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The International Fishery for Shrimp (*Pandalus borealis*) in Division 3M (Flemish Cap), 1993-1998

by

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1. INTRODUCTION

The fishery for northern shrimp at Flemish Cap began in the spring of 1993 and has since continued with estimated annual catches (unofficial) of approximately 28,000, 24,000, 33,000, 49,000 and 27,000 tons from 1993 to 1997, respectively. Removals to August 1998 of about 19,000 tons appear to be slightly higher than those reported for the same period in 1997 (17,000 tons). Vessels from as many as 15 nations have participated in this fishery since its beginning.

The following is an overview of the fishery for shrimp on Flemish Cap, describing and interpreting trends in catch and effort based on data provided by the fleets of several nations. A standardized catch per unit effort (CPUE) series also is constructed which addresses differences in catch rate due to fishing power of vessels, seasonality of the fishery and area fished.

2. BACKGROUND

STACFIS conducted annual assessments of the resource at the Annual Meetings from 1993 to 1997, inclusive, but lacked a basis for the calculation of a TAC. In 1994, Scientific Council agreed that a reduction in effort would be required to protect younger animals at lower stock size (NAFO, 1995). Although the Fisheries Commission did make several decisions on conservation and enforcement measures for the shrimp fishery in Div. 3M in 1995 (NAFO/FC Doc. 94/8), no regulations to effectively reduce the exploitation were introduced. Minimum mesh size was set at 40 mm; maximum bar spacing of sorting devices was set at 22 mm; vessels were required to immediately change fishing area (minimum of 5 n. mi.) if by-catches of all regulated groundfish species in any haul exceeded 5% by weight; and observer coverage was required for a minimum of 10% of a Contracting Party's total estimated fishing days for shrimp.

Data from the 1995 fishery indicated that the exploitation pattern was imprudent and, in order to improve the situation, it was recommended that fishing mortality on male shrimp be minimized. Scientific Council recognized that, in practice, this would mean closure of the fishery in 1996 (NAFO, 1996a). This recommendation was not followed and, instead, effort control was implemented. The details of the effort limitations, which effectively allowed for more effort (and catch) in 1996 than in any previous year, are given in NAFO/FC Doc. 95/21. Other management measures were carried over from the previous year (see above). Observer coverage was increased through a decision by Fisheries Commission to implement a Pilot Observer Project for 100% observer coverage of all vessels fishing in the Regulatory Area (NAFO, 1996b).

In 1996, Scientific Council reiterated the need for a significant reduction in fishing intensity to conserve both the male (recruitment) and female (spawning biomass) components of the stock (NAFO, 1997). The response of the Fisheries Commission was to "tighten" the effort regulations stipulated the previous year. This limited the number of fishing days for each Contracting Party in 1997 to 90% of the maximum number of fishing days observed in one year from 1993 to 1995 (NAFO/FC Doc. 96/5).

Scientific Council's advice in 1997 was essentially the same as that provided in 1996. Although effort (and catch) in 1997 was much reduced compared to 1996, the reduction was not a direct result of NAFO's effort control system (NAFO, 1998). Fisheries Commission maintained the effort control system for 1998 with some amendments (NAFO/FC Doc. 97/8).

3. COMMERCIAL FISHERY

3.1 History of the Fishery

The shrimp fishery in Div. 3M began in late April 1993. Fishing activity (monitored by Canada) increased to include about 50 vessels from several nations in early July but subsequently declined over the remainder of the year. Only 4 vessels were reported fishing shrimp at the end of December. Fishing continued into 1994 at low intensity. Activity increased over winter to 17 vessels by late February and remained near that level until late March, decreasing thereafter. From early April to mid June, the number of vessels increased from 7 to 47 and then decreased steadily to 3 at the end of the year.

This pattern of increasing activity to June-July followed by a decrease to the end of the year continued in subsequent years. Maximum vessels observed were 71 in July 1995, 91 in July 1996, 35 in June-July 1997 and 33 in June 1998.

A summary of the number of vessels by country and year is given below. The numbers represent best estimates of fleet size but might not be accurate for all nations.

Country/Year	1993	1994	1995	1996	1997	1998
CAN	13	7	7	6	4	3
E/DNK	2	2	1	-	-	-
EST	-	4	6	5	5	6
EU	-	2	2	1	1	6
FRA	-	-	-	-	1	-
FRO	11	10	9	11	8	7
GRL	12	8	5	4	2	2
ISL	5	9	21	40	14	7
LVA	-	2	3	4	2	2
LTU	-	2	4	6	5	5
NOR	21	19	26	15	2	2
POL	-	-	-	-	1	-
POR	-	-	1	-	-	-
RUS	2	4	15	17	3	-
St. Vin	-	1	-	-	-	-
N. Zea	-	-	-	1	-	-
TOTAL	**66**	**70**	**100**	**110**	**48**	**40**

3.2 **Trends in Catch**

3.2.1 **By Nation and Year**

Estimates of preliminary catches (tons) by nation and year are provided in the following table.

In 1993, Faroe Islands and Norway took 56% of the estimated total catch in tons. Canada and Greenland each caught approximately 3700 tons, Iceland about 2200 and Honduras 1265. Lesser amounts were reported for other nations.

Faroese and Norwegian vessels accounted for over 60% of the estimated catch in 1994. Estonia, Latvia and Lithuania joined the fishery that year and, combined, caught about 2600 tons. Canadian vessels caught 1041 tons, substantially less than in 1993. Greenlandic and Danish catches were also less than those of the previous year whereas Icelandic catches remained about the same.

Data for 1995 showed some changes in the distribution of the catches by nation. Most noteworthy are the substantial increases in catches by Iceland and Russia. Catches by Canada, Faroe Islands and Greenland were about the same as in 1994. One vessel from Portugal fished for shrimp in 1995 with an estimated catch of 150 tons.

Nation	**1993**	**1994**	**1995**	**1996**	**1997**	**1998***
Canada	3724	1041	970	906	807	426
EU/Denmark	800	400	200	-	-	-
Estonia	-	1081	2092	1900	3240	3129
Faroe Is.	8545	6567	5987	8677	7387	6866
Greenland	3788	2275	2400	1107	105	853
Honduras	1265	-	-	-	-	-
Iceland	2243	2300	7623	21077	6483	4072
Latvia	-	300	350	1940	997	675
Lithuania	-	1225	675	2900	1785	1707
Norway	7183	8460	9534	5595	3663	983
Poland	-	-	-	-	288	-
Portugal	300	-	150	-	170	203
Russia	-	300	2838	4444	1090	-
EU/Spain	240	300	158	50	421	243
St. Vincent's	-	75	-	-	150	-
Total	**28 088**	**24 324**	**32 977**	**48 596**	**26 586**	**19 157**

* Provisional to July 31

The 1996 data show substantial increases in catch for several nations. Icelandic catches increased from about 7600 tons in 1995 to over 21,000 tons in 1996. Catches by Faroe Islands increased from 6000 tons to 8700 tons and Russian catches from 2800 to 4400 tons. Latvia and Lithuania also increased their catches from 1995 to 1996 while catches by Canada, Greenland and Norway decreased.

Catches in 1997 of about 26,600 tons were much lower than in 1996. The reduction was due, in part, by the Icelandic quota of 6800 tons (in effect, about 14,000 tons less catch than in 1996) and possibly by a generally depressed market for northern shrimp which affected all nations. Catches to the end of July 1998 were approximately 19,000 tons.

3.2.2 By Month and Year

Following a recommendation of an *ad hoc* working group on shrimp in Div. 3M (NAFO SCS Doc. 96/19), a standardized data set was constructed which included catch and effort from Canada, Greenland, Iceland and Norway. Although these data represent only part of the total catch and effort, they are assumed to reflect temporal and spatial trends in the fishery.

Monthly catches show an increasing trend from January to June or July, followed by a decrease to the end of the year. The June-July period has accounted for more than 30% of the logged catch each year from 1993 to 1997.

CATCH (TONS)

Month/Year	1993	1994	1995	1996	1997	1998
JAN	-	485	28	363	73	-
FEB	-	975	130	355	133	65
MAR	-	679	387	1220	190	203
APR	0	501	814	3027	960	371
MAY	837	1740	2611	3647	1049	904
JUN	6129	3593	4754	4730	1235	918
JUL	4098	2645	5439	3655	1396	319
AUG	1928	1356	2265	2422	1031	
SEP	1404	593	940	1566	872	
OCT	876	317	624	973	692	
NOV	542	21	187	397	286	
DEC	281	64	162	136	146	
TOTAL	**16095**	**12969**	**18342**	**22491**	**8063**	**2780**

3.2.3 By Area and Year

The standardized data set included a reference to area fished for each nation except Norway. The bank was separated into four areas - northeast, southeast, southwest and northwest - at 47^0 10' N and 45^0W. The logbook data showed that most of the recorded catch was taken in the northwest quadrant (area 4) each year. However, changes are evident between years. Most of the catch was taken in the north (areas 1 and 4) in 1993 compared to the west (areas 3 and 4) in 1994. In 1995, the west was again the most productive area but a substantial catch was also taken in the northeast (area 1). All areas produced substantial catches in 1996, including the southeast quadrant (area 2), but the northwest (area 4) was most important. About half the logged catch was taken in the northwest in 1997 and 1998 records indicate that most of the catch in the first half of the year has been taken in the northern areas (1 and 4).

CATCH (TONS)

Area/Year	1993	1994	1995	1996	1997	1998
1	2870	294	1365	3079	1492	1113
2	190	1	61	1221	182	7
3	1605	1997	3488	4601	1501	82
4	4246	2216	3896	7992	3057	1578
TOTAL	**8911**	**4508**	**8809**	**16893**	**6232**	**2780**

3.3 **Trends in Effort**

The standardized data set also was used to describe temporal and spatial trends in fishing effort, assuming the data are representative of total fleet activities despite being incomplete. The observations are hours fished for both single and double trawls.

3.3.1 **By Month and Year**

The temporal trend in effort is similar to that for catch. Activity generally increased from January to June-July and then decreased to December. The May to August period accounted for more than 60% of the logged effort each year to 1997 and, the June-July period, more than one-third. Activities of the individual fleets are reported separately in research documents.

EFFORT (HRS)

Month/Year	1993	1994	1995	1996	1997	1998
JAN	-	1887	149	1504	414	-
FEB	-	3067	520	1061	626	156
MAR	-	3209	1661	3590	574	533
APR	4	2433	3553	12126	2736	959
MAY	1381	5939	8366	14801	4318	2042
JUN	14419	13622	14878	18446	4801	1814
JUL	12634	10669	17864	16268	4605	479
AUG	6674	6821	10156	11328	3753	-
SEP	4875	3578	5469	8122	2962	-
OCT	3640	2243	2808	5901	2262	-
NOV	2242	181	1094	2042	945	-
DEC	865	309	942	651	486	-
TOTAL	**46734**	**53958**	**67460**	**95840**	**28482**	**5983**

3.3.2 By Area and Year

The effort data were further examined based on the spatial designation described above. In 1993, fishing activity was concentrated in the north (areas 1 and 4), particularly in the northwest (area 4). More effort was deployed in the southwest (area 3) in 1994 while there was a large reduction in activity in the northeast (area 1). Effort increased in all areas in 1995 with renewed interest in the northeast. The 1996 fishing effort was extensive over the entire Cap, including the southeast sector (area 2). Effort was greatly reduced over all areas in 1997 with about half the reported activity in the northwest (area 4). The records available for 1998 indicate most fishing in northern areas (1 and 4).

EFFORT (HRS)

Area/Year	1993	1994	1995	1996	1997	1998
1	7541	1533	5210	11701	5059	2203
2	521	4	215	4583	542	21
3	3543	7411	11772	21019	5848	246
4	10473	7931	12618	32084	11108	3513
TOTAL	**22078**	**16879**	**29815**	**69387**	**22557**	**5983**

3.4 Trends in Catch Rates

The main purpose for constructing the standardized catch and effort data set was for the calculation of catch per unit of effort (CPUE). The following analyses are based on single trawl data from the logbook records of Canada, Greenland, Iceland and Norway.

3.4.1 By Month and Year

Seasonality in catch rates is evident in the data. The fishery began in spring 1993 and catch rates in May were about 600 kg/hr. CPUE declined steadily to November and recovered slightly during the December - February period. During the remainder of 1994, CPUE increased from a low of 178 kg/hr in March to about 290 in May, declining thereafter to November. In 1995, catch rates again were highest in May at 300 kg/hr, declined to August and then varied between 150 and 200 kg/hr to the end of the year. The pattern in 1996 is different in that catch rates were more stable over the year. CPUE's from September to November were lower than other months when values were about 200 kg/hr or greater. In 1997, catch rates varied during the first half of the year but stabilized at roughly 250 kg/hr from July to October. Preliminary data for 1998 indicate low catch rates in April with increases in May and June to levels observed for those months in 1994 and 1995.

The general pattern in the first three years was an increase in CPUE to May followed by a decline to November and some recovery during winter. This convention breaks down in 1996 and 1997. The pattern for 1998, with partial data, is not yet clear.

CATCH PER HOUR (KG)

Month/Year	1993	1994	1995	1996	1997	1998
JAN	-	251	189	217	175	-
FEB	-	281	250	240	213	-
MAR	-	178	233	236	341	-
APR	63	206	227	215	272	132
MAY	606	293	299	210	185	319
JUN	420	259	289	221	201	258
JUL	317	239	258	203	254	-
AUG	273	185	204	196	241	-
SEP	258	166	166	174	259	-
OCT	230	141	199	155	242	-
NOV	187	116	154	180	296	-
DEC	262	206	172	209	-	-

3.4.2 **By Area and Year**

CPUE also can be presented spatially, based on the four general areas described above. Catch rates were similar over all areas in 1993, 1995 and 1996. In 1994, catch rates in the northeast (area 1) were much lower than to the west and there was virtually no fishing in the southeast. Although effort has remained relatively low in the southeast (area 2), CPUE's from this area were substantially higher than all other areas in 1997 and to date in 1998. The catch rate in the northeast (area 1) also is considerably higher in 1998 than in the previous four years.

CATCH PER HOUR (KG)

Area/Year	1993	1994	1995	1996	1997	1998
1	371	167	233	207	252	333
2	358	-	243	210	328	427
3	386	256	237	189	221	210
4	396	238	238	204	223	236

3.4.3 By Nation and Year

Annual catch rates from single trawl effort show variation among nations. Canadian and Greenlandic CPUE's were generally higher than those of Iceland and Norway up to 1996 but the Greenlandic rate was the lowest in 1997. CPUE's from all nations declined from 1993 to 1994 and, except for Canada, increased in 1995. Declines were seen for all nations between 1995 and 1996. In 1997, Canadian, Icelandic and Norwegian rates increased while the Greenlandic CPUE continued to decline.

CATCH PER HOUR (KG)

Nation/Year	1993	1994	1995	1996	1997	1998
CAN	403	263	235	229	318	310
GRL	379	267	294	258	172	-
ICE	359	181	232	197	229	283
NOR	291	228	253	212	242	-

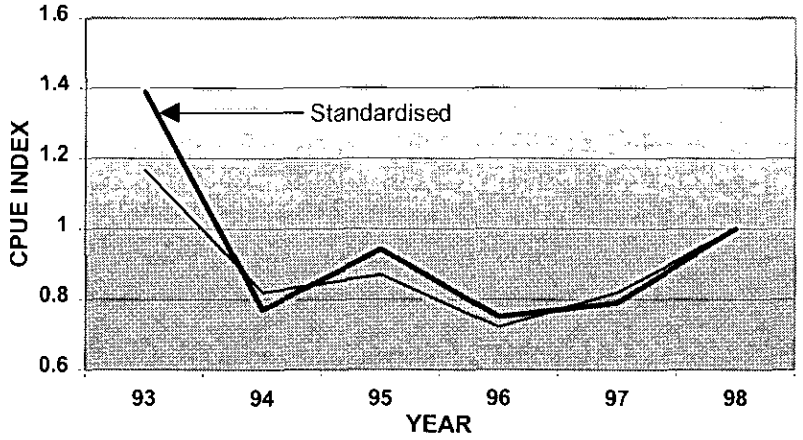
3.4.4. **Standardized CPUE**

The annual CPUE's (∑catch ÷ ∑effort) from the standardized data set (single trawls only) were 333, 232, 248, 204, 233 and 285 kg per hour for 1993 to 1998, respectively. They show a decrease between 1993 and 1994, some recovery or stability in 1995, another decrease in 1996 followed by increases in 1997 and 1998. It is noted that current year values, based on incomplete data for the first few months, overestimate the annual estimate.

Given the differences described above for the raw data, a standardized catch rate series was developed to account for effects such as seasonality, fishing power of vessels and area fished. The log (ln(catch/effort)) data (Norway omitted) were analysed for year, vessel, month and area effects using a SAS multiple regression procedure (GLM). An investigative model revealed that VESSEL was a more significant class variable than NATION and the former was included in the final formulation. No investigation of interaction terms was attempted in this analysis but significant interaction of main effects is common in such data sets.

The final model, with 5 outliers removed based on the penultimate run (IF -1.25<RESID.<1.25), used records where CATCH > 0 and EFFORT > 10. Also, the number of tows associated with each catch-effort record was used as a weighting factor. The model explained 77% of the variation and all class variables were significant ($P < 0.05$) using type III sum of squares (Table 1). Results showed that only the positive estimate for 1993 was significantly different ($P < 0.05$) from zero, the 1998 standard, whereas the negative coefficients for 1994 to 1997, inclusive, were not ($P > 0.05$). A plot of residuals is given in Figure 1.

The standardized series produced a trend similar to the unstandardized - a substantial decline between 1993 and 1994, some increase in 1995, a decrease in 1996 and further increases in 1997 and 1998. Standardization statistics suggest that there has been no significant change in CPUE since the initial decline that occurred between 1993 and 1994.



4. **SUMMARY**

Catches of shrimp on Flemish Cap have been maintained at a high level (averaging more than 30,000 tons annually since the fishery began) due to increasing effort up to 1996 and an expansion of the fishing grounds to target smaller shrimp

in shallower water (NAFO, 1998). Both the unstandardized and standardized catch rates for 1994 were much lower than the 1993 estimate. Catch rates since 1994 have varied without significant trend.

Despite standardization, the CPUE data are still difficult to interpret as an index of stock size due to the major changes in fishing pattern between years (i.e. areas/depths fished reflect targeting of the recruiting age class). Also, incomplete data for the current year overestimate the catch rate including the value predicted from the multiplicative model.

5. ACKNOWLEDGEMENT

Appreciation is expressed to all those who provided data for inclusion in this paper in advance of the 1998 Annual Meeting.

6. REFERENCES

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NAFO. 1996a. Scientific Council Reports, 1995, p. 146.

NAFO. 1996b. Meeting Proceedings of the General Council and Fisheries Commission for 1995, p. 152.

NAFO. 1997. Scientific Council Reports, 1996, p. 147.

NAFO. 1998. Scientific Council Reports, 1997, p. 182-183 and 207.

TABLE 1. MULTIPLICATIVE, YEAR-VESSEL-MONTH-AREA MODEL, 1993 - 1998

General Linear Models Procedure
Class Level Information

Class	Levels	Values
YEAR	6	93 94 95 96 97 98
VESSEL	71	1128 12 1352 1383 1407 1462 1484 1506 1514 1576 1628 1634 1742 1752 1753 1757 1768 1807 1809 1903 1905 1942 2013 2061 21 2155 2190 2197 2204 2206 2211 2212 2216 2218 2220 2237 2244 2258 2259 2262 2266 2279 2286 29 40 41 43 44 47 5 58 66 68 69 70 OUKV OUOQ OWGG OWQU OWTI OWVM OYBZ OYCK OYHO OYKK OYRT OYXT OYZL OZDH OZKQ ZZZZ
MONTH	12	1 2 3 4 5 7 8 9 10 11 12 99
AREA	4	1 2 3 4

Number of observations in data set = 906

Dependent Variable: LNCPUE
Weight: WFACTOR

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	89	2678.56354649	30.09621962	30.74	0.0001
Error	816	799.03706564	0.97921209		
Corrected Total	905	3477.60061213			

R-Square	C.V.	Root MSE	LNCPUE Mean
0.770233	18.00077	0.98955146	5.49727216

Source	DF	Type I SS	Mean Square	F Value	Pr > F
YEAR	5	1338.96563123	267.79312625	273.48	0.0001
VESSEL	70	1193.20380404	17.04576863	17.41	0.0001
MONTH	11	137.80024941	12.52729540	12.79	0.0001
AREA	3	8.59386181	2.86462060	2.93	0.0330

Source	DF	Type III SS	Mean Square	F Value	Pr > F
YEAR	5	443.54253128	88.70850626	90.59	0.0001
VESSEL	70	1041.81580558	14.88308294	15.20	0.0001
MONTH	11	143.30133868	13.02739443	13.30	0.0001
AREA	3	8.59386181	2.86462060	2.93	0.0330

Parameter		Estimate	T for H0: Parameter=0	Pr > |T|	Std Error of Estimate
INTERCEPT		5.961628940 B	37.01	0.0001	0.16110182
YEAR	93	0.328486497 B	2.09	0.0370	0.15723989
	94	-0.258514204 B	-1.65	0.0986	0.15632794
	95	-0.061575082 B	-0.39	0.6937	0.15629712
	96	-0.277466353 B	-1.78	0.0760	0.15617980
	97	-0.235728136 B	-1.54	0.1244	0.15324305
	98	0.000000000 B	.	.	.

TABLE 1 (CONT'D.). Univariate Procedure

Variable=R

Moments

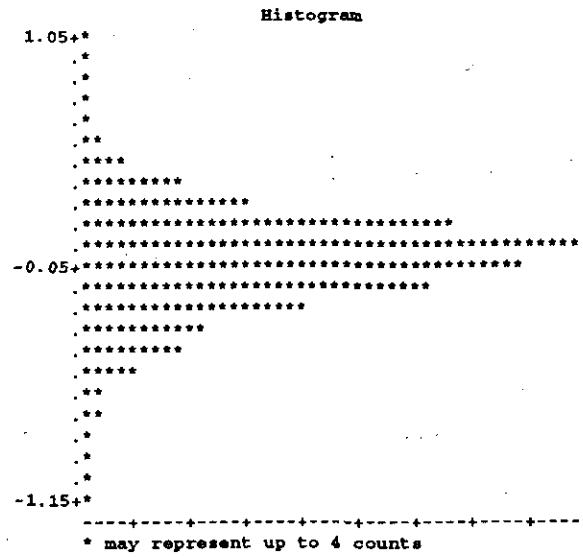
N	906	Sum Wgts	906
Mean	-0.0374	Sum	-33.8866
Std Dev	0.266829	Variance	0.071198
Skewness	-0.41228	Kurtosis	2.323558
USS	65.70124	CSS	64.43379
CV	-713.398	Std Mean	0.008865
T:Mean=0	-4.21922	Pr>|T|	0.0001
Num ^= 0	906	Num > 0	429
M(Sign)	-24	Pr>=|M|	0.1184
Sgn Rank	-26691.5	Pr>=|S|	0.0007
W:Normal	0.963934	Pr<W	0.0001

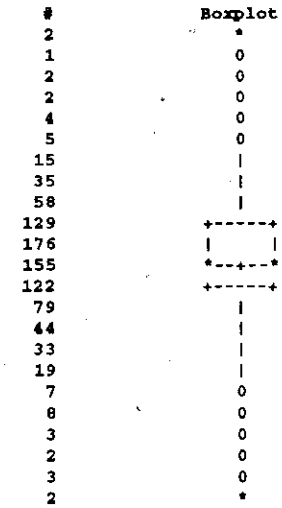
Quantiles(Def=5)

100% Max	1.029458	99%	0.608893
75% Q3	0.118861	95%	0.350193
50% Med	-0.01214	90%	0.245135
25% Q1	-0.17338	10%	-0.36664
0% Min	-1.19123	5%	-0.46461
		1%	-0.88995
Range	2.220686		
Q3-Q1	0.292241		
Mode	-1.19123		

Extremes

Lowest	Obs	Highest	Obs
-1.19123(	434)	0.826807(	288)
-1.14136(	155)	0.880798(	680)
-1.09148(	687)	0.915185(	75)
-1.06248(	724)	1.008263(	433)
-1.01653(	277)	1.029458(	685)





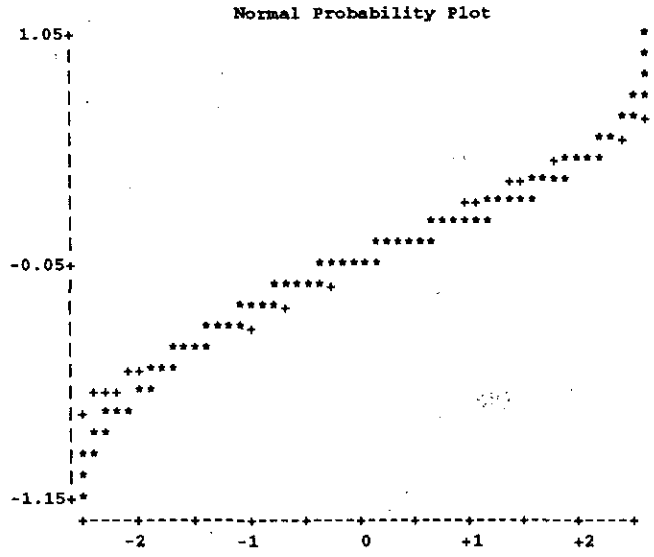


FIGURE 1. Plot of Residuals (R2*P2). Legend: A = 1 obs, B = 2 obs, etc.