Effect of artificial enrichments and inherent production capacity on the fish production in Taoyuan reservoirs

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施肥與魚池生產潛能對魚產量的影響

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本研究主要以複迴歸方法對桃園地區 1975 年的 44 個魚池進行魚產量分析，探討各種有機、無機肥料，魚池面積及生產潛力對魚產量的影響。所使用的自變數 (Independent variable) 包括水肥、雞糞、化肥、青草、面積及代表魚池生產潛力的前三年總魚產平均。依變數 (Dependent variable) 爲鰱魚、鯽魚、鯉魚、鯁魚、鱅魚、草魚、鱸魚、鯰魚等八種魚產量及總魚產量。雞糞、水肥、青草、化肥各因子對總魚產量的關係均顯著，其相關係數 (γ) 分別爲 0.54, 0.48, 0.43, 0.42。而對各別魚產量的影響則不一，相關係數最高者分別爲：青草對於草魚，化肥對於鯁魚、水肥對於鱅魚，它們對魚產變異所能解釋的部分 ($\gamma^2\times 100$)，分別爲 66%，21%，27%，而其他魚種，各因子能解釋魚產量變異的程度均小於 20%。

對總魚產量 (Y) 具有最大預測能力的迴歸方程式爲：$Y=296.91+0.547X_1+0.003X_2+0.051X_3$，其中 X_1 爲生產潛力，X_2 爲水肥投放量，X_3 爲雞糞投放量。此方程式可解釋總魚產量變異的 84%，其中生產潛力解釋 45%，水肥解釋 26%，雞糞解釋 13%。

To determine the function relationship between fish yield and artificial enrichments, we have analyzed, primarily by the multiple regression methods, the data from Taoyuan Serviceman of Fish Propagation Administration. The independent variables were size of reservoirs, inherent production capacity, amount of superphosphate, night-soil, chicken-dung and grass. The dependent variables are the yields of silver carp, crucian carp, common carp, mud carp, bighead, grass carp, perch, catfish and total fish yield. The average of the total fish yield in the 44 reservoirs was 1557 kg/ha/yr. The correlation between the total fish yield and inherent production capacity, and the four enrichments was significant at 1% level.

The best equation to predict the total fish yield (Y) for any reservoirs is calculated to be $Y=296.91+0.547\,X_1+0.003\,X_2+0.051\,X_3$, where X_1 is inherent production capacity, X_2 is night-soil and X_3 is chicken dung, all variables in kg/ha/year. The equation indicates that 84% of the variability in total fish yield of which 45% is due to inherent production capacity, 26% to night-soil and 13% to chicken dung.

INTRODUCTION

The ultimate objective of acquaculture is the manipulation of ponds with the purpose

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of increasing their production. An extensive review on pond fertilization has been made by Mortimer and Hickling (1954)[1], Maciolek (1954)[2] and Prowse (1966)[3] for Europe and North America. Yet these literatures are of limited value in explaining the variations in fish yields among the reservoirs in Taiwan.

Since Lin and Chen(1966)[4] demonstrated the effectiveness of superphosphate in increasing harvest of freshwater ponds and reservoirs, the use of superphosphate has become a common practice in Taiwan. Many studies related to the addition of superphosphate in freshwater ponds were conducted by Liaw (1969)[5], Lin (1968)[6] and Lin (1969)[7] and Lin (1970)[8]. However, no serious consideration has been given concerning the functional relationship between fish yield and the amount of various artificial enrichments.

The purposes of this study are (1) to find the artificial enrichments related closely to fish yield in Taoyuan reservoirs and (2) to determine the functional relationships between fish yield and the various amount of artificial enrichments by mineral and organic fertilizers.

MATERIALS AND METHODS

Taoyuan reservoirs located along the Taoyuan Canal irrigation systems are used for fish culture by the Taoyuan Retired Serviceman Fish Propagation Administration (TRSFPA). These ponds varies from 4 to 11 hectares each in surface areas with a mean depth of 3–4 m, and with a total of 854 hectares. Fishes like silver carp, crucian carp, mud carp, bighead, common carp, perch, grass carp, and catfish are raised in a polyculture ecosystem. Stocks of fishes were introduced in the spring and various amount of superphosphate, night-soil, grass and chicken dung added through the culure periods. In late winter or the next spring the fish were harvested by draining the water and yields for each species of fish were recorded.

To analyze the functional relationship between fish yield and the amount of artificial enrichments, regressions of fish yield of each species and total fish yield were computed and their significance tested (Draper and Smith, 1966)[9]. The independent variables were the sizes of the reservoir, amounts of superphosphate, night-soil, chicken dung and grass. Since the records of stocking rate are unreliable, they were not considered to be indepent variable in the present study. The yields of silver carp, crucian carp, common carp, mud carp, bighead, grass carp, perch, catfish and total fish yield constituted the dependent variables. Considering the great variability of natural productivity in every individual reservoir, we have taken the mean fish yields in the 1972–1974 period as an index of inherent production capacity which is one of the independent variables. The size of reservoirs were transformed for a better fit of the linear relationship. Multiple correlation coefficient, R^2, was calculated and expressed as coefficient of determination 100 R^2, which measured the percent reduction in the total sum of squares of the dependent variables, attributable to the other independent variables.

Fish yield for each species and the data in the amount of artificial enrichments in 1975 were obtained for the 44 reservoirs from Taoyuan Retired Serviceman of Fish Propagation Administration. To facilitate this study a computer program for multiple regression was used for the determination of the partial regression coefficient and the results were tested for significance. The multiple regression programs were written for CDC computer by the Statistical Teaching Committee, National Taiwan University.

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Table 1. Fish yield, size of reservoirs and the amount of night-soil, grass, chicken dung, superphosphate treatment of the 44 reservoirs with fish cultivated only

Pond No.	Area (ha)	Artificial enrichments (kg/ha)				Fish yield (kg/ha)								
		Nightsoil $\times 10^3$	Grass	Chicken dung	Super-phosphate	Silver carp	Grass carp	Bighead	Perch	Common carp	Mud carp	Catfish	Crucian carp	Total fish yield
1015	7.0	64	1348	4877	497	465	22	407	56	61	53	29	265	1357
1017	3.9	11	8127	10600	954	914	76	305	64	20	26	0	472	1885
2011	5.6	41	6527	5921	636	531	64	347	53	89	110	28	386	1608
2014	5.5	37	5445	9669	618	224	86	362	39	61	68	17	450	1313
2020	5.9	40	5815	8569	603	473	43	338	62	75	55	43	674	1762
2204	4.9	29	2424	7343	653	379	19	343	77	68	99	29	520	1535
2404	6.0	57	2790	4339	351	355	64	161	11	47	29	13	381	1064
3008	2.5	31	9972	13656	1136	736	82	426	38	120	145	32	322	1904
4001	8.0	5	1384	4375	630	453	5	243	24	12	63	5	548	1356
4002	6.0	19	4405	5925	840	167	36	189	48	57	69	29	629	1245
4003	4.7	16	2132	8340	1123	675	62	216	23	73	147	17	570	1784
4005	7.6	10	989	5368	600	368	33	194	52	47	108	9	362	1175
4006	9.2	6	1376	5315	848	403	38	293	0	75	50	20	531	1417
4007	10.5	1	763	5181	743	269	25	136	1	52	70	13	406	972
4009	4.0	52	1290	8410	730	580	32	294	6	45	107	29	247	1340
4011	2.5	83	2562	12464	1072	638	53	413	20	84	198	43	806	2255
4012	4.5	188	7622	5727	604	655	98	290	16	48	115	45	1051	2325
4013	3.0	113	10490	9914	880	630	105	432	11	69	75	26	528	1886
4015	5.0	129	5178	8978	744	715	98	537	41	88	163	38	451	2131
5001	5.5	20	827	5809	909	451	32	132	16	28	130	16	400	1205
5002	4.0	44	2555	9863	1160	390	43	273	21	102	75	9	610	1524
5004	11.0	15	450	3377	525	360	10	190	35	60	120	10	710	1496
5005	2.8	35	1339	11571	1514	724	17	258	45	58	168	16	586	1923

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Table 1. Fish yield, size of reservoirs and the amount of night-soil, grass, chicken dung, superphosphate treatment of the 44 reservoirs with fish cultivated only (continued)

Pond No.	Area (ha)	Artificial enrichments (kg/ha)				Fish yield (kg/ha)								
		Nightsoil $\times 10^3$	Crass	Chicken dung	Super-phosphate	Silver carp	Grass carp	Bighead	Perch	Common carp	Mud carp	Catfish	Crucian carp	Total fish yield
5007	6.0	38	1872	7542	940	399	54	290	24	163	91	12	741	1773
5018	4.0	150	2273	7395	740	551	35	467	27	111	74	28	409	1702
6002	6.6	10	2638	5068	830	405	39	187	46	28	105	22	294	1126
6003	4.0	14	1198	7313	1100	528	20	270	80	0	138	16	416	1467
6004	4.4	18	2802	10864	1418	374	73	409	70	86	171	16	865	2063
6005	4.7	11	811	7319	1100	457	13	502	26	76	124	17	428	1644
6006	3.0	22	3822	14483	1160	325	66	360	8	136	81	21	740	1738
6010	3.0	76	750	9527	960	620	29	503	33	58	198	9	600	2050
6012	4.0	65	6150	8300	700	556	75	201	26	45	76	27	189	1198
6013	6.0	81	1350	4762	473	375	13	294	9	34	77	11	137	951
7009	3.8	2	718	7368	1316	461	17	84	37	52	114	14	272	1052
7012	5.5	5	6437	8433	764	1002	116	273	9	60	27	91	509	2101
7013	5.0	83	2712	8124	688	713	33	301	27	40	128	48	519	1809
7014	4.5	78	4313	6211	578	537	46	152	9	38	97	24	564	1468
7015	3.5	30	2194	9771	777	526	39	219	8	63	152	29	401	1438
8102	4.8	136	2100	7583	1167	272	48	454	26	130	137	15	1043	2125
8103	4.8	37	443	6167	1042	331	5	349	34	79	118	12	354	1281
8104	5.7	62	444	6982	1039	539	1	59	54	34	51	62	748	1547
9006	9.0	14	0	7933	553	574	33	199	23	43	99	48	125	1145
9012	4.9	10	4517	8204	427	872	37	112	58	0	42	49	337	1508
9015	9.0	11	1486	7333	369	432	20	170	30	34	40	19	124	875
Mean	5.4	45.3	3064.5	7778.9	829.8	509.2	44.4	287.1	32.3	62.5	99.6	25.1	493.6	1557.3
S.D.	2.0	43.5	2623.8	2481.5	279.9	180.1	28.9	119.1	20.8	34.3	44.7	17.0	217.8	376.9

RESULTS

Fish yield

The harvest of various species of fish and the amount of artificial enrichments in the 44 reservoirs in 1975 is presented in Table 1. The total fish yield of the 44 reservoirs, which cover a total area of 238 hectares, was 68508 kg, or 1557 kg/ha. However, the fish yield per hectare varied greatly from pond to pond, with a minimum of 875 kg/ha in pond 9015 and a maximum of 2325 kg/ha in pond 4012.

Based on the total fish yield of 44 reservoirs, it was observed that silver carp constituted the main crop, making up 35% of the total fish yield. The next important yield was crucian carp, which amounted to 28.1 %, followed by bighead (16 %), grass carp (7 %), common carp (6 %) and less than 5% for all other fishes.

Inherent Production Capacity

Since the experiment conducted by Swingle in the 1930's, it has become a common belief that the carrying capacity of any pond is a rather stable quantity that differs little from year to year. Lin (1977)[10] discovered a significant correlation between total fish yield in his studies of 1965, 1966 and 1967 and the corresponding averages of previous year since 1959. Hence, there probably exists an inherent production capacity which influences fish yield in the past as well as in the future. For the present study, the mean of the total fish yield of 1972-1974 was considered as an index of inherent production capacity of the reservoirs.

The regrssion equation of the total fish yield in 1975 on the inherent production capacity was $Y=364.46+0.877X$, where Y is total fish yield in 1975 and X is the mean fish yield of 1972-1974 (Figure 1). The coefficient of determination suggests that 72% of the variability of the total fish yield in 1975 was controlled by the inherent production capacity of the reservoirs.

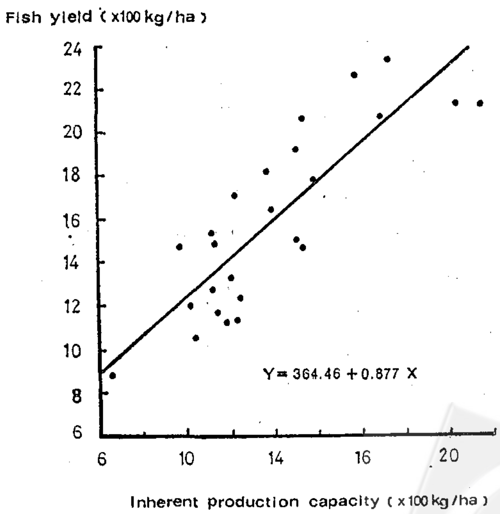

Fig. 1. Relation between fish yield in 1975 and the mean fish yield of 1972-1974 (inherent production capacity) in 25 reservoirs.

Except silver carp, catfish and perch, all other species of fish were found to be correlated with the inherent production capacity in their production (Table 2). The coefficient of determination indicated that the percentages of variability of individual species of fish production attributed by the inherent production capacity were 48% for grass carp, 38% for bighead, 18% for common carp, 29% for mud carp and 46% for crucian carp.

Table 2. Correlation coefficients between individual species of fish, total fish yield and the amount of artificial enrichments, size of reservoirs and inherent production capacity respectively

	Area	Night-soil	Grass	Chicken dung	Super-phosphate	Inherent production capacity
Area	1.00					
Night-soil	−0.32*	1.00				
Grass	−0.39**	0.28	1.00			
Chicken-dung	−0.77**	0.03	0.39**	1.00		
Super-phosphate	−0.58**	−0.10	−0.07	0.56**	1.00	
Silver carp	−0.40**	0.13	0.43**	0.37*	0.04	0.23
Grass carp	−0.32*	0.32*	0.81**	0.42**	0.01	0.69**
Bighead	−0.41**	0.45**	0.27	0.40**	0.23	0.62**
Perch	−0.04	−0.20	0.06	0.05	0.12	0.08
Common carp	−0.26	0.25	0.13	0.40**	0.38*	0.43**
Mud carp	−0.47**	0.20	−0.19	0.33*	0.52**	0.54**
Catfish	−0.05	0.18	0.28	0.15	−0.19	0.21
Crucian carp	−0.20	0.36*	0.12	0.20	0.39**	0.68**
Total fish production	−0.55**	0.48**	0.43**	0.54**	0.42**	0.85**

* $p<0.05$
** $p<0.01$

Superphosphate

Phosphate fertilizers are probably the mineral fertilizers with the most favorable and effective action in increasing fish production. Wunder (1949)[11] demonstrated that there was an average increase of 96% in fish yield, and a maximum increase of 158% was noted at Wielenbach in 1914–1922. In Taiwan, Lin (1968)[6] also showed that in 1966 and 1967 the Taoyuan reservoirs alone applied 282 kg/ha and 407 kg/ha, respectively, resulting in 53 to 85% increase in fish yield over the mean yield of the 1959–1964 period during which no superphosphate were added. In European carp ponds, Schäperclaur (1933)[12] observed that the ponds treated with 150 kg/ha of superphosphate, combined with lime and potassium manures, can be relied upon to approximately double the fish yield.

In 1975, the amount of superphosphate added to the reservoirs ranged from 351 to 1514 kg/ha (Table 1). The linear regression between total fish yield and the amount of superphosphate dosage was found to be $Y=1092.7+0.56\,X$, where Y is the total fish yield in kg/ha and X is the amount of superphosphate in kg/ha (Figure 2). The coefficient of determination suggests that 15% of the variability of total fish yield could be explained by the suserphosphate

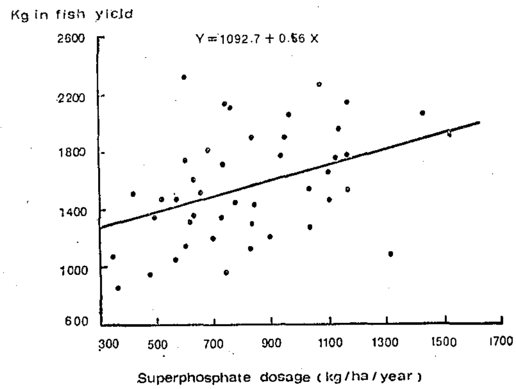

Fig. 2. Relation between total fish yield and the amount of superphosphate added in 44 reservoirs.

variable. The percentage is rather low. Therefore, factors other than superphosphate may also influence fish yield in Taoyuan reservoirs.

The effectiveness of superphosphate on fish yield varied greatly with species. Out of eight correlation coefficients (Table 2) from the superphosphate dosage on individual species of fish yields, only three were significant : 0.39 for crucian carp, 0.52 for mud carp and 0.38 for common carp. The results also showed that there were no correlation of the harvest of silver carp ($r=0.04$) and bighead ($r=0.23$) with the superphosphate dosages, in contradiction to a positive correlation which is commonly expected. Tominage, *et al.* (1964)[13] showed that the sharp increase in the yield of the phytoplankton-feeders like silver carp, crucian carp an l goldfish responsed directly to nitrogenous and phosphate fertilizers application. Both I in 1968)[6] and Lin (1970)[8] demonstrated that silver carp was most benefited by the application of superphosphate due to their phytoplankton feeding behavior.

Furthermore, the unexpected significant correlations between superphosphate and common carp and mud carp were also in contradiction with the common beliefs. Lin (1968)[6] suggested that as inorganic fertilizers increase the phytoplankton population. Since shading will cut down light penetration to the bottom of the ponds, little bottom fauna will be available for the bottom carp and mud carp to feed on. Therefore, the significant correlation between the yield of common carp and mud carp and superphosphate was rather unexpected. This may imply that the interrelations among the factors and various species of fish were more complicated than we initially supposed.

Grass

The addition of grass effected an increase in total fish yield in Taoyuan reservoirs. Large quantities of grass or aquatic plants were added to some fish ponds. The wet weight of grass ranged from 0 to 10490 kg/ha in 1975. Most of the grass or aquatic plants were used directly as food by grass carp. Lin (1940)[14] had shown that grass carp can be fed with submerged vegetation, floating plants, certain emergent plants and even tender land plants.

Fertilizers help the development of phytoplanktons and hinder the growth of aquatic plants. Consequently, the reservoirs for intensive culture of fish are always devoid of adequate weeds for grass carp. The production of grass carp will then heavily depends on the supplement of

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land plants, grass or aquatic weeds from other sources. As expected, there was a significant positive regression with yield of grass carp, increasing with the increase amount of grass (Fig. 3). The linear regression formula between these two variables was $Y=17.103+0.009X$, where Y is the fish yield of grass carp and X is the amount of grass added in kg/ha in 1975. The variable of grass can explain 66% of variability of yield of grass carp.

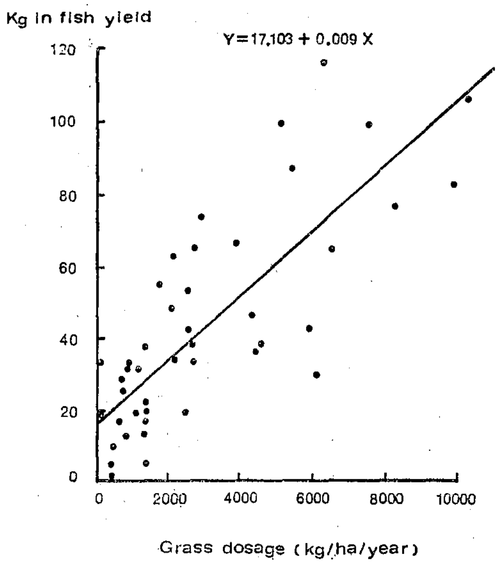

Fig. 3. Relation between the yield of grass carp and the amount of grass dosage added in the 44 reservoirs.

Chicken dung

Fish yield appeared to be greatly influenced by the addition of chicken dung. The amount of chicken dung added to the reservoirs ranged from 3377 to 14483 kg/ha, with a mean of 7779 kg/ha. There was a positive correlation ($r=0.54$) between the amount of chicken dung and the total fish yield. The regression of total fish yield on the amount of chicken dung was $Y=919.36+0.08X$, where Y is the total fish yield and X is the amount of chicken dung in kg/ha (Figure 4). The coefficient of determination suggests that 29% of the variability of

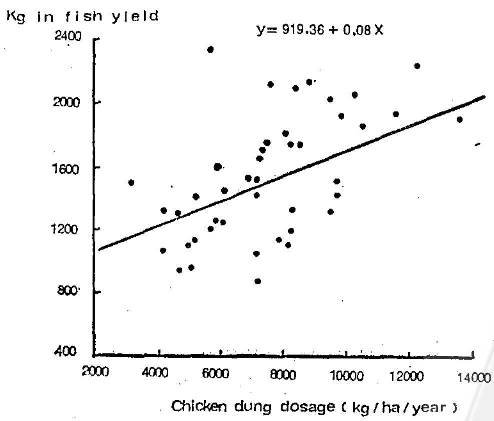

Fig. 4. Relation between total fish yield and the amount of chicken dung dosage in 44 reservoirs.

total fish yield could be explained by the chicken dung variable. Similar results have been observed by Walter (1930)[15] who demonstrated that crop increased by 100–150 % after the application of guano, which is probably similar to chicken dung in their ingredients.

Out of eight correlations (Table 2) chicken dung with species of fish, five were significant: 0.37 ($p<0.05$) for silver carp, 0.42 ($p<0.01$) for grass carp, o.4 ($p<0.01$) for both common carp and bighead and 0.33 ($p<0.05$) for mud carp. Compared with other artificial enrichments it is noted that more species of fish were affected by the addition of chicken dung. This is because chicken dung not only has the properties of other organic manures, its high content of P_2O_5 (1.5%) might play a similar role as superphosphate (Lin, 1970)[8]. Multipled by the mean dosage of chicken dung added to the reservoirs, the total amount of P_2O_5 was about 135 kg/ha/year, which could have a great influence on the fish yield as that of superphosphate used in 1975.

Night-soil

In general the total fish yield of the reservoirs increases as night-soil dosage increases. The amount of night-soil added to the 44 reservoirs ranged from 1200 kg/ha to 188,000 kg/ha, with a mean of 45,300 kg/ha (Table 1). The correlation coefficient between the total fish yield and the amount of night-soil dosages was 0.48, which is significant at 1% level. The regression equation for this relationship is $Y=1369.5+0.004\,X$, where Y is total fish yield and X is the amount of night-soil in kg/ha (Figure 5). The coefficient of determination suggests that 20 % of the variability of the fish yield can be explained by the night-soil variable. However, night-soil was less effective substantially than other artificial enrichments in increasing fish yield. The regression coefficient 'b' in the formula suggests that one ton of night-soil may increase only 4 kg of fish in the Taoyuan reservoirs. Therefore, the use of night-soil in the Taoyuan reservoirs needs to be re-evaluted.

Night-soil is a kind of organic manure which contains a major portion of nitrogenous fertilizers. In the past 50 years, the effects of notrogenous fertilizers were rather contradictary in the literatures. According to Swingle and Smith (1938)[16]. nitrogenous fertilizers have a

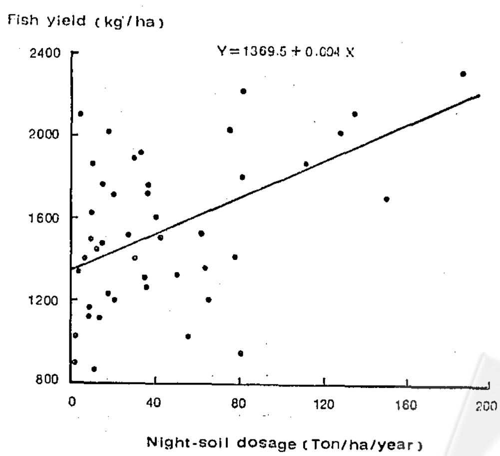

Fig. 5. Relation between total fish yield and the amount of night-soil added in 44 reservoirs of Table 1.

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a stimulating influence on the growth of phytoplanton. However, Wunder (1949)[11] showed that nitrogenous fertilizers did not play any beneficial role in the productivity of carp ponds; rather they had harmful effects on the fish. Mixtures of phosphate and organic manure produced crops no large than those produced by the appplication of phosphate alone (Demoll, 1925)[17]. Demoll (1925)[17] and Krügel and Heinrich (1939)[18] observed that as soon as a typical pond mud was formed, the addition of organic fertilizers would fail in stimulating plankton growth and fish yield. Therefore, overuse of organic manure may have harmful effect on fish production because of de-oxygenation. However, there was no sign of any adverse effects regarding the amount of night-soil presently used. The mean fish yield of the highest night-soil dosages of over 10^5 kg/ha was 2059 kg/ha of fish, which is substantially greater than the mean yield of 1493 kg/ha estimated from the other 39 reservoirs.

An analysis of the harvest per hectare in respect to fish species reveals that there was significant increase with increased amount of night-soil. The variability of the harvest which could de explained by night-soil was 10% for grass carp, 20% for bighead and 13% for crucian carp, correlation coefficients being 0.32, 0.45 and 0.36, respectively. The corresponding regressions also show that 1 ton of night-soil can increase production by 0.2 kg and 1.8 kg in grass carp, bighead and crucian carp, respectively. The effectiveness of night-soil on the production of these fishes can be explained by their feeding habits. Wunder (1949)[11] indicated that night-soil is a powerful fertilizer for the growth of green algae, and also for cyclops and *Daphina*, which are food stuffs for bigheads and crucian carps. Furthermore, the night-soil can speed up growth of hard plants, which are the major food of grass carp. It is interesting to note that the combined supplement production of grass carp, bighead, and crucian carp by one ton of night-soil dosage was 3.2 kg/ha, which is close to the amount from the regression analysis between night-soil and total fish yield.

The size of reservoirs

It is generally believed that the surface area plays an important part in the productivity of reservoirs. Rounsefell (1946)[19] showed a negative regression of standing crop and annual fish yield with the area of the lake. Jenkins (1966)[20] demonstrated that with increase in area a decrease in sporting fishes was noted. Furthermore, Rawson (1953)[21] illustrated that there was a general trend of increasing productivity with decreasing depth. Consequently, the negative relation between productivity and size of lake was due to the general association between greater depth and large size of lake.

The size of reservoirs in those 44 reservoirs ranged from 3.0 to 11.0 hectares, The logarithm of the size of reservoirs is plotted against fish yield in Figure 6. The regression equation between these two variables was $Y = 3782.1 - 568.16 \ln X$, where Y is the total fish yield in kg/ha and X is logarithm of size of reservoir in hectare. However, the negative relationship of these two variables could not be simply explained by "large area, greater depth and thus lower productivity". Since the mean depth of the Taoyuan reservoirs is about 2.5 m and the individual difference among ponds is very limited. Besides. the negative correlation between the area and various artificial enrichments (Table 2) suggests that the artificial enrichment received per hectare was less for larger reservoirs, We therefore conclude that the lower productivity of larger reservoirs in Taoyuan reservoirs is due to lesser artificial enrichment received per hectare, rather than a result of a greater depth and larger size. The insignificance of the partial correlation, 0.04, between the area and total fish yield calculated with all other variables held constant also lends support to this point of view.

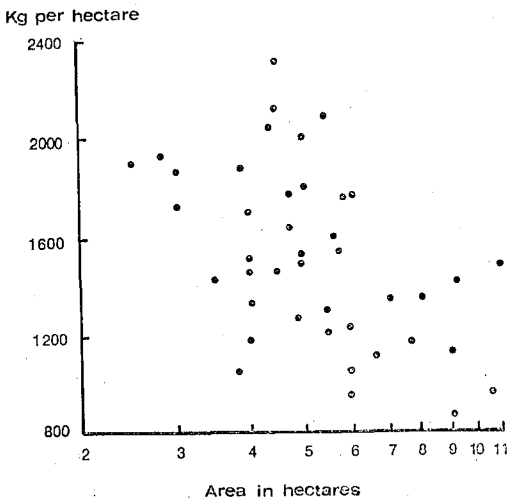

Fig. 6. Relation between total fish yield and size of reservoirs.

Multiple regression analysis

To further clarify the interrelationships concerning inherent production capacity, the four artificial enrichments and total fish yield in reservoirs(25 reservoirs) having complete data were calculated by multiple computer programs and tested for significance. The selected multiple regression equation to predict total fish yield for any reservoirs is $Y=296.91+0.547\,X_1+0.003\,X_2+0.051\,X_3$, where Y is the total fish yield, X_1 is the inherent production capacity, X_2 is the night-soil and X_3 is the chicken dung. This equation possess the highest multiple correlation and the least mean square error of estimation than any of other types of multiple regressions. The calculated multiple regression coefficient suggests that these three variables (X_1, X_2 and X_3) accounts for 84% of the variability in total fish yield, of which 45% is due to inherent production capacity, 26% to night-soil and 13% to chicken dung. Based on this multiple regression studies, it is concluded that the inherent production capacity is the most important factor in fish production.

DISCUSSION

Buck *et al.* (1970)[22] indicated that no single factor maintained a dominant influence through two consecutive seasons and that prediction of the future performance of any individual pond would be extramely difficult. This is probably true for their data, due to the small variation of fish production in their series of ponds. Our data did not support such a view. Our studies support the commonly believed concept that the total weight of all the fish that a pond will support remains relatively constant. In other words, there is an inherent production capacity. Nevertheless, the natural fertility, which apparently exercises some degree of effect on fish harvest, may possibly be altered by artificial enrichment resulting in the increase of production.

This study demonstrated that fish yields are probably influenced by all the artificial enrichments night-soil, grass, chicken dung and superphosphate. The coefficient of determination suggests that 23% of the variability of the total fish yield could be explained by night-soil, 17% by superphosphate, 18% by grass and 24% by chicken dung. However, these percentages can not be additive due to the interdependence among these independent variables.

The significant correlation between the fish yield in 1975 and that of 1972–1974 suggests that inherent production capacity or residual effects of artificial enrichments may be the determinative factor in fish yield. About 72% of the total variability of total fish yield could be explained by inherent production capacity, which was probably reflected from the soil fertility. Tackett (1968)[23] suggested that production might be directly related to certain constituents in the soils. Experiments in Wielenbach, Walter (1925)[15] showed that the residual effect in the first year after treatment of fertilizers produced a crop increase of 70–100 % above that in the controls; and in the second year the increase was 50 %. Raymont (1949)[24] also showed that the effect of fertilization could last for at least two and a half year after the cease of application. These observations probably explain the high correlation between fish yield in 1975 and mean fish yield of 1972–1974. Since large amont of artificial enrichments added to the reservoirs will increase fish production in the current year, the residual will also fertilize the ponds soil in the next few years to influence the fish production. In view of the complicated conditions involved in fish production, 84% of the variability of the total fish yield could be explained by the inherent production capacity, night-soil and chicken dung. There results were rather striking. This study strongly suggests that fish production of the future performance of any individual pond is not difficult as Buck *et al's* thought.

The unexpected results regarding the ineffectiveness of superphosphate demand the re-evaluation of the dosage used. Many author (Walter 1925[15]; Nolte, 1931[25]; Schäperclaus, 1933[12]; and Wunder, 1949[11]) recommended a dosage of 150–200 kg/ha of superphosphate. Demoll (1925)[17] found 150 kg/ha to be an optimum dosage and Rossler (1931)[26] obtained his best results with 300 kg/ha. However, the mean dosage of superphosphate applied in the Taoyuan reservoirs was 830 kg/ha, with maximum of 1514 kg/ha in pond 5005 and minimum of 351 kg/ha in pond 2404. Therefore, the very low correlation between the yield of silver carp and bighead and the amont of superphosphate may suggest that excess amount of superphosphate is unnecessary in Taoyuan reservoirs.

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