SEAFDEC Training Department

Southeast Asian Fisheries Development Center

TD/RES/14 September 1987

AN ASSESSMENT OF THE INTERACTIONS BETWEEN SPECIES IN MULTISPECIES DEMERSAL FISHERIES IN THE SOUTHERN PART OF THE GULF OF THAILAND

by

Prichar Sommani

Published by the Training Department, Southeast Asian Fisheries Development Center
P.O. Box 4, Phrapradaeng, Samutprakarn, Thailand.

Research Paper Series No.14
September 1987

AN ASSESSMENT OF THE INTERACTIONS BETWEEN SPECIES IN MULTISPECIES DEMERSAL FISHERIES IN THE SOUTHERN PART OF THE GULF OF THAILAND

by

Prichar Sommani

Training Department
Southeast Asian Fisheries Development Center

AN ASSESSMENT OF THE INTERACTIONS BETWEEN SPECIES IN MULTISPECIES DEMERSAL FISHERIES IN THE SOUTHERN PART OF THE GULF OF THAILAND

Prichar Sommani

INTRODUCTION

The demersal fisheries in the Gulf of Thailand are a good example of multispecies fisheries which have been studied intensively. Since the early 1960's, catch per unit of fishing effort (CPUE) statistics, in terms of kilograms per hour of otter board trawling by a research vessel, have been systematically compiled by the Thai Department of Fisheries. These statistics and the annual commercial trawl catch have been employed to assess the status of the demersal fish stocks and fisheries based on the surplus-production models. These studies were reported on by many authors such as Isarankura (1971), Gulland (1972), Marr *et al.* (1976), Boonyubol and Hongskul (1978) and Boonyubol and Pramokchutima (1982). In these studies, the authors assumed a single fish stock for the whole of the Gulf of Thailand.

Recently, Pope (1979), Pauly (1979) and Sommani (1983) have considered the demersal fisheries in the Gulf of Thailand as multispecies fisheries and studied the effects of the fisheries on these stocks.The first two authors treated the demersal fish stocks inhabiting the whole of the Gulf as a single stock but the last author assumed that the demersal fish stocks in the Southern part of the Gulf, covering the areas off the coast of Surat Thani to Narathivat Provinces, are isolated from those inhabiting the other parts of the Gulf.

In this paper, an attempt has been made to assess the interactions between species groups of these demersal fish stocks. The study is concentrated in the same area as my previous report (Figure 1).

MATERIALS AND METHODS

The data of the average annual stock biomass during 1966 to 1978 were taken from my previous study (Sommani 1983). The stock biomass was estimated by dividing the CPUE by the coefficient of catchability which was computed using Fox's method (Fox 1970). Only 17 species groups were used to analyze the interactions. The species groups and their numbers are reproduced here for reference in Table 1.

The interactions between species groups were studied by using the simple correlation analysis (Snedecor 1956). The relationship may be written as:

$$Y = \alpha + \beta X \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

where X and Y are the natural logarithms of the stock biomass of the species group i and j respectively; and α and β are the constants. The logarithmic transformation is used simply for reducing the variations. When P is greater than 0.05, the t-test is employed, where

$$t = \frac{r}{\sqrt{(1-r^2)/(n-2)}} \quad \ldots\ldots\ldots\ldots \quad (2)$$

with degree of freedom = n-2.

RESULTS AND DISCUSSIONS

Since in this study there are 17 species groups, we have 136 pairs of them to analyze for their correlations.

The relationships between the average annual stock biomass of a given species group to those of the other species groups show very similar patterns of scatter diagrams. Only five figures are shown as examples in Figures 2 to 6. They are given in accordance with the confidence levels of the correlation from 95 to 50%. It should be noted that during the early stage of the fisheries, from 1966 to 1971, the datum points are located above and to the right of those of the later period, 1972 to 1978.

The results of the correlation analyses for the period of 1966 to 1978 are given in Table 2. According to this Table, there are 106 relationships that are positively significant and 30 which are not significant with one of them showing a negative sign; namely the relationship between *Priacanthus* spp. and Leiognathidae.

The positive relationships simply mean that the stock sizes of the fishes have declined with time. In general, the stock sizes were high during the early stage of the fisheries, 1966 to 1971, and then declined to reach the low level during the period of 1972 to 1978. This makes the datum points for the early stage located above and to the right of those for the later period and results in a positive relationship for many pairs of species groups even though during the later period some groups tend to decline as the others increase. This can be observed, for example, in Figure 2 for *Priacanthus* spp. and Plectorhynchidae. Thus, there is no biological meaning for such positive relationships.

The decline in stock sizes with time is simply due to the effect of heavy fishing. According to Sommani (1983), the demersal fisheries in this area developed very rapidly during 1966 to 1971. The fishing effort increased from 165 thousand hours in 1966 to 862 thousand hours in 1971. After 1971, the fisheries seemed to be rather steady; i.e. there was no specific trend of change in fishing effort. The estimated amount of fishing effort was 1306 thousand hours in 1972 and 1350 thousand hours in 1978, with an average of 1220 thousand hours.

In the steady state of the fisheries, if the stocks of fish could adjust themselves to compensate the effects of fishing, the interactions between the species might possibly show up. Under this hypothesis, the correlation analysis was reconducted for the period of 1972 to 1978. The results of the correlation analysis are shown in Tables 3 and 4.

The results of this reanalysis show that there are 46 pairs of species groups in which the correlation coefficients are negative. Only two of them are significant at the 95% level. These are the relationships between *Priacanthus* spp. and the rays ($r = -0.850$, $n = 7$) and *Priacanthus* spp. and Leiognathidae ($r = -0.976$, $n = 4$). These relationships are shown in Figure 2.

For the other 44 pairs of species groups, the values of the correlation coefficients, in most cases, are low and not significant at the 95% level. However, three pairs of them are correlated at the 90% level. These include the relationships between Tachysuridae and Synodontidae ($r = -0.690$, $t = -2.132$, $n = 7$), *Sphyraena* spp. and *Scolopsis* spp. ($r = -0.682$, $t = -2.085$, $n = 7$) and *Priacanthus* spp. and *Pomadasys* spp. ($r = -0.995$, $t = -9.962$, $n = 3$). The relationships between these pairs of species groups are shown in Figure 3.

Four pairs of species groups show correlations at the 80% level. They are the relationships between *Priacanthus* spp. and Lutjanidae ($r = -0.626$, $t = -1.795$, $n = 7$), *Priacanthus* spp. and Serranidae ($r = -0.602$, $t = -1.686$, $n = 7$), the sharks and *Sphyraena* spp. ($r = -0.588$, $t = -1.626$, $n = 7$), and *Priacanthus* spp. and Plectorhynchidae ($r = -0.615$, $t = -1.774$, $n = 7$). Only the relationships of the first three pairs are demonstrated in Figure 4. For *Priacanthus* spp. and Plectorhynchidae, the low correlation is due to the deviation from the line of the 1978 datum; when this year is excluded from the reanalysis, the relationship is significant at the 95% level ($r = -0.843$, $n = 6$). This relationship is shown in Figure 2.

For the whole period of 1972 to 1978, there are two pairs of species groups which are negatively correlated at the 75% level. They are the relationships between *Priacanthus* spp. and Rhinobathidae ($r = -0.549$, $t = -1.469$, $n = 7$) and *Priacanthus* spp. and *Psettodes erumei* (r = -0.519, t = -1.358, n = 7). The low correlations of these two pairs are again caused by the deviations from the lines of the 1978 datum. When this year's datum is excluded from the analysis, both relationships are significant at the 95% level. The correlation coefficients of the relationships between *Priacanthus* spp. and Rhinobathidae and *Priacanthus* spp. and *Psettodes erumei* are -0.832 and -0.829 respectively, both with n = 6 (Figure 2). Thus, there are now five pairs of species groups which show significant negative relationships.

Besides the 80, 90 and 95% confidence levels, attempts were made to examine the possibility of negative correlations at lower confidence levels, *i.e.* at the 50 and 60% levels. There are four pairs of species groups which are negatively correlated at the 60% level. They are *Sphyraena* spp. and Rhinobathidae (r = -0.479, t = -1.210, n = 7), *Sphyraena* spp. and *Priacanthus* spp. (r = -0.397, t = -0.967, n = 7), Tachysuridae and *Nemipterus* spp. (r = -0.488, t = -1.250, n = 7), and Plectorhynchidae and Synodontidae (r = -0.458, t = -1.152, n = 7). relationships are shown in Figure 5. At the 50% level, there are six pairs of species groups that correlate negatively. These are Synodontidae and the rays (r = -0.343, t = -0.817, n = 7), Carangidae and the rays (r = -0.341, t = -0.811, n = 7), *Sphyraena* spp. and *Psettodes erumei* (r = -0.349, t = -0.833, n = 7), Mullidae and *Priacanthus* spp. (r = -0.360, t = -0.863, n = 7, Mullidae and Synodontidae (r = -0.335, t = -0.795, n = 7), and Carangidae and *Psettodes erumei* (r = -0.326, t = -0.771, n = 7). The relationships of the first five pairs are shown in Figure 6. For the last pair, *i.e.* Carangidae and *Psettodes erumei*, the low correlation is due to the deviation from the line of the 1978 datum. When it is excluded from the analysis, the two species groups are negatively correlated at the 80% level (r = -0.596, t = -1.660, n = 6) and the relationship is given in Figure 4.

Table 4 provides the results of the analysis including the y-intercepts, the slopes, the correlation coefficients and the coefficients of determination. At the 50% level, the range of the coefficients of correlation are from -0.360 to -0.355 with the determination coefficients of 12.97 and 11.19% respectively. For the 60% level, the correlation coefficients range from -0.488 to -0.397 which make the coefficients of determination equal to 23.83 and 15.74% respectively. Both coefficients are low when compared with those of the 80, 90 and 95% levels. At the 80% level, the correlation coefficients are from -0.629 to -0.588 with the coefficients of determination of 39.56% and 34.57% respectively. The correlation coefficients for the 90% level are, in general, from -0.690 to -0.682 and the coefficients of determination are 47.61 and 46.51% respectively; except the pair *Priacanthus* spp. and *Pomadasys* spp. whose correlation coefficient is -0.995 and the coefficient of determination is 99.00% both are rather high but the degree of freedom is low and equal to 1. At the 95% level, the correlation coefficients are, in general, between -0.850 to -0.829

with the coefficients of determination of 72.25 and 68.72% respectively; there is an exception again for *Priacanthus* spp. and Leiognathidae whose coefficients of correlation and determination are -0.976 and 95.26% respectively. Both coefficients are rather high but the degree of freedom is too low and equal to 2.

It is, therefore, possible to state that the coefficients of determination increase as the levels of the confidence increase. In general, they are 11.19 - 12.97%, 15.74 - 23.83%, 34.57 - 39.56%, 46.51 - 47.61% and 68.72 - 72.25% for the confidence levels of 50, 60, 80, 90 and 95% respectively. These figures hold true for the sample sizes of 6 and 7; but do not hold for the small sample sizes of 3 or 4 as in the cases of the interactions between *Priacanthus* spp. and *Pomadasys* spp. (90% level) and *Priacanthus* spp. and the Leiognathidae (95% level).These can be observed in Table 4.

In the above 12 pairs of relationships at the 80 to 95% confidence levels, the least correlation coefficient is -0.588 for the sharks and *Sphyraena* spp. interaction. But, in general, at the 50 to 60% confidence levels and for the remaining pairs of species groups, the correlation coefficients are rather low. These low values of correlation coefficients are not unexpected for biological data such as the ones used in this study because, for this kind of data, the variations are usually high. There are many reasons for this expectation. But the main and important reasons might be as follows:

1. Case A. The interaction among any pair of species groups is not so marked and it is difficult or impossible to detect at the usual confidence level however it is detectable when the sample size is large. This is likely to be true for a fish community in a tropical region where there are many species inhabiting the same area.

2. Case B. One predator might feed on many species of prey, and *vice versa.* In other words, there is no selective feeding. Thus, the abundance of any prey species is not dependent on only one species of predator but on many species of predators. Also, the stock size of the predator does not depend upon only one prey but on more than one prey species. This phenomenon will obscure the relationship between one pair of predator and prey.

3. Case C. One Species or more might be both predator and prey depending on the stage of their life cycle. That is, while the young are preyed on by another species, the adults may feed on that species, whether large or small. In this situation, it would be difficult or even impossible to determine the correlation between them by using the data of the single stage of the life cycle as in this study.

4. Case D. The correlations are obscured due to the effect of fishing. The fishing pressure during this period is very high. The average annual fishing effort is 1220 thousand hours while the estimated optimum common fishing effort, as given by Sommani (1983), is only 753 thousand hours. Therefore, the stocks of these demersal fishes are much overfished. The high level of fishing must have a much greater effect than the ability of the fish stocks to adjust themselves to compensate their loss due to fishing. That is, the fisheries have a greater effect than the interactions. Sommani (1983) has also suggested the same reason. This need not be discussed further.

If we consider all observed interactions at the confidence levels from 50 to 95%, there are 21 pairs of negative relationships and all of the 17 species groups interacts with another species group. The frequency that one species group correlates with others is different. The most frequent species group is *Priacanthus* spp. which shows 10 interactions with others. *Sphyraena* spp. follows with 5 relationships with other species groups. Four species groups interact with Synodontidae. The correlations of the rays and *Psettodes erumei* with other species groups occur 3 times. Only 2 species groups correlate with each of the following; Rhinobathidae, Carangidae, Plectorhynchidae, Tachysuridae and Mullidae. For each of the remaining species groups, *i.e.* the sharks, Serranidae, *Nemipterus* spp., Lutjanidae, *Pomadasys* spp. *Scolopsis* spp. and Leiognathidae, interaction with another species group occurs only once. These are summarized in Table 5.

At present, there are no reports containing detailed information on the food and feeding habits of the demersal fishes in this area. It is not known which predator feeds on which prey. This makes it impossible to identify any pair of predation or competition although it is possible to observe the negative interactions for many pairs. However, it is likely that the young of one or more species groups are consumed by the adults of the other groups and the opposite might also hold true. Besides predation, competition may also occur among these species groups, either for food or for other purposes.

It might be easier to explain by recombining these 17 species groups into 3 large main groups, namely:

1. The large size predators. This group includes the sharks, the rays, Rhinobathidae and Serranidae.

2. The medium size predators. This group is composed of many species groups such as *Psettodes erumei*, *Priacanthus* spp., *Sphyraena* spp., Synodontidae, Lutjanidae, Carangidae, Plectorhynchidae, Tachysuridae and *Pomadasys* spp.

3. The prey. This group includes *Scolopsis* spp., *Nemipterus* spp., Mullidae and Leiognathidae.

For the interaction between the large size predators and the other species groups, it might be possible to state that the first group consumes the latter. The rays, Rhinobathidae and Serranidae may feed on *Priacanthus* spp., either the young or the adults or both. The sharks and Rhinobathidae consume *Sphyraena* spp. Both Synodontidae and Carangidae are prey to the rays.

Priacanthus spp. could feed on Leiognathidae and Mullidae. Mullidae is also prey to Synodontidae while *Sphyraena* spp. feeds on *Scolopsis* spp. *Nemipterus* spp. either small or large fish, is consumed by Tachysuridae. These interactions conform with Case B.

For the other interactions the relationships might be more complicated for example, the interactions among the species groups in the medium size predator category. It is possible that *Priacanthus* spp. might feed on the young of Plectorhynchidae, *Psettodes erumei, Pomadasys* spp., Lutjanidae and *Sphyraena* spp. but the reverse might also be naturally probable. The same phenomenon might occur for the correlations between Synodontidae and Plectorhynchidae, and *Psettodes erumei* and *Sphyraena* spp. It is obvious that in this case one predator feeds on many prey and *vice versa*. Therefore, this is in accordance with Case B. It is also easy to see that in this case, again, one or more species groups could be both the predator and the prey depending on the stage of their life cycle as hypothesized in Case C.

In the case of the medium size predators, the interactions might be the results of competition for food. For example, the competition might occur among the rays, Rhinobathidae, Serranidae, Plectorhynchidae, *Psettodes erumei, Pomadasys* spp., Lutjanidae and *Sphyraena* spp. While the first three species groups consume either the small or large *Priacanthus* spp., the remaining five species groups would probably feed on the many stages of young and adults of *Priacanthus* spp. Another example of competition for food may happen among Tachysuridae, Plectorhynchidae and the rays which feed on Synodontidae, either the young or adults. The rays and *Psettodes erumei* could well compete for Carangidae.

According to the previous three paragraphs, it can be clearly seen that the interactions are rather complicated, even in the case of the large size predators such as the sharks which show only one interaction with *Sphyraena* spp. at the 80% confidence level (r = -0.588). The reason for this low correlation may be that the sharks do not depend only on this prey but also on other prey. Therefore, the expectations of a low correlation coefficient are not unreasonable (Case A). To increase the sample size or to use data on many stages of the life cycle may solve the problems in the increase of the confidence level or in detecting the interactions which could not be observed in this study. But one should keep in mind that this requires a longer time period to compile the data and this in turn will result in greater variations in the data to be obtained.

At present, it is difficult to state which one is the most significant in causing the interactions among the predation and the competition of the pairs of species groups. But in a situation as in this study, it is reasonable to believe that both are equally significant.

CONCLUSIONS

The correlations between species groups were analyzed for 136 pairs of species groups. For the period 1966 to 1978, 106 of them correlated positively at the 95% level. But there are no biological explanations for this. The positive relationships are simply the results of the decline with time of all fish stocks due to the effect of heavy fishing.

For the period 1972 to 1978, during which the fisheries appeared to be steady, there are 46 pairs which show a negative trend. Five relationships are negatively significant at the 95% level. These are the relationships between *Priacanthus* spp. and other species groups; namely the rays, Leiognathidae, Plectorhynchidae, Rhinobathidae and *Psettodes erumei*, although for the last three pairs of relationships the 1978 data must be excluded from the calculations. Three pairs of species groups are negatively interacted at the 90% level. These include the relationships between *Priacanthus* spp. and *Pomadasys* spp., Tachysuridae and Synodontidae, and *Sphyraena* spp. and *Scolopsis* spp. At the 80% confidence level, there are four pairs of species groups which are negatively correlated. They are *Priacanthus* spp. and Lutjanidae, *Priacanthus* spp. and Serranidae, the sharks and *Sphyraena* spp., and Carangidae and *Psettodes erumei*.

At the 60% confidence level, negative interactions are found between *Sphyraena* spp. and Rhinobathidae, and *Priacanthus* spp.; Tachysuridae and *Nemipterus* spp., and Plectorhynchidae and Synodontidae. Five species groups interact at the 50% level, they are Synodontidae and the rays, Carangidae and the rays, *Sphyraena* spp. and *Psettodes* spp., Mullidae and *Priacanthus* spp., and Mullidae and Synodontidae.

About 11.19 - 12.97%, 15.74 - 23.83%, 34.57 - 39.56%, 46.51 - 47.61% and 68.72 - 72.25% variations in any species group could be explained by variations in the other species groups at the confidence levels of 50, 60, 80, 90 and 95% respectively. The causes of these interactions are expected to be the predation and/or the competition. At present, it is not known which one is the most prominent due to the lack of information on the food and feeding habits of these fishes. But in this tropical area, it is likely that both predation and competition are equally important depending on the species groups and the stage of their life cycles.

Except for 80 to 95% confidence levels, the correlation coefficients for the 50-60% levels and for the rest of them are rather low. This phenomenon is not unexpected for the biological data as employed in this study. There are many reasons for this, but the main reasons for the low correlations are proposed as follows:

1. Case A. The interactions among species are too low so that they cannot be detected by the small sample size analysis, especially at the usual, 95%, confidence level.

2. Case B. One species of predator feeds on many species of prey and *vice versa*. That is, there is no selective feeding.

3. Case C. One species or more are both predator and prey depending on the stage of their life cycle.

4. Case D. The fishing has a much greater effect than the effect of predation and/or competition, therefore, these could not cause so marked an interaction until they can be detected.

For the 50 to 95% confidence levels, there are 21 pairs of interactions and each of the 17 species groups shows at least one interaction with another species group. The most frequent species group is *Priacanthus* spp. which has 10 interactions with others, and is followed by *Sphyraena* spp. which interacts with 5 other species groups. The interaction of Synodontidae with others occurs 4 times. The rays and *Psettodes erumei* have 3 interactions with others. Correlations with other species groups occur only twice for the following groups: Rhinobathidae, Carangidae, Plectorhynchidae, Tachysuridae and Mullidae. For the remaining species groups interactions take place only once.

For the sharks, the rays, Rhinobathidae and Serranidae which feed on others, the interactions with them might be quite simple, although they feed on many species and may compete with each other. But the interactions among the species groups of the medium size predators which include *Psettodes erumei*, *Priacanthus* spp., *Sphyraena* spp., Synodontidae, Lutjanidae, Carangidae, Plectorhynchidae, Tachysuridae and *Pomadasys* spp. are more complicated than those occurring among the large size predators. In this case, the young of one or more species group are prey to the adults of the other species groups and the reverse also occurs. It is also obvious that one or more species group could be both predator and prey depending upon the stage of the life cycle. Therefore, in this group, the interactions are in accordance with both Case B and C. The competition for food also exists among these species groups. The competition occurs at all stages of the life cycle. Thus, the competition is also important.

The occurrences of interactions among the species groups are likely to be caused by predation as well as competition. In some pairs of species groups, predation and competition may take place at the same time. While in some cases, they might occur at different stages of the life cycle. However, in all cases, both of them could be equally significant in causing interactions.

ACKNOWLEDGEMENTS

The author wishes to thank Mrs. Matana Boonyubol who kindly provided the unpublished data on the catch per unit effort used in this study, without her assistance this study would not have been possible. Thanks are also due to the staff of SEAFDEC/TD for their assistance, especially Dr. Veravat Hongskul, the Secretary-General, who reviewed the manuscript and made many valuable comments and recommendations.

REFERENCES

BOONYUBOL, M. and V. HONGSKUL (1978). Demersal fish resources and exploitation in the Gulf of Thailand, 1960-1975. SCS/GEN/77/13, 120 p.

BOONYUBOL, M. and S. PRAMOKCHUTIMA (1982). Trawl fisheries in the Gulf of Thailand. Paper submitted to the Second National Seminar on Marine Science, Bangsan, 8-11 September 1982. 7 pages, 9 figs., 8 tables.

FOX, W. W. (1970). An exponential surplus production model for optimizing exploited fish population. Trans. Amer. Fish. Soc., 99(1): 80-88.

GULLAND, J.A. (1972). Some notes on the demersal fish resources of Southeast Asia. Proc. IPFC. 13: 51-60.

ISARANKURA, A.P. (1971). Present status of trawl fisheries resources in the Gulf of Thailand and management programme. Proc. IPFC. 14: 105-114.

MARR, J.C., G. CAMPLEMAN and W.R. MURDOCH (1976). Kingdom of Thailand: An analysis of the present, and recommendations for future, fishery development and management policies, programmes and institutional arrangements. South China Sea Fisheries Development and Coordinating Programme, Working Paper No. SCS/76/WP/45, 105 p. and appendices.

PAULY, D. (1979). Theory and management of tropical multispecies stock: A review with emphasis on the Southeast Asian demersal fisheries. ICLARM Studies and Review. No.1, 35 p.

POPE, J. (1979). Stock assessment in multispecies fisheries, with special reference to the trawl fishery in the Gulf of Thailand. SCS/79/19, 106 p.

SNEDECOR, G.W. (1956). Statistical methods. The Iowa State University Press. Ames, Iowa. 534 p.

SOMMANI, P. (1983). An assessment of the multispecies demersal fisheries and fish stocks in the Southern part of the Gulf of Thailand. SEAFDEC Joint Research Paper (Thailand), No.4, 30 p.

Figure 1. The Gulf of Thailand showing the study area

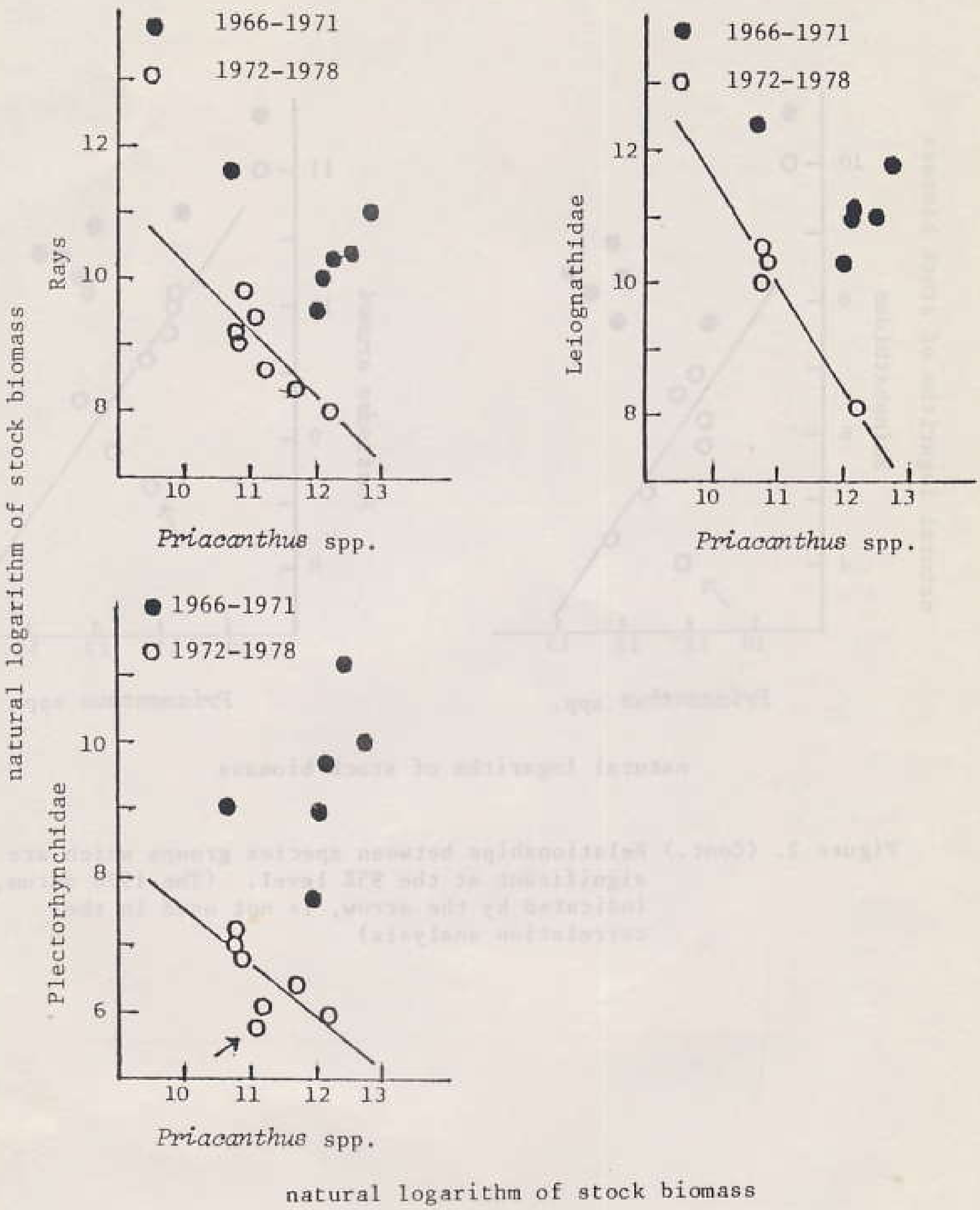

Figure 2. Relationships between species groups which are significant at the 95% level. (The 1978 datum, indicated by the arrow, is not used in the correlation analysis)

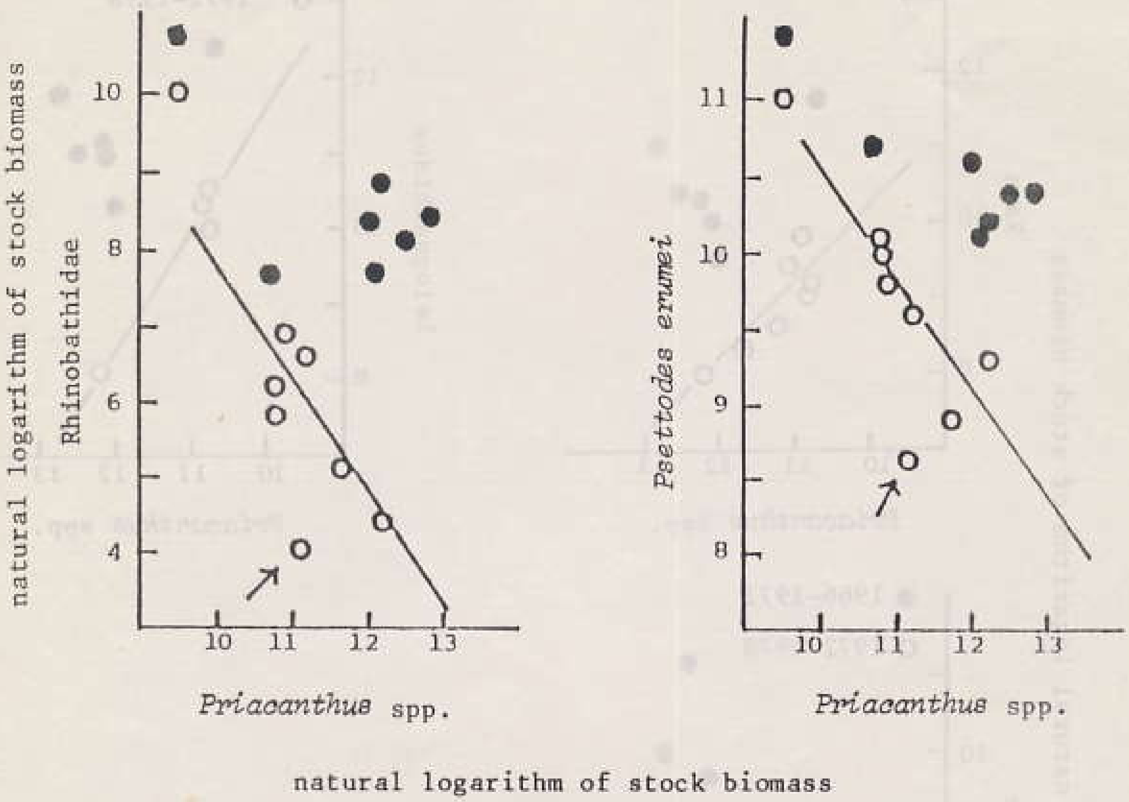

Figure 2. (Cont.) Relationships between species groups which are significant at the 95% level. (The 1978 datum, indicated by the arrow, is not used in the correlation analysis)

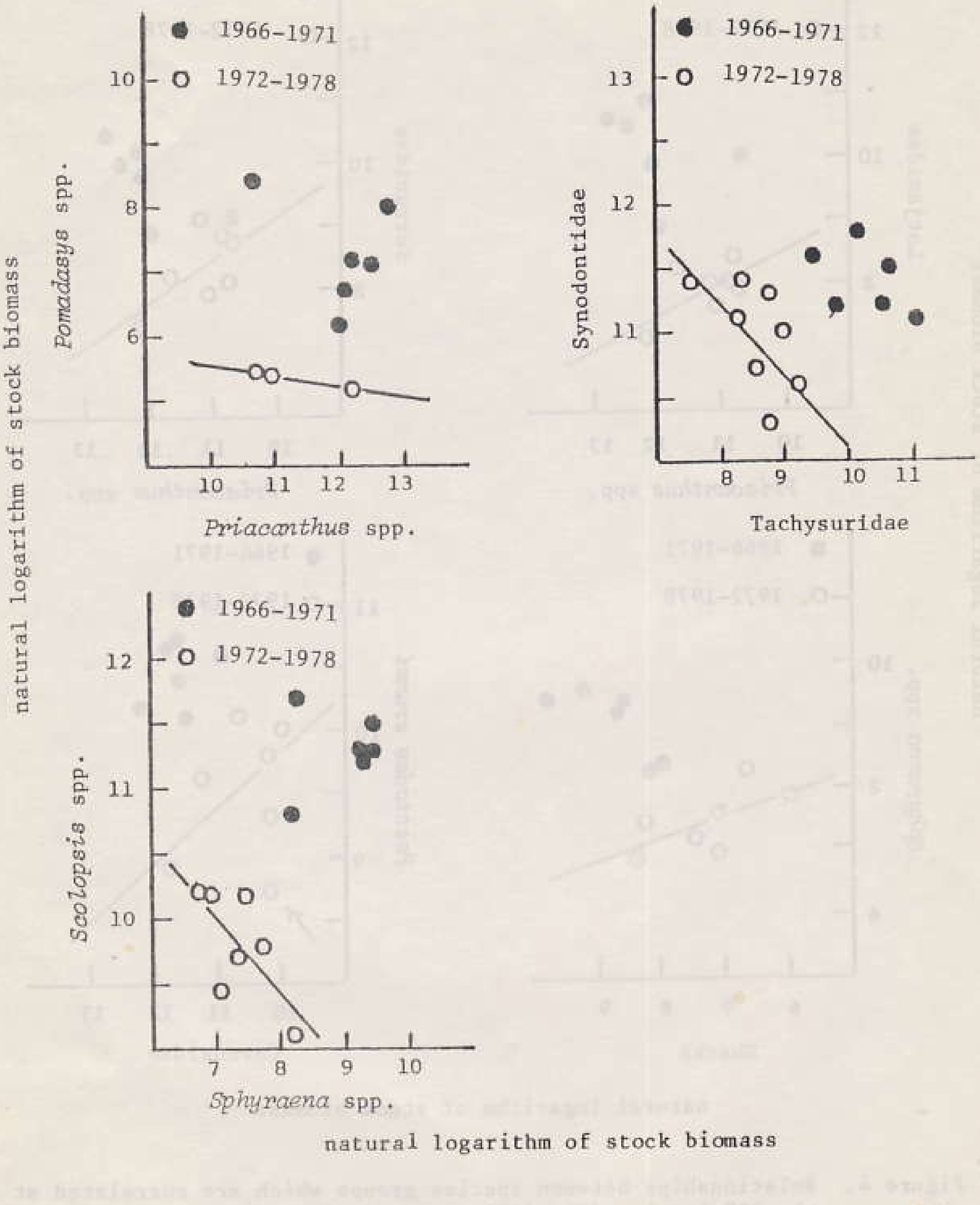

Figure 3. Relationships between species groups which are correlated at the 90% level

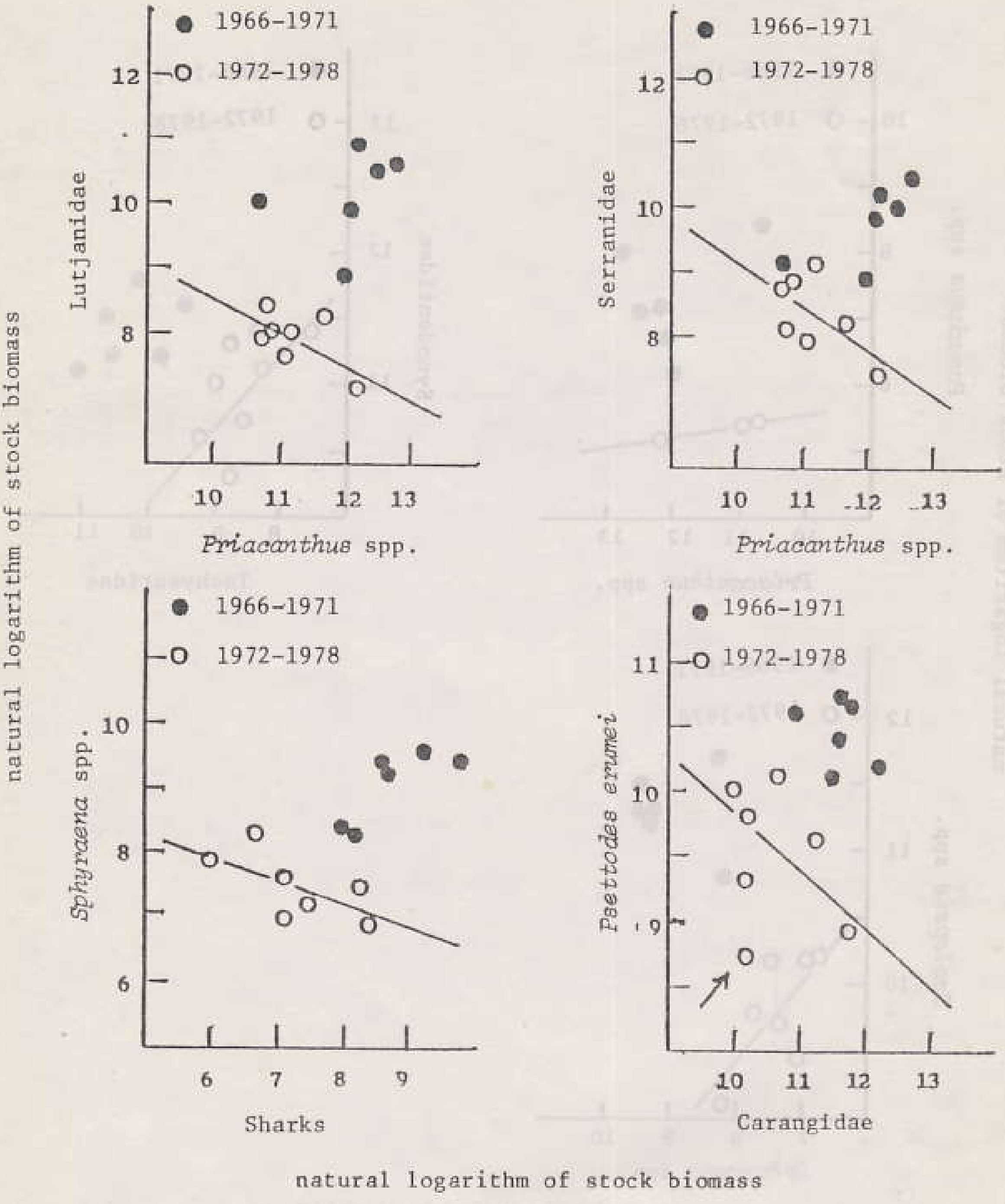

Figure 4. Relationships between species groups which are correlated at the 80% level. (The 1978 datum, indicated by the arrow, is not used in the correlation analysis)

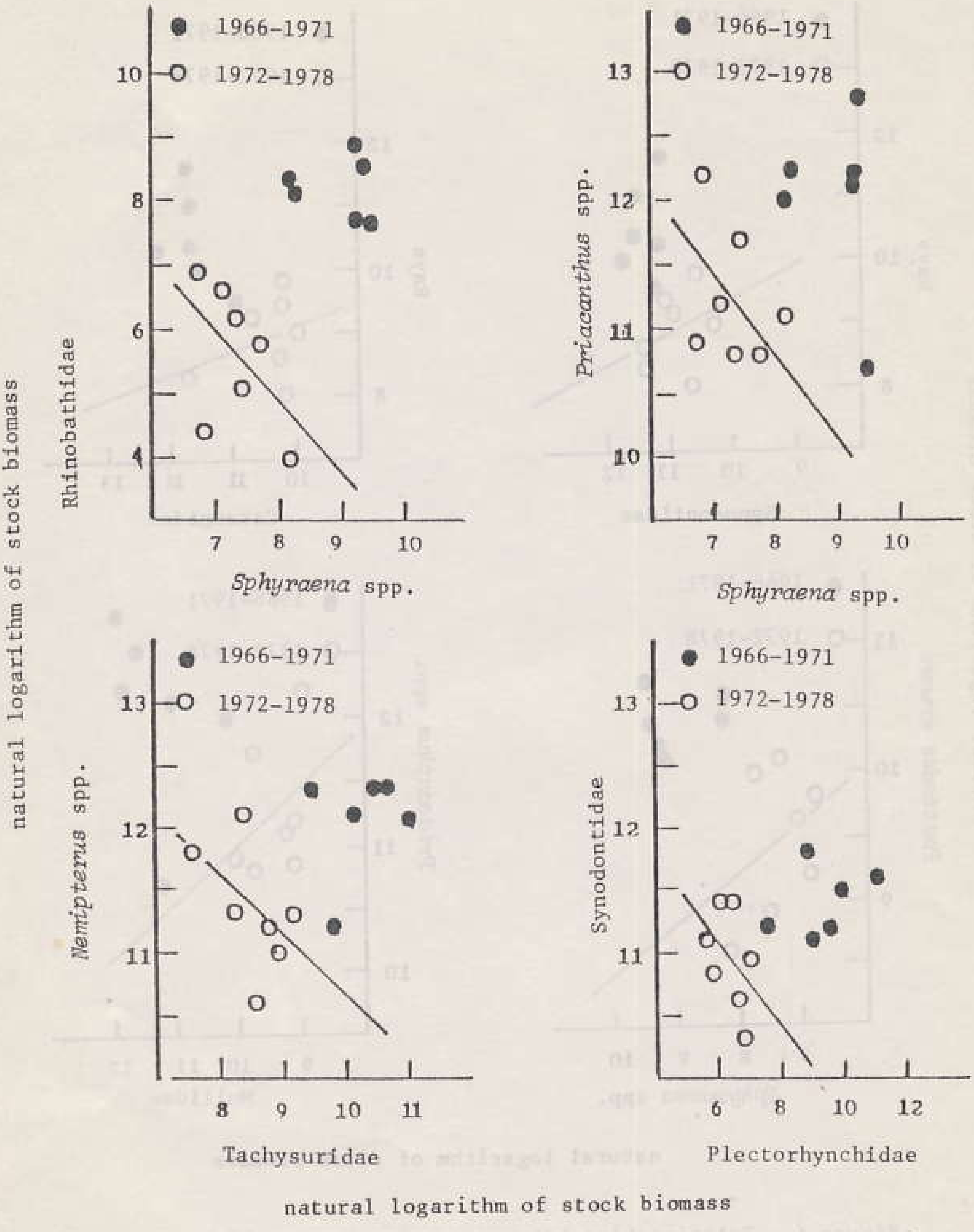

Figure 5. Relationships between species groups which are correlated at the 60% level

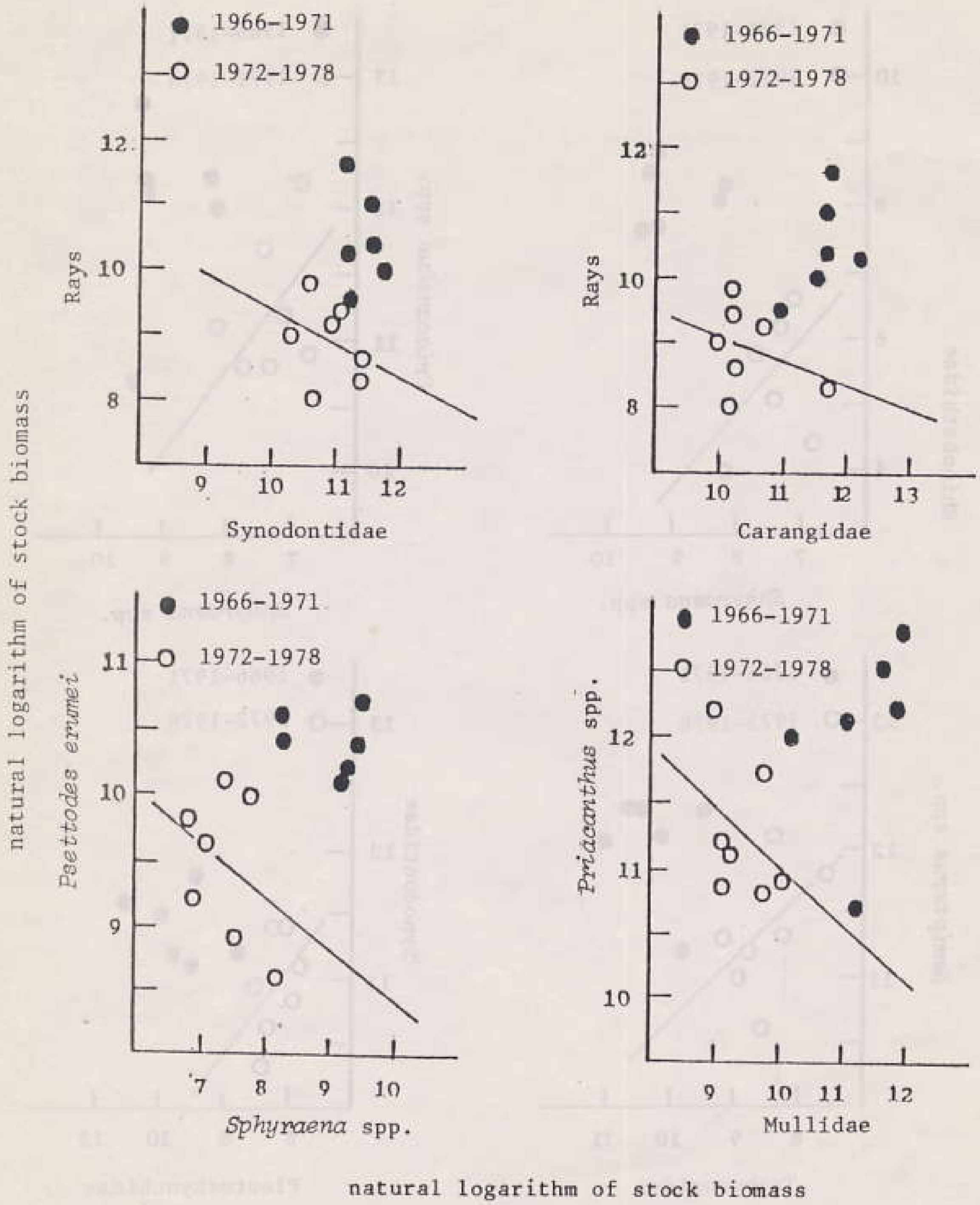

Figure 6. Relationships between species groups which are correlated at the 50% level.

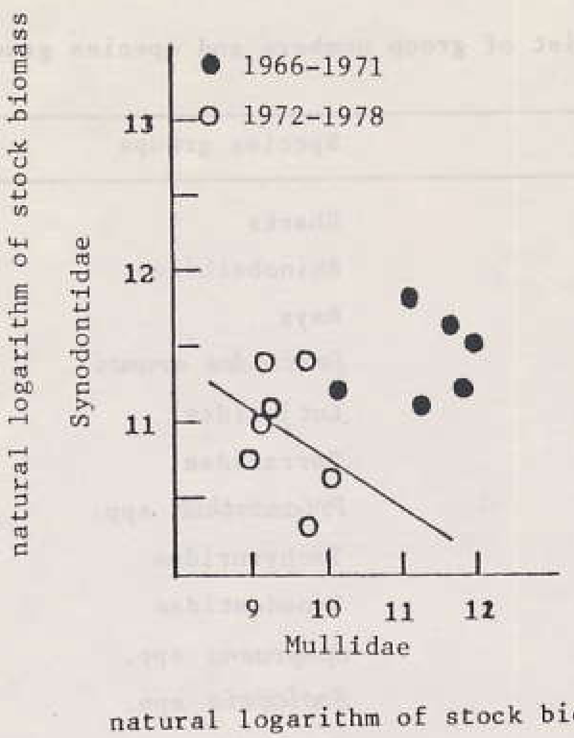

Figure 6. (Cont.) Relationships between species groups which are correlated at the 50% level

Table 1. List of group numbers and species groups

Group number	Species groups
1	Sharks
2	Rhinobathidae
3	Rays
4	*Psettodes erumei*
5	Lutjanidae
6	Serranidae
7	*Priacanthus* spp.
8	Tachysuridae
9	Synodontidae
10	*Sphyraena* spp.
11	*Scolopsis* spp.
12	Carangidae
13	Mullidae
14	Leiognathidae (and Gerridae)
15	*Nemipterus* spp.
16	Plectorhynchidae
17	*Pomadasys* spp.

Table 2. Correlation analysis for the period 1966 to 1978

species groups	1	2	3	4	5	6	7	8	9	10	11	12	13	14 1/	15	16	17 2/
1	1	.773	.769	.649	.756	.645	.344	.800	.494	.616	.696	.660	.714	.628	.502	.672	.762
2		1	.721	.862	.866	.882	.403	.764	.456	.630	.790	.665	.824	.775	.712	.823	.699
3			1	.701	.816	.712	.133	.865	.319	.811	.720	.622	.839	.952	.613	.800	.910
4				1	.693	.645	.185	.753	.745	.524	.725	.449	.641	.814	.417	.748	.713
5					1	.906	.519	.827	.623	.840	.866	.884	.959	.784	.841	.949	.848
6						1	.506	.657	.571	.709	.734	.686	.900	.776	.765	.862	.742
7							1	.331	.603	.333	.600	.517	.533	-.038	.438	.552	.222
8								1	.294	.846	.849	.729	.850	.843	.545	.786	.925
9									1	.525	.499	.699	.502	.453	.721	.535	.575
10										1	.695	.771	.820	.831	.709	.742	.910
11											1	.815	.893	.656	.682	.902	.860
12												1	.832	.728	.844	.779	.872
13													1	.809	.822	.934	.863
14 1/														1	.852	.737	.882
15															1	.733	.851
16																1	.798
17 2/																	1

1/ 1966-1975 only;

2/ 1966-1974 only

Table 3. Correlation analysis for the period 1972 to 1978

species groups	1	2	3	4	5	6	7	8	9	10	11	12	13	14 1/	15	16	17 2/
1	1	.567	.349	.327	.426	.096	-.156	.292	.219	-.588	.239	.144	.067	.070	-.106	.299	.997
2		1	.414	.770	.663	.802	-.549	.150	-.100	-.476	.185	-.094	.415	.871	.260	.652	.967
3			1	.321	.385	.389	-.850	.470	-.343	.283	-.300	-.341	.478	.880	-.046	.445	.952
4				1	.417	.441	-.519	.461	.625	-.349	.240	-.326	.153	.893	-.241	.858	.923
5					1	.572	-.626	.107	.259	.099	-.013	.512	.413	.840	.597	.645	.959
6						1	-.602	-.216	-.015	-.096	-.132	-.129	.527	.932	.609	.357	.862
7							1	-.254	.225	-.397	.449	.246	-.360	-.976	-.167	-.615	-.995
8								1	-.690	-.148	.522	-.090	.434	.741	-.488	.681	.953
9									1	.102	-.299	.647	-.335	-.332	.563	-.458	.156
10										1	-.682	.084	-.064	.543	.119	-.095	.437
11											1	.306	.413	-.524	-.101	.334	-.500
12												1	.171	.079	.608	.029	.528
13													1	.751	.456	.437	.634
14 1/														1	.968	.920	.994
15															1	-.048	.930
16																1	.954
17 2/																	1

1/ 1972-1975

2/ 1972-1974

Table 4. Summary of the results of the analysis for some pairs of species groups during the period 1972 to 1978

Species groups (Y and X)	Y-intercept	Slope	Correlation[1] coefficient (r)	Coefficient of determination (r^2)	Sample size (n)
95% level					
Rays and *Priacanthus* spp.	20.0254	-0.9882	-0.850	72.25	7
Leiognathidae and *Priacanthus* spp.	27.4162	-1.5834	-0.976	95.26	4
Plectorhynchidae and *Priacanthus* spp.	15.3853	-0.7809	-0.843	71.07	6
Rhinobathidae and *Priacanthus* spp.	22.0040	-1.4340	-0.832	69.22	6
Psettodes erumei and *Priacanthus* spp.	17.3336	-0.6839	-0.829	68.72	6
90% level					
Pomadasys spp. and *Priacanthus* spp.	6.4801	-0.1013	-0.995	99.00	3
Synodontidae and Tachysuridae	15.5511	-0.5406	-0.690	47.61	7
Scolopsis spp. and *Sphyraena* spp.	14.3576	-0.6182	-0.682	46.51	7
80% level					
Lutjanidae and *Priacanthus* spp.	13.7683	-0.5236	-0.629	39.56	7
Serranidae and *Priacanthus* spp.	15.9014	-0.6739	-0.602	36.24	7

1/ For $P > 0.05$, t-test is used, $t = \frac{r}{\sqrt{(1-r^2)/(n-2)}}$ with degree of freedom = n-2.

Table 4. (Cont.) Summary of the results of the analysis for some pairs of species groups during the period 1972 to 1978.

Species groups (Y and X)	Y-intercept	Slope	Correlation[1/] coefficient (r)	Coefficient of determination (r^2)	Sample size (n)
Sphyraena spp. and Sharks	9.8520	-0.3387	-0.588	34.57	7
Psettodes erumei and Carangidae	14.3920	-0.4535	-0.596	35.54	6
60% level					
Rhinobathidae and *Sphyraena* spp.	13.7837	-1.1134	-0.479	22.89	7
Priacanthus spp. and *Sphyraena* spp.	14.3794	-0.4259	-0.397	15.74	7
Nemipterus spp. and Tachysuridae	15.5129	-0.4867	-0.488	23.83	7
Synodontidae and Plectorhynchidae	12.9564	-0.3145	-0.458	20.97	7
50% level					
Rays and Synodontidae	14.7231	-0.5315	-0.343	11.75	7
Rays and Carangidae	12.7219	-0.3633	-0.341	11.60	7
Psettodes erumei and *Sphyraena* spp.	12.4597	-0.4031	-0.349	12.16	7
Priacanthus spp. Mullidae	15.4936	-0.4479	-0.360	12.97	7
Synodontidae and Mullidae	13.8856	-0.3121	-0.335	11.19	7

1/ For $P > 0.05$, t-test is used, $t = \frac{r}{\sqrt{(1-r^2)/(n-2)}}$ with degree of freedom = n-2.

Table 5. Summary of the occurrences of interactions between species groups given in the order of the most to the least frequent1/

Species groups	Frequency	Correlated species
1. *Priacanthus* spp.	10	Rays, Leiognathidae, Plectorhynchidae, Rhinobathidae, *Psettodes erumei*, *Pomadasys* spp., Lurjanidae, Serranidae, *Sphyraena* spp. and Mullidae.
2. *Sphyraena* spp.	5	*Scolopsis* spp., Sharks, Rhinobathidae, *Priacanthus* spp. and *Psettodes erumei*.
3. Synodontidae	4	Tachysuridae, Plectorhynchidae, Rays and Mullidae.
4. Rays	3	*Priacanthus* spp., Synodontidae and Carangidae.
5. *Psettodes erumei*	3	*Priacanthus* spp., Carangidae and *Sphyraena* spp.
6. Rhinobathidae	2	*Priacanthus* spp. and *Sphyraena* spp.
7. Plectorhynchidae	2	*Priacanthus* spp. and Synodontidae.
8. Carangidae	2	*Psettodes erumei* and Rays.
9. Mullidae	2	*Priacanthus* spp. and Synodontidae.
10. Tachysuridae	2	Synodontidae and *Nemipterus* spp.
11. Sharks	1	*Sphyraena* spp.
12. Serranidae	1	*Priacanthus* spp.
13. *Nemipterus* spp.	1	Tachysuridae
14. Lutjanidae	1	*Priacanthus* spp.
15. *Pomadasys* spp.	1	*Priacanthus* spp.
16. *Scolopsis* spp.	1	*Sphyraena* spp.
17. Leiognathidae	1	*Priacanthus* spp.

1/ They are given in the repeated form for easy cross checking