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Comparisons of Soviet and United States Ichthyoplankton Sampling

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COMPARISONS OF SOVIET AND UNITED STATES ICHTHYOPLANKTON SAMPLING

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INTRODUCTION

During the 1970s and 1980s ichthyoplankton was sampled on many cruises by Soviets and Americans(United States) in the Bering Sea and Gulf of Alaska primarily to investigate the early life history of walleye pollock (Theragra chalcogramma). Some of this sampling was done independently by ships of each nation, but some was on cooperative Soviet/American cruises aboard Soviet ships using American 60 cm bongo nets. Usually the Soviets processed the sample from one side of the bongo on board and the Americans preserved the sample from the other side for processing ashore. In addition to these shared samples, the Soviets used an IKS (ИКС) net for their own studies with the samples processed on board, and the Americans used a 60 cm bongo for theirs with the samples processed ashore. On some cooperative Soviet/American cruises, comparative tows were also made with the IKS and bongo nets at certain stations. Comparing the bongo catches tests differences in American and Soviet sample processing. Comparing the bongo and IKS catches tests differences in the two types of nets and towing procedures. Such comparative tows were made at a total of 87 stations on two cruises in the Bering Sea in 1988 and 1991.

Here we compare the pollock egg and larval catches from these comparative tows. The ultimate purpose of this study is to see if regression models can be fit to the data to predict bongo catch of pollock eggs or larvae per 10 m^2 given Soviet IKS catch per 10 m^2.

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[1] The Soviet Union no longer exists, and the laboratory involved in collecting the data used in this study is now in Russia, however we use "Soviet" here because the field work for this study was done before this transition occurred.

METHODS

This study is based on comparative IKS and bongo tows for walleye pollock eggs and larvae from two cooperative Soviet/American cruises in the Bering Sea, the 1988 R/V Darvin (4/11/88-5/8/88) and the 1991 R/V Melchny Put (4/14/91-5/8/91). There were 42 comparative tows on the Darvin cruise and 45 on the Melchny Put cruise. At each comparative station, the catch of pollock eggs and larvae was determined for the bongo sample processed by the Americans ashore, the bongo sample processed by the Soviets aboard ship, and the Soviet IKS net sample which was also processed on board. Data from samples processed by the Soviets used in this study was supplied by Dr. S.S. Grigorev at Kamchatka Department of the Pacific Fisheries and Oceanography Research Institute, Petropavlovsk-Kamchatsky, Russia. The bongo nets had diameters of 60 cm and were equipped with 0.505 mm mesh nets. The IKS net was 70 cm in diameter and equipped with a 0.500 mm mesh net. The bongo net was towed obliquely to 200 m depth where there was sufficient water depth or, in shallower water, to within about 10 m of the bottom. A 45° wire angle was maintained during the bongo tows with the wire let out at 50 m/min and retrieved at 20 m/min. Although these were the desired tow specifications for cooperative Soviet/American ichthyoplankton surveys, they were not fully met during some cruises because of constraints imposed by winches aboard the Soviet ships. The IKS net was hauled vertically through the water column from a depth of 200 m, or less in shallower water (Bulatov 1982). In order to make tows comparable, all hauls were standardized by calculating the catch per 10 m^2, that is the number of eggs or larvae beneath 10 square meters of sea surface area. For bongo tows this number is derived by multiplying the actual catch of pollock eggs or larvae by a "standard haul factor" (SHF) where

$$\text{SHF} = \frac{(10)(\text{DEPTH FISHED})}{(\text{REVS OF FLOWMETER})(\text{MOUTH AREA OF NET})(\text{CALLIBRATION FACTOR})}$$

The 'revs of flowmeter' are the number of revolutions recorded by the flowmeter. The calibration factor is the length in meters of the column of water needed to effect one revolution of the flowmeter at the average speed of the haul (Kramer et al. 1972). For IKS tows catch per 10 m^2 is derived by multiplying the actual catch of pollock eggs or larvae times the mouth area of the net ($0.4^2 * \pi \approx 2$) times the depth from which it was hauled times 10.

After examining the data, it was noted that at station G078B in the Melchny Put data set the catch per 10 m^2 for eggs for the Soviet bongo and Soviet IKS was relatively large (16,442.55 and 96,460 respectively) whereas the American bongo had zero catch. This significant discrepancy suggested that perhaps the American record had been lost therefore this observation was considered suspicious and was deleted. The rest of the data appeared to follow a log-normal distribution so a natural log transformation was applied to the catches per 10 m^2 to help normalize the data and stabilize the variances. One was added to the observations so that zero counts could be log-transformed. To see if there were any differences between the three nets, an Analysis of Variance (ANOVA) table was created for both egg data and larval data by treating the experiment as a 3-factorial design where net type was the treatment (American bongo, Soviet bongo, or Soviet IKS), cruise was a factor (Darvin or Melchny Put), and station number was a randomized block nested within cruise. The interaction between net and cruise was also included in the model. Due to the significant cruise effect which resulted, an ANOVA was then created for each cruise separately to facilitate interpretation of the results. A regression model was fit to each cruise using American bongo catch as the response variable and IKS catch as the predictor variable. The software used was SYSTAT FOR WINDOWS.

RESULTS

The data for each cruise is listed in Tables 1 and 2. Figures 1-4 show the distributions of catches per 10 m^2. The resulting ANOVAs for both eggs and larvae are shown in Table 3. For the egg model, there was a significant cruise and station effect ($p \approx .000$ for both), but no significant net or net/cruise interaction effect. For the larval model, there was a significant cruise, station and cruise/net interaction effect ($p \approx .000$ for all). ANOVAs were run for each cruise with results given in Table 4 (eggs) and Table 5 (larvae) in order to further explore net effect within cruise. The Melchny Put cruise showed a significant net effect for eggs ($p \approx .001$), however the Darvin cruise did not. For the larval data, the reverse was the case; there was a significant net effect for the Darvin cruise ($p \approx .000$) but not for the Melchny Put cruise ($p \approx .056$), however the latter was borderline insignificant and may be due to zero counts for larvae at 22 out of 44 stations for all three nets. Tukey multiple comparison tests indicate that the differences in nets for the Melchny Put eggs and Darvin larvae were between the bongo and Soviet IKS nets. There were no significant differences at the 0.05 significance level between the American bongo and the Soviet bongo.

Data from the American bongo and Soviet IKS was used to further study the relationship of bongo and IKS gear. For the egg data, scatterplots of log-transformed bongo catch per 10 m^2 versus IKS log-transformed catch per 10 m^2 indicated a linear relationship. However, the larval data did not due to many zero counts and no linear pattern in the plots (see Figures 5 and 6). Therefore a regression model was fit to the log-transformed egg data for each cruise but not to the larval data. The stations where zero counts were observed did not fall in line with the rest of the data (see Figure 7), and since measuring relative sampling efficiency depends on the presence of sufficient density of eggs in the water column, these observations were removed and analyzed separately. The scatterplots of the nonzero log-transformed egg data for both Darvin and Melchny Put with their respective fitted lines are shown in Figures 8 and 9. Even though the previous ANOVAs showed a significant cruise effect indicating the need for separate models for each cruise, there was a practical need for just one model to predict bongo catches from IKS catches for cruises other than the Darvin and Melchny Put. There appeared to be no reason to choose one model over the other so the data was pooled to get an "average" fitted model for eggs. The final regression model for predicting bongo catch per 10 m^2 for eggs given nonzero Soviet IKS catch per 10 m^2 is given by

$$Y = 1.606\, X^{.935} .$$

Although exponential, this model is intrinsically linear since it can be transformed to a straight line through the logarithmic transformation

$$LN\, Y = .474 + .935(LN\, X) .$$

A plot of the log-transformed data and the fitted line is shown in Figure 10. It may be noted here that in the log-transformed model, the constant is not significantly different from zero and the slope is not significantly different from one. In fact, if the constant is dropped from the model, the slope is even closer to one, indicating that an even simpler model could be justified, that is LN Y = LN X. However, it was decided that the best fit to the data is the model given above.

A separate analysis of egg data was performed on those observations having zero count in either the bongo or IKS net. It was assumed that for those observations where there were zero counts for both IKS and bongo nets, there simply were no eggs in the water column. Therefore, it was of interest to only look at proportions of zeros at stations having zero count in only one gear. For the Darvin cruise, 8 out of 10 stations having zero count in only one of the gear had zero for the IKS and a positive count for the bongo, whereas only 2 out of 10 stations had zero count for the bongo and positive count for the IKS. For the Melchny Put cruise, 12 out of 13 stations had zero count for the IKS and positive count for the bongo leaving 1 out of 13 stations that had the reverse. A chi-square test of independence was applied to Darvin and Melchny Put frequencies of observations where there were zero counts for bongo/positive counts for IKS, and vice versa. The test showed that the zero/positive relationships were not dependent on cruise, therefore the data was pooled and a McNemar test of correlated proportions (Sokal and Rohlf 1981) was applied to the pooled proportions to see if there was a significant change in zero/positive relationships due to gear. The pooled proportions were 20 out of 23 stations having zero count in the IKS, positive count in the bongo, and 3 out of 23 stations having zero count in the bongo, positive count in the IKS. The McNemar test showed a significant difference in proportions due to gear at a 0.01 significance level. Assuming this indicates a difference in catch efficiency between the two gear when there are relatively small numbers in the water column (less than 75 catch per 10 m^2), these results suggest that the bongo net is more effective than the IKS at catching eggs making the IKS a poor predictor of bongo catches of eggs per m^2 when numbers are small.

DISCUSSION

An analysis of this same data with similar objectives has been pursued by the Russian scientist, Sergey Grigorev (personal communication, February 1993). He used t-tests instead of randomized block ANOVAs to compare American and Soviet bongo catch per 10 m^2. His results showed no significant difference between all three nets compared two at a time for both larvae and egg data at a 0.05 significance level, which is in agreement with our study. However, a t-test of Soviet bongo versus Soviet IKS catch per 10 m^2 (using the American standard haul factor) also showed no significant difference for both larvae and eggs which is in contrast to the results of our study (see below). Grigorev notes that the data deviates from normality. Our study attempted to correct for this as well as stabilize the variances, a necessary assumption for valid ANOVAs and t-tests, by log-transforming the data. This transformation may explain the difference in the two results. Also, it is not clear whether he treated the data as two dependent samples (paired t-test) or two independent samples. A paired t-test would be equivalent to using station as a randomized block as was done in the ANOVAs above, but if the t-test was run as if samples were independent, then the variance explained by differing stations would not have been accounted for. This unexplained variance would have been added to the mean squared error thus reducing the power of the test and therefore explaining the lack of significance.

Grigorev concludes from his analysis that it is impossible to justify any reliable dependence between IKS and bongo catches, which again is in contrast to our results in that a reasonable regression model for eggs, although not for larvae, was fit for each cruise as well as for pooled data, using nonzero log-transformed American bongo catch per 10 m^2 verses nonzero log-transformed Soviet IKS catch per 10 m^2.

Our study indicates that Soviet and American bongo sample processing resulted in no significant differences in catches of pollock eggs and larvae. However gear comparisons between the bongo and the IKS are not as simple to interpret since the results of the two cruises were not consistent. A significant difference between gear was found for eggs in the Melchny Put cruise and for larvae in the Darvin cruise. It is not clear why there was a significant difference between nets for eggs in the Melchny Put cruise and not the Darvin cruise. The analysis on zero/positive egg count relationships indicates that there were significantly more stations where the IKS net had zero count while the American bongo net had positive count. This was especially true for the Melchny Put cruise where this occurred at 12 stations. In fact, if these 12 stations were removed from the data, there would no longer be a significant difference between gear, suggesting that the difference may be attributable to the inefficiency of the IKS net when there are relatively small numbers of eggs in the water column. The relative proportions of zero counts may also explain the inconsistent results for the larval data. It is likely that the reason why no difference was found between gear for larvae in the Melchny Put cruise is that at 31 out of 44 stations there were zero counts for both the bongo and the IKS nets. Therefore the Darvin cruise, which showed a significant difference between nets for larvae, may be a better representation of gear comparison since there were more larvae.

The regression equation given in this study further supports the hypothesis that there is no important difference between bongo and IKS gear with respect to eggs in that the exponent is near one. The fact that the exponent is slightly less than one however results in a mathematical relationship where the American bongo catches more eggs than the IKS for smaller numbers, but the IKS catches more eggs for larger numbers. For example, if the IKS yields 100 eggs per 10 m^2, then the predictive model predicts 120 eggs per 10 m^2 for the bongo. However, if the IKS yields 10,000 eggs per 10 m^2, then the model predicts 8800 eggs per 10 m^2 for the bongo. The reasons that the bongo caught more eggs at the low end may involve lower efficiency of the IKS when there are fewer eggs in the water column as was suggested by the zero/positive analysis mentioned above. The reasons why the IKS may catch more eggs at the higher end may involve the towing procedures which may result in more water being filtered than is thought due to the angle of the tow, which is assumed to be vertical. Further analysis would require more in depth study of towing procedures.

Larval catches were too low to make meaningful comparisons between nets. The cruises used in this study were conducted early in the season, when eggs were abundant, but few larvae had hatched. This is the major reason why the catches of larvae were so low. With similar comparative tows taken later in the year, larval catches should be greater, and more valid comparisons of catch rates could be made. The length distributions of larvae from the American bongo catches indicated that the larvae were recently hatched. Pollock larvae from the Bering Sea hatch at 3.5-4.4 mm (Yusa 1954). For the Darvin cruise, about 92.1% of the larvae were between 3 and 7 mm in length, while the Melchny Put cruise had 97.7% between 3 and 6 mm(see Figures 11 and 12). It has been found that the bongo is efficient at catching larvae between 4 and 10 mm in length (Shima and Bailey 1994), however the range of larval fish sizes effectively caught by the IKS is not known.

The depth distribution of pollock eggs in the Bering Sea is not completely understood. It seems that most eggs and larvae are found within 200 m of the surface, in fact the development of eggs and larvae occurs mainly in the upper 100 m. Some eggs have been found as deep as 1000 m, however, those found at depths greater than 500 m were generally deformed and possibly dead (Serobaba 1974). Although both the IKS and bongo nets sampled similar depth ranges, from the surface to 200 m, had the tows been deeper, a better indication of total egg abundance might have been realized.

LITERATURE CITED

Bulatov, O.A. 1982. Comparative analysis of vertical and surface tows of ichthyoplankton with the IKS-80 net. Biol. Morya. 6:46-49 [In Russ., Engl. abstr.].

Kramer, David, Mary J. Kalin, Elizabeth G. Stevens, James R. Thrailkill, and James R. Zweifel. 1972. Collecting and processing data on fish eggs and larvae in the California current region. NOAA Technical Report NMFS CIRC-370.

Serobaba, I.I. 1974. Spawning Ecology of the Walleye Pollock (Theragra chalcogramma) in the Bering Sea. J. of Ichthyol. 14:544-552.

Shima, Michiyo, and Kevin M. Bailey. 1993. Comparative analysis of ichthyoplankton sampling gear for early stages of walleye pollock (Theragra chalcogramma). Fish. Ocean. 3: 50-59.

Sokal, Robert R., and F. James Rohlf. 1981. Biometry, 2nd Edition. New York, NY: W.H. Freeman and Company, 859 p.

Yusa, T. 1954. On the normal development of the fish, Theragra chalcogramma (Pallas), Alaska pollock. (In Japanese with English summary.) Bull. Hokkaido Reg. Fish. Lab. 10:1-15, Plates I-VII.

LIST OF FIGURES

1988 R/V DARVIN

AMERICAN STATION NUMBER	SOVIET STATION NUMBER	GMT DATE	BOTTOM DEPTH	SAMPLE DEPTH	LATITUDE		LONGITUDE		AMERICAN BONGO SHF-A	AMERICAN BONGO RAW NO. EGGS	AMERICAN BONGO RAW NO. LARVAE	AMERICAN BONGO #/10m2 EGGS	AMERICAN BONGO #/10m2 LARVAE	SOVIET BONGO SHF-A	SOVIET BONGO RAW NO. EGGS	SOVIET BONGO RAW NO. LARVAE	SOVIET BONGO #/10m2 EGGS	SOVIET BONGO #/10m2 LARVAE	IKS RAW NO EGGS	IKS RAW NO LARVAE	IKS #/10m2 EGGS	IKS #/10m2 LARVAE
G158A	1	4/11/88	215	197	54	45.2	165	30	5.409	13	185	70.32	1000.66	7.171	18	102	129.0842	731.4769	0	0	0	0
G159A	2	4/11/88	65	55	54	45.0	164	55	5.190	493	77	2558.81	399.65	5.395	500	78	2697.545	420.817	37	5	740	100
G160A	3	4/11/88	89	83	55	2.5	164	50	6.575	246	9	1617.48	59.18	6.864	176	5	1208.061	34.31992	35	1	700	20
G161A	4	4/12/88	90	76	55	22.0	164	6	5.588	311	31	1737.79	173.22	5.963	270	34	1609.884	202.7261	87	0	1740	0
G162A	5	4/12/88	40	31	55	15.3	163	20	5.475	14	288	76.65	1576.82	5.865	13	325	76.23903	1905.976	8	31	160	620
G163A	6	4/12/88	80	71	55	40.0	163	30	9.034	4471	1042	40391.94	9413.64	9.607	4441	174	42665.99	1671.669	1553	579	31060	11580
G164A	7	4/12/88	44	38	55	35.0	163	0	10.286	399	1473	4103.96	15150.70	11.643	381	1443	4435.88	16800.46	160	103	3200	2060
G165A	8	4/12/88	50	41	55	49.5	162	25	8.365	2836	1215	23723.55	10163.65	8.943	4446	1689	39761.94	15105.25	686	299	13720	5980
G166A	9	4/12/88	76	71	56	2.5	162	48	7.873	5785	1588	45543.18	12501.74	7.866	6119	2041	48133.69	16055.05	1671	154	33420	3080
G167A	10	4/13/88	81	70	56	22.0	162	0	7.601	236	11	1793.95	83.62	7.621	253	6	1928.163	45.72719	95	0	1900	0
G168A	11	4/13/88	51	43	56	17.5	161	18	7.491	1700	125	12734.38	936.35	7.672	1830	150	14039.35	1150.766	1312	6	26240	120
G169A	12	4/15/88	90	74	56	3.0	164	3	4.045	13954	3350	56443.93	13550.75	3.928	13637	3432	53563.83	13480.32	4932	35	98640	700
G170A	13	4/15/88	93	77	55	40.0	164	48	6.539	1876	27	12266.52	176.54	7.090	2080	18	14747.83	127.6254	724	7	14480	140
G171A	14	4/16/88	112	98	55	25.2	165	27	6.925	36	37	249.31	256.23	7.463	76	39	567.2223	291.0746	73	19	1460	380
G172A	15	4/16/88	135	113	55	6.0	166	7	10.327	27	5	278.83	51.64	10.237	14	15	143.318	153.555	21	10	420	200
G173A	16	4/16/88	320	290	54	47.2	166	55	5.913	9	49	53.22	289.73	6.576	1	77	6.575651	506.3251	1	36	20	720
G174A	17	4/16/88	580	292	54	25.5	166	10	5.544	3	59	16.63	327.08	5.989	0	43	0	257.5446	1	4	20	80
G175A	18	4/17/88	500	298	54	30.0	167	21	8.924	0	84	0.00	749.58	9.632	1	83	9.632032	799.4586	0	1	0	20
G176A	19	4/17/88	2190	279	54	9.0	168	7	8.490	1	88	8.49	747.15	9.150	0	103	0	942.4124	0	0	0	0
G177A	20	4/17/88	2580	292	54	53.0	169	23	7.233	7	70	50.63	506.33	7.671	0	52	0	398.9115	0	6	0	120
G178A	21	4/18/88	165	143	55	27.2	168	4	7.133	8	7	57.06	49.93	5.872	6	4	35.23336	23.4889	5	0	100	0
G179A	22	4/18/88	163	148	55	8.0	167	28	8.811	0	1	0.00	8.81	8.826	0	5	0	44.13177	1	0	20	0
G180A	23	4/18/88	131	120	55	29.7	166	44	6.140	2	0	12.28	0.00	6.398	0	1	0	6.398488	0	0	0	0
G181A	24	4/19/88	120	106	55	48.0	166	4	7.222	5	0	36.11	0.00	7.581	0	0	0	0	1	0	20	0
G182A	25	4/19/88	90	74	56	8.0	165	20	7.217	4410	60	31825.49	433.00	7.424	2784	44	20669.53	326.6735	1485	9	29700	180
G183A	26	4/19/88	80	71	56	27.0	164	40	6.205	752	2	4665.82	12.41	6.644	3171	35	21066.99	232.5275	256	11	5120	220
G184A	27	4/21/88	85	72	56	27.8	165	58	7.949	2989	28	23758.82	222.57	8.649	3215	19	27806.23	164.3292	775	0	15500	0
G185A	28	4/21/88	117	105	56	9.1	166	40	7.874	233	6	1834.74	47.25	8.102	306	5	2479.139	40.5088	100	1	2000	20
G186A	29	4/21/88	130	123	55	50.6	167	20	8.771	0	0	0.00	0.00	9.464	2	0	18.92764	0	0	0	0	0
G187A	30	4/22/88	490	297	55	5.5	167	49	8.913	1	26	8.91	231.74	9.557	7	16	66.899	152.912	0	7	0	140
G188A	31	4/22/88	1500	247	55	15.0	168	18	7.501	5	64	37.51	480.06	8.041	4	63	32.164	506.583	0	1	0	20
G189A	32	4/23/88	152	142	55	53.3	168	43	8.729	1	2	8.729	17.46	8.947	0	6	0	53.68451	1	1	20	20
G190A	33	4/23/88	140	122	56	15.0	168	0	8.834	0	4	0.00	35.34	8.573	3	1	25.72007	8.573356	2	0	40	0
G191A	34	4/23/88	100	88	56	35.5	167	17	6.488	5415	66	35132.52	428.25	6.629	5136	49	34046.58	324.8214	3246	0	64920	0
G192A	35	4/24/88	80	66	56	55.0	167	53	7.132	3955	90	28208.68	641.92	7.414	3885	105	28803.96	778.4854	800	0	16000	0
G193A	36	4/25/88	108	95	56	35.3	168	35	9.645	773	85	7455.41	819.81	10.206	737	100	7521.654	1020.577	255	0	5100	0
G194A	37	4/25/88	195	182	56	16.0	169	16	7.831	92	61	720.49	477.71	8.169	94	29	767.8958	236.904	8	2	160	40
G195A	38	4/25/88	198	183	56	0.0	169	54	8.594	4	2	34.37	17.19	9.307	3	6	27.92002	55.84004	11	0	220	0
G196A	39	4/25/88	2300	297	55	37.8	170	35	9.128	2	5	18.26	45.64	9.975	4	2	39.89854	19.94927	0	1	0	20
G197A	40	4/25/88	3196	302	55	17.0	171	23	12.059	1	3	12.06	36.18	12.683	3	0	38.04829	0	0	1	0	20
G198A	41	4/26/88	2300	303	56	0.0	171	18	9.284	8	3	74.27	27.85	10.044	2	2	20.08897	20.08897	1	3	20	60
G199A	42	4/26/88	120	105	56	18.0	170	40	7.116	58	17	412.72	120.97	7.561	40	4	302.4596	30.24596	23	0	460	0
											Mean	8048.424	1720.675				8797.466	1788.766			8745.714	634.7619
											Std Dev.	14623.4	3967.244				15208.23	4495.123			19352.42	2026.739

Table 1. Data associated with comparative American and Soviet bongo and Soviet IKS tows for pollock eggs and larvae from the 1988 Darvin cruise in the Bering Sea.

1991 MELCHNY PUT

AMERICAN STATION NUMBER	SOVIET STATION NUMBER	GMT DATE	BOTTOM DEPTH	SAMPLE DEPTH	LATITUDE		LONGITUDE		AMERICAN BONGO SHF-A	AMERICAN BONGO RAW NO. EGGS	AMERICAN BONGO RAW NO. LARVAE	AMERICAN BONGO #/10m2 EGGS	AMERICAN BONGO #/10m2 LARVAE	SOVIET BONGO SHF-A	SOVIET BONGO RAW NO. EGGS	SOVIET BONGO RAW CO LARVAE	SOVIET BONGO #/10m2 EGGS	SOVIET BONGO #/10m2 LARVAE	IKS RAW NO. EGGS	IKS RAW NO. LARVAE	IKS #/10m2 EGGS	IKS #/10m2 LARVAE
G029A	8	4/17/91	112	102	55	22	165	27	7.827	8	4	62.62	31.31	7.807	6	0	46.84	0.00	5	1	100	20
G033A	10	4/17/91	373	245	54	39	166	48	8.637	0	1	0.00	8.64	8.634	0	2	0.00	17.27	0	0	0	0
G034A	11	4/17/91	655	197	54	26	167	23	6.667	1	36	6.67	240.01	6.675	2	13	13.35	86.77	0	6	0	120
G037A	13	4/17/91	1400	180	54	30	168	46	3.330	0	0	0.00	0.00	3.705	0	2	0.00	7.41	1	0	20	0
G039A	15	4/19/91	157	156	55	8	167	22	4.138	1	5	4.14	20.69	4.737	1	6	4.74	28.42	1	0	20	0
G042A	17	4/19/91	93	85	56	6	165	17	6.136	417	0	2558.84	0.00	6.235	354	0	2207.33	0.00	70	0	1400	0
G053A	20	4/21/91	133	124	55	51	167	18	8.021	9	0	72.18	0.00	8.183	5	0	40.92	0.00	0	0	0	0
G054A	21	4/21/91	138	120	55	31	168	0	6.625	7	16	46.38	106.00	6.748	4	0	26.99	0.00	0	1	0	20
G055A	22	4/22/91	2200	181	55	12	168	41	3.023	1	6	3.02	18.14	3.976	3	1	11.93	3.98	0	0	0	0
G057A	23	4/21/91	153	145	55	55	168	40	7.774	4	0	31.10	0.00	5.398	5	0	26.99	0.00	0	0	0	0
G058A	24	4/22/91	135	111	56	15	168	0	7.188	2	0	14.38	0.00	6.330	1	0	6.33	0.00	1	0	20	0
G059A	25	4/22/91	103	79	56	33	167	18	6.260	824	0	5158.12	0.00	6.310	610	0	3849.08	0.00	250	0	5000	0
G066A	26	4/23/91	80	68	56	55	167	53	7.031	1338	0	9407.42	0.00	7.154	1316	0	9414.11	0.00	577	0	11540	0
G068A	27	4/24/91	277	181	56	14	169	17	6.567	40	24	262.69	157.61	6.718	11	1	73.90	6.72	3	0	60	0
G069A	28	4/23/91	350	193	55	57	169	59	10.857	0	0	0.00	0.00	8.000	4	1	32.00	8.00	0	1	0	20
G070A	29	4/24/91	2068	212	55	18	170	0	7.552	0	1	0.00	7.55	7.735	0	0	0.00	0.00	0	3	0	60
G071A	30	4/24/91	2625	208	55	37	170	38	7.318	1	1	7.32	7.32	7.537	2	0	15.07	0.00	0	0	0	0
G072A	31	4/24/91	2000	197	55	58	171	18	6.506	3	26	19.52	169.15	7.636	8	0	61.09	0.00	0	0	0	0
G073A	32	4/24/91	118	90	56	18	170	34	7.031	6	4	42.18	28.12	7.246	0	2	0.00	14.49	0	0	0	0
G075A	33	4/24/91	87	77	56	48	170	9	7.102	4410	0	31317.71	0.00	7.256	4326	0	31391.15	0.00	2088	0	41760	0
G076A	34	4/24/91	72	65	56	57	169	15	6.866	35750	2	2.45E+05	13.73	4.810	18368	0	88356.07	0.00	59563	0	1191260	0
G078B	35	4/26/91	71	57	57	16	168	33	6.774	0	0	0.00	0.00	6.985	2354	0	16442.55	0.00	4823	0	96460	0
G092A	36	4/26/91	100	90	56	54	170	44	7.366	992	0	7306.71	0.00	8.823	868	0	7658.02	0.00	368	0	7360	0
G093A	37	4/25/91	1118	94	56	38	171	19	7.108	11	0	78.19	0.00	6.778	21	0	142.34	0.00	4	0	80	0
G094A	38	4/27/91	2000	212	56	21	171	53	6.004	0	0	0.00	0.00	6.351	1	5	6.35	31.75	0	0	0	0
G096A	40	4/27/91	2650	189	56	22	173	11	4.700	1	0	4.70	0.00	5.072	0	0	0.00	0.00	0	0	0	0
G097A	41	4/27/91	133	115	56	42	172	30	4.945	30	0	148.36	0.00	4.973	37	0	184.00	0.00	11	0	220	0
G098A	42	4/27/91	110	97	57	0	171	50	7.914	70	0	553.99	0.00	7.686	89	0	684.08	0.00	16	0	320	0
G105A	44	4/29/91	140	113	57	27	173	52	6.629	31	0	205.50	0.00	6.663	15	0	99.94	0.00	1	0	20	0
G110A	45	4/29/91	1500	200	58	11	175	12	6.888	0	0	0.00	0.00	6.896	1	0	6.90	0.00	0	0	0	0
G112A	46	5/1/91	2650	212	57	52	175	55	7.046	0	0	0.00	0.00	7.407	0	0	0.00	0.00	0	0	0	0
G121A	47	5/3/91	3150	189	57	35	176	30	4.867	0	0	0.00	0.00	4.964	0	0	0.00	0.00	0	0	0	0
G123A	48	5/4/91	3451	185	56	50	175	10	6.160	0	0	0.00	0.00	6.290	0	1	0.00	6.29	0	0	0	0
G125A	49	5/4/91	3328	185	56	5	173	10	6.029	0	0	0.00	0.00	6.184	0	0	0.00	0.00	0	0	0	0
G126A	50	5/4/91	3383	197	55	45	173	10	6.252	0	0	0.00	0.00	6.317	0	0	0.00	0.00	0	0	0	0
G127A	51	5/5/91	3480	193	55	25	172	23	6.374	7	0	44.62	0.00	6.385	11	1	70.23	6.38	0	0	0	0
G128A	52	5/5/91	3217	220	55	18	171	18	7.236	0	0	0.00	0.00	7.235	0	3	0.00	21.70	0	0	0	0
G129A	53	5/6/91	3506	200	55	0	171	55	6.755	0	0	0.00	0.00	6.834	1	0	6.83	0.00	0	0	0	0
G130A	54	5/6/91	3300	212	55	0	170	40	7.249	0	0	0.00	0.00	7.166	0	0	0.00	0.00	0	0	0	0
G131A	55	5/6/91	2634	201	54	52	169	26	7.060	0	0	0.00	0.00	7.064	0	1	0.00	7.06	0	0	0	0
G132A	56	5/6/91	1870	216	54	33	170	7	6.916	5	0	34.58	0.00	6.146	1	0	6.15	0.00	0	0	0	0
G133A	57	5/7/91	3200	212	54	40	171	18	6.333	3	0	19.00	0.00	6.425	0	0	0.00	0.00	0	0	0	0
G134A	58	5/7/91	2000	201	54	17	170	40	5.473	0	0	0.00	0.00	5.678	0	1	0.00	5.68	0	0	0	0
G135A	59	5/7/91	2013	193	54	10	169	28	5.990	0	0	0.00	0.00	5.820	0	1	0.00	5.82	0	0	0	0
G136A	60	5/8/91	2068	223	53	50	170	8	5.043	5	0	25.21	0.00	5.510	5	1	27.55	5.51	1	0	20	0
											Mean	6730.719	17.962				3575.840	5.850			30125.778	5.333
											Std Dev.	3.67E+04	50.154				1.40E+04	14.453			1.78E+05	20.181

Table 2. Data associated with comparative American and Soviet bongo and Soviet IKS tows for pollock eggs and larvae from the 1991 Melchny Put cruise in the Bering Sea.

ANALYSIS OF VARIANCE
EGG DATA
DARVIN / MELCHNY PUT

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
NET	17.990	2	8.995	7.503	.118
CRUISE	527.154	1	527.154	15.359	.000
STATION {CRUISE}	2883.150	84	34.323	26.499	.000
CRUISE*NET	2.398	2	1.999	.926	.398
ERROR	217.606	168	1.295		

ANALYSIS OF VARIANCE
LARVAL DATA
DARVIN / MELCHNY PUT

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
NET	94.907	2	47.454	2.861	.259
CRUISE	914.017	1	914.017	98.306	.000
STATION {CRUISE}	781.007	84	9.298	5.280	.000
CRUISE*NET	33.177	2	16.589	9.420	.000
ERROR	295 854	168	1.761		

Table 3. Results of Analysis of Variance of comparative tows for pollock eggs and larvae from both Darvin and Melchny Put cruises.

ANALYSIS OF VARIANCE
EGG DATA
DARVIN

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
NET	4.104	2	2.052	1.423	.247
STATION	1541.111	41	37.588	26.058	.000
ERROR	118.282	82	1.442		

ANALYSIS OF VARIANCE
EGG DATA
MELCHNY PUT

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
NET	16.573	2	8.287	7.175	.001
STATION	1342.036	43	31.210	27.023	.000
ERROR	99.324	86	1.155		

Table 4. Results of Analysis of Variance of comparative tows for pollock eggs from both Darvin and Melchny Put cruises.

ANALYSIS OF VARIANCE
LARVAL DATA
DARVIN

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
NET	117.373	2	58.686	27.068	.000
STATION	640.229	41	15.615	7.202	.000
ERROR	177.782	82	2.168		

ANALYSIS OF VARIANCE
LARVAL DATA
MELCHNY PUT

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
NET	8.172	2	4.086	2.976	.056
STATION	140.779	43	3.274	2.385	.000
ERROR	118.072	86	1.373		

Table 5. Results of Analysis of Variance of comparative tows for pollock larvae from both Darvin and Melchny Put cruises.

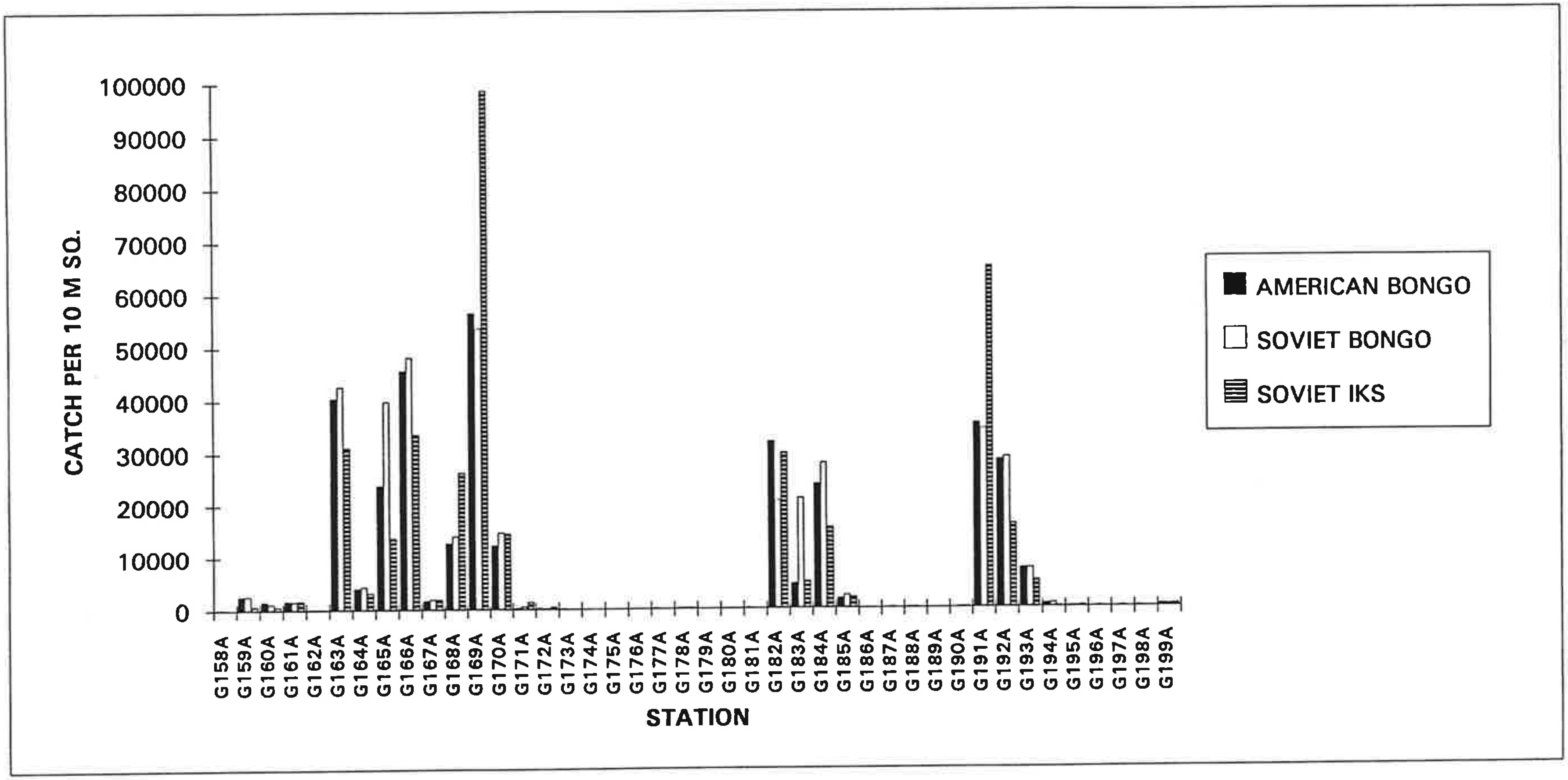


Figure 1. Catches per 10 m sq. of pollock eggs by station for American bongo, Soviet bongo, and Soviet IKS nets during the DARVIN cruise.

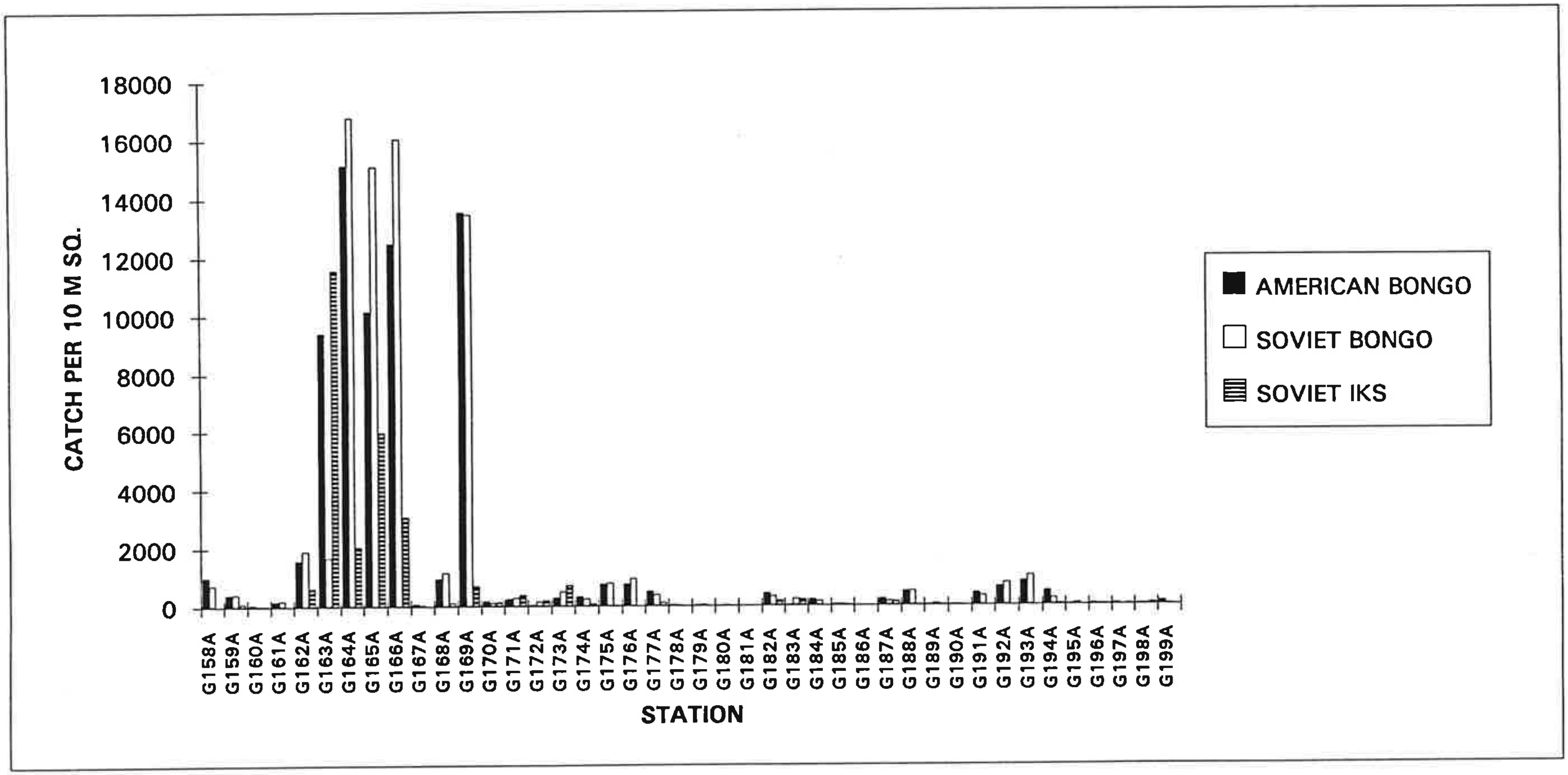


Figure 2. Catches per 10 m sq. of pollock larvae by station for American bongo, Soviet bongo, and Soviet IKS nets during the DARVIN cruise.

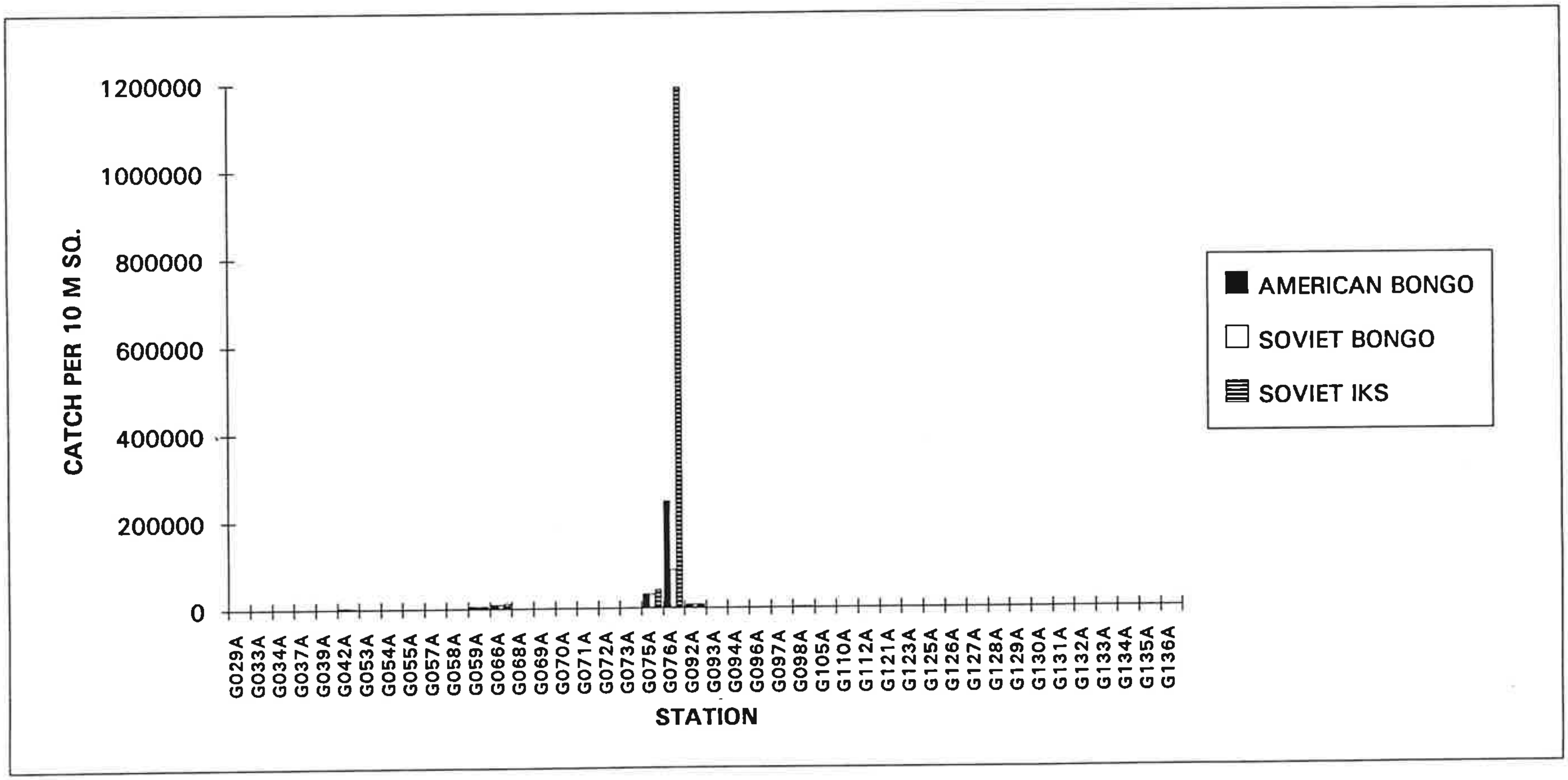


Figure 3. Catches per 10 m sq. of pollock eggs by station for American bongo, Soviet bongo, and Soviet IKS nets during the MELCHNY PUT cruise.

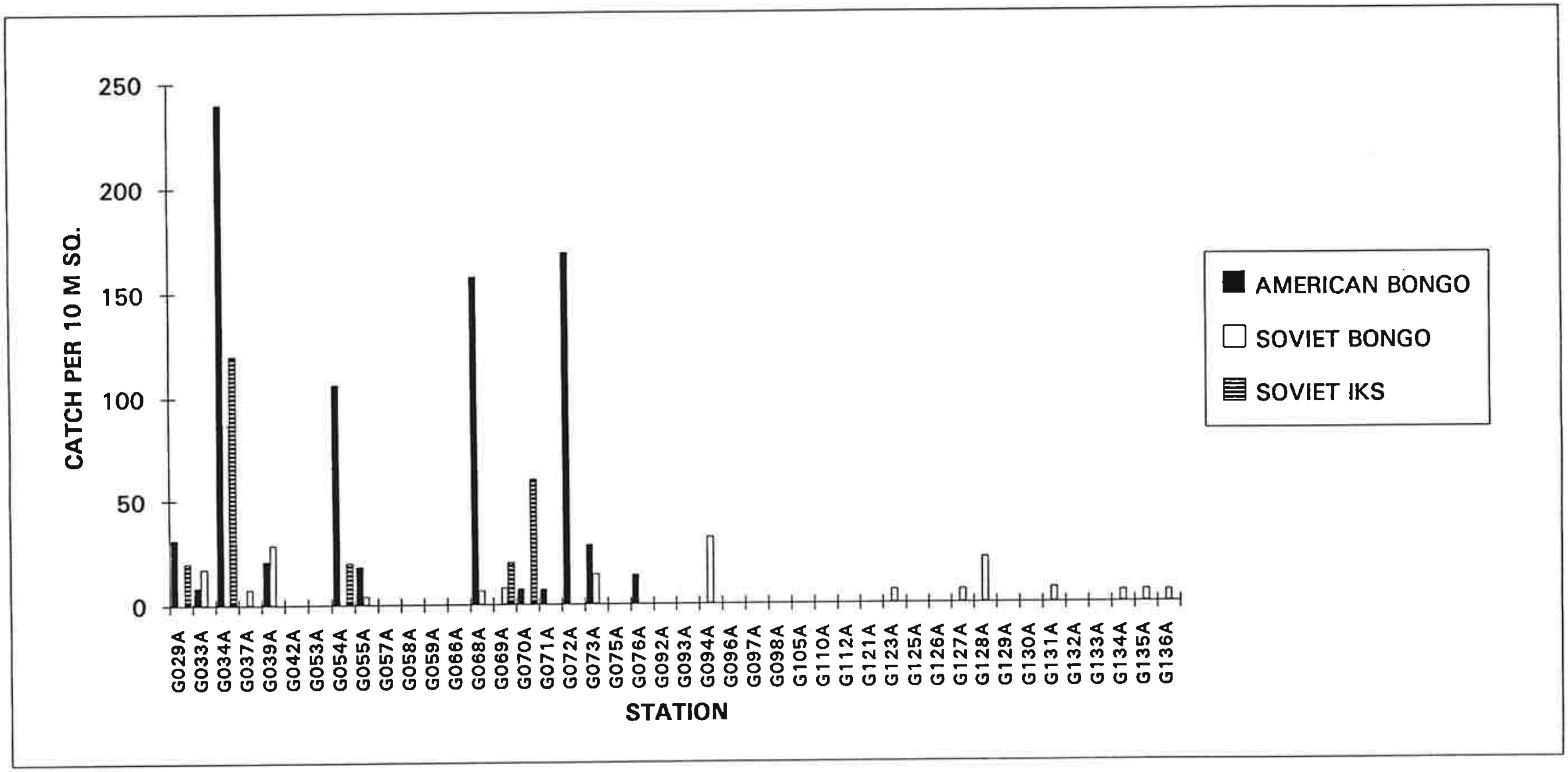


Figure 4. Catches per 10 m sq. of pollock larvae by station for American bongo, Soviet bongo, and Soviet IKS nets during the MELCHNY PUT cruise.

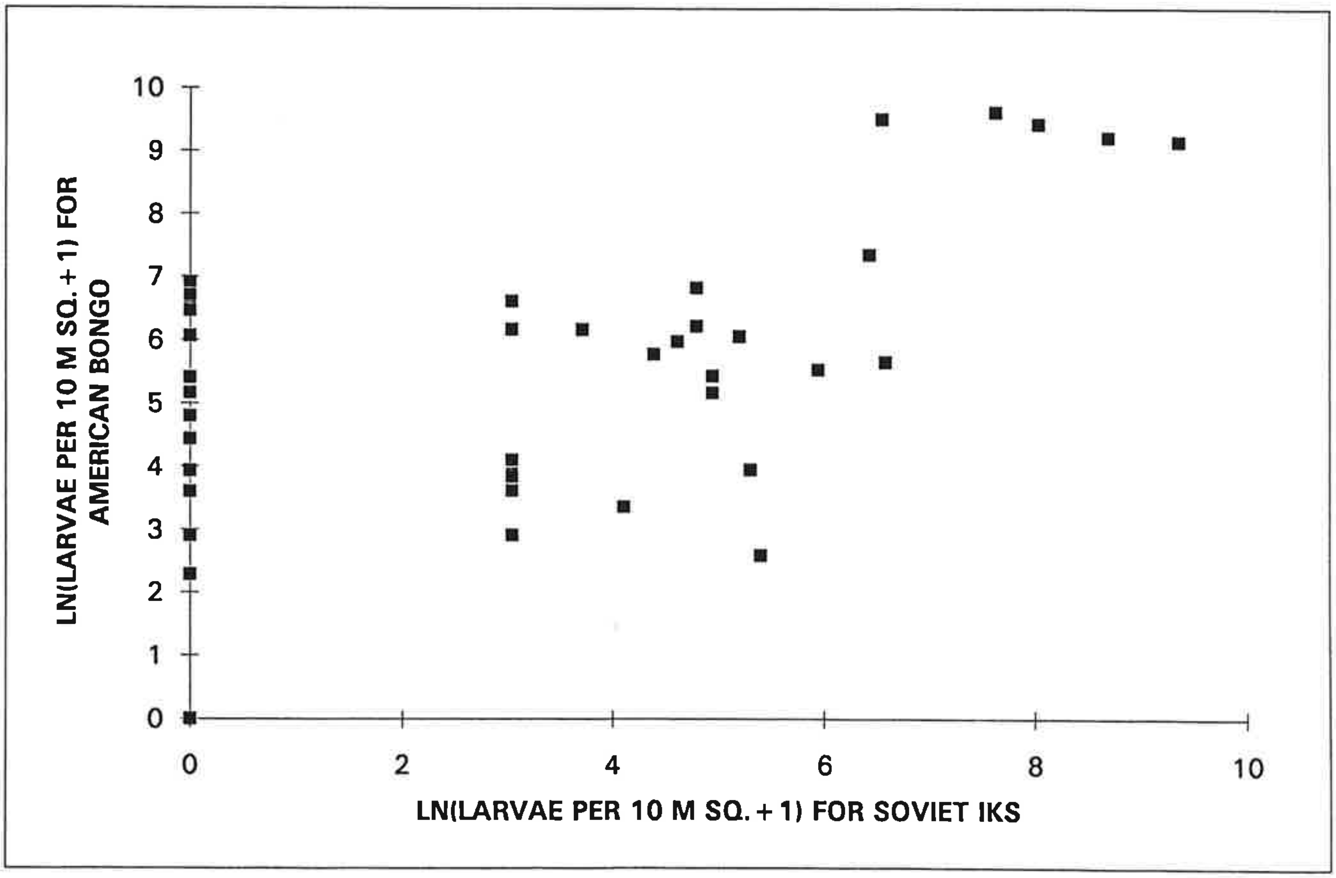


Figure 5. Scatterplot of American bongo vs. IKS pollock larvae log-transformed catch per 10 m sq. for the DARVIN cruise [transformations were ln(X+1) and ln(Y+1)].

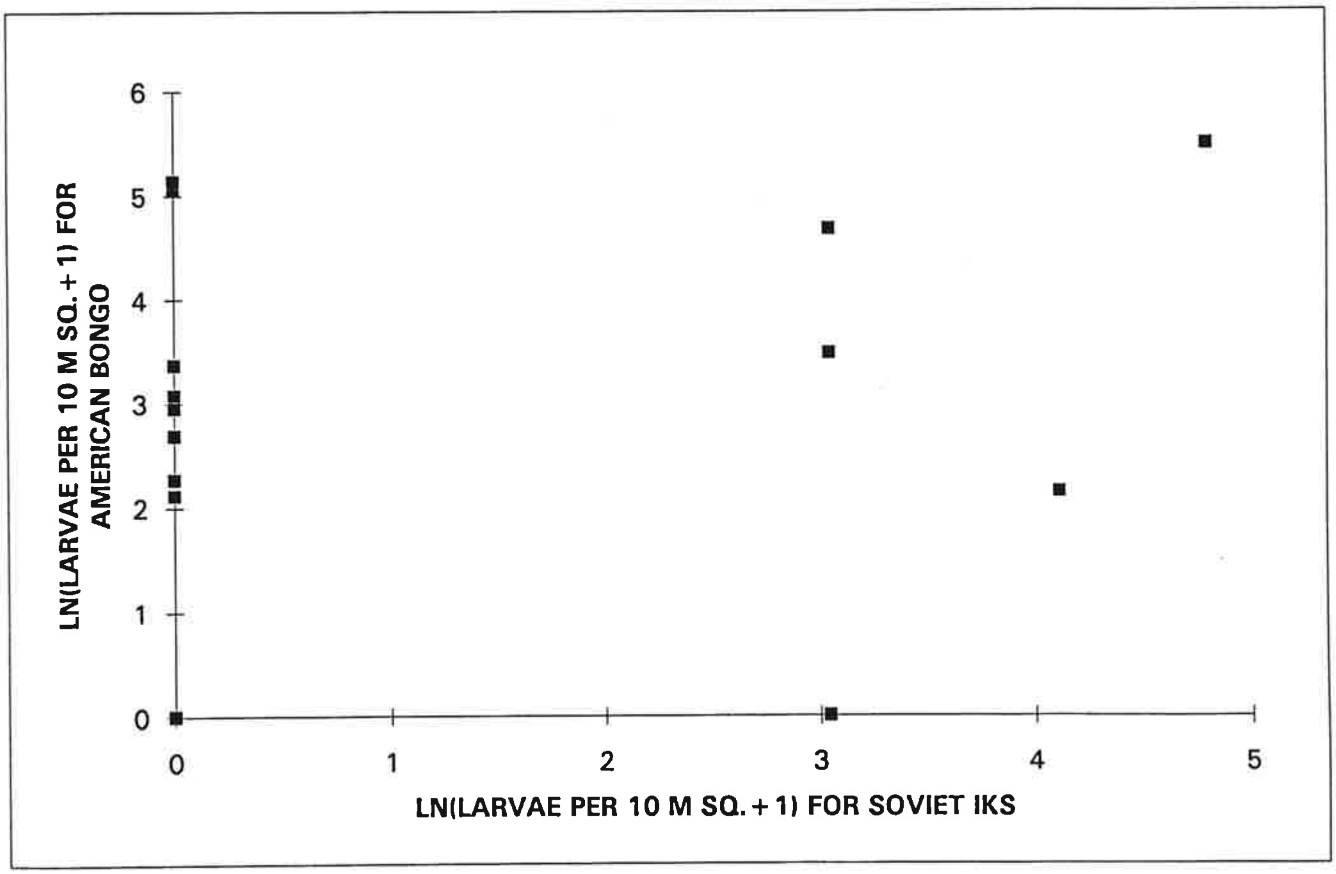
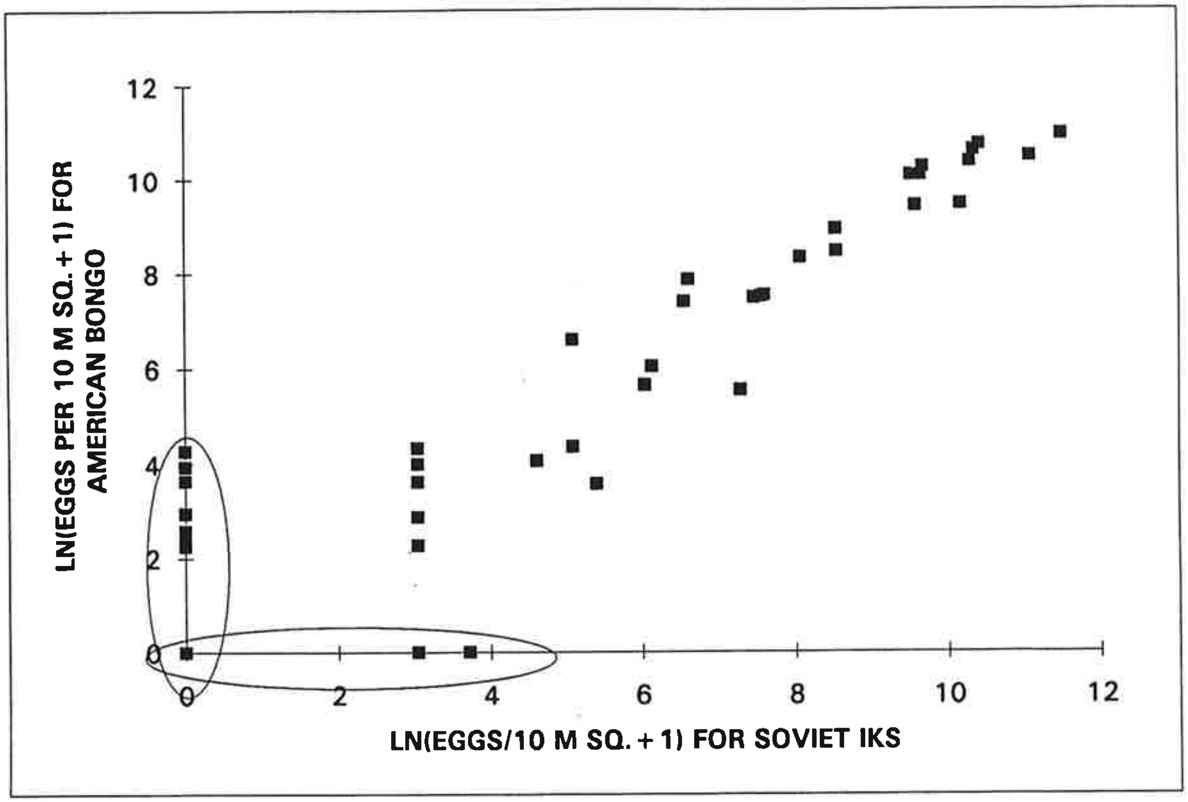


Figure 6. Scatterplot of American bongo vs. IKS pollock larvae log-transformed catch per 10 m sq. for the MELCHNY PUT cruise [transformations were ln(X+1) and ln(Y+1)].



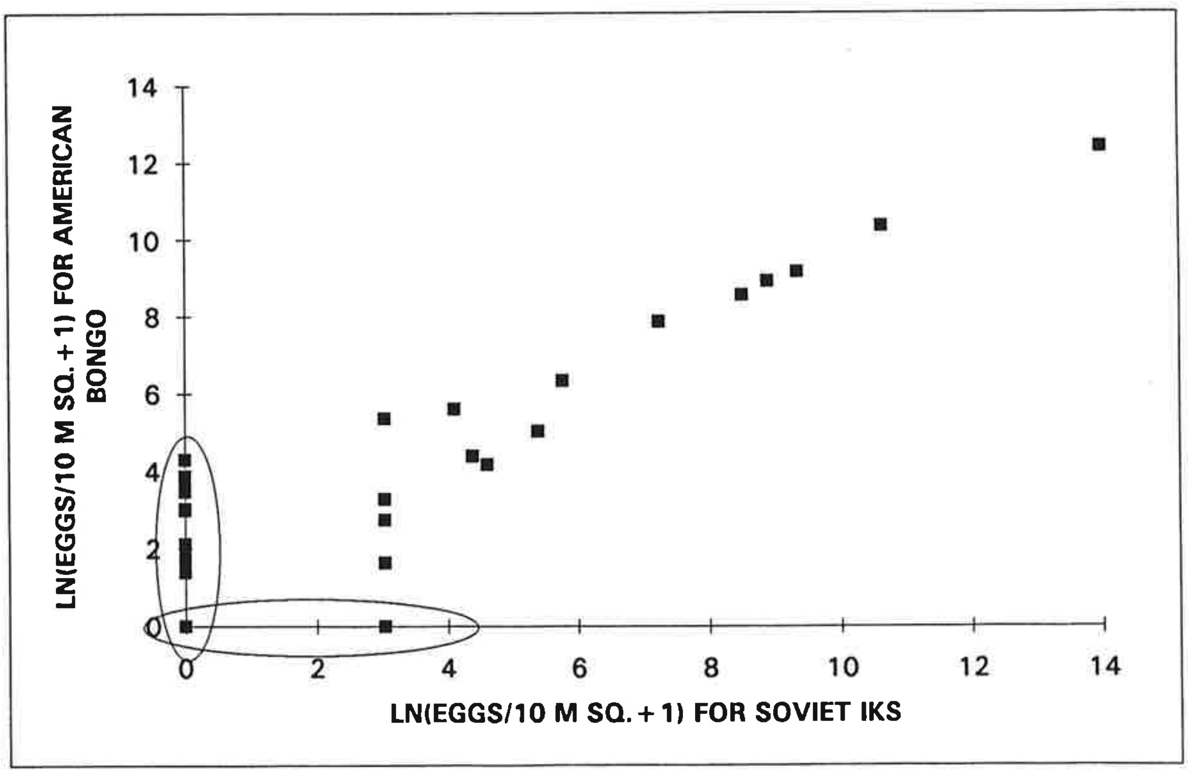


Figure 7. Scatterplots of log-transformed pollock egg data from the Darvin (top) and Melchny Put (bottom) cruises [transformations were ln(X+1) and ln(Y+1)]. Zero catches for either bongo or IKS are shown within ovals.

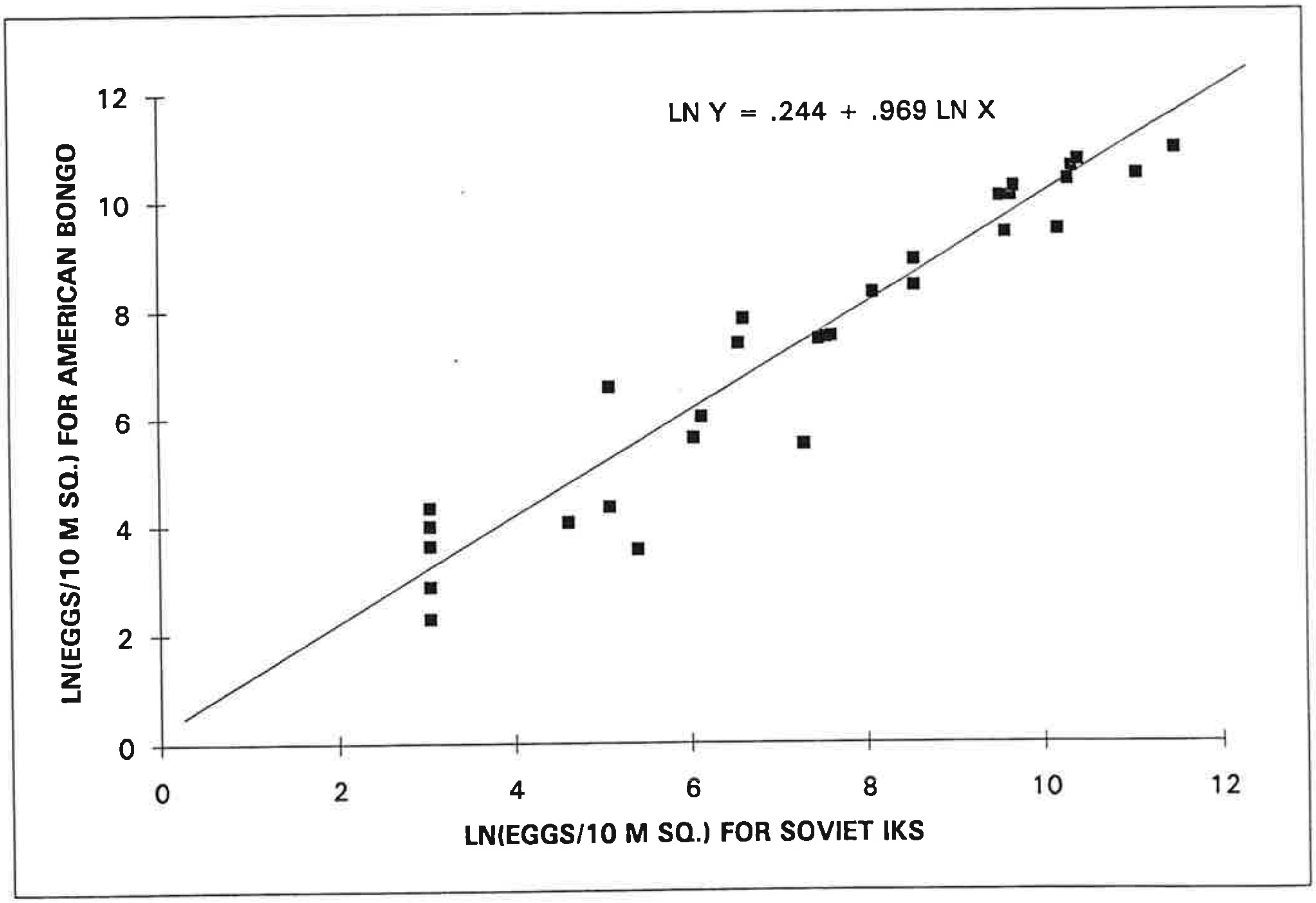


Figure 8. Scatterplot of nonzero pollock egg data from the DARVIN cruise with the fitted regression line, $\ln Y = .244 + .969 \ln X$.

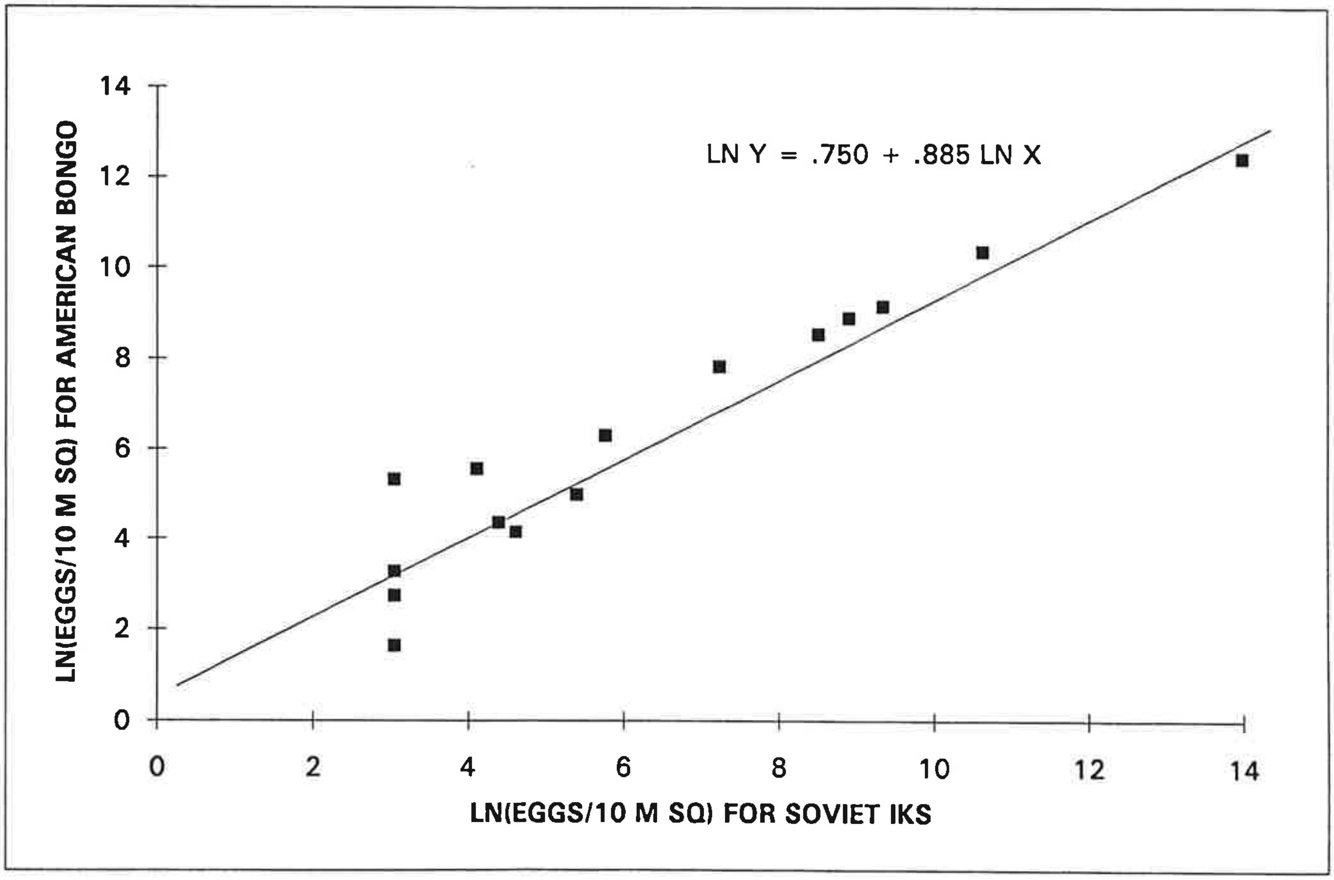


Figure 9. Scatterplot of nonzero pollock egg data from the MELCHNY PUT cruise with the fitted regression line, $\ln Y = .750 + .885 \ln X$.

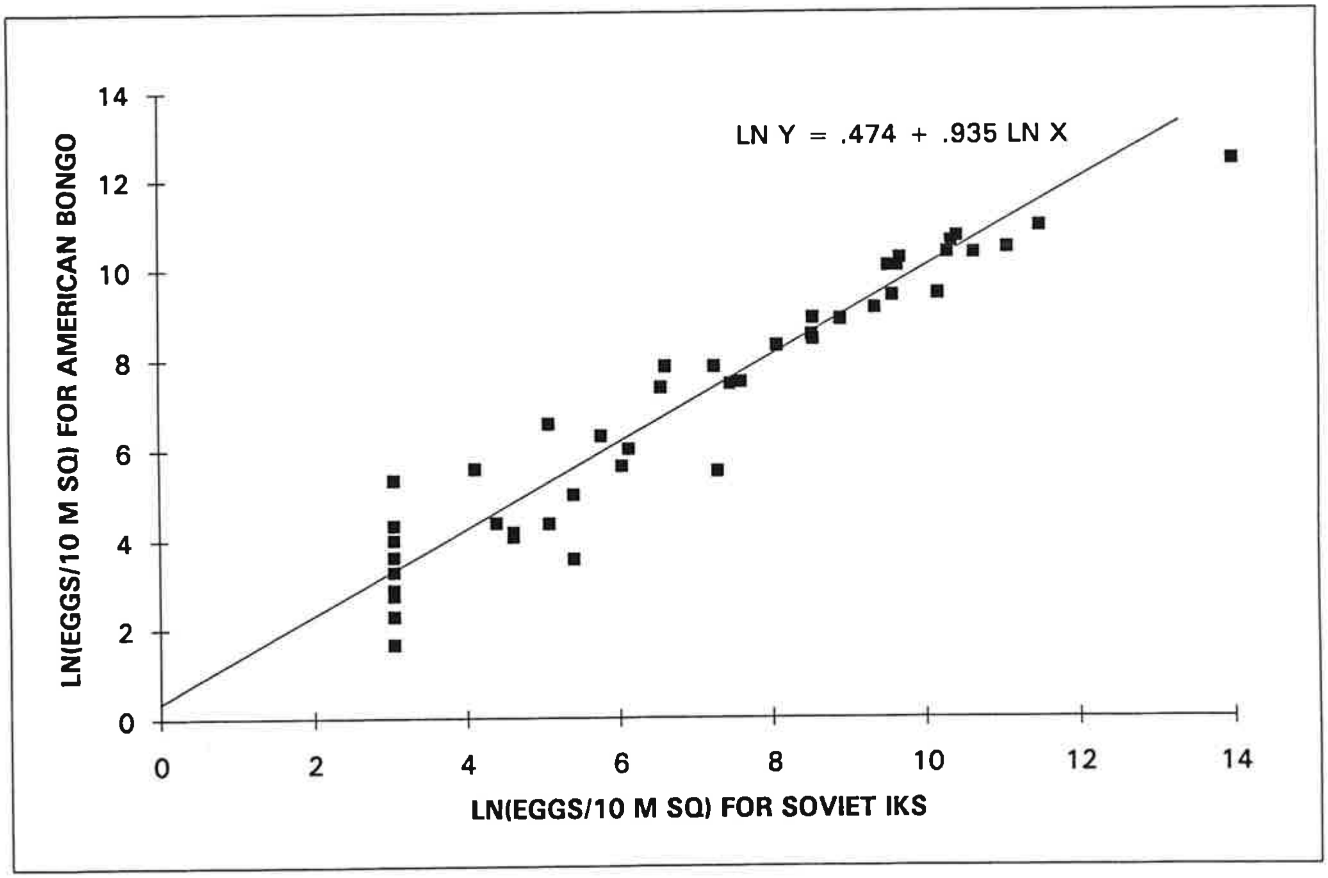


Figure 10. Scatterplot of nonzero pollock egg data from both the Darvin and Melchny Put cruises with the fitted regression line, ln Y = .474 + .935 ln X.

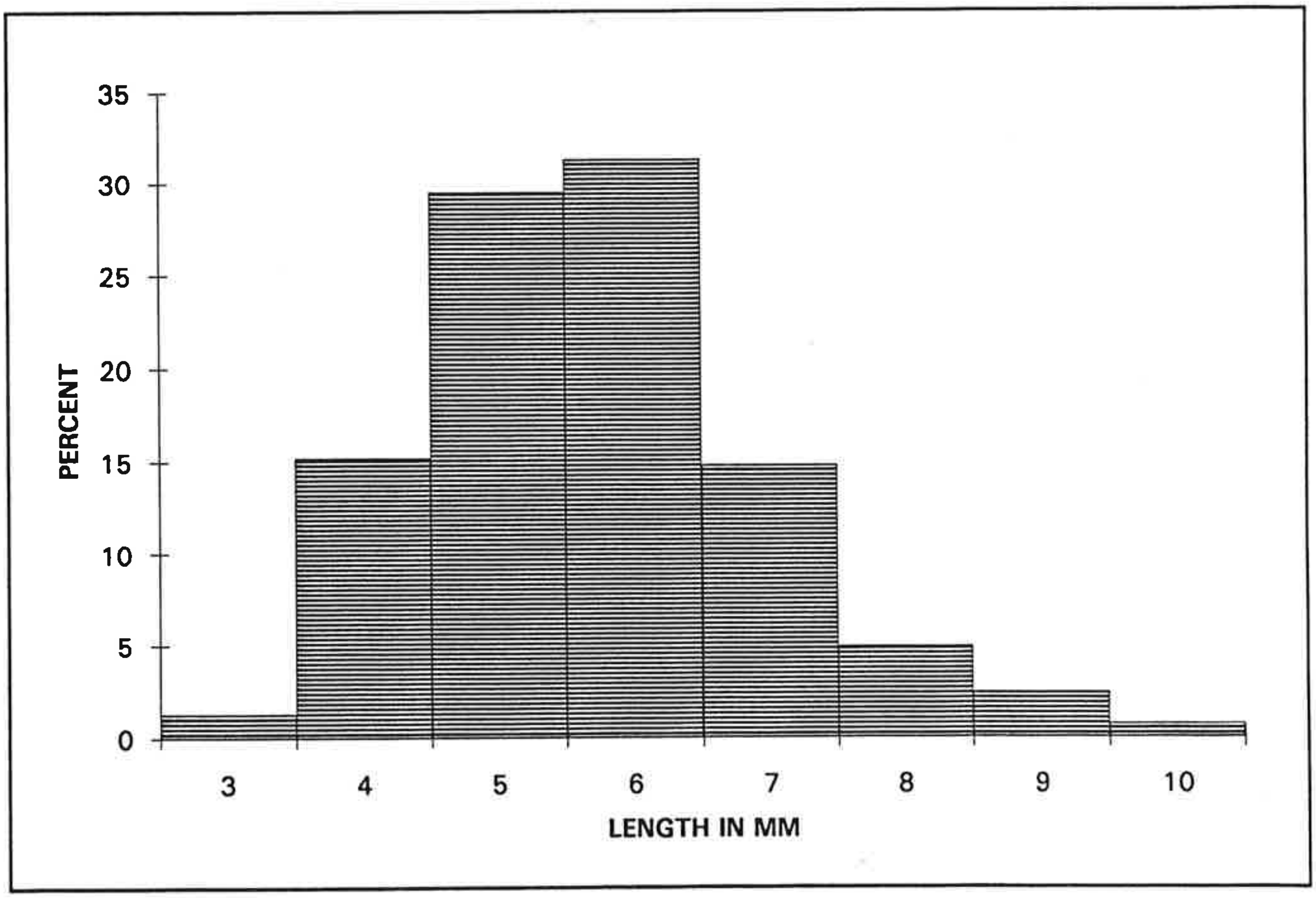


Figure 11. Histogram of length frequencies of pollock larvae from the Darvin cruise.

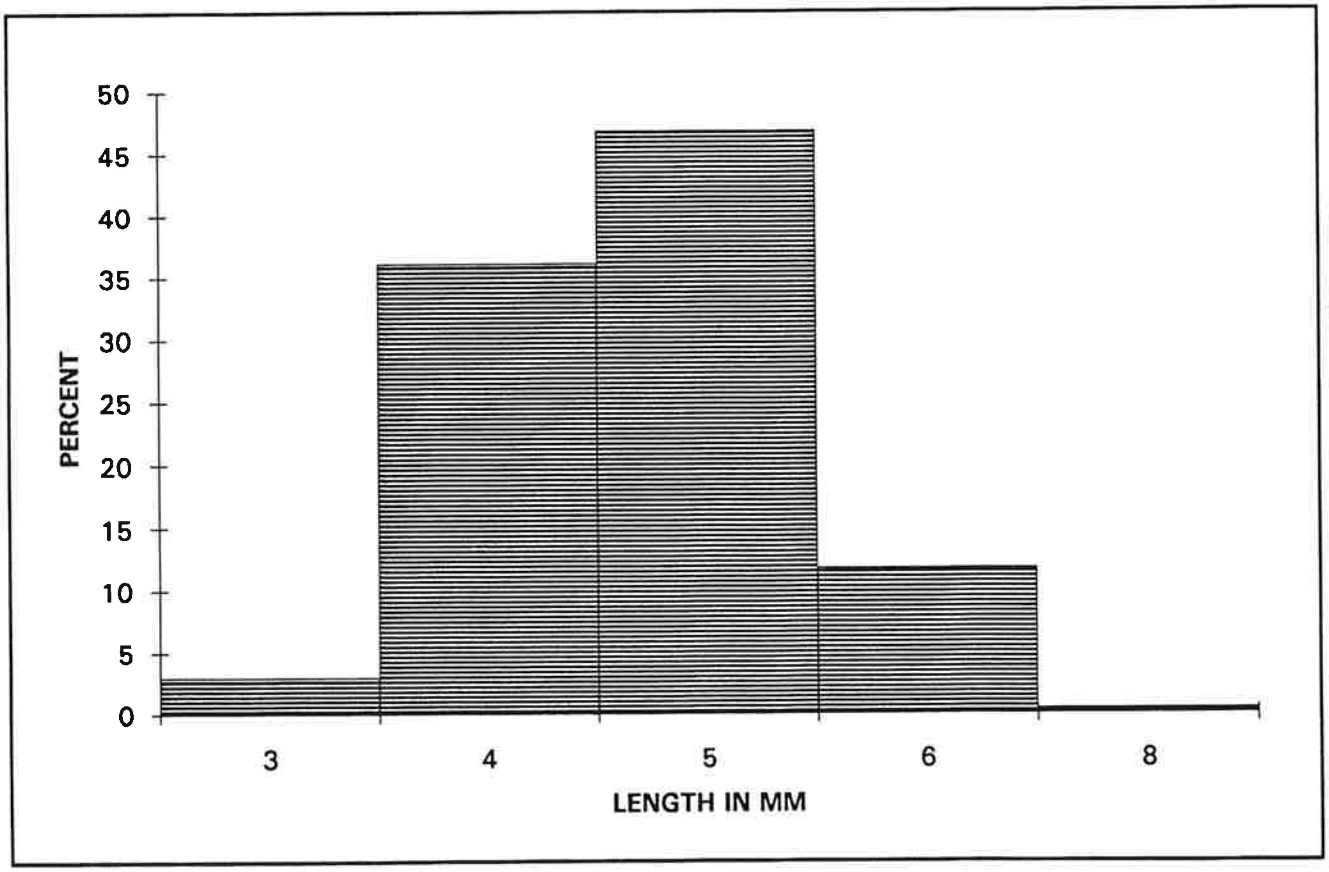


Figure 12. Histogram of length frequencies of pollock larvae from the Melchny Put cruise.