

**Attainment of conservation limits in the Burrishoole River, Co. Mayo, Ireland since 1980 –
implications for local management.**

**N. Ó Maoiléidigh, E.C.E Potter , P. McGinnity, K. F. Whelan. , A. Cullen, D. McLaughlin and T.
McDermott.**

Abstract

There are very few individual salmon stocks in the North East Atlantic with sufficient data to derive stock/recruitment relationships and to estimate biological reference points. ICES has been developing national and regional conservation limits for combined North East Atlantic salmon stocks as an input to the provision of management advice for distant water fisheries of Greenland and Faroes since 1997. While these regional conservation limits will be used in the short term, development of river specific reference points which can be transported to other rivers is also being undertaken. Characteristics of a single stock stock/recruitment relationship are compared to a catch based model for the associated fisheries district. The implications of these analyses suggest strong coherence in the pattern of attainment of conservation limits in the river where input data are known precisely compared to the combined stocks in the district where the data are less precise. It is also shown that severe catch restrictions would have been required in most of the last 20 years if the conservation limit were to have been attained for all stocks in the district..

INTRODUCTION

In 1998, the North Atlantic Salmon Conservation Organisation (NASCO) adopted the precautionary approach to fisheries management (as outlined in FAO 1996). Central to this was the agreement that management measures should be aimed at maintaining all salmon stocks in the NASCO Convention Area above pre-agreed conservation limits (CLs). The CL for Atlantic salmon is currently defined by NASCO as “the spawning stock level that produces maximum sustainable yield” (NASCO 1998). This is also known as S_{MSY} .

This CL can be estimated empirically for individual rivers provided a stock and recruitment relationship with sufficient resolution is available to estimate the specific point on the Stock/Recruitment curve. Unfortunately, only a handful of rivers in the NEAC area have sufficient data to derive adequate S/R curves and even fewer have sufficient resolution to allow for unequivocal reference points to be derived.

The wild salmon run on the Burrishoole River has been monitored continuously since the 1960's. Information is available on the total number of adult salmon ascending and the total number of smolts descending, providing more than 30 points to derive an S/R relationship. It has therefore been possible to define reference points from these data in order to establish a preliminary river specific CL for this system (ICES 2001, McGinnity pers. comm.). Since 1980, hatchery smolts from the same system have been tagged and released with coded wire tags (CWTs) to provide an estimate of marine survival and exploitation rates for both the wild and hatchery stocks. These data provide estimates of the total returns to the coast and the number removed in commercial fisheries. It is therefore possible to assess over a significant period of time the relationship between catch and attainment of the CL for the wild Burrishoole stock.

In , order to establish CLs for salmon stocks in regions where there are no monitored rivers, a model has been developed to establish “pseudo”-stock and recruitment relationships based on catch data and estimates of exploitation rates and unreported catches (Potter et al, 1998). Establishment of appropriate CLs can then be used to provide similar relationships between catch and the attainment of these CLs

within defined regions. The method has been applied to district catch data and CWT returns for the Bangor district of the North Western Fisheries Region. Finally, the historical recruitment, spawners and the surplus over the CL for the river and the district are compared.

STUDY AREA

Salmon fishery management in Ireland is administered from seven geographically distinct fishery regions (Figure 1). The Bangor fishery district is situated in the middle of three fishery districts within the North West Fisheries Region. There are approximately five significant and three minor salmon producing rivers in this district comprising 93,000 ha. The Burrishoole is a short river which flows into Clew Bay in Co. Mayo, in the Bangor district. The total catchment area is 11,000 ha. A description of the physical characteristics of the system is given by Piggins (1985).

MATERIALS AND METHODS

Since 1970 there has been a full upstream and downstream counting facility for salmon on the Burrishoole River. The total counts of downstream migrating salmon smolts (wild and reared), upstream migrating adults and the numbers of fish caught in the system are available for the Burrishoole River for the derivation of a river specific CL.

Catch data and estimates of unreported catch from 1970 and exploitation rates generated from coded wire tagging and recovery provide the main inputs into the derivation of the district CLs based upon a "pseudo"-stock/recruitment relationship. Reared salmon smolts are micro-tagged and adipose fin-clipped before being released into the system. Tag recoveries are generated from international high-seas fisheries in the Faroes and Greenland and from homewater fisheries (drift nets, draft nets, angling etc). Data on declared salmon landings in each fisheries district are collected by the seven regional fisheries boards and compiled into a national dataset by the Marine Institute. Salmon landings are also provided by the Foyle Fisheries Commission and tag recovery information is provided by the Dept. of Agriculture and Rural Development for Northern Ireland. The number of adult recaptures taken in these fisheries is estimated by multiplying the number of tags recovered in each fishery district by the ratio of the reported commercial catch in these districts to the sample size examined. Over 30 tag recovery locations situated around Ireland, covering fish dealers, processors and private fisheries are scanned for the presence of fin-clipped salmon. There is also a non-catch fishing mortality (NCFM) associated with these fisheries which includes losses from nets and non-reporting of catches. An estimate of NCFM is derived annually from local knowledge and experience. This can then be used to expand the net recovered tags to estimate the total number of tagged fish killed in the fishery.

The total stock returning to the river is estimated by summing the counts of reared salmon in the upstream trap, together with those taken by the recreational fishery. The total number of fish available to the coastal fishery can then be estimated by adding the number of fish killed to the number returning to the river. For the purposes of this analysis it is assumed that the tags are randomly distributed throughout the fishery and that non-recognition or non-detection of tags is minimal. Exploitation is estimated by dividing the number of fish caught in a fishery by the number available to the fishery.

ESTIMATION OF TOTAL RETURNS PRIOR TO COASTAL FISHERIES (BURRISHOOLE) AND PRE-FISHERY ABUNDANCE (BANGOR DISTRICT)

Burrishoole

Examination of data on coded wire tagging and tag recoveries for the Burrishoole and other Irish rivers provides sufficient information to suggest that exploitation by commercial fisheries on wild stocks is generally less than on the hatchery fish (Anon. 2001). It also suggests that exploitation of the hatchery stocks has not varied significantly over the twenty year period examined (O' Maoiléidigh et al 1994, O' Maoiléidigh et al 1996). It has therefore been assumed that the maximum exploitation rate on wild Burrishoole salmon is 70% and the annual wild fish exploitation rates are therefore 70% of the values for hatchery fish. This provides an estimate of total returns of wild fish prior to coastal fisheries.

Bangor District

Catch records from commercial dealers registers are available from 1970. The model used to estimate the pre-fishery abundance of salmon from countries in the NEAC area employs a simple run-reconstruction approach similar to that described by Potter and Dunkley (1993). Following Potter *et al* (1998), the model takes the catch in numbers of one-sea winter (1SW) and multi-sea winter (MSW) salmon in each country which are then raised to account for estimates of non-reported catches and exploitation rates on the two sea-age groups. Finally, they are raised to take account of the natural mortality between January 1st in the first sea winter, which is the date they recruit to the first fishery (Faroes). As some of the above parameters cannot be estimated precisely (i.e. unreported catch and exploitation rate) minimum and maximum values are provided which are considered likely to encompass the true values (Table 1). These values are used to delimit uniform distributions for these parameters in a Monte Carlo simulation. The simulation, which uses the software package “Crystal Ball” (Risk assessment software add-in for Microsoft Excel™ from Decisioneering Inc, Decisioneering UK, Ltd., 1996) is run in Microsoft EXCEL to generate estimated distributions of the PFA values by simulating 1000 runs of the model.

ESTIMATION OF SPAWNING STOCKS AND CONSERVATION LIMITS (CL)

Burrishoole

Estimation of the total spawning stock for the Burrishoole is based on total trap counts of all ascending adults. Stock and recruitment curves were generated to identify reference points (McGinnity *et al*, in prep). Examination of the data set suggested that the period 1987 to 1993 provides a realistic model in terms of present day stock in the Burrishoole). In order to produce the maximum smolt output the model indicated that 616 adult spawners would be required. Although this is not the MSY point it is sufficiently close to be used here for illustrative and comparative purposes.

Bangor District

Following Potter *et al* (1998), estimates of spawning stocks are derived as model outputs from the information on catches, unreported catch and exploitation rate. However, stock and recruitment relationships cannot be derived directly from these data because the spawners in year “n” contribute to the 1SW recruitment in year “n+3” to year “n+5”, depending on the relative proportions of 1 to 3 year old smolts which could be produced. Thus for example, spawners in year “n” may produce : 1 year old smolts in year “n+2” which generate 1SW recruits in year “n+3” : 2 year old smolts in year “n+3” which produce 1SW recruits in year “n+4” and so forth (Table 2).

1SW and MSW salmon also contribute to the recruitment in different proportions, principally because of the greater egg deposition from the MSW salmon resulting from their greater size and higher proportion of females and this is taken into account. This is addressed by converting the numbers of 1SW and MSW spawners into numbers of eggs deposited.

The egg deposition in year “n” is assumed to contribute to the recruitment in year “n+3” to “n+5” in proportion to the numbers of smolts produced of ages 1 to 3. Thus the number of “lagged eggs” which contribute to the recruitment of maturing and non-maturing 1SW fish in each year can be estimated.

The lagged eggs estimates provide a measure of the relative spawning level which gave rise to the recruitment figures expressed above as the pre-fishery abundance (PFA). These data can then be plotted to provide a “pseudo” stock recruitment relationship. It is not possible to estimate the CL based upon S_{MSY} without making further assumptions about marine survival. As a result alternative options have been proposed for deriving conservation reference points from such data (Figure 2) (Potter, *et al*, 1998):

Option 1: the minimum stock size previously observed (defined by ICES as the minimum requirement for MBAL where there is great uncertainty about the stock-recruitment relationship).

[i.e. $V_{opt1} = L_{min}$]

Option 2: the stock size where the 90th percentile of survival intersects the 90th percentile of recruitment (Serebryakov, 1991).
[i.e. $V_{opt2} = (R_{90\%ile}) / (R/L)_{90\%ile}$]

Option 3: the stock size where the 90th percentile of survival intersects the median recruitment level.
[i.e. $V_{opt3} = (R_{med}) / (R/L)_{90\%ile}$].

Selection of Option 1 would be inappropriate, as there is evidence of a reduction in recruitment at stock sizes greater than the lowest level previously recorded. In addition, Options 2 and 3 both appear to underestimate the stock size at which recruitment begins to decline

A further option (Option 4, Figure 3) can be derived from a simple method for setting biological reference points from noisy stock-recruitment relationships (Potter and Nicholson 2001). The model assumes that there is a critical stock level below which recruitment decreases linearly towards zero stock and recruitment, and above which the recruitment is constant. The position of the critical stock level is determined by searching for the value which minimises the residual sum of squares. This approach removes some of the subjectivity associated with the preceding options and makes better use of the entire data set in the derivation of the reference point value. This Option indicates a higher CL than Option 1-3.

The final process is to convert the egg CLs derived from the above analyses to age- specific CLs i.e. number of adult fish based on the expected sea age distribution of the population being examined : in this case the Bangor salmon. In this analysis the CL is compared to PFA and therefore is raised to take account of natural mortality between the 1st of January in the first sea winter and the time of return to homewaters. This Spawning Escapement Reserve (SER) will be used as the CL estimate for the purposes of the ensuing results and analyses.

HISTORICAL ATTAINMENT OF CONSERVATION LIMITS

Catches in the North Western Region and Bangor district are significantly correlated with the actual returns to the Burrishoole River ($p < 0.01$, Figure 5). This suggests that the main factors affecting the overall size of all populations in the district combined are probably similar. An examination of the total returns of Burrishoole fish compared with the CL indicates that the CL would have been met in all years if all fish had been allowed to enter the system. However, the removal of fish by commercial fisheries has resulted in the spawning stock being less than the CL in all years except one.

Similarly, total recruits (prior to the commercial fisheries) for the Bangor district have been above the CL in all years except 1981, 1984 and the most recent two years (1999 and 2000, Figure 6). The number of fish remaining after commercial catches (spawners) has only been above the CL consistently from 1973 to 1976 and in only a small number of years after this. Subsequently, the number of spawners has been significantly less than the estimated CL.

The percentage of the CL attained for the Burrishoole has fluctuated considerably and has been as low as 60% under-attained in some years (Figure 7). Greater than 70% under-attainment has been suggested for the Bangor district in some years (notably the most recent two years) although in the past there was a considerable return above the required CL (Figure 7).

With these data, it is possible to estimate the proportion of the catch which was available provided the CL had been achieved. This is illustrated for the Burrishoole River and for the Bangor district (Figure 8). The analysis of the single river example suggests that in most years a modest reduction of between 10 and 20% in the total catch would have been sufficient to meet the management objective of attaining the CL of 660 fish. However, when the same analysis is carried out for the Bangor District, the level of catch reduction is much higher suggesting that many of the stocks are seriously under-escaped. Only a very short period from 1973 to 1976 is apparent where the catch could have been higher and the CL would still have been achieved. In more recent years it is suggested that even with a complete cessation of fishing, the CL would not have been attained.

DISCUSSION

Catch statistics alone do not provide a sufficiently reliable index of the stocks of salmon returning to the coast or of the number of fish surviving to spawn. However, a very long time series of catch data is available in the Republic of Ireland, and in general these catches have been reported in a consistent manner. With the development of new concepts in salmon fisheries management (i.e. CLs and other biological reference points) and the general acceptance of the Precautionary Approach, it has been necessary to look again at the contribution catch statistics can make to salmon stock assessment once the best information from other sources has been applied to them. The extensive data sets generated on marine survival and exploitation rates from the Irish national coded wire tagging and recovery programme has provided results which can be applied to the catch data to produce estimates of recruitment, total returns and spawners. Development of new fishery models has allowed the establishment of biologically-based reference points to aid managers in allocating this resource to the relevant user groups while still providing sufficient spawning capacity to safeguard national stocks.

Four Options have been considered for establishing the Bangor District CL from the "pseudo"-stock-recruitment relationship. Option 4, which gave the largest CL estimate, is considered to remove much of the subjectivity associated with selecting the CL compared with the other three options. This option also provides a better use of the entire data set in the derivation of the single point value. While not shown here, it is also possible to derive confidence limits around the Option 4 estimate, allowing the uncertainty around the CL to be taken into account in the management of the stocks.

The consistent under-attainment of the CL for the Burrishoole reflects a similar but more serious under-attainment in the Bangor district. Caution is therefore advised when using index river data to manage a number of rivers within a given district. Except for a brief period in the mid 1970's, the Bangor district appears to have been severely under-escaped for a protracted period, although in most years the district has been capable of producing more fish than the CL, and therefore providing a harvestable surplus. However, this long period of over-exploitation has probably led to historic lows in returns, catch and spawners in the most recent three years. Even if no fish are caught the CL would probably not be met in coming years if the same level of catch is made. Catch restrictions are therefore required as soon as possible to ensure that the proposed CLs can be met. If the spawning populations continue to decline, then the option of stock rebuilding will need to be seriously considered.

The example above using the Bangor District of the North Western Fisheries Region demonstrates a possible approach to applying CLs to combined local stocks where individual river CLs cannot be set due to lack of information. Examination of the historical attainment of the CL may prove to be useful in determining starting points for biologically meaningful quotas, set-asides, buy-outs, moratoria, bag-limits, etc. However, the analysis is limited to providing only the relative attainment of the previous year or years and may not be a true reflection of the potential stock (or catch) in the current year. Development of predictive Pre-fishery Abundance models or in-season assessments will be required in order to set true quotas. This analysis is equally applicable to all other fishery districts in Ireland. While CLs can be derived they are very much preliminary at present and more work is required to ensure that they reflect real events in individual fisheries. It should also be noted that, where district CLs are being met, this does not necessarily mean that all of the individual river stocks are above their CLs (or *vice versa*) and caution should be exercised in applying the CLs in the absence of other supporting information which may be available.

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[N. Ó Maoiléidigh: Salmon Management Services Division, Marine Institute, Newport, Co. Mayo, Ireland: Phone 00353 98 41107, Fax 00353 98 41107: email niall.omaileidigh@marine.ie]

Table 1 Input data for Bangor district pre-fishery abundance analysis using Monte-Carlo Simulation.

Year	Catch (numbers)		Unrep. as % of total 1SW		Unrep. as % of total MSW		Exp. rate 1SW (%)		Exp. rate MSW (%)	
	1SW	MSW	min	max	min	max	min	max	min	max
1971	13,848	1,539	30	45	30	50	50	70	40	50
1972	13,677	1,520	30	45	30	50	50	70	40	50
1973	27,841	3,093	30	45	30	50	50	70	40	50
1974	42,703	4,745	30	45	30	50	50	70	40	50
1975	38,351	4,261	30	45	30	50	50	70	40	50
1976	30,634	3,404	30	45	30	50	50	70	40	50
1977	21,617	2,402	30	45	30	50	50	70	40	50
1978	20,393	2,266	30	45	30	50	50	70	40	50
1979	27,221	3,025	30	45	30	50	50	70	40	50
1980	18,126	2,891	30	45	30	50	50	70	40	50
1981	2,827	523	30	45	30	50	62	76	40	50
1982	15,191	605	30	45	30	50	61	81	21	42
1983	32,292	1,892	30	45	30	50	54	74	7	14
1984	4,491	367	30	45	30	50	59	75	14	27
1985	20,825	819	30	45	30	50	66	86	25	50
1986	19,994	1,137	30	45	30	50	63	77	27	55
1987	16,747	1,289	20	40	20	45	60	85	23	47
1988	14,819	811	20	40	20	45	45	77	22	44
1989	24,484	1,994	20	40	20	45	60	81	29	58
1990	14,024	1,142	20	40	20	45	46	76	26	53
1991	11,033	898	20	40	20	45	40	64	28	56
1992	21,752	1,771	20	40	20	45	47	79	29	58
1993	15,704	1,279	15	35	20	45	46	68	18	37
1994	21,143	1,722	15	35	20	45	47	77	21	41
1995	21,786	1,774	15	35	20	45	51	83	21	42
1996	17,911	1,459	15	35	15	30	50	74	28	56
1997	9,131	744	10	20	10	20	30	74	22	43
1998	10,994	895	10	20	10	20	30	72	31	61
1999	5,713	465	10	20	10	20	45	75	25	50
2000	6,149	501	10	20	10	20	45	74	25	50

Table 2 Lagged egg deposition analysis for the Bangor district.

	Est. 1SW spawners	Est MSW spawners	Egg deposition egg x 10 ⁻³	Smolt age composition						Lagged egg dep. S egg x 10 ⁻³	Total 1SW recruits R	R/S
				1 yr	2 yr	3 yr	4 yr	5 yr	6 yr			
Egg	3400	7000										
Fem	60%	85%		0.20	0.70	0.10	0.00	0.00	0.00			
1971	15,098	3,193	49,796							n/a	93,592	
1972	14,804	3,156	48,978							n/a	92,457	
1973	30,185	6,384	99,563							n/a	142,408	
1974	46,221	9,818	152,709	9,959						n/a	176,488	
1975	41,708	8,860	137,801	9,796	34,857					n/a	163,794	
1976	33,580	7,033	110,350	19,913	34,285	4,980				59,177	121,792	2.06
1977	23,469	5,016	77,723	30,542	69,694	4,898	0			105,134	98,279	0.93
1978	22,402	4,675	73,518	27,560	106,896	9,956	0	0		144,413	89,940	0.62
1979	30,066	6,271	98,649	22,070	96,461	15,271	0	0	0	133,802	125,816	0.94
1980	19,961	6,009	76,474	15,545	77,245	13,780	0	0	0	106,570	89,905	0.84
1981	2,058	1,092	10,698	14,704	54,406	11,035	0	0	0	80,145	47,264	0.59
1982	10,323	2,390	35,276	19,730	51,463	7,772	0	0	0	78,965	99,390	1.26
1983	30,134	28,566	231,441	15,295	69,055	7,352	0	0	0	91,701	109,227	1.19
1984	3,555	2,518	22,233	2,140	53,532	9,865	0	0	0	65,536	29,884	0.46
1985	11,013	2,493	37,299	7,055	7,489	7,647	0	0	0	22,191	78,960	3.56
1986	13,957	2,944	45,991	46,288	24,694	1,070	0	0	0	72,052	77,059	1.07
1987	9,413	3,775	41,666	4,447	162,009	3,528	0	0	0	169,983	56,056	0.33
1988	14,245	2,606	44,567	7,460	15,563	23,144	0	0	0	46,167	71,697	1.55
1989	15,174	4,124	55,493	9,198	26,109	2,223	0	0	0	37,531	71,298	1.90
1990	13,673	2,766	44,349	8,333	32,194	3,730	0	0	0	44,257	44,717	1.01
1991	15,399	2,028	43,482	8,913	29,166	4,599	0	0	0	42,678	46,962	1.10
1992	19,067	3,686	60,831	11,099	31,197	4,167	0	0	0	46,462	67,359	1.45
1993	16,631	5,316	65,555	8,870	38,845	4,457	0	0	0	52,171	52,789	1.01
1994	18,107	6,287	74,345	8,696	31,044	5,549	0	0	0	45,290	62,157	1.37
1995	15,291	5,969	66,712	12,166	30,438	4,435	0	0	0	47,039	55,680	1.18
1996	15,343	2,719	47,475	13,111	42,581	4,348	0	0	0	60,041	46,540	0.78
1997	11,414	1,926	34,745	14,869	45,888	6,083	0	0	0	66,841	27,022	0.40
1998	14,228	1,330	36,940	13,342	52,042	6,555	0	0	0	71,939	31,275	0.43
1999	4,734	990	15,548	9,495	46,698	7,435	0	0	0	63,628	14,352	0.23
2000	5,252	1,044	16,923	6,949	33,232	6,671	0	0	0	46,853		

Figure 1 Fishery regions in Ireland with districts indicated (Bangor is designated BR)

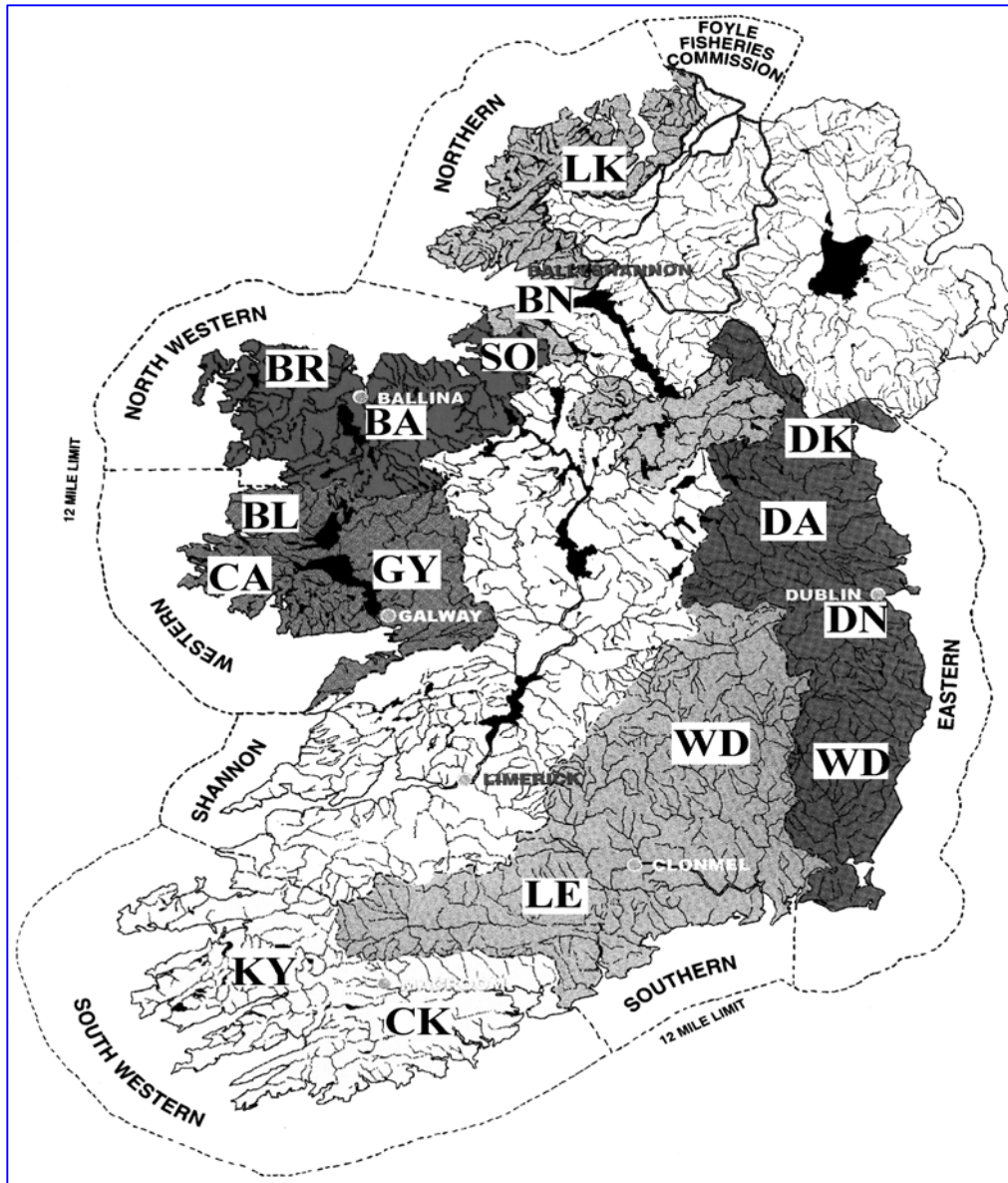
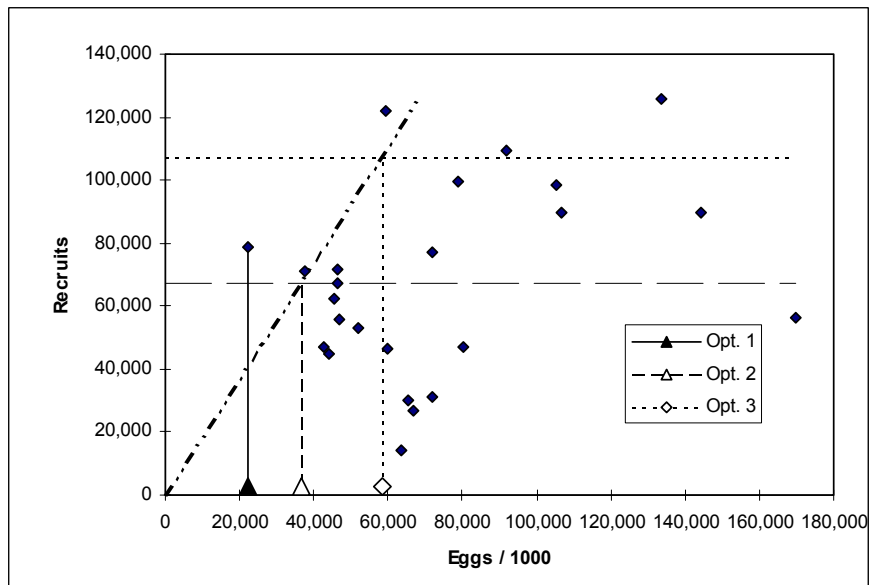
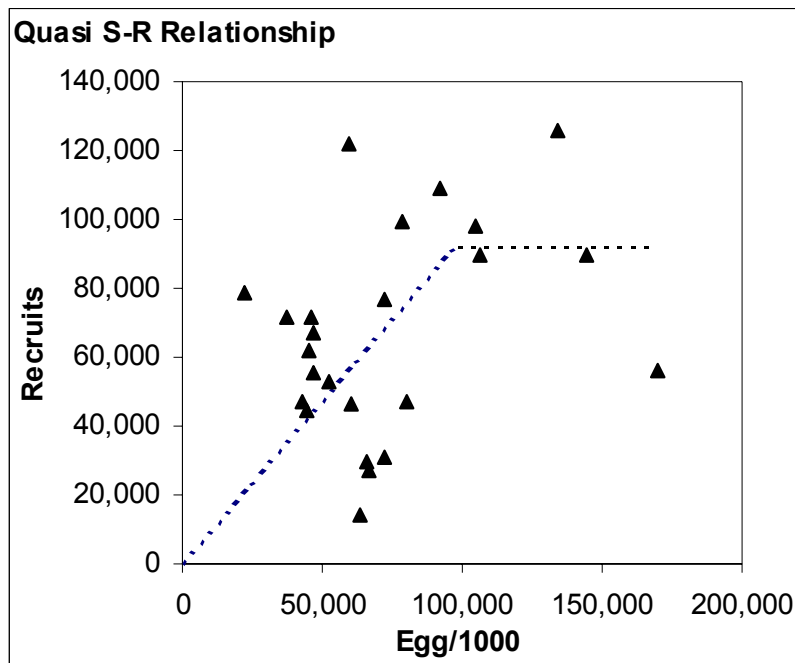


Figure 2 Conservation limit options for the Bangor district.



Conservation limits		Eggs	1SW	MSW	Total.
Option 1	(Min Lag. eggs)	22,191	6,517	1,495	8,012
Option 2	(Med R./90%L)	36,801	10,807	2,480	13,287
Option 3	(90%Rec/90%L)	58,600	17,208	3,949	21,157

Figure 3 Conservation limit Options 4 for the Bangor district.



Conservation limit:			
Eggs /1000	1SW	MSW	Total salmon
98,590	28,874	6,670	35,544

Figure 4 Comparison of Burrishoole returns and regional and district catches

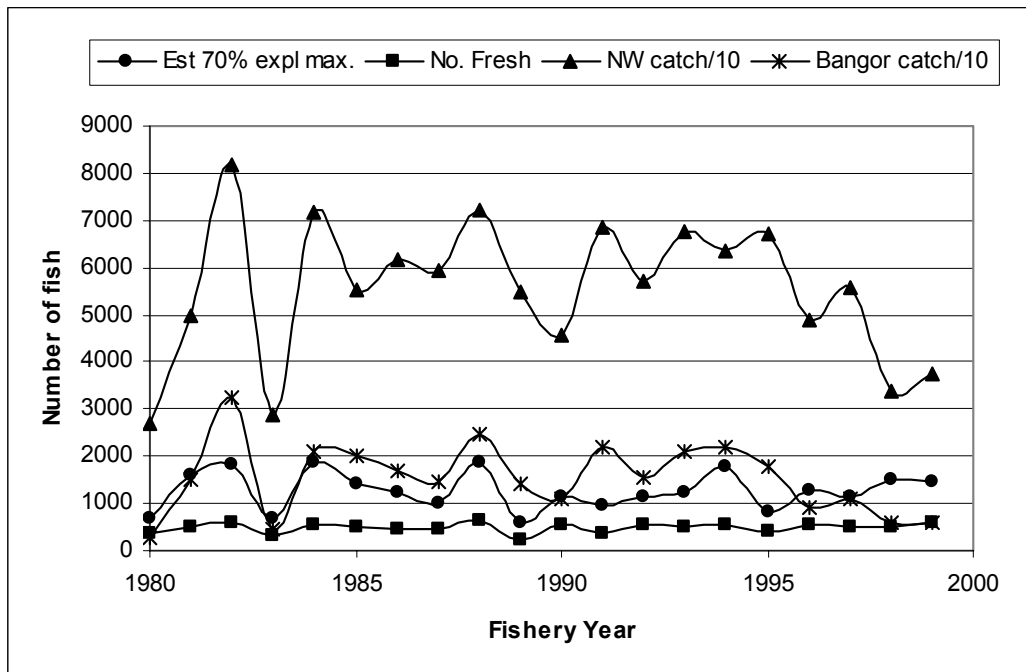


Figure 5 Attainment of conservation limit for the Burrishoole River.

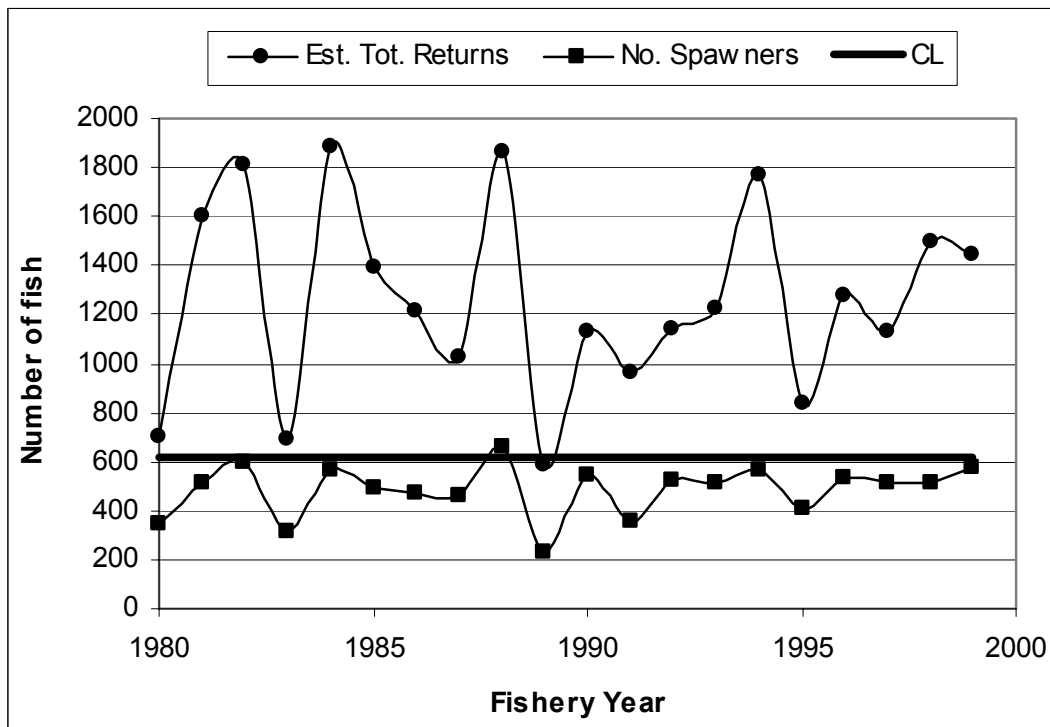


Figure 6 Attainment of conservation limit for the Bangor District

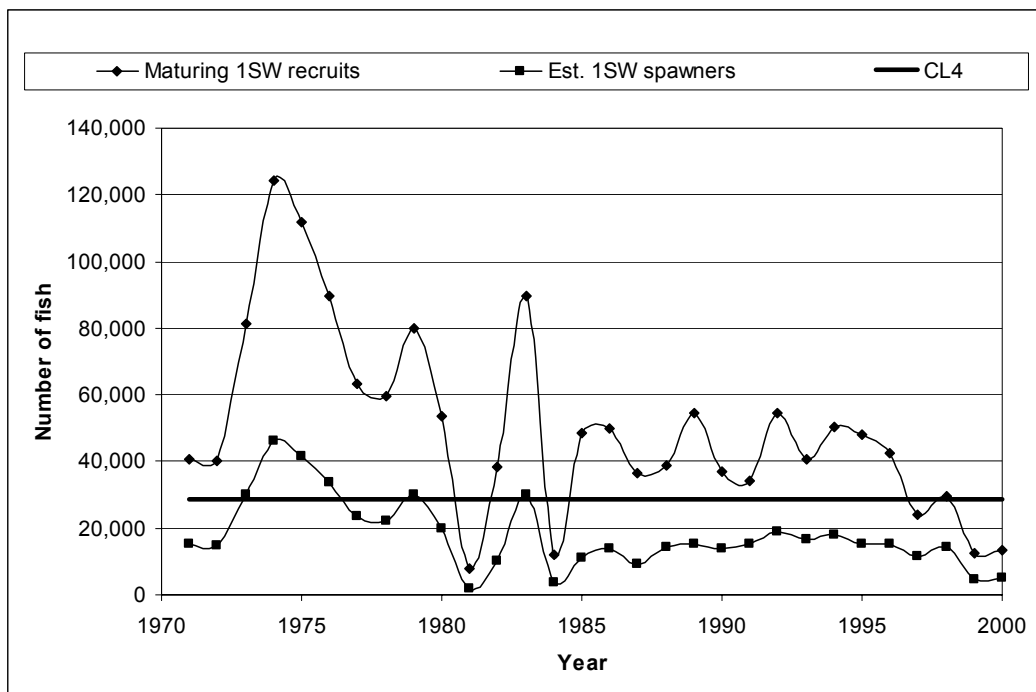


Figure 7 Percentage of conservation limit achieved

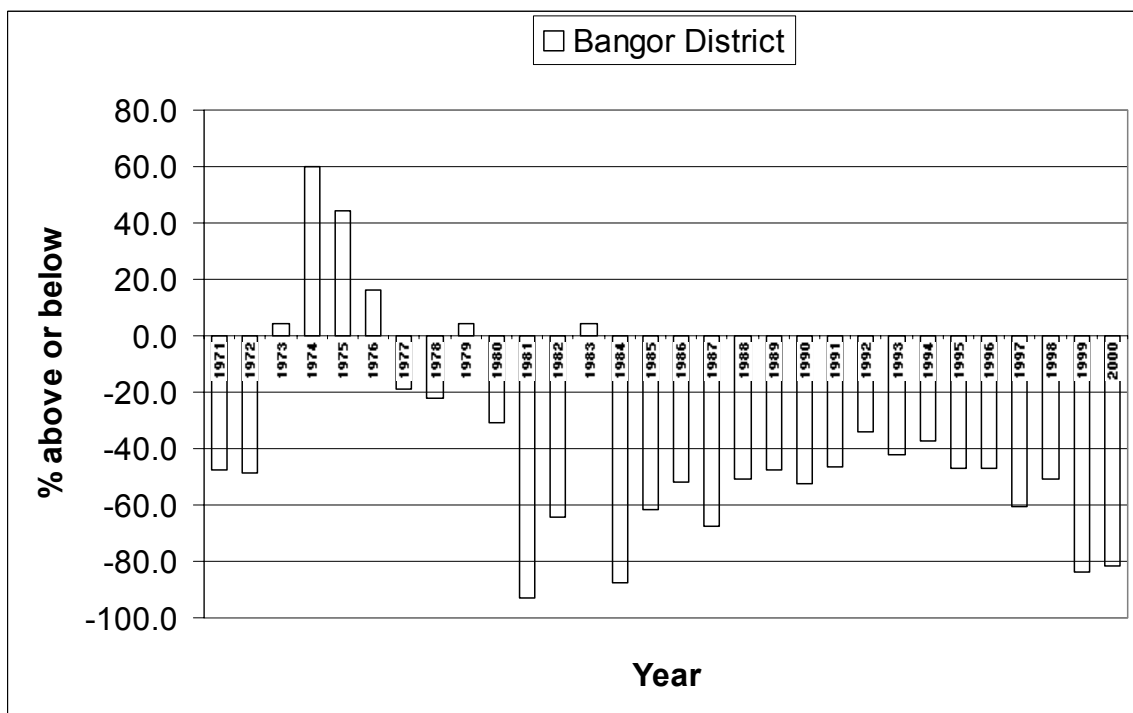
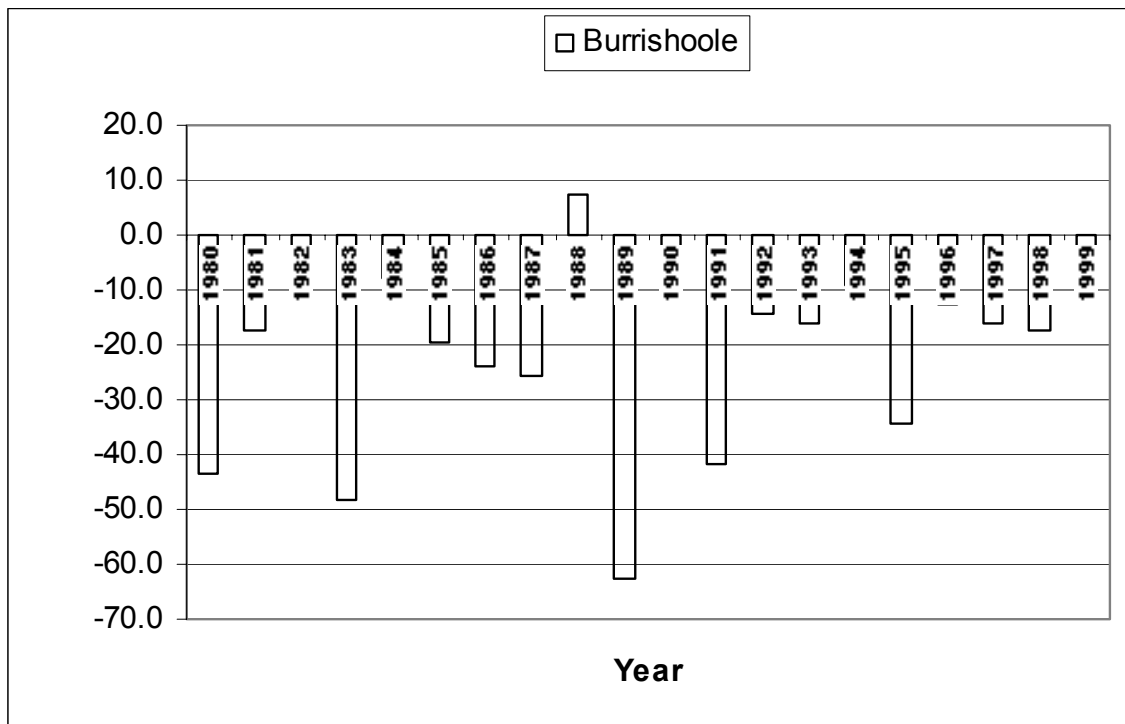
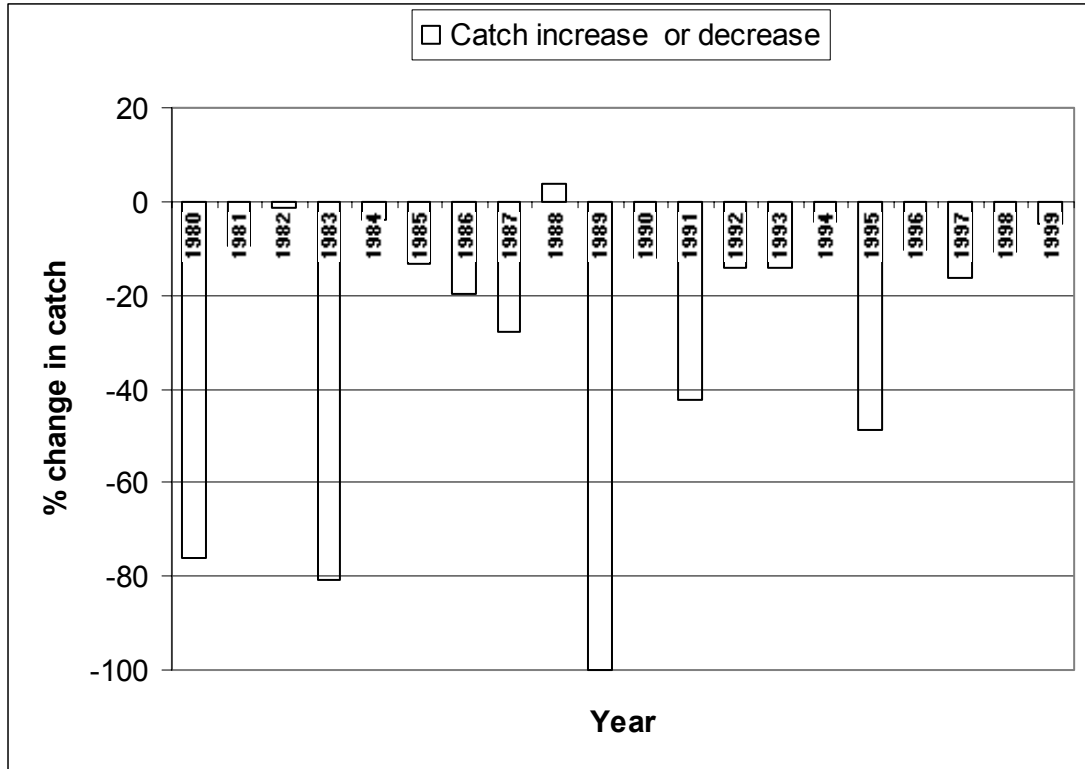


Figure 8 Illustration of the percentage of the catch increase possible or the catch decrease necessary relative to attainment of the conservation limit for the Burrishoole stock and combined Bangor district stocks

Burrishoole



Bangor District

