

Mather- Freshwater fish proposal

TITLE:

Patterns and processes for freshwater fish distribution in northeastern National Parks: inventory, monitoring, and a model of governing processes

JUSTIFICATION:

Freshwater fish provide recreation for both anglers and non-anglers. In addition, freshwater fish act as key predators in many aquatic food webs. However, hydrologic alterations, acid rain, nutrient loading from adjacent development, exotic fish introductions, and recreational fishing pressure in both freshwater and estuarine habitats complicate the management of these resources. Furthermore, comprehensive and current fish inventories for North Atlantic Region parks are lacking. Thus, an urgent need exists for parkwide inventories to form the basis for long-term monitoring programs, to describe present trophic structure in aquatic habitats, and to identify problems facing the sustainability of the ecosystems which support freshwater fish communities.

BACKGROUND:

What we know - stream fish. Ultimately the goal of ecological research is to describe patterns, identify sources of spatial and temporal variation, and understand mechanisms underlying these patterns. To accomplish these goals, we need to document and understand the role played by important abiotic and biotic factors that affect freshwater fish communities in both lakes and streams (Table 1). In streams, flow affects the structure of fish communities (Bain et al. 1988; Poff and Allan 1995; Schlosser 1995; Poff et al. 1997) both through natural water level fluctuations (Capone and Kushlan 1991) and anthropogenic influences (Manny 1984). Physical parameters, e.g., current, depth, and substrate, also influence stream fish microhabitat choice (Baldes and Vincent 1969; Sheppard and Johnson 1985; Beecher et al. 1995). For example, water velocity at the fish's snout was the principal variable that defined Atlantic salmon habitat use (DeGraaf and Bain 1986).

Macrohabitat features such as channel-units also play a role in stream fish behavior and survival (Bisson et al. 1988; Bozek and Rahel 1991; Mather and Stein 1993a). Spawning habitat (Beard and Carline 1991), instream structure such as woody debris (Bryant 1983; Benke et al 1985; Lisle 1986; Flebbe and Dolloff 1995; Hilderbrand et al. 1997) and cover (Brusven et al 1986) further alter fish biodiversity in many lotic systems. Other abiotic factors including sediment load (Murphy et al. 1981; Alexander and Hansen 1986), pH (Haines 1981; Pinder and Morgan 1995), temperature (Barton et al. 1985), and turbidity (Lloyd 1987) can also impact stream fish communities. Furthermore, anthropogenic effects such as land use can modify salmonid standing crop (Grant et al 1986). For example, maximum temperature related to fraction of bank forested within 2.5 km upstream of a site determined the suitability of southern Ontario streams for trout (Barton et al. 1985).

Biotic interactions such as predation (Power 1984; Bowlby and Roff 1986; Mather and Stein 1993b) and competition for food and space (Hearn 1987; DeWald and Wilzbach 1992) can also change stream fish distribution and abundance although species interactions are often modified by physical factors such as flow (Schlosser and Ebel 1989) and habitat heterogeneity (Fraser and Cerri 1982; Power 1992). Trophic structure also varies with longitudinal stream location (Doucett et al. 1996). Furthermore, many investigators have found that fish

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communities or guilds are a useful way to select target species for instream flow studies (Leonard and Orth 1988) or to describe communities (Lobb and Orth 1991; Austen et al. 1994).

Finally, multivariate models based primarily on physical variables have successfully predicted stream fish abundance especially for western salmonids (Binns and Eiserman 1979; Hubert and Rahel 1989; Winkle et al. 1990; Clarkson and Wilson 1995) although other models have incorporated both biotic and abiotic variables and are applicable to other geographic regions (Bowby and Roff 1986; McClendon and Rabeni 1987; Putman et al. 1995). Consequently a number of abiotic and biotic variables, e.g., flow, microhabitat, macrohabitat, structure, cover, temperature, water quality, land use, food, and fish community structure including competitors and predators, must be examined to understand and predict factors that influence stream fish distribution and abundance (Table 1).

What we know - pond and lake fish. Lake and pond fish are also affected by a number of the same factors. In particular, abiotic factors such as temperature (Magnuson et al. 1990; Headrick and Carline 1993; Snucins and Gull 1995) and dissolved oxygen (Coutant and Benson 1990; Breitburg 1992) influence lake and estuarine fishes. In lakes, aquatic vegetation plays a major role in largemouth bass foraging behavior (Bettoli et al. 1992), influences northern pike habitat selection (Cook and Bergersen 1988), can predict sport fish production (Wiley et al. 1984), and influences fish distribution in general (Weaver et al. 1997). For example, muskellunge selected inshore areas generally less than 10 ft. deep where vegetation and woody debris provided cover (Hanson and Margenau 1992). Other abiotic factors such as water diversion, floodwater storage, temperature, turbidity, and substrate firmness may also alter lake fish distributions (Manny 1984; Mitzner 1984; Miner and Stein 1993). In most lentic systems, physical structure and habitat complexity have an impact on lake and pond fish habitat use (Crowder and Cooper 1982; Gilinsky 1984; Persson and Eklov 1985).

Although in many lentic systems, abiotic factors, especially temperature, appear to set the overall bounds to the movements and habitats utilized, ecological interactions are probably responsible for the finer resolution of microhabitat utilization among size classes and species in the littoral zone (Hall and Werner 1977). Foraging success of lake and stream fish is further influenced by habitat, food availability, fish size (Mittelbach 1981; Werner et al. 1983), and competitors (Mittelbach 1988; Crowder and Crawford 1984; Hodgson et al. 1991). Structure, in particular, can affect foraging success in littoral and benthic communities (Anderson 1984; Matthews 1992; Bevelhimer 1996). In the pelagic and littoral habitats, zooplankton is an important food for many larval, juvenile, and adult fishes. Zooplankton species composition and abundance varies across systems (Amott and Vanni 1993) and can affect fish recruitment (Crowder et al. 1987; Miller et al. 1990; Welker et al. 1994). In addition, in lakes, predation can also modify community structure (Werner et al. 1983; Mittelbach 1984; He and Kitchell 1990; Szalai and Dick 1991; Tabor and Wurtsbaugh 1991; Diehl 1992). For example, direct and indirect effects of piscivory affects an assemblage of small fishes in a bog lake (He and Kitchell 1990). An important conceptual framework for understanding freshwater community structure in lakes has developed based on trophic interactions among nutrients, producers, consumers, and top predators (Hecky et al. 1981; Carpenter et al. 1987; Vanni 1987; McQueen et al. 1989; Bronmark et al. 1992; Schindler et al. 1993; Bronmark 1994; Mather et al. 1995; Dettmers and Stein 1996; Decenzo et al. 1996; Yako et al. 1996). Moreover, land use surrounding lakes can alter water quality (Wichert 1995) and nutrient loading (Soranno et al. 1996), which can, in turn, may affect food supply, fish community and fish growth rates

(Hayward and Margraf 1987). In addition, the riparian zone can alter lake habitats and potentially fish abundance (France 1997). Furthermore, system response to nutrients varies with salinity (Caraco et al. 1987).

As in stream communities, multivariate models have successfully described fish communities in many lakes and ponds (Tonn and Magnuson 1982; Tonn et al. 1983; Rahel 1984; Hinch et al. 1991). Specifically, multivariate community analyses reveal patterns among fish assemblages and demonstrate a link between these fish assemblages and habitat characteristics (Tonn et al. 1983). Similarly, three alternate and distinct fish assemblages were identified in 43 northern Wisconsin lakes encompassing a gradient from bog ponds to small, oligotrophic lakes having little bog character (Rahel 1984). Thus, to document and understand freshwater distribution and abundance in freshwater lakes and ponds, we need to document system morphometry, adjacent land use, availability of structure and cover in littoral habitats, temperature, water quality, food, and community structure including competitors and predators (Table 1).

In both lotic and lentic systems, fish introductions remain an important tool in fisheries management. But because they have had both beneficial and detrimental outcomes, they must be carefully evaluated (Courtenay and Taylor 1986). For example, on the West coast, hatcheries may pose the greatest single threat to the long-term maintenance of salmonids (Hilborn 1992). Furthermore, the consequences of introductions may be unpredictable (Magnuson 1976) and have community wide consequences (Flecker and Townsend 1994). Thus, in monitoring freshwater fish communities in both streams and ponds, the influence of exotic introductions, both past and present, needs to be examined (Table 1).

OVERVIEW:

The freshwater fish inventory proposed here will include ~~Sage-Cod National Beach~~, Wellfleet, MA (CACO); ~~St. Gaudens NHS~~, Cornish, NH; ~~Saratoga NHP~~, Saratoga NY; ~~Roosevelt-Vanderbilt NHS~~, Hyde Park, New York; ~~Morristown NHP~~, Morristown, NJ; ~~Marsh Billings NHP~~; and ~~Weir Farm NHP~~. Although all resources at CACO will be sampled during the extensive survey, i.e., 20 kettle ponds with variable surface areas (Fig. 1), inter-dune ponds, Pilgrim Lake, Herring River (Wellfleet) and Pamet River (Truro), likely, some subset of the water resources at this park will form the basis for the functional model. In particular, tidal freshwater and estuarine creeks (salinity < 2 ppt) will be included in the inventory of migratory fishes. In addition, the resources at St. Gaudens NHS (2 streams, i.e., Blow Me Up and Blow Me Down Brooks and 1 pond); Saratoga NHP (ponds, streams, canal); Roosevelt NHS (small streams, small pond, tidal marsh); Morristown NHS (several streams and tributaries); Weir Farm (3.6 acre pond); Marsh Billings (14 acre pond) will also be sampled twice during the project. Specifically, in the first year, an extensive, comprehensive sample will help formulate the monitoring protocol. In the final year, aquatic resources at all sites again will be sampled to test the protocol.

SCOPE:

Thus, this project seeks to address information gaps of the National Park Service by conducting a seasonal inventory of fish and their food base, i.e., zooplankton, benthos, fish, to collect information that will help us understand the impact of abiotic and biotic factors as well

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as consequences of human impacts on the trophic dynamics of aquatic food webs including freshwater fishes.

SPECIFIC OBJECTIVES:

- 1) Compile historical records on stocking, resource surveys, harvest, chemical treatments, etc, from CACO; St. Gaudens NHS; Saratoga NHP; Roosevelt-Vanderbilt NHS; Morristown NHP; Marsh Billings NHP; and Weir Farm NHP. This compilation of historical records should include synthesis and critical review of the available literature, both peer review and grey, especially those relative to NPS resources. The findings of the present study will be compared to and integrated into the existing local/regional literature.
- 2) Compile existing information on system size, morphometry, and landscape features that may affect abiotic and biotic features of freshwater resources in northeastern parks.
- 3) Determine composition of fish community at all sites in all major habitats.
- 4) Sample select aquatic resources intensively across all season.

In select systems, assess trophic structure (species composition and relative abundance) and functional ecology (species-specific effects on pond trophic of freshwater systems on a seasonal basis). Specifically quantify the distribution, abundance, and impact of the following:

- (a) Fish predators (both resident and migratory)
 - (b) Planktivorous fish (prey and young-of-year piscivores)
 - (c) Seasonal migratory fish, i.e., movements and functional ecology in both stream and lake
 - (d) Zooplankton species composition and relative abundance
 - (e) Benthos
- 5) Analyze the pond fish and zooplankton inventory data in relation to abiotic, biotic, landscape, historical, and anthropogenic factors (including introduction of exotics and fishing pressure) to construct a model of governing processes.

In so doing, build and test a conceptual model of factors that influence freshwater fish distribution in freshwater ponds. The goal of the conceptual model is to document the state and cause of the "current state of affairs."
 - 6) Test, evaluate, and recommend appropriate protocols for the long-term monitoring of all important fish species and aquatic habitats.

APPROACH:

Historical records and extant morphometric information on system size, landscape patterns will be compiled. Then, an initial spring/summer survey of stream and lake/pond fishes at all parks in the region will be conducted. These inventories will provide baseline information on species composition and relative abundance for the protocol and in-depth sampling that will cumulate in a predictive model. Next, kettle ponds at CACO which encompass the range of size, depth, surrounding development intensity, water chemistry (pH, nutrients), productivity, habitat, stocking history, fishing pressure, and other factors, will be intensively sampled. From this intensive sampling, a model of factors governing freshwater fish distribution and abundance will be constructed. Based on all information collected in both the extensive and intensive surveys, a protocol for sampling freshwater fishes at northeastern parks will be compiled. This protocol will then be tested in all northeastern parks with a second extensive survey in the final year of the study.

METHODS:Compilation of existing data

State agency, research, survey, stocking, chemical treatment, and land use alteration records will be integrated with published reports and articles in professional journals to determine a historical record of park freshwater fish resources. Compilation of historical records will include synthesis and critical review of the available literature, both peer review and grey, especially relative to NPS resources and that the findings of the present study will be compared to and integrated into the existing local/regional literature. Experts on Massachusetts fauna such as K. Hartell and D. Halliwell will be consulted throughout but especially in the compilation of existing data portion of the study.

Morphometric synthesis

Using topographic maps and existing GIS resources, system size (surface area, depth, volume for ponds and order, length, drainage area for streams), landscape patterns including connectedness, and land use patterns will be summarized.

General survey - extensive

First, major habitats of all aquatic resources at all park sites will be identified, inventoried, and mapped (Table 2). Quantitative assessments of specific habitats will be made including the amount and type of substrate and spatial distribution and species composition of vegetation (Orth 1983).

A variety of methods will be employed to obtain both qualitative (species composition) and quantitative data (relative abundance or catch per unit effort) on freshwater fish from a variety of habitats (Table 2, 4; Mather et al. 1997). First, littoral fish, both predator and large prey, will be sampled by pulsed DC boat electrofishing (Parrish 1983). Voltage gradients of 0.1 to 1.0 volts/cm are most effective for stunning fish and in waters of normal conductivity (100-500 microhmhos), this can be achieved by adjusting current voltage to produce a current of 3-6 amperes (Parrish 1983). A low pulse rate (5-40 pulses per sec) will be used for spiny rayed centrarchids. Electrofishing is most effective along shore in lakes with a shallow slope, extensive shoreline development, at night when predators move inshore to feed (Parrish 1983). If complete electrofishing coverage of the entire pond is not possible, the shoreline will be divided by habitats and a stratified random design implemented (Johnson and Nielsen

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1983). Next, smaller prey will be sampled in the same littoral habitat with a 30 m, 1-cm mesh bag seine pulled parallel to shore for 50 m at three locations in each pond resulting in three 1500 m² quantitative estimates of relative fish abundance in each system. Beach seines are generally selective for small, slow-moving or schooling fish whose normal habitat is shallow water (Hayes 1983). Third, fyke and trap nets with 1.0 m diameter hoops and 1 cm cod end mesh will be set to sample primarily large littoral predators. Fyke nets are modified hoop nets with one or two wings of webbing attached to the mouth to guide fish into the enclosure (Hubert 1983). The net will be set so that the wings and leader intercept the movement of the fish along shore. When fish follow the wing or leader in an attempt to get around the netting they swim into the hoop. Three fyke nets each with one lead on shore and the other lead perpendicular to shore will be set overnight in each pond. Fourth, experimental gill nets, 2 m deep, 100 m long, with 8 m panels of 38-, 51-, 64-, 76-, 87-, and 102-mm stretch mesh, will be set on the bottom in deeper areas to sample pelagic predators (Hubert 1983). Gill nets are vertical walls of netting set out in a straight line where capture is based on fortuitous encounter with the net. Gill nets catch most species but are especially selective for species that move substantial distances (Hubert 1983). Fifth, throw traps, used extensively to sample nekton in shallow estuarine salt marshes, will be tested and, if effective, will be used to sample fish along shorelines. Finally, minnow traps and angling will be used as needed to sample littoral and pelagic predators and prey. Electrofishing, seining, fyke nets, gillnets, throw traps, and minnow traps will provide quantitative estimates of relative abundance (number of fish per sample unit) which can be compared across sites. Life stages to be sampled include juveniles and adults in the littoral (vegetated and non-vegetated) and pelagic habitats (for pond fish) and riffles and pool both inshore and channel for stream fish (Table 2). For stream fish, 30 m long, 1 cm mesh block nets will be stretched across the upstream and downstream section of the study reach to enclose a representative section of stream through which three passes with a backpack electroshocker will be made (Parrish 1983). All fish, juveniles and adults, will be identified, enumerated, measured and released. Large invertebrates will also be identified and enumerated. Length and wet weight measurements of target species will allow a rough estimation of natural growth rates. If possible, fish will be qualitatively examined for parasites. This sampling scheme will allow for an identification of preferred or critical habitat for individual species or species assemblages.

In conjunction with the biological sampling, water temperature, pH, conductivity, dissolved oxygen, and turbidity will be monitored at the deepest part of the pond or center of the stream sample area with the appropriate meters using standard techniques.

Intensive survey - CACO

An intensive sample of all abiotic and biotic factors that may affect freshwater fish distribution and abundance will be undertaken in Cape Cod kettle ponds (Table 3). These systems may differ in their evolution (Winkler and Sanford 1995) and size (Fig. 1) so clear selection criteria will be important. Fish will be sampled as described above during spring, summer, fall (Table 3, 4; Mather et al. 1997). For migratory fish, traps and drift nets will be set for upstream migrating adults and outmigrating juveniles (Table 2). A subsample of ponds also will be sampled monthly (May-November).

In addition, zooplankton will be sampled from whole column net hauls or tube samples (Graves and Morrow 1988) collected both at the center and within the littoral zone of each pond (Table 3, 4; Mather et al. 1997). Benthic prey will be sampled inshore with a sweep net. Major prey species will be identified to the lowest taxonomic order necessary. Fish stomach contents will be examined in concert with zooplankton sampling to look at the effect of fish on this aspect of

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the prey community. Again, in conjunction with the biological sampling, water temperature, pH, conductivity, dissolved oxygen, and turbidity will be monitored with the appropriate meters using standard techniques. N, P, and chlorophyll a samples from other NPS monitoring programs will be integrated with the intensive sampling data.

Data Analyses:

Fish density (overall and species specific), diversity and dominance will be compared among systems and habitats using analysis of variance (ANOVA). Appropriate multivariate analyses (ordination, cluster, discriminant function analysis, multiple regression) will be used to classify lakes and relate physical and biological variables to fish communities. In particular, multivariate techniques (e.g., principal component analysis) can be used to investigate factors (e.g. water chemistry, trophic relationships) that may cause differences in fish and zooplankton community structure among lakes and habitats.

Protocol:

Based on the above, a written protocol that includes clear objectives and detailed methods that are collated in a handbook format will be prepared. The goal of the protocol is to recommend a monitoring program that is capable of detecting change in fish communities, with some statistical degree of certainty. As a result of this study, recommendations will be made for monitoring a suite of characters that are expected to contribute to changes. The protocols will address objectives, sampling methods, data management and analysis guidance. Monitoring should collect information that is as general to northeastern National Park resources while still documenting accurately conditions at each park. Hence, the protocols will focus on one general methodology for each habitat type where possible. When unique resources exist at each park, individual protocols for specific types of fish resources will be included. In addition, recommendations will be made on how the fish sampling program can best fit with other monitoring protocols. The needs and expertise of Park personnel will be considered throughout the study. NPS staff input will be sought at most stages of the sampling. A second survey of all aquatic resources in northeastern parks will be undertaken in the last year of the study to test protocols and involve park managers in the sampling procedures.

REPORTING:

Progress will be reported in semi-annual reports detailing methods and preliminary results. The inventory data obtained from this project will be presented in final technical reports and as professional peer-reviewed publications. A final technical report will be prepared for each park to include specific information or recommendations regarding 1) long-term monitoring needs and recommended protocols, 2) identification of management concerns, and 3) future research needs. This study will be integrated with other studies in the initial sampling protocol development, field tests, final synthesis, and recommendations. Finally, park resource management and interpretation staffs will be provided periodic technical updates and a final oral presentation on the key findings of the inventory.

PERSONNEL:

Dr. Martha E. Mather, Massachusetts Cooperative Fish and Wildlife Research Unit, University of Massachusetts, Holdsworth Hall, Amherst, MA 01003, mather@forwild.umass.edu

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1 graduate student (M.S. or Ph.D)

1 post-doctoral fellow or full-time technician

Seasonal technicians as needed

SCHEDULE:**FY98 (4 months- June-September, 1998)****Review what has happened in the past**

Identify sources of historical stocking information

Map what we know about the aquatic resources

Identify sources of physical, water quality, morphometric information

Compile data on size (surface area, depth, volume), morphometry, land use, landscape features.

Field Work

Visit all field sites; preliminary sampling protocol

Choose final sampling gear

FY99 (12 months)**Overview**

Finish data synthesis (historical and physical) and site mapping

FIELD SEASON -1**Extensive, comprehensive sample**

Sample all sites and habitats once

Intensive, select site sample

Sample fish, zooplankton, benthos, physicochemistry in kettle ponds intensively

Propose conceptual model**FY00 (12 months)****FIELD SEASON - 2**

Intensive sample - sample kettle ponds intensively

Protocol - Propose sampling protocol

Extensive sample - Sample all sites to test protocol

Model

Build model

FY01 (8 months)

Analyze data, write report, present results, model, and protocol to NPS/NHS

BUDGET - Patterns and processes for freshwater fish distribution in northeastern National Parks: an inventory, a monitoring protocol, and a model of governing processes

	<u>1ST YEAR</u> <u>FY 1998</u>	<u>2ND YEAR</u> <u>FY 1999</u>	<u>3RD YEAR</u> <u>FY 2000</u>	<u>4TH YEAR</u> <u>FY 2001</u>
Labor				
Technician ¹	\$6,200	\$19,000		
Graduate student ²		\$15,000	\$15,000	\$12,500 ¹⁵
Technician ³		\$24,000	\$24,000	
Technician ⁴		\$6,000	\$6,000	
Travel				
Mileage and repairs	\$1,200 ⁵	\$6,000 ¹³	\$6,000	
Site visits		\$17,000 ¹⁴	\$17,000 ¹⁴	
CACO-Lodging	\$1,900 ⁶			
PerDiem	\$560 ⁷			
Other-Lodging	\$2,025 ⁸			
PerDiem	\$600 ⁹			
Professional meetings				\$2,000
Consultant¹⁰				
Zooplankton, L. Yako	\$1,000	\$1,500	\$1,500	
Supplies¹¹	\$1,515	\$15,065	\$13,000	\$2,000
Equipment¹²		\$10,000	\$2,000	
TOTAL DIRECT	\$15,000	\$113,565	\$84,500	\$16,500
INDIRECT (15%)	\$2,250	\$17,035	\$12,675	\$2,475
TOTAL	\$17,250	\$130,600	\$97,175	\$18,975
GRAND TOTAL				\$264,000

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BUDGET JUSTIFICATION

Labor

- 1 Technician to synthesize extant historical data and collate existing physical data on system morphometry, water quality, land use, development, etc. This person will be full time for FY98 (4 months) and FY99 (12 months) at \$9/h X 40 h/wk X 4.3 wk/mo (\$1800/mo) = \$6,200 (FY98) and \$19,000(FY99).
- 2 Graduate student salary = \$13,000/y + \$1,500 mandatory health insurance (Masters or Ph.D).
- 15 FY2001, October 1, 2000 - July 30, 2001 (10 months)
- 3 Masters level full time technician or post doctoral fellow to oversee (with PI) all aspects of data collection and analysis at a rate of \$11/h X 40h/wk X 52 wk/y = \$24,000. Minimal benefits will be included.
- 4 Seasonal field tech (June-September) at \$8/h X 40h/wk, 4.3 wk/mo X 4 mo = \$6,000

TravelFY98

- 5 10 trips to Cape Cod and other field sites at 400 miles/trip, \$.30/mile (gas/minor maintenance)
- 6 CACO field site scouting trips - lodging, 16 days, 14 nights, \$135/night = \$1890
- 7 CACO field site scouting - per diem, \$20/day X 2 people X 14=\$560
- 8 Other sites scouting - lodging, 5 sites X 3 days@ X 135=\$2025
- 9 Other sites scouting - per diem, 15 days X \$20/day X 2 people=\$600

FY99, FY00

- 13 50 trips @400 miles X \$0.30 = \$6,000/year for gas and maintenance.
- 14 Rent a house for 5 people for on site housing, \$800/wk X 4.3 wk X 5 months (May-September). Note: If we can get lower cost housing though the NPS, this money will be rebudgeted for personnel, supplies, and equipment

Consultant

- 10 Lisa Yako has worked extensively on Cape Cod zooplankton and will supervise the sampling, identification, and analysis.

Supplies

- 11 Maps, thermographs, sampling containers, replacement nets, buckets, waders, miscellaneous field supplies, office supplies, etc

Equipment

- 12 Zooplankton nets, gill nets, trap nets, dipnets, drift nets, angling gear, and a portable computer.

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Table 1. Variables to be considered in survey, protocol, and conceptual model of freshwater fish community structure in northeastern parks.

Abiotic

Discharge
 Velocity
 Depth
 Substrate
 Structure
 Cover
 Habitat
 Quantity/quality
 Macrohabitat/Microhabitat
 Riffle/Pool
 Littoral/Pelagic
 Temperature
 Dissolved oxygen
 pH
 Conductivity
 Turbidity
 Salinity

Food

Landscape

System morphometry
 Surface area, Depth, Volume
 Area of littoral area
 Connectedness
 Shoreline development
 Land use
 Urbanization/Agriculture/Forest type/Riparian zone

Trophic

Food web configuration
 Fish community (potential competitors and predators)
 Conspecific density
 Heterospecific density
 Overall productivity

Past history

Stocking

Human impacts

Development
 Water level fluctuations/Hydrological alterations
 Harvest

Mather- Freshwater fish proposal**Table 2. Taxa, habitats, and factors to be sampled in extensive, all-system freshwater fish inventory.**

Extensive (all habitats in all systems)**Fish**

Resident stream fish
Pond predators - littoral
Pond prey- littoral
Pond predators and prey - pelagic

Abiotic

Temperature
DO
pH
Discharge
Velocity
Hydrograph (present and historical)
Conductivity
Turbidity
Habitat
Salinity

Biotic

Conspecific density
Competitors
Predators
Exotics vs natives

Landscape

Size
Land use
Connectedness

Table 3. Taxa, habitats, and factors to be sampled in freshwater fish inventory in intensive, select-system survey.

Intensive survey - select systems only

Fish

- Migrants in stream
- Residents in stream
- Pond predators and prey - littoral
- Pond predators and prey - pelagic
- Estuarine

Zooplankton

- In pond

Benthos

- In pond

Abiotic

- Temperature
- DO
- pH
- Discharge, Velocity, Hydrograph (present and historical)
- Conductivity
- Turbidity
- Habitat

Nutrients (N, P)

Biotic

- Conspecific density
- Competitors
- Predators
- Exotics vs natives

Landscape

- Size
- Land use
- Connectedness

Timing of samples

- All kettle ponds- three times a year to include
 - Recruitment (summer)
 - When resources are limiting (summer)
 - Pre-winter (fall)
 - Spring (post winter survival)
- Select kettle ponds - Once a month

Table 4. Summary of methods for assessing trophic structure of ponds, lakes, and streams related to freshwater fish communities on northeastern National Parks.

Organism	Lateral Habitat	Vertical Habitat	Sampling Method
A. Ponds and lakes			
Adult fish (Predators)	Inshore	Pelagic/ Benthic	Seine Electroshock Trap nets
"	Offshore	Pelagic	Gillnets
YOY, juvenile, planktivorous fish	Inshore	Pelagic/ Benthic	Seine Electrofishing
Zooplankton	Offshore	Pelagic	Vertical tow/ center of pond Tube sampler
"	Inshore		Horizontal tow/ littoral zone Vegetation sampler
Macroinvertebrates	Inshore	Benthos	Sweep net
Phytoplankton Nutrients (N, P)	Offshore	Pelagic	Water sampler
B. Streams			
Fish (resident)	All	All	Stream electroshock Seine
Upstream migrants	"	"	Weir traps
Downstream migrants	"	"	Drift nets