CHAPTER 4

DISCUSSIONS

Distribution

At Khang Khao Island, the number of the associations between the gobies and alpheid shrimps on the western side is much smaller than that on the eastern and northern sides. Factors that controlled the distribution of these associations might be the physical factors represented by wave and wind forces. The strong wave and wind occurred during the periods of S-W and N-E monsoon. Because of its location in relation to Sichang Island and the mainlan, Khang Khao Island is protected from the N-E monsoon, therefore the effect of the S-W monsoon is stronger and affects the western side.

Wave and wind forces affect the stability of bottom system, especially in the shallow areas. If wave and wind were always strong, the stability of the bottom system will be low. The associations of the gobies and alpheid shrimps occurred mainly on the shallow bottom where the sediment is composed of course sand packed with shell and coral fragments which tends to collapse easily. On the western side where wave and wind are always strong, the instability of the substrate makes it difficult for the burrowing animals, such as alpheid shrimp and its partner goby, to live. Not only the associations between the gobies and alpheid shrimps is low in number on this side but it is also true with the density and coverage of individual corals species (Sakai *et al.*, 1986). Menasveta *et al.* (1986) suggested that the differences in fish population on Khang Khao Island may be influenced by physiographical differences.

Biological interactions cannot clearly explain their distribution, because the occurrence of predator fishes, *Plectorynchus pictus* and *Epinepnerus malabaricus* are predominant in all stations around Khang Khao Island (Monkolprasit, 1986).

The gobiid fishes and alpheid shrimps which living in association

Colour variation in gobiid fishes. Since gobiid fishes are able to show colour variation in the same species, in this study, colour variation is also found in some species of gobiid fishes studied. This variation can be categorized into 2 case ; yellow colour pattern and vertical streaks.

In yellow colour pattern, the colour of the fishes appear in bright yellow rather than their normal colour patterns. This yellow colour patter was found in *Cryptocentrus cinctus*, *C. cyanotaenia*, *Cryptocentrus* sp.1 and *Cryptocentrus* sp.2. This phenomena was also recorded in *C. cinctus* from Japan (Yoshino & Senou, per. comm.) Details colouration of some species, such as blue spots on head of *C. cinctus* and blue broken straks on head of *C. cyanotaenia* do not change. In *Cryptocentrus* sp.1 and *Cryptocentrus* sp.2, prominent marking such as bands and blotches still appear but in brownish yellow.

In general, colour variations are the result from physiological changes concerning behaviour, social stage, sexual stage and environmental changes etc. In the case of yellow colour pattern, sex of the fish may play the important role, since the yellow colour pattern ocuure in female (Yoshino, per. comm.)

However, environmental adaptations should also be taken into consideration because some specimens of yellow goby when kept in the aqurium, their colour change into normal pattern in 1-3 days.

In the second case, the present and absent of ten to twelve equidistant vertical thin blue streaks, was found in *Cryptocentrus cinctus* and *C. cyanotaenia* both in normal and yellow colour pattern. This is also found in yellow *C. cinctus* from Japan (Senou, per. comm.)

Species specificity. The goby-alpheid shrimp associations showed a remarkable variation in the degree of species specificity. The combinations of the different species of the gobies and alpheid shrimps in this study are summarized in Table 10. This evidence was similar to that reported from the Red Sea (Karplus *et al.*, 1974), Seychelles Island, Western Indian Ocean (Polunin & Lubbock, 1977) and Shikoku Island, Japan (Yanagisawa, 1984).

The observations of many authors (Polunin & Lubbock, 1977 : Preston, 1978) and in this study indicated that the different species of alpheid shrimps showed differences in sensitivity to the movement of their partner gobies. For the gobies, Karplus *et al.* (1979) suggested that the different species of the gobies which associated with alpheid shrimp had evolved different levels of warning signal. This indicated that the different species of gobies and alpheid shrimps had different levels of communication system development, and the establishment of the association may occur for the pairs having a high level of communication development. But the association is established at the juvenile stage soon after settlement and maintained throughout their lives (Yanagisawa, 1984). In nature, there are many species of both gobies and alpheid shrimps occurring within the same area. If the establishment of the associations were random, then combinations of all species must be found. But this evidence has never been reported earlier. All these show that only the suitable

Table 10 Species specificity of gobiid fishes and alpheid shrimps found at Khang Khao and Sichang Island

Alpheid Shrimps / Gobiid fishes	*Alpheus* sp.1	*Alpheus rapacida* ?	*Alpheus distinguensus*	*Alpheus* sp.A	*Alpheus djiboutensis*	*Alpheus bellulus*	Uncollected alpheid shrimp
Myersina macrostoma			+	+			
Myersina sp.A			+				+
Ctenogobiops pomastictus					+	+	
Cryptocentrus caeruleomaculatus				+	+(21)	+	
Cryptocentrus singapurensis		+	+	+(3)	+(50)		
Cryptocentrus cyanotaenia		+					
Cryptocentrus cinctus	+(1)				+(2)	+(33)	
Cryptocentrus sp.1	+(8)					+(93)	
Cryptocentrus sp.2	+(13)					+(17)	+
Amblyeleotris sp.1						+(5)	
Amblyeleotris fontanesii	+						
Amblyeleotris gymnocephala	+(12)					+(15)	

Remark : Numbers in the brackets are the occurrence of each combination which is summarized from Tables 2, 6 and 7 combination pairs could survive against predatory or other pressures. Species specificity is likely to enhance the efficiency of transmission (Polunin & Lubbock, 1979) which allows a higher chance of survival. On the other hand, for non-specifics, there is provision for a greater number of availabe partners, and this will enable attainment of higher population densities. The balance of these two elements may be the reason for the variation in degree of specificity of these associations. So, the combination between the gobies and alpheid shrimps are not necessarily monospecific, but may be the combination between species group which had same or close communication development level between both animals.

The gobies and the alpheid shrimps may be grouped based on their associative behaviours. Yanagisawa (1978) distinguished symbiotic gobiid fishes in Japan into three groupings based on the differences in nature of the interrelationship with alpheid shrimp and the ways of utilizing their burrows. First, the species that hovers above the bottom and has never been observed to engage in the tactile alarm system which are represented by *Vireosa hanae* and the goby from Red Sea *Lotilia graciliosa*(Klausewitz, 1960). Second, the bottom dweller species which establish a tactile alarm system but the association seem rather weak. This group is respresented by *Acentrogobius pflaumi*, and from general observation in this study *Cryptocentroides insignis* can also be included in this group. These two groups had very weak relationship, so, they were excluded from this study. Lastly, the bottom dweller species that usually utilize burrows of snapping shrimps as sheltering place and have developed a tactile alarm system. All of the species found in this study are treated in this group. The differences in nature of utilization of their burrows and their social behaviour could further distinguish fishes of this last group into three sub-groups.

1. Species that always hover above the burrow entrance and feed on planktonic organisms. This sub-group is represented by *Myersina macrostoma* and *Myersina* sp.A . *Stonogobiops* spp. (Hoese & Randall, 1982) may also be included in this sub-group.

2. Species that guard the burrow entrance but always leaving its burrow to the adjacent burrow which have other gobies of the same species on guard, and sometimes dwelling freely on the bottom surface. Social interaction has always be seen among goby population. Gobies of this group feed on small benthic animals that live among the sediment, as shown by their sand-nipping feeding behaviour, *Ctenogobiops pomastictus* represented this sub-group. *Vanderhorstia ornatissima* (Polunin & Lubbock, 1979 ; Yanagisawa 1978) can also be included in this group.

3. Species that always guard at the burrow entrance and keeping in contact with alpheid shrimp. They always feed on small benthic organisms, but sometimes have been observed to feed on planktonic organisms. Other species in this study represent this sub-group. In the case of *Cryptocentrus caeruleomaculatus, C. singapurensis* and *C. cyanotaenia,* their tactile alarm system do not seem to be highly developed. They had rarely been observed to give warning signals by their various fin movement. For *Amblyeleotris gymnocephala, A. fontanesii* and *Amblyeleotris* sp.1, their tactile alarm system appear advanced, they always give warning signals by various fin movement, but they always move far away from the burrow entrance for social interaction. In *Cryptocentrus cinctus, Cryptocentrus* sp. 1 and *Cryptocentrus* sp.2, their general activities are always related to their partners activities.

For the alpheid shrimps, the differences in nature to response to movement of their associated goby and their activities outside the burrow are recognizable. They can be distinguished into two groups.

1. Species that responded to generalized movement of the goby. Activities outside the burrow of this group are restricted to the burrow entrance. Antennal contact with the partner goby is maintained all the time while it is outside the burrow. This group is represented by *Alpheus djiboutensis, A. distinguensus, Alphus rapacida*? and *Alpheus* sp.1.

2. Species that responded primarily to specilized warning signals of the goby. This group always moves far from the burrow entrance during its construction of the shallow depression straight from the burrow entrance. It will venture to distances beyond the range of antennal contact with the goby. This group is represented by *Alpheus bellulus* and *Alpheus* sp.1. This behaviour pattern is in similar to the of *A. purpurilenticularis* reported from the Red Sea (Karplus, 1979).

Relationship of the different association pairs.

Behavioural patterns in nature of two association pairs, *Cryptocentrus singapurensis-Alpheus djiboutensis* and *Cryptocentrus* sp.1-*Alpheus bellulus*, are clearly different (Fig. 23 and 24). In *C. singapurensis-A. djiboutensis*, the association pair does not seem to share a close relationship. Activities outside the burrow of this pair were discussed in another paper (Manthachitra, M.S.). Activities outside the burrow of *C. singapurensis* were mainly those of guarding and feeding, but these two activities had little relation. Although feeding at guarding position of the goby had been observed, it always left its partner shrimp and moved to the area around the burrow entrance for feeding. In *A. djiboutensis*, activities outside the burrow occurred only during the guarding period of the goby and were restricted to the burrow entrance. The alpheid shrimp had never been observed to move beyond 15 cm radius of the burrow entrance. So, its behaviour pattern is simple. *A. djiboutensis* is very sensitive to the movement of the goby. This may be one reason why shrimp activities were restricted to the burrow entrance, because each time the goby moves to other positions, the alpheid shrimp withdraws quickly into the burrow. This indicated that tactile alarm communication of this association is not highly developed.

For *Cryptocentrus* sp.1-*Alphus bellulus*, this association pair showed much closer relationship than the former. Activities outside the burrow of *Cryptocentrus* sp.1 were mainly on guarding and feeding and these two activities always occurred together. The other activities were also related to guarding. This indicated that the goby had a close relationship with its partner.

In *A. bellulus*, it is not sensitive to generalized the movements of the goby as in *A. djiboutensis*, but it always responds only to specialized warning signals of the goby. Therefore it has been observed performing its activities outside the burrow. Eventhough activities outside the burrow of *A. bellulus* are limited by activities of the goby, the goby also seemed to provide a chance for the alpheid shrimp to perform its activities outside the borrow. Thus, behavoural pattern outside the burrow of *A. bellulus* is much more complex than that of *A. djiboutensis*.

The major differences in behaviour outside the burrow of these two alpheid shrimps are that *Alpheus bellulus* always built a shallow depression on the bottom surface extending from the burrow entrance, which was never been observed in *A. djiboutensis*. This behaviour of the same species is also reported from Japan (Harada, 1969 ; Yanagisawa, 1984) and also reported for *A. purpurilenticularis* from the Red Sea (Karplus, 1979). *A. bellulus* built a depression while under the guard of *Cryptocentrus* sp.1, the goby moved forwards together side by side, and maintained contact with the shrimp. Sometimes the goby performed guard position away at the distal part of the depression, which might be as far away as 80cm from burrow entrance. The shrimp would leave its burrow without antennal contact with the goby and would repeatedly move between the entrance and the distal part of the depression. This behaviour is also reported from Seychelles (Polunin & Lubbock, 1977) and Japan (Yanagisawa, 1984). In laboratory, *Cryptocentrus* sp.1-*A. bellulus* also showed this behaviour. This behaviour indicated that the association between *Cryptocentrus* sp.1 and *A. bellulus* has well-developed communication, suggesting their close relationship.

Hence, communication or tactile alarm system development may explain the differences in relationship between the different association pairs. Although, the signalling of the gobiid fishes had not been recorded in this study but they were observed. For the gobies, *Cryptocentrus singapurensis* and *Cryptocentrus* sp.1. It is not clear that the signalling system between them are different, but it is belived that signalling development of *Cryptocentrus* sp.1 is more developed than that of *C. singapurensis*. From observations, *C. singapurensis* gave signal with one or two patterns of tail movement, tail beat and tail wave, while tail movement of *Cryptocentrus* sp.1 had three to four patterns ; tail flick, tail beat and tail wave. Furthermore, movement of second dorsal fin and anal fin were always seen while the anternal contact was maintained. Karplus *et al.* (1979) concluded that the communication systems between *C. steinitzi* (now placed to the genus *Amblyeleotris* by Hoese & Steene (1976)) and *Alpheus purpurilenticularis* are probably the most advanced, because their warning signals were given with several fins movement and the dominant element is tail flicking. They also suggested the evolution of tail flick signal which is a more effective warning than another type of tail movement. The possibility of singalling with several fins movement enable the alpheid shrimp to move further away from the goby and still be protected through the warning system. Various fins movement of *Cryptocentrus* sp.1 is very close to that of *C. steinitzi.* So, it is believed that the development of warning signal of *Cryptocentrus* sp.1 is high too.

For the alpheid shrimps, *Alpheus djiboutensis* and *A. bellulus*, their response to the goby movements are clearly different. *A. djiboutensis* always responded to generalized movement of *Cryptocentrus singapurensis* by withdrawing or fleeing into the burrow whereas *A. bellulus* responded only to specialized movement of *Cryptocentrus* sp.1. The length of antennae may affect the tactile alarm system development of the alpheid shrimp. Preston (1980) suggested that the differences in the length of antennae of *A. rapax* and *A. rapacida* may affect the development of different behavioural symbiosis. The alpheid shrimp with long antennae can distinctly detect differences between a general movement and specialized signal of the goby whereas the alpheid shrimp with short antenae cannot distinguish these easily. To clarify this problem, antenna length of *A. djiboutensis* and *A. bellulus* were measured for comparison. Antenna length was expressed in relation to carapace length. Antenna length was taken by only the flagellum part of the longer side. Carapace length was measured from the tip of rostrum to middle of posterior margin of carapace. The result showed that *A. bullulus* had antenna longer than *A. djiboutersis* : *A. bellulus* 3.65 $\pm$ 0.38 (n=6) and *A. djiboutensis* 2.82 $\pm$ 0.30 (n=10). This result agrees with Preston's (1978) suggestion. The long antennae may indicate highly developed sense organ with high sensitivity. So, they can distinguish any movement better than short antennae, which have lower sensitivity. These long antennae may provide high development of tactile alarm system of the alpheid shrimp. Furthermore, they may induce the goby to develop the signal system.

Relationship of gobiid fishes and alpheid shrimps which living in association.

Although, relationship between the difference association pairs are different, but nature of relationship of these associations are the same. These associations are of mutually beneficial partnership. The goby used the burrow prepared by the alpherd shrimp as shelter and nesting site. With the presence of the goby to warn it against danger, the shrimp can place more energy toward shelter preparation and maintainance. The relationships between these associations can be summarized as in Fig. 26. The connections between different elements in that figure was the result of this study together with summarized information from of many authors (Harada, 1969 ; Karplus *et al.*, 1972, 1974, Karplus, 1979 ; Karplus *et al.*, 1979 ; Polunin & Lubbock, 1977 ; Yanagisawa, 1982, 1984)

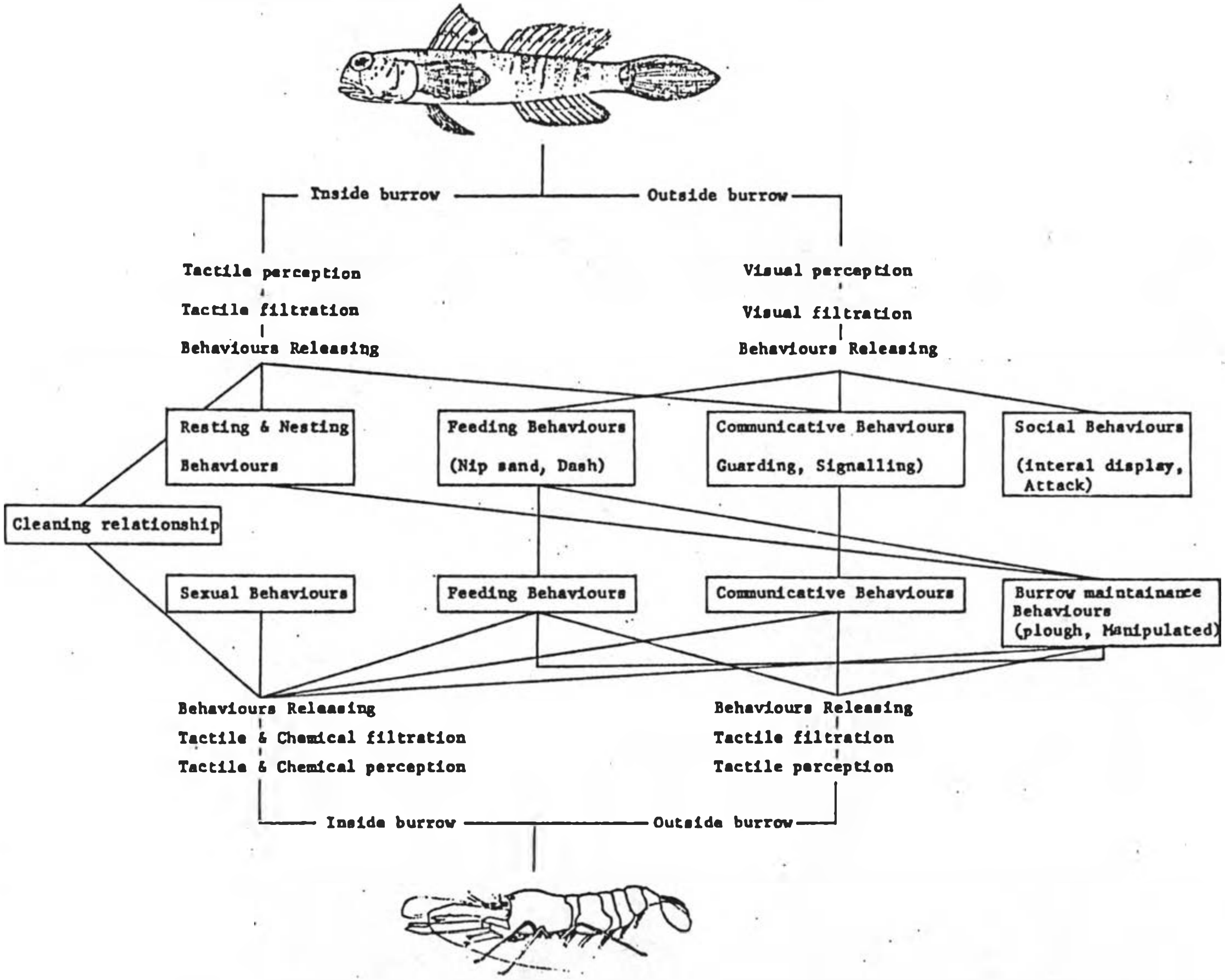

Fig. 26 Schematic diagram showing relationship between gobiid fishes and alpheid shrimps which living in association.

Outside the burrow, stimulus perception of the goby are mainly visual perception. Behaviour outside the burrow of the goby is mainly on feeding, communicative and social behaviour. The goby always feeds while it is on guard. So, feeding might be related to communicative behaviours. For the alpheid shrimp which has poor vision (Karplus, 1979), tactile perception is the most important. Behaviour outside the burrow of alpheid shrimp are mainly on burrow maintainance, communicative and feeding behaviours. Burrow maintainance and feeding outside the burrow depends on its communicative behaviour since these two activities occurred while antennal contact was maintained or under the guard of the goby. Feeding is always concerned with burrow maintainance. During its activity in scooping sediment out of the burrow and the depression, the alpheid shrimp often showed feeding behaviour on the materials found among the sediment. This has also been reported by some authors (Karplus, 1979, Yanagisawa, 1984). Communicative behaviours of the goby and the alpheid shrimp are related directly, this part is the most important for relationship of the goby-alpheid shrimp association. Communication between them occurred during contact between antenae of alpheid shrimp and various fins of the goby. Therefore, the signals are given with various fins, as well as by fins touched by the antenna of the alpheid shrimp.

From obsorvation of *Cryptocentrus* sp.1-*Alpheus bellulus*, while *A. bellulus* built a depression by ploughing sediment. the goby moved forward together side by side. During these activities, the goby often showed feeding behaviour on the sediment which was scooped up, by the alpheid shrimp. This showed that feeding behaviours of the goby might be concerned with burrow maintainance behaviours of the alpheid shrimp. For *C. singapurensis*-*A. djiboutensis*, while the goby showed feeding behaviour by nipping sediment, sometimes it has been observed transporting a small hermit crab or small bivalve back and leaving it within the burrow. It is belived that these activities may show food relationship. To clarify this problem, double minute hooks with bivalve flesh as baits were used and found that the goby always kept the first bait and brought it into the burrow. When the bait was pulled back gently to the burrow entrance, the alpheid shrimp would came out immediatly and tried to pull the bait back into the burrow. After the goby left the first bait in the burrow, it moved to the other bait, pulled it back to the burrow entrance at guarding position and fed on the bivalve flesh. Hence, it was often caught by this method. This demonstrate that if there were numerous food, the goby may collect food materials for its partner.

From laboratory observations, the alpheid shrimp always showed food storage behaviour but this behaviour occurred only when there were plenty of food. Thus in the presence of numerous food, the goby may collect food for the alpheid shrimp. The alpheid shrimp may feed on this food directly or may store it if it cannot consume all of that food. The stored food may be used later by the alpheid shrimp and the goby together. These relationships required more observations.

For behaviour inside the burrow observed in the laboratory, tactile perception might be important for the goby's communication. Auditory perception, although snapping sound had been heard in laboratory (Karplus *et al.*, 1972 ; Preston, 1978) is not well understood. The activities of the goby inside the burrow were very low because it used the butrow for resting. Many authors believed that nesting also occurred inside the burrow. This evidence was reported by Yanagisawa (1982). The goby can use the burrow only when that burrow was maintained by the alpheid shrimps. For the alpheid shrimp, tactile perception is still important. Chemical attraction may be involved in the shrimp's perception inside the burrow. Karplus *et al.* (1972) reported that the alpheid shrimp, *Alpheus djiboutensis* was chemically attracted to the goby, *Cryptocentrus cryptocentrus.* Preston (1978) suggested the possibility that a goby's presence or absence from the burrow entrance was transmitted to the shrimp by chemical means. Behaviour inside the burrow of the alpheid shrimp were mainly on burrow maintainance, feeding and communicative behaviours. But each behaviour was independent from the other to a higher degree than those occurring outside the burrow. For sexual behaviour, this seem to occur inside the burrow but there was no direct evidence to support. Yanagisawa (1984) suggested that a solitary shrimp could establish a pair bond when a resident of the conjoint burrow was a solitary one of the opposite sex. However, he had no direct evidence to describe how a solitary shrimp gets to meet with a mate. The further study in this aspect is necessary.

Karplus (1972) reported that the alpheid shrimp cleaned the goby inside the burrow near the entrance, but this was never been obserred in this laboratory study. Nevertheless, these cleaning activities may be involved and play important role in the goby-alpheid shrimp associations.