately 34 kg of biomass is expected for runs and 88 kg for pools and for high water 370 kg in runs and 62 kg in pools.

Median predicted biomass for the eight species expected in the Peconic River are: banded sunfish 1.4 g, bluegill 148 g, brown bullhead 347 g, chain pickerel 60 g, creek chubsucker 28 g, golden shiner 27 g, largemouth bass 326 g, and pumpkinseed 100 g.

The species with the highest expected biomass in glides are: chain pickerel (48%), bluegill (24%), pumpkinseed (15%), brown bullhead (10%), and creek chubsucker (3%). In runs: chain pickerel (86%), creek chubsucker (7%), and pumpkinseed (5%). In pools: chain pickerel (43%), brown bullhead (39%), golden shiner (10%), creek chubsucker (4%), pumpkinseed (2%), and largemouth bass (2%).

Table 1 shows the expected species composition in each habitat type at each water level in the Peconic River. Chain pickerel are expected to be found in the highest numbers in all water levels and all habitats. Brown bullhead, chain pickerel, creek chubsucker, and pumpkinseed are predicted to be generalists found in all habitats and all water levels. By contrast, banded sunfish, bluegill, and largemouth bass are specific to distinctive water levels or habitat types.

4 Discussion

We used a direct approach for predicting a new stream environment and the fishes it can support in terms of species composition, population density, and biomass. Depending on the volume of water used to maintain the upper Peconic River, we project that from 9,475 to 133,276 m^2 of aquatic habitat will be created to support eight fish species, from 31 to 432 kg of fish biomass, and from 464 to 7,361 individuals. These values serve as clear benefits and expected accomplishments of the restoration measures being considered for the Peconic River and can be used to justify the outcome of using water for habitat creation. Though not verified, the resulting expected fish fauna was important to decision makers seeking a solution to an environmental problem.

The challenge was to depict the future of a flowing stream in a setting where no present stream existed. Our approach used very basic data and regional habitat analogs from human occupied areas to predict fish community characteristics. We believe streams from human dominated landscapes are more relevant analogs for the Peconic River than natural reference sites. Our predicted restoration outcome shows a diverse and potentially abundant community of fishes that can be used to justify stream creation.

In our approach we assumed that short-term reoccupation of newly wetted habitat will occur from adjacent waters: downstream sections of the Peconic River and other waterways in the river valley. Consistent with stream geomorphology principles (Dunne and Leopold 1978), our habitat characterization indicates that glides will exist with greater frequency at low water, pools at low and mid water, and runs at high water. Fish biomass is predicted to increase with the amount of water in the Peconic River channel because it provides more aquatic space and presumably associated resources for resident fish. Biomass is predicted to be highest in glides comprising shallow, slowly moving water (Glova 1998; Modde et al. 1991). Runs are also expected to be high in biomass with pool habitats the lowest. These expected patterns of habitats and fish community support are combined with stream analogs to provide a basis for our predictions.

5 Acknowledgements

We thank Bob Litzke (BNL) and Hollie Kitson for their help with fieldwork and Todd Richards (MA DFW), Chart Guthrie (NYDEC) and Neal Hagstrom (CTDEP) for their biomass estimate data. This study was supported by BNL.

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March 15, 2011

Dear Coordinating Editor and reviewers:

Thank you very much for your suggestions on revisions to the manuscript ECOLENG-D-10-00334: Predicting ecological outcomes of stream creation using fish community attributes. We have revised the manuscript following the comments of the reviewers as closely as possible. Please refer to our responses and explanations below in which we list all changes made to the manuscript in response to the comments raised by the reviewers.

Responses to the comments of the coordinating editor:

Comment 1:
I am willing to consider your paper if you willing to resubmit it as a Short Communication. Short Communications are less than or equal to 10 manuscript pages (not counting references), double-spaced, with no more than 4 Figures + Tables. You are close now with essentially a 12 pp manuscript and 4 figures+tables.

Response 1:
Thank you for considering our paper for your journal. We have reduced the manuscript to 10 pages and 4 figures/tables so it could be considered as a Short Communication.

Comment 2:
I would like you to cite maybe a couple more papers from Ecological Engineering on stream restoration to better tie your paper to the fields of ecological engineering and ecosystem restoration.

Response 2:
We added the following citations from Ecological Engineering on stream restoration.

Cairns Jr., J., 2000. Setting ecological restoration goals for technical feasibility and scientific validity. Ecological Engineering 15, 171-180.

Gattie, D.K., Smith, M.C., Tollner, E.W., McCutcheon, S.C., 2003. The emergence of ecological engineering as a discipline. Ecological Engineering 20: 409-420.

Shields, F.D., Cooper Jr., C.M., Knight, S.S., Moore, M.T., 2003. Stream corridor restoration research: a long and winding road. Ecological Engineering 20, 441-454.

Comment 3:
We no longer require bios and pictures with the manuscript. This was added to the guidelines by the publisher Elsevier in error without asking the editors and we have since removed that requirement.

Response 3:
We have removed our bios and pictures from our submission.

Responses to the comments of reviewer #3:

Comment 1:
The authors present a creative analysis of the effects of various levels of flow restoration on a stream fish population. The lack of verification for the methodology presented is a serious shortcoming.

Response 1:
We intended our submission to be regarded as an idea paper with an emphasis on the approach and not testing or verification. We expect that the idea of creating a new aquatic environment, without copying a reference site, is innovative and important for many applications where this is increasingly happening. We have added the words “not verified” to the last paragraph in the introduction and the end of the first paragraph in the discussion to emphasize the approach of this idea paper and acknowledge that our idea was not tested or verified:

Comment 2:
In the abstract, the expression "no current stream," might be ambiguous for some readers, since current also means velocity. Maybe the phrase "restoration of flow to a dewatered stream" would be more apt.

Response 2:
We agree and thus changed the word “current” to the word “present.” Thus, the changed sentence (in both the abstract and introduction) reads as follows: “The challenge was to depict the future of a flowing stream in a setting where no present stream existed.”

Comment 3:
The paper fails to acknowledge that stream ecosystems depend on flow continuously varying about some long-term mean. The frequency distribution of discharge is usually log-normal or displays some similar pattern. So relating ecosystem characteristics to a single discharge is tricky business. See Doyle et al. (2005). Are the three discharges given in the analysis the mean annual discharge? The one- or two-year return interval flow? Or what?

Response 3:

We are familiar with the concept that varying flows are important to many aspects of a stream: geomorphology, biology, and ecological processes. Mark Bain was an author on the Natural Flow Paradigm paper (BioScience 1997). The issue here was showing what the predicted relative fish responses could be to different water levels from BNL releases, and the number of fish and species could inhabit the new stream. Surface runoff would add to these flows during precipitation events, and shallow groundwater would contribute substantially during the non-foliage period of the year. The stream will vary in flows on a seasonal basis somewhat because Long Island has very sandy soil and most streams there have very stable flows. However, we needed to show ecological benefits in the form the public can understand relative to the proposed BNL flows. The method we used was simple but effective for showing relative fish responses to proposed flows. Although we say our predictions were not verified, they illustrated some benefits for nature in the forested valley.

Comment 4:
Fish populations may be limited by many factors in addition to flow. The analysis presented seems to be pretty one-dimensional and deterministic. (see lines 154-155: ".habitat will likely support eight species and from 464 to 7,361 individual fishes.") If you increase flow in the stream, will the modeled species have adequate food, cover and habitat for all life stages? What about interference due to climatic events, pollution or exotic species? What is the real precision on your predictions? Similar comments apply to the biomass predictions, p. 11.

Response 4:
Multiple factors can limit fish populations but here the issue was flows from BNL. Thus we aimed for comparison of fish responses to the flows that could be provided. We assume that over time the stream would develop an invertebrate community, plants, and microhabitats that can be used by fish. Pollution should not be a problem because the water will be released in good quality. Climatic events could matter, but over the long term average conditions we think our predictions are realistic and relative. There are some exotic species on the predicted species list because those species are widespread now in Northeast US coastal streams. As far as precision we do not know that, because our model was to support restoration planning. We inserted in a coupe places that the predictions were not verified. However, they were taken and used as the best possible predicted information for decision-making and public illustration of benefits to nature of restoring flows.

Comment 5:
Was the habitat classification methodology presented in lines 53-80 verified in any way? Lines 76-80 indicate that the habitat mapping is a very weak point in the analysis.

Response 5:
We did not perform verification of the predicted habitat classification methodology as the stream was mostly dewatered at the time we performed this study and thus verification was not possible. However, we did present the predicted habitat classification maps to the Brookhaven National Laboratory engineering staff for comment. They did not voice any concerns about the legitimacy of our predictions.

Comment 6:

Lines 73-74. Maybe just artificial nit-picking semantics, but "water moves at a run" seems to be an unnecessary anthropomorphism. Also, how can the mainstem go "into a side channel"? If it does, it isn't the mainstem any more, is it? When refuge areas (pools) occur on the outside of a bend, how did you decide how much of a given cross section was pool and how much was run? Also, Figure 3 shows pool habitat on the inside of one bend and several bends with no pool habitat at all.

Response 6:
Agreed. We addressed the anthropomorphism issue and the mainstem issue by rewording the sentence as follows: "habitat is considered a run at high water unless the stream goes around a bend or into a side channel."

We used calculations made in the field based on geomorphology, changes in habitat, vegetation and substrate and measurements of bankfull and wetted width, in addition to our best judgment, to make predictions about the presence/absence of different habitats and the extent of pool verses run or glide (as seen on Figure 3).

Comment 7:
Lines 43-45. The Peconic River in this area has been non-flowing, dry..for many years. How many years? The environmental restoration program began in the early 2000s and the fish data you use are from 1988-2001 (line 83).

Response 7:
In the report published by Brookhaven National Laboratory "Estimation of Potential Water Levels in the Peconic River near Brookhaven National Laboratory Based on a Review of Hydrologic Data," the author states that "in the vicinity of BNL, the Peconic River is an intermittent stream" and that "between the months of September and December there has been essentially no flow since 1996." There is uncertainty in the data but the report seems to indicate that there were "reported zero flows from 1982 –1995" at least for some months of the year however "flow most likely did occur in the 1983 – 1984 and 1989 – 1990 time periods based on high flows measured at the Riverhead station in the Peconic River and precipitation well above average." Thus, the data show that flow has been very intermittent over the last 30 years. Figures in the report show that prior to 1982, flows were quite a bit higher. Our statement in the manuscript that the river has largely been non-flowing and dry is perhaps an overstatement. Thus, we modified our manuscript to read that the river flows intermittently and has experienced extended dry periods over the last 30 years.

Sullivan, T., 2003. Estimation of potential water levels in the Peconic River near Brookhaven National Laboratory based on a review of hydrologic data. Environmental Research and Technology Division, Brookhaven National Laboratory, Upton, New York. http://www.bnl.gov/erd/Peconic/Docs/WaterFlowPeconicRiver.pdf

Comment 8:
Defend choices of reference streams (lines 84-87). Watershed size? Land use? Discharge statistics? Water quality?

Response 8:
Like the Peconic River, these supplemental waterbodies used for biomass estimation are also in the northeast with sandy, coastal, low gradient channels. Water quality for the reference rivers was generally fair in quality (as reported in the National Coastal Condition Report III, 2008). Further, like the Peconic River, these reference rivers experienced heavy human water use and periodic flow reduction. Finally, they were deemed suitable analogues by fish biologists in Massachusetts, Connecticut, and New York.

Comment 9:
Basically the adjustment formula you use for electrofishing inefficiency is Y = 2X. The exponent is likely not significantly different from 1.0. The factor of 2 seems high. Electrofishing efficiency varies with water depth and species as well as fish size. Did you attempt to make any corrections for these factors?

Response 9:
Several studies state capture probabilities using electrofishing equipment in the range of 50% while taking into account various factors affecting electrofishing efficiency such as water depth and fish size (Dauwalter and Fisher 2007 for smallmouth bass 53%; Speas et al. 2004 for rainbow trout 56%; Bayley and Peterson 2001 for common carp 57%). Many other fish species had lower reported capture probabilities (Bayley and Peterson 2001). Based on the results of these studies, we concluded that our adjustment rate of 2X was reasonable and appropriately accounted for the variability in efficiency based on factors such as water depth and fish size.

Bayley, P.B., Peterson, J.T., 2001. An Approach to Estimate Probability of Presence and Richness of Fish Species. American Fisheries Society 130:620–633.

Dauwalter, D.C., Fisher, W.L., 2007. Electrofishing Capture Probability of Smallmouth Bass in Streams. North American Journal of Fisheries Management 27:162–171

Speas, D.W., Walters, C.J., Ward, D.L., Rogers, R.S., 2004. Effects of Intraspecific Density and Environmental Variables on Electrofishing Catchability of Brown and Rainbow Trout in the Colorado River. North American Journal of Fisheries Management 24:586–596.

Figure captions

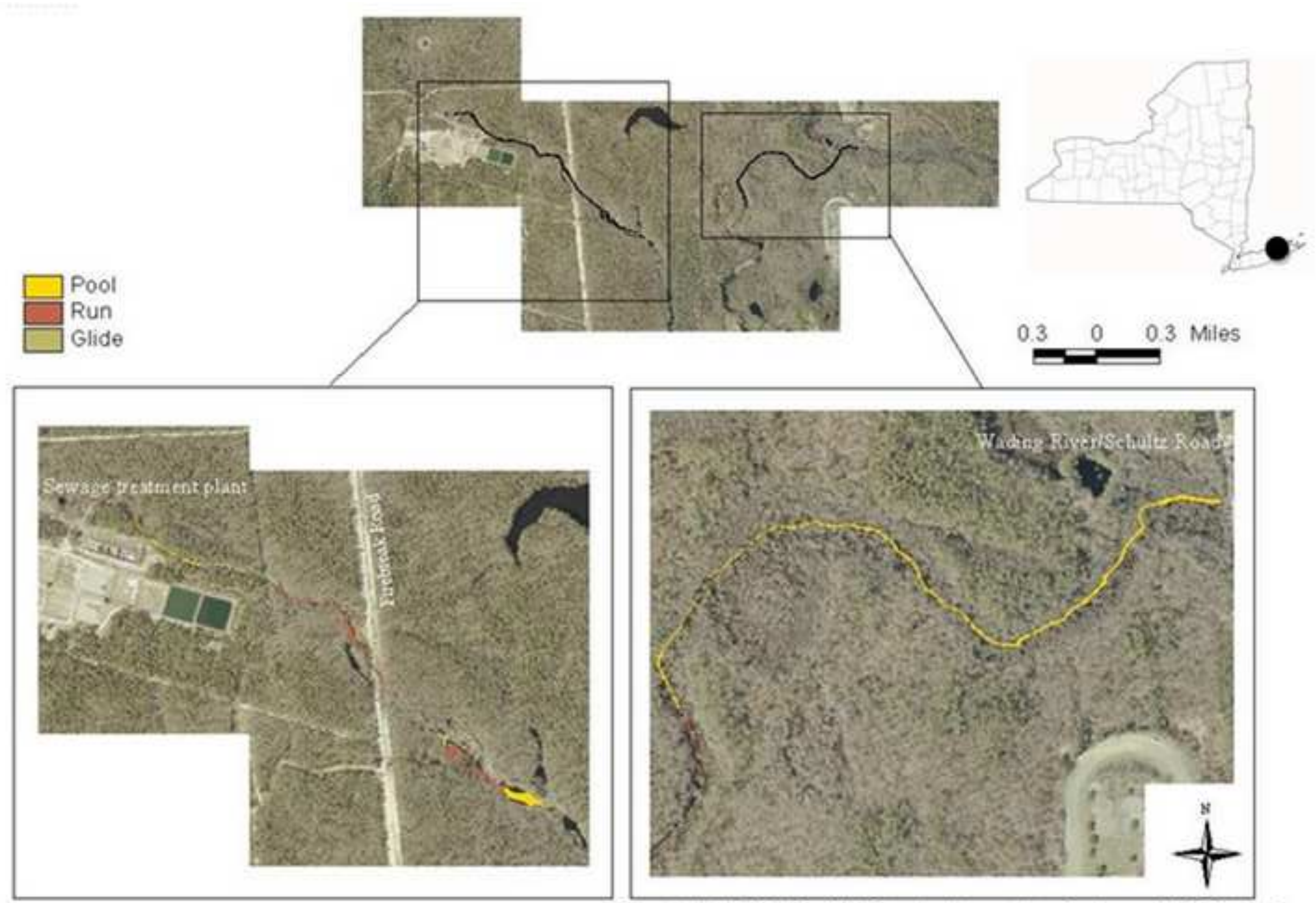
Figure 1. Approximate habitat on the Peconic River from Wading River/Schultz Road to the sewage treatment plant at low water.

Figure 2. Approximate habitat on the Peconic River from Wading River/Schultz Road to the sewage treatment plant at mid water.

Figure 3. Approximate habitat on the Peconic River from Wading River/Schultz Road to the sewage treatment plant at high water.

Note: Color figures are intended for color reproduction on the Web and in black-and-white in print.

Figure1



Pool
Run
Glide
0.3 0 0.3 Miles
Sewage treatment plant
Firebreak Road
Wading River/Schultz Road
N

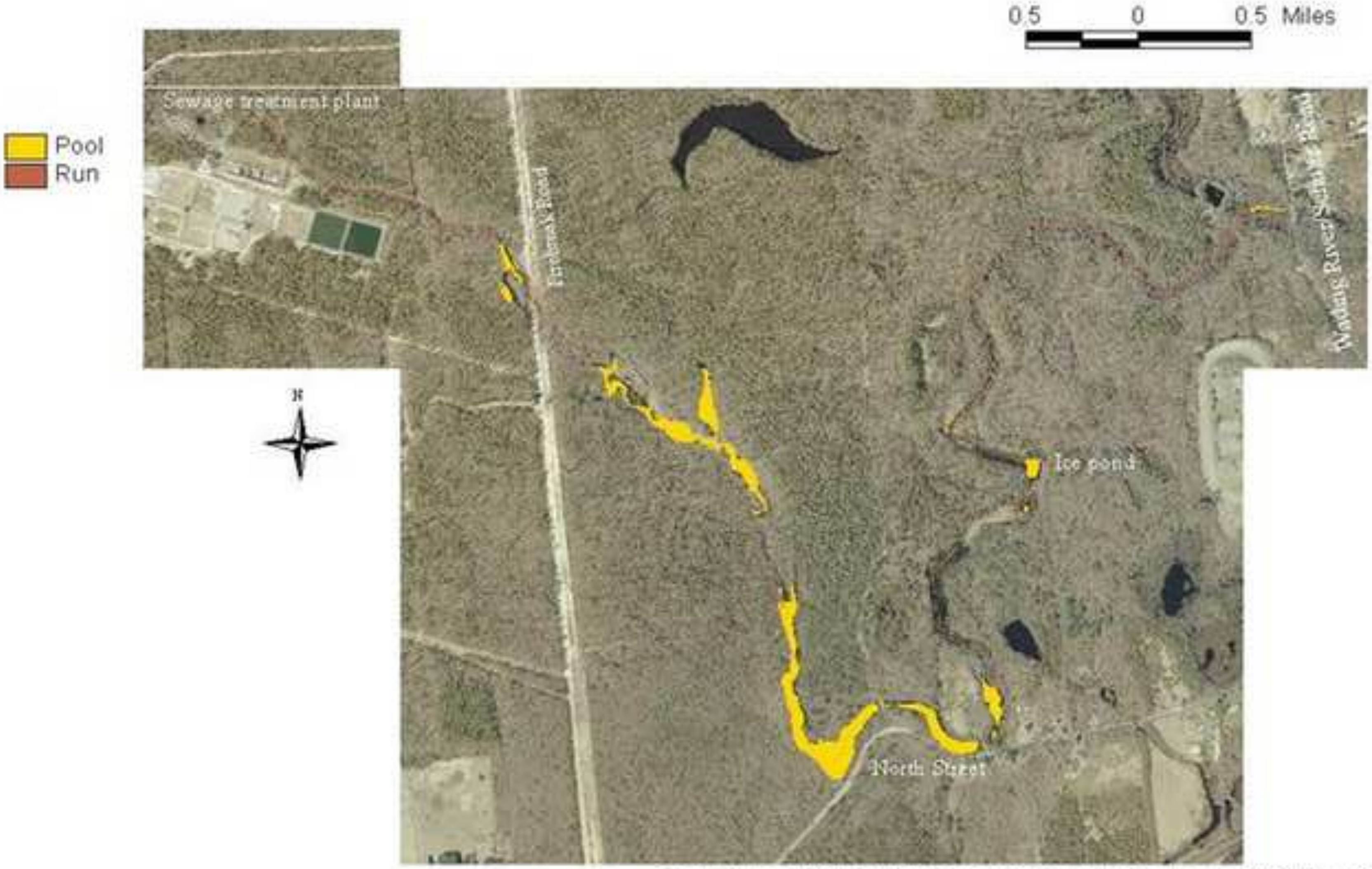

🟨 Pool
🟥 Run
0.5 0 0.5 Miles
N
Sewage treatment plant
Firebreak Road
Wading River Manor Road
Ice pond
North Street

Figure3

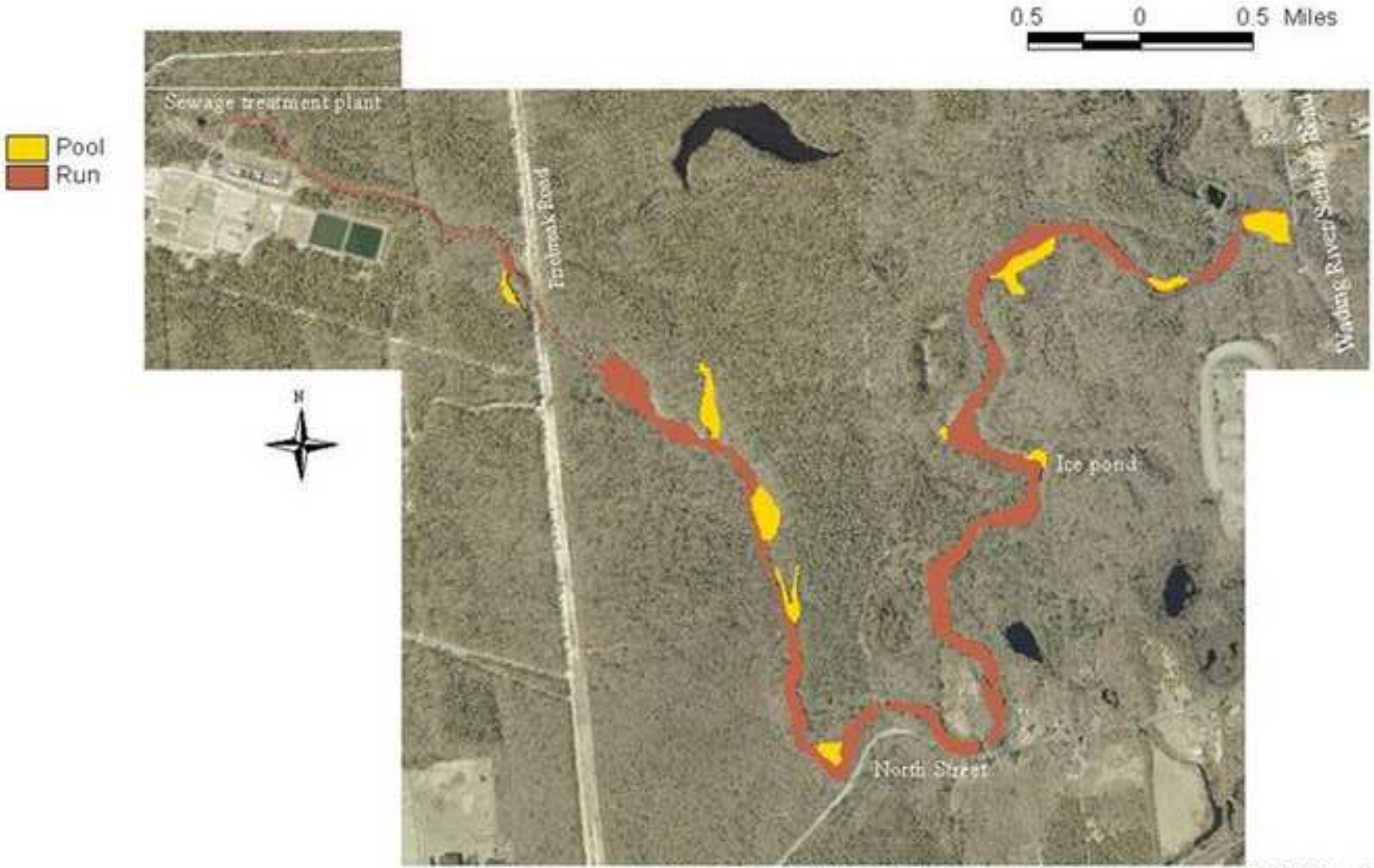


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Table 1. Expected number of each species in each habitat type at each water level in the study section of the Peconic River.

Water level	Habitat type	Total area (m^2)	Percent of area	Approx-imate biomass (kg)	Banded sunfish	Bluegill	Brown Bullhead	Chain Pickerel	Creek chub-sucker	Golden shiner	Large-mouth bass	Pumpkin-seed	Approx-imate total number of fish
Low	Glide	1207	13	7	3	11	2	55	7	0	0	10	88
Low	Run	3682	39	13	0	1	0	184	31	1	0	7	224
Low	Pool	4586	48	10	8	0	12	76	15	38	1	2	152
Mid	Run	9800	21	34	0	2	1	491	82	3	0	18	597
Mid	Pool	37940	79	88	67	0	100	629	124	314	5	20	1259
High	Run	106378	80	370	0	17	9	5325	891	34	0	192	6468
High	Pool	26898	20	63	48	0	71	446	88	223	3	14	893