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A review of the status of the 4VWX flatfish stocks (exclusive of the halibuts)

by

J. D. Neilson and P. Perley
Marine Fish Division
Fisheries Research Branch
Department of Fisheries and Oceans
Biological Station
St. Andrews, New Brunswick E0G 2X0

Abstract

Landings of flatfish (exclusive of the halibuts) in NAFO Divisions 4VWX remained at comparatively low levels in 1984 relative to the catches obtained in the late 1960's and early 1970's. Recent indications from research vessel cruises suggest a relatively stable population of witch and yellowtail with slight increases in American plaice. Abundance indices from commercial fishery data suggest more substantial recent increases, although questions regarding the reliability of those data exist. On the basis of "short-cut" TAC calculations and the continued ambiguity surrounding the status of these stocks, the existing TAC of 14,000 t may be too high.

Résumé

Les débarquements de poissons plats (à l'exclusion du flétan) dans les divisions 4VWX de l'OPANO sont demeurés relativement faibles en 1984 comparativement aux prises obtenues à la fin des années 60 et au début des années 70. Les données récentes obtenues par des navires de recherche indiquent une population relativement stable de plies grises et de limandes à queue jaune et une légère augmentation de la population de plies canadiennes. Les indices d'abondance dérivés des données de la pêche commerciale laissent supposer des augmentations récentes plus importantes, mais la fiabilité de ces données est mise en doute. Si l'on tient compte des calculs "abrégés" du TPA et de l'incertitude qui persiste concernant la situation de ces stocks, le TPA actuel de 14 000 t pourrait être trop élevé.

Introduction

Four members of the Pleuronectid family (exclusive of the halibuts) are exploited commercially on the Scotian Shelf. Listed in order of decreasing landings in 1984, they are:

American plaice (Hippoglossoides platessoides)
Yellowtail flounder (Limanda ferruginea)
Witch flounder (Glyptocephalus cynoglossus)
Winter flounder (Pseudopleuronectes americanus)

Of these, only American plaice, witch flounder and yellowtail flounder are under quota management. Winter flounder have not been sufficiently abundant on the Scotian Shelf to warrant quota management. The landings of winter flounder are comparatively low as it is a coastal species, only abundant along the Nova Scotia coast and in the Bay of Fundy. The only significant offshore fishery is around Sable Island (Halliday MS 1973).

A review of the biology of Scotian Shelf flatfish is given by Halliday (MS 1973). A preliminary examination of stock structure was presented by Neilson and Dale (MS 1984) and was based on their examination of distributions of ripe females and eggs.

The current assessment differs from those presented in past years inasmuch as the halibuts (Hippoglossus hippoglossus, Reinhardtius hippoglossoides) are now included in a separate document, following the recommendation made by Neilson and Dale (MS 1984). Also, due to the manpower constraints of St. Andrews Statistics and Sampling Section charged with age determination, it was not possible to provide age determinations for either the commercial fishery or research vessel collections of yellowtail or witch flounder.

Patterns of Exploitation and Landings

Flatfish landings increased considerably from 14,463 t in 1963 to 55,256 t in 1968. Since then, fluctuations have occurred but catches have generally followed a declining trend until 1977 when they stabilized (Fig. 1, Table 1). However, in 1983 and 1984, the quota of 14,000 t was not reached.

American plaice typically comprise the largest fraction of all flatfish landings (Table 1) with catches in 4V making the largest contribution to the total plaice catch (Table 2). Use of large otter trawlers of Tonnage Class (TC) 4 was the preferred method for exploiting the fishery (Table 6).

Witch flounder usually were the next largest contribution to the total flatfish landings. However, since 1971 when 17,864 t were landed, catches have decreased markedly with a low of 1473 t reported in 1982. In 1984, catches increased slightly, with 1714 t landed (Table 1). The witch flounder fishery was traditionally exploited in NAFO Divisions 4V and 4W. However, since 1977, the catch from 4X has comprised a significant fraction of the total landings (Table 3) and has equalled or exceeded that from 4W. The gear employed in the 4VW witch fishery has been the stern otter trawler, with the Danish seine being increasingly employed recently (Table 7). Landings from TC2 vessels comprise the largest fraction of total landings over the period 1980-1984.

Yellowtail flounder landings have remained stable over recent years (Table 1), but again are down from peak landings in the late 1960's. NAFO Division 4V contributes the bulk of the landings (Table 4). Use of otter trawlers (TC4) has been the preferred means of prosecuting the fishery over the period 1980-1984 (Table 8).

Winter flounder annual landings have remained fairly constant from 1975-82, fluctuating between 1000 and 1400 t. In the last 2 yr, winter flounder landings have declined slightly (Table 5). Most (>90%) of the winter flounder catches are taken by TC1 trawlers over the period 1980-1984 (Table 9).

The flatfish fisheries of the Scotian Shelf have generally been considered to be bycatch fisheries. However, when one plots the percentage of total flatfish catch taken as main species caught (species comprising the largest fraction of total catch weight) over time, it is apparent that there is an increasing trend (Fig. 2) since 1977. Whether this reflects a real trend in fishermen directing their efforts for those species to a greater extent is difficult to determine with certainty.

Recent exploitation by the foreign fisheries has been minimal. In 1984, 102 t of American plaice were taken (USSR - 83 t, Cuba and Portugal - 9 t each, and France 1 t). Foreign catches of witch and yellowtail flounder were 6 t each.

Age Composition of the Commercial Catch

Commercial sampling for flatfish has included all four species (Tables 6-9). Age-size information (1948-78) for these stocks was provided by Cleary (MS 1979). Minimal sampling occurred prior to 1976. Sampling has been adequate since 1977 for all four species with the exception of yellowtail flounder in 1979 and winter flounder in 1978. However, the trends in landings of unidentified flounder are again increasing and should be viewed with concern (Table 1).

Both catch-at-age (Table 10) and weight-at-age (Table 11) matrices were constructed for 4V plaice and 4VW witch from Canadian commercial fishery age-length keys by splitting the samples by gear, applying them to the appropriate catches by gear type (Tables 6-9) and combining the results. In 1984, data from 22 commercial samples were used to construct the American plaice matrices. The commercial samples were collected throughout the year, with sampling intensity generally reflecting seasonal trends in fishing activity (Fig. 3). Data for 1982- 84 witch flounder, 1982 American plaice, and 1984 yellowtail flounder are unavailable as age determinations are not yet complete .

The 1972 year-class of American plaice appeared quite strong and has contributed substantially to the NAFO 4V fishery. The 1977 year-class also appears relatively strong (Table 10).

Catch-Per-Unit-Effort Indices from the Commercial Fishery

The commercial CPUE index was calculated from catch per hour (t) of side otter trawlers, tonnage class 4. These data were chosen because catches are highest for this tonnage class and side otter trawlers had a

complete data set. The months March-May were chosen due to consistently high catch rates over the years. Only those trips directed for flatfish species which had recorded effort and non-zero catches were included. However, while complete data series were available for American plaice, witch and yellowtail, in some instances the annual CPUE index was calculated on the basis of a catch of 200 t. This problem was particularly apparent for witch flounder in recent years, hence the CPUE series should be viewed with caution. Due to very small annual catches, a commercial CPUE series could not be obtained for 4X winter flounder, even when all months and tonnage classes were pooled.

Data were smoothed using the '4253H twice' algorithm proposed by Tukey and developed by Velleman (1980). The algorithm consists of successive applications of running median smoothers followed by the Hamming running average:

$$Z(t) = 0.25\ y(t-1) + 0.5\ y(t) + 0.25\ y(t+1)$$

This procedure was used for smoothing all time series data presented here.

American plaice catch rates have generally declined since 1970 (Table 12a, Fig. 4). A slight increase in the CPUE index was evident in 1984. Witch flounder catch rates have followed an increasing trend since 1977, and have recently stabilized (Table 12b, Fig. 4). Yellowtail flounder catch rates have followed a similar trend, with the increasing trend evident somewhat earlier (Table 12c, Fig. 4).

Catch-Per-Unit-Effort Indices and Age Compositions from Research Cruises

Catch rates from 1970-81 were calculated using data from cruises conducted during the summer months onboard the A.T. Cameron. In 1982, the data were collected from a cruise on the Lady Hammond and in 1983, from the Alfred Needler. The indices of abundance, stratified mean catch per tow (numbers and weight), were obtained by use of the 'Strat' program for analyses of research cruise data. No conversion factor was used between the catch rate series of American plaice from the Lady Hammond and the Alfred Needler cruises. Following the recommendation made at the fall, 1984 CAFSAC SSSS Meeting, the proportion of total American plaice catch taken in 1982 < 28 cm was multiplied by 0.7 to account for differences in the fishing performance between A.T. Cameron and Lady Hammond.

American plaice catch rates have increased somewhat recently (Fig. 5, Table 12a). The detailed catch per tow-at-age values presented in Table 13 indicated that equal numbers of males and females were caught at each age (two-sample t-test, $p = 0.71$). The 1980 year-class of American plaice appears relatively strong (Table 13), as does the 1977 year-class. In the latter instance, the observation is corroborated by examination of the commercial catch-at-age data in Table 10, where the 1977 year-class also appears relatively strong. When we re-examined the trends in catch rate using adult (age 6+) fish, a similar pattern to that shown in Fig. 5 emerged, with a slight increase in the most recent CPUE index apparent.

Witch flounder catch rates have remained more or less stable since 1977 (Fig. 5, Table 12b). Yellowtail flounder catch rates have declined since the peak value observed in 1977, with more recent values remaining stable (Fig. 5, Table 12c).

Recruitment and Mortality

We calculated recruitment of American plaice using a formula suggested by Dale and O'Boyle (MS 1983):

$$R = \frac{\frac{X_3}{\overline{X}_3} + \frac{X_4}{\overline{X}_4}}{2}$$

where X_3 = catch-at-age 3 (year t)
X_4 = catch-at-age 4 (year t+1 for the same cohort).

The index was calculated separately for males and females and the data are shown in Table 14. A time series plot of the index is also provided (Fig. 6). On the basis of this index over the past 2 yr, recruitment to the adult fishery will improve somewhat.

Dale and O'Boyle (MS 1983) provided estimates of total mortality (Z) based on research cruise data. However, the analysis seemed to produce erroneous results, as negative Z values were often obtained. Unresolved problems with the survey may be responsible. We therefore discontinued the calculation of total mortality.

The Calculation of the TAC

Shepherd (1984) suggested a method for the calculation of Total Allowable Catch in instances where population age structure data were either unavailable or unreliable. His technique, referred to as SHOT (Shepherd's Hang-Over TAC), was provided in three formulations. The method calculates the expected catch level under the assumption that no change in F will occur in the year(s) over which the forecast is made (i.e. the status quo is maintained). In the simplest form, only annual landings weight data are required and in the more complex modifications, either a recruitment index or a recruitment index and an estimate of stock biomass are required. An assessment of the validity of the method was given in the 1984 report of the ICES Working Group on Stock Assessments, and the details of the methods given below are from that document. The two versions of the SHOT formulation applicable to the stocks under consideration here are:

Landings data only (4VW Witch, 4VWX yellowtail

$$Y_{sq} = (1-\tilde{F})\ Y(n) + \tilde{F}\tilde{Y} \qquad (1)$$

where $\tilde{Y}$ is the average catch over a number of years, $\tilde{F}$ denotes a yield-biomass ratio for each year and Y_{sq} is the status quo catch in the upcoming year. The biomass term refers to exploited biomass, not total biomass. The method relies on the assumption that recruitment is near average and may therefore fail to give sufficiently conservative results in instances where the stock is declining. An estimate of $\tilde{F}$ can be obtained from examination of the regression Y(n+1) on Y(n), where the slope is equal to $(1-\tilde{F})$.

For the calculation Y_{sq}, we chose the data series from 1977 to 1984, the period following the removal of foreign fishing effort for flatfish species. We determined Y_{sq} to be 2288 and 1366 t for yellowtail and witch flounder, respectively (Appendix 1).

Recruitment index and landings data (4V plaice)

$$Y_{sq} = (1-\tilde{F})\ Y(n) + \tilde{F}\frac{\bar{P}}{\bar{r}}r(n)$$

where $\bar{r}$ is the mean annual index of recruitment (obtained from Table 14) and P is stock production due to recruitment (equivalent to $\bar{Y}$ in Shepherd's first approximation). To determine F through the regression of Y(n+1) on Y(n), it was necessary to include values from 1975 to 1984, a period which included a suitably wide range of annual landings. However, for the calculation of average yield, the period from 1977 to 1984 was again selected. This was in keeping with Shepherd's recommendation that $\bar{Y}$ should be calculated over a period when other factors, such as the level of exploitation, were equal. The 1985 status quo TAC for 4V American plaice was determined to be 6038 t (Appendix 1).

The Future of the Assessment

A considerable amount of effort from the St. Andrews Statistics and Sampling Section has been expended in the age determination of witch, yellowtail and winter flounder collected during research surveys and commercial sampling operations. Yet, for a variety of reasons, those data have not been used in a detailed fashion in any of the recent assessments of 4VWX flatfish. We propose that in order to conduct a detailed analytical assessment of 4V American plaice, the most important flatfish stock, that the commercial sampling effort should be more directed to that stock. The backlog of samples remaining from 1982 should also be cleared up. The sampling intensity should also be increased. For example, only one sample of the commercial landings of Danish and Scottish seiners was obtained in 1984, a gear type comprising 24% of the total landings (Table 6).

Commercial samples of witch, winter and yellowtail flounder are probably no longer required, thus allowing the port technicians to concentrate on other species, including Atlantic halibut.

Conclusions and Recommendations

Landings of all flatfish species except winter flounder increased slightly in 1984 compared with the previous year. However, they remain at very low levels compared with landings in the late 1960's and early 1970's. For example, catches in 4W have dropped in excess of a full order of magnitude for American plaice, witch and yellowtail, to the point that the fisheries are virtually non-existent. On the positive side, continued improved recruitment appears likely for the 4V American plaice fishery. The catch-per-unit index from the commercial fishery also has increased recently for witch and yellowtail flounders (Fig. 4). Indices of abundance of yellowtail and witch flounder from the research vessel cruises have been stable for the past 5-6 yr, with American plaice increasing slightly recently. The recent increases are probably due to improved recruitment (Fig. 6). Given the small annual catches upon which the recent commercial CPUE indices were calculated, we believe the CPUE indicators from the RV surveys carry more weight.

While the Shepherd method used here for TAC calculations is comparatively crude relative to a full analytical assessment, the technique is an improvement over the qualitative judgements rendered for these stocks in the past. While the SHOT calculations indicate that the existing quota of 14,000 t may be somewhat high, it is not yet possible to suggest a new TAC with any degree of confidence. It may be that with an analytical assessment of American plaice next year, a TAC with a more precise basis may be forthcoming.

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Table 1. Total landings (t) for 4VWX flatfish between 1963-84.

Year	American plaice	Witch flounder	Yellowtail flounder	Winter flounder	Flatfish (N.S.)	Total
1963	2309	7486	3972	696	-	14,463
1964	3082	8629	5399	1311	194	18,615
1965	8198	12943	6104	1339	90	28,674
1966	14206	14512	4851	1346	30	34,945
1967	10770	7816	5196	944	-	24,726
1968	19265	21682	13128	1181	-	55,256
1969	13735	14093	3826	1416	-	33,070
1970	8358	6048	3682	1530	11	19,629
1971	14301	17864	1775	3084	1	37,025
1972	10653	11351	1485	1454	724	25,667
1973	12432	13969	1513	1909	873	30,696
1974	16772	7415	939	2756	817	28,699
1975	11747	8922	1568	1374	1118	24,729
1976	11147	5742	904	1297	1043	20,133
1977	7752	2431	1443	1257	944	13,827
1978	6756	2291	1628	1207	1060	12,942
1979	6354	2071	2090	1088	1303	12,906
1980	7572	2321	2491	1174	1887	15,445
1981	6772	1741	2889	1448	1577	14,427
1982	5697	1473	2623	1236	1774	12,803
1983[1]	6002	1485	2422	992	2071	12,972
1984[2]	5780	1714	2319	877	-	10,690

[1]All countries except USA.
[2]Provisional (Maritime catches only).

Table 2. Total American plaice catch (t) for NAFO Division 4VWX for 1963-84.

Year	4V	4W	4X	Total	Canadian catch		Foreign catch	
1963	1376	683	250	2309	2108	(91)[3]	201	(9)
1964	1967	603	512	3082	2838	(92)	244	(8)
1965	4707	2797	694	8198	5542	(68)	2656	(32)
1966	8167	5313	726	14206	9113	(64)	5093	(36)
1967	8884	780	1106	10770	10524	(98)	246	(2)
1968	10489	7830	946	19265	9828	(51)	9437	(49)
1969	8076	4789	870	13735	9300	(68)	4435	(32)
1970	5242	2481	635	8358	6303	(75)	2055	(25)
1971	7765	5991	545	14301	7513	(53)	6788	(47)
1972	6912	3175	566	10653	6855	(64)	3798	(36)
1973	8686	3407	339	12432	5146	(41)	7286	(59)
1974	11363	4951	458	16772	6967	(42)	9805	(58)
1975	7336	4115	296	11747	6623	(56)	5124	(44)
1976	8488	2350	309	11147	6932	(62)	4215	(38)
1977	6711	592	449	7752	7654	(99)	98	(1)
1978	5501	743	512	6756	6679	(99)	77	(1)
1979	5028	498	828	6354	6329	(100)	25	(0)
1980	6293	598	681	7572	7490	(99)	82	(1)
1981	5677	581	514	6772	6586	(97)	186	(3)
1982	4920	400	377	5697	5621	(99)	76	(1)
1983[1]	5094	428	480	6002	5963	(99)	39	(1)
1984[2]	5351	209	220	5780	5780	(100)	-	

[1]All countries except USA.
[2]Provisional (Maritime catches only).
[3]Percentage of total catch.

Table 3. Total witch flounder catch (t) for NAFO Division 4VWX for 1963–84

Year	4V	4W	4X	Total	Canadian catch		Foreign catch	
1963	4971	2440	75	7486	6972	(93)[3]	514	(7)
1964	5808	2564	257	8629	8406	(97)	223	(3)
1965	5068	7454	421	12943	7710	(60)	5233	(40)
1966	5241	9047	224	14512	7046	(49)	7466	(51)
1967	5740	1693	383	7816	7496	(96)	320	(4)
1968	7598	13349	735	21682	8772	(40)	12910	(60)
1969	4338	8963	792	14093	6671	(47)	7422	(53)
1970	3282	1959	807	6048	4920	(81)	1128	(19)
1971	5640	11083	1141	17864	6816	(38)	11048	(62)
1972	4894	5759	698	11351	5909	(52)	5442	(48)
1973	6572	6862	535	13969	5854	(42)	8115	(58)
1974	4913	2004	498	7415	5830	(79)	1585	(21)
1975	3284	5307	331	8922	3406	(38)	5516	(62)
1976	2718	2683	341	5742	2466	(43)	3276	(57)
1977	1555	455	421	2431	2307	(95)	124	(5)
1978	1540	563	188	2291	2139	(93)	152	(7)
1979	1572	209	290	2071	2057	(99)	14	(1)
1980	1801	189	331	2321	2298	(99)	23	(1)
1981	1123	156	462	1741	1687	(97)	54	(3)
1982	789	101	583	1473	1411	(96)	62	(4)
1983[1]	877	126	482	1485	1473	(99)	12	(1)
1984[2]	1164	119	431	1714	1714	(100)		

[1]All countries except USA.
[2]Provisional (Maritime catches only).
[3]Percentage of total catch.

Table 4. Total yellowtail flounder catch (t) for NAFO Division 4VWX for 1963-84.

Year	4V	4W	4X	Total	Canadian catch		Foreign catch	
1963	1740	2148	84	3972	3784	(95)[3]	188	(5)
1964	4084	1165	150	5399	5288	(98)	111	(2)
1965	4330	1550	224	6104	5378	(88)	726	(12)
1966	3521	1164	166	4851	3770	(78)	1081	(22)
1967	3808	1163	225	5196	5152	(99)	44	(1)
1968	6953	5970	205	13128	5377	(41)	7751	(59)
1969	2491	1134	201	3826	1263	(33)	2563	(67)
1970	670	2686	326	3682	947	(26)	2735	(74)
1971	889	668	218	1775	1033	(58)	742	(42)
1972	697	624	164	1485	1007	(68)	478	(32)
1973	980	394	139	1513	424	(28)	1089	(72)
1974	573	130	236	939	593	(63)	346	(37)
1975	1101	254	213	1568	1083	(69)	485	(31)
1976	473	201	230	904	610	(67)	294	(33)
1977	1101	40	302	1443	1424	(99)	19	(1)
1978	1085	156	387	1628	1610	(99)	18	(1)
1979	1655	144	291	2090	2088	(100)	2	(0)
1980	2158	78	255	2491	2486	(100)	5	(0)
1981	2539	123	227	2889	2881	(100)	8	(0)
1982[1]	2360	51	212	2623	2620	(100)	3	(0)
1983[2]	2043	59	320	2422	2422	(100)	-	(0)
1984	2112	44	163	2319	2319	(100)		

[1]All countries except USA.
[2]Provisional (Maritime catches only).
[3]Percentage of total catch.

Table 5. Total winter flounder catch (t) for NAFO Division 4VWX for 1963-84.

Year	4V	4W	4X	Total	Canadian catch		Foreign catch	
1963	17	65	614	696	668	(96)[3]	28	(4)
1964	12	19	1280	1311	1282	(98)	29	(2)
1965	32	179	1128	1339	1237	(92)	102	(8)
1966	55	34	1257	1346	997	(74)	349	(26)
1967	37	5	902	944	926	(98)	18	(2)
1968	10	28	1143	1181	1128	(96)	53	(4)
1969	4	12	1400	1416	1392	(98)	24	(2)
1970	8	44	1478	1530	1480	(97)	50	(3)
1971	237	1364	1483	3084	1430	(46)	1654	(54)
1972	78	551	825	1454	824	(57)	630	(43)
1973	480	655	774	1909	904	(47)	1005	(53)
1974	777	1005	974	2756	1321	(48)	1435	(52)
1975	179	525	670	1374	802	(58)	572	(42)
1976	235	345	717	1297	908	(70)	389	(30)
1977	226	9	1022	1257	1244	(99)	13	(1)
1978	186	137	884	1207	1202	(100)	5	(0)
1979	228	13	847	1088	1085	(100)	3	(0)
1980	30	10	1134	1174	1173	(100)	1	(0)
1981	26	11	1411	1448	1448	(100)	-	
1982[1]	82	10	1144	1236	1231	(100)	5	(0)
1983[2]	72	8	912	992	992	(100)	-	(0)
1984	2	5	870	877	877	(100)		

[1]All countries except USA.
[2]Provisional (Maritime catches only).
[3]Percentage of total catch.

Table 6. Nominal catch (t) of American plaice by gear in NAFO Division 4V for all countries, 1972-84 (# of Canadian commercial fishery samples indicated in parentheses).

Year	Side otter trawl	Stern otter trawl[4]	Danish and Scottish seine	Longline	Other[1]	Total
1972	3012 (4)	3267	364	189	80	6912 (4)
1973	1971 (2)	5987 (2)	482	152	94	8686 (4)
1974	2193 (7)	8318	510	125	217	11363 (7)
1975	2779 (5)	3455 (1)	657	171	274	7336 (6)
1976	2438 (4)	4678 (3)	1178 (8)	87	107	8488 (15)
1977	2661 (5)	2285 (4)	1443 (17)	218	104	6711 (26)
1978	1766 (9)	2150 (6)	1222 (11)	164	199	5501 (26)
1979	1745 (11)	2201 (4)	806 (1)	192	84	5028 (16)
1980	1871 (12)	2674 (9)	1523 (3)	211	14	6293 (24)
1981	2080 (14)	2222 (7)	941 (1)	431 (4)	3	5677 (26)
1982[2]	1868 (12)	1546 (8)	716 (3)	786 (1)	4	4920 (24)
1983[3]	1159 (1)	2191(14)	1020 (7)	716 (2)	8	5094 (24)
1984[3]	1262 (4)	2228(11)	1265 (1)	564 (3)	32	5351 (19)

[1]Includes NK and MISC gears.
[2]All countries except USA.
[3]Provisional (Maritime catches only).
[4]On the basis of purchase slip information and log records, catches recorded as unspecified otter trawl were assumed to be from stern otter trawlers. This assumption also holds for data in Tables 7-9.

Table 7. Nominal catch (t) of witch flounder by gear in NAFO Division 4VW for all countries, 1972-84 (# of Canadian commercial fishery samples taken indicated in parentheses).

Year	Side otter trawl	Stern otter trawl	Danish & Scottish seine	Other[1]	Total
1972	2459 (2)	6925	1257 (2)	12	10,653 (4)
1973	2194 (2)	9700 (1)	1464 (1)	76	13,434 (4)
1974	1968 (4)	3675 (2)	1221 (2)	53	6,917 (8)
1975	1121 (5)	6360 (4)	995 (1)	115	8,591 (10)
1976	751	3709 (2)	869 (12)	72	5,401 (14)
1977	272 (2)	785 (6)	838 (8)	115	2,010 (16)
1978	406 (11)	715 (3)	930 (12)	52	2,103 (26)
1979	419 (1)	512 (1)	792 (7)	58	1,781 (9)
1980	290 (7)	791 (5)	866 (5)	43	1,990 (17)
1981	342 (6)	354 (3)	564 (1)	19	1,279 (10)
1982[2]	164 (1)	209 (1)	511 (2)	6	890 (4)
1983[3]	95	217 (6)	678 (6)	13	1003 (12)
1984[3]	39 (3)	212 (5)	1012 (2)	20	1283 (10)

[1]Includes NK and MISC gears.
[2]All countries except USA.
[3]Provisional (Maritime catches only).

Table 8. Nominal catch (t) of yellowtail flounder by gear in NAFO Division 4VWX for all countries, 1972-84 (# of Canadian commercial fishery samples taken indicated in parentheses).

Year	Side otter trawl	Stern otter trawl	Danish and Scottish seine	Longline	Other[1]	Total
1972	787 (1)	622	63	11	2	1485 (1)
1973	327 (1)	1094	71	20	1	1513 (1)
1974	208 (1)	640	56	32	3	939 (1)
1975	647	832 (1)	40	49	-	1568 (1)
1976	209	610	61	24	-	904
1977	769 (3)	444 (3)	141	14	75	1443 (6)
1978	684 (6)	729 (1)	92 (3)	18	105	1628 (10)
1979	1239	653	132	42	24	2090
1980	1306 (10)	837 (6)	299	11	38	2491 (16)
1981	1622 (19)	1032 (10)	174	13	48	2889 (29)
1982	1853 (18)	694 (7)	62	14	-	2623 (25)
1983[2]	1390 (9)	746 (19)	187	32	67	2422 (28)
1984[3]	1230 (6)	721 (12)	316	36	16	2319 (18)

[1]Includes NK and MISC gears.
[2]All countries except USA.
[3]Provisional (Maritime catches only).

Table 9. Nominal catch (t) of winter flounder by gear in NAFO Division 4VWX for all countries, 1972-84 (# of Canadian commercial fishery samples taken in parentheses).

Year	Side otter trawl	Stern otter trawl	Longline	Danish and Scottish seine	Other[1]	Total
1972	249	1135	39	1	30	1454
1973	527 (2)	1290	39	2	51	1909 (2)
1974	784	1818	2	98	54	2756
1975	456	810	14	32	62	1374
1976	546 (10)	661 (1)	41	15	34	1297 (11)
1977	566	480 (3)	40	2	169	1257 (3)
1978	512	575	50	8	62	1207
1979	290	635 (1)	70	18	75	1088 (1)
1980	2 (1)	962	52	21	137	1174 (1)
1981	18	1303 (9)	57	8	62	1448 (9)
1982[2]	72	1064 (13)	35	7	58	1236 (13)
1983[2]	-	881 (13)	16	7	88	992 (13)
1984[3]	2	730 (13)	6	5	134	877 (13)

[1]Includes NK and MISC gears.
[2]All countries except USA.
[3]Provisional (Maritime catches only).

Table 10. Catch at age (x 10^3) of male and female American plaice in 4V for 1976-84.

Age	MALE								FEMALE							
	1976	1977	1978	1979	1980	1981	1982*	1983	1984	1976	1977	1978	1979	1980	1981	1982*	1983	1984
3	-	-	-	-	-	-		-	-	-	2	-	-	-	-		-	-
4	-	-	-	-	-	4		3	-	-	-	-	-	-	1		-	-
5	6	19	1	37	19	6		11	-	-	4	2	8	21	21		9	-
6	60	50	39	108	158	40		130	17	38	85	66	109	28	85		192	23
7	139	161	105	309	373	327		113	200	1	444	129	406	245	208		87	487
8	330	255	218	840	1003	364		45	157	179	666	199	226	772	454		104	402
9	872	745	458	481	618	590		223	234	718	601	439	524	322	999		300	258
10	983	708	529	672	304	345		350	162	775	1102	390	294	537	500		352	460
11	1020	837	524	328	333	129		395	310	1403	994	657	423	283	405		740	436
12	1289	679	298	217	466	354		377	123	851	999	732	546	333	434		555	811
13	942	208	310	433	452	250		246	309	1060	778	694	719	639	169		362	633
14	414	70	145	64	239	186		171	38	664	541	364	343	684	443		277	565
15	141	13	101	26	159	112		132	43	130	417	284	209	505	373		220	496
16	52	18	24	11	56	68		112	28	239	145	242	126	368	486		339	264
17	13	-	37	5	29	52		57	16	113	50	195	39	154	210		289	297
18	78	-	1	-	18	1		54	14	186	64	100	19	155	202		227	157
19	40	1	-	-	5	8		63	18	127	15	66	7	20	58		144	160
20	4	-	6	-	4	3		44	20	57	11	43	10	32	37		116	123
21	-	-	6	-	-	-		13	3	43	31	17	-	70	26		62	68
22	2	-	-	10	-	-		-	-	18	60	16	2	75	21		72	15
23	-	-	-	-	-	-		-	-	7	1	15	1	14	1		19	48
24	-	-	-	-	-	-		5	-	28	6	14	-	4	29		31	52
25	-	-	-	-	-	-		6	-	-	-	4	-	-	-		17	34
26	-	-	-	-	-	-		-	-	2	-	12	-	35	21		29	29
27	-	-	-	-	-	-		-	-	-	-	-	-	-	3		11	5
28+	-	-	-	-	-	-		-	-	-	-	-	-	-	-		-	-

*Catch-at-age data unavailable for 1982.

Table 11. Commercial weight at age (kg) of male and female American plaice for all gears in NAFO Division 4V for 1976-84.

Age	MALE									FEMALE								
	1976	1977	1978	1979	1980	1981	1982*	1983	1984	1976	1977	1978	1979	1980	1981	1982*	1983	1984
3	-	-	-	-	-	-		-	-	-	0.12	-	-	-	-		-	-
4	-	-	-	-	-	0.17		0.10	-	-	-	-	-	-	0.18		-	-
5	0.20	0.19	0.17	0.16	0.23	0.22		0.18	-	-	0.14	0.21	0.28	0.24	0.36		0.29	-
6	0.32	0.19	0.21	0.27	0.24	0.31		0.29	0.24	0.38	0.35	0.27	0.40	0.27	0.42		0.34	0.37
7	0.30	0.28	0.25	0.25	0.30	0.39		0.32	0.32	0.23	0.37	0.39	0.38	0.38	0.46		0.39	0.42
8	0.32	0.34	0.36	0.30	0.30	0.37		0.42	0.36	0.44	0.38	0.41	0.54	0.38	0.47		0.53	0.46
9	0.35	0.37	0.40	0.35	0.40	0.40		0.38	0.36	0.55	0.46	0.52	0.44	0.60	0.52		0.47	0.46
10	0.41	0.41	0.44	0.41	0.42	0.52		0.40	0.39	0.64	0.52	0.53	0.63	0.55	0.69		0.58	0.51
11	0.43	0.43	0.48	0.56	0.49	0.65		0.43	0.39	0.64	0.61	0.60	0.69	0.66	0.69		0.61	0.57
12	0.51	0.45	0.55	0.63	0.50	0.54		0.46	0.59	0.71	0.76	0.76	0.88	0.78	0.76		0.62	0.60
13	0.56	0.57	0.55	0.64	0.49	0.50		0.48	0.43	0.85	0.85	0.79	0.88	0.85	0.68		0.78	0.81
14	0.68	0.71	0.72	1.01	0.51	0.52		0.52	0.56	0.94	0.86	0.93	1.06	0.98	1.05		0.89	0.74
15	0.73	0.68	0.93	1.48	0.67	0.53		0.58	0.63	1.36	1.10	1.00	1.43	0.85	1.09		1.02	0.82
16	0.87	1.23	1.02	1.17	0.66	0.52		0.72	0.72	1.01	1.24	1.21	1.60	1.18	1.18		1.14	1.29
17	1.17	-	0.93	1.48	0.99	0.52		0.66	0.71	1.70	1.44	1.26	1.53	1.17	1.12		1.16	1.13
18	0.57	-	1.28	-	0.74	1.67		0.68	0.69	1.56	1.65	1.47	1.33	1.34	1.31		1.29	1.43
19	0.49	0.97	-	-	0.74	1.07		0.72	0.82	1.83	1.81	1.61	1.68	1.92	1.51		1.39	1.26
20	1.49	-	0.84	-	0.92	0.74		0.83	0.95	1.69	1.62	1.57	1.99	1.82	1.41		1.34	1.40
21	-	-	0.84	-	-	-		0.79	0.68	1.98	1.34	1.79	-	1.42	1.73		1.71	2.03
22	1.34	-	-	2.16	-	-		-	-	2.03	1.50	2.49	3.27	1.46	1.78		1.63	2.06
23	-	-	-	-	-	-		-	-	2.14	1.91	1.62	3.10	1.39	2.10		2.22	1.73
24	-	-	-	-	-	-		0.91	-	-	2.59	2.21	-	2.24	2.14		1.73	1.82
25	-	-	-	-	-	-		1.12	-	-	-	3.05	-	-	-		2.53	1.89
26	-	-	-	-	-	-		-	-	3.32	-	2.85	-	2.30	2.13		2.12	2.31
27	-	-	-	-	-	-		-	-	-	-	-	-	-	2.19		2.48	2.60

*Weight-at-age data unavailable for 1982.

Table 12a. American plaice commercial and research CPUE in NAFO Division 4V for 1970-84.

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
Canadian OTB1/TC4															
(t/h)	.401	.275	.300	.225	.254	.340	.296	.296	.242	.238	.153	.197	.144	.155	.232
Smoothed	.370	.306	.269	.263	.273	.284	.288	.281	.259	.226	.195	.179	.178	.186	.200
Research															
#/tow	80.27	79.11	69.64	40.62	77.85	60.50	127.79	58.59	26.77	56.84	71.69	55.04	50.50	61.21	67.83
Smoothed	80.27	76.48	72.39	69.02	67.22	65.62	62.64	58.97	56.71	55.95	55.72	55.99	57.48	61.54	68.15

Table 12b. Witch flounder commercial and research CPUE in NAFO Division 4VW for 1970-84.

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
Canadian OTB1/TC4															
(t/h)	.186	.184	.171	.260	.235	.105	.066	.016	.077	.057	.069	.065	.255	.244	.176
Smoothed	.186	.190	.197	.201	.183	.130	.078	.057	.055	.056	.074	.122	.170	.186	.186
Research															
#/tow	5.13	5.92	4.23	9.13	18.39	5.55	3.08	3.52	3.12	2.41	3.24	3.84	3.23	8.41	2.01
Smoothed	5.13	5.93	6.89	7.30	7.13	6.11	4.40	3.35	3.15	3.14	3.23	3.39	3.47	3.47	3.47

Table 12c. Yellowtail flounder commercial and research CPUE in NAFO Division 4VWX for 1970-84.

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
Canadian OTB1/TC4															
(t/h)	.099	.341	.277	.126	.052	.170	.120	.086	.139	.170	.154	.157	.346	.332	.244
Smoothed	.191	.191	.191	.174	.139	.119	.119	.124	.133	.145	.171	.217	.254	.264	.264
Research															
#/tow	20.00	17.17	18.43	19.01	25.56	30.71	19.18	49.95	12.64	26.96	17.09	23.84	22.20[1]	14.82	21.83
Smoothed	19.51	19.51	19.64	20.66	22.74	24.34	24.74	24.25	23.13	22.06	21.48	21.31	21.31	21.31	21.31

[1]No summer datum available. March survey datum reported, to allow completion of time series for data smoothing purposes.

Table 13. Stratified mean catch per tow at age (number) calculated for American plaice from summer bottom trawl surveys in NAFO Division 4V, 1970-84.

Age	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
							M A L E								
1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.047	0.000	0.090	0.020	0.00	0.00	0.02	0.00
2	0.069	0.473	0.841	0.084	1.893	0.878	0.260	0.085	0.153	0.510	0.240	0.28	0.62	0.51	0.66
3	2.453	0.542	2.075	1.000	3.359	5.817	3.863	0.878	0.099	0.910	3.190	0.90	1.40	1.88	0.57
4	4.201	7.369	0.979	1.203	3.471	2.727	18.292	2.671	0.901	1.470	1.210	7.54	2.86	3.00	3.45
5	11.550	7.462	2.744	1.177	5.331	2.523	6.166	5.741	1.328	4.980	2.210	1.80	5.72	3.41	5.48
6	8.608	12.575	4.205	3.087	1.368	1.792	6.650	2.339	2.902	4.110	4.930	1.22	3.53	6.02	3.62
7	7.036	6.865	12.237	3.910	5.927	1.606	4.208	3.131	1.806	7.150	6.210	4.70	3.33	2.68	9.16
8	5.015	4.669	2.916	5.536	6.530	4.006	4.929	3.068	1.574	3.200	7.880	3.38	2.75	2.23	3.73
9	2.467	3.299	2.847	2.043	5.341	2.699	8.009	3.918	1.369	2.890	4.280	4.07	2.48	2.71	1.84
10	0.725	1.664	3.245	0.933	2.346	3.486	5.965	2.314	1.448	2.420	3.330	1.43	2.06	2.32	4.35
11	0.624	0.931	0.689	0.697	1.199	2.356	2.464	0.636	0.858	1.530	2.050	0.55	0.23	1.74	1.55
12	0.405	0.567	1.022	0.417	1.265	0.628	1.351	0.457	0.960	1.220	1.980	0.38	0.04	0.55	1.40
13+	0.246	1.526	0.976	0.163	0.377	1.456	0.626	0.488	0.122	0.620	0.740	1.47	0.74	1.17	2.46
NK	0.616	0.237	-	1.121	0.495	0.956	0.023	0.076	0.000	0.000	0.000	0.00	0.00	0.00	0.00
Total	44.014	48.164	34.768	21.362	38.240	30.930	62.792	25.841	13.528	31.100	38.270	27.70	25.75	28.25	38.27
							F E M A L E								
1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00	0.20	0.00
2	0.000	0.275	0.231	0.137	1.488	0.328	1.137	0.015	0.053	0.400	0.450	0.23	1.53	0.63	0.50
3	1.398	0.252	1.051	0.977	3.204	5.436	3.466	0.200	0.099	0.310	3.190	0.79	2.67	2.33	2.07
4	4.514	2.061	2.354	1.440	3.559	2.483	16.305	1.989	0.771	0.530	1.740	4.74	2.69	3.99	3.47
5	7.613	2.991	4.015	0.611	4.009	2.707	6.661	8.515	1.115	2.690	1.790	1.48	6.92	3.65	3.51
6	6.462	6.987	4.158	3.065	2.687	1.587	7.544	2.339	2.953	3.090	2.670	1.28	1.87	7.66	3.24
7	5.999	2.727	7.348	3.182	3.466	1.028	5.106	5.188	1.088	6.060	2.780	4.05	2.21	2.35	4.66
8	3.494	3.669	4.981	4.527	5.850	2.521	3.258	4.501	1.154	1.950	4.450	2.04	3.27	1.53	1.88
9	2.276	3.065	1.817	1.678	6.815	2.697	7.269	2.058	0.937	2.260	3.070	4.17	2.37	2.80	0.96
10	1.055	2.123	3.729	1.183	2.727	4.191	4.298	2.681	0.925	1.620	2.810	1.13	2.97	1.50	1.82
11	0.649	0.887	1.168	0.366	2.305	1.853	4.714	2.537	1.144	1.290	2.070	1.05	0.85	2.01	1.54
12	0.557	1.990	0.660	0.504	1.034	1.886	2.847	1.606	0.889	1.380	1.260	0.69	1.00	0.83	1.99
13+	1.636	3.760	3.370	0.412	2.557	2.467	3.701	1.127	2.077	4.160	7.140	5.68	4.25	3.48	3.92
NK	0.615	0.157	0.000	1.177	0.000	0.401	0.092	0.000	0.031	0.000	0.000	0.00	0.00	0.00	0.00
Total	36.257	30.942	34.868	19.262	39.613	29.574	66.994	32.745	13.240	25.740	33.420	27.34	32.63	32.96	29.56

Table 14. Recruitment indices for 4V American plaice, based on ages 3 and 4 of the same cohort (year-classes 1967-80). Data are from summer bottom trawl surveys.

Year-class	Recruitment index	
	Male	Female
1967	1.4746	0.6912
1968	0.2489	0.4102
1969	0.6517	0.5039
1970	0.6564	0.7883
1971	1.1473	2.5229
1972	7.1870	3.8821
1973	1.2643	1.2642
1974	0.6443	0.1675
1975	0.1984	0.1043
1976	0.3666	0.3381
1977	1.6757	1.5826
1978	0.5595	0.6031
1979	0.7082	2.6105
1980	0.8857	2.2745

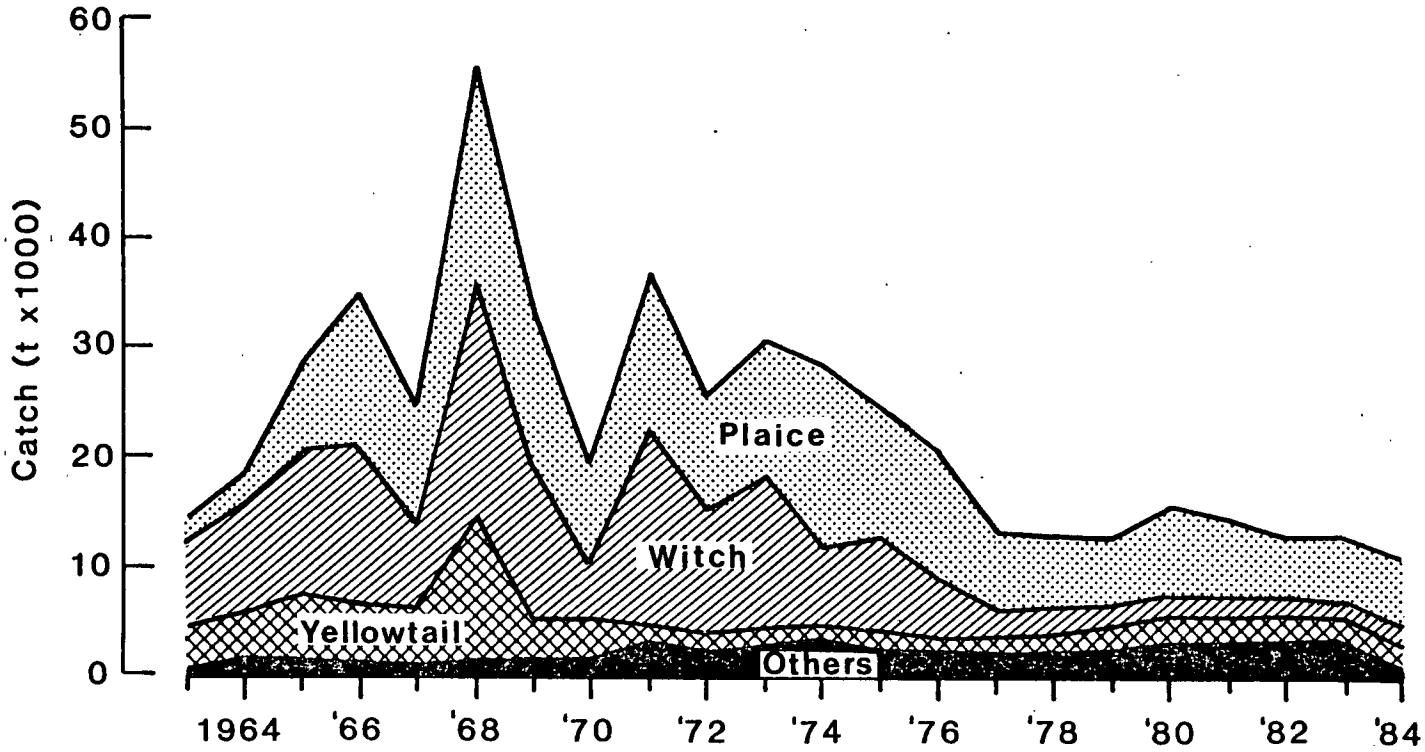


Fig. 1. Total catch of flatfish species (exclusive of the halibuts) in NAFO Divisions 4VWX, 1963-1984.

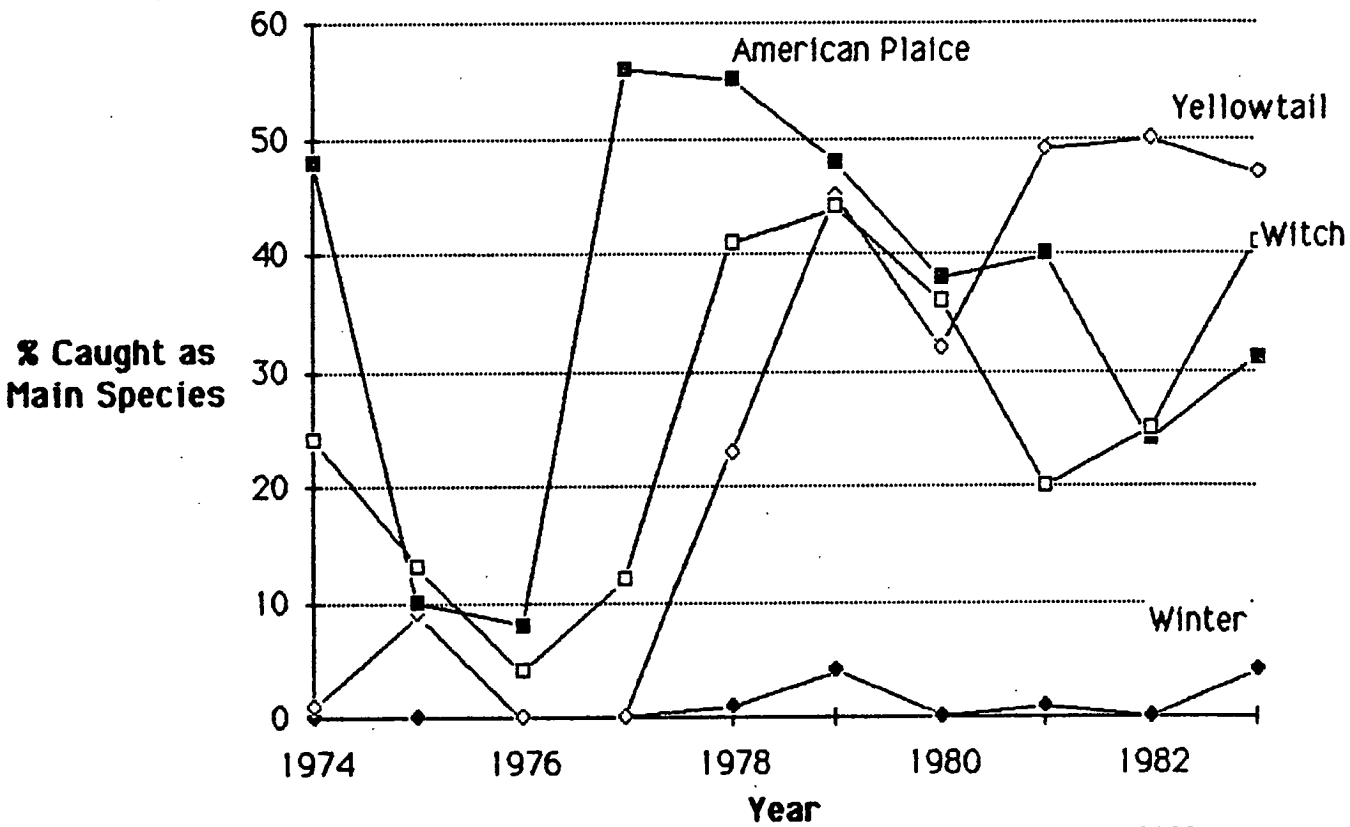
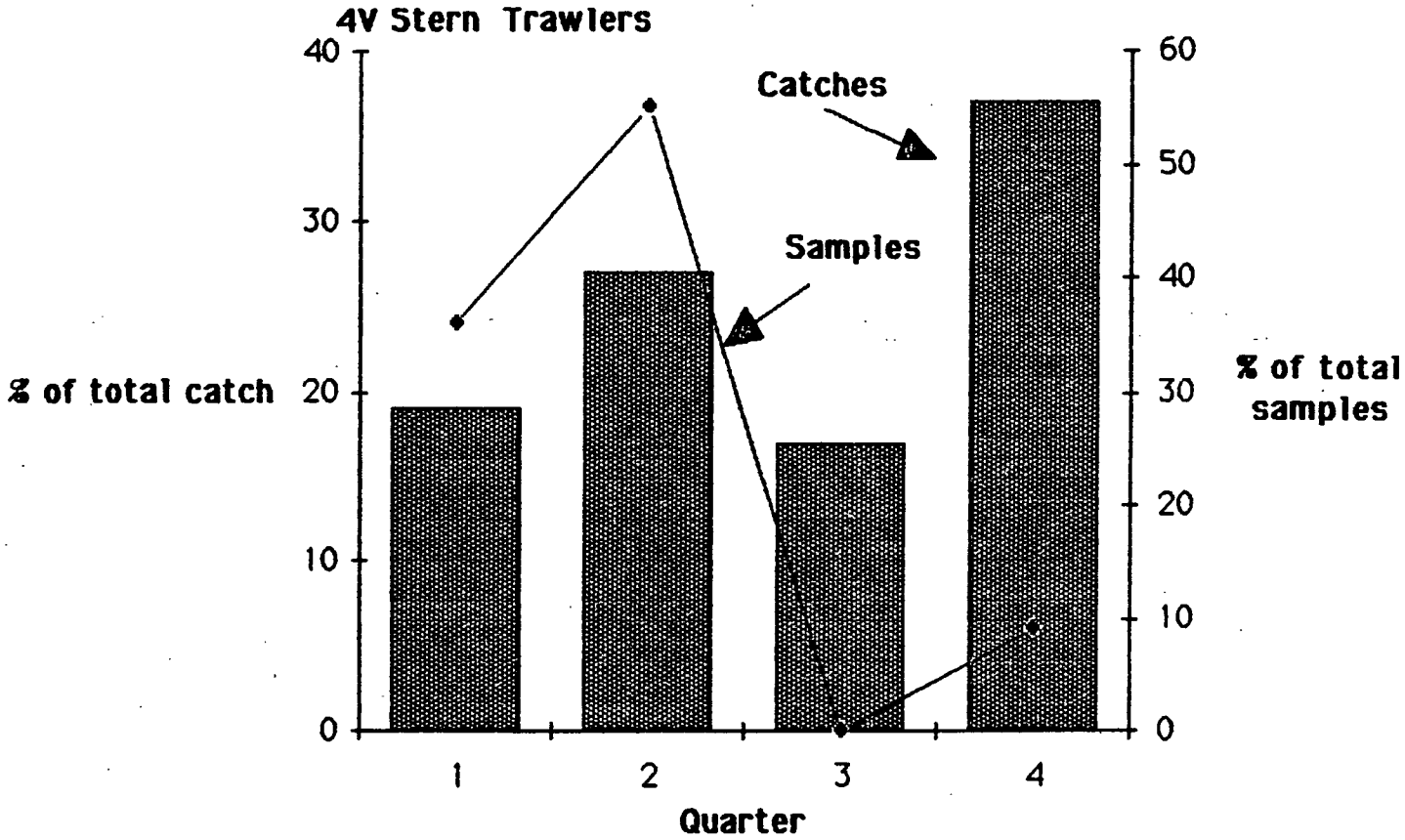


Fig. 2. Flatfish (exclusive of the halibuts) landings from 1974-1983, expressed as percentage caught as main species compared with total annual landings of American plaice, yellowtail, witch and winter flounder.



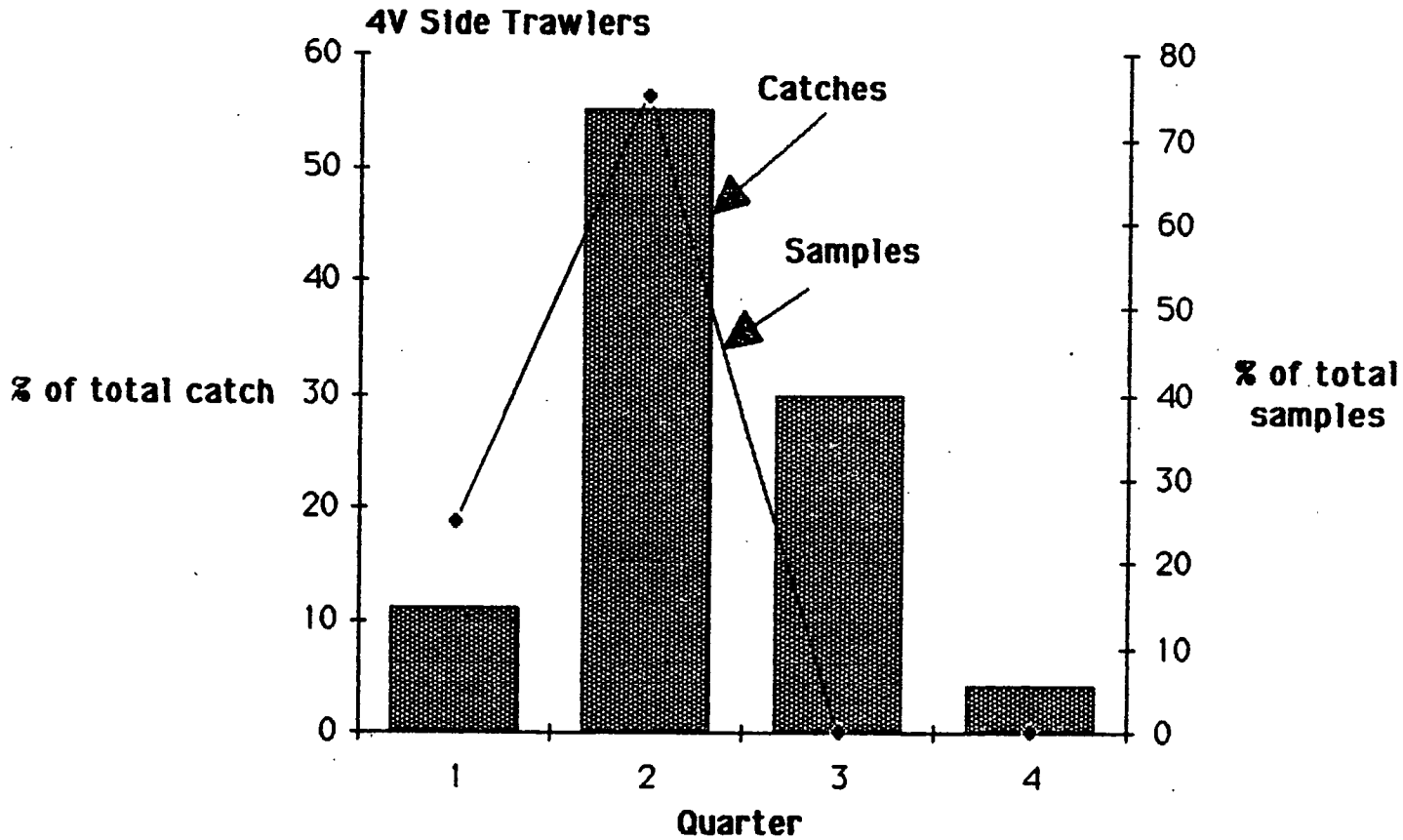


Fig. 3. 1984 catches of American plaice by stern and side trawlers in NAFO Division 4V, by quarter. To assess how well the commercial sampling program followed the seasonality of the fishery, the number of commercial samples collected by quarter are shown by each gear type.

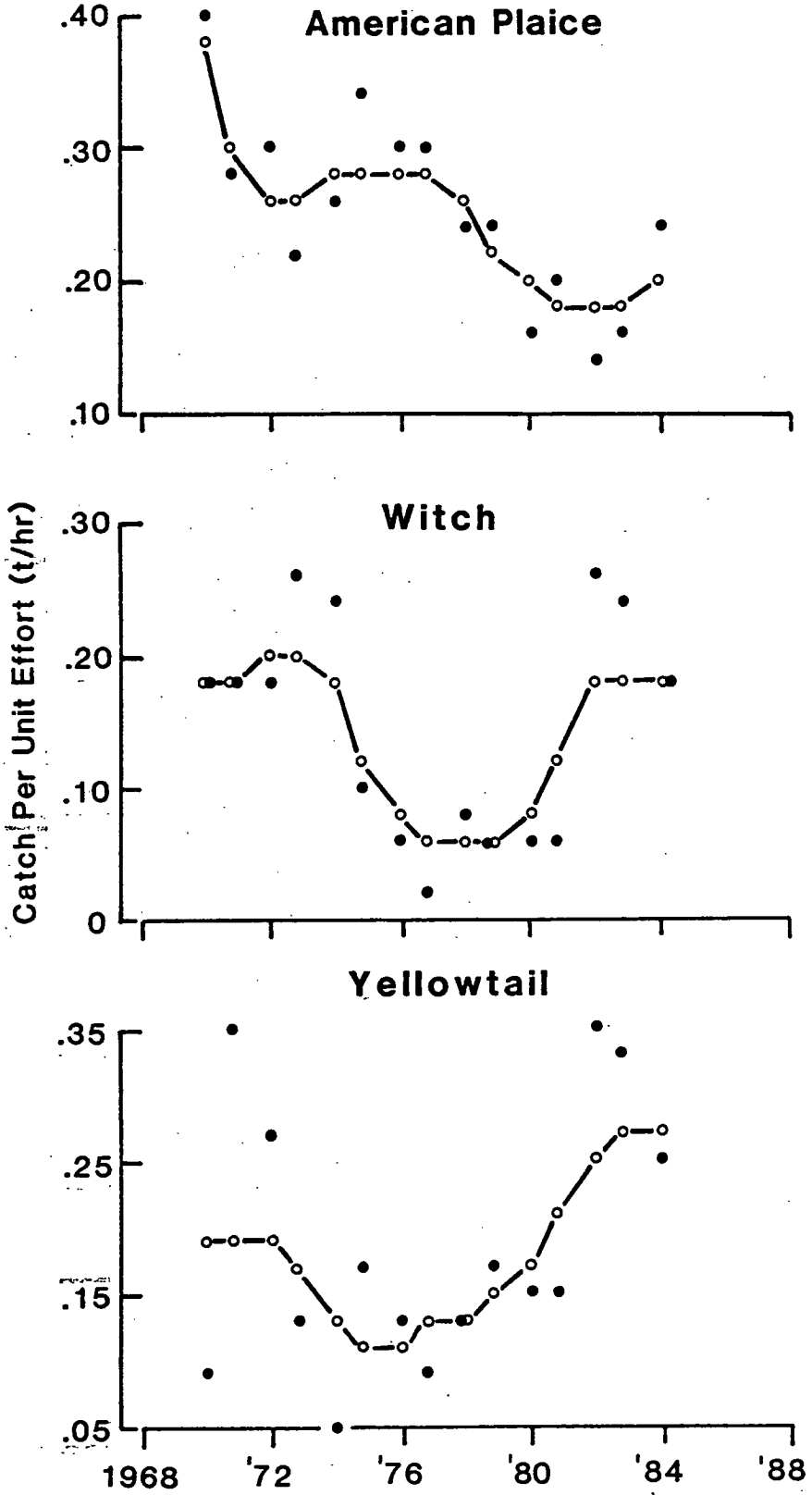


Fig. 4. Trends in catch per unit effort for 4V American plaice, 4VW witch flounder and 4VWX yellowtail flounder, 1968-1984. CPUE statistics from Canadian stern trawlers, TC4.

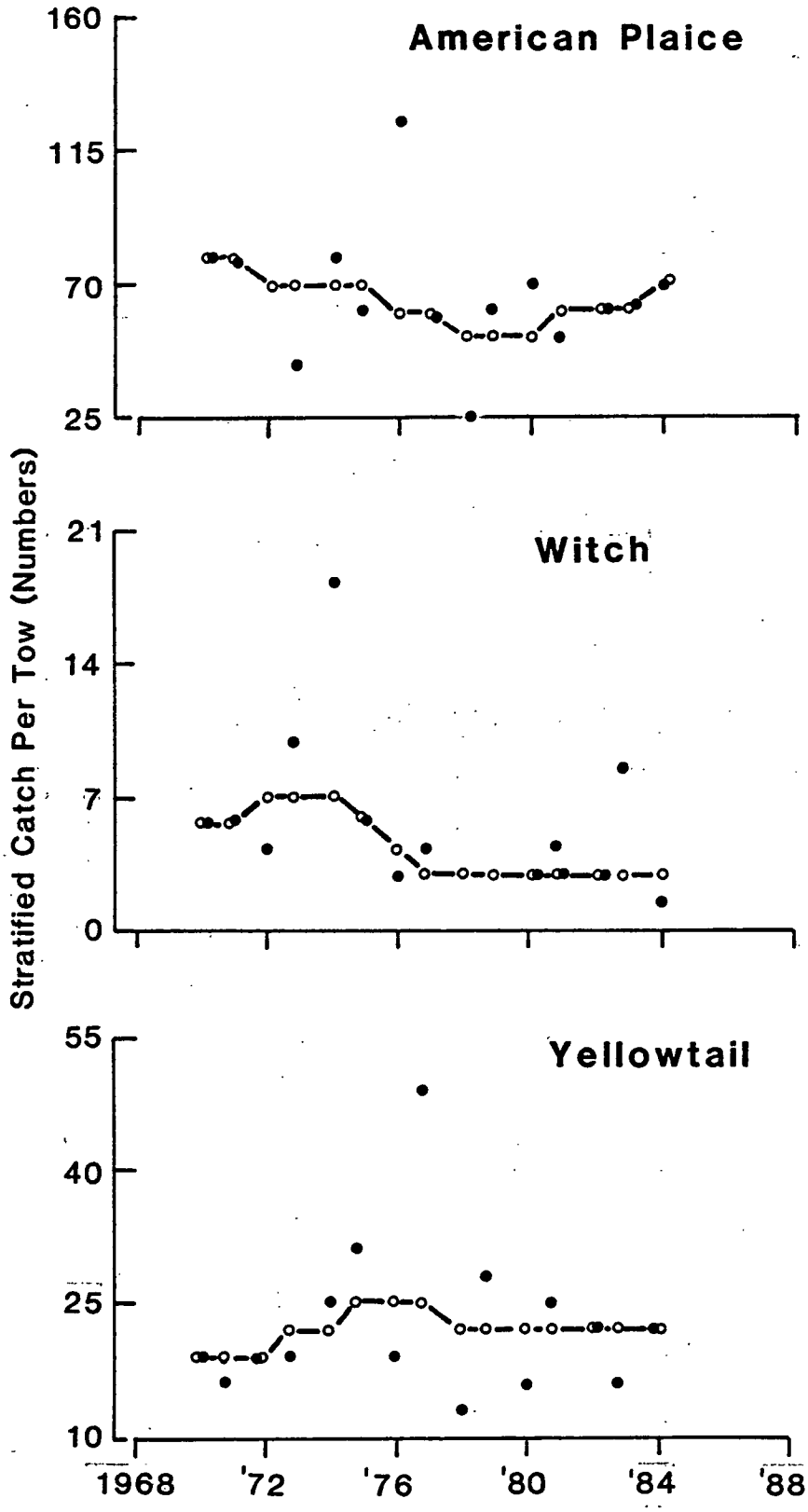


Fig. 5. Trends in stratified catch per tow (numbers caught) in summer research cruises, 1968-1984.

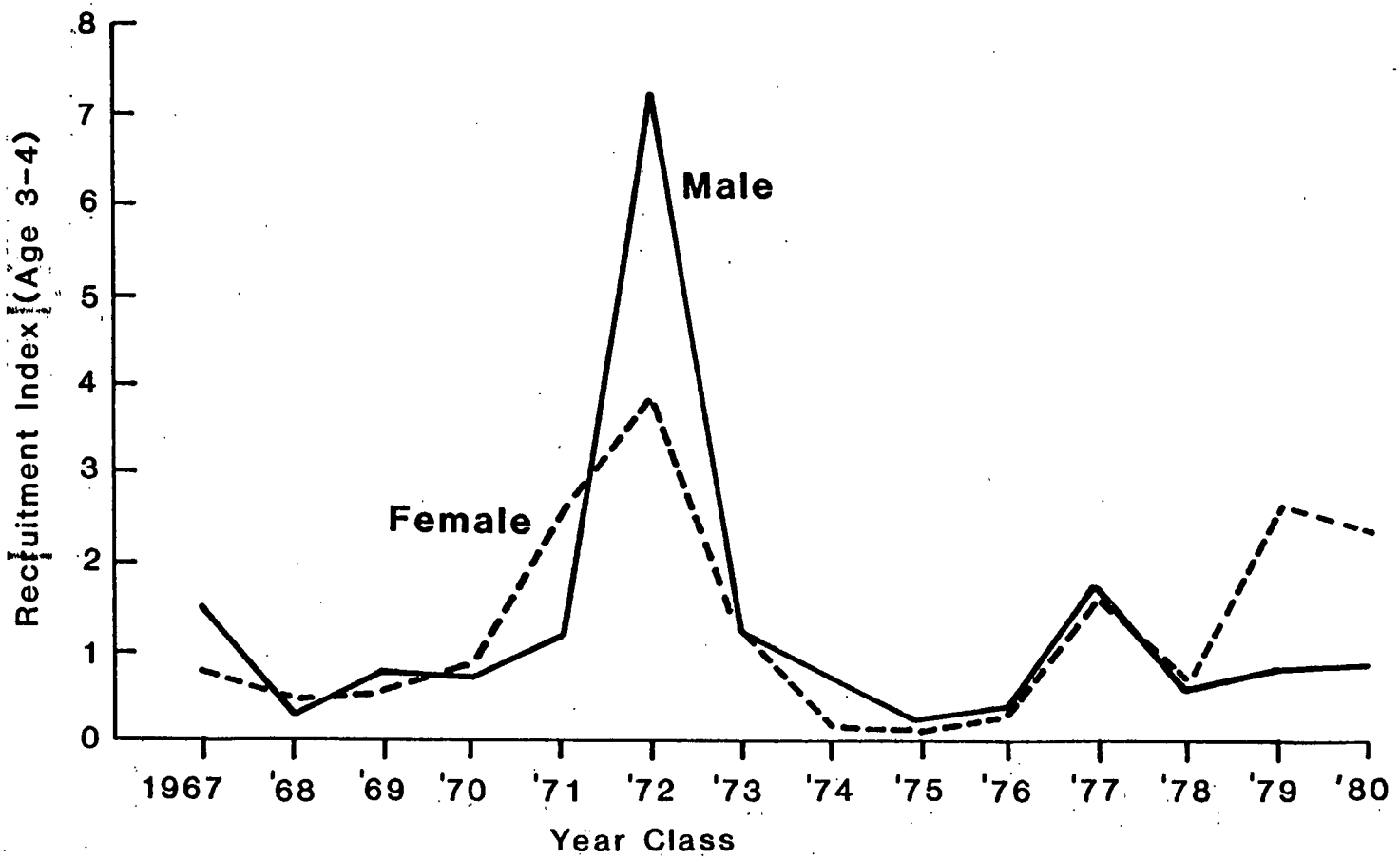


Fig. 6. Recruitment index of NAFO Division 4V American plaice, based on years 3 and 4 of the same cohort (year-classes 1967-1980).

Appendix 1

SHOT Calculations

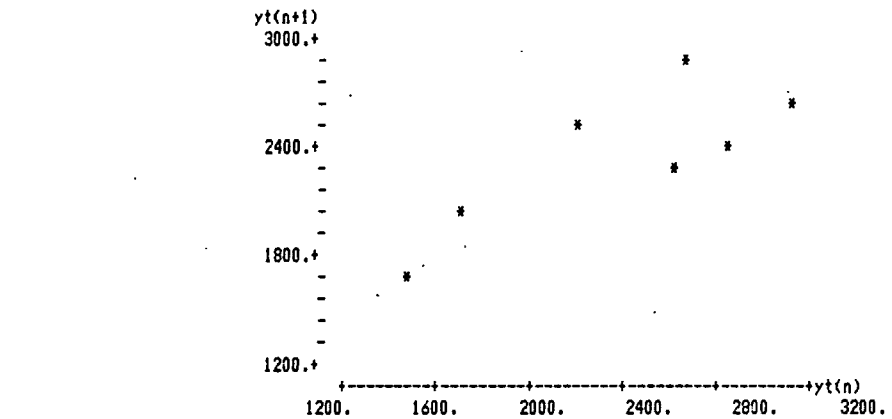
```
MTB > NOTE ***********INPUT   DATA - SHOT CALCULATIONS  4WWX YELLOWTAIL*********

MTB > PRINT C2,C8,C9

ROW    year   yt(n)   yt(n+1)

  1    1977    1443      1628
  2    1978    1628      2090
  3    1979    2090      2491
  4    1980    2491      2889
  5    1981    2889      2623
  6    1982    2623      2422
  7    1983    2422      2319
  8    1984    2319         *

MTB > PLOT C9 C8
```




```
  1 MISSING OBSERVATIONS

MTB > REGRESS Y IN C9 USING 1 PREDICTOR IN C8

THE REGRESSION EQUATION IS
yt(n+1) = 975 + 0.618 yt(n)
```

(0.618 is from equation 1 in the text:

$Y_{SQ} = 0.618\ (2319) + 0.382\ (2238) = 2288\ t$)

```
    7 CASES USED     1 CASES CONTAIN MISSING VALUES

                                ST. DEV.     T-RATIO =
COLUMN      COEFFICIENT         OF COEF.     COEF/S.D.
                 975.1            451.3          2.16
yt(n)           0.6183           0.1979          3.12

S = 257.7

R-SQUARED  = 66.1 PERCENT
R-SQUARED  = 59.3 PERCENT, ADJUSTED FOR D.F.

ANALYSIS OF VARIANCE

 DUE TO      DF          SS       MS=SS/DF
REGRESSION    1      647922         647922
RESIDUAL      5      332018          66404
TOTAL         6      979939
```

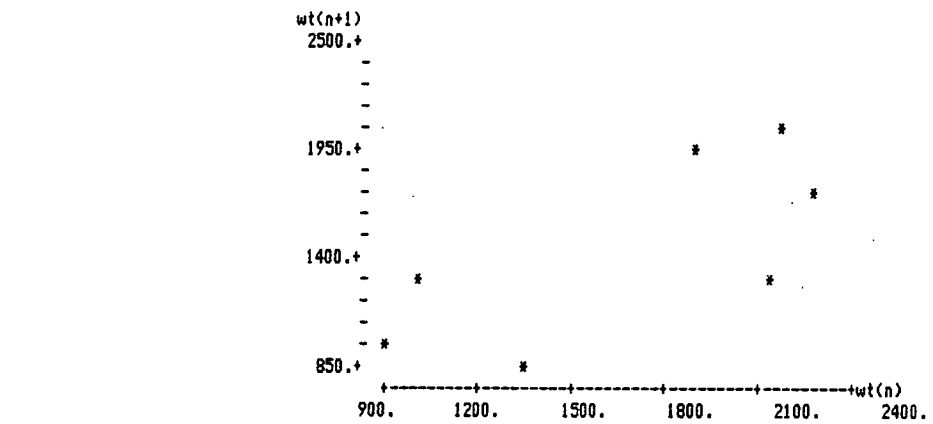
```
MTB > NOTE ********INPUT  DATA - SHOT CALCULATIONS  4VW WITCH**********

MTB > PRINT C2,C6,C7

ROW    year   wt(n)   wt(n+1)

  1    1977    2010      2103
  2    1978    2103      1781
  3    1979    1781      1990
  4    1980    1990      1279
  5    1981    1279       890
  6    1982     890      1003
  7    1983    1003      1283
  8    1984    1283         *

MTB > PLOT C7 C6
```




```
  1 MISSING OBSERVATIONS

MTB > REGRESS Y IN C7 USING 1 PREDICTOR IN C6

THE REGRESSION EQUATION IS
wt(n+1) = 401 + 0.680 wt(n)
```

(0.680 is from equation 1 in the text:

$$Y_{SQ} = 0.680\ (1283) + 0.320\ (1542) = 1366\ t)$$

```
    7 CASES USED      1 CASES CONTAIN MISSING VALUES

                                ST. DEV.     T-RATIO =
COLUMN       COEFFICIENT        OF COEF.     COEF/S.D.
                   401.0           481.6          0.83
wt(n)             0.6803          0.2921          2.33

S = 365.6

R-SQUARED  = 52.0 PERCENT
R-SQUARED  = 42.4 PERCENT, ADJUSTED FOR D.F.

ANALYSIS OF VARIANCE

 DUE TO      DF          SS       MS=SS/DF
REGRESSION    1      725091         725091
RESIDUAL      5      668441         133688
TOTAL         6     1393532
```

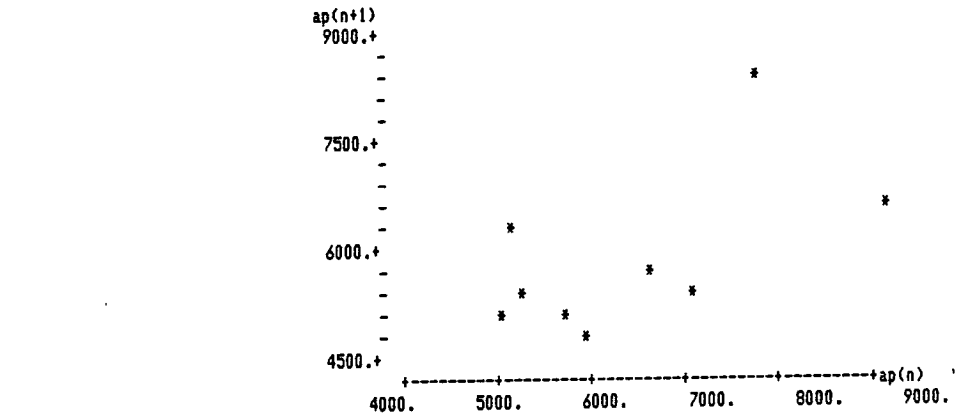
```
MTB > NOTE ***********INPUT   DATA - SHOT CALCULATIONS  4V PLAICE**************

MTB > PRINT C2,C5,C11,C12,C13

ROW    year     aprec     C11    ap(n)   ap(n+1)

  1    1977    2.5285    1975     7336      8488
  2    1978    0.8118    1976     8488      6716
  3    1979    0.3027    1977     6716      5501
  4    1980    0.7047    1978     5501      5028
  5    1981    3.2583    1979     5028      6293
  6    1982    1.1626    1980     6293      5677
  7    1983    3.3187    1981     5677      4920
  8    1984    3.1602    1982     4920      5094
  9                      1983     5094      5351
 10                      1984     5351         *

MTB > PLOT C13,C12
```




```
  1 MISSING  OBSERVATIONS

MTB > REGRESS  Y IN C13 USING 1 PREDICTOR  IN C12

THE REGRESSION  EQUATION  IS
ap(n+1)  = 2311  + 0.586  ap(n)
```

(0.586 is from equation 2 in the text:

$$Y_{SQ} = 0.586\ (5351) + 0.314\left(\frac{5573}{1.9059}\right)\ 3.1602\ = 6038\ t)$$

```
    9 CASES  USED      1 CASES  CONTAIN  MISSING  VALUES

                                 ST. DEV.     T-RATIO =
COLUMN       COEFFICIENT         OF COEF.     COEF/S.D.
                    2311             1732          1.33
ap(n)             0.5861           0.2784          2.11

S = 953.8

R-SQUARED  = 38.8  PERCENT
R-SQUARED  = 30.0  PERCENT,  ADJUSTED  FOR D.F.

ANALYSIS  OF  VARIANCE

 DUE TO      DF          SS        MS=SS/DF
REGRESSION    1     4031076         4031076
RESIDUAL      7     6367610          909659
```