Monitoring and assessment programme on plastic litter in Viet Nam shoreline Report 2020

Chu The Cuong, Bui Thi Thu Hien, Nguyen Thi Thu Trang & Nguyen My Quynh

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Acknowledgements

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I. INTRODUCTION

Marine plastics are one of the most serious and alarming global environmental problems. The issue of plastic pollution was first recognized in the 1970s, but so far the quantification and identification of its sources is still incomplete. In 1975, the maritime transport industry, military activities, and ship accidents at sea alone released into the ocean an estimated 6.4 million tons of plastics, and 80% of plastic debris in the ocean originated from land. However, this data was unclear and could not fully enumerate the amount of plastics that have entered the ocean. In a research published in 2015, Jenna R. Jambeck and her colleagues estimated that out of 275 million tons of plastic produced by 192 coastal countries in 2010, 4.8 to 12.7 million tons of plastic waste entered the ocean (J. R. Jambeck et al., 2015). At the moment, according to the United Nation Environment Programme's Report (Programme, 2018), each year the world consumes about 500 billion plastic bags and 13 million oil barrels to produce plastic, one million plastic bottles are purchased every minute and 100,000 marine animals die from plastic debris. The quantity of plastic products produced annually has increased by 20 times in the last 50 years and is expected to double in the next 20 years. It is predicted that by 2050, the entire world will produce 1,124 million tons of plastic unless plastic products are thoroughly collected, recycled, and reused, creating a global "white pollution".

The amount of waste entering the natural environment or buried underground is ever-increasing, 10% of which is plastic waste. Plastic waste pollutes several natural habitats, including terrestrial, freshwater, marine habitats, and even high-altitude habitats. In the early 1960s, there were some of the first reports on plastic waste found in birds collected from the beach. By now, from coastal waters, tidal flats, to the deep sea, from the poles to the equator, marine plastic waste has become too ubiquitous and the level of its harmful impacts cannot be overstated. Most of plastics can float on water, so a large amount of marine plastic debris is washed ashore by waves or currents. That resulted in plastic making up a considerable percentage (50-80%) of the waste found on the shoreline (Barnes, Galgani, Thompson, & Barlaz, 2009). Certain plastics can sink to the sea bottom, sometimes even to a depth of thousands of meters, where their decomposition time will be seriously slowed down because of the lack of light and low temperature.

In addition to plastic waste spoiling beach landscapes, they also threaten marine economic activities including fishing and tourism. Floating abandoned fishing nets (ghost nets) can really adversely affect fishermen. Floating plastic debris becomes a means of transport for non-native species, many of which are invasive. The most serious and visible issue to the public and media is the widespread presence of plastic in the digestive system of animals or how it has become a trap for larger wildlife. More than 260 species including invertebrates, sea turtles, fish, sea birds and mammals have been found to ingest or get entangled in plastic debris, leading to impaired digestion, movement, reproductive output and death. A wide range of small invertebrates are also vulnerable to ingesting plastic debris, but studies on the impacts of plastic on these species are still very limited. There are several populations with a very high rate of having plastic in the digestive systems. 95% of the eels washed ashore in the North Sea have plastic in their intestines. An estimated 90% of seabirds ingest plastic, which is projected to increase to 99% by 2050. This figure is 35% in of fish species that eat plankton in the North Pacific. Other examples include mollusks, crustaceans, etc. (Gregory, 2009). In addition, more and more microplastics (size <5 mm) are detected in the digestive systems of marine animals (Barnes et al., 2009).

In addition to the mechanical impacts, plastic debris also transfer harmful substances to the food chain (Thompson, Moore, vom Saal, & Swan, 2009). In the marine environment, plastic debris contains hazardous organic chemicals such as polychlorinated biphenyl (PCB), polycyclic aromatic hydrocarbon, dichlorodiphenyltrichloroethane (DDT), polybrominated diphenyl ether (PBDE), alkylphenol, and bisphenol A (BPA). The transfer rates of these polluting compounds vary depending on the animals' exposure to the chemicals and the movement of the polluting chemical compound (Thompson, 2015) Laboratory exposure studies have shown that Phthalates and BPA affect fertility in all studied animal groups and impair growth in crustaceans and amphibians. Most plasticizers are endocrine disruptors. Through laboratory studies on the effects of plastics, it is possible to identify their impacts on wild populations (Oehlmann et al., 2009). These chemical compounds not only affect the organisms that directly ingest them, but can also accumulate in the food chain and affect organisms higher on it, and in some cases, can even affect human health.

Vietnam is one of the countries with the highest amount of plastic waste entering the ocean in the world. Among the 20 countries studied, the amount of plastic waste from Vietnam entering the sea varies from 0.28 to 0.73 million tons/year, which is equivalent to 6% of the total amount of plastic waste in the sea, putting Vietnam in the 4th place among the top 20 (Jenna R. Jambeck et al., 2015). According to the report of the Plastics Association, in 2015, Vietnam produced and consumed about 5 million tons of plastic, with 80% of the imported materials derived from plastic scraps. The amount of imported plastic scraps in 2016 was

18,548 tons, which increased to 90,839 tons in 2017 and 381,700 tons in 2018 (Vietnambiz, 2019). Plastic consumption per capita in Vietnam increased rapidly from 3.8kg/ year/person in 1990, to 41kg/year/person in 2015, with 37.43% of the consumed products being packaging and 29.26% being household appliances (Vietnam Plastics Association, 2019). According to the statistics of the Ministry of Natural Resources and Environment (MONRE), Hanoi and Ho Chi Minh City alone already release a daily amount of 80 tons of plastics and plastic bags into the environment. Notably, the amount of plastic waste and plastic bags nationwide accounts for about 8-12% of domestic solid waste. On average, one person uses and discards 1 plastic bag/day and more than 31.4 billion plastic bags are discarded each year, of which only 17% are reused.

Recognizing the serious threats that plastic waste pose to the environment, a series of legal documents at different levels have been issued. Decision No. 582/QD-TTg dated April 11, 2013 of the Prime Minister on "Approving the Project on Improving the Environmental Pollution Control Associated with the Use of Non-Biodegradable Plastic Bags by 2020", which identify tasks and solutions that simultaneously target economic and social aims as well as environmental pollution treatment with the goal of "By 2020, reduce 65% of non-biodegradable plastic bag used in supermarkets and malls compared to 2010”. In Resolution No. 36-NQ/TW dated October 22, 2018 of the 12th Party Central Committee on "Strategy for sustainable development of Vietnam's marine economy to 2030, vision to 2045”, it is stated that "...Marine environment pollution is still a serious, ongoing problem in many places, plastic pollution has become an urgent issue..." and advocated to "... manage marine waste, especially plastic waste...". Resolution No. 69/2018/QH14 dated November 8, 2018 of the National Assembly on the "2019 Socioeconomic Development Plan" and Resolution 01/NQ-CP dated January 1, 2019 of the Government on "Key Tasks and Measures to Implement the Socioeconomic Development Plan and State Budget Estimate in 2019” also set out the task “...to prevent marine pollution, especially plastic waste". Many coastal provinces and cities also include the issue of marine plastic pollution and treatment in the local socioeconomic development plans. However, there were no actual quantitative studies or statistics compilation conducted on plastic waste amount in coastal areas, including Marine Protected Areas (MPA), which are the most severely impacted by marine waste pollution. With the goal of developing a standard method for monitoring plastic pollution and assessing the state of waste pollution and of plastic waste on beaches, IUCN Vietnam, GreenHub (in 2019) and WWF-Viet Nam joined in 2020, coordinated with the Management Boards of 11

MPAs and National Parks[1] to conduct monitoring survey and assess the beaches debris items. This can be considered as one of the first quantitative studies on plastic waste in coastal areas of Vietnam.

II. MATERIALS AND METHODS

II.1. Research methodology

Field data collection was in line with “Methods for surveying and monitoring coastal plastic waste”, a document that was based on the guidelines of the United States Oceanic Atmospheric Administration (NOAA) and United Nations Environment Programme (UNEP) and adjusted to the actual conditions in Vietnam. The criteria for beach selection for survey are as follows: Sandy beach, gravel beach or beach with a coral reef; Easy to access, low seasonal fluctuations; At least 100m long; No regular cleaning activities (or if there are, last cleaning activity must occur at least 3 months prior to survey time); Located in an MPA and/or there are rare, migratory species such as seabirds and sea turtles dispersed there. Survey and monitoring principles include: ensure a consistent and cohesive survey process, analyze samples and process data differences between localities participating in the Program; ensure no harm and disturbance to the environment, biodiversity, and species during the survey and monitoring process; ensure the availability and accessibility of data, survey results, and assessments to facilitate source analysis and assessment of changes in plastic waste across the region over time; ensure security of people and property for individuals and communities participating in the survey and monitoring process.

The plastic waste survey and monitoring process followed the order stated below: (1) prepare; (2) conduct survey and monitoring; (3) analyze data and write status report; (4) share data with stakeholders and local authorities.

The scope of survey and monitoring is limited to high-tide and intertidal zones. A length of 100m in each beach is selected, of which 04 cross sections are randomly selected, with each section being 5m wide and of different lengths depending on the distance from the high-tide zone to the edge of the water. Waste collection is carried out on each selected section and in the high-tide and intertidal zones (from the high-tide zone to the edge of the water) during low tide. The waste collected had a range size of 2.5cm and above, which was then classified into 42 categories under the following groups: Plastic (18 types), Glass (4 types), Metal (4 types), Rubber (5 types), Paper (4 types), Fabric (6 types) and mixed waste. Debris

[1] Bai Tu Long NP, Bach Long Vy MPA, Cat Ba NP, Con Co MPA, Cu Lao Cham MPA, Ly Son MPA, Nha Trang Bay MPA, Nui Chua NP, Hon Cau MPA, Con Dao NP, Phu Quoc NP;

of large size and quantity was photographed and measured to estimate its mass. Thus, the waste collected from 4 cross-sections which represented 20% of the total beach length was selected for the survey.

II.2. Survey time and location

A total of 11 sites were surveyed in 4 phases (2 phases in 2019, 2 phases in 2020) during the northeast monsoon season (from November to April) and southwest monsoon season (from May to October). The survey sites were categorized by their biological characteristics and divided into two regions:

Northern region (from Quang Ninh to Thua Thien Hue): (1) Bai Tu Long (Quang Ninh), (2) Bach Long Vi, (3) Cat Ba (Hai Phong), (4) Quang Tri coastline;

Southern region (from Da Nang to Kien Giang): (5) Cu Lao Cham Island (Quang Nam), (6) Nha Trang (Khanh Hoa), (7) Nui Chua (Ninh Thuan), (8) Ly Son (Quang Ngai), (9) Hon Cau (Binh Thuan); (10) Con Dao (BR-VT); (11) Phu Quoc (Kien Giang);

Analysis of the surveyed areas by location (or population density) is divided into 3 categories: (1) beaches on coastal islands (or islands with high population density or number of visitors), including: Bai Tu Long, Cat Ba, Cu Lao Cham, Phu Quoc (2): offshore islands (or low population density): Bach Long Vi, Ly Son, Hon Cau, Con Dao and (3) onshore beaches in: Quang Tri, Nha Trang, and Nui Chua.

II.3. Data analysis

Data were collected by Management Boards of the MPAs (Bach Long Vi, Con Co, Cu Lao Cham, Nha Trang, Hon Cau), National Parks (Bai Tu Long, Cat Ba, Nui Chua, Con Dao, Phu Quoc) and volunteers.

After compiling data and correcting errors using Microsoft Excel, data analysis was done through Minitab 19 software. Mann Whitney U was used to verify the differences in the numbers and mass of beach waste of the two seasons and regions, while Kruskal–Wallis one-way analysis of variance was used for the differences between survey locations. The data were then exhaustively examined using Tukey's Honestly Significant Difference (HSD) test. The average index is calculated per 1 m of beach length, which is a relatively common method used by studies on oceanic plastic waste quantification in many regions in the world.

The Coastal Clean Index (CCI) calculation method is based on the research of (Alkalay, Pasternak, & Zask, 2007). According to the research, CCI is calculated using the following formula:

$$\text{CCI} = \frac{\text{The average quantity of plastic debris per a } 5m \text{ cross section}}{\text{The average area of the surveyed cross section}}\ x\ K$$

In which, K is the correlation coefficient with value = 20.

The pollution ratings based on CCI are as follow:

0-2: very clean; 2-5: clean; 5-10: moderate; 10-20: polluted with plastic; >20: extremly polluted with plastic

III. RESULTS AND DISCUSSIONS

III.1. Overview of the current state of waste at the beaches

The result of waste counting at 33 beaches in 4 phases (2 in 2019 and 2 in 2020) was a total of 165,706 debris items of varying sizes that had been collected, meaning an average of 63.25 items/m (SD ± 78.78). This is equivalent to a total mass of 2718.07 kg with an average of 1.04 kg/m (SD ± 1.74kg). The number and mass of plastic debris (consisting of 20 types) was overwhelmingly higher than other types of waste at an average of 58.15±76.03 items/m and 0.60±1.03 kg/m, accounting for 92% of total number and 58% of total mass. The remaining types of debris items include: Metal, Glass, Rubber, Wood-paper, Fabric and Other Waste. These debris types made up a small number but a high percentage in term of mass, especially Other Waste Items, which accounted for only 1.3% in number but up to approximately 10% in mass.

The number and mass of debris at beaches in Vietnam is higher than that of South Korea (Hong, Lee, Kang, Choi, & Ko, 2014; Lee et al., 2017), making Vietnam one of the regions with a highest amount of plastic waste in the world (an average of 18.36 items/m) (Serra-Goncalves, Lavers, & Bond, 2019).

Table 1. Number and mass of waste collected at the beaches

Type of debris	**Number**				**Mass**			
	Total (33 beaches x 4 phases)	Proportion	Average (items/m)	SD	Total (33 beaches x 4 phases)	Proportion	Average (kg/m)	SD
Plastic	152.350	91.9%	58.15	76.03	1,573.4	57.9%	0.60	1.03
Metal	2.092	1.3%	0.80	1.72	83.26	3.1%	0.03	0.16

Glass	2.556	1.5%	0.98	1.53	215.33	7.9%	0.08	0.23
Rubber	3.145	1.9%	1.20	2.15	227.83	8.4%	0.09	0.46
Wood, paper	2.031	1.2%	0.78	2.13	234.64	8.6%	0.09	0.52
Fabric	1.404	0.8%	0.54	1.11	109.13	4.0%	0.04	0.11
Other waste	2.128	1.3%	0.81	2.37	274.44	10.1%	0.10	0.56
Total	**165.706**		**63.25**		**2.718**		**1.04**	

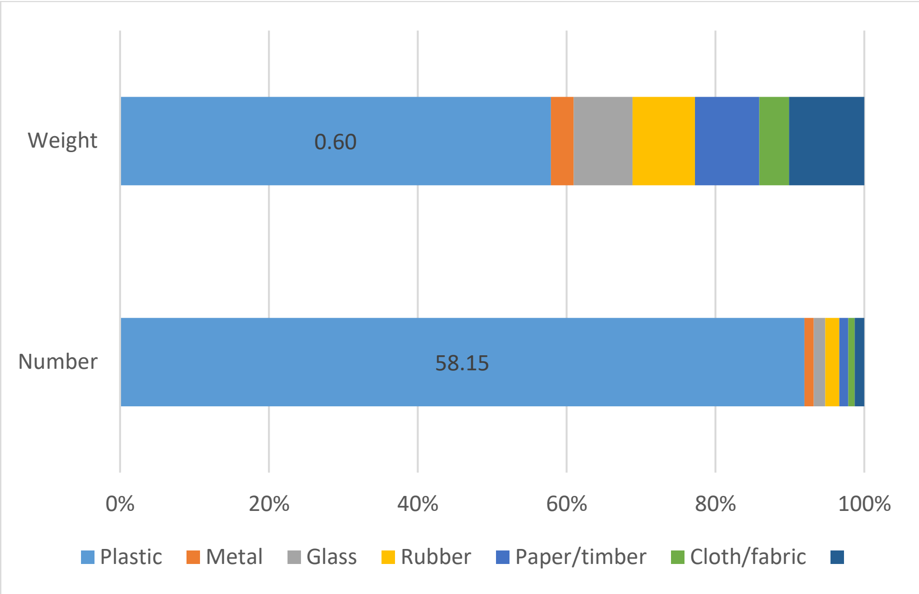
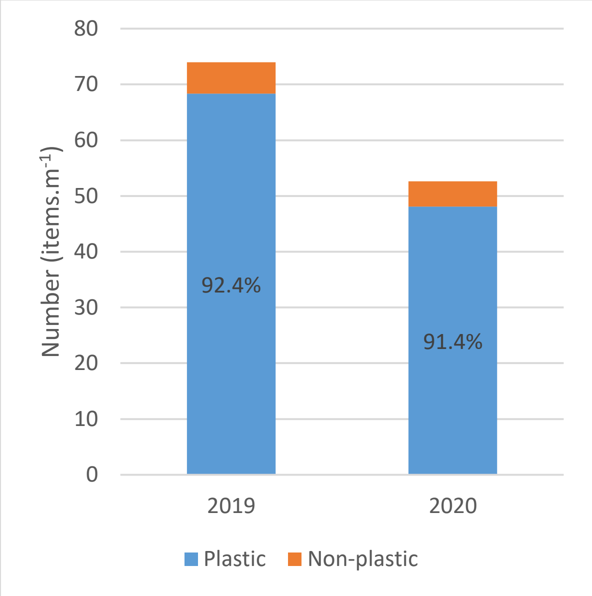


Figure 1. Proportions of waste type over each meter of beach length by number (items) and mass (kg)

Comparison between 2019 and 2020 shows that 2020 has a lower mass but a higher number of plastic debris than 2019, but these differences are not statistically significant (Mann Whitney U test, p=0.148 and p=0.486) Plastic waste made up 92.57% (92.2-93%) of the total number of debris items, but only made up 58% (52-64%) of the total mass. This reflects the reality that plastic waste is small in term of mass and size, and yet there is a huge number of plastic debris items on the beaches.



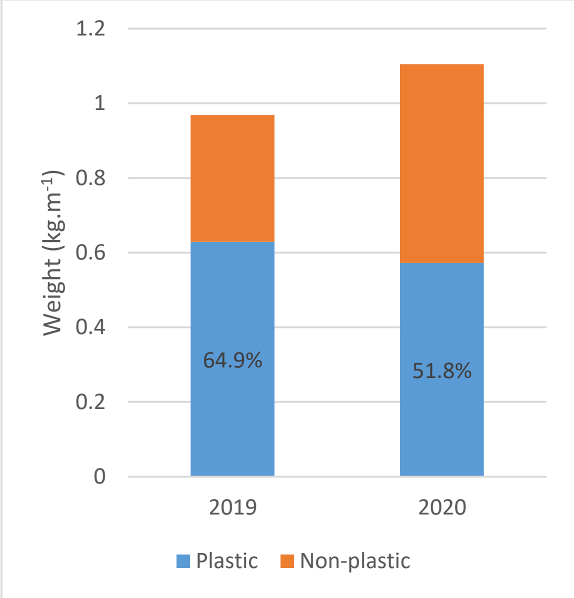


Figure 2. Comparison of the average number and mass of waste by year

Table 2. The average number of debris items on the survey beaches (piece/m) by type

Type of debris	Phase 1	Phase 2	Phase 3	Phase 4	Average
Plastic	80.33±99.11	55.97±83.25	41.71±39.48	54.62±64.88	58.15±76.03
Metal	1.41±2.61	0.47±0.9	0.61±1.21	0.7±1.47	0.8±1.72
Glass	1.57±1.93	0.87±1.25	0.74±1.53	0.72±1.14	0.98±1.53
Rubber	1.16±1.68	0.95±1.65	1.41±2.61	1.28±2.45	1.2±2.15
Wood, paper	1.32±2.95	0.48±1.18	0.89±2.6	0.41±0.87	0.78±2.13
Fabric	0.59±1.29	0.28±0.5	0.55±1.02	0.72±1.36	0.54±1.11
Other waste	0.87±1.48	1.33±4	0.59±1.77	0.47±1.04	0.81±2.37
Total	**87.23±102.56**	**60.56±85.38**	**46.5±43.54**	**58.92±66.53**	

Table 3. The average mass of debris on the surveyed beaches (kg/m)

Type of debris	Phase 1	Phase 2	Phase 3	Phase 4	Average
Plastic	0.61±0.84	0.64±1.19	0.48±0.54	0.67±1.36	0.6±1.03
Metal	0.04±0.14	0.01±0.03	0.02±0.07	0.05±0.27	0.03±0.16
Glass	0.08±0.16	0.06±0.1	0.13±0.41	0.06±0.11	0.08±0.23
Rubber	0.07±0.16	0.07±0.13	0.06±0.14	0.15±0.89	0.09±0.46
Wood, paper	0.06±0.15	0.04±0.09	0.08±0.27	0.18±0.98	0.09±0.52
Fabric	0.02±0.05	0.04±0.11	0.06±0.17	0.04±0.1	0.04±0.11
Other waste	0.06±0.15	0.13±0.43	0.04±0.17	0.19±1.01	0.1±0.56
Total	**0.94±1.13**	**1±1.38**	**0.88±0.99**	**1.33±2.81**	

Comparison of the average plastic waste quantities between the survey phases shows that the differences in number are statistically significant (Kruskal – Wallis H test, $p<0,05$), but the differences in mass are not ($p = 0.716$). The first survey phase had the highest average number of plastic debris items (80.33±99.1 items/m) and the third phase had the lowest, but the forth phase had the highest average plastic waste mass (0.67±1.36 kg/m).

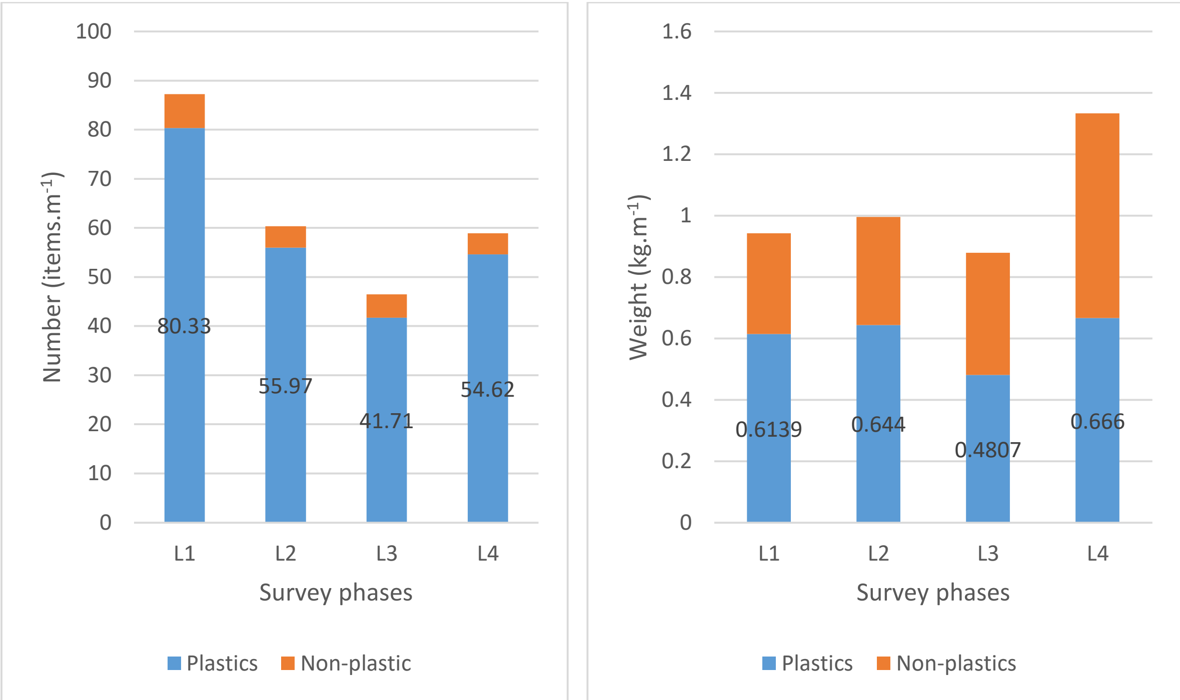


Figure 3. Comparison of the average number and mass of waste of the four phases

Similarly, there were no statistically significant differences between the northeasterly wind season and the southwesterly wind season in term of either number or mass (Mann Whitney U test's results were, respectively, $p=0.207$ and $p=0.605$).

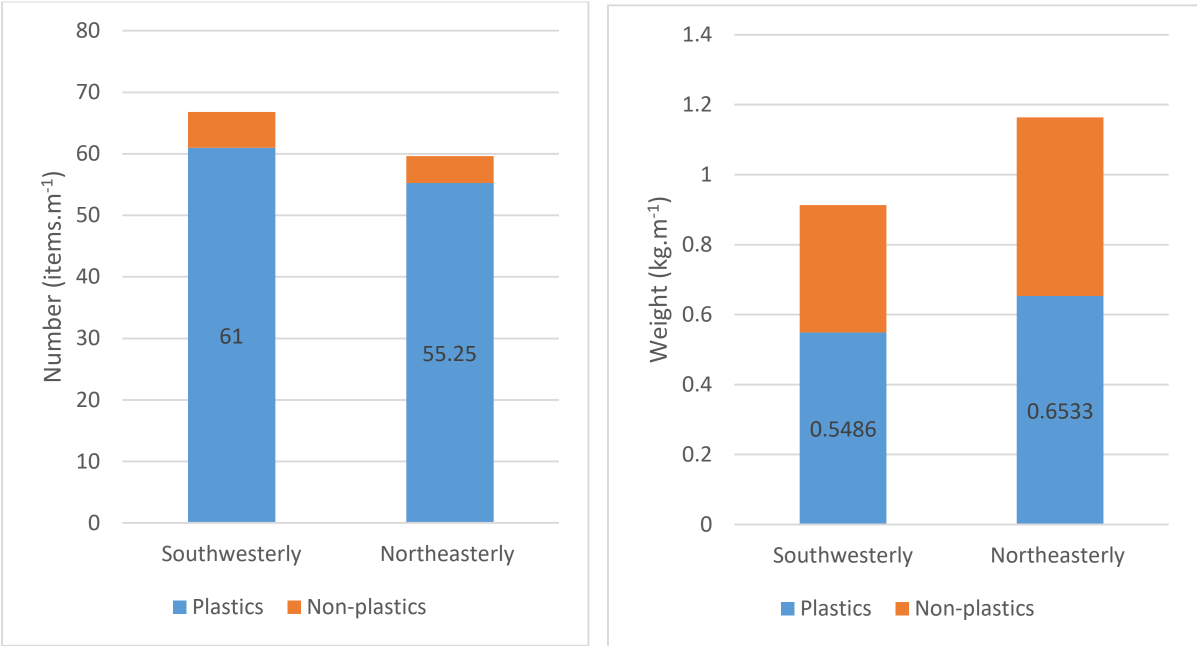


Figure 4. Comparison of average number and mass of the two wind seasons

The results of waste survey at the Northern and Southern beaches were considerably different, with an average number of 49.81±53,91 (items/m) and average mass of 0,53±0,7 (kg/m) in the North, which is lower than in the South (62.97±85.98 items/m and 0.64±1.18 kg/m, respectively). However, these are not statistically significant differences (Mann Whitney U test, $p=0.291$ and $p=0.234$ respectively).

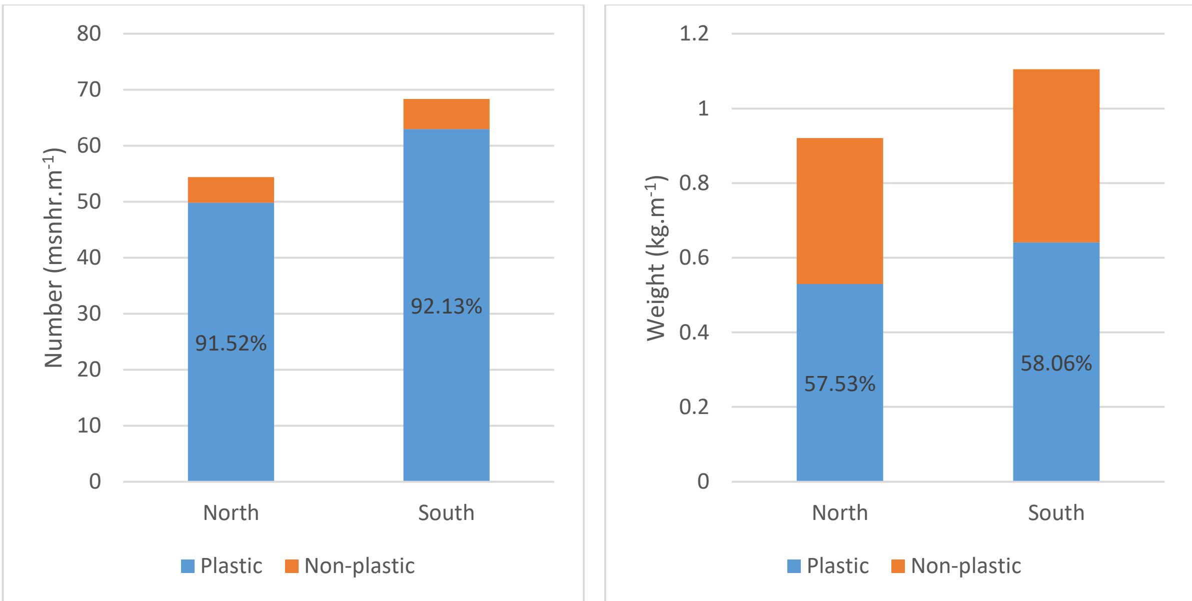


Figure 5. Average number and mass of waste by location categories

A comparison between the beaches on offshore islands, coastal islands, and the mainland shows that there were statistical differences in the number and mass of plastic debris of the beaches, with the beaches on coastal islands having the lowest number and mass among all the beaches (Kruskal-Wallist H test, $p < 0.05$). The average number of waste items on the coastal islands (41.88 ± 54.1 items/m) is lower than that of the beaches on the mainland and offshore islands (respectively 64.01 ± 84.25 items/m and 64.49±80.88 items/m). In terms of mass, the onshore and offshore beaches had the highest average at 0.69±0.77 kg/m and 0.67±1.3 kg/m, respectively, while the beaches of coastal islands had the lowest average at 0.4 ± 0.65 kg/m. One of the causes of this phenomenon is, as beaches on coastal islands are mostly located in areas that attract a lot of tourists and offer tourism services (for example, in Cat Ba, Cu Lao Cham, Phu Quoc), there are more frequent beach cleaning activities on these beaches than those of the other two location categories.

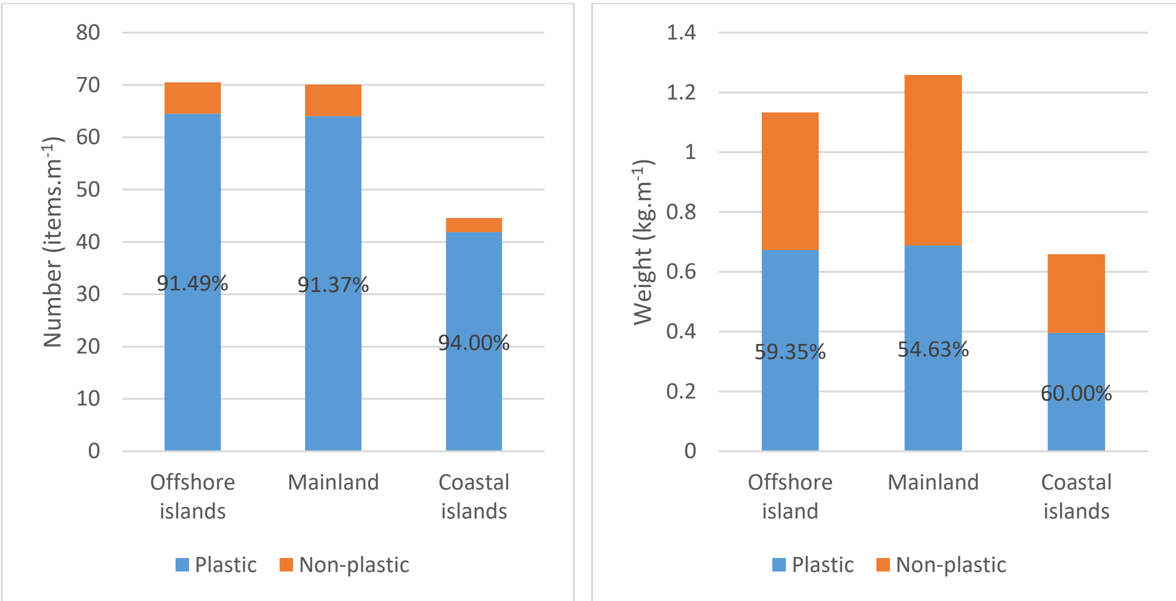


Figure 6. Average number and mass of waste by locations

The results of the waste survey conducted in 11 locations show that plastic waste made up a hight proportion in all locations. Specifically, beaches in Nha Trang, Nui Chua, and Phu Quoc had significantly higher average numbers of waste items compared to other locations, while Con Dao and Ly Son had the highest average waste mass.

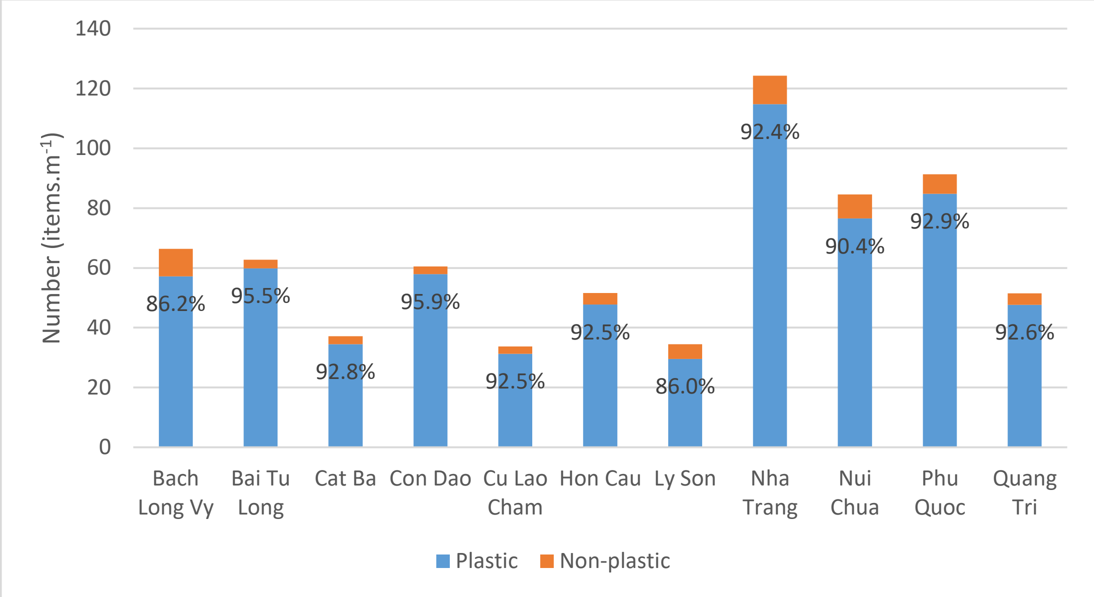


Figure 7. Number and proportion of plastic debris items on the beaches by locality

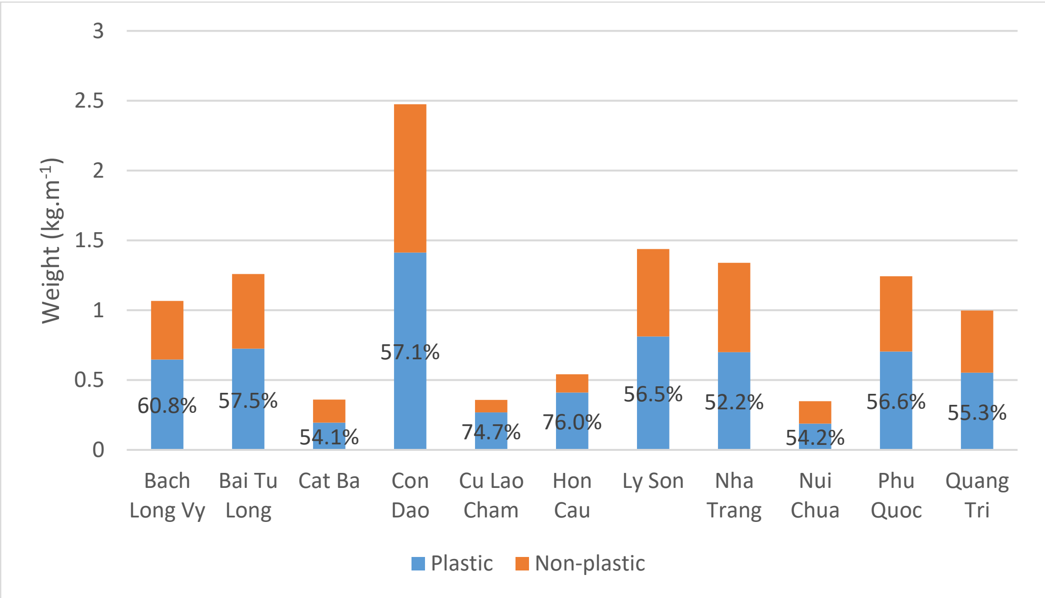
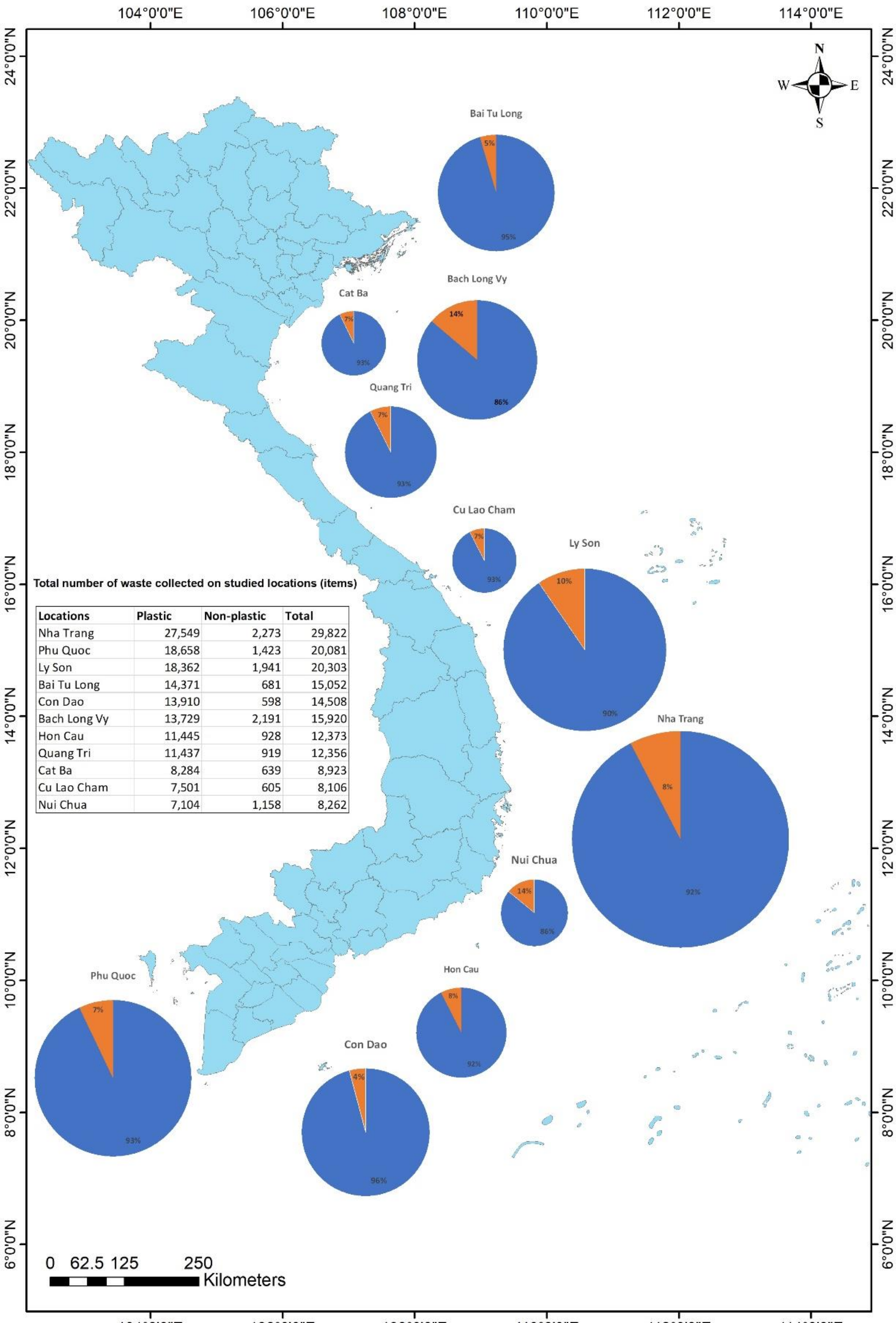
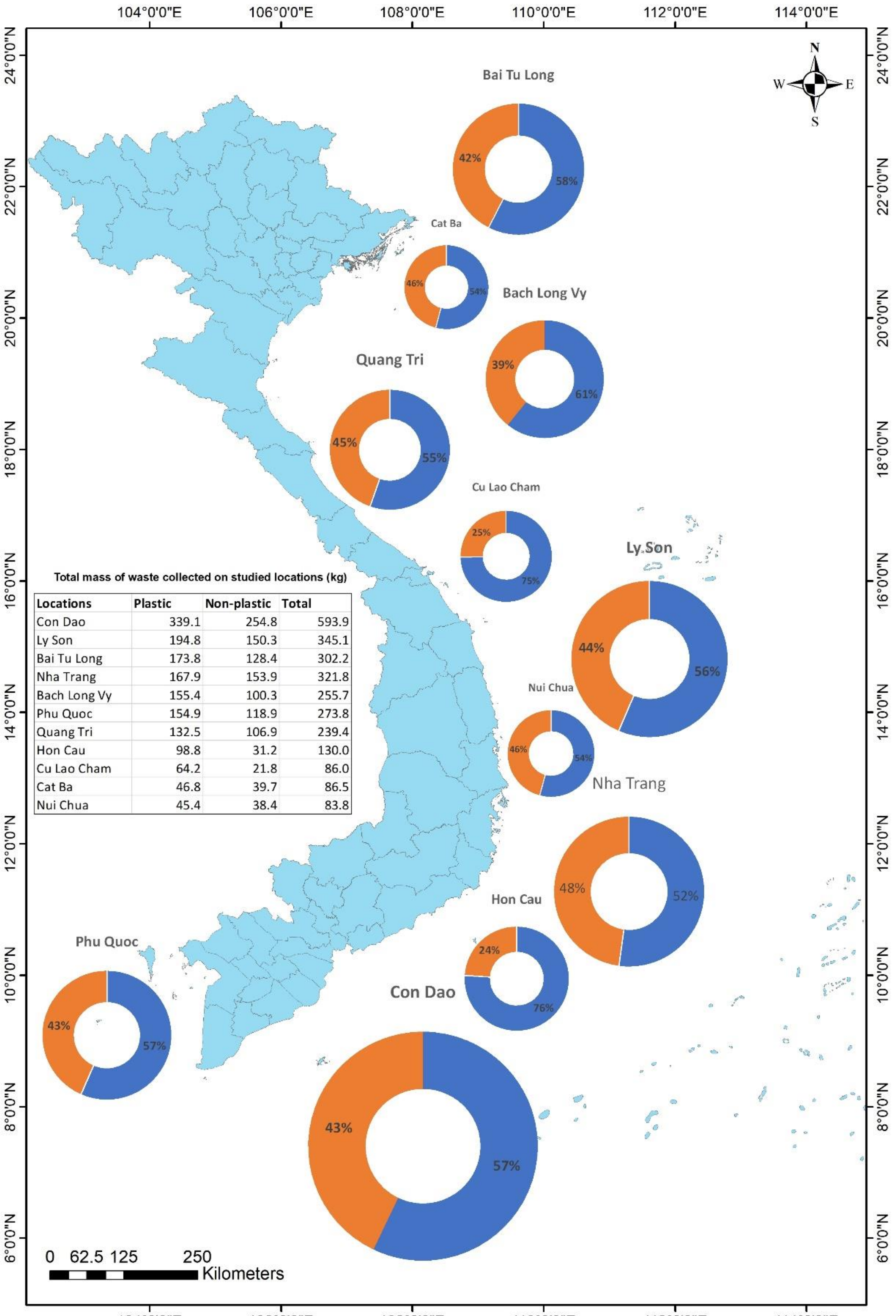


Figure 8. Number and proportion of plastic debris on the beaches by locality



Locations	Plastic	Non-plastic	Total
Nha Trang	27,549	2,273	29,822
Phu Quoc	18,658	1,423	20,081
Ly Son	18,362	1,941	20,303
Bai Tu Long	14,371	681	15,052
Con Dao	13,910	598	14,508
Bach Long Vy	13,729	2,191	15,920
Hon Cau	11,445	928	12,373
Quang Tri	11,437	919	12,356
Cat Ba	8,284	639	8,923
Cu Lao Cham	7,501	605	8,106
Nui Chua	7,104	1,158	8,262

Figure 9. The total number of waste (items) in survey locations
(blue: plastic waste; orange: non-plastic waste)



Total mass of waste collected on studied locations (kg)

Locations	Plastic	Non-plastic	Total
Con Dao	339.1	254.8	593.9
Ly Son	194.8	150.3	345.1
Bai Tu Long	173.8	128.4	302.2
Nha Trang	167.9	153.9	321.8
Bach Long Vy	155.4	100.3	255.7
Phu Quoc	154.9	118.9	273.8
Quang Tri	132.5	106.9	239.4
Hon Cau	98.8	31.2	130.0
Cu Lao Cham	64.2	21.8	86.0
Cat Ba	46.8	39.7	86.5
Nui Chua	45.4	38.4	83.8

Figure 10. The total mass of waste (kg) in survey locations
(blue: plastic waste; orange: non-plastic waste)

The beaches also had very different quantities of waste in general and of plastic waste in particular. In terms of number, most of the beaches (32 out of 34 beaches) had a higher number of plastic debris items than the world average (18.6 pieces/m). The beaches with the highest average number of plastic debris were in Bach Long Vi island, Phu Quoc island, Con Dao island and Nha Trang. Only two beaches had a lower number than the world average: Xep Tren (Cu Lao Cham Island, Quang Nam) and Su Sung (Minh Chau Island, Quang Ninh).

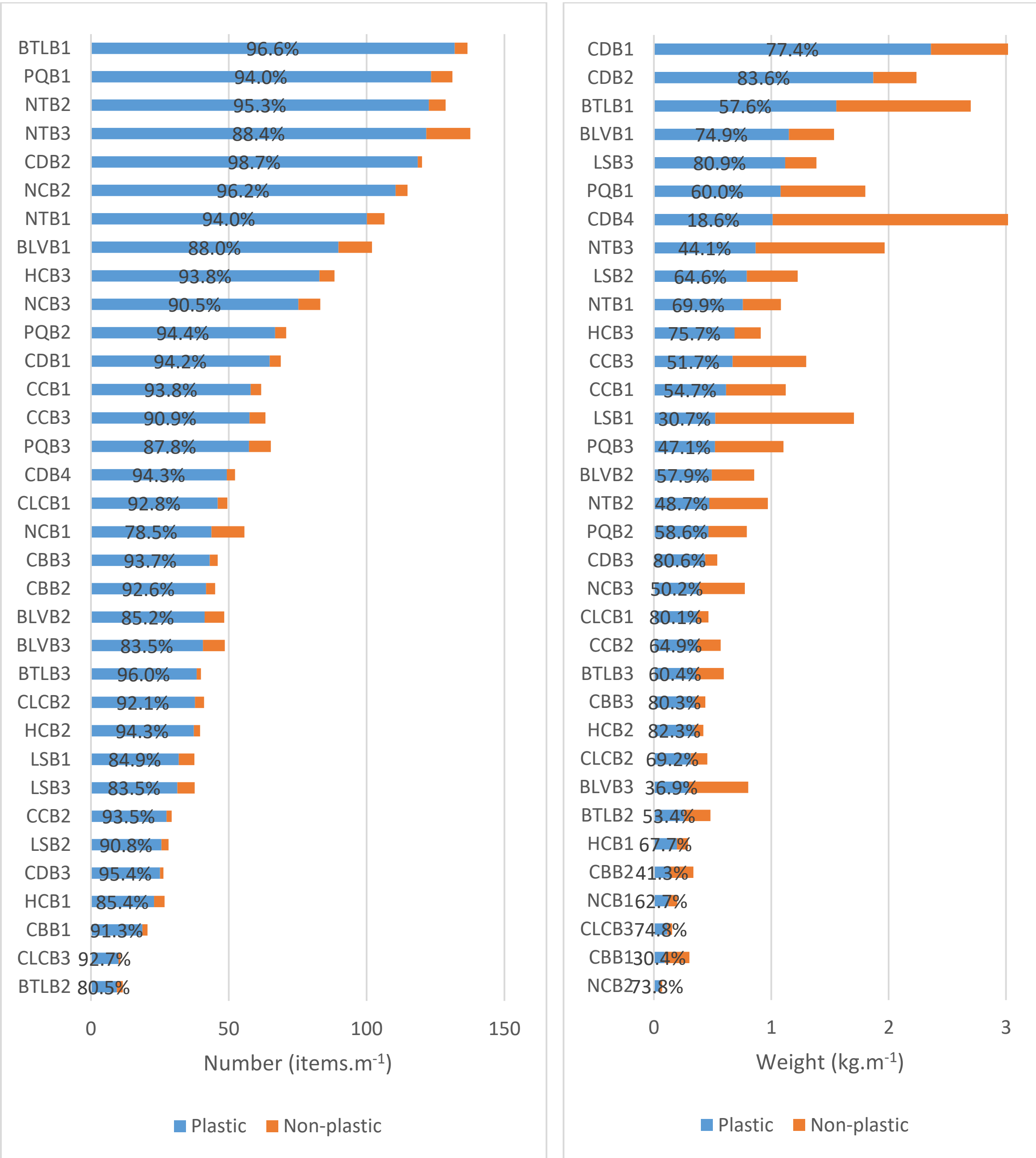


Figure 11. Number and mass of waste on survey beaches

(note: please find annex for detail)

III.2. Composition of plastic waste on the beaches

Among plastic debris types, foam buoys and ropes-small nets account for the largest proportion in terms of density, while in term of mass, it's ropes, small nets and foam buoys (Table 2). More specifically, fishery or fishery-related products (foam buoys, ropes-small nets, plastic buoys, fishing lines) account for 44.8% of the total waste item number and 47.6% of total waste mass. Plastic waste from domestic sources takes second place in both number (26%) and mass (26%). In third place is single-use plastic, which accounts for 21% in number but only 12% in mass. These results show that activities associated with fishing, aquaculture and aquatic trade are the biggest source of waste, both in term of number and mass. However, current policies focus mainly on domestic waste (such as nylon bags, plastic bottles, etc.) Therefore, it is necessary to have more in-depth researches done on a larger spatial scale (on water surface, rocky reefs, coral reefs, mangroves, etc.) to more accurately identify the threats presented by this sector to the environment, especially in regards to plastic pollution.

Table 4. The number and mass of plastic debris on the survey beaches

Type of plastic debris	Number			Mass		
	Average (items/m)	SD	Proportion	Average (kg/m)	SD	Proportion
1. Fishery						
Foam buoy	14.88	36.14	25.6%	0.09932	0.1989	15.0%
Rope/small net	9.73	23.62	16.7%	0.1809	0.7818	27.4%
Plastic buoy	0.9813	2.2477	1.7%	0.03224	0.0877	4.9%
Fishing line	0.4527	2.0346	0.8%	0.002081	0.00992	0.3%
2. Domestic						
Bottle cap/HDPE	3,493	7,059	6.0%	0.01124	0.02676	1.7%
Hard plastic	3,444	8,566	5.9%	0.0349	0.07385	5.3%
Beverage bottle	2,586	5,102	4.4%	0.06552	0.14486	9.9%
Food packaging	2.54	4.59	4.4%	0.02491	0.07073	3.8%
Cigarette filter	1.6	10,522	2.8%	0.001021	0.005176	0.2%
Other types of bottle	0.5664	1.1722	1.0%	0.0218	0.05199	3.3%
Personal hygiene products	0.5073	0.8751	0.9%	0.007101	0.016674	1.1%
Lighter	0.3802	0.5919	0.7%	0.004493	0.012215	0.7%
3. Single-use						
Styrofoam food container	6.86	31.56	11.8%	0.00893	0.03677	1.4%
Nylon bag	2,609	11,388	2.9%	0.05341	0.16841	2.1%
Single-use plastic	1,705	3.06	1.8%	0.01358	0.03705	0.2%
Straw	1.0302	1.7884	4.5%	0.001073	0.002616	8.1%
4. Other sources (multiple sources or unidentifiable sources)						

Other plastics	3,323	16,115	5.7%	0.08803	0.21393	13.3%
Soft plastic	1,162	3,101	2.0%	0.004985	0.016261	0.8%
Thin plastic	0.3038	1.3903	0.5%	0.003999	0.020008	0.6%
Balloon	0.01031	0.07704	0.02%	0.001123	0.012036	0.2%

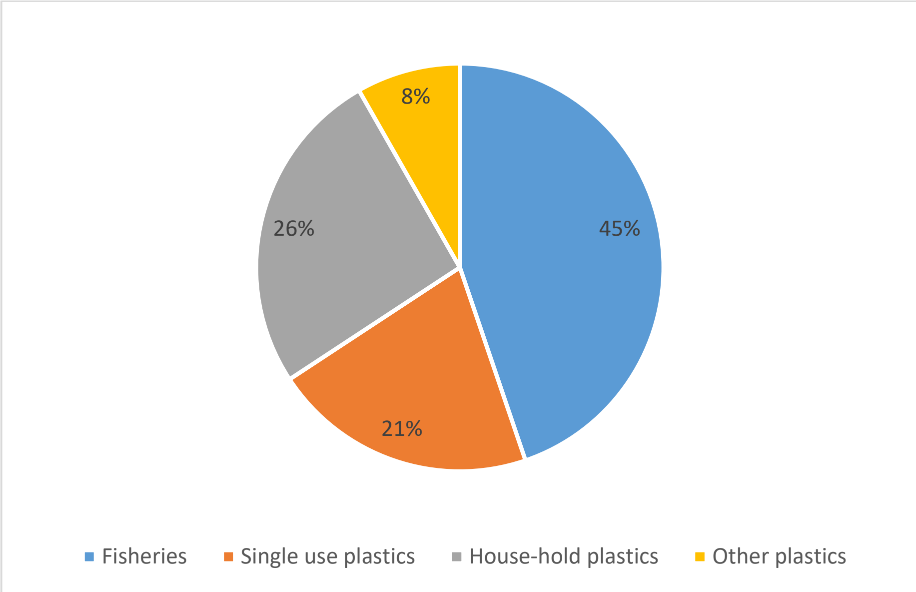


Figure 12. Proportion of plastic item number by waste source

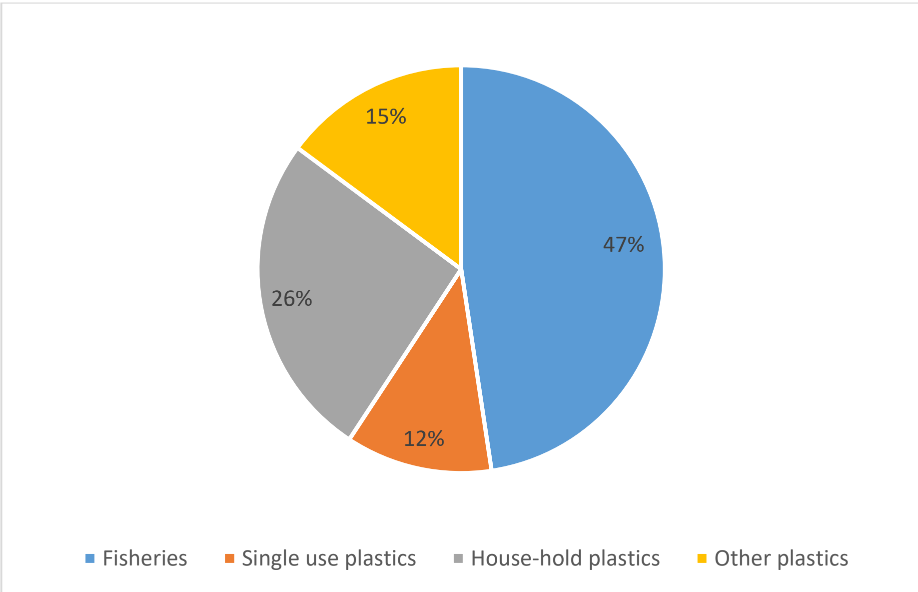


Figure 13. Proportion of plastic waste mass by waste sources

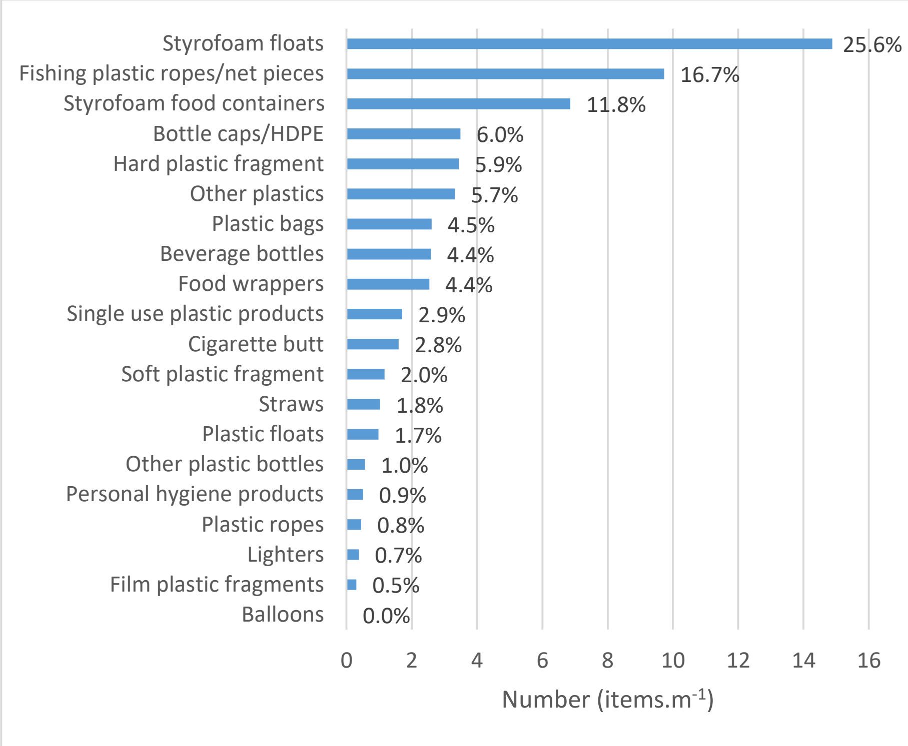


Figure 14. Number and proportion of plastic debris items on the beaches by waste source

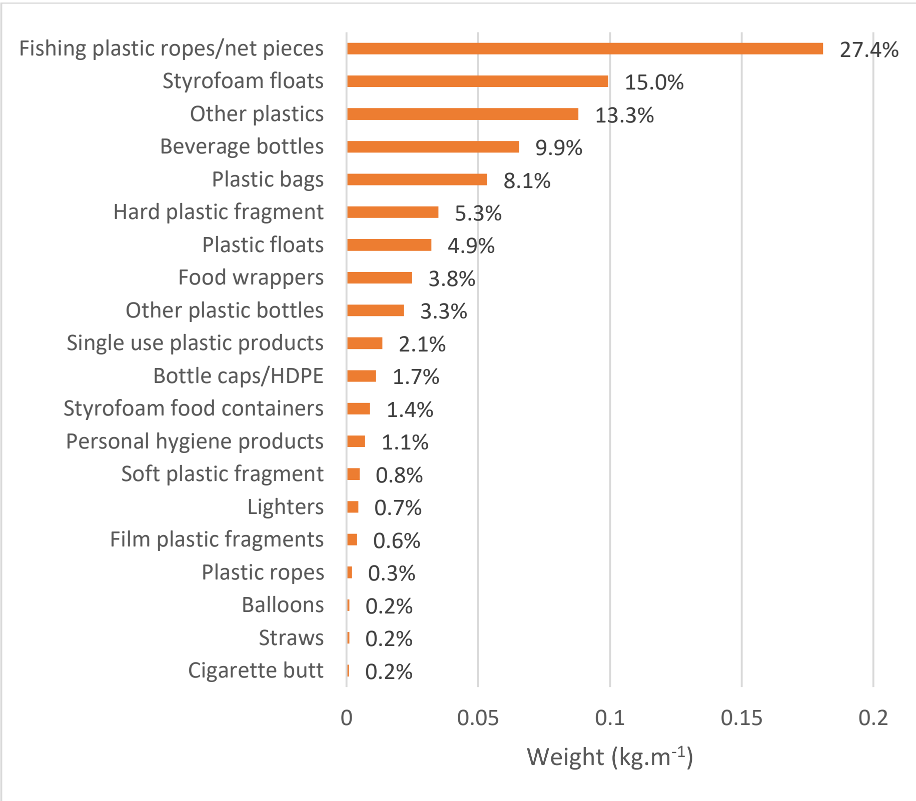


Figure 15. Mass and proportion of plastic debris on the beaches by waste source

In addition to the differences in the total number and mass of plastic waste among the localities, plastic waste composition also varies by localities. Fishery waste was the most prevalent in 8 localities, with high proportions in term of number (from 32% to 70%). The beaches in Núi Chúa had the highest number and proportion of fishery waste (53.6 items/m), 70%) and the beaches in Lý Sơn had the lowest (9.7 items/m, 32.9%). However, when it comes to mass, fishery plastic waste in Côn Đảo (0.97 kg/m) accounted for a much higher percentage here, and in fact Côn Đảo had twice the fishery plastic waste mass of the locality in second place, Lý Sơn (0.42 kg/m). Notably, Núi Chúa had a very high number of fishery waste items, but a very low fishery waste mass (0.07 kg/m). Testing the data with Kruskal Wallis H test shows a clear difference in the numbers of the survey phases. Specifically, Phase 1 (March 2019) had a higher number of waste than the other phases, which contributed to the differences between monsoon seasons (northeast monsoon season higher than southwest season) and survey years (2019 higher than 2020). There were no differences between Northern and Southern survey locations.

Single-use plastic was most prevalent in two localities - Nha Trang and Phu Quoc (57 items/m, 49.6% and 31 items/m, 36.5% respectively), A comparison of survey locations in the North and the South shows significant differences regarding single-use plastic, with Southern locations displaying a higher number of this waste type than Northern locations (Kruskal-Wallis H test, p = 0.002). Domestic plastic waste is most prevalent in one locality which is Bach Long Vy Island (23 items/m, 40.2%), but compared to fishery plastic waste (22.7 pieces/m, 39.7%), the difference was not too notable.

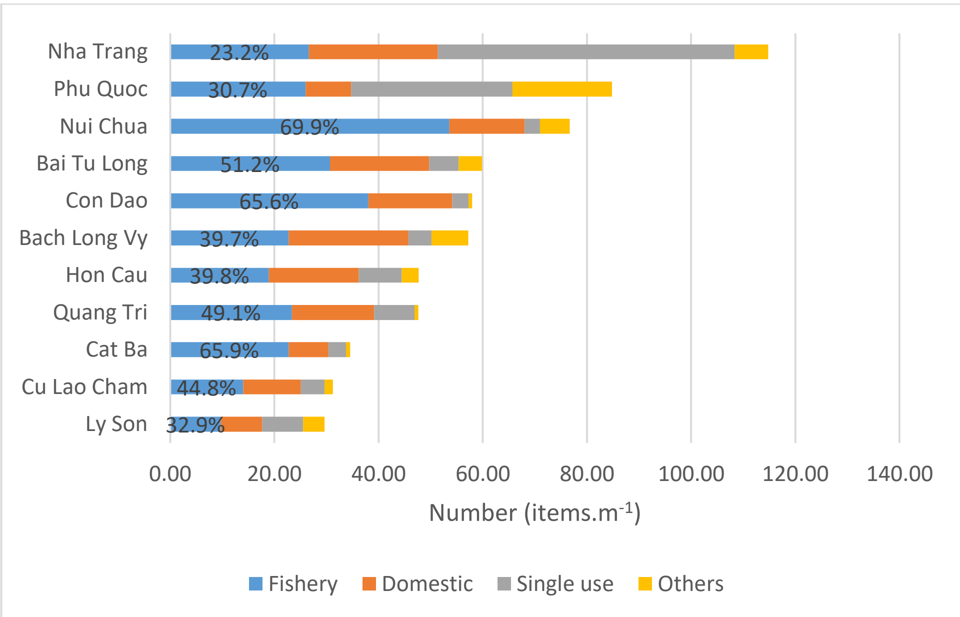


Figure 16. Number of plastic debris items on the beaches by locality

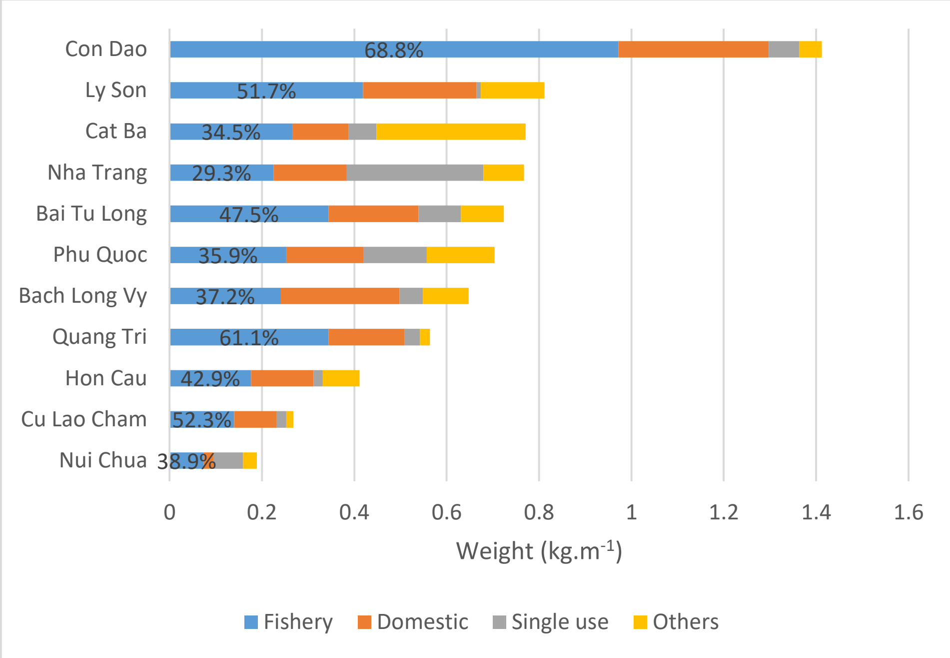


Figure 17. Mass of plastic debris on the beaches by locality

Among the plastic debris of which brand identities could still be recognized, Acecook was the most prevalent (14%), followed by Vinamilk (13%), CocaCola (9%), and Vinabata (8%). Brands that accounted for the lowest percentages included Sun (1%), Orion (2%), and Kinh Do (2%).

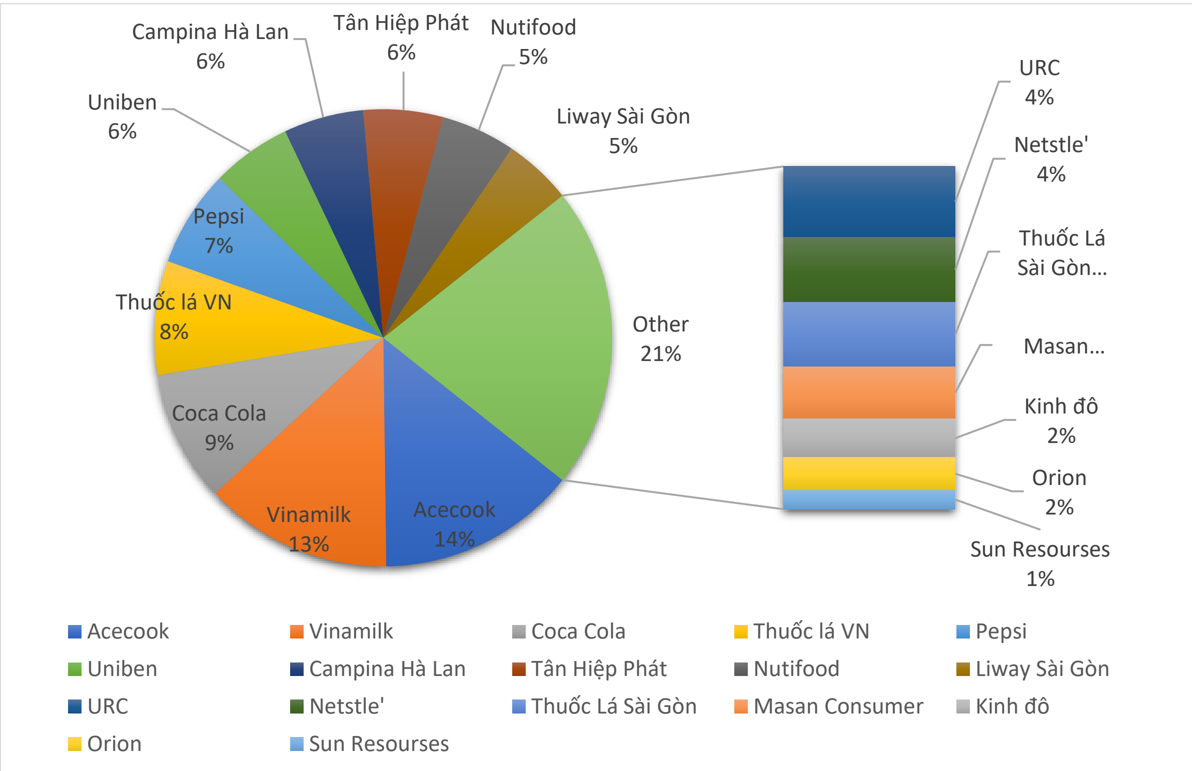


Figure 18. Proportion of the most prevalent brands found in beach waste

III.3. Assessing the plastic pollution levels of survey beaches

Through 4 survey phases in 43 beaches and 11 locations, the CCI shows that the majority of beaches suffer from heavy plastic pollution. In the 1st phase, 72.7% of the beaches were rated very polluted (CCI>20). This figure went down to 53% in the 2nd phase and went up again to 60.6% and 63.6% in phase 3 and phase 4. The (10<CCI<20) pollution level was quite uncommonly encountered in the first phase (6%), but substantially increased in phase 2, 3 and 4 Therefore, the number of beaches with bad environmental quality (polluted rating and above) stayed relatively the same from 25 to 26 beaches in all four phases (75% to 79%). The number of beaches that were rated moderate to clean ranged only from 7 to 8 beaches (22 to 25%), among which only 1 to 3 beaches were rated very clean (3% to 9%).

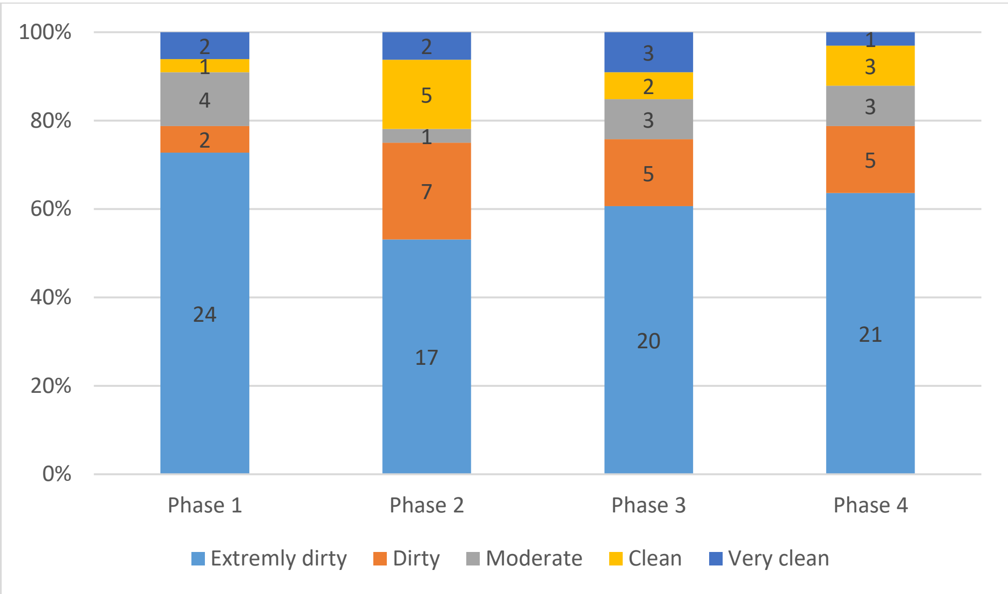


Figure 19. Quality proportions of survey locations according to CCI

A number of beaches had an alarming plastic pollution level of over 120, most of which were found in Ly Son and Nha Trang. The most surprising finding was that some island beaches such as Con Dao (CBD1), Cu Lao Cham (CLCB1, CLCB2), Cat Ba (CBB3), Hon Cau (HCB2, HCB3), Bai Tu Long (BTLB1), and Bach Long Vy (BLV) were also suffering from plastic pollution.

Table 5. CCI of survey locations in 2019 and 2020

Score	Abr	Phase 1	Phase 2	Phase 3	Phase 4
Bach Long Vi - Bai Au	BLVB1.	20.72846	51.34668	7.947393	26.49625
Bach Long Vi - Mom Dong	BLVB2.	7.178079	4.158655	10.2716	8.947129
Bach Long Vi - Bai Tam	BLVB3.	7.938694	4.668954	30.04626	5.154996

Bai Tu Long - Bai Rua	BTLB1.	96.15587	70.2451	78.65769	198.9997
Bai Tu Long - Bai Sa Sung	BTLB2.	1.313544	2.232218	1.273251	1.200724
Bai Tu Long - Bai Minh Chau	BTLB3.	21.56953	4.321835	4.956233	9.687784
Cat Ba - Duong Gianh	CBB1.	0.919154	0.909775	1.842998	3.343658
Cat Ba - Cat Dua	CBB2.	29.76727	18.28719	41.79928	33.00524
Cat Ba - Va Rong	CBB3.	56.47336	53.97323	30.05049	28.57983
Con Co - Bai Bac Son	CCB1.	13.78087	17.63331	43.92814	44.57453
Con Co - Bai Thon 6	CCB2.	9.971496	3.85038	2.538712	14.58349
Con Co - Bai Thon 9	CCB3.	20.9926	10.42416	16.19532	35.43855
Con Dao - Bai Ong Dung	CDB1.	102.4432	65.38382	77.77978	87.73507
Con Dao - Bai Dam Trau Nho	CDB2.	12.5791	27.08059		
Con Dao - Bai Dam Quoc	CDB3.	2.630374	1.040971	0.593843	2.738663
Con Dao - Bai Dam Tre	CDB4.			25.70129	60.84836
Cu Lao Cham - Bai Bac	CLCB1.	52.7394	74.58702	27.84074	45.32973
Cu Lao Cham - Bai Xep Duoi	CLCB2.	43.43747	63.05256	33.03295	32.35068
Cu Lao Cham - Bai Xep Tren	CLCB3.	5.287501	14.79432	5.287501	17.25114
Ho Cau_Bai Truoc	HCB1.	21.59877	11.4729	10.86906	40,968
Hon Cau_Bai Trang Dao	HCB2.	69.44723	56.65609	41.72192	31.94439
Ho Cau_Bai Tau	HCB3.	123.5624	23.31283	39.27075	109.5658
Ly Son - Bai Hang Cau Duoi	LSB1.	54.3768	7.553283	12.71412	12.30399
Ly Son - Bai Hang Cau Tren	LSB2.	41.60175	11.73782	7.271216	45.60091
Ly Sơn_Bai Tay	LSB3.	42.61204	17.98484	18.60635	18.37328
Nui Chua - Bai Hon Mot	NCB1.	74.59064	37.98298	23.98712	4.894505
Nui Chua - Bai Ngang	NCB2.	260.9603	30.01157	23.67537	20.82978
Nui Chua - My Hoa	NCB3.	142.4456	34.03369	35.34095	59.68292
Nha Trang - Bai Hon Mun	NTB1.	222,747	48.13946	68.72951	44.87576
Nha Trang - Bai Vinh Hoa	NTB2.	42.51687	238.7726	62.27495	38.50291
Nha Trang - Bai Cua Song Cai	NTB3.	201.8635	48.18718	48.15451	19.79758
Phu Quoc - Bai Cay Sao	PQB1.	46.31332	67.72063	37.08228	44.05992
Phu Quoc - Bai Gam Ghi	PQB2.	55.82849	96.43638	37.43447	124.5857
Phu Quoc - Bai Hon Vong	PQB3.	113.2491		173.6821	57.42634

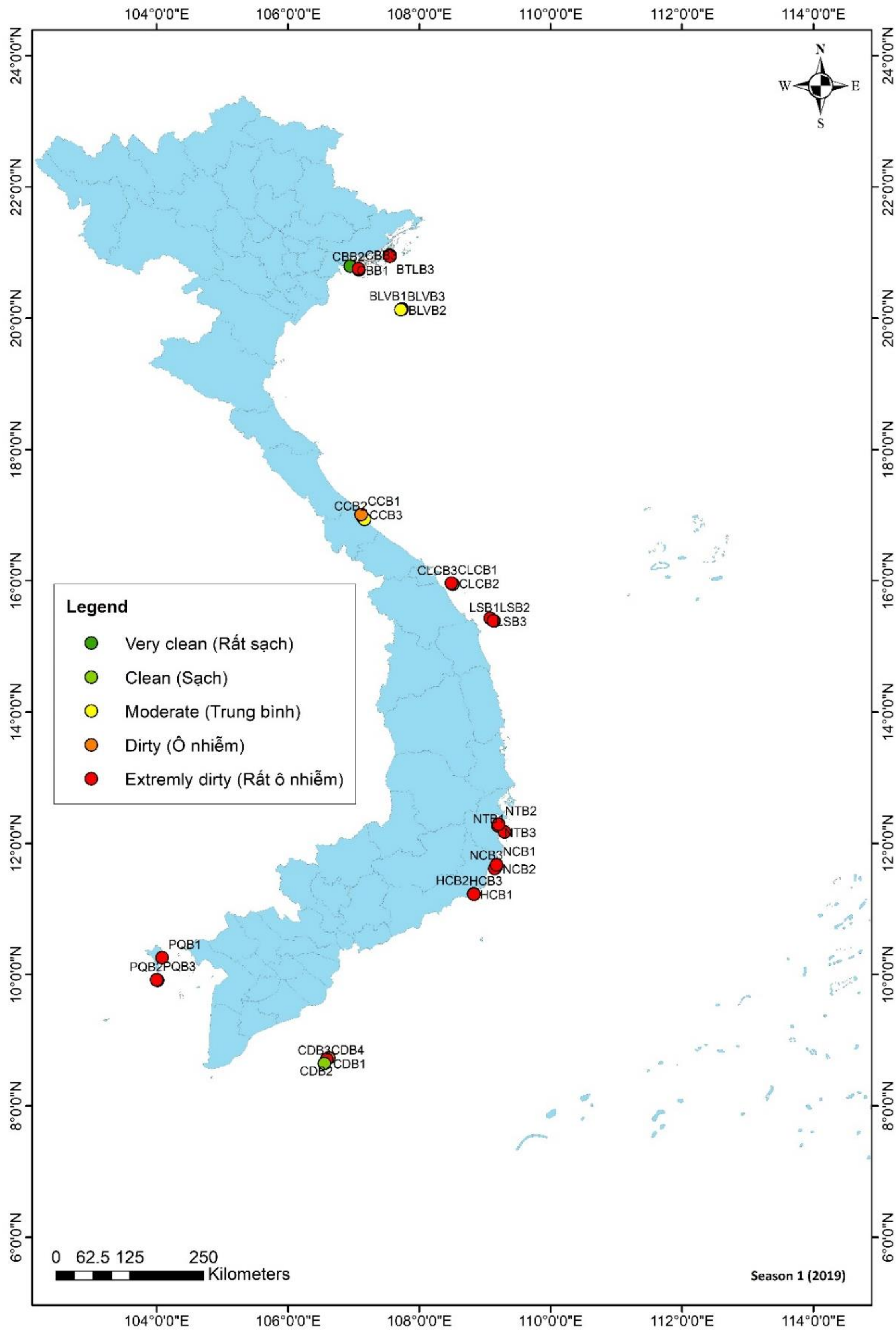


Figure 200. CCI comparison of survey locations in 2019 (Season 1)

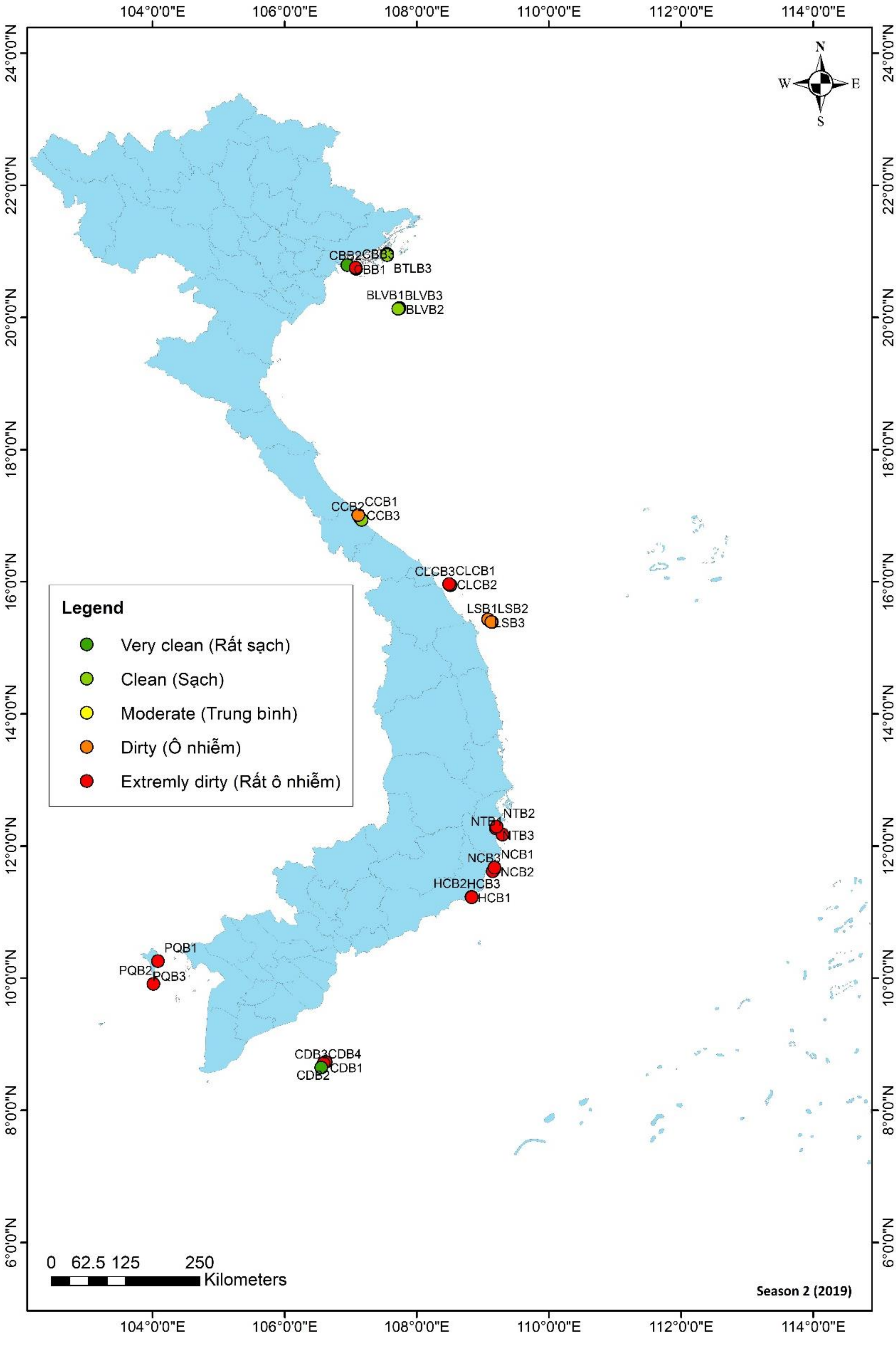


Figure 211. CCI comparison of survey locations in 2019 (Season 2)

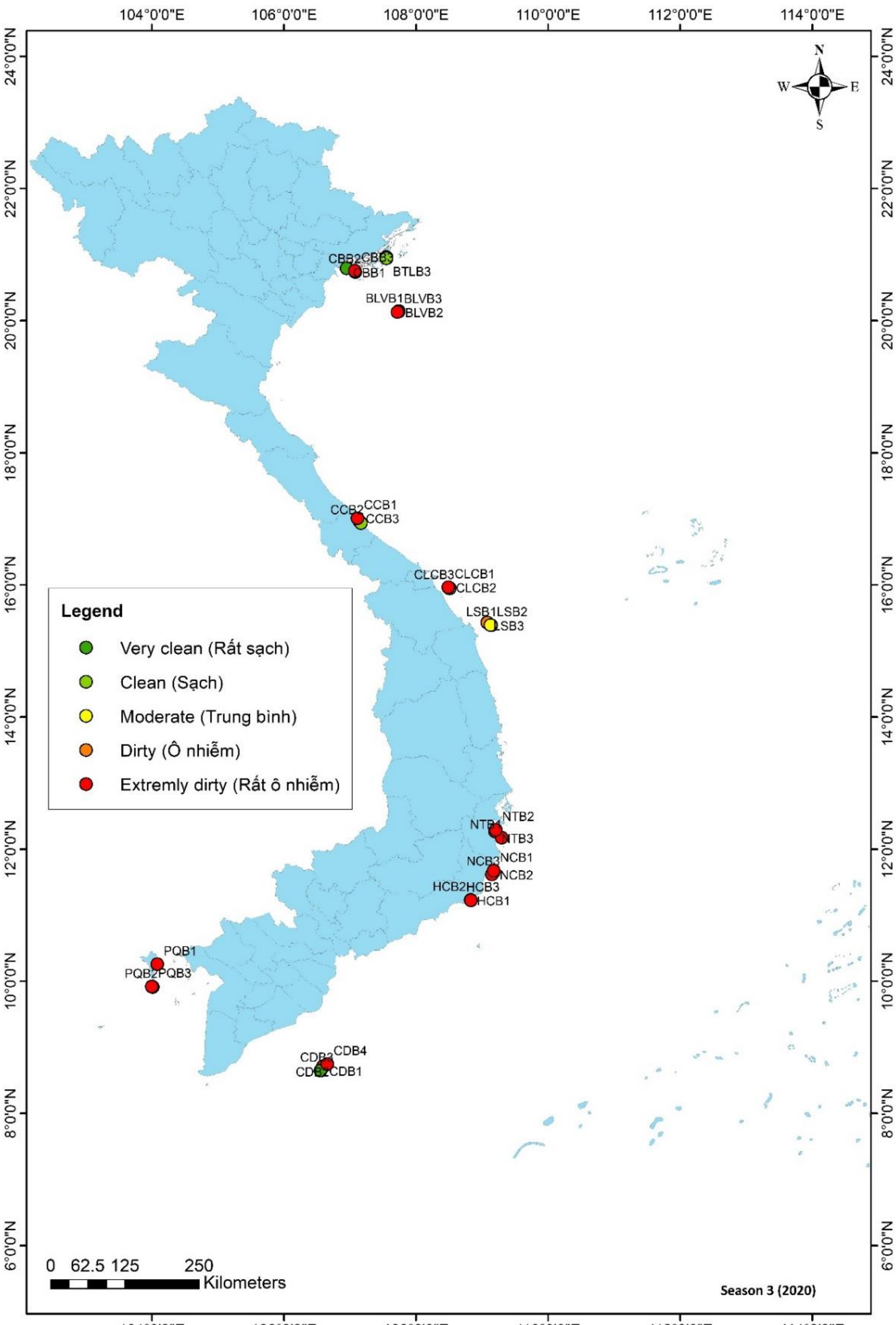


Figure 22. CCI comparison of survey locations in 2020 (Season 3)

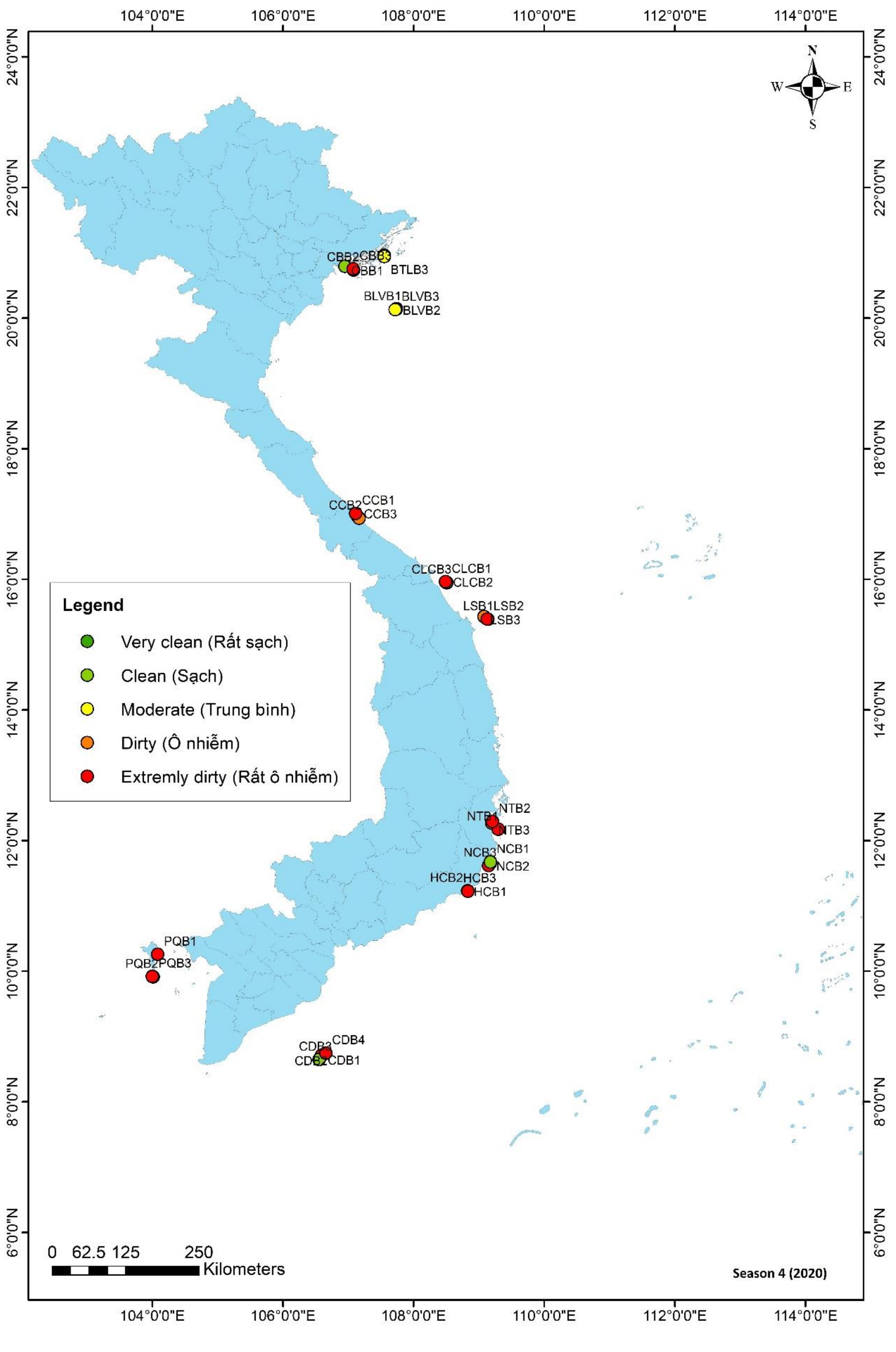


Figure 223. CCI comparison of survey locations in 2020 (Season 4)

IV CONCLUSION

1. The average number and mass of waste found on survey beaches was relatively high, reaching an average of 63.25 (pieces/m) and 1.04 (kg/m). Specifically, plastic debris accounted for a huge proportion in term of number (92%) and mass (58%). In the composition of plastic waste, plastic waste that originated from fishery activities (aquaculture, fishing, trading, etc) accounted for an overwhelming proportion (44.8% in term of number, 47.6% mass), followed by single-use plastic products (26% number, 26% mass) and plastic generated by other activities (21% number, 12% mass).
2. The first survey in 2019 had the highest number of waste items, followed by fourth survey, and the third survey having the lowest in number of items. However, the waste mass in phase 4 was significantly higher than that of the three previous phases. The number and mass of waste on the beaches during the northeasterly monsoon season is similar to that of the southwesterly season.
3. Southern beaches (beaches from Hai Van Cape to the end of Kien Giang) had a higher waste mass than the Northern beaches, however this is not a statistically significant difference.
4. A comparison between the beaches on offshore islands, coastal islands, and the mainland shows that there were statistical differences in the number and mass of plastic debris of the beaches, with the beaches on coastal islands having the lowest number and mass among all the beaches. The average number and mass of waste on coastal islands was lower than that of the other two location categories. The beaches of Ly Son and Nha Trang had higher number and mass of waste compared to the beaches in other localities. Among 34 survey beaches, only two had a lower number and mass of plastic debris than the world average, while the rest all exceeded it.
5. The Coastal Clean Index (CCI) shows that the majority of the beaches included in the survey were heavily polluted with plastics, with more than 70% rated at very polluted, while clean and very clean beaches only accounted for 10% to 23% of all survey beaches.

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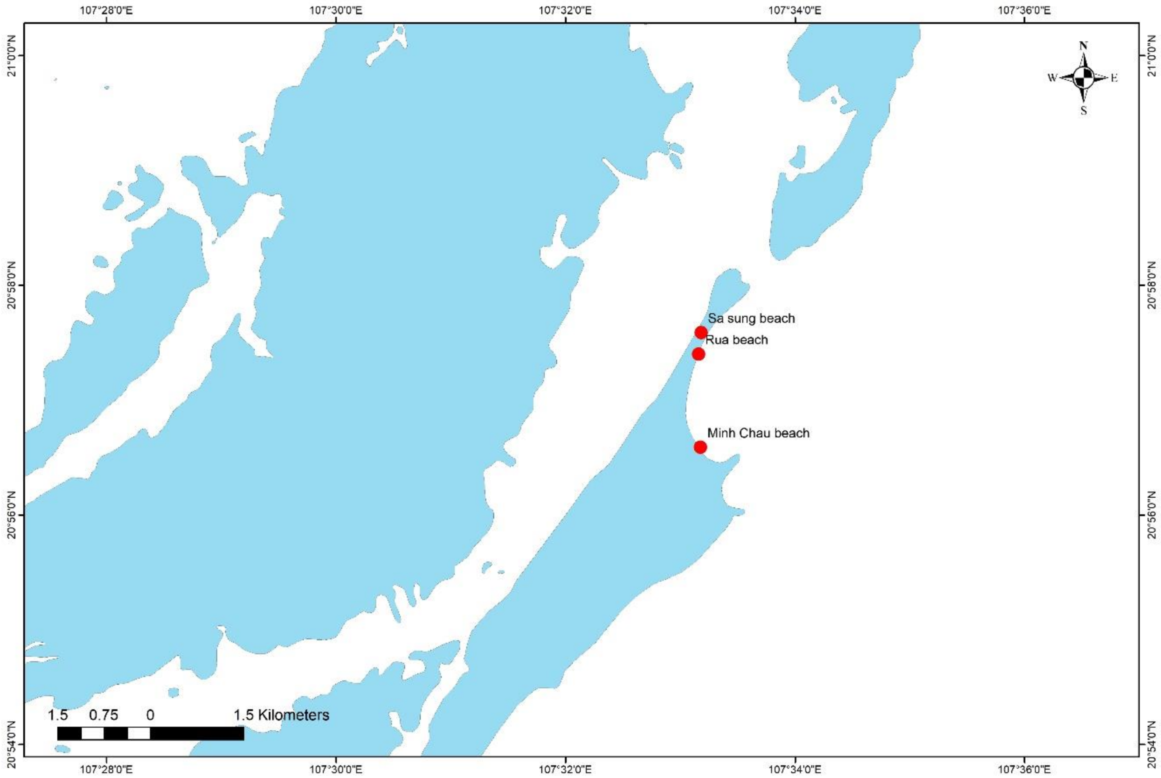
APPENDIX:

	Locations	Beaches	Abbreviations	Areas (ha)
1	Bai Tu Long	Rua beach	BTLB1	2377.39
2		Sa sung beach	BTLB2	12409.18
3		Minh chau beach	BTLB3	7566.23
4	Bach Long Vy	Au tau beach	BTLB1	6744.35
5		Mom dong beach	BTLB2	10796.76
6		Bai tam beach	BTLB3	6789.53
7	Cat Ba	Duong Gianh beach	CBB1	21323.95
8		Cat dua beach	CBB2	2717.75
9		Va rong	CBB3	2039.9
10	Quang Tri	Bai Bac Son	CCB1	3867.68
11		Thon 6 beach	CCB2	7090.21
12		Thon 9 beach	CCB3	5544.81
13	Cu Lao Cham	Bac beach	CLCB1	1835.44
14		Xep Duoi beach	CLCB2	1758.85
15		Xep Tren beach	CLCB3	1872.34
16	Ly Son	Hang Cau Duoi beach	LSB1	2925.88
17		Hang Cau Tren beach	LSB2	1925.4
18		Tay beach	LSB3	2574.39
19	Nha Trang	Hon Mun beach	NTB1	2083.53
20		Vinh Hoa beach	NTB2	2566.04
21		Cua Song Cai beach	NTB3	3060.98
22	Nui Chua	Hon Mot beach	NCB1	2472.16
23		Ngang beach	NCB2	2635.65
24		My Hoa beach	NCB3	2218.39
25	Hon Cau	Truoc beach	HCB1	2152.9
26		Trang Dao beach	HCB2	1493.22
27		Tau beach	HCB3	2243.4
28	Con Dao	Ong dung beach	CDB1	1556.96
29		Dam trau nho beach	CDB2	11964.29
30		Dam quoc	CDB3	28627.11
31	Phu Quoc	Cay sao beach	PQB1	5059.02
32		Gam ghi beach	PQB2	1701.64
33		Hon vong beach	PQB3	997.8

Bai Tu Long


107°28'0"E
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Sa sung beach
Rua beach
Minh Chau beach
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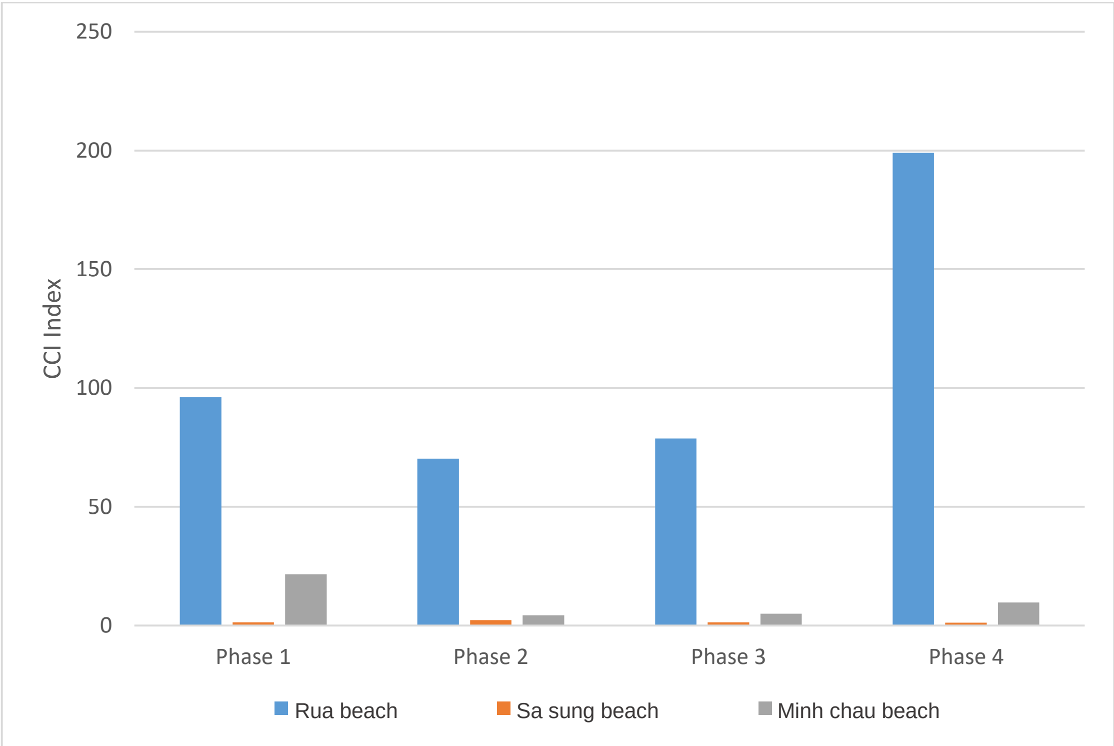
CCI Index
250
200
150
100
50
0
Phase 1
Phase 2
Phase 3
Phase 4
Rua beach
Sa sung beach
Minh chau beach

Bach Long Vi

107°42'0"E
107°42'30"E
107°43'0"E
107°43'30"E
107°44'0"E
107°44'30"E
107°45'0"E
107°45'30"E
107°46'0"E
107°46'30"E
20°9'0"N
20°8'30"N
20°8'0"N
20°7'30"N
20°7'0"N
20°6'30"N
N
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W
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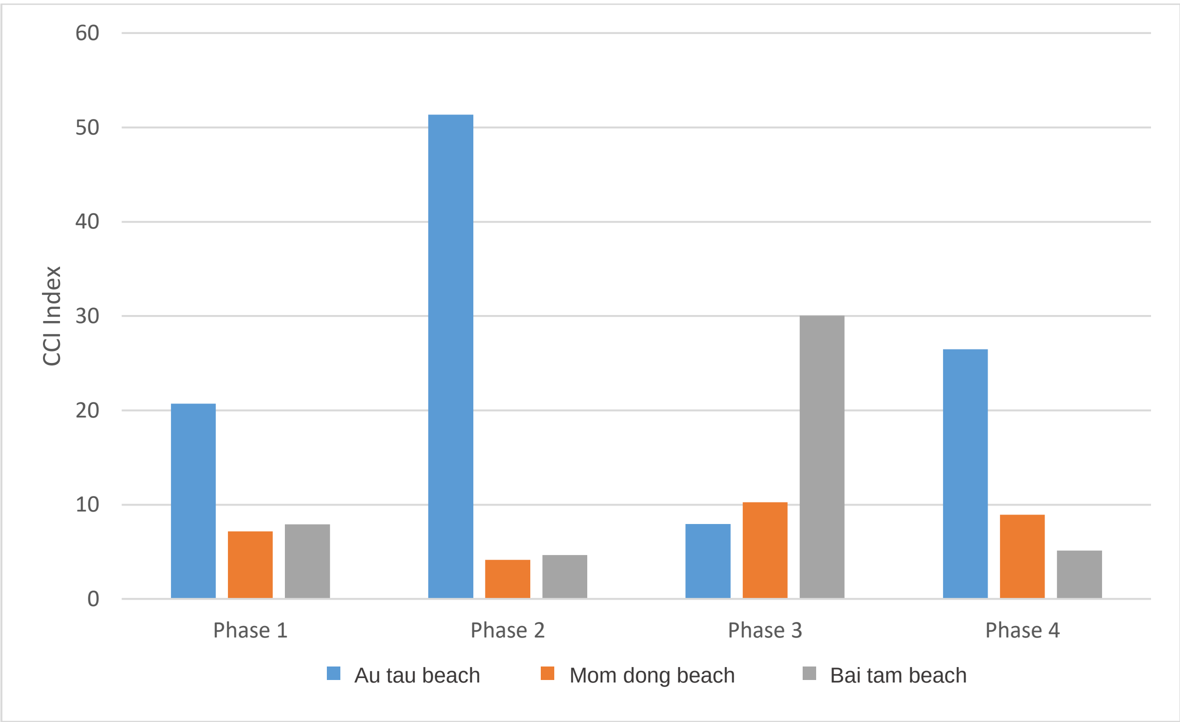
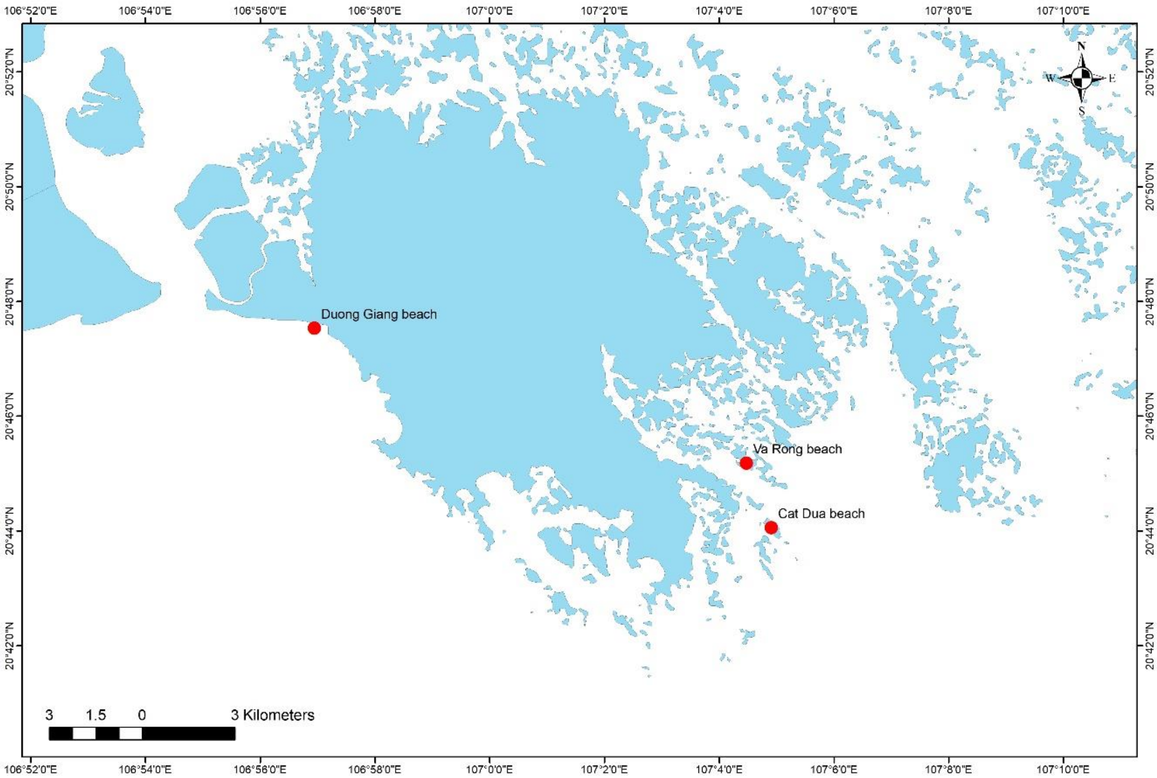
Mom Dong beach
Au Tau beach
Bai Tam beach
0.75 0.375 0 0.75 Kilometers



CCI Index
60
50
40
30
20
10
0
Phase 1
Phase 2
Phase 3
Phase 4
Au tau beach
Mom dong beach
Bai tam beach

Cat Ba



Duong Giang beach
Va Rong beach
Cat Dua beach
3 1.5 0 3 Kilometers
N
S
W
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106°52'0"E
106°54'0"E
106°56'0"E
106°58'0"E
107°0'0"E
107°2'0"E
107°4'0"E
107°6'0"E
107°8'0"E
107°10'0"E
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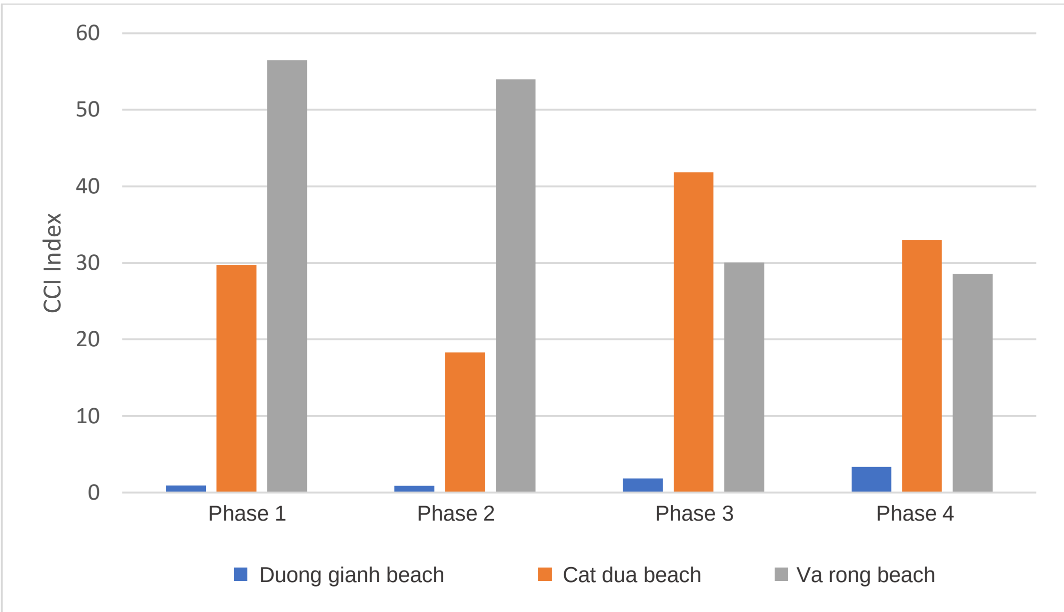
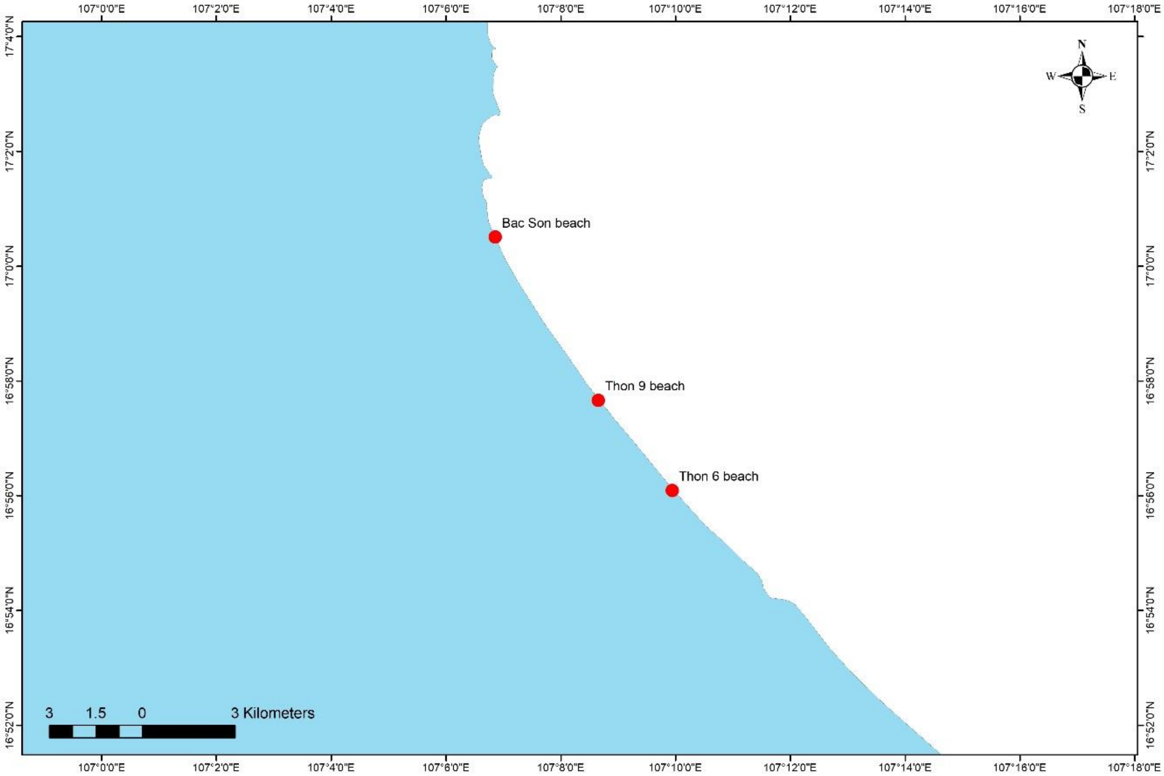
20°42'0"N

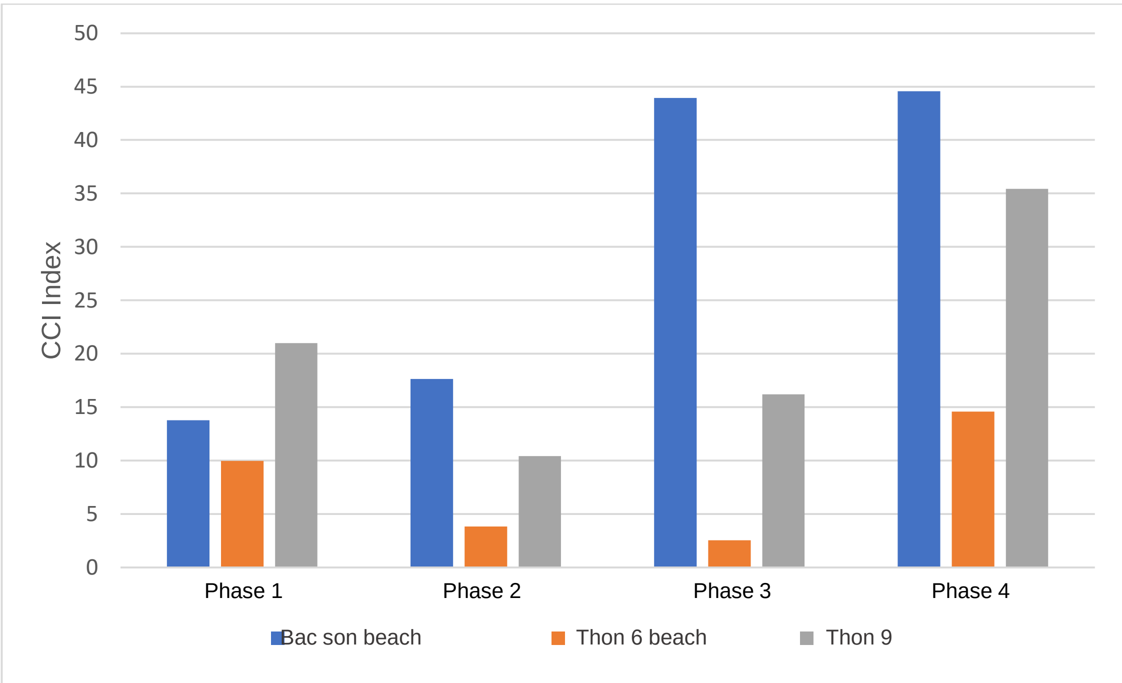


CCI Index
60
50
40
30
20
10
0
Phase 1
Phase 2
Phase 3
Phase 4
Duong gianh beach
Cat dua beach
Va rong beach

Quang Tri

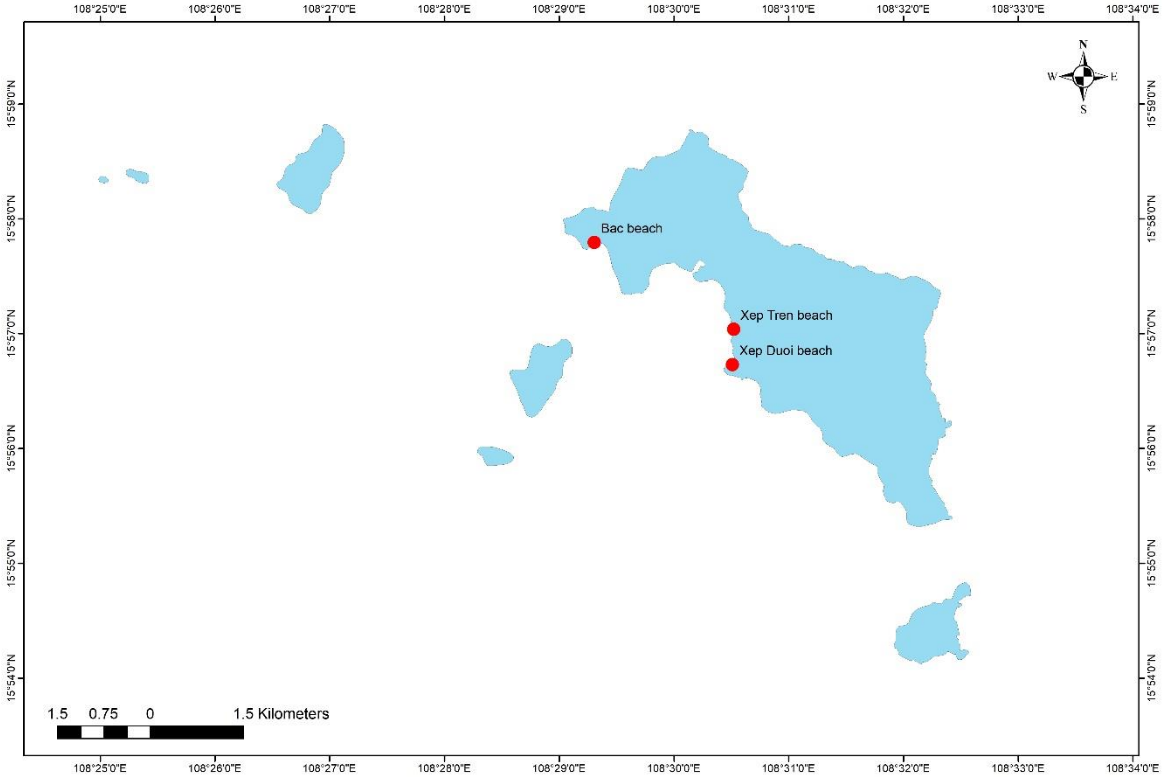


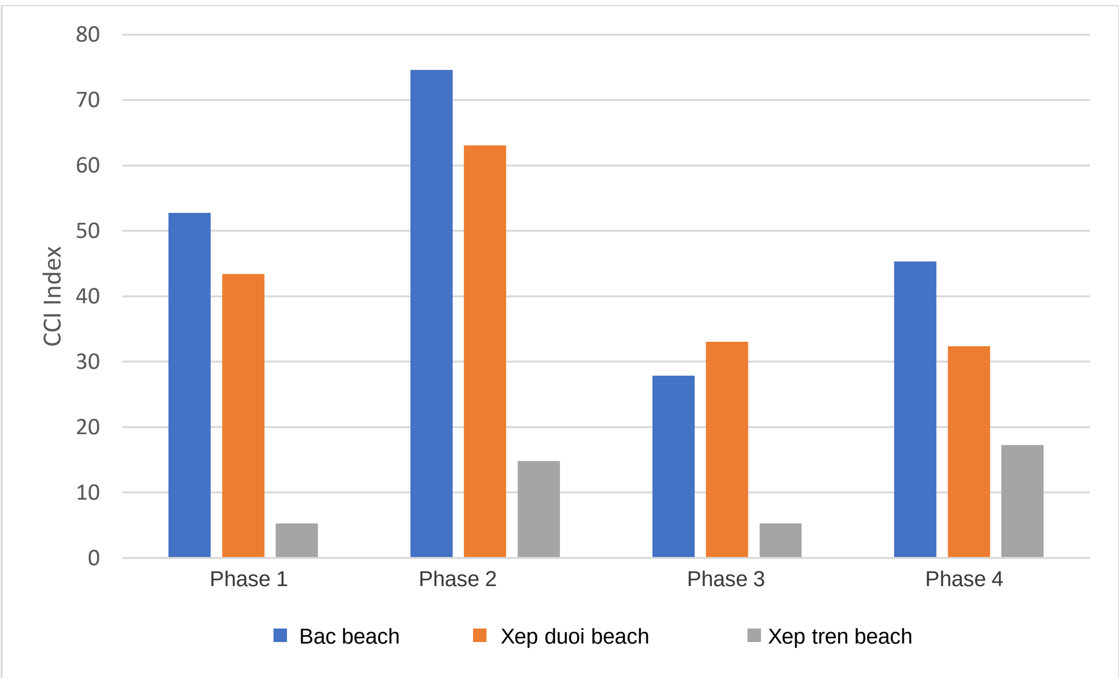
107°0'0"E
107°2'0"E
107°4'0"E
107°6'0"E
107°8'0"E
107°10'0"E
107°12'0"E
107°14'0"E
107°16'0"E
107°18'0"E
17°4'0"N
17°2'0"N
17°0'0"N
16°58'0"N
16°56'0"N
16°54'0"N
16°52'0"N
N
W
E
S
Bac Son beach
Thon 9 beach
Thon 6 beach
3 1.5 0 3 Kilometers



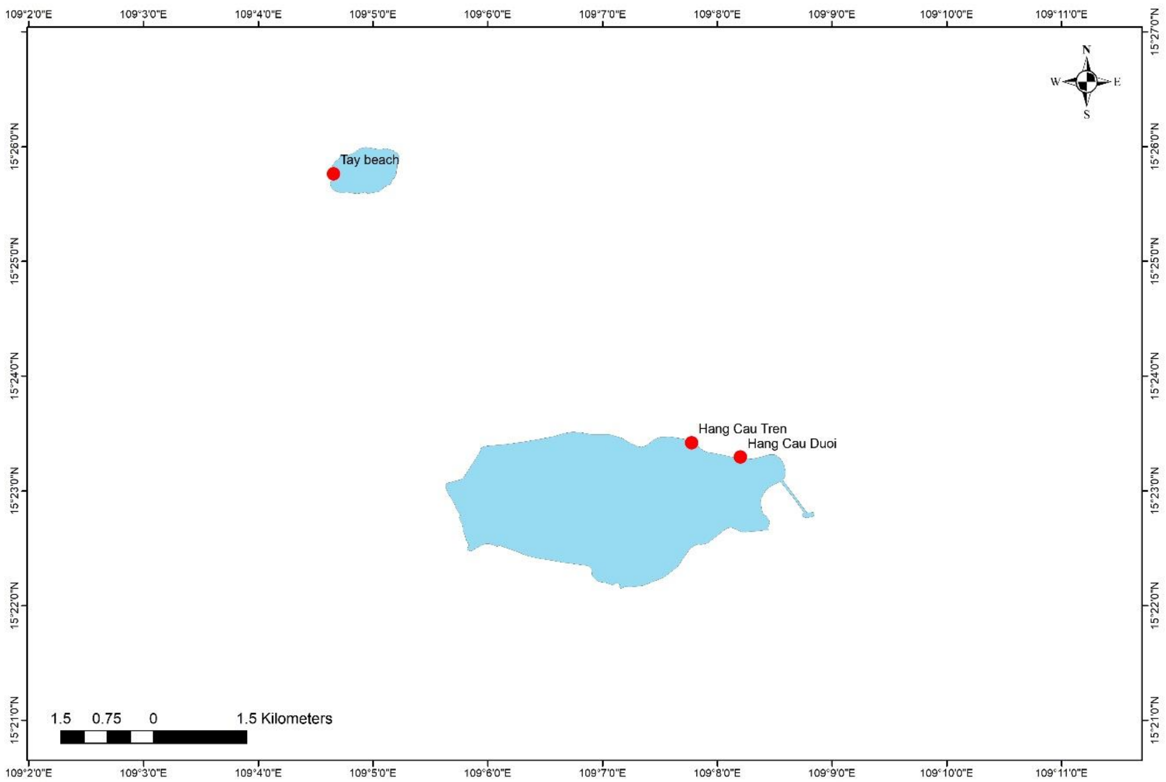
CCI Index
50
45
40
35
30
25
20
15
10
5
0
Phase 1
Phase 2
Phase 3
Phase 4
Bac son beach
Thon 6 beach
Thon 9

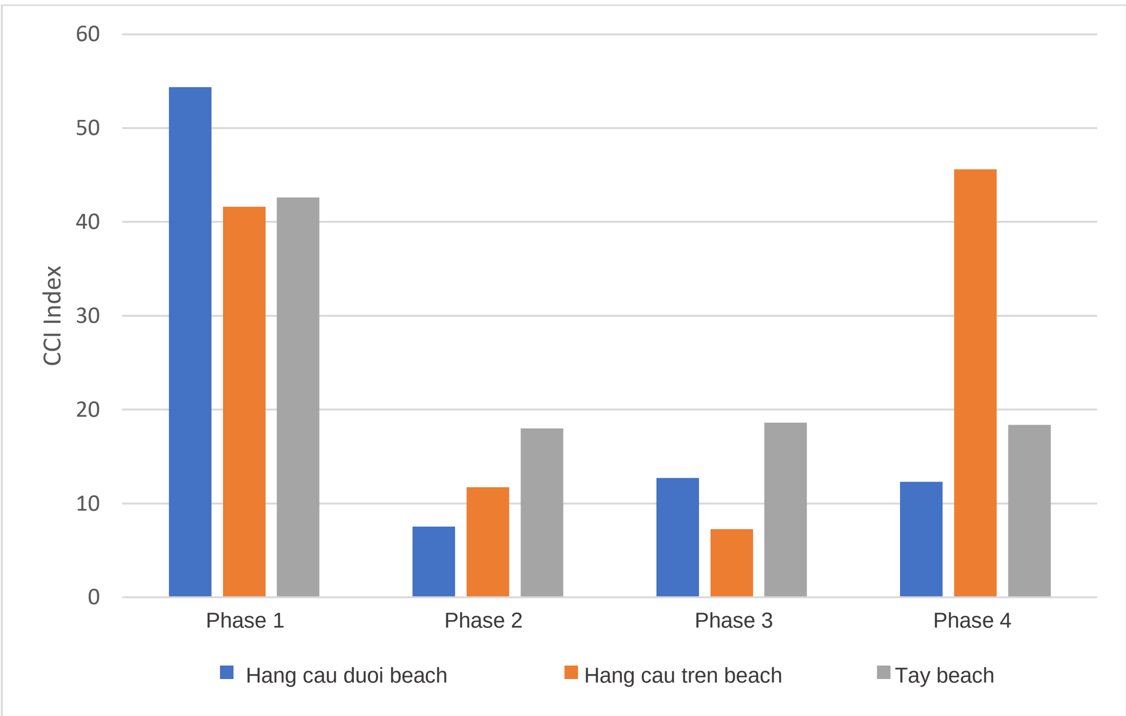
Cu Lao Cham


Bac beach
Xep Tren beach
Xep Duoi beach
1.5 0.75 0 1.5 Kilometers
N
S
W
E

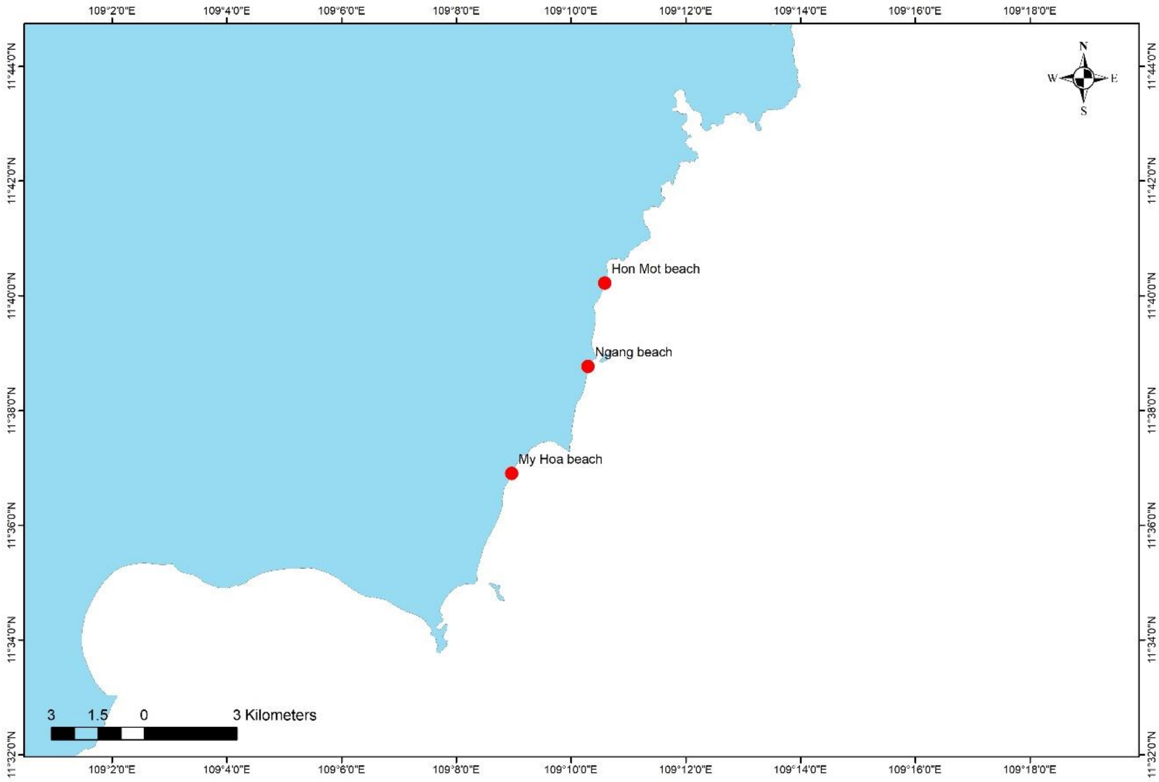

CCI Index
Phase 1
Phase 2
Phase 3
Phase 4
Bac beach
Xep duoi beach
Xep tren beach

Ly Son

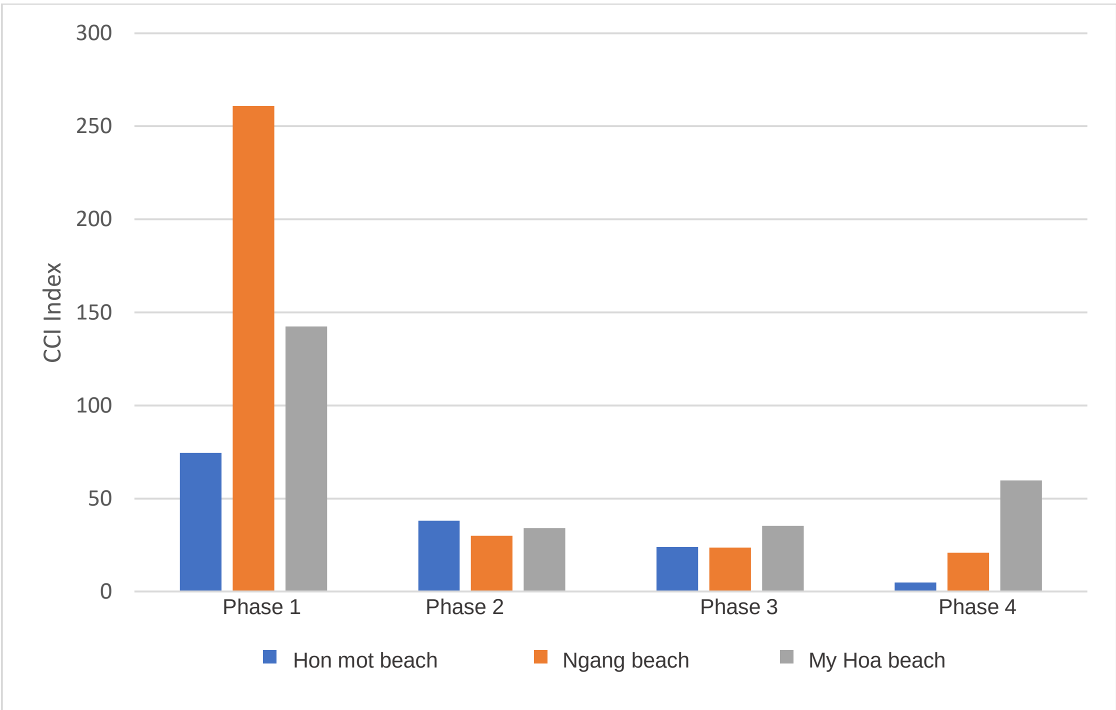

Tay beach
Hang Cau Tren
Hang Cau Duoi
1.5 0.75 0 1.5 Kilometers
N
S
W
E


CCI Index
60
50
40
30
20
10
0
Phase 1
Phase 2
Phase 3
Phase 4
Hang cau duoi beach
Hang cau tren beach
Tay beach

Nui Chua

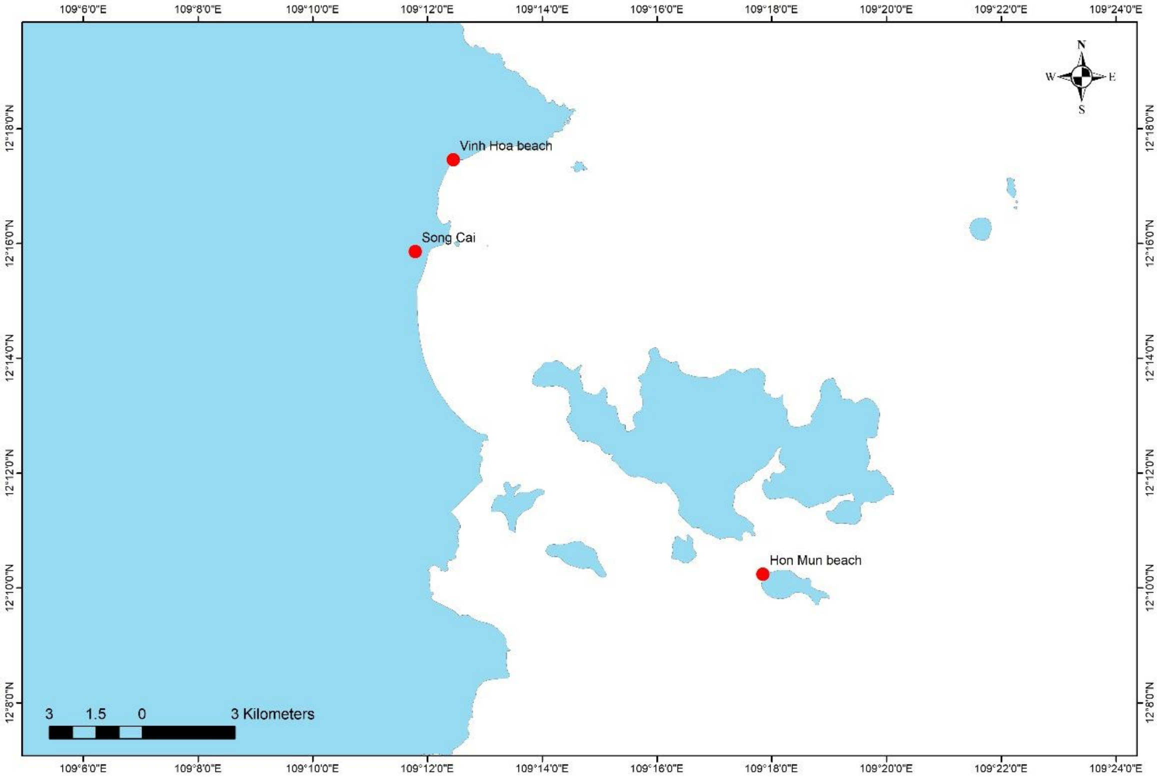


Hon Mot beach
Ngang beach
My Hoa beach
3 1.5 0 3 Kilometers
N
W
E
S

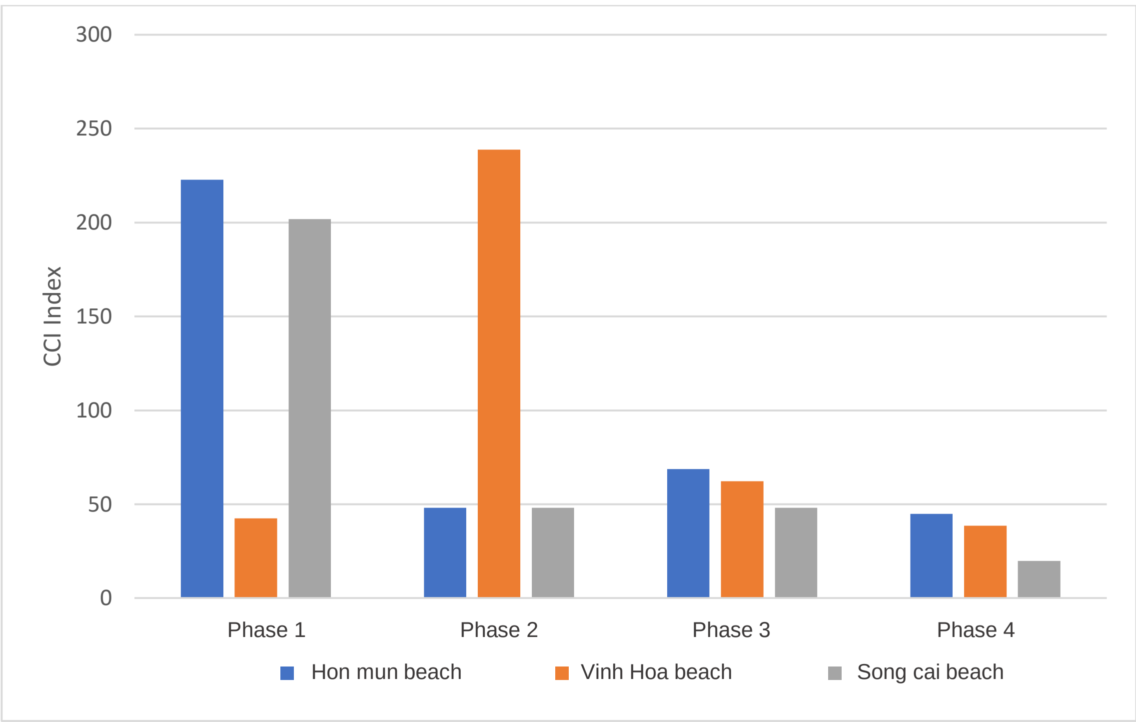


CCI Index
300
250
200
150
100
50
0
Phase 1
Phase 2
Phase 3
Phase 4
Hon mot beach
Ngang beach
My Hoa beach

Nha Trang

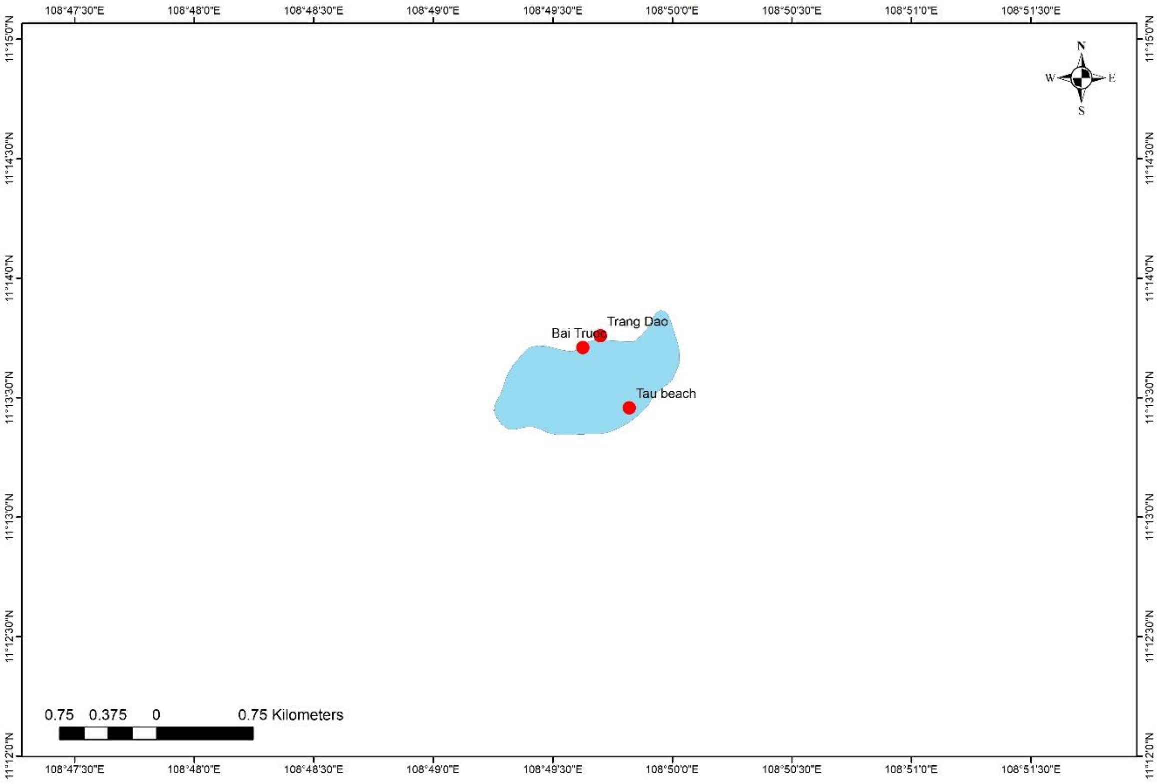


109°6'0"E
109°8'0"E
109°10'0"E
109°12'0"E
109°14'0"E
109°16'0"E
109°18'0"E
109°20'0"E
109°22'0"E
109°24'0"E
12°18'0"N
12°16'0"N
12°14'0"N
12°12'0"N
12°10'0"N
12°8'0"N
N
W
E
S
Vinh Hoa beach
Song Cai
Hon Mun beach
3 1.5 0 3 Kilometers

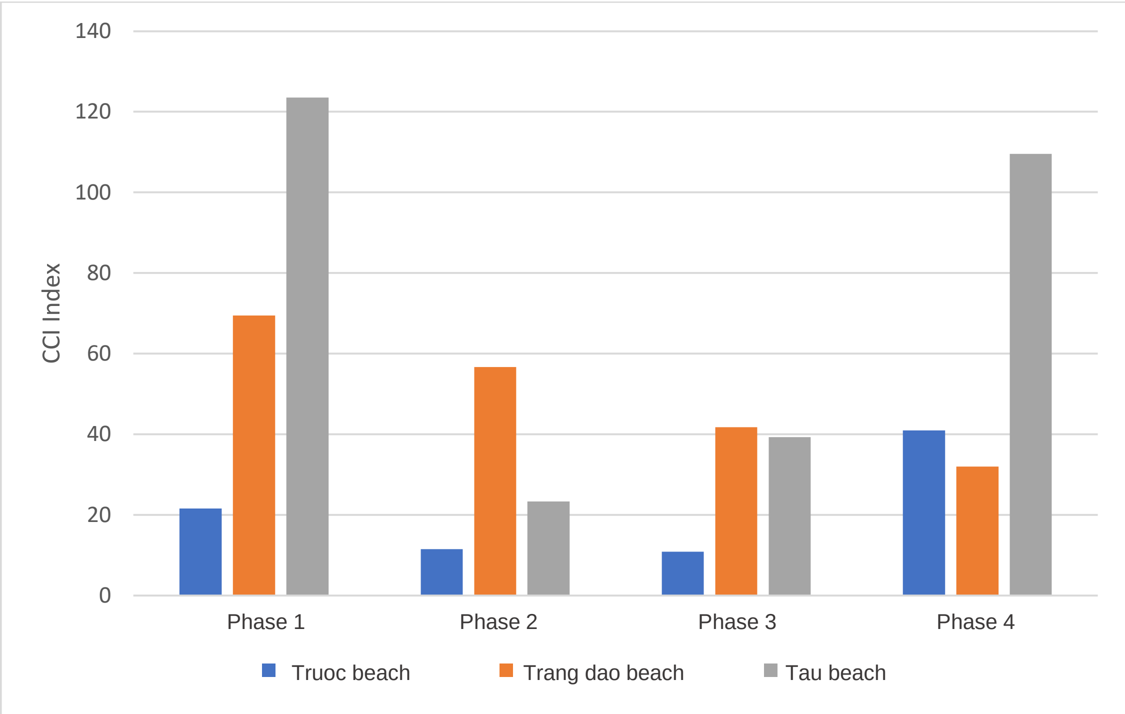


300
250
200
150
100
50
0
CCI Index
Phase 1
Phase 2
Phase 3
Phase 4
Hon mun beach
Vinh Hoa beach
Song cai beach

Hon Cau

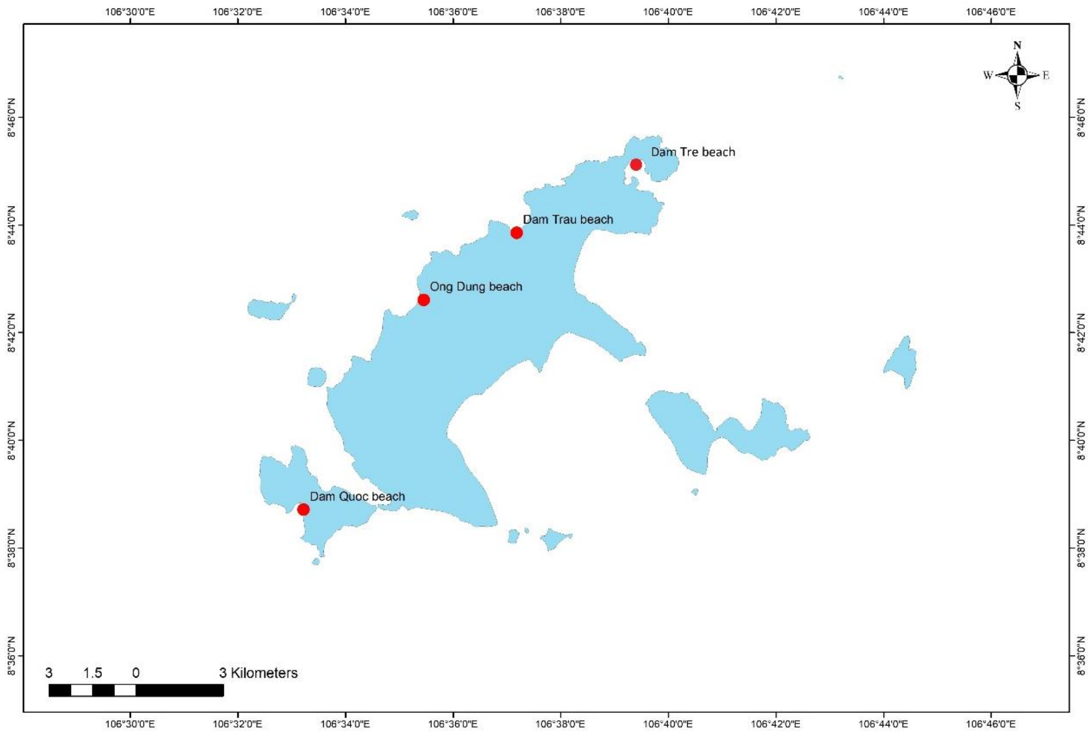


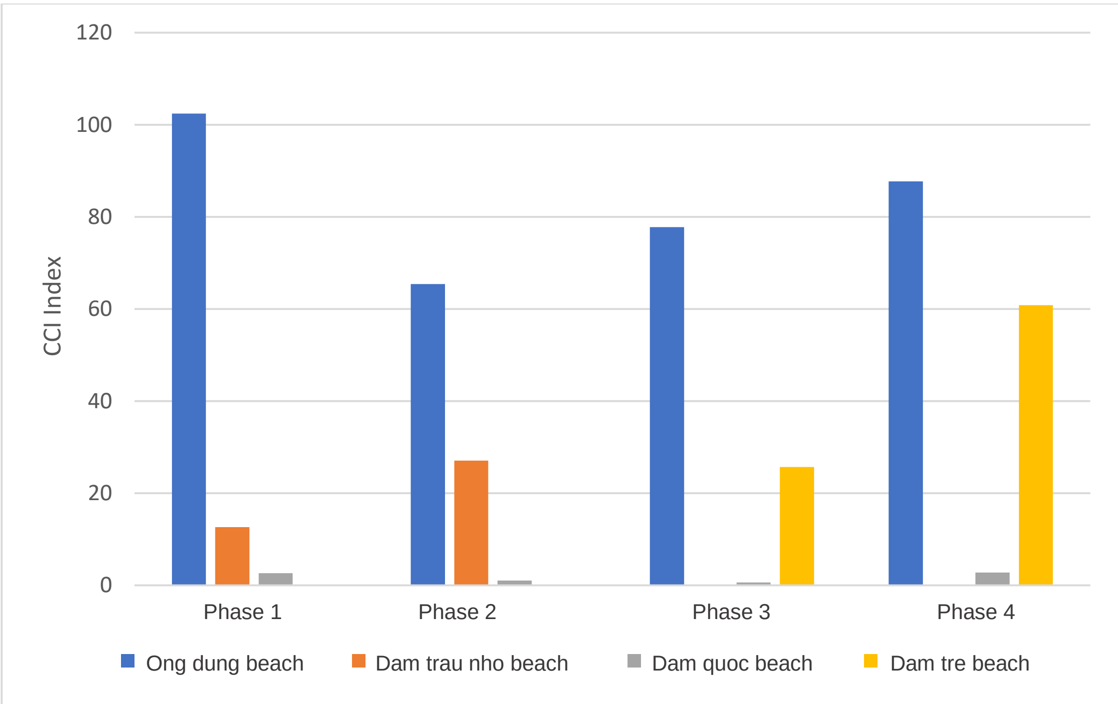
108°47'30"E
108°48'0"E
108°48'30"E
108°49'0"E
108°49'30"E
108°50'0"E
108°50'30"E
108°51'0"E
108°51'30"E
11°15'0"N
11°14'30"N
11°14'0"N
11°13'30"N
11°13'0"N
11°12'30"N
11°12'0"N
N
W
E
S
Trang Dao
Bai Truoc
Tau beach
0.75 0.375 0 0.75 Kilometers

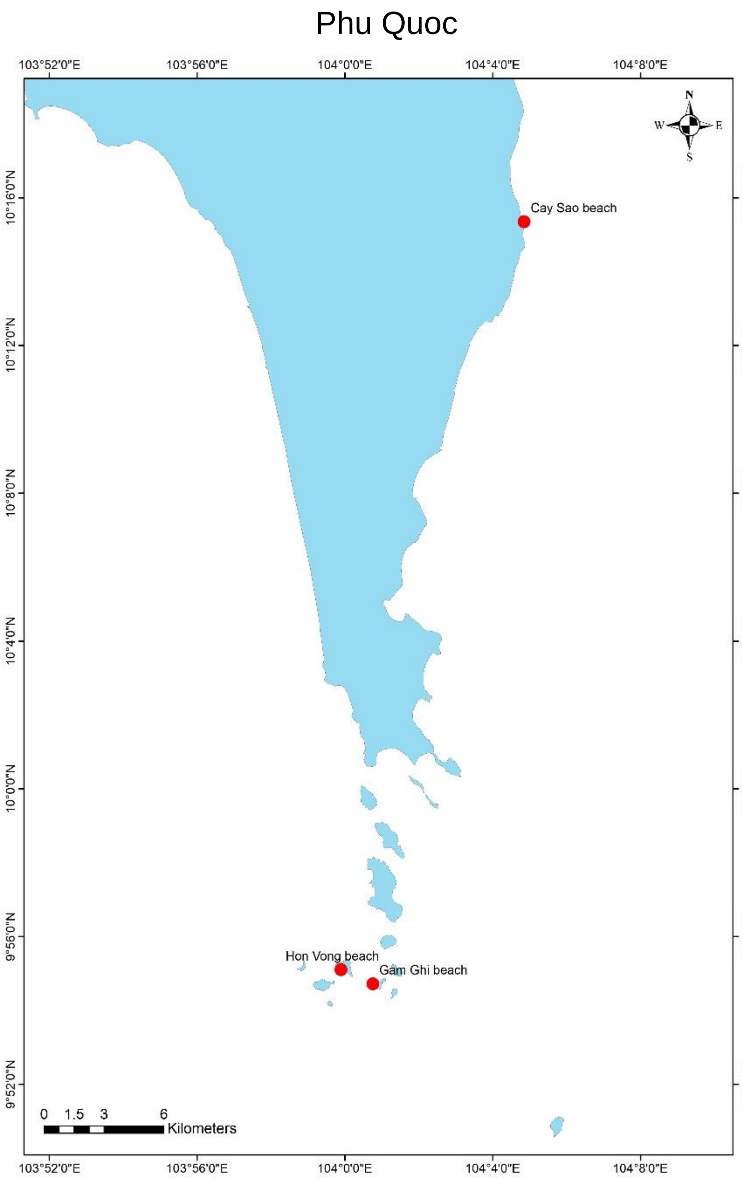


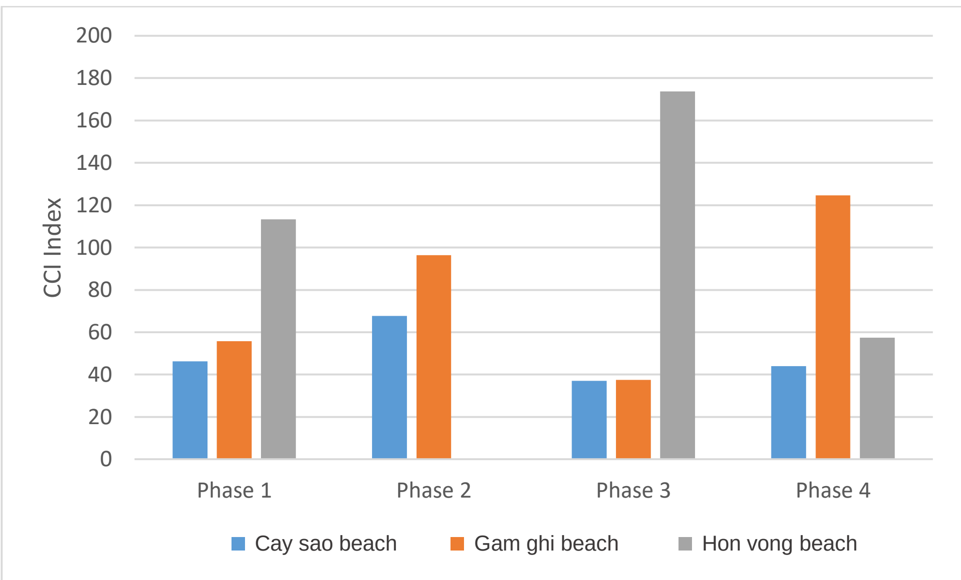
CCI Index
140
120
100
80
60
40
20
0
Phase 1
Phase 2
Phase 3
Phase 4
Truoc beach
Trang dao beach
Tau beach

Con Dao


Dam Tre beach
Dam Trau beach
Ong Dung beach
Dam Quoc beach
3 1.5 0 3 Kilometers
106°30'0"E
106°32'0"E
106°34'0"E
106°36'0"E
106°38'0"E
106°40'0"E
106°42'0"E
106°44'0"E
106°46'0"E
8°46'0"N
8°44'0"N
8°42'0"N
8°40'0"N
8°38'0"N
8°36'0"N
N
S
W
E


CCI Index
120
100
80
60
40
20
0
Phase 1
Phase 2
Phase 3
Phase 4
Ong dung beach
Dam trau nho beach
Dam quoc beach
Dam tre beach


Phu Quoc
103°52'0"E
103°56'0"E
104°0'0"E
104°4'0"E
104°8'0"E
10°16'0"N
10°12'0"N
10°8'0"N
10°4'0"N
10°0'0"N
9°56'0"N
9°52'0"N
N
W
E
S
Cay Sao beach
Hon Vong beach
Gam Ghi beach
0 1.5 3 6
Kilometers


CCI Index
200
180
160
140
120
100
80
60
40
20
0
Phase 1
Phase 2
Phase 3
Phase 4
Cay sao beach
Gam ghi beach
Hon vong beach

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