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Estimates of wild Atlantic salmon smolt production in Gold and Medway Rivers derived from concurrent abundance and survival of wild and hatchery smolts in LaHave River, 1996

by

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Abstract

Wild Atlantic salmon (*Salmo salar*) smolt production was estimated from known hatchery smolt stocking, the concurrent wild smolt migration estimate and the subsequent one-sea-winter return rate from smolts stocked above Morgan Falls on the LaHave river. A range of possible return rates was applied to known stocking numbers of hatchery smolts in the Gold and Medway rivers in 1996, and estimates of proportions of wild and hatchery fish in the harvest fishery for fish less than 63.0 cm in 1997, to derive estimates of the wild smolt emigration from these rivers in 1996. The 1997 return rate of hatchery smolts from above Morgan Falls was 0.00469 and the modal ratio of wild to hatchery return rate was 4.6565 (4.82 - 4.53; 5^{th} and 95^{th} percentiles). The modal estimate of the wild smolt run in the Gold River in 1996 was 6,894 (6,692 - 7,096; 5^{th} and 95^{th} percentiles) or 0.389 smolts $m^{-2}*100$. The modal estimate of the wild smolt run in the Medway River in 1996 was 6,788 (6,589 - 6,987; 5^{th} and 95^{th} percentiles) or 0.1005 smolts $m^{-2}*100$. The numbers of smolts spawner^{-1} was 15 above Morgan Falls suggesting that low areal smolt production was not the result of low survival from egg to smolt. Applying this technique may assist in rationalizing estimates of required conservation escapements to these lowland and acid-impacted rivers.

Résumé

La production de saumoneaux sauvages de saumon de l'Atlantique (*Salmo salar*) a été estimée à partir des saumoneaux ensemencés, de la migration de saumoneaux sauvages estimée et du taux de retour après un an en mer des saumoneaux ensemencés en amont de Morgan Falls, dans la rivière LaHave. Une gamme de taux de retour possible a été appliquée aux effectifs d'ensemencement connus de saumoneaux d'élevage dans les rivières Gold et Medway en 1996 et aux proportions estimées de poissons sauvages et d'élevage au sein des prises conservées de poissons de moins de 63,0 cm en 1997 afin d'obtenir des estimations de l'émigration de saumoneaux sauvages de ces rivières en 1996. Le taux de retour de saumoneaux d'élevage en 1997 en amont de Morgan Falls était de 0,00469 et le rapport modal du taux de retour des poissons sauvages à celui des poissons d'élevage était de 4,6565 (4,82-4,53 au 5^{e} et 95^{e} percentiles). L'estimation modale de la remontée de saumoneaux sauvages dans la rivière Gold en 1996 était de 6 894 (6 692-7 096 au 5^{e} et 95^{e} percentiles) ou de 0,389 saumoneaux par 100 m^2. L'estimation modale de la remontée de saumoneaux sauvages dans la rivière Medway en 1996 était de 6 788 (6 589-6 987 au 5^{e} et 95^{e} percentiles) ou de 0,1005 saumoneau par 100 m^2. Le nombre de saumoneaux par géniteur était de 15 en amont de Morgan Falls ce qui porte à croire que la faible production de saumoneaux par surface ne découlait pas d'une faible survie entre le stade d'oeuf et de celui de saumoneau. Cette technique pourrait faciliter la rationalisation des estimations des échappées nécessaires à la conservation dans les zones basses et les rivières acidifiées.

Introduction

One signal of the status of an Atlantic salmon (*Salmo salar*) stock relative to a standard of production is the output of seaward migrating smolts. Established norms of smolt production range from lows of 1.0 to highs of 6.0 smolts m^{-2} x 100 for smolts of age-4 to age-2 respectively (Elson 1975;Symons 1979). Counting seaward migrating smolts is both difficult and sometimes detrimental to the survival of the fish (Ritter 1989). Derivation of survival rates of wild smolts is further complicated by the need to obtain estimates of cohort adult returns. Dependable estimates are most often obtained from permanent assessment facilities, usually fishways. While fishways can determine survival rates for hatchery smolts stocked above the facility, few examples of concurrent estimates of wild smolt populations migrating from above fishways exist in the North American salmon data.

Knowledge of the concurrent survival of hatchery and wild smolt cohorts enables a variety of analytical opportunities. One opportunity is the assessment of wild smolt production for a near-by river where hatchery smolts of similar life history and husbandry characteristics are also stocked. Rivers in close proximity have been shown to exhibit similar genetic traits (McConnell et al. 199X) and similar life-history traits (Anon 1978). These similarities support the assumption of equal marine survival necessary for this analysis.

Hatchery smolts of proximate stocks grown in the same facility, under near identical conditions and released into the rivers of origin may be expected to survive similarly. Monitoring the returning population for relative proportion of hatchery and wild recruits provides the essential information to estimate the ratio of the survival of hatchery to wild smolts in the index river. This ratio, the known numbers of hatchery smolts stocked in the proximate river together with an estimate of the proportion of hatchery returns, can be used to estimate the production of wild smolts for the proximate river.

This paper examines the use of concurrent estimates of wild and hatchery survival rates determined at Morgan Falls, 23 km above the head of tide on the LaHave River, Lunenburg County, Nova Scotia, known stocking of hatchery smolts and estimates of the proportions of hatchery fish taken in the angling fishery in the Gold River, and Medway River in 1997 (Figure 1), to estimate the number of wild smolts emigrating from the Medway River and the Gold River in 1996.

Methods

Atlantic salmon broodstocks were collected from the LaHave, Medway and Gold rivers, grown at the Mersey Fish Culture Station and the resulting age-1^{+} parr and smolts stocked in the respective donor rivers in 1996 (Table 1).

Estimates of the numbers of wild smolts migrating past Morgan Falls were obtained by mark (adipose-clipped hatchery smolts) and recapture techniques. Smolts were sampled in the by-pass facility of the Morgan Falls Power Company during May, 1996 (Amiro and Jefferson MS 1997).

Returning one-sea-winter (1SW) salmon were counted at the Morgan Falls fishway in 1997. Wild salmon were identified by presence of a complete adipose fin and verified by scale interpretation of 20% of fish less than 63.0 cm fork length. Estimates of the return rates to the 1SW stage were derived for wild and hatchery components. Return rates for wild 1SW fish were determined for a range of possible smolt populations derived from the Bayesian posterior distribution of possible populations from mark and recapture data (Gazey and Staley 1986).

Samples of the 1997 angling fisheries of the Gold and Medway rivers were obtained by roving creel samplers, diary keeping anglers, and voluntary mail-in samples from randomly sampled anglers. All basic statistics such as name of the angler, location of capture, date, time, fork length, and origin (hatchery or wild) were reported by creel samplers and anglers. Proportions of hatchery and wild 1SW fish were also obtained through scale reading. Scale reading was done without knowledge of the basic data. Partitioning into wild and hatchery categories was calibrated by re-reading the creel surveyors' observed sample until agreement between the scale reader and the surveyor was obtained. This standard set for a river was used to scale read and classify all remaining scales in the sample.

Estimates of the wild smolt migration from the test river were obtained from the equations:

1) Equivalent to wild smolt (EWS) $_{\text{year i}}$ = (Stocked smolt$_{\text{Year i-1}}$ x No. of Wild grilse sample)/ No. of Hatchery grilse in sample$_{\text{Year i}}$

2) Wild smolts $_{\text{Year i-1}}$ = EWS $_{\text{year i}}$ / (Wild smolt return rate$_{\text{LaHave smolt year i-1}}$ / Hatchery smolt return$_{\text{LaHave year i-1}}$)

where the wild return rate to Morgan Falls LaHave was determined for the range of possible wild smolt populations in 1996.

Atlantic salmon producing habitat for the area above Morgan Falls was that reported by Amiro et al. (MS 1996). Area was measured using aerial photographs and ortho-photographic maps (Amiro 1993) and includes all measurable stream area above the Morgan Falls that has a stream gradient greater than 0.12%. Habitat areas for the Gold and Medway rivers were measured using the same technique and personnel.

Results

LaHave River return rates of wild and hatchery one-sea-winter salmon

The estimated hatchery smolt migration from above Morgan Falls in 1996 was 52,139 smolts including adipose-clipped and tagged smolts. A total of 15,776 smolts were examined in the Morgan Falls Power assessment facility in 1996. Hatchery smolts numbered 11,323. The modal estimated wild smolt population migrating from above Morgan Falls in 1996 was 20,511 (19,886 - 21,086 5th and 95th percentiles) (Figure 2).

There were 303 wild 1SW fish counted at the fishway in 1997 (Amiro and Jefferson MS 1998). The total catch of fish <63.0 cm by angling was 373 fish. The estimated number of hatchery 1SW angled in 1997 was 77 fish. The modal return rate to the LaHave River of wild smolts migrating in 1996, estimated using 0.49 of the production of wild smolts derived from above Morgan Falls, was 0.0218 (0.0225 - 0.0212 ^{5th} and 95th percentiles) (Table 2).

An estimated 47,111 adipose-clipped untagged hatchery smolts migrated from above Morgan Falls in 1996. There were 144 1SW hatchery fish counted at the fishway in 1997. An estimated 77, 1SW hatchery fish were angled below Morgan Falls in 1997 that were destined to return to above Morgan Falls. The return rate of hatchery smolts to 1SW fish in 1996 was therefore 0.00469.

The modal ratio of wild to hatchery smolt return was 4.6565 (4.8029 - 4.5296; 5th and 95th percentiles).

Gold River

A total of 15,000 age1^{+} hatchery smolts was stocked in the Gold river in 1996.

There were 9 hatchery grilse in the 28 samples obtained from the angling fishery in 1997. These samples indicate that 0.3214 of the catch was hatchery origin.

The preliminary estimate of the 1SW angling catch for 1997 was 132 fish <63.0cm. Therefore, there were 42 hatchery grilse angled and 90 wild grilse angled.

These numbers of fish and equations 1 and 2 above indicate a 1996 modal wild smolt run of 6,894 (6,692 - 7,096; 5th and 95th percentiles)(Figure 3). At 17,741x100 m^2 of habitat the modal number of smolts m^{-2} x100 was 0.389 smolts.

Medway River

There were 50,634 age-1^{+} hatchery smolts stocked in 1996.

There were 16 hatchery grilse in 26 samples obtained from the angling fishery in 1997. These samples indicate that 0.6154 of the catch was hatchery origin.

The preliminary estimate of the 1SW angling catch for 1996 was 104 fish <63.0cm. Therefore there were 64 hatchery grilse angled and 40 wild grilse angled.

These numbers and equations 1 and 2 above indicate a 1996 modal wild smolt run of 6,788 (6,589 - 6,987; 5th and 95th percentiles)(Figure 4). With 67,653x100 m^2 of habitat the modal number of smolts m^{-2} x100 was 0.1005 smolts.

Discussion

Smolt production estimates for 1996 from the Gold and Medway rivers were low relative to published standards. Estimates may have been low relative to the standard because the numbers of smolts were low or because estimates of habitat area of these rivers is higher than that determined for the standards. While habitat areas for the standard production estimates provided by Elson (1975) may have unknown bias, the Symons (1979) analysis was theoretic and therefore unbiased by habitat measurment. The minimum value given by Symons was 1.0 smolts m^{-2} x 100. The value determined for Gold River was 0.39 smolts m^{-2} x100, less than half the minimum standard. The value determined for the Medway River was 0.10 smolts m^{-2} x 100, 10% of the minimum standard. These production estimates are low because the estimates of smolts were low, not because the estimate of area for these rivers was biased.

Smolt estimates were the product of: a) the relative contribution of hatchery fish to the angling catch, b) the numbers of smolts stocked and c) relative return rates of hatchery and wild smolts determined at Morgan Falls, LaHave River. Major assumptions in this analysis are: 1) that hatchery and wild salmon are equally exploited in the angling fishery, 2) that annual return rates of salmon to adjacent or near by rivers do not differ, 3) that salmon entering the river after the angling season would be in the same proportion as the exploited population; and 4) that the spring smolt migration of 1996 was measured without bias.

Reasons to accept these assumptions are: 1) Exploitation of wild and hatchery salmon has not been shown to differ in any river where assessments have been conducted; 2) Counts at Morgan Falls (unadjusted for removals below the fishway) and catches in the St. Mary's River (unadjusted for smolt production or environmental conditions) have been shown to be correlated (O'Neil et al. MS1997). Indeed, coherence among the North Atlantic salmon stock has been

noted and reported previously; 3) There is no reported evidence of a late run of salmon to any river in Salmon Fishing Area 21 or 20. Run timing may be related to environmental conditions, but run timing has not been shown to differ between hatchery or wild salmon (Harvie and Amiro, MS 1998). Run timing may be related to broodstock selection (Ritter and Newbould 1977) but has not been shown to be related to hatchery rearing of smolts; 4) Fall migration of pre-smolts is known to occur within the LaHave River. Fall migrations of parr may contribute to an underestimate of the smolt production. Some of these pre-smolt parr are captured in fall fisheries such as the fall eel weir fishery. In the fall of 1995 these fisheries were monitored. Few pre-smolts were captured and, in fact, none of 500 wild large parr tagged while electroofishing in 1995, were recaptured in this fishery. There is little evidence that fall migration of parr has significantly biased the smolt production estimate above Morgan Falls in 1996.

Spawning escapement above Morgan Falls, LaHave River, in 1993 may have been as high as 1,364 fish, which is about the level of the required conservation escapement of 1,320 fish above Morgan Falls. Escapement above Morgan Falls in 1993, resulted in about 20,500 wild smolts in 1996 (a few smolts may be age-3^{+}). Therefore , the escapement of 1,364 salmon and grilse in 1993 resulted in a smolt run of about 15 smolts$*$adult^{-1} salmon escaped. This production is greater than the average of 10.5 smolts spawner^{-1} for the Western Arm Brook in Newfoundland (Chadwick *et al.* 1978). The difference in production of smolts$*$adult^{-1} may be because of the contribution of more larger salmon in the LaHave where about 50% of the egg deposition is derived from two-sea-winter and older salmon and the younger smolt age in the LaHave River. These data indicate that while production of smolts may be lower on a per-unit-area basis, production of smolts relative to escapement is comparable to other Atlantic salmon rivers. Rationalizing the difference in measures of the relative production (15 smolts$*$adult^{-1}) with high target area-production (2.4 eggs$*$m-^{2} resulting in 2.0 - 3.0 smolts$*$m^{-2}) is a key in developing meaningful conservation requirements for these lowland and acid-impacted rivers. Monitoring smolt runs resultant from escapements greater than 1,364 may reveal the escapement level at which smolt production begins to level out and maximizes. These data would contribute to rationalizing the estimates of required spawning escapements to these rivers.

Acknowledgements

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Table 1. Distribution of hatchery-stocked Atlantic salmon smolts and fall fingerlings to rivers of SFA21 during 1996.

River	pH category [1]	Origin of stock	Number of Smolt	Percent of SFA 21	Number of fall fingerlings
Clyde	1	LaHave	18,559	6	
Jordan	1	LaHave	5,000	2	1,001
Sub-total			23,559	8	
Mersey	2	LaHave	18,000	6	
Sackville	2	LaHave	1,852	1	
Sackville	2	Sackville	16,101	5	14,009
Tusket	2	Tusket	50,044	17	31,004
Sub-total			85,997	29	
Gold	3	Gold	15,000	5	
LaHave	3	LaHave	49,376	17	40,703
Medway	3	Medway	50,634	17	37,990
Salmon River - Digby	3	Salmon River	19,040	6	15,003
Sub-total			134,050	45	
Meteghan	4	Tusket			10,014
Mushamush	4	LaHave	21,440	7	13,000
Petite	4	LaHave	21,440	7	13,000
Sub-total			42,880	14	
Bear River		Tusket	11,605	4	
Total			298,091		175,724

1. pH category as per Watt 1997.

Table 2. Results of bayesian estimates of wild smolt population estimates, 1996, return rates of wild and hatchery 1SW Atlantic salmon to LaHave River, 1997, ratio of wild to hatchery return rate in 1997, and estimates of wild smolt migrations from Gold and Medway rivers, 1996, indexed from the numbers of hatchery smolts stocked and the return rates to LaHave River.

River		Wild smolt estimates		Percentiles		Return rate/or	Percentiles	
	Number	type	number	5th	95th	population	5th	95th
LaHave								
Smolt population data								
Marks	52,139	Mean	20,513					
Recaptures	11,323	Median	20,486	19,886	21,086			
Catch	15,776	Mode	20,511					
Wild One-Sea-Winter returns								
Count at Morgan Falls	303					0.0218439	0.02253	0.02125
Total angled <63.0 cm	373							
Hatchery angled below	-77							
Hatchery One-Sea-Winter returns								
Smolt	47,111							
1SW count	144					0.004691	na	na
Hatchery angled below	77							
Wild : Hatchery return rate						4.6565401	4.80289	4.52956
Gold								
Stocked smolt	15,000							
1SW Hatch angled	42							
Total 1SW angled	90							
Wild smolt estimate						6,894	6,692	7,096
Medway								
Stocked smolt	50,634							
1SW Hatch angled	64							
Total 1SWangled	40							
Wild smolt estimate						6,788	6,589	6,987

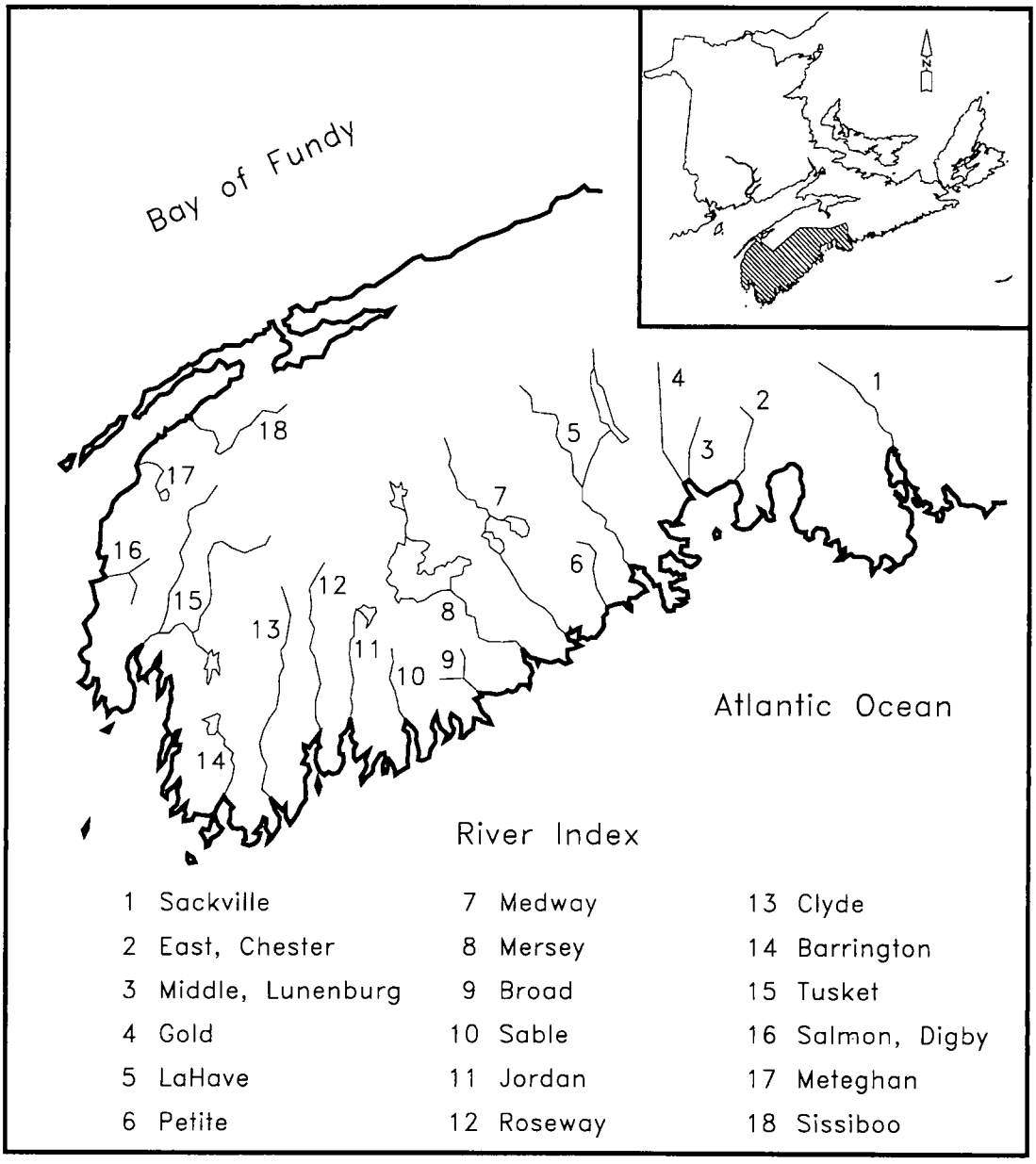

Figure 1. Map of Salmon Fishing Area 21 showing the location of potential Atlantic salmon rivers.

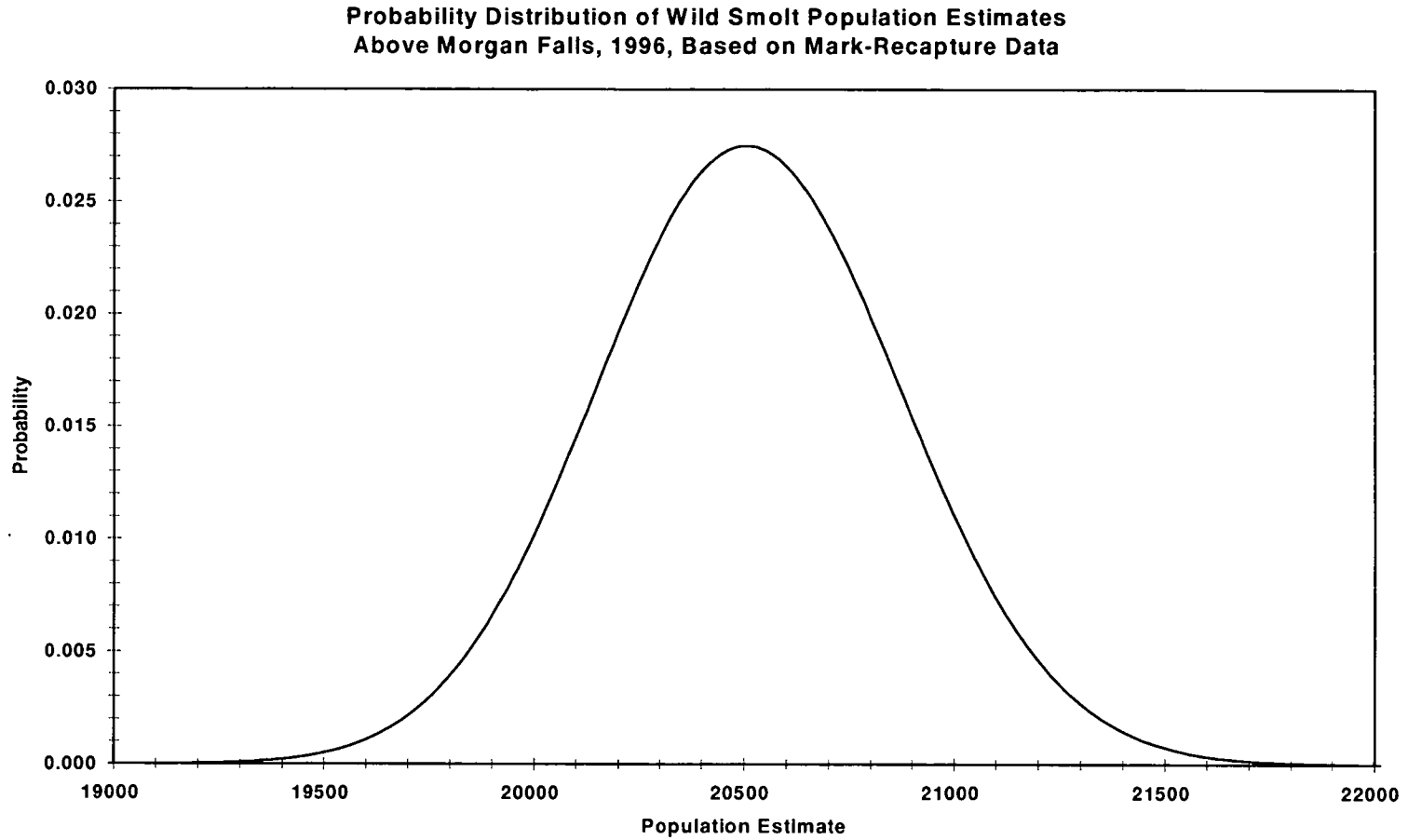

Figure 2. Probability distribution of wild smolt population estimates from above Morgan Falls on the LaHave River, 1996.

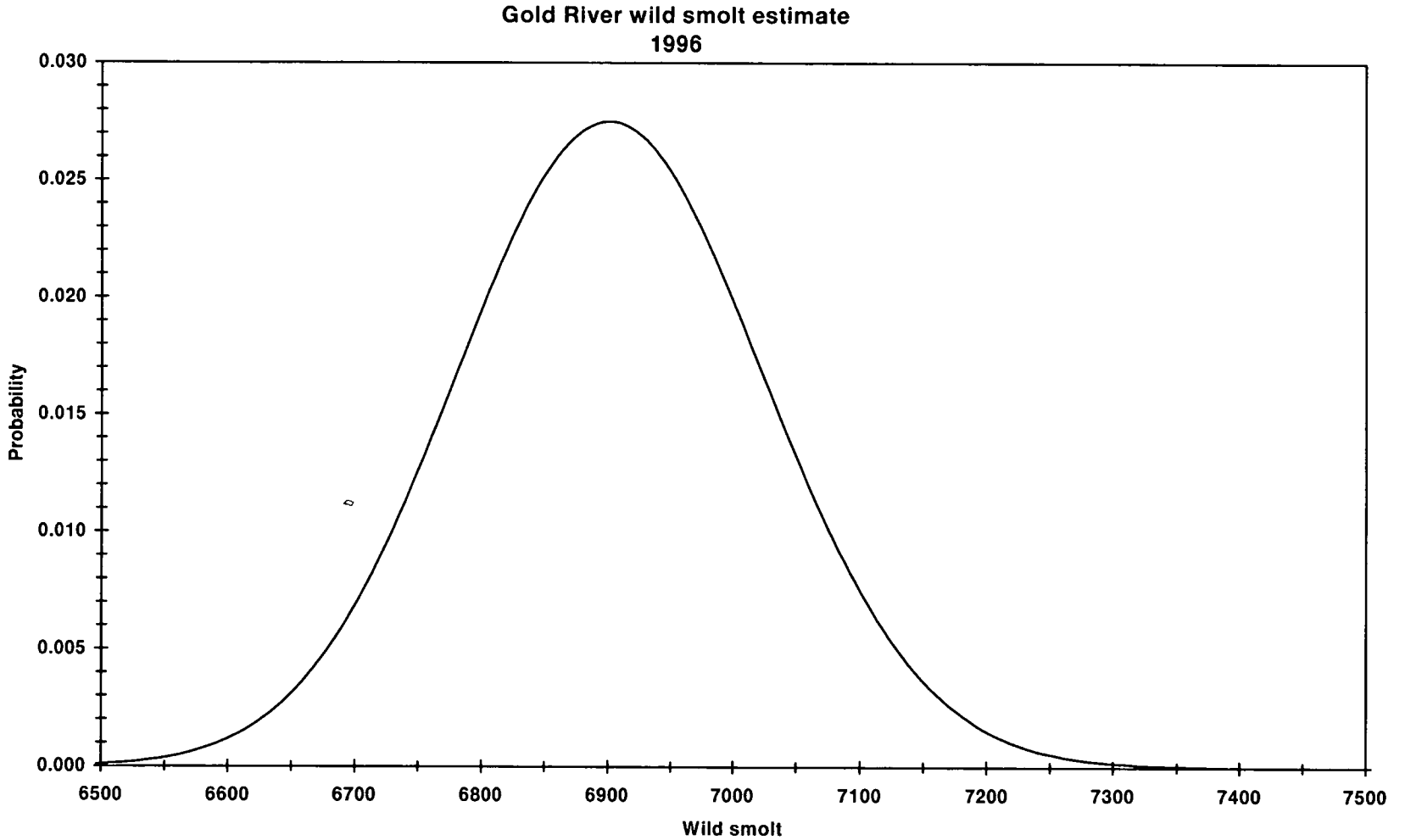

Figure 3. Probability distribution of population estimates of wild smolt migration from Gold River, 1996.

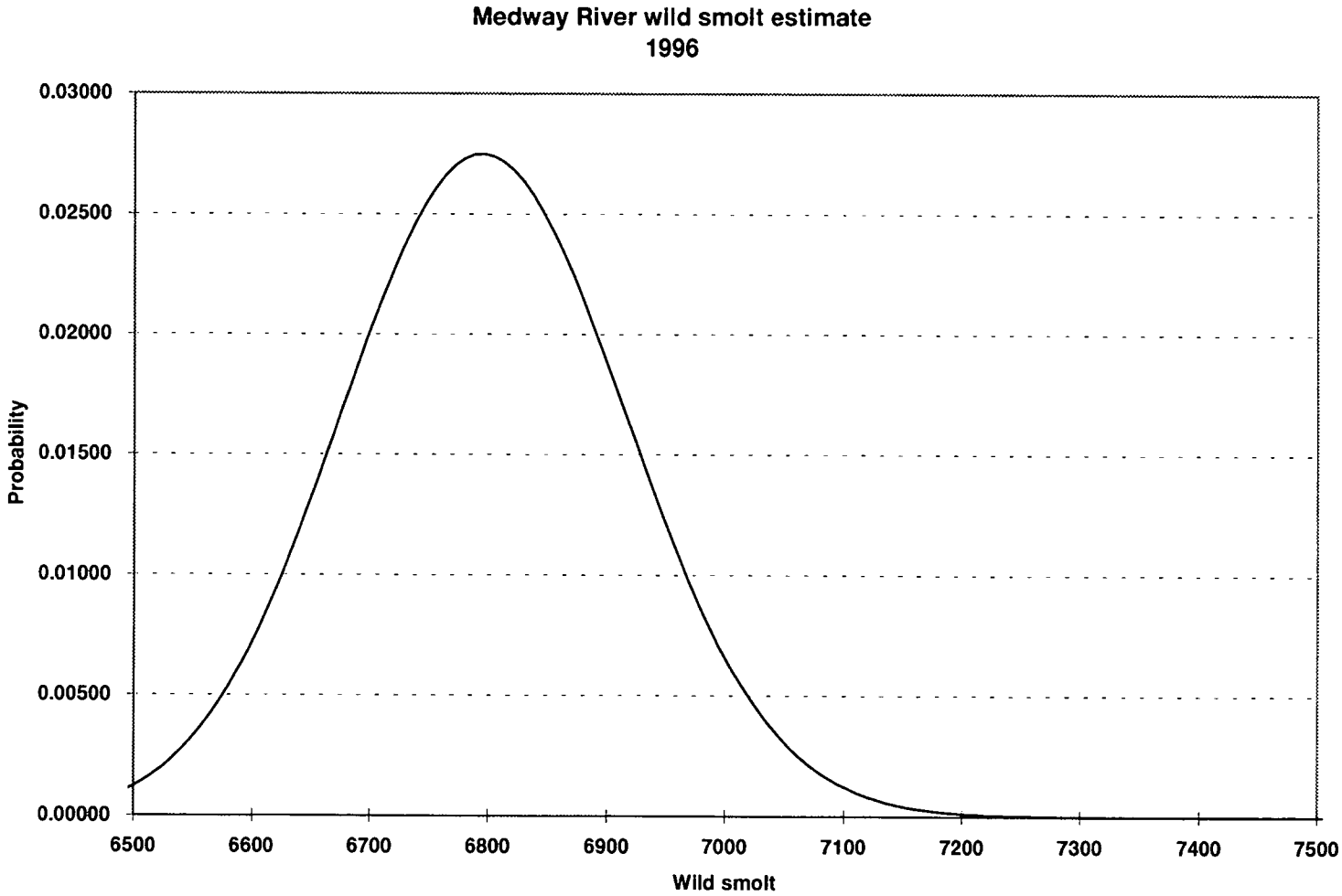

Figure 4. Probability distribution of possible population estimates of wild smolts migrating from the Medway River 1996.