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Anadromous and Catadromous Fish Committee
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Will Atlantic Salmon Restoration Enter The 21st Century? Merrimack River, USA

Lawrence W. Stolte and Joseph F. McKeon

I. Introduction and Background

The first work relating to recent anadromous fish restoration efforts for the Merrimack River began in 1963. Based on this work, Newell and Nowell (1963) reported that excellent potential for salmon restoration existed within the upper reaches of the watershed, an area located in the State of New Hampshire. They identified obstacles to restoration as dams located on the mainstem of the river and major tributaries. Bridges and Oatis (1969) concluded that the lower portion of the watershed located within the State of Massachusetts did not contain Atlantic salmon (*Salmo salar*) spawning or nursery habitat. These early surveys documented migration and habitat constraints associated with the restoration of salmon in the river. Thus it was known at the inception of the anadromous fish restoration program that salmon returning to the river would encounter obstacles while transiting waters in Massachusetts and New Hampshire, and traveling a total of 241 river kilometers (rkm) to spawning and nursery areas.

Anadromous fish restoration commenced on a formal basis in 1969 when the fishery agencies of Massachusetts and New Hampshire, and two federal fisheries agencies, the U.S. Fish and Wildlife Service and National Marine Fisheries Service, mutually agreed to support a fisheries program for the river. A third federal agency, the U.S. Forest Service joined the effort in 1982. Today, anadromous fish restoration is a multi-agency, cooperative effort, and the Strategic Plan and Status Review, Anadromous Fish Restoration Program, Merrimack River (in draft, 1996) provides a comprehensive description of the program.

The unique salmon stock that had evolved in the river was extirpated in the 1800s. As a result, state and federal hatcheries have focused on producing juvenile life stages from donor stocks. Initially, hatcheries produced fry, parr, and smolt for release, but the program has since been modified to emphasize fry and smolt production. Releases from 1975 through 1996 totaled approximately 17.7 million fry, 0.8 million parr, and 1.8 million smolt. Annual fry and smolt release totals have varied greatly among years: 8,000 - 2,900,000 fry ($\bar{x}$ = 821,000); and 2,100 - 189,000 smolts ($\bar{x}$ = 80,000). A total of 64,900 units (1 unit = 100 m^2) of salmon nursery habitat has been quantified within the basin and it is anticipated that adult sea run salmon will have access to approximately 65% of this habitat some time in the future. Spawning stock escapement for full or complete restoration has been estimated at 1,400 multi-sea winter (MSW) females.

Upstream fish passage development is based on stock abundance of salmon and other anadromous fishes, notably American shad *(Alosa sapidissima)*, and herring *(Alosa spp)*. Upstream passage facilities at key mainstem dams are functional, yet work continues to improve efficiency and effectiveness. Efforts have been underway to provide both hatchery fry origin smolt and hatchery smolt safe downstream passage. In some cases, excellent fish passage facilities have been provided at dams, but in most cases passage routes have not been adequate to ensure safe and efficient passage.

Salmon returning to the river are captured at the first dam and transported to a holding facility where held until eggs are taken. The facility has a capacity of 300 salmon and when exceeded additional fish are transported to the spawning grounds and released. Since the inception of the program, there has been only one occasion when the known number of returning fish exceeded 300. In 1991, 332 salmon were known to have returned to the river.

Known adult returns to the river for the period 1982 through August of 1996 totaled 1,821 fish (226 grilse, 1,552 two-sea-winter salmon, 37 three-sea-winter salmon, and 6 repeat spawners). Adults of hatchery fry stocking origin composed 52% of the returns, whereas 3% were from hatchery parr releases and 45% from hatchery smolt releases.

The program requires six million eggs annually to sustain fish culture needs. With 300 sea run adult fish, the projected egg take approaches 1.5 million eggs, 75% less than that required for the program. To overcome the egg deficit, a broodstock rearing program has been established. Broodstock, reared within the hatchery system, are first generation salmon produced from sea run eggs. Broodstock become surplus to the program after artificial spawning, and first generation year-classes are reared to supplement the spawning cycle.

Since 1993, surplus broodstock have been re-conditioned in the hatchery and these post-spawners have been released in the main stem of the river to provide angling opportunities. To distinguish them from sea run salmon, they are marked with disc tags. It is intended that this interim release program be phased out as the number of sea run returns increases sufficiently to provide comparable angling opportunities.

Beginning in 1994, small numbers of pre-spawner broodstock were released on the spawning grounds in the headwaters to determine the efficacy of their use in enhancing production of juvenile salmon. Though the results have been inconclusive, the initiative is expected to continue through the remainder of this Century.

II. Merrimack River Basin Description

The 12,975 km^2 watershed (Figure 1) consists of densely populated metropolitan areas in the lower reaches to mountainous rural communities in the headwaters. The mainstem of the river is formed by the joining of the Pemigewasset River and the Winnipesaukee River. From the extreme headwaters to the ocean, the river covers approximately 291 km. The Merrimack River has an average annual flow of approximately 2,240 m^3/second at the mouth of the river, with extreme fluctuations occurring among the seasons and within a given month.

As recently as the 1960s, the river was among the ten most polluted in the United States. Today, largely as a result of the construction of municipal and industrial wastewater treatment plants and the enactment of laws regulating discharges into the river, it is significantly cleaner.

The mainstem of the Merrimack River has five hydroelectric dams, whereas the mainstem of the Pemigewasset River has two hydroelectric dams and an open flood control structure. The tributary system contains more than 100 dams, some utilized for power production and others providing only water control. Upstream fish passage facilities exist at the first three dams on the river and at three dams on two lower river tributaries. Downstream fish passage facilities of some configuration exist at all of the important dams.

During the last 300 years approximately 20 new fish species have colonized the river. Recreationally important species include largemouth and smallmouth bass (*Micropterus spp.*), northern pike (*Esox lucius*), walleye (*Stizostedion vitreum*), carp (*Cyprinus carpio*), rainbow trout (*Oncorhyncus mykiss*), brook trout (*Salvelinus fontinalis*), brown trout (*Salmo trutta*), catfish (*Ictalurus punctatus*) and goldfish (*Carassius auratus*). Today, the watershed supports approximately 50 species of fish, nine of which are anadromous (Stolte 1982).

III. Historical Perspective

Colonial records (Farmer and Moore 1822, Whiton 1845, Little 1888, Livermore and Putnam 1888, and Musgrove 1904) indicate that salmon frequented the Merrimack River and many of its tributaries. They also indicated that the Pemigewasset River contained the principal salmon spawning and juvenile production areas. Following colonization of the watershed by the English in the 1600s, and until the late 1700s, anadromous fish resources remained abundant. Development of the river by colonists focused on the lower tributaries. The affects of this development on anadromous fish were not adverse, since spawning and nursery habitats remained accessible and unaffected. However, by the middle of the 19th century, manufacturing along the river had grown tremendously.

The river and its fishery resources were soon affected by pollution resulting from human population increases and development in the lower watershed. Runs of anadromous fish declined during the period of rapid industrial development within the watershed (Stolte 1981). Salmon stocks were acutely affected in 1847, when the Essex Dam in Lawrence, MA was constructed without fish passage at rkm 48. By the mid-1850s, salmon ceased to enter the river and American shad and herring stocks were only remnants of their former levels.

In 1866, salmon restoration was attempted in the watershed. Initially, eggs were obtained from Canada and the State of Maine. The effort was abandoned in 1896 due to fish passage problems. However, during that 30 year period, a fish hatchery was constructed; approximately 6.3 million salmon fry were released into the watershed; five fish passage facilities were constructed; 839 adults were counted passing upstream through the fish passage facility at Lawrence, MA; and

438 adults were captured in the headwaters.

IV. The Present Setting

The Atlantic salmon restoration program for the Merrimack River is now in its most critical and precarious position since inception. Eno (1995), an ardent supporter of Atlantic salmon conservation, when speaking of the entire Atlantic salmon program within New England, stated "The key issue that you must grasp is that Atlantic salmon conservation efforts for the last 20 years have been a failure. The issue is: To date we have failed. You may choose the adjective depending on your humor; "spectacular" failure, if you're of sardonic mind; "miserable" failure, if you are of dour disposition."

The status of the program is best revealed when consideration is given to four key areas: 1) public perception and expectation, 2) program accomplishments, 3) the salmon constituency, and 4) political climate. We believe, in the context of public expectation, one that fishery resource agencies played a role in developing, that the program has been a failure.

Salmon stocks have not responded to management initiatives. Some accomplishments have been significant in that donor stocks have been identified, an infra-structure established to meet life stage production targets, and quality habitat reclaimed via fish passage. Maintenance of a strong constituency has stalled perhaps due to false expectations. Political support is wavering as economic constraints require greater scrutiny of benefits gained for monetary resources expended.

Public Perception and Expectation

In the early years of program development administrators provided the public with information related to adult returns from anticipated smolt and fry stocking initiatives. A planning document prepared in 1982 (Stolte 1982) contained a wild smolt production estimate of 103,000 fish and expected adult returns of 1,820, annually. No timetable for achieving the numbers was reported. A revised document (Merrimack River Policy and Technical Committees 1985) contained adult return estimates that ranged from 142 in 1989 to a total of 2,450 in 1996. An Environmental Impact Statement (United States Fish and Wildlife Service 1989) contained language stating that for the period 1989-1996, the average adult return to the river would be 1,170 fish. Return estimates provided to the public and the actual number observed are tabulated in Table 1. Clearly the projected number of homewater returns has not been achieved nor public expectation satisfied.

Results of the Present Atlantic Salmon Restoration Program

Although the program has many components, one aspect most often addressed centers on the number of salmon returning to the river. Total returns to the river now number 1,821 (Table 2).

Annual returns have varied from a low of 21 to a high of 332, yet have remained comparatively low for the last five years.

The return rates are tabulated in Table 3 and it is noted that they vary greatly among years. No trend is apparent with respect to rates of return for hatchery smolt origin salmon with the exception that they are low. The rates of return of hatchery fry origin salmon have declined significantly from those of previous years.

Hypotheses have been offered to explain low and declining rates of return. Smolt losses may be high at hydroelectric facilities, stock genetics may be poorly suited to the river, predation on salmon smolts may be high in the lower river, and present ocean conditions may limit post-smolt survival.

The Salmon Constituency

Constituency groups for salmon restoration include private sector organizations such as Trout Unlimited, the New England Salmon Association, Salmon Unlimited, and the Atlantic Salmon Federation. The effectiveness of the various organizations is sometimes compromised by their competition for funds and membership and leadership positions. Programmatic involvement is usually directed at only those issues of importance to their respective memberships. One particular organization, the Merrimack River Salmon Association, was extremely active in the early 1980s. However, because of unrealized expectations, which lead to a general lack of interest by the membership, the organization was disbanded.

No direct sport fishing constituency for sea run salmon currently exists since salmon numbers are low and directed angling is not permitted. An unorganized sport fishing constituency related to the domestic broodstock fishery in the river's mainstem has grown significantly in the last few years and is now an extremely vocal and supportive group. The growth of the latter is related directly to the number of domestic broodstock released into the river and the angling success that has occurred. This has been fully described by Greenwood and Stolte (1996) and McKeon and Stolte (1993).

The Political Climate

At one time salmon restoration was directly supported at the Congressional level of the United States government. However, leadership and interest in salmon restoration is now lacking (Baum, et. al. 1995). This waning leadership and interest is perhaps directly related to the lack of positive program results.

In addition to the general lack of interest, federal as well as state agencies are being restructured and staffs reduced. This, coupled with budget reductions at the federal and state levels, equates to fewer dollars available for salmon restoration.

V. The Future of Atlantic Salmon in the Merrimack River

Current low rates of homewater returns denote a lack of program success. This aspect and wavering public and political support have increased the challenges associated with the restoration of extirpated salmon stocks. Favorable rates of return observed in the previous decade for the Merrimack River and other New England salmon restoration rivers suggest that new and complex factors are reducing stock abundance. Credible hypotheses profess that an increase in the abundance of predators that prey on salmon, and the effects of intermittent biotic and abiotic factors in the marine environment, may be adversely affecting salmon abundance and limiting restoration success. The processes occurring in the marine environment are now better defined, and although predator prey interactions are not well understood, scientists remain optimistic that restoration is possible for the Merrimack River, albeit on a reduced scale than previously anticipated.

Faced with these increased challenges, we believe it necessary to alter the focus of the restoration program to ensure that the achievement of short term objectives and goals are recognized and understood. Recognition of achievement and accomplishments will mold public perception and expectation, inspire interest in the program, and develop public and political support. We also intend to identify and implement strategies that reflect a philosophy not narrowly focused on expectations of large numbers of salmon returning to the river in the near term. Program initiatives incorporate alternative scientific strategies; promote a stewardship ethic; provide an understanding of watershed production potential; and emphasize the benefits to be derived from wise use of watershed resources.

An abbreviated description of scientific, socio-economic, and political strategies is presented here, but they are outlined in greater detail in a plan to be available for public review and comment. The plan identifies actions to be taken and strategies to be implemented within the next five years. It is intended that soliciting comment from the public and involving water resource users in plan development will promote a watershed stewardship ethic among users. Such action develops a constituency with realistic expectations of the outcome of program actions and initiatives.

Scientific strategies address critical components of the culture program including the production of broodstock, fry, and smolt. The target number of fry to be released has been increased, a strategy that required an increase in the number of broodstock reared in culture facilities. Increased production of broodstock has supported the creation of an interim sport fishery for non-migratory adult salmon. Broodstock, surplus to the program after artificial spawning, have been tagged, released to the river, and made available to anglers through a regulated fishery. The fishery is linked to the restoration program, for without it, riverine angling opportunities for salmon would not exist. The fishery provides large dividends including economic support from permit sales; a knowledgeable public and political constituency interested in salmon; and public awareness of anadromous fish restoration and watershed resources.

The increase in broodstock numbers provides opportunities to experiment with alternative production schemes for salmon. One such opportunity involves the release of pre-spawners or ripe fish in headwater spawning areas. The release of pre-spawners at river sites yields information about the quality and quantity of spawning and juvenile rearing habitat; the effects of environmental factors and human activities on the survival of large salmon, particularly in the headwaters; and may decrease the dependence on hatchery produced and distributed juvenile salmon. Sport fishery and pre-spawner releases provide high visibility for the restoration program. These releases place Atlantic salmon on the spawning grounds, within river reaches proximal to urban areas, and where adult salmon have been absent for well over 150 years.

Hatchery protocols are being refined to achieve annual fry and smolt production target levels. Production of these life stages has been variable, which has limited the ability to meet target numbers in some years. Additional release sites for fry and alternative release sites for smolts are identified to maximize production and survival, and minimize predation. Also, changes in hatchery production furnish smolts derived not only from sea run returns, but from progeny of donor stocks with genetic characteristics thought to be well suited to the river.

A large and diverse predator population, in conjunction with mainstem dams and an estuarine physiography that concentrates predators and prey, suggests that predation may be acute in the Merrimack River. Smolts of hatchery fry origin from the headwaters, and hatchery smolt released in the lower river are likely being affected. Accordingly, an initiative will be undertaken to evaluate the extent of smolt predation in the estuary and if desirable to design, implement, and evaluate a predator avoidance conditioning program for hatchery smolt. The initiative would determine the efficacy of the program in enhancing return rates, and include an evaluation of mortality of downstream migrant smolt of hatchery fry origin. These evaluations are to be conducted in cooperation with hydroelectric power producers and will require the development of partnerships to leverage resources to implement objectives.

A second initiative to mitigate the impacts of production involves a capture-and-haul program that places large numbers of alewife, *Alosa pseudoharrengus,* and blueback herring, *Alosa aestivalis,* at upriver spawning sites currently inaccessible due to dams. It is anticipated that stocks will respond, with a potential for the numbers of fish to increase by an order of magnitude over that observed at counting facilities in the last few years. The achievement of desirable results has been demonstrated in rivers near the Merrimack River. Herring should provide an alternate forage base for striped bass (*Marone saxatilis*), and perhaps limit their predation on smolts. Adult herring and striped bass, enter the estuary coincident with the arrival of downstream migrant smolt. In the Merrimack River, herring stocks are depressed, yet strong year classes of striped bass are anticipated in the river and the Gulf of Maine for at least five years. Smolt predation by birds may also be significant as double-crested cormorants *(Phalacrocorax auritus)* are abundant in the estuary. Thus, the capture-and-haul program for herring provides multiple benefits: it has great potential to mitigate the impacts of avian and piscine predation on smolts in the estuary; enhance commercial and recreational angling opportunities for anadromous fishes; increase visibility of program activities; and develop public awareness of restoration efforts.

Political strategies are devised to gain economic support for program objectives and center on actions to augment public visibility. The broodstock sport fishery is a key element in the strategy to increase political and economic support. Since its inception in 1993, fishery permit sales have grown from 930 to 2,035, and dollars expended by anglers has increased from $66,000 to $217,000. These economic benefits are shared by business, municipalities and fishery resource agencies. Also, a new watershed education program called Adopt-A-Salmon Family has been developed that involves students and teachers. Students gain an understanding of the biological and cultural dynamics of a watershed by focusing on anadromous fish restoration. Juvenile salmon are raised in the classroom and students learn about watershed resources; experience ownership in their watershed; and develop a stewardship ethic. Although immediate benefits may be difficult to evaluate, the Adopt-A-Salmon Family Program is uniquely positioned to engage students in the study of watershed dynamics and influence their environmental activities and attitudes. Ostensibly these efforts will foster an enlightened public and political constituency.

Ongoing activities include informational sessions with regional political leaders; the distribution of briefing packages to interest groups describing anadromous fish restoration programs and related initiatives; news releases and public service announcements; and active and concerted effort among program staff to articulate program goals, strategies and objectives.

VI. Conclusions

We believe it appropriate to continue salmon restoration on the river for at least the next five years, when objectives and strategies are to be reevaluated. Fish culture protocols have been refined and target production levels are near optimal. Program components are now fully integrated and to immediately abandon or minimize the program is not prudent. We intend to ensure that scientific strategies are well founded and strive to implement socio-economic and political strategies that are innovative and lend support to program objectives. Our approach to program operation can be described as one of adaptive management. Achievement and accomplishments are recognized and setbacks analyzed to develop pragmatic solutions. Interim or short-term strategies have been established and implemented, the results of which are to be used to develop further action. The program is dynamic which ensures flexibility to alter or revise strategies based on new and additional information.

Given accomplishments to date, we must now challenge the public, program constituents, and watershed resource stakeholders to assist in identifying the measurement of restoration success. Measuring success will require a candid portrayal of expectations and agreement on whether program results are scientifically, economically, and politically acceptable.

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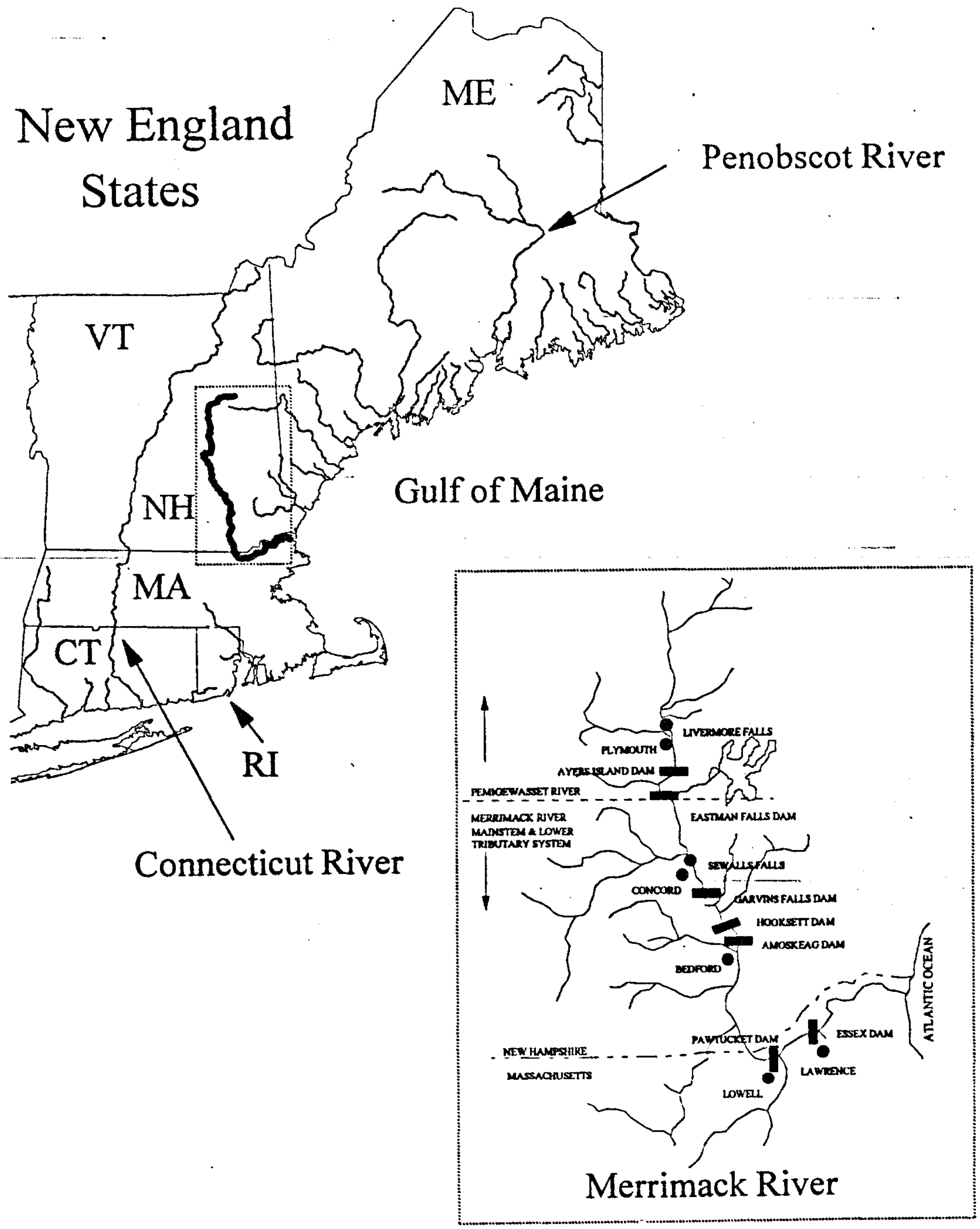

Figure 1. Merrimack River in relation to other important rivers in New England.

Table 1. Projected and observed Atlantic salmon returns to the Merrimack River, 1989 through 1996.

Year	Projected Number of Adults Returning to the River	Observed Number of Adults that Returned to the River
1989	142	84
1990	255	248
1991	707	332
1992	892	199
1993	1,012	61
1994	1,050	21
1995	1,283	34
1996	2,450	70[1]

[1] Returns include only fish observed through August.

Table 2. Total Atlantic salmon returns to the Merrimack River, 1982 through 1996.

Year	Number of Adults that Returned to the River
1982	23
1983	114
1984	115
1985	213
1986	103
1987	139
1988	65
1989	84
1990	248
1991	332
1992	199
1993	61
1994	21
1995	34
1996	70[1]
Total	**1,821**

[1] Returns include only fish observed through August.

Table 3. Rates of return for Atlantic salmon of Merrimack River origin.

Release Year	Number of Fry Released in 1,000s	Adults Returned / 1,000 Fry Released	Number of Smolts Released in 1,000s	Adults Returned / 1,000 Smolts Released
1978	106.1	0.17	47.2	No Information
1979	76.9	0.56	39.7	No Information
1980	125.5	0.34	31.0	0.65
1981	57.0	1.42	100.9	0.56
1982	50.0	0.96	71.0	0.37
1983	8.4	2.74	109.9	1.42
1984	525.5	0.09	68.2	0.54
1985	148.4	0.40	189.3	0.55
1986	524.6	0.21	104.0	0.22
1987	1,078.3	0.26	141.6	0.19
1988	1,717.8	0.06	94.4	1.21
1989	1,033.5	0.04	58.6	1.38
1990	975.2	0.02	116.9	0.58
1991	1,458.3	0.01 [1]	120.1	0.37
1992	1,117.5	0.01 [1]	96.4	0.48

[1] Life cycle not complete.