Food Agricultural Sciences and Technology (FAST)
Food Agricultural Sciences and Technology, 2025; *11*(3)

Research Article

The relationship between coral disease and abnormal symptoms with coral reef fish in the inner Gulf of Thailand: Si Chang Island coral reefs and adjacent area in Chon Buri, Thailand

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Abstract - The coral reefs in Chon Buri province are prone to degradation, given their proximity to estuaries and the influence of widespread tourist activities. This research assesses the impact of coral diseases and abnormal symptoms on the composition and diversity of coral reef fish species. The study focuses on Si Chang Island and its surrounding coral reefs at six stations. A video census technique was used to collect data for fish species diversity along 50-meter survey lines, with three replicates. For coral disease and abnormal symptoms, a photo belt transect method was employed within 0.5 m² areas along 30-meter survey lines, with three replicates at each station. The relationship between coral disease and abnormal symptoms in coral reef fish was suggested. Abnormal symptoms were significant in 17 species of coral reef fish. In addition, it was found that the relationship could not be determined, and species richness, diversity, and functional groups were not found to be related to coral disease or abnormal symptoms in corals. However, there is a trend of an inverse relationship between the coral disease and coral abnormalities with fish. To gain a comprehensive understanding of the relationship, it is imperative to gather more information on coral diseases that may affect coral reef fish. Future research should focus on expanding the study area and conducting a thorough examination of additional environmental factors.

Keywords: Coral disease, reef fish, species composition, environmental impact, Si Chang Island

Received: 7th May 2024
Revised: 27th December 2024
Accepted: 27th December 2024

Citation: Meenapha, A., Ruangjaroon, C., Boonrattanakom, V., Siriwong, S., & Putchakarn, S. (2025). The relationship between coral disease and abnormal symptoms with coral reef fish in the inner Gulf of Thailand: Si Chang Island coral reefs and adjacent area in Chon Buri, Thailand. *Food Agricultural Sciences and Technology (FAST), 11*(3), 208-220. https://doi.org/10.14456/fast.2025.16

1. Introduction

Coral abnormalities have significant impacts on coral reefs that have caused widespread mortality of coral colonies, reducing the overall abundance of corals, loss of coral cover, and decreasing biodiversity of marine life associated with a coral reef ecosystem, and can disrupt trophic dynamics and food webs (Bruno et al., 2003; Sutherland et al., 2004; Harvell et al., 2007). Coral abnormalities were separated into two groups. The first abnormal group is infected by pathogenic microorganisms, such as bacteria, fungi, virus, or protists. The second is impacted by environment such as temperature stress, sedimentation, toxic chemicals, nutrient imbalance and UV radiation (Raymundo & Harvell, 2008). The disease coral symptoms could be morphological abnormalities such as lost coral tissue with color band. However, the symptom might be the result from non-disease-related factors, such as predation from fish, crown-of-thorns starfish, disturbances from storms or anchor damage, competitive interactions between corals and other marine creatures (Raymundo et al., 2008).

In Thailand, the coral diseases and compromised health states on massive coral (*Porites* sp.) were reported both in the inner and western Gulf of Thailand and the Andaman Sea. The nine coral diseases were found as follows, pigmentation responses (e.g., pink lines, pink patches, pink spots, and pink borers), white syndromes (e.g., white patches, white bands, and ulcerative white spots), growth anomalies, and unusual bleaching patterns (Samsuvan et al., 2019). These coral diseases were found to be the same as in the Lord Howe Island Marine Park in Australia. The results showed that the coral diseases within the high-latitude reef and coral diseases were identified by four symptoms, such as white syndrome, skeletal eroding band, growth anomalies, and overgrowth of fungi (Endolithic hypermycosis). *Acorpora* spp. and *Pocillopora* spp. are high prevalence of disease cover (Moriarty et al., 2023). Coral abnormalities often lead to changes in the physical structure of coral reef which impact on shelter, feeding ground, and breeding for reef fish. The changed structure of coral reef may also be influential on the coral reef fish community change (Pratchett et al., 2011). Coral reefs support extensive biodiversity and provide important ecosystem services, giving essential food to many millions of people. Coral reefs are degrading rapidly in response to anthropogenic activities and increasing populations, e.g., nutrient runoff, coastal development, climate change, anchor damage, and pollution from marine tourism (Hawkins & Roberts, 1992; Fabricius, 2005; Hoegh Guldberg, 2007; Hughes et al., 2017). At present, climate change is one of the most common factors in coral abnormalities, especially coral bleaching (Heron et al., 2016; Hughes et al., 2017). Ocean warming anomalies possibly enhance outbreaks of some diseases, because corals are less able to be against disease under temperature stress (Raymundo et al., 2008). The high seawater temperature increases carbon dioxide (CO_2) in the seawater which contributes to ocean acidification, and interrupts the ability to build calcium carbonate structures of coral skeleton (Kleypas et al., 1999). The lost calcium carbonate of coral skeleton will lead to reduce habitat for reef fish species, trending to decline in biodiversity and fish communities (Graham et al., 2011). Coral reef degradation directly impacts on shelter and food sources (abundance of small invertebrates and algae associated with coral) that lead to change feeding behavior and migration patterns of reef fish species (Sale et al., 2005; Munday et al., 2008; Wilson et al., 2010). Raymundo et al. (2009), who have studied functionally diverse reef-fish communities, ameliorate coral disease on coral reefs across the central Philippines, and they found that butterflyfish (Chaetodontidae) have a strong positive relation ($P < 0.05$) with coral disease prevalence. On the other hand, in Thailand, there is no data about

the relationship between coral disease and abnormal symptoms that may affect coral reef fish species and the community, especially in the inner Gulf of Thailand, where numerous human activities such as marine tourism, fishery, and commercial port. Si Chang Islands and surrounding area have many coral reefs that are famous for tourist attractions and local fishery which is economic base of local people. Therefore, it is very necessary to study the status of coral reefs which may affect the deterioration of coral reefs caused by tourist activities, global warming, coral diseases, and abnormal symptoms of corals that affect the reef fish community. Understanding the impacts of coral diseases on the species composition and diversity of coral reef fish is crucial for developing effective conservation and management strategies to protect and restore coral reef ecosystems.

2. Materials and methods

This study investigated the relationship between coral diseases and abnormal symptoms with coral reef fish at Si Chang coral reefs adjacent area on six stations (Figure 1).

Figure 1. The study areas are at the Si Chang coral reefs adjacent area.

2.1 Coral diseases and abnormal symptoms on corals

The diseases and abnormal symptoms were collected by the Photo belt transect method on three replicates of a 30-meter survey line (Hodgson et al., 2006). Then, the photos were taken on a quadrat size 0.5 m^2 on both sides of survey line, covering 30 m^2 for each line, and all images were identified to coral genera by the program Coral Point Count with Excel extensions (CPCe) (Kohler & Gill, 2006). The program was set up by specifying the stratified points, assigned to random five rows and columns, 25 points in each picture to assess the percentage prevalence of coral diseases, modified from the methodology of Beeden et al. (2008) and Raymundo et al. (2008) (Table 1).

Table 1. Diseases and abnormal symptoms on corals.

Disease/compromised health sign	Code	Descriptions
Partial mortality	PM	The recent or old death of part or all of a colony
Growth anomalies	GA	Skeletal deformations from normal coral lifeform
Borers	BR	Skeletal deformations with the presence of invertebrates such as crabs and barnacles within or above the colony surface
Sediment damage	SED	The colony surface and living tissue accumulated with sediment
Pigmentation response	PR	Multifocal and diffuse patterns of tissue loss, showing bright pink, purple or blue tissue discoloration

2.2 Diversity of coral reef fish

The biodiversity of coral reef fish was collected by Video census method (Hill & Wilkinson, 2004) on three replicates of the 50x5 meters survey line (250 m^2 for each station). Coral reef fish species were identified and counted number of fish was counted from a recorded video in the laboratory. The diversity indices were calculated using Simpson's Index from the data of coral reef fishes.

2.3 Relationship between coral diseases and abnormality with coral reef fish

The relationship between coral diseases and abnormal symptoms on the species composition and diversity of coral reef fish was investigated using Spearman rank Correlation (Aggarwal & Ranganathan, 2016), with the maximum level of significance set at P value less than 0.05 ($P < 0.05$).

3. Results and discussion

3.1 Coral diseases and abnormal symptoms on corals and coral cover

The diseases and abnormal symptoms of corals on six stations showed 8 types of diseases as follows: borers, sediment damage, growth anomalies, partial mortality, pigmentation response, partial mortality joined with borers, partial mortality joined with sediment damage, and borers joined with sediment damage. Borers are the predominant abnormality, prevalent at 49.7%, a common abnormal symptom worldwide (Haapkylä et al., 2007; Hoeksema et al., 2022), followed by sediment damage at 12.95% (Table 2), caused in the inner Gulf of Thailand influenced by sediment through its four main rivers by wastewater from domestic and industrial sources (Ubonyaem et al., 2023). Percentage of coral cover, 22 genera of coral were found, and the massive coral (*Porites* sp.) at 86.4%, followed by *Turbinaria* sp. at 19.2% (Figure 2), are predominant corals in this study. *Porites* sp. is consistent with other coral reefs in the Gulf of Thailand in which *Porites* sp. is the dominant coral species (Yeemin et al., 2009; Phongsuwan et al., 2013; Aunkhongthong et al., 2021). Considering in detail, borers are predominant abnormal symptom which is consistent with the coral cover. The borer was found in the dominant Porites coral. The borers are often found on Porites coral and tendency is towards increased violence when compared with other diseases (Wongnutpranont et al., 2021). Borers is caused by parasites and are spread through nutrient-rich water and suspended sediments (Bruno et al., 2003). Corresponding with this study, Si Chang

Island has been used for transportation industry, community tourism for a long time and high loading of nutrients in this area, which supports borers as the dominant abnormal symptom in the Si Chang study areas.

Table 2. The percentage prevalence of diseases and abnormal symptoms on corals.

Disease or abnormal symptom	% Prevalence						AVG.
	St1	St2	St3	St4	St5	St6	
Borers	49.05	66.13	48.30	47.24	49.40	38.11	49.71
Sediment damage	9.31	21.83	3.20	5.45	6.55	31.38	12.95
Growth anomalies	3.02	0.00	0.00	0.00	0.00	0.00	0.50
Partial mortality	21.16	4.48	9.86	22.47	5.51	0.00	10.58
Pigmentation response	0.00	0.00	13.47	10.99	12.50	0.00	6.16
Partial mortality joined with borers	0.00	0.00	0.00	0.00	0.00	1.67	0.28
Partial mortality joined with sediment damage	0.00	0.00	0.00	0.00	0.00	23.86	3.98
Borers joined with sediment damage	0.00	7.56	0.00	0.00	0.00	0.00	1.26

3.2 Diversity of coral reef fish

The number of coral reef fishes at Si Chang Islands showed 12,628 fishes from 51 species and 21 families. Pomacentridae is the predominant family and abundance of coral reef fish in this study (11 species), followed by Labridae (5 species). Pomacentridae and Labridae are prominent coral reef fish families on coral reefs in Thailand and the Gulf of Thailand (Manthachitra & Sudarab, 2002; Noonsang et al., 2016). Considering coral reef fish abundance, *Neopomacentrus anabatoides* was the most prominent coral reef fish (4,254 individuals), followed by *N. filamentosus* (3,532 individuals). *Neopomacentrus* usually occurs in large schooling fish. They are the main species found on coral reefs around the world (Froese & Pauly, 2024). As a result, the population of this schooling fish is large when compared with that of other fish species. While 9 coral reef fish species were found, only one fish in the field survey is as follows: *Halichoeres marginatus*, *Epinephelus quoyanus*, *Cephalopholis boenak*, *Taeniamia fucata*, *Arothron stellatus*, *Plectorhinchus gibbosus*, *Gerres erythrourus*, *Upeneus tragula*, and *Plotosus lineatus* (Figure 3). These coral reef population is normally low, except cardinal fish (*T. fucata*) that school under the caves (Myers, 1991) and shelter of branching corals (Randall, 1990). However, *Acropora* coral in this study was found in low cover area (2.3%), while *T. fucata* was found only one individual. The western part of Ko Khang Khao (Station 3) has a high species richness (29 species), while Had Thai Ta Muen (Station 4) has the lowest species richness (18 species). The diversity index was found that Ko Kham (Station 6) has high diversity (0.81), followed by Had Thai Ta Muen (Station 4) (0.80), while Ko Khang Khao (Station 3) is the lowest diversity (0.63) (Figure 4).

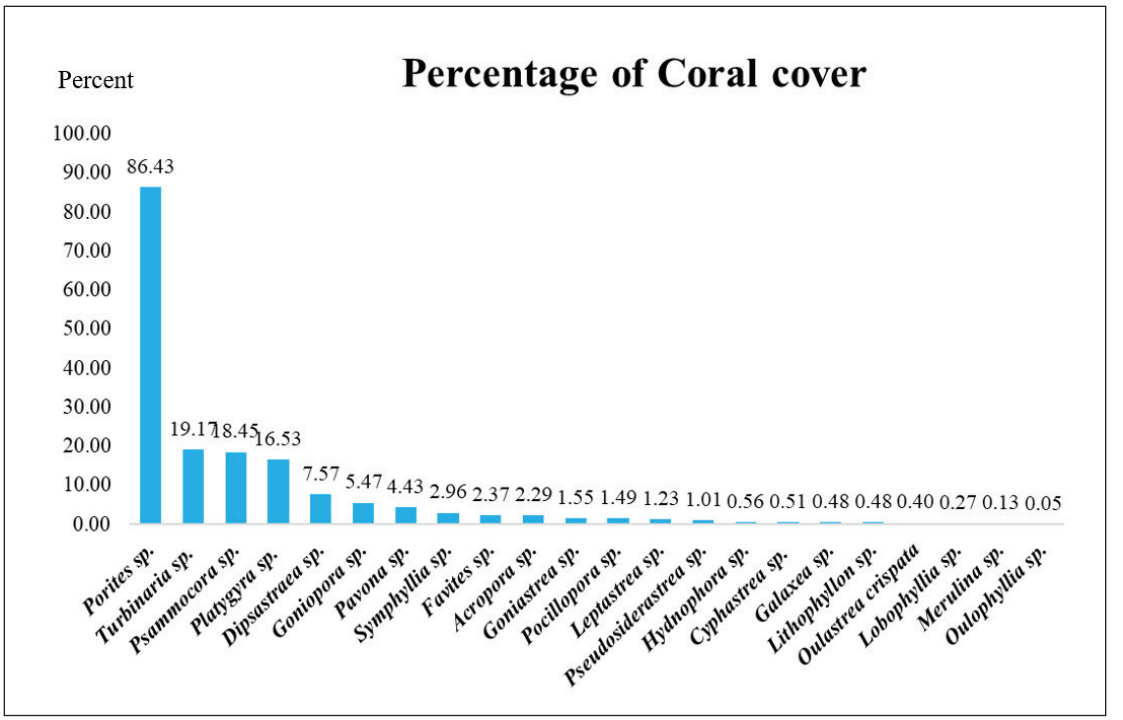

Figure 2. The percentage of coral cover in Si Chang Islands (six stations).

3.3 Relationship between coral disease and abnormal symptoms with coral reef fish

The results showed that 17 fish species were found to be associated with disease and coral abnormalities. However, the relationship cannot be determined in detail, but there is a trend of an inverse relationship between the coral disease and coral abnormalities and coral fish. To understand the relationship more clearly, the relationship between coral disease and abnormal symptoms of corals and fish at the genus level, species richness, and diversity, including functional groups of coral reef fish was analyzed. The results found that the species richness, diversity, and functional groups were not related to coral disease or abnormal symptoms of corals (Table 3). The study of relationships at the genus level was still in doubt; the true relationship is the same as the result of the relationship at the species level. The results of this study are different from studies abroad that mostly found a relationship between coral disease and reef fish communities, such as in the study by Raymundo et al. (2009), which found that butterflyfish have a positive relationship with the disease. This may be due to the difference in coverage of coral species, especially in the inner Gulf of Thailand, where massive coral (*Porites* sp.) is the highest cover area in coral reef, while other study areas of that relationship are mostly covered with *Acropora* sp. (Harvell et al., 2007; Raymundo et al., 2009). *Acropora* species are particularly susceptible to damage from environmental stresses (Palacio-Castro et al., 2021). In addition, the different results could be due to the disturbances on coral health in the Indo-Pacific that are more impacted by environmental pressures than disease (Harahap & Sunarto, 2021).

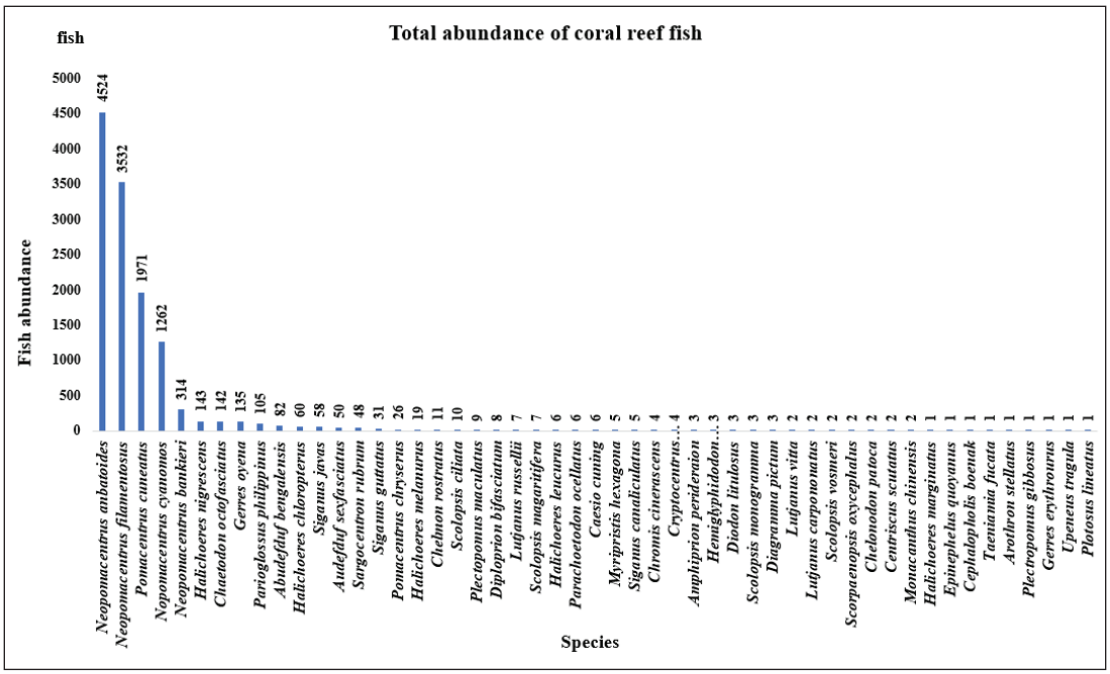

Figure 3. Total abundance of coral reef fish on six stations.

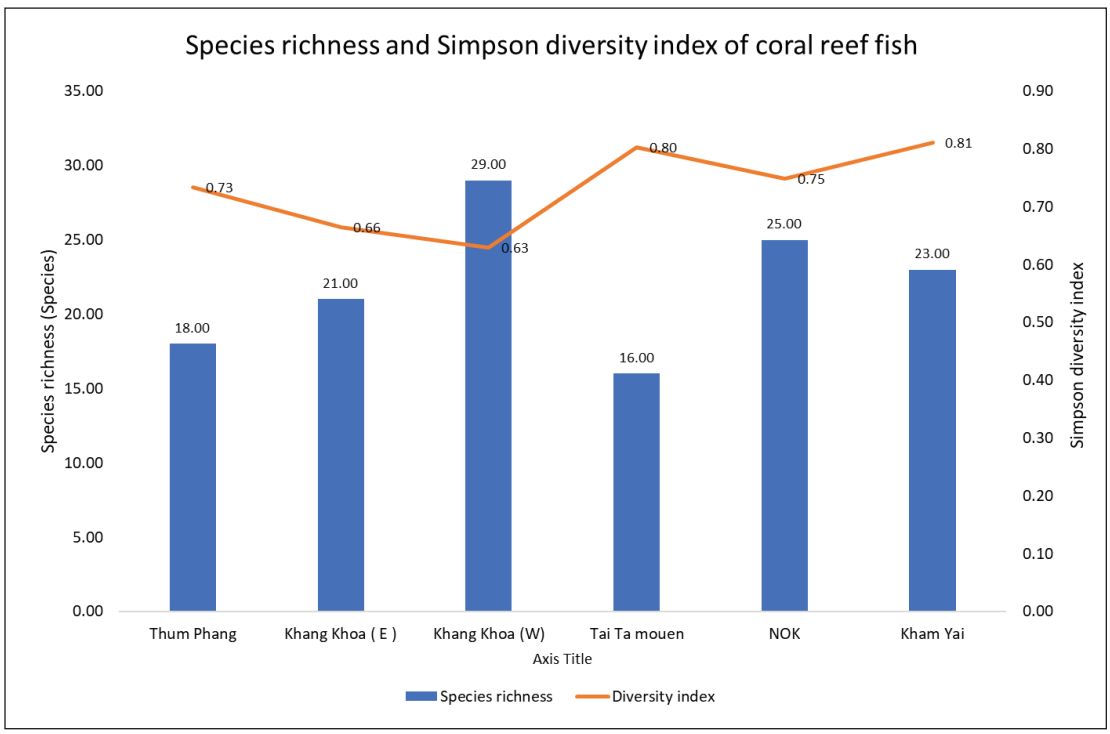

Figure 4. Species richness and Simpson diversity index of coral reef fish.

Table 3. Spearman's correlation coefficient analysis between coral disease and abnormal symptoms with coral reef fish (* = Significant, P < 0.05).

Fish taxa / functionally	Spearman's correlation coefficient							
	BR	**SED**	**GA**	**PM**	**PR**	**PMBR**	**PMSED**	**BRSED**
Audefduf sexfasciatus	0.38	-0.71	-0.39	0.60	0.88*	-0.65	-0.65	-0.13
Abudefduf bengalensis	-0.13	0.39	-0.20	-0.39	-0.42	-0.20	-0.20	1.00**
Amphiprion perideraion	-0.13	0.39	-0.20	-0.39	-0.42	-0.20	-0.20	1.00**
Halichoeres marginatus	-0.22	-0.85*	-0.31	0.03	0.47	-0.31	-0.31	-0.31
Plectopomus maculatus	-0.79	0.78	-0.13	-0.90*	-0.80	0.66	0.66	0.40
Sargocentron rubrum	-0.22	-0.85*	-0.31	0.03	0.47	-0.31	-0.31	-0.31
Diodon litulosus	0.46	-0.76	-0.42	0.64	1.00**	-0.42	-0.42	-0.42
Scolopsis magaritifera	-0.13	0.39	-0.20	-0.39	-0.42	-0.20	-0.20	1.00**
Scorpaenopsis oxycephalus	-0.13	0.39	-0.20	-0.39	-0.42	-0.20	-0.20	1.00**
Chelonodon patoca	-0.57	0.85*	-0.31	-0.85*	-0.65	0.77	0.77	0.46
Diagramma pictum	0.84*	0.00	0.63	0.83*	0.22	-0.32	-0.32	-0.32
Cryptocentrus caeruleopunctatus	-0.53	0.65	-0.20	-0.65	-0.42	1.00**	1.00**	-0.20
Gerres oyena	-0.53	0.65	-0.20	-0.65	-0.42	1.00**	1.00**	-0.20
Gerres erythrourus	-0.53	0.65	-0.20	-0.65	-0.42	1.00**	1.00**	-0.20
Upeneus tragula	-0.53	0.65	-0.20	-0.65	-0.42	1.00**	1.00**	-0.20
Centriscus scutatus	-0.53	0.65	-0.20	-0.65	-0.42	1.00**	1.00**	-0.20
Plotosus lineatus	-0.53	0.65	-0.20	-0.65	-0.42	1.00**	1.00**	-0.20
Species richness of coral reef fish	-0.20	0.49	-0.13	-0.14	-0.03	0.65	0.65	-0.39
Diversity of coral reef fish	-0.51	-0.41	-0.40	-0.46	-0.03	-0.13	-0.13	0.27
Carnivore	-0.06	-0.26	-0.65	0.14	0.70	0.13	0.13	-0.39
Herbivore	-0.75	0.43	-0.13	-0.77	-0.70	0.13	0.13	0.65
Omnivore	-0.55	-0.49	-0.39	-0.43	0.03	-0.13	-0.13	0.13
Planktontivore	0.38	-0.71	-0.39	0.60	0.88*	-0.65	-0.65	-0.13

The results showed that the species richness and diversity of coral reef fish were not significant in terms of coral disease and abnormal symptoms. However, the relationship trend of those factors with quadratic regression was found; the diversity of coral reef fish increased when the percentage of prevalence of disease and abnormal symptoms increased. When disease and abnormal symptoms increased by 87%, the diversity of coral reef fish would decrease, while the species richness of coral reef fish would invert the relationship of the diversity. The species richness will decrease when the prevalence of disease and abnormal symptoms increases. The species richness of coral reef fish increased when disease and abnormal symptoms of coral increased after 85% (Figure 5). Although there are not many studies on the relationship between fish communities with diseases and abnormalities, the results

showed that most of the diseases and abnormal symptoms of corals were borers (Table 2). Those borer corals could still be alive, but there are a large number of borers, which may cause coral death and affect the health of the coral reef. This will be a consecutive change in the fish community. Pratchett et al. (2011) reported that the dead coral cover increased, and fish community decreased. In addition, when the rate of dead coral cover increased to approximately 40% of the area, they found that the fish community increased, which is the result of changes in functional groups of the fish population. From Spearman's correlation coefficient analysis (Table 3), the results show that the carnivorous fish groups decreased; on the other hand, herbivorous fish immigrated and were replaced when there was a higher incidence of disease and abnormal symptoms.

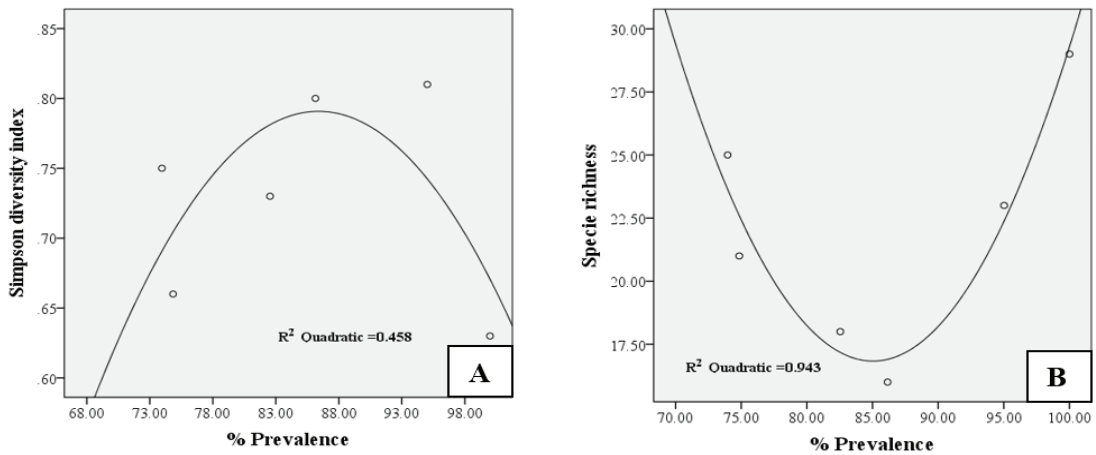

Figure 5. The quadratic regression between (A) diversity with percentage prevalence, and (B) species richness with percentage prevalence.

4. Conclusion

The study conducted at six stations around Si Chang Island revealed a significant relationship between coral diseases and abnormal symptoms and coral reef fish; 17 species were found affected, but no clear pattern of relations was established. The species richness and diversity of coral reef fish showed no significant correlation with these coral diseases and abnormal symptoms. However, there is a trend of an inverse relationship between coral disease and coral abnormalities and fish. In detail, borers were extremely prevalent in Porites coral, but these corals remained alive despite being damaged by borers and had no effect on changes in the status of coral reefs in the study area. Nevertheless, an excessive number of borers could lead to coral mortality, impacting the overall health of the reef, and alter the coral reef fish community, particularly affecting on functional groups of fish, which may be replaced by others as different groups decline. The variety of coral lifeforms and coral cover are factors influencing coral reef fish communities. In the inner Gulf of Thailand, massive coral (*Porites* sp.) is a predominant coral cover; therefore, the fish community living on massive corals is more diverse than the fish living in the branching corals. This may be a factor that makes not clearly identify the relationship between fish communities and coral disease when compared to studies in other countries, where the coverage rate of coral reefs is mostly branching coral. Moreover, the location of Si Chang Islands may cause environmental stress to coral abnormalities (e.g., sediment, transportation,

industrialization, and expansion of coastal communities) rather than climate change. To gain a comprehensive understanding of these relationships, it is imperative to gather more information on coral diseases that may affect coral reef fish. Future research should focus on expanding the study area and thorough examination of additional environmental factors.

Ethics declaration

In our data collection process, we did not get out whole living things and there is no life on the coral reef. By the way, the study took pictures and videos to collect information, and the diver will float 1-1.5 meters above the coral reef to prevent diving equipment or any part of the researcher from contacting the coral. As well as all researchers receive training in diving skills to collect scientific data and have a diving license from a diving institute that meets standards.

Acknowledgement

We would like to appreciate the Institute of Marine Science, Faculty of Marine Technology, Burapha University. This research field works and the preparation of the manuscript was supported by the assistant researchers and researchers of the Sustainable human resource potential development on marine taxonomy was supported by Burapha University, Thailand Science Research and Innovation (TSRI), National Science Research and Innovation Fund (NSRF) (Fundamental Fund: Grant no.4/2565 and Grant no.2/2566).

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