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Progress and problems in fish abundance estimation

INDEX PROGRAMS: THEIR VALUE IN SOUTHERN GULF OF ST. LAWRENCE FISH STOCK ASSESSMENTS

by

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ABSTRACT

Index programs, detailed sampling of a small portion of a fishery or stock, either in terms of geopgraphy or numbers of fishermen, have become an important means of improving southern Gulf of St. Lawrence stock assessments in recent years. These improvements have arisen by using two types of programs, LOGBOOK programs, in which representatives of the harvesting industry provide data collected from their fisheries; and SITE programs, which use small representative geographic sites to identify the trends in larger geographic areas. LOGBOOK programs are used to derive abundance indices for Atlantic herring and gaspereau assessments while SITE programs have contributed most to Atlantic salmon assessments in developing abundance indices and forecast models. Combining LOGBOOK and SITE programs has been advantageous for testing model asssumptions and deriving parameter estimates for catchability, selectivity, tag non-reporting rate, and angler reporting bias. Index programs offer a means of involving industry in the assessment process and are often cheaper to administer and easier to maintain than large scale projects. As a result, long-term data bases are established which also attract researchers from a variety of disciplines. Thus, these programs can assist in creating an active and diverse research and assessment program.

INTRODUCTION

In the southern Gulf of St. Lawrence, stock assessments are completed each year for one pelagic, Atlantic herring (Clupea harengus), and three anadromous species gaspereau (Alosa aestivalis) and (A. pseudoharengus), and Atlantic salmon (Salmo salar). Each of these assessments provides advice on available harvest relative to a target level of fishing mortality, $F_{0.1}$, for herring and gaspereau, or expected numbers above a target escapement level, optimal spawning requirements for Atlantic salmon. Initially these assessments may seem very different, however, the essential data and analytical requirements are similar. Each assessment requires that (1) a relative or absolute measure of abundance be derived and (2) the assumptions associated with each model be tested.

We have found that an efficient and cost-effective means of meeting these requirements is to concentrate on sampling small representative portions of our fisheries or stocks in a detailed manner. This approach has lead to the development of index programs. This term should not be confused with numerical indices that describe abundance or diversity but rather it refers to a specific type of research project.

Index programs are best explained by example and we have established two types of these programs in the southern Gulf of St. Lawrence. First, we have those which involve representatives from the harvesting industry, for example, commercial gillnetters or recreational salmon anglers. These industry programs are used to answer specific questions regarding the fisheries involved and generally require participants to keep a logbook of catches during the season or to answer questions about the fishery after the season has ended. We refer to these as LOGBOOK programs in the text. Second, we have established index sites which are representative of larger geopgraphical areas. These sites are used to collect data which are not available through normal fishing activity, for example, fishing before or after regulated fisheries or using non-commercial gear to obtain more representative population samples. We refer to these as SITE programs in the text. Exclusively with LOGBOOK, and as often as possible with SITE programs we involve industry representatives in the data collection. This reduces the cost of research budgets and facilitates co-management of the resource by involving government and industry directly in the assessment process.

This paper provides examples of how LOGBOOK and SITE programs have been incorporated into southern Gulf of St. Lawrence assessment research and identifies areas we have targeted for improvement. We also hope to stimulate discussion with other research groups employing these types of programs. Requests for greater industry involvement in assessment and management procedures is increasing from within and outside government. As a result, these programs are going to become a more important part of assessment research and it will be necessary to develop models which efficiently incorporate these types of data.

ASSESSMENT MODELS

Assessments of pelagic species in the southern Gulf of St. Lawrence fall into two categories; (1) those used for Atlantic salmon and (2) those used for herring and gaspereau. Atlantic salmon advice is provided in terms of whether or not optimal spawning requirements have been met or if they are likely to be met in the coming year. All salmon surplus to these requirements are considered available for harvest. Four parameters must be estimated: 1) removals, 2) spawning requirements, 3) spawning escapement, and 4) total returns one year in advance. Removals include landings from three types of fisheries, Native, commercial, and recreational, as well as removals resulting from poaching and disease. Spawning requirements are estimated from the total estimated juvenile rearing area in each river. Spawning escapement is determined by subtracting removals from total returns. Total returns are estimated using index traps, counting fences, or fisheries exploitation rates. Forecasts of total returns depend on developing long time-series of data. Hence, the model is a simple one:

(1) spawning escapement=total returns-removals

(2) available harvest=spawning escapement-spawning requirement

and the status of the stock is judged with respect to spawning escapement and spawning requirement levels. In the Gulf of St. Lawrence we provide this type of advice for four major rivers on an annual basis (Chaput and Jones 1991; Chaput and Mullins 1991; Courtenay et al. 1991; Moore et al. 1991) and for larger geographic areas as required (Claytor and Mullins 1990; Mullins and Jones 1991).

Herring (Claytor et al. 1990) and gaspereau (Chaput et al. 1991) advice is provided in terms of a target fishing mortality, currently $F_{0.1}$. Assessments generally use an age-structured model such as virtual population analysis. The analysis is strengthened when it can be calibrated with an abundance index. Two types of input data are required, catch-at-age and one or more abundance indices. A procedure called ADAPT (Gavaris 1988) is used to calibrate the virtual population analysis, rebuild the population, and estimate fishing mortalities. Projections from the population matrix are used to provide advice for the coming year assuming various management options.

LOGBOOK PROGRAMS

Commercial catch-rates form the basis for abundance indices in herring and gaspereau assessments. Herring purchase slip data collected by Statistics Branch, Gulf Region provide information about daily catches and the number of trips required to make that catch. These data are improved by conducting a telephone survey which determines the average number of nets used each year per gillnetter in the southern Gulf of St. Lawrence.

For this survey, a systematic random sample of active gillnetters from all areas of the southern Gulf of St. Lawrence is selected and telephoned to obtain information that permits the following indices of effort and fishing activity to be calculated: 1) the average number of net-hauls per gillnetter per season and day, 2) average length of net, and mesh sizes and numbers of nets fished for each mesh size, 3) the catch and percent of catch that was kept for bait, dumped, and sold to processors, and 4) a qualitative assessment of the gillnetters opinion on the abundance of herring in the current year compared to previous years (Nielsen 1991). Approximately 30% of the active 1200 herring gillnetters are surveyed each year during the two months (January-February) that the survey takes place.

There is also a program of index gillnetters, in which 2-6% of active gillnetters has participated. They provide daily logbooks of their catch and effort and are asked for amounts caught, kept, dumped, sold, and used for bait, as well as, mesh-size, length of net, number of hauls and soak-time (Claytor et al. 1990). Over one-third of index gillnetters have remained with this program for five years.

For both the spring and fall seasons, abundance indices are calculated from these catch-rates using a multiplicative model (Gavaris 1980) standardized for annual, area, and weekly effects. Each of these herring abundance indices indicate the same general trend (Fig. 1). Thus, the smaller set of index gillnetters, which is less costly to monitor, may become the principal abundance index when the time series is long enough.

A similar program is also in place for the gaspereau trapnet fisheries and also provides additional information which is not on the purchase slips, such as, number of traps, time spent fishing, and by-catch (Chaput et al. 1991). This program also allows us to obtain reliable abundance indices for smaller fishing areas which would not normally receive any assessment attention.

While these LOGBOOK programs produce improved abundance indices, they will also allow us to take into consideration factors besides abundance which may influence catch-rates, such as; restrictions on fishing activity imposed by markets, quotas, weekend closures, or differences in the fisheries (fishing on spawning grounds or migrating stocks) (Cairns et al. 1988; Nielsen 1991).

SITE PROGRAMS

Forecasts are an important part of assessments because they allow managers to choose among a variety of management options. Index SITES have been the principal tool for developing forecast models in southern Gulf of St. Lawrence fisheries. We have found that timing of herring, gaspereau, salmon, and smelt (Osmerus mordax) to our various index sites (Fig. 2) has strong species and area effects but weak year effects (Fig. 3). Thus, run-timing is a well-defined stock characteristic which can be used to assist in the management of these species (Chadwick and Claytor 1989).

On the Miramichi River, New Brunswick, we have operated an index SITE trapnet at Millbank (Fig. 2) since 1954. This trap is located downstream from all fisheries and because we have estimated the efficiency of the trap, using mark-recapture, we are able to obtain daily estimates of total numbers of salmon returning each year. Pre-season forecasts of multi-sea-winter (MSW) salmon are made from one-sea-winter (1SW) salmon returns the previous year and in-season run-timing is used to update the pre-season forecast.

The forecast model described above has been developed following the non-parametric probability distribution models described by Noakes (1989). We have comapared this approach to parametric regression models on the Miramichi River data using jackknife (Claytor et al. 1991) and Monte-Carlo simulation procedures (in preparation). In addition to reducing the variance in pre-season forecasts this approach offers a flexible means of reporting the forecast uncertainty. For Miramichi salmon, the 1991 pre-season forecast indicates a 58% probability that target spawning requirements will be exceeded (Fig. 4). By including run-timing information in the model the variance in the pre-season forecast is reduced by another 60% by mid-season (Fig. 4).

Procedures which can combine pre- and in-season information thus appear to provide a powerful means of improving pelagic and anadromous assessments. Non-parametric models seem to have a variety of applications in assessment research and may be a good procedure to investigate with other fisheries data. Unlike parametric techniques which require a variety of restrictive assumptions, such as normally-distributed errors; probability distribution models require no assumptions (Evans and Rice 1988; Rice and Evans 1988).

An important component of index programs is the capability of providing in-season information and we plan to investigate the use of these techniques with the catch-rate information we collect from the herring and gaspereau LOGBOOK programs.

In-season advice can also be provided by comparisons among index SITES. For example, we wanted to determine if low 1SW catches at angling camps on the Miramichi River were the result of in-river Native and angling fisheries. In addition, to the Millbank trap, which is downstream from all fisheries, we have four counting fences upstream from all fisheries (Fig. 2) where complete counts of all migrating salmon are obtained. We found that returns to SITES above all fisheries were proportional to those below all fisheries and that in-river fisheries were not adversely affecting potential spawning escapement (Fig. 5).

We have also used index SITES to estimate total returns and provide relative abundance estimates for two geographical areas in western Newfoundland. Home water returns for the Northern Penninsula in northwest Newfoundland (Fig.2) have been calculated using commercial and angling catch for these homewaters and adult returns to Western Arm Brook (Chadwick 1983). Western Arm Brook is an index SITE where complete counts of migrating smolts and adults have been obtained since 1971. Smolts migrating to sea and counted at Western Arm Brook are then used to predict 1SW salmon returns to the Northern Penninsula the next year. This relationship (Fig. 6) has been used to determine the optimal spawning requirements for Western Arm Brook (Chadwick and Claytor 1990).

Counts of adult returns at Fischells Brook and juvenile densities at Harrys River were used to assess the status of western Newfoundland stocks in St. Georges Bay (Fig. 2). Significant correlations between Fischells Brook and Harrys River angling catches with other St. Georges Bay rivers (Fig. 7) indicates that these two rivers are representative of relative trends in this area. In addition, the similarity in catch and run-timing between St. Georges Bay and Fischells Brook supports the conclusion that Fischells Brook represents the relative trends in these stocks (Fig. 8) (Claytor and Mullins 1990).

COMBINING LOGBOOK AND SITE PROGRAMS

Combining LOGBOOK and SITE programs provides a powerful means of testing model assumptions and estimating parameters for assessment models. Atlantic salmon LOGBOOK and SITE programs have been used to obtain parameter estimates and test the following model assumptions: (1) that catchability does not change with stock size, (2) the selectivity of gillnets, (3) non-reporting rate in a mark-recapture experiment, and (4) angler report reliability of kept versus released fish.

The assumption that catchability does not change with stock size was tested with gillnetter LOGBOOK data from the Atlantic salmon fishery at St. Barbe Bay, Newfoundland (homewaters for Western Arm Brook). A multiplicative model was used to calculate annual catch rates standardized for gillnetter and week effects. These catch rates were compared to the abundance of the homewater stock counted at Western Arm Brook. We found that catchability did not change with stock size in this fishery. However, the year with the highest abundance did not fit this model. (Fig. 9) (Chadwick and Claytor 1990). Additional years of data from these LOGBOOK and SITE programs will enable us to determine the cause for this outlier.

Data from the LOGBOOK and SITE programs at St. Barbe Bay and Western Arm Brook have also been used to study selectivity of salmon commercial gillnet fisheries. The fishery in Western Arm Brook is selective towards larger fish. The fork length of salmon harvested in the commercial fishery was consistently 1-4 cm greater than those returning to the river. In addition, the proportion of large salmon (≥ 63 cm) comprising the commercial catch exceeded the proportion of large salmon returning to the river (Fig. 9). Hence, the mesh size of 127 mm used by the fishery appears to be removing most of the larger salmon, including repeat spawners, from the spawning stock (Chadwick and Claytor 1990).

The index SITES on the Miramichi River have been combined with an angling camp LOGBOOK program to estimate non-reporting rate of tags in the Miramichi Atlantic salmon angling fishery. Five angling camps provide us with daily LOGBOOKS of catches and all tagged salmon caught. By comparing tagged to untagged ratios at the Millbank trap (below fisheries), and counting fences (above fisheries), to those reported by angling camps, we were able to estimate the non-reporting rate of tags and angling exploitation rate (Fig. 9) (Randall et al. 1990).

Similarly, on the Margaree River, Nova Scotia (Fig. 2), by comparing angler LOGBOOK reports, population estimates from an index SITE, report cards which anglers complete and mail in after the season, and a creel survey, we were able to determine the relative accuracy of angler reports of kept versus released fish in the salmon angling fishery for that river (Fig. 9) (Claytor and O'Neil, in press). Quantification of this relative accuracy removed a large portion of the variability in the assessment of this stock.

CONCLUSIONS AND IMPROVEMENTS

Atlantic salmon assessments have provided a good model for demonstrating the utility of index programs in pelagic assessments. Although some may argue that herring, gaspereau, and salmon have little in common and that the salmon experience has little relevance to those assessing marine species, we argue that these species and assessments have more similarities than differences. These species have several life history traits in common, for example discrete spawning sites, predictable run-timing, and repeat spawning. Thus, there are many opportunities for expanding these programs to marine species such as herring. For example, we are now in the fourth year of developing an abundance index from spawning bed surveys at Fishermens Bank, Prince Edward Island (Fig. 2). This SITE appears to have the same potential for improving herring assessments that we have found for Atlantic salmon SITES.

One advantage of index programs is the potential to develop long-term data bases on stock characteristics. This potential exists because index programs are often less costly and easier to administer than large scale projects. These long-term data sets are attractive to researchers from other agencies. For example, Western Arm Brook has attracted numerous research projects over the years (i.e.; Blouw et al. 1988; Cunjak et al. 1989) and Fishermens Bank is becoming a similar attraction for marine research; in addition to the spawning bed survey, investigations are examining the selectivity of herring gillnet fisheries, spawning wave dynamics, and predator-prey interactions. Juvenile herring recruitment is another area where we expect index SITES to be valuable and we are currently examining several potential SITES in the southern Gulf of St. Lawrence for their utility in such a program.

Index programs are also a good method of involving industry directly in the assessment process. We rely exclusively on industry for the success of our LOGBOOK programs and many of our SITE programs are run in cooperation with industry. In many cases private groups have identified projects of interest and obtained outside funding to maintain the facilities. In these cases, we provide scientific and technical support for ensuring the integrity of the operation and interpreting results from the projects. As requests for greater industry involvement in the assessment process increase from both within and outside government agencies, it will be important for us to develop assessment models which can efficiently incorporate these types of data and projects.

ACKNOWLEDGEMENTS

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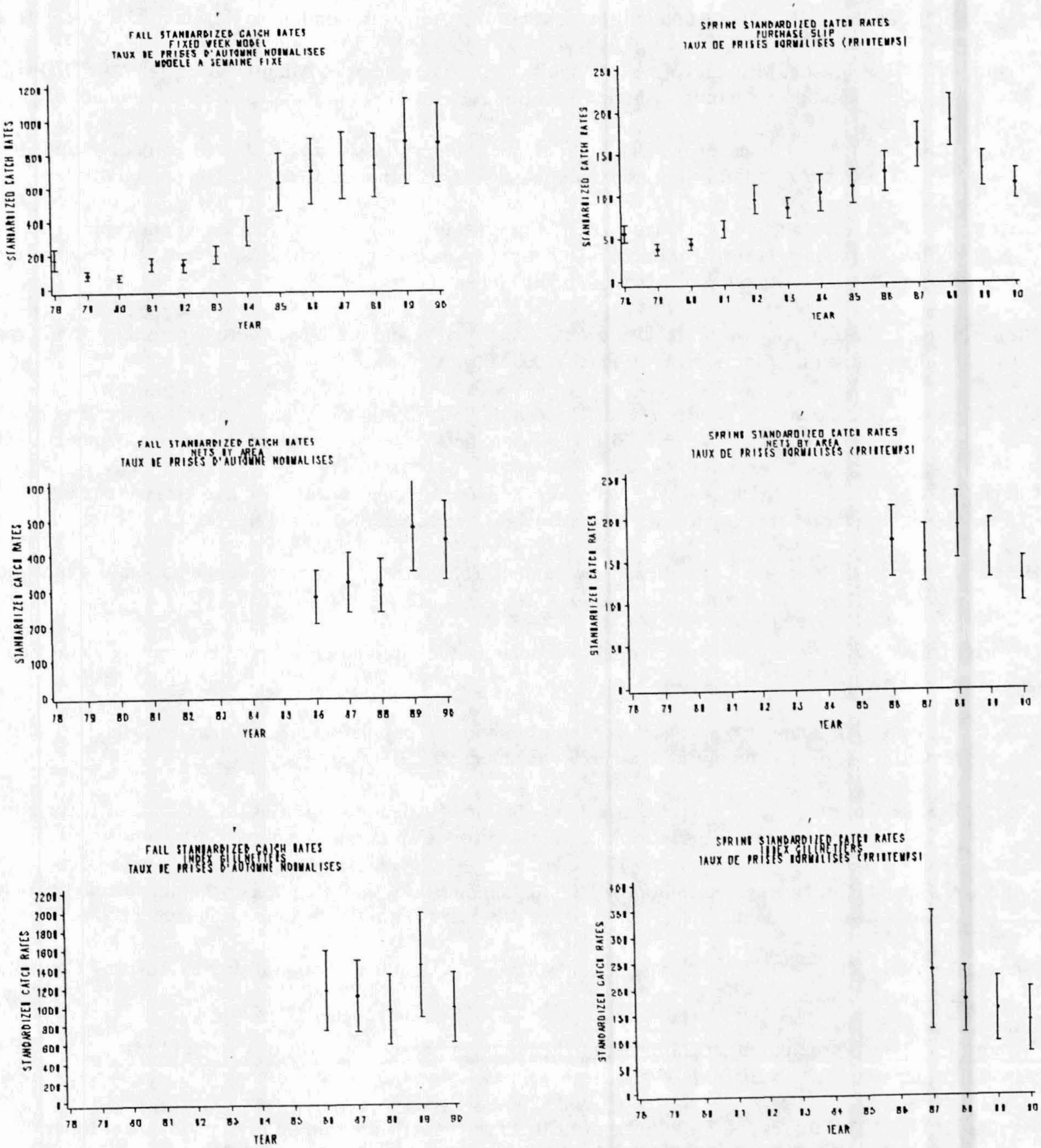
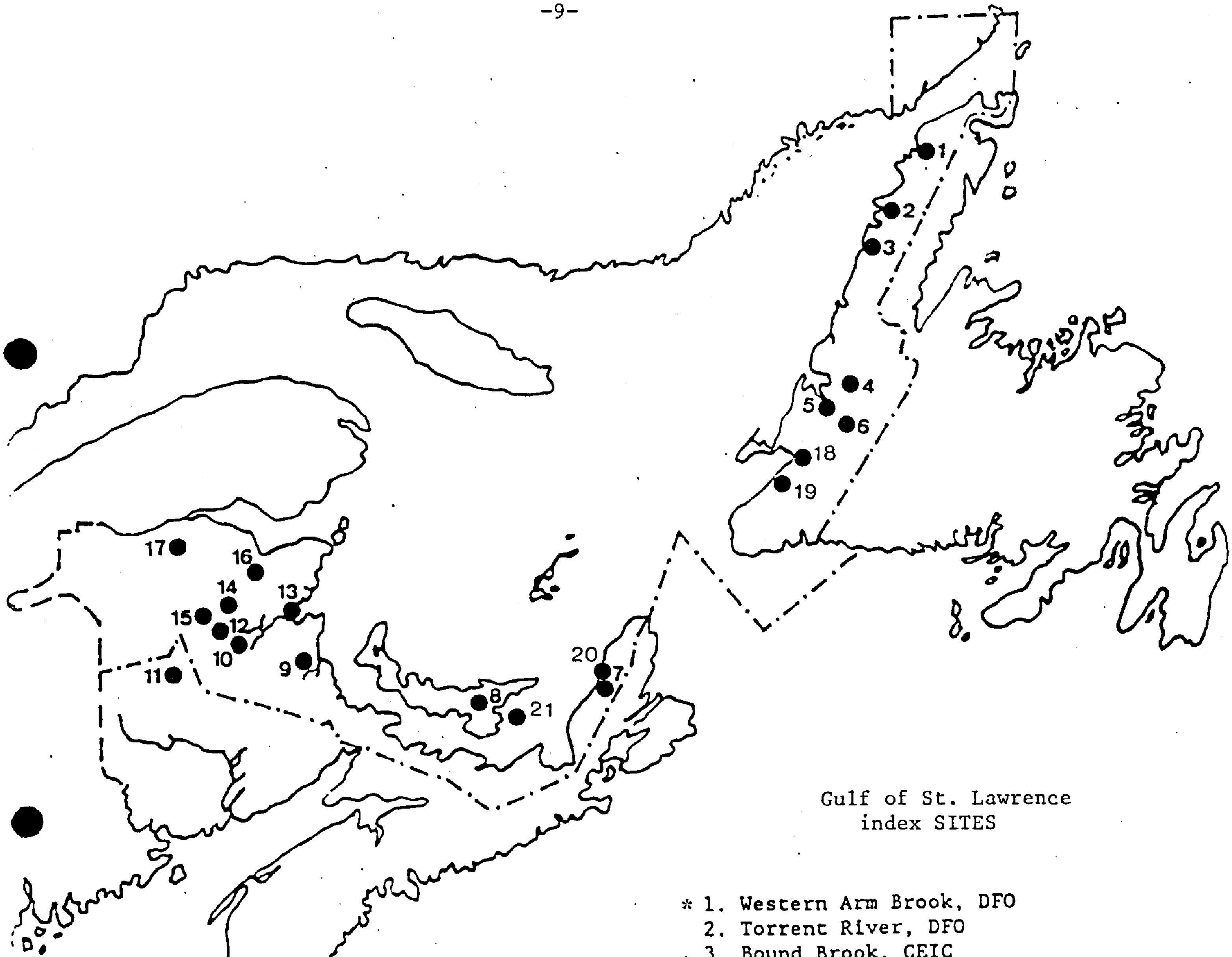


Fig. 1. Catch-rate indices derived for fall (left) and spring (right) sourthern Gulf of St. Lawrence herring fisheries from purchase slips (top), gillnetter telephone survey (middle), and index gillnetters (bottom).



* 1. Western Arm Brook, DFO
2. Torrent River, DFO
3. Bound Brook, CEIC
4. North Brook, CEIC
5. Hughes Brook, CEIC
6. Humber, DFO
7. Lake O'Law, DFO
8. Morell River, DFO
9. Black River, PC
* 10. Bartholomew River, DNRE
* 11. North Branch SW Miramichi River, DNRE
* 12. Dungarvon River, DNRE
* 13. Millbank Trap, DFO
* 14. NW Miramichi, DNRE
15. Catamaran Brook, DFO
16. Nepisiguit River, CEIC
17. Upsalquitch River, DNRE
* 18. Harrys River, DFO
* 19. Fischells Brook, SPAWN
* 20. Margaree River, DFO
* 21. Fishermens Bank, DFO

Fig. 2. Index SITES in southern Gulf of St. Lawrence used in herring, gaspereau, and Atlantic salmon assessments. SITES designated DFO are run by the Department of Fisheries and Oceans. CEIC, Canada Manpower and Emigration; PC, Parks Canada; DNRE, New Brunswick Department of Natural Resources and Energy; SPAWN, Salmon Preservation Association for the Waters of Newfoundland. Those indicated by a * are mentioned in the text.
Sites 10-14 are index SITES for the Miramichi River.

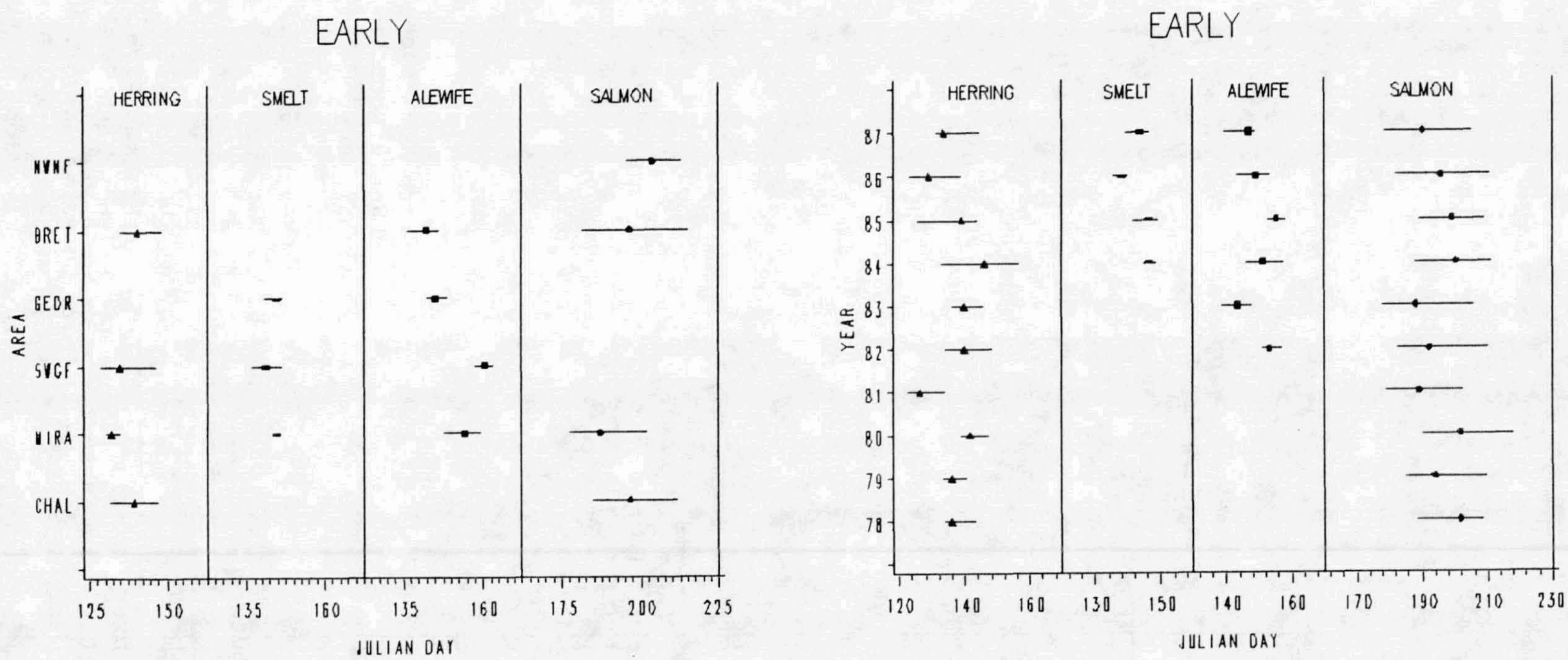


Fig. 3. Variation in early (spring and summer) run timing of alewife, herring, salmon, and smelt in six areas (left) and ten years (right) in the southern Gulf of St. Lawrence. NWNF, northwest Newfoundland; BRET, Cape Breton; GEOR; St. Georges Bay, Newfoundland; SWGF, southwest Gulf; MIRA, Miramichi; CHAL, Chaleur Bay.

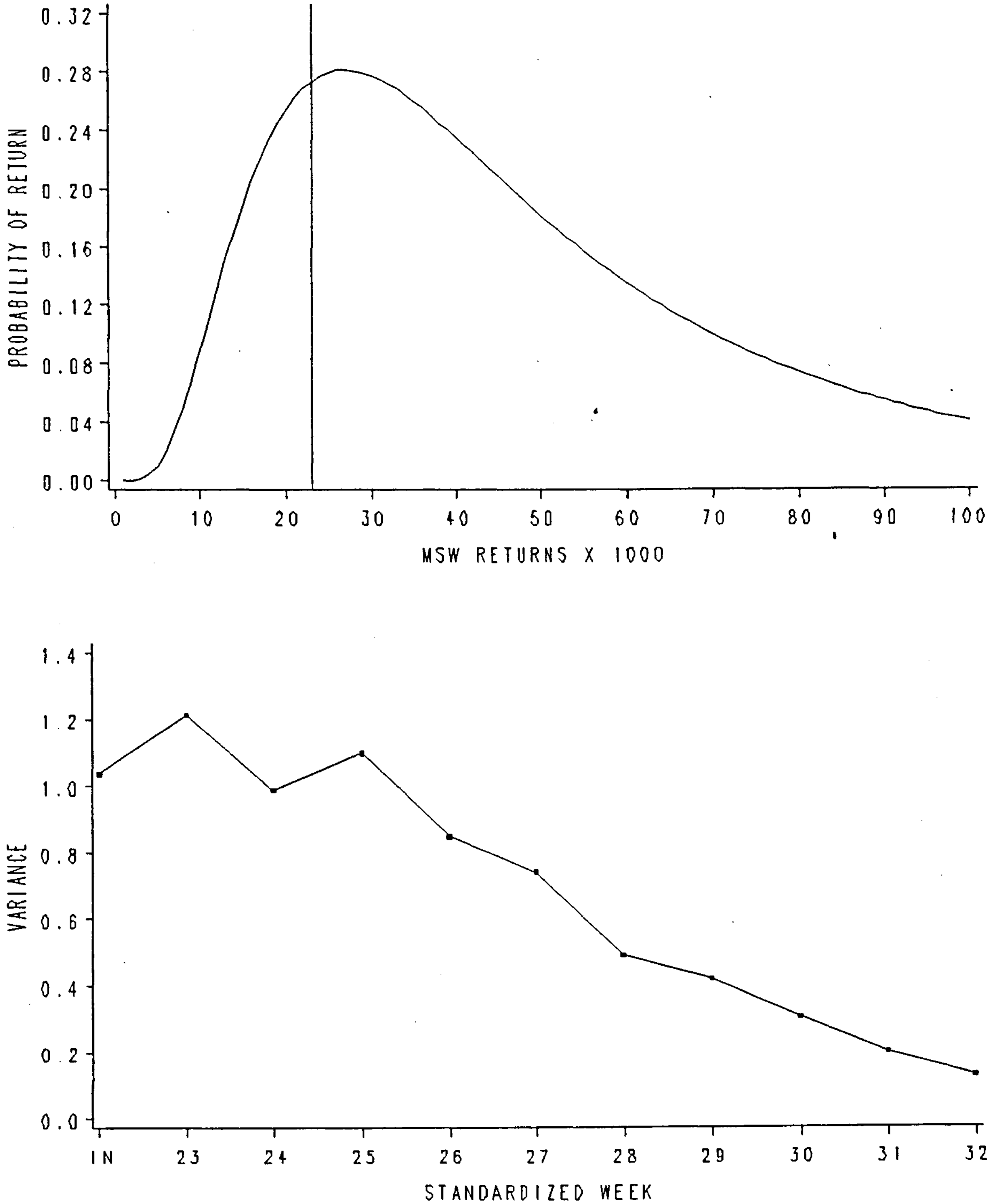


Fig. 4. Probability distribution (top) of pre-season forecast for Miramichi River salmon. The vertical line represents spawning requirements. The sum of the probabilities to the right of the line indicates a 58% probability of exceeding requirements. Reduction in variance from pre-season model (IN) by including inseason information is shown in the bottom figure.

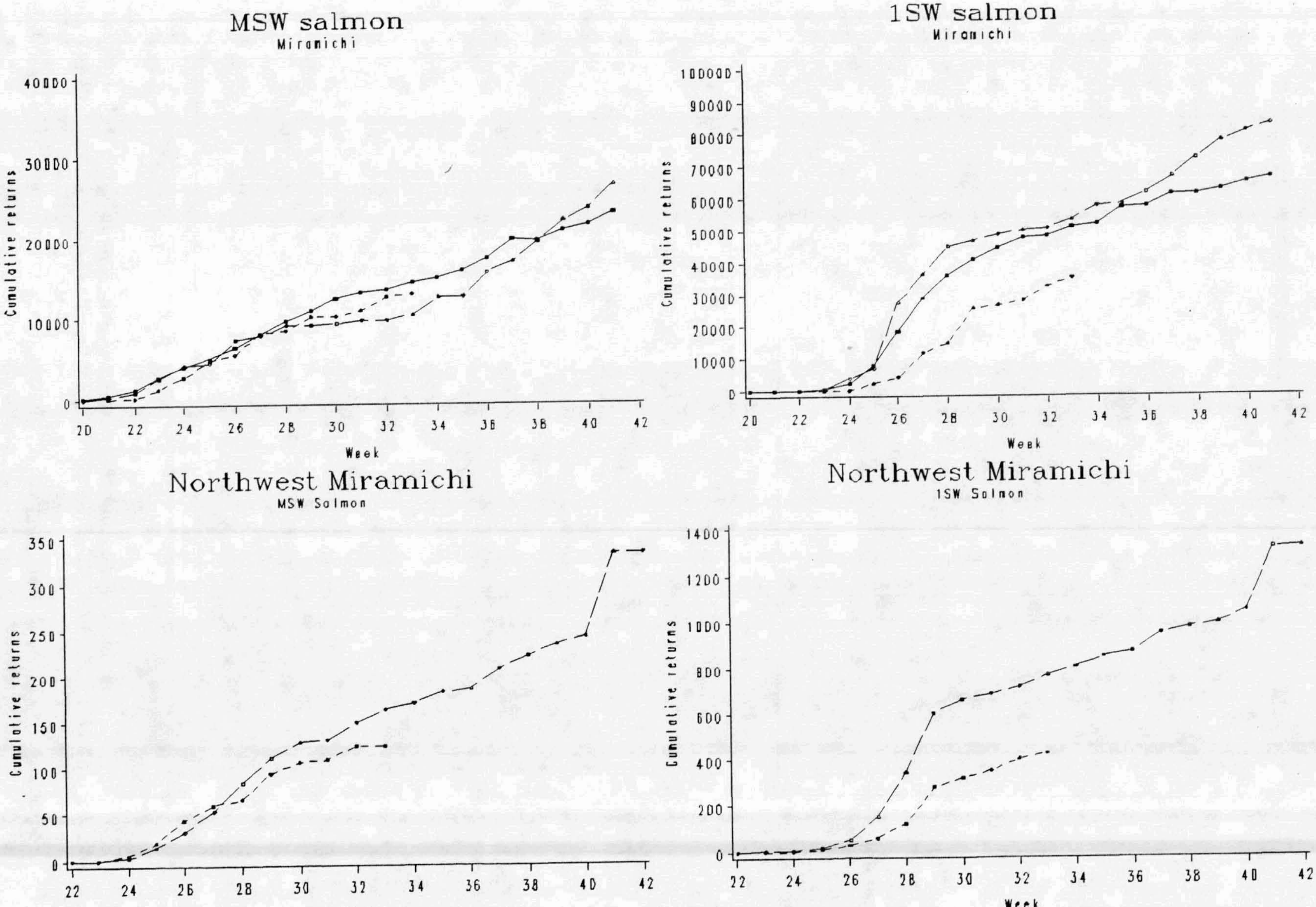


Fig. 5. Total returns of Atlantic salmon to Millbank index trap (top) compared to a site upstream from all fisheries on the Miramichi River (bottom) for multi-sea-winter (MSW) salmon (left) and one-sea-winter (1SW) (right).

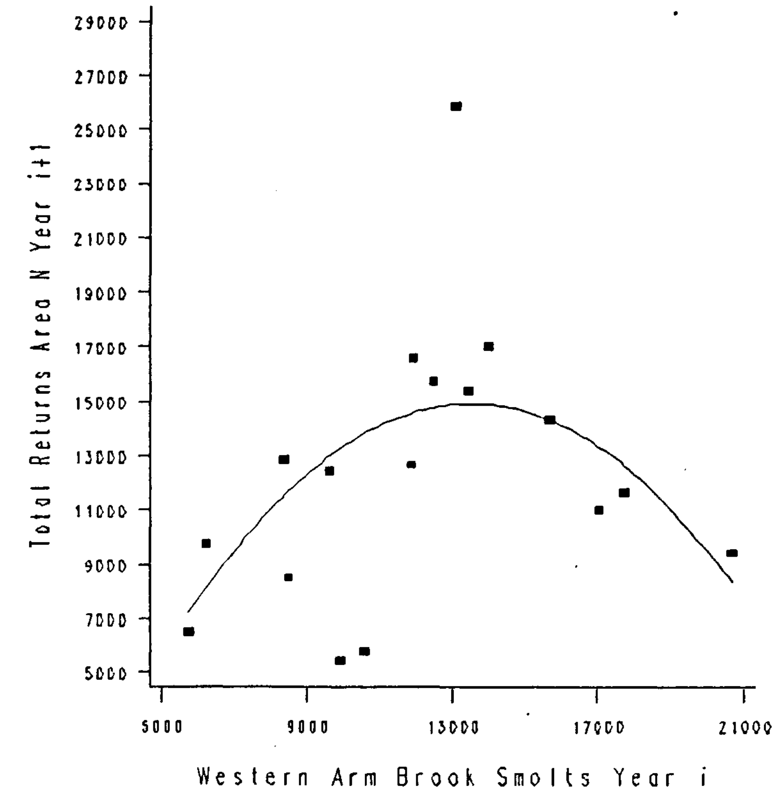


Fig. 6. Relationship between smolts counted at Western Arm Brook index SITE and total returns to western Newfoundland, Northern Penninsula, (Area N).

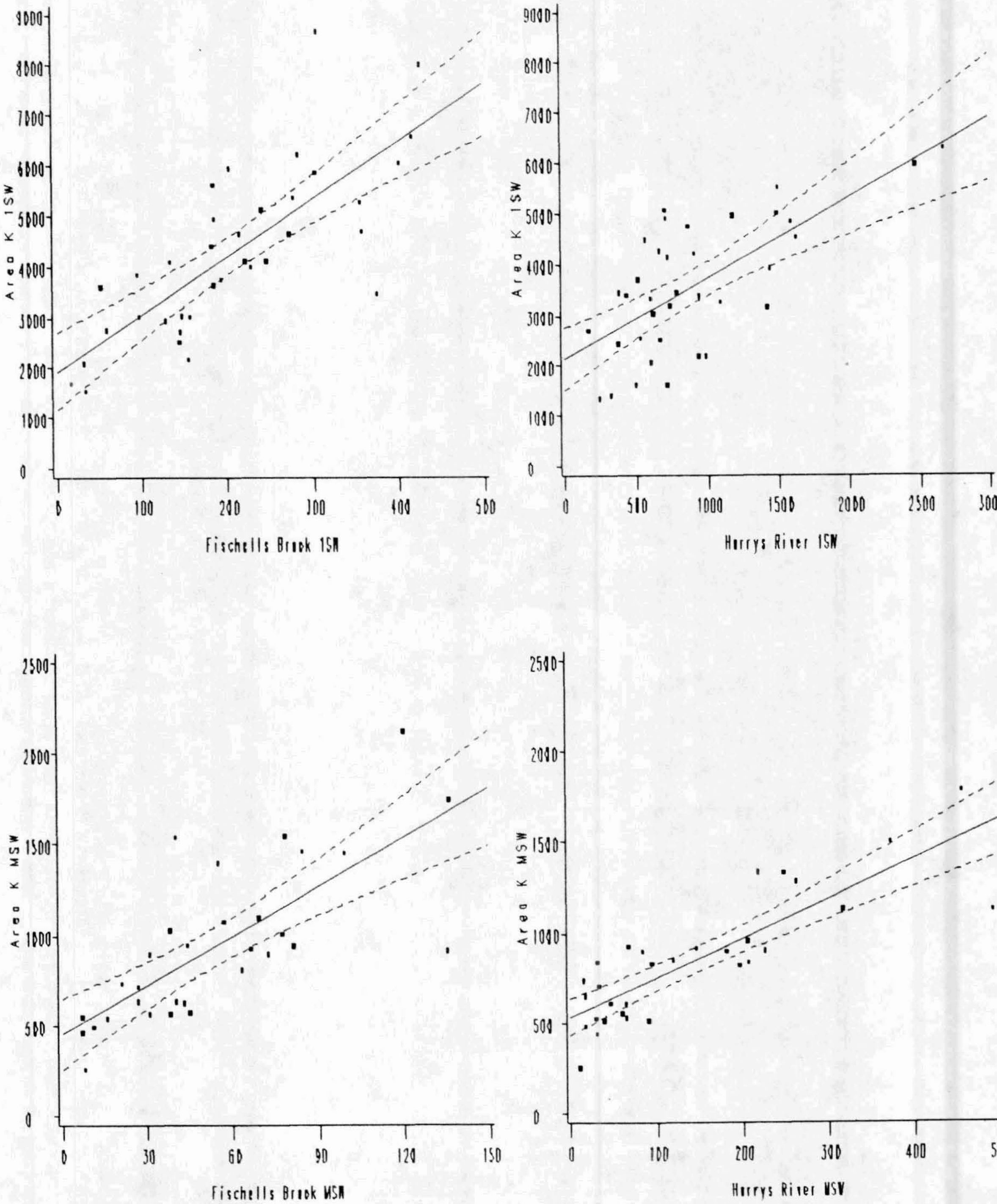


Fig. 7. Regression lines (solid lines) and 95% confidence limits for the mean for relationships between Fischells Brook, Harrys River, and other St. Georges Bay, Newfoundland, (Area K) rivers. Confidence limits are shown by dotted lines.

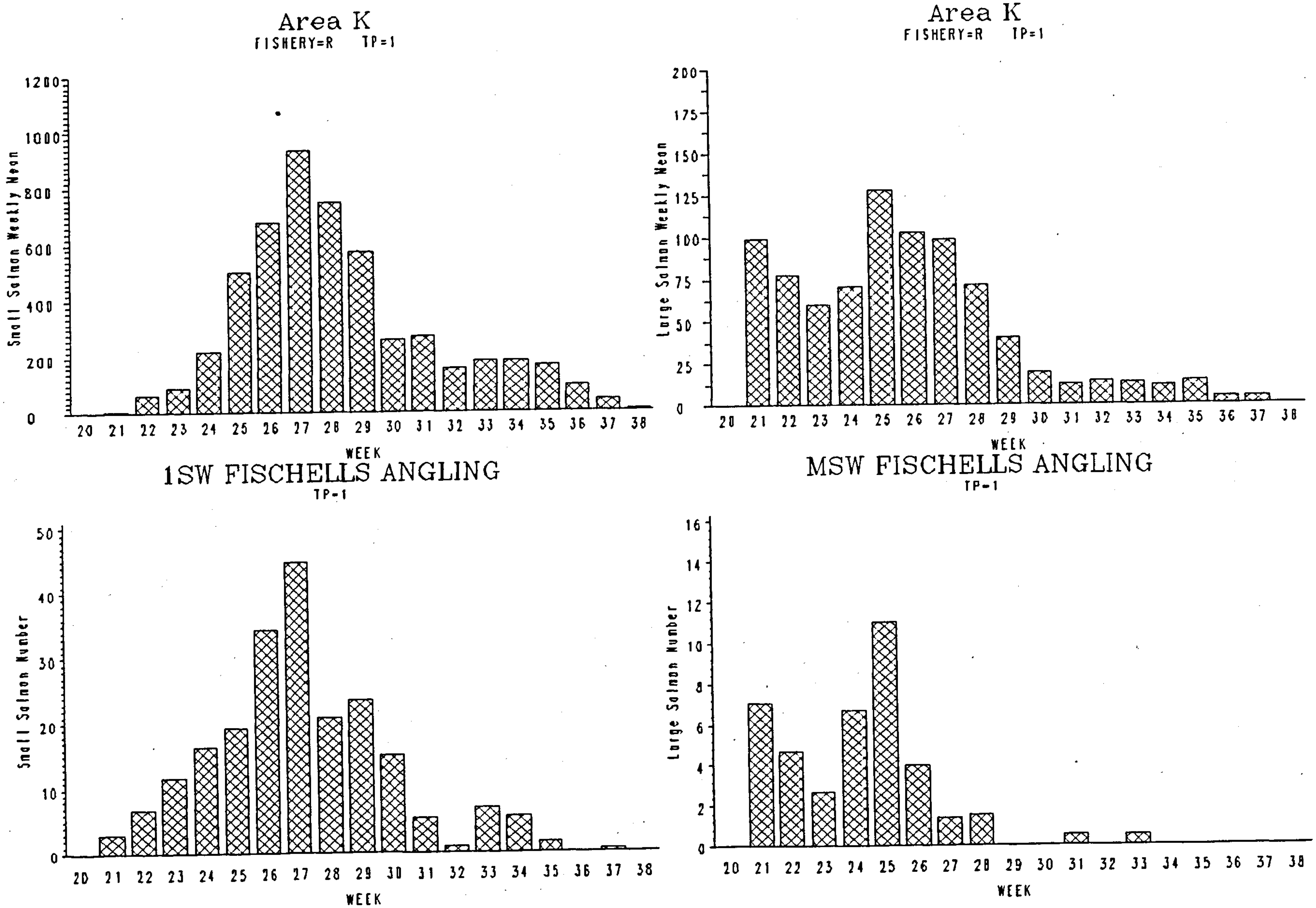


Fig. 8. Mean numbers of small (left) and large (right) salmon caught each week during the recreational Atlantic salmon season in St. Georges Bay, Newfoundland (Area K) rivers (top) and Fischells Brook (bottom).

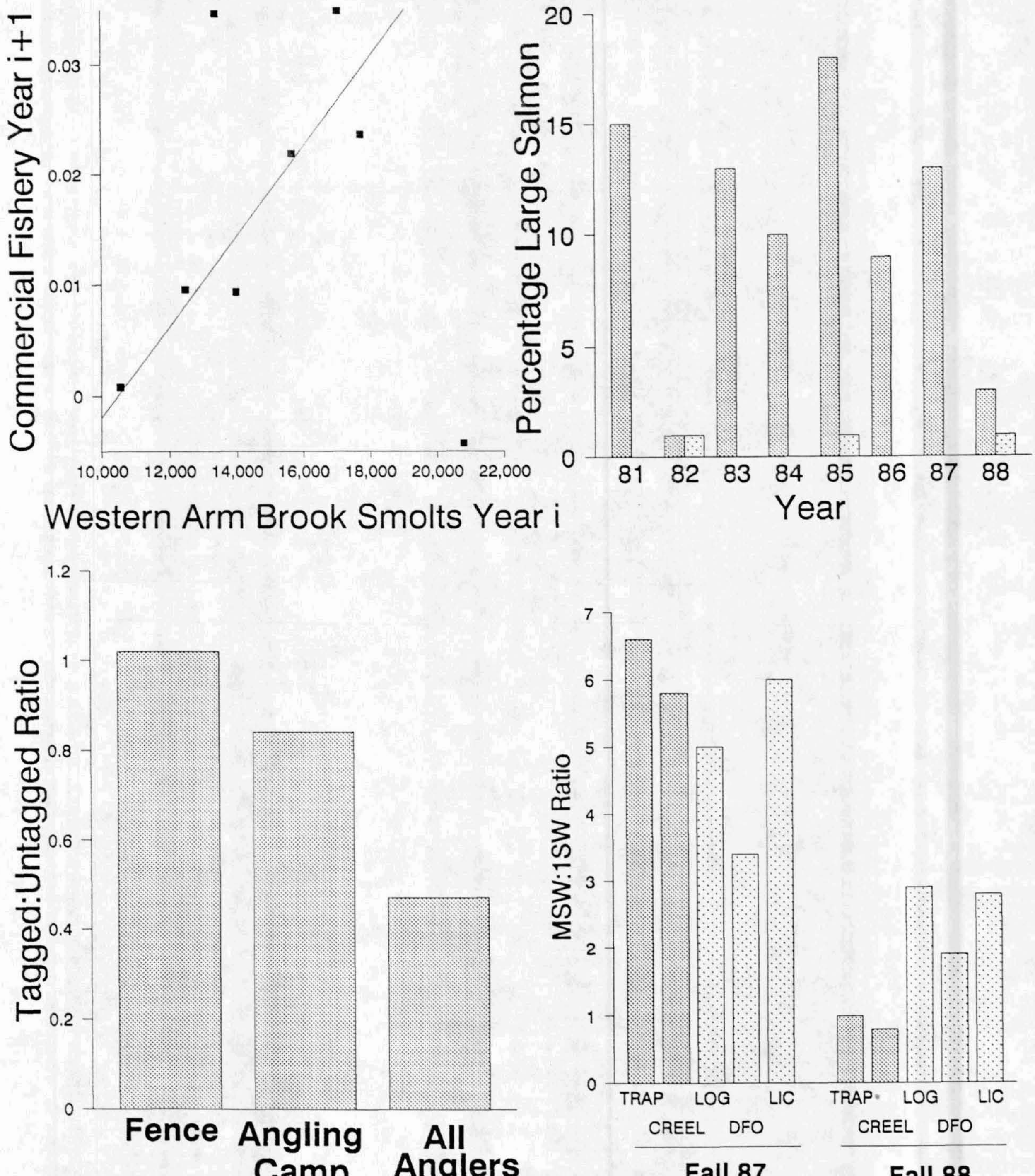


Fig. 9. Standardized commercial catch-rate in year i+1 against smolts leaving leaving Western Arm Brook in year i (top left). Percentage of large salmon in total commercial catch compared with percentage of large salmon returns counted at Western Arm Brook (top right). Tagged:untagged ratio of Atlantic salmon obtained from counting fences (SITES), angling camp (LOGBOOK), and all anglers on the Miramichi River (bottom left). Multi-sea-winter (MSW):one-sea-winter(1SW) ratios from index SITE (TRAP), LOGBOOK (LOG), creel (CREEL), fisheries officer (DFO), and angler license returns (LIC) on the Margaree River.