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Status of coconut crab *Birgus latro* (Linnaeus, 1767) in Nicobar Island

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Abstract

Coconut Crabs *Birgus latro* (Linnaeus, 1767) is the largest living terrestrial arthropod, listed as Vulnerable in the IUCN red list. In this paper, we described the existing condition of distribution, population, and measurement of morphometric traits of coconut crabs, as well as the management recommendations to prevent the over exploitation of coconut crab population. Intensive and extensive surveys were carried out at 52 sites in the Nicobar group of Islands (Great Nicobar Island, Little Nicobar, and Nancowry group of Islands) and Little Andaman during the period of April 2015 to March 2018. Transect survey and bait station survey methods were used for the determination of population density of coconut crabs, Catch Per Unit Effort (CPUE), respectively. A total of 103 coconut crabs were recorded during the survey and reveals that the sex ratio of crabs was observed as 1: 0.6. The average Thoracic Length (TL) of female coconut crab was measured as 32.0 ± 8.7 and 37.9 ± 13.5 for the male coconut crab. Estimation of size class of coconut crabs was observed as 76% of female and 59% of males are greater than 25 mm of TL and less than 50 mm. Furthermore, hardly 24% of male crabs were with greater than 50 mm of TL. The study discloses that the Catch Per Unit Effort (CPUE) of one crab per bait corresponds to a population density of 4.6 crabs/km^2, and the male coconut crab was dominated in size as well as population in Andaman and Nicobar Islands. The study concludes that, the factors like differences in body size, availability of natural foods, disturbance level and environmental conditions suitability could influence in character size. The current study perceived that, the population of coconut crabs are declining due to the harmful anthropogenic activities such as habitat destruction and hunting. Eventually, we recommend management strategies for the prevention of overexploitation of coconut crabs and the conservation of coconut crabs along with its natural habitats.

Keywords: Andaman and Nicobar, Coconut Crab, Islands, Population

Introduction

Andaman and Nicobar Islands are indeed a chain of 836 oceanic islands located (Lat. 06-14°N and Long. 92-94°E) between Bay of Bengal and Andaman Sea at a length of 800 km with a coastline of 1962 km. These are truly oceanic islands, they have never been connected to the mainland in the era of Pleistocene epoch (Ripley & Beehler, 1989). These islands have a geological linkage with the Arakan Yoma of Burma in the north and Achin Head of Sumatra in the south. Total landmass of Andaman and Nicobar Islands is 8249 km^2. Andaman group of Island covers a landmass of 6408 km^2 and it comprised of 324 major islands. Out of these, around 20 islands are inhabited. Nicobar group comprises of 24 major islands with a landmass of 1841 km^2 of which 13 islands are inhabited. The presence of marine environment around the immaculate islands in the form of Coco Channel in Northern side, Andaman Sea in Eastern side, the Great Channel in Southern side and Bay of Bengal in Western side carries the pride of enriched marine biodiversity. The environmental clues had taken various vital roles in the successful succession of enriched biodiversity both in marine and terrestrial domes.

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Coconut Crab or Robber Crab

The Coconut crab or Robber crab or Palm thief (*Birgus latro*) is the largest terrestrial arthropod in the World which is related to hermit crabs and lobsters (Lavery *et al*., 1996). The crab is named because it is associated with coconut tree. This is the monospecific of the genus *Birgus* that can be adapted to exist on land. This species carries an empty gastropod shell for protection at juvenile stage, but the adult develops a strong exoskeleton on their abdomens and stop carrying a shell. Generally, they are exhibited in solitary form. Coconut crabs' closest evolutionary relatives are terrestrial hermit crabs (*Coenobita* spp.). *Birgus latro* is considered as a grade T4 terrestrial species based on the level of dependence it has on the aquatic environments. Species within this grade do not require immersion in standing water but are dependent on water for the pelagic larvae (Powers & Bliss, 1983; Greenaway, 2003). The taxonomical systematics of this species is given below.

Phylum: Arthropoda von Siebold, 1848

Sub phylum: Crustacea Brünnich, 1772

Class: Malacostraca Latreille, 1802

Order: Decapoda Latreille, 1802

Infra order: Anomura MacLeay, 1838

Super family: Paguroidea Latreille, 1802

Family: Coenobitidae Dana, 1851

Genus: *Birgus* Leach, 1816

Species: *Birgus latro* (Linnaeus, 1767)

Morphology: Like Decapoda, the body of the coconut crab is comprised of cephalothorax, which has (five pairs) ten legs, and the abdomen. The first and front-most pair of legs are large and with strong chelae (claws) that are used for peeling the shells of coconuts. Generally, the left chelae are larger than the right one. The next two pairs are huge, dominant walking legs with sharp tips like hermit crabs that are employed in climbing the coconut tree vertically. The fourth pair of legs are smaller with tweezers-like chelae at the end, allowing juvenile coconut crabs to dwell inside the shell or coconut husk for protection. But in case of adult, it uses this pair for walking and climbing. The last pair of legs is very tiny with small claws that are used by the female to tend their eggs, and by the males to mate. Storch *et al.* (1979) described general morphology of *Birgus latro* in the island of Olango, Philippines.

Colour: The colour of full-grown adult crab can be varied from reddish orange to purplish blue with blue is the prime colour. However, in the Seychelles, most individuals are red and therefore, the colouration of the animal may vary due to geographical region (Fletcher, 1993).

Size: The size of adult coconut crabs can vary, generally reaching up to 40 cm; a leg can reach more than 1.0 m. The males are normally larger than females. The length of carapace is about 78 mm; a width is 200 mm. The weight of this crab can be measured up to 4.5 kg (Naskrecki, 2005).

Reproduction and Life Cycle: Coconut crabs display sexual dimorphism, and the males are larger than females. The presence of pleopods in female abdomen is the distinctive characteristic that helps in carrying the egg masses. Spermatophores are present in the male crab that is deposited on the abdomen of the female's gonopore. The fertilization process occurs on the external surface of the female abdomen and the females carry the eggs until hatching on pleopods. Later the mature females move from land to the shallow intertidal water and disperse the larvae in the sea in new phase. There is no parental care by male. The zoeal stage is the initial stages of its life, occurred in marine habitat and is consists of five stages with a span of 25 to 33 days. During post larvae or Glaucothoe or amphibious phase, it shifts into a vacant shell of gastropod and migrates into the land and undergoes metamorphosis. The amphibious stage is followed by the juvenile stage. Around 5 years after the hatching process, coconut crab attains sexual maturity (Figure 1). Larval development was studied in laboratory by Reese and Kinzin (1968). The mode of reproduction of coconut crab have been studied by Schiller *et al.* (1991) in the Republic of Vanuatu. Hicks *et al.,* (1984) studied spawning particularly in the Christmas Island.

Habits: The Coconut crab is secretive, unsociable excluding the gravid females which are observed at large densities (Schiller *et al.,* 1991). They are spotted as nocturnal, diurnal or both. The behavioral pattern of coconut crabs is dependent upon the factors in particular, local population density and possibly the level of human activity. Day time foraging is observed among them which may be the mechanism for reducing the number of

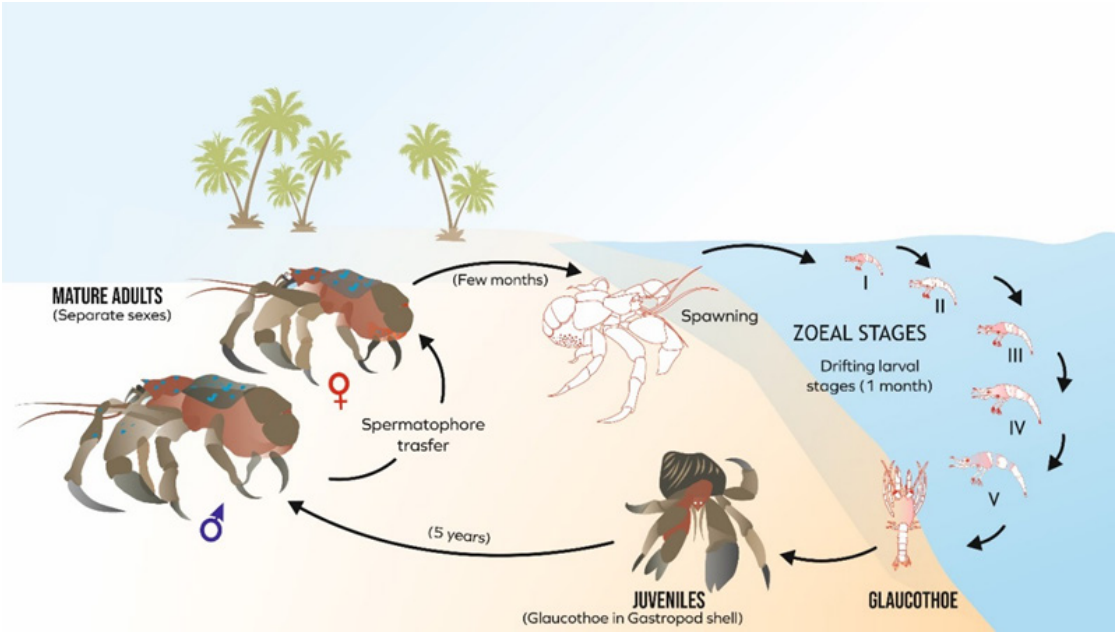

Figure 1. The reproduction and life cycle of coconut crab.

intraspecific encounters in large populations as the crabs are highly aggressive (Helfman, 1977). These interactions can lead to the point of physical aggression, and as a result one or both antagonists can be seriously injured. Cannibalistic behaviour has been observed among larger crabs attacking and eating smaller individuals (Altevogt & Davis, 1975; Helfman, 1977). After foraging, the crabs immediately go back to a particular sheltering site or cracks (Fletcher *et al.,* 1990). Coconut crabs live near to a source of coconuts, where they acquire large quantities of husk and broken kernels are often seen near the entrances of crab's lairs (Reese, 1987). It explains the terrestrial habit due to the characteristics of osmotic regulation (Gross, 1955).

Habitat: The Coconut Crab *Birgus latro* is typically found on island habitats within a distance of 4 km from the sea (Fletcher & Amos, 1994). They predominantly inhabit dense forest zone but can be copious in sandy coconut groves (Grubb, 1971). Although rarely observed physically, tracks can be seen on the dunes and the upper shore along the coastline (Grubb, 1971). These crabs usually inhabit in shelters like crevices, caves, hollow logs, tree roots, or earth burrows during the day time. Furthermore, they are usually found within a few kilometers of the sea. But in favorable conditions, some individuals make their way further inland (Fletcher, 1993).

Food: Most studies conclude that, the coconut crab is omnivorous and probably a scavenger in nature (Reyne, 1939; Altevogt & Davis, 1975). Cannibalistic behavior of this crab has also been observed by Altevogt & Davis (1975) and Helfman (1977). Fruits of Pandanus, *Canarium* spp., *Barringtonia* spp. and the bread fruit, *Artocarpus* spp. are the major food items consumed by the coconut crabs (Fletcher, 1993). Coconut crabs are also known as a scavenger by eating dead birds, rats, and crabs (*Coenobitids, Brachyuran*), and occasionally other *Birgus* (Fletcher, 1993). Recently it was observed that a large coconut crab immobilized and consumed a red footed booby (Buehler, 2017). It can live in divergent salinity to maintain osmotic balance of their body (Gross, 1955).

Predators: Humans and other coconut crabs are the known predators of adult coconut crabs. It is widely hunted for consumption and it is very rarely observed on islands with a human population because of its large size and quality of meat (Wolcott, 1988).

Relationship with Human Beings: The coconut crab is served for food item and is considered a delicacy and an aphrodisiac. Coconut crabs are protected at the Cook Islands and the Mariana Islands where the people are following the traditional belief that ancestral spirits can return in the form of animals such as the coconut crab (Orlando, 2009).

Status: The statistics shows that the coconut crab populations in several areas are decreasing or becoming locally extinct due to human predation as well as habitat loss (Brown & Fielder 1991; Fletcher, 1993; Schiller, 1992; Lavery *et al*., 1996). In many of the countries the crab is effectively extinct (Schiller, 1992). Hence, it is protected internationally and nationally.

Globally: In 1981, it was categorized as a vulnerable species by the IUCN Red List. But later it was relegated to 'Data deficient' category due to lack of biological data (Eldredge, 1996).

India: Coconut crabs are listed as Schedule - I, Part - I under Wildlife Protection Act, 1972.

Distribution: Globally: Coconut crabs have a wide distribution range that extend over the tropical Indo-Pacific region that starts from Mauritius in the western Indian Ocean to the Tuamotu Archipelago in the eastern Pacific region (Reyne, 1939; Davis & Altevogt, 1978; Harries, 1983; Robertson, 1991). They have not been recorded from east Africa, the Indian sub-continent, mainland Asia or Australia and the reports are only from island habitats (Brown & Fielder, 1988). The studies on Coconut crabs in several islands were made by researchers namely Amesbury (1980) from Guam (Mariana Islands); Fletcher (2003) from Vanuatu; Fletcher and Amos (1994) from Australia; Anagnostou and Schubart (2014) from Christimas Islands; Kadiri-Jan and Chauvet (1998) from Lifou, New Caledonia; Chauvet and Kadiri-Jan (1999) from Tuamotu archipelago, French Polynesia; Vogt (2004) from Diego Garcia; Sato and Yoseda (2008) from Hatoma, Japan; Helagi *et al.* (2015) from Niue Island, New Caledonia; Storch *et al.* (1979) reported from Olango Island, Philippines; Matamaki *et al.* (2016) from Cooks Islands, New Caledonia; Serosero *et al.* (2018) from Indonesia.

Andaman and Nicobar Islands: At most few studies have been carried out on Coconut crab in Andaman and Nicobar Islands. Distribution of coconut crab from south sentinel was reported (Alcock, 1905; Davis & Altevogt, 1976) and Nicobar Islands (Hume, 1874; Alcock 1902, 1905; Man, 1938; Bhaskar & Rao, 1992). Daniel & Premkumar (1968) studied about the feeding and breeding behavior in the Great Nicobar Island. Altevogt and Davis, (1975) reported on the observation of habitat, activity patterns, feeding bahaviour in South Sentinel, Andaman Islands. First post-tsunami sighting of the coconut crab in the Nicobar Islands was by Patankar (2007). Recently, Patankar and D'Souza (2012) reported 31 individuals of coconut crabs from Menchal and Camorta Islands. Under the present study, status, distribution, abundance and relative density of Coconut crab, sex ratio and morphometric characteristics of coconut crabs and size variations of male and female were estimated, and the distribution map of Coconut crab was prepared.

Study Area

This study was carried out from April 2015 through March 2018 in Little Andaman and the Nicobar group of Islands (Great Nicobar Island, Little Nicobar Island, and Nancowry group of Islands).

Little Andaman

Location and Topography: Little Andaman is the southernmost island of the Andaman Archipelago. It is the southernmost island of the South Andaman District. It is separated by the Duncan Passage from the Andaman Island Group in the North and separated from the Nicobar Island Group by the Ten Degree Channel in the South, situated approximately 120 km away from Port Blair. Little Andaman has underlain by marine sedimentary group of rocks, other igneous rocks and coralline limestone rocks. This island is considered as an incredible part of biodiversity with the presence of quantum of lives with its natural habitat and phenomenon, pristine sandy beaches of the islands, presence of several ecosystems such as evergreen forests, deciduous forests, and mangrove forests.

Nicobar Islands

Location and Topography: Geographically, the Nicobar group of Islands is an archipelagic chain in the eastern Indian Ocean. It is pertained of a great island arc formed by the collision of the Indo-Australian Plate with Eurasia. They are located south of Port Blair, and around 150 km north of Aceh on Sumatra, and it is separated from Thailand to the east by the Andaman Sea. In the year of 2013, the UNESCO has declared the Great Nicobar Island as one of the World Network of Biosphere Reserves (UNESCO, 2013). These groups of Islands are flat, fertile islands with un-spoilt seas all around. The climate in the Nicobar group of islands is warm and tropical, and the temperatures ranging from 22 to 30°C. Heavy annual rainfall of 3000 to 3800 mm is recorded in Nicobar group

of islands due to annual monsoons. The vegetation of the Nicobar is typically classified into the coastal mangrove forests, evergreen, deciduous, tropical and subtropical moist broadleaf forests. In addition, many of the islands contain extensive grasslands and coconut plantations. The presence of pristine sandy beaches of the islands, several vegetation's and suitable climates make this group of oceanic islands as incredible habitat for coconut crabs.

Geography: The area of Nicobar group of Islands is 1,841 km^2. They consist of three distinct groups, namely, Northern group, Central group and Southern group.

Southern Group: Great Nicobar, Kondul Island, Little Nicobar, and Pulo Milo, Meroe, Trak, Treis, Menchal, Kabra, Pigeon and Megapod.

Central Group: Chowra, Bompuka, Teressa, Katchal, Camorta, Nancowry, Trinket, Laouk and Tillangchong.

Northern Group: Car Nicobar and Battimalv.

The objectives of this survey are

- To assess present status and distribution of Coconut crab population
- To estimate the sex ratio
- To measure morphometric characteristics of male and female coconut crab populations
- To establish conservation and monitoring action plan which will be the most beneficial to Coconut crab populations in Nicobar group of Islands.

Materials and Methods

Sampling Location

The coconut crabs were collected from 52 various sites in the Nicobar group of Islands (Great Nicobar Island, Little Nicobar, and Nancowry group of Islands) and Little Andaman. All the locations of study areas were clearly delineated in Table 1.

Coconut Crabs Sampling

Counting the coconut crab in a given region is a herculean task due to cryptic nature and the rocky areas, crevices they inhabit. There were no proper assessments of coconut crabs by using appropriate sampling methods in Andaman and Nicobar Islands. Hence, sampling methods like spot and relocate; transect of plain areas (coastal regions, grass lands) have been attempted to determine the density and abundance of coconut crabs. However, the above-mentioned methods are not suitable for assessing crabs on islands with a rocky forest landscape. Instead, Catch Per Unit of Effort (CPUE) has been applied for assessing abundance. Since, the coconut crab is both nocturnal and diurnal. The survey was carried out during day-time and night-time. The higher the human activities in inhabited islands, the lesser the probability to find the coconut crabs. Hence, night-time was more suitable to conduct the study.

Transect Survey (Coconut Crab Transect Density)

Line Intercept Transects (LIT) method proposed by Burnham *et al.* (1980) was used to estimate the density of coconut crab population (ind./km^2) in the Andaman and Nicobar Islands (Little Andaman and Nicobar group of Islands). Survey using transect method was employed to find out the quantity of the relationship between the relative abundance (number of crabs caught per bait) and crab density (crabs per transect area) through the use of a conversion equation. This is highly important, especially for the determination of coconut crab density, abundance, population size and distribution level at various locations. The transect survey was carried out after the bait station survey. The length of transect was analyzed from GPS waypoints. All crabs encountered 4 m either side of the transect path were measured, sex was determined, and the information was recorded.

Transect density of coconut crab population = Total individuals of coconut crabs along the transect survey/ the total transects areas (km^2) surveyed of each region in which species occurred

Abundance

The abundance of coconut crab = Total individuals of coconut crabs along the transect survey/the total no. transects of each region in which species occurred

Bait Station Survey

Bait station surveys was carried out in Little Andaman and Nicobar group of Islands (Fletcher & Amos, 1994; Matamaki *et al.,* 2016). In this method, the unhusked coconuts were cut into half, and half coconuts were kept in 25 m interval in coconut crab's habitat (*i.e.*, front of stone holes, tree, crevices, and ground holes) for baits at each station. Each of the station was marked for relocation of baits at night and the GPS was recorded for each bait station simultaneously. During the time of night searches,

Table 1. Details of survey of location, number of transects and length

S. No.	Location	GPS co-ordinates		No. of transects	Length surveyed (km)
	Great Nicobar				
1	Habra Bay	93°42.198′ E	07°11.193′ N	2	1
2	Trinket Bay	93°51.030′ E	07°12.477′ N	1	7.05
3	Lawful	93°52.428′ E	07°10.181′ N	1	0.05
4	Navy Dera	93°53.070′ E	07°08.144′ N	1	1
5	Govind Nagar	93°52.759′ E	06°59.953′ N	1	1
6	Magar Nallah	93°54.952 ′ E	06°59.482′ N	1	1
7	Chingam Village	93°55.150′ E	06°58.145′ N	1	1
8	Jogindar Nagar	93°54.106′ E	06°57.329′ N	2	3
9	Vijay Nagar	93°54.178′ E	06°57.203 ′ N	1	2
10	Gandhinagar	93°53.725′ E	06°50.390′ N	2	4
11	Sastri Nagar	93°53.264′ E	06°49.522′ N	2	3
12	Galathea 3	93°51.757′ E	06°49.600′ N	1	2
13	Indira Point	93°49.541′ E	06°45.579′ N	3	6
14	PuloBhabi	93° 46.133′ E	06°54.024′ N	1	1
15	Kosingdon	93°45.088′ E	06°56.168′ N	1	1
16	Alexandria	93°42.281′ E	06°59.615′ N	3	2
17	Dagmar	93°40.440′ E	07°01.669′ N	1	2
18	PuloKunji	93°40.536′ E	07°01.432′ N	1	2
19	Pilo Bakka	93°47.847′ E	06°49.502′ N	1	1
20	Pulo Bed	93°40.106′ E	07°03.520′ N	1	1
21	Kondul	93°43.118′ E	07°12.606′ N	1	1
	Little Nicobar				
22	Pulo Patia	93°43.416′ E	07°19.185′ N	1	1
23	North Patia	93°44.783′ E	07°21.182′ N	1	1
24	Pulo Panja	93°44.371′ E	07°22.561′ N	2	1
25	School Point	93°43.332′ E	07°23.394′ N	2	1
26	Minlana	93°42.596′ E	07°25.035′ N	1	1
27	Muhincohin	93°37.804′ E	07°18.275′ N	1	1
28	Bahua	93°38.275′ E	07°19.350′ N	1	1
29	Enfok	93°38.299′ E	07°22.177′ N	1	1
30	Menchal	93°45.949′ E	07°23.721′ N	1	1
31	Meroe	93°32.577′ E	07°30.978′ N	2	1
	Nancowry				
32	Connaught Bay	93°34.461′ E	07°56.059′ N	1	1
33	North to Cape Connaught	93°33.781′ E	07°56.344′ N	1	1
34	South to Hindrah	93°32.650′ E	07°57.304′ N	1	2
35	North Lapat	93°33.322′ E	07°59.187′ N	1	2
	Katchal				

Table 1. continued

	Katchal				
36	South Point	93°27.795′ E	07°55.085′ N	2	3
37	South to Jula	93°23.019′ E	08°01.207′ N	2	4
	Camorta				
38	Dring	93°29.298′ E	08°06.184′ N	1	1
39	South to Dring Harbour	93°29.076′ E	08°04.486′ N	1	1
40	Ronyok	93°27.605′ E	08°07.992′ N	1	1
41	Kakana North (Interior)	93°32.220′ E	08°12.355′ N	2	2
	Teressa				
42	North to Bangala	93°07.723′ E	08°18.559′ N	2	3
43	Alurang	93°05.670′ E	08°19.224′ N	2	2
44	Kalasi	93°07.300′ E	08°16.671′ N	1	2
45	Rakraka	93°12.097′ E	08°12.064′ N	1	1
46	Luxi	93°09.874′ E	08°12.146′ N	2	4
47	Bampooka	93°13.442′ E	08°14.479′ N	2	3
	Little Andaman				
48	Netaji Nagar	92°32.464′ E	10°38.935′ N	1	1
49	Butlar Bay	92°34.835′ E	10°39.461′ N	1	1
50	Light House	92°32.178′ E	10°32.057′ N	3	7
51	Herimidhar Bay	92°33.154′ E	10°33.604′ N	1	3
52	Krishna Nallah	92°32.377′ E	10°40.695′ N	1	2

coconut crabs that found were captured, measured, their sex was determined and then they were released. Similarly, crabs that were seen in the holes of trees or rock crevices but that could not be captured were recorded as counts. The baits were removed at the end of assessing each station.

Catch Per Unit Effort (CPUE) = Number of crab individuals observed at all bait locations within regions/ total number baits set in particular region

Statistical Analysis

Pearson's correlation was used to measure the strength of the association between catch per unit efforts and coconut crab density of studied areas using statistical software JMP ver. 13 software (Pearson, 1895).

Population Size Structures

The size structure of observed Coconut Crab was examined based on the morphological data collected during the field study. The morphometric characters were analyzed by following the methods of Fletcher *et al.* (1989) and Anagnostou and Schubart (2014). A Digital Vernier Caliper with a precision of 0.01 mm was used to measure the Thoracic Length (TL), Thoracic Width (TW) and Length of Cephalothorax plus Rostrum (Cp + r), Length of Head (HL) of observed coconut crabs. A hanging digital scale with a precision of 0.1 gram was used for measuring the weight of crabs. The distribution of the morphometric sizes was displayed with average sizes and standard deviation (± SD).

Sex Ratio

All the sighted Coconut Crabs were observed and evaluated sex ratio at the study areas.

Sex ratio = total number of females/ 1000 males

Results

In the present study, intensive surveys on distribution and density of coconut crab population were made during the period of April 2015 to March 2018 at 52 sites in the Nicobar group of Islands (Great Nicobar Island, Little Nicobar, and Nancowry group of Islands) and Little

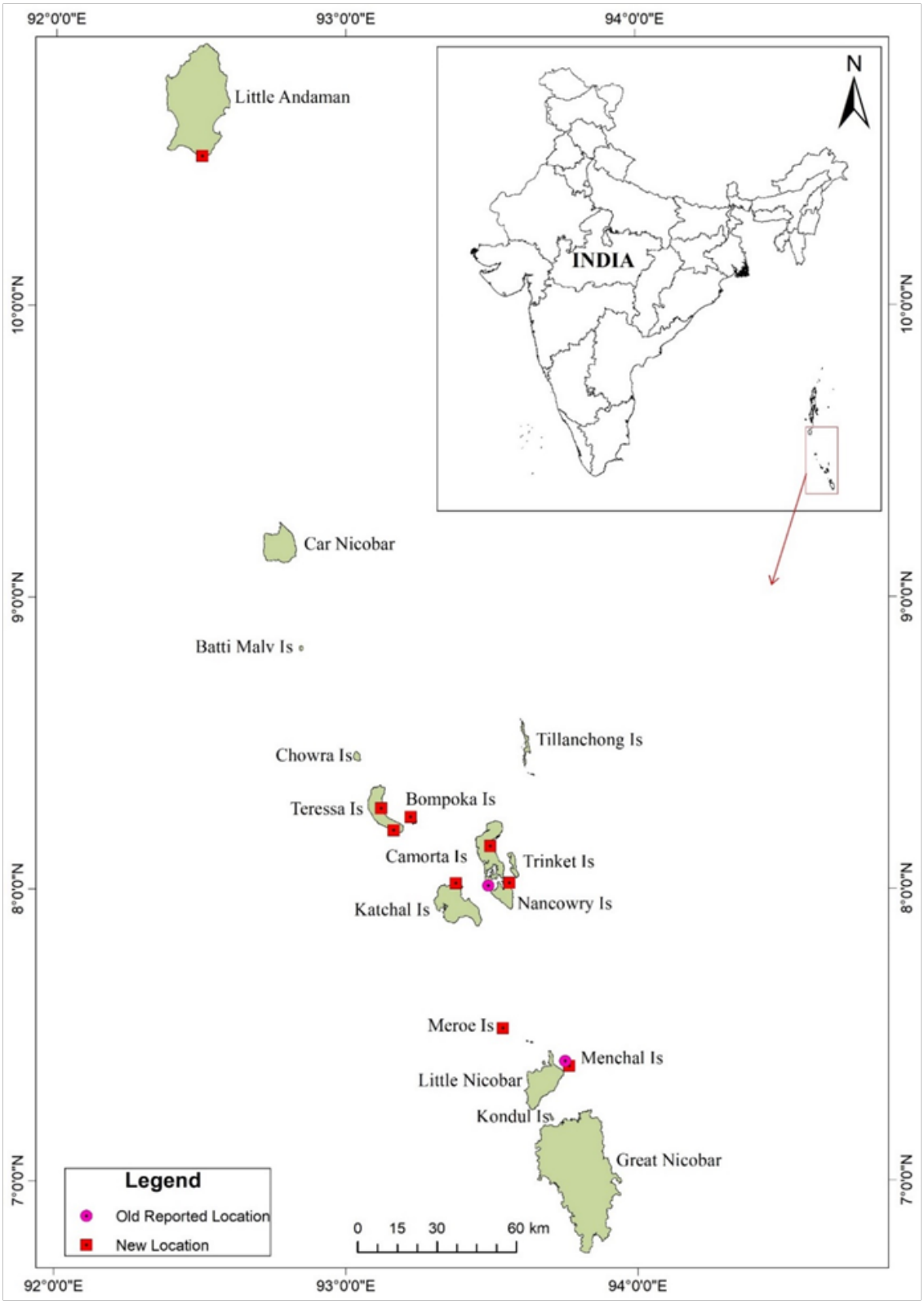

Figure 2. Distribution of coconut crab in different islands.

Figure 3. Study areas in Andaman and Nicobar Islands.
[a: Teressa Island; b: Katchal Island; c: Camorta Island; d-f: Menchal Island]

Andaman. Details of survey areas are given in Table 1 and Figures 2 and 3. A total of 72 transect surveys were carried out at 52 study sites of 11 regions of Andaman and Nicobar Islands.

Coconut Crab Density

A total of 61 coconut crab individuals were reported during 72 transect surveys (100.1 km^2) from 52 field stations of 11 regions of Andaman and Nicobar Islands. Out of which Nicobar group of islands are recorded with 56 individuals of coconut crab and Little Andaman with 5 individuals. The transect densities obtained from this study were ranged from 0 to 14.00 with an average value of 2.21 (±4.16) coconut crabs per km^2 (Figure 4). Throughout this survey, there was no record of coconut crab at Great Nicobar Island. Menchal is the small island (about 2 km^2 areas), located in the near shore of Little Nicobar represented with maximum abundance of coconut crab population (14) from single transect survey. Bampooka is small Island, comes under Teressa which is signified 15 individuals of coconut crab and the

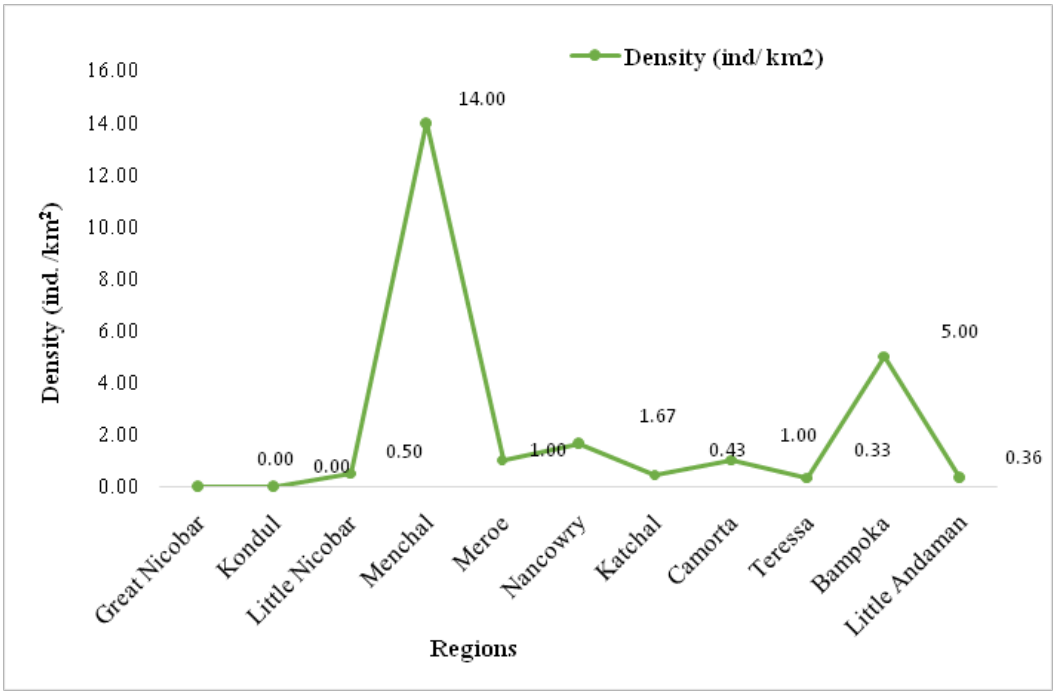

Figure 4. The density of coconut crabs at different regions of Andaman and Nicobar Islands

Table 2. Coconut crab population estimates in Andaman and Nicobar Islands

S. No.	Location	Total area (km²)	No. of transects	Transect area (km²)	No. of days spent for field survey	Number of individuals observed	Transect density (ind/ km²)	Abundance
1	Great Nicobar	1045.1	28	42.1	156	0	0.00	0
2	Kondul	4.6	1	1	4	0	0.00	0
3	Little Nicobar	159.1	10	8	33	4	0.50	0.4
4	Menchal	2	1	1	10	14	14.00	14
5	Meroe	66.9	2	1	2	1	1.00	0.5
6	Nancowry	66.9	4	6	12	10	1.67	2.5
7	Katchal	174	4	7	9	3	0.43	0.75
8	Camorta	188.2	5	5	4	5	1.00	1
9	Teressa	101.4	8	12	15	4	0.33	0.5
10	Bampoka	13.3	2	3	3	15	5.00	7.5
11	Little Andaman	707	7	14	19	5	0.36	0.71
		2528.5	**72**	**100.1**	**267**	**61**	**24.3**	
	The Average density of the coconut crab = 2.21±4.16 crabs/ km²							

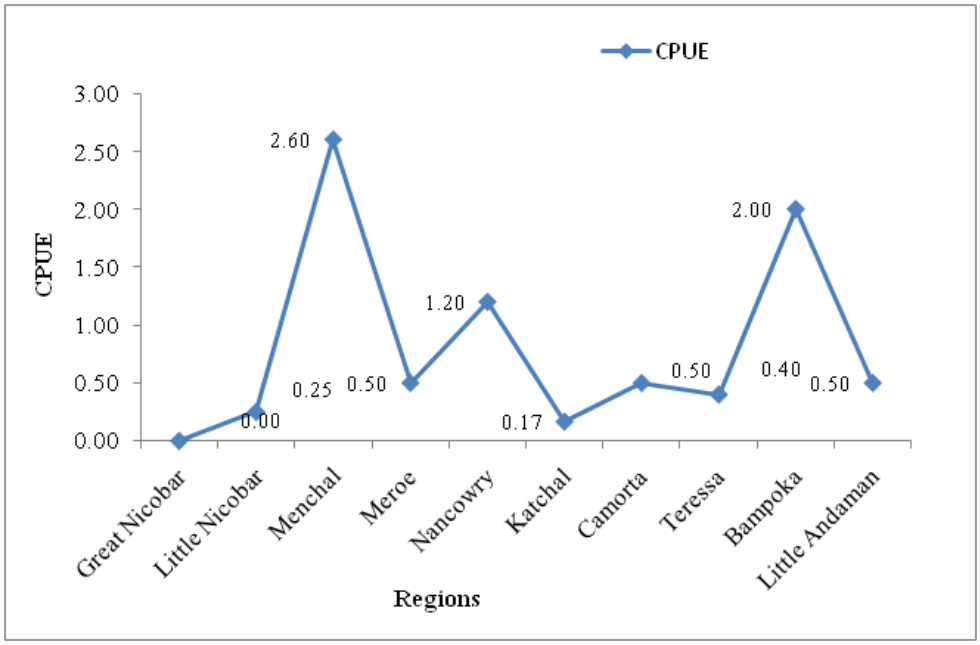

Figure 5. Number of coconut crab CPUE (crabs per bait) at different regions of Andaman and Nicobar Islands.

Table 3. Number of coconut crab CPUE (crabs per bait) in Andaman and Nicobar Islands

S. No.	Regions	No. of baits	Number of individuals observed	CPUE
1	Great Nicobar	12	0	0.00
2	Little Nicobar	8	2	0.25
3	Menchal	5	13	2.60
4	Meroe	4	2	0.50
5	Nancowry	5	6	1.20
6	Katchal	6	1	0.17
7	Camorta	6	3	0.50
8	Teressa	5	2	0.40
9	Bampoka	5	10	2.00
10	Little Andaman	6	3	0.50
		62	**42**	**8.12**
		Average CPUE = 0.81±2.35		

abundance value is 7.5 and transect density is 5.0 coconut crabs per km^2. In Teressa, the density as well as abundance value of coconut crab are 0.33 and 0.5 respectively. The assessment of coconut crab densities and abundance are mentioned in Table 2.

Bait Station Survey

In this study, a total of 62 baits were made for Catch Per Unit Effort (CPUE) within 20 field stations of 10 regions in Andaman and Nicobar Islands. Moreover, so far 42 individuals were recorded during the bait survey. The average catch per unit effort (crabs per bait) was obtained about 0.81±2.35 (Figure 5). Menchal Island is marked the maximum CPUE value with 2.60. This was followed by Bampooka Island with a CPUE value of 2.00. During the time of bait survey, there was no record available for the presence of coconut crabs at Great Nicobar Island. However, during the time of bait survey, 39 individuals were recorded from Nicobar group of Islands and 3

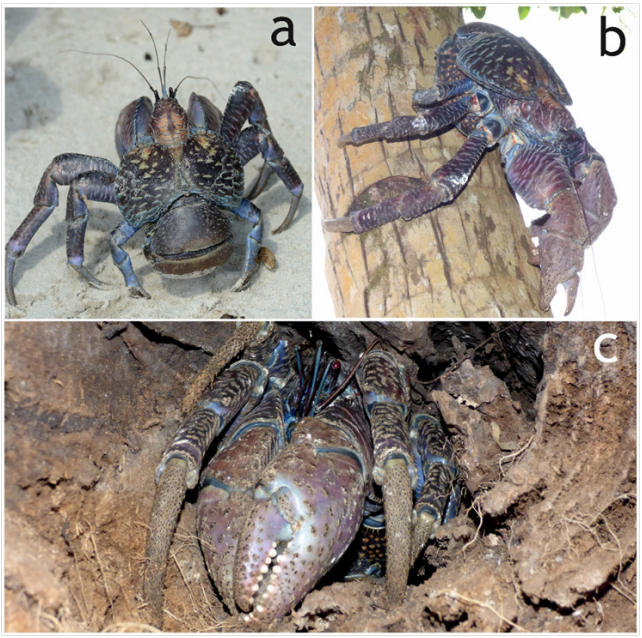

Figure 6. Coconut crab in different habitat of Andaman and Nicobar Islands.
[a: coconut crab in sandy bottom; b: climbing in the tree; c: dead tree hole]

crabs from Little Andaman. The estimation of catch per unit effort (crabs per bait) is mentioned in Table 3. The coconut crabs are found at different habitat like coconut tree, crevices, sandy shore, and dead tree hole (Figure 6).

Scatter Plot

Additionally, the scatter plot is prepared for an accurate picture of the relationship between the coconut crab densities (Crabs/transect area) and CPUE (Crabs per bait) (Figure 7). It is evident that, there is significant strong positive correlation between CPUE and the coconut crab densities. The values of Pearson's correlation, r (8) =0.91, the coefficient of determination, R^2 = 0.829; the Standard Error (SE) is 1.983 that is the measure of how far the actual points are from the regression line. Moreover, in this linear regression, the computed *p* value = 0.0006 which is less than the significance level of α = 0.05, signifying a significant linear relationship. From this scatter plot it is deduced that the value of the correlation coefficient, r, is 0.91 which provides a very strong positive correlation between the coconut crab density (crabs/transect area) and CPUE. The coefficient of determination (R^2) has a value of 0.83. This indicates that about 83% of the relationship is the result of the CPUE which is the factor being for the coconut crab density.

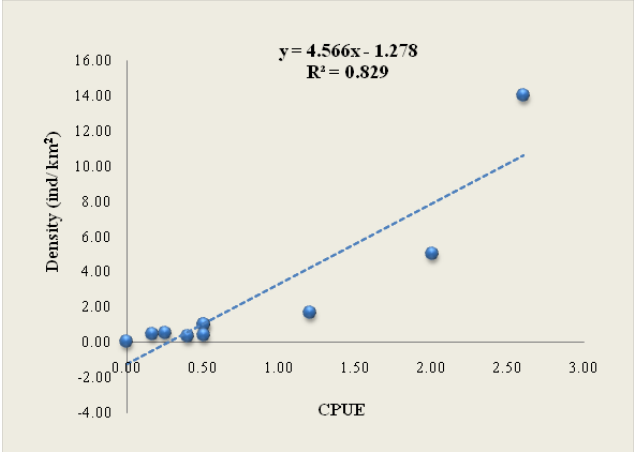

Figure 7. The relationship between coconut crab density (crabs/ transect area) and CPUE in study region.

The linear regression equation was denoted by

Coconut crab density = 4.566 x CPUE

From the above equation it was assessed that a CPUE of one crab per bait corresponds to a coconut crab density (Crabs/ transect area) of 4.6 crabs per km^2.

Population Size Structure

In this study, the population of coconut crab in Andaman and Nicobar Islands exhibited morphometric variation in size. A total of 103 coconut crabs are recorded and measured during transect and bait surveys. Among the collected crabs, 37 individuals were observed as female (35.9%) and 66 individuals were male (64.1%). The male-to-female ratio for coconut crab population in Andaman and Nicobar Region is analyzed as 1: 0.6. Moreover, the average size of the Thoracic Length (TL) of female coconut crab is 32.0±8.7 whereas; the thoracic length of male coconut crab is 37.9±13.5. The size class of coconut crab was estimated and observed as 76% of female and 59% of males are greater than 25 mm of TL and less than 50 mm of TL. In addition to that, only 24% of male recorded were greater than 50 mm of TL (Table 4).

Body Size Based on the Morphometric Characters

The present study states that, coconut crabs have difference in size and weight among male and female coconut crabs of Andaman and Nicobar Islands (Table 5; Figure 8). The morphometric characteristics (mean ± SD) of different parameters like Thoracic Length (TL), Thoracic Width (TW) and Head Length (HL), length of cephalothorax plus rostrum (Cp + r), coconut crabs are provided herein.

Table 4. Summary of size information for male and female crabs recorded during the present study [TL= thorax length]

Category	Female	Male
Sample size	37	66
Proportion	35.9%	64.1%
Smallest measured (TL in mm)	14.2	13
Largest measured (TL in mm)	41.8	61
Average (mm)	32.0±8.7	37.9±13.5
size class TL ≥ 25 mm < 50 mm	76%	59%
size class TL ≥ 50 mm	nil	24%

The body sizes of coconut crabs are based on the carapace (TL, TW, Cp+r, HL) manifested that the male coconut crabs have a larger average size than the female ones.

Discussion

During the period of study, in aggregate 103 individuals of coconut crabs were obtained from transect survey and bait surveys. From this present study it was analyzed that a Catch Per Unit Effort (CPUE) of one crab per bait corresponds to a population density of 4.6 crabs/km^2. Male coconut crab was dominated in size as well as in population in Andaman and Nicobar Islands. The sex ratio of crab population was observed is of 1: 0.6. Similarly, sex wise morphometric variation was studied thoroughly in Andaman and Nicobar Islands from all study locations. The study reveals that the coconut crabs were shown different morphometric character size such as the thoracic length, thoracic width, cephalothorax plus rostrum and head length in each individual. In case of female coconut crabs the weights were ranged from 83.5 to 473gm, whereas the weight of male coconut crabs was 70-779 grams. Furthermore, the average size of Thoracic Length (TL) of female is recorded as 32.0±8.7 mm whereas; the thoracic length of male is observed as 37.9±13.5 mm. The size class of coconut crab was estimated about 76% of female and 59% of males are greater than 25 mm of TL and less than 50 mm. The results manifests that, only 24% of male recorded were greater than 50 mm of TL. The factors like differences in body size, availability of natural foods, disturbance level and environmental conditions suitability could cause differences in character size. During this present survey, the average and maximum size of females were smaller than the males. A study conducted by Drew *et al*. (2010) concluded that, the male coconut crabs were constantly larger than female coconut crab from Christmas Island, Australia which is aggregable with the findings of this study. Similarly, Drew and Hansson (2014) also stated that the male coconut crabs have a larger size class while comparing with the female one. In parallel, there was no assessment of season wise and location wise morphometric measurements of coconut crabs.

Table 5. Sizes of coconut crabs' morphometric characters (Mean and SD) in Andaman and Nicobar Islands

Sampling location	Sex	n	Parameters	Minimum	Maximum	Mean± SD
Andaman and Nicobar Islands	FEMALE	37	TL in mm	14.2	41.8	32.0±8.7
			TW in mm	40.7	75	60.6±9.6
			Cp+r in mm	44.3	79.2	62.8±10.7
			HL in mm	6.9	10.2	8.6±3.1
			Weight in gm	83.5	473	244.2±137.1
	MALE	66				
			TL in mm	13	61	37.9±13.5
			TW in mm	39	112	71.8±13.6
			Cp+r in mm	42.7	119	75.4±11.2
			HL in mm	6.2	15.8	9.4±3.6
			Weight in gm	70	779	357.5±232.04

[TL: thoracic length, TW: thoracic width; Cp+r: cephalothorax plus rostrum; HL: head length]

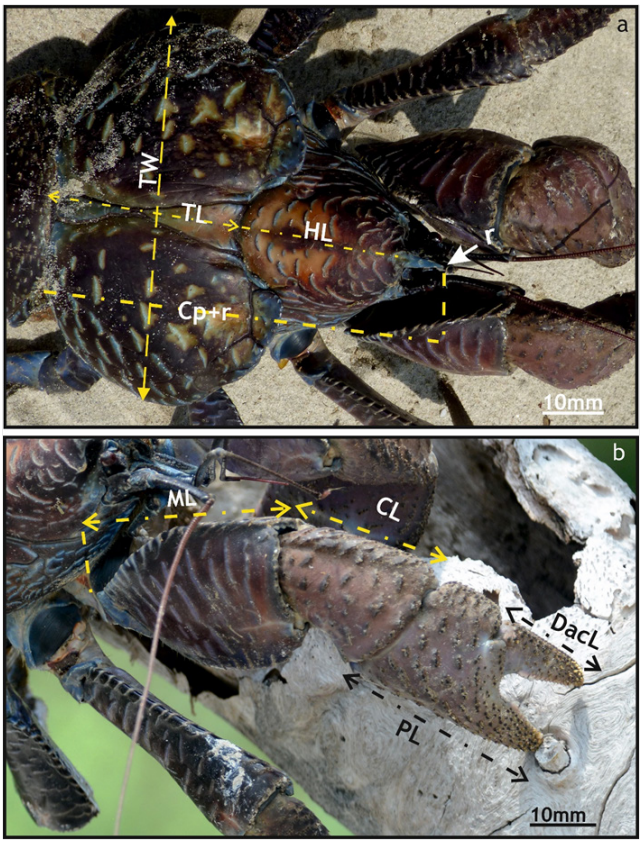

Figure 8. Morphometric measurements of coconut crab in Andaman and Nicobar Islands. [TL: thorax length, TW: thorax width; Cp+r: cephalothorax plus rostrum; r: rostrum; HL: head length; DacL :dactilus length; PL: propodus length; CL: carpus length; ML: merus length]

In India, the coconut crab population is primarily found on a few islands in the Andaman and Nicobar archipelago. Previously, the presence of coconut crab was reported from Great Nicobar Island by Daniel and Premkumar (1968). Unfortunately, during this survey, there was no evidence for the occurrence of coconut crab from these islands especially after tsunami 2004. The coastal habitats and coconut plantations were severely wrecked in these islands due to the disastrous event tsunami on 26 December 2004 which caused adverse effect on the coconut crab population (Ramachandran *et al.,* 2005; Sankaran *et al.,* 2005). In addition, indigenous Nicobarese groups and Somphen tribes have occupied much of the interior of the Nicobar Group of islands. The Coconut crab is categorized in the Schedule-I of Wildlife Protection Act, 1972 in India, but these tribal communities are exempted from this Wildlife Protection Act. In consequence, they are involved in massive hunting of the coconut crabs that lead to the decrease in coconut crab population. In addition, the anthropogenic threat like cultivation, hunting and predation has been growing in the area of Nicobar group of Islands.

In Menchal Island, the highest number of coconut crabs (27 individuals) were observed during this present survey (transect and bait surveys), as differentiate with other localities. In earlier studies, Patankar and D'Souza (2012) recorded 14 individuals of coconut crabs from this region. Menchal is uninhabited island and also the coconut crab is protected in the name of traditional belief that ancestral spirits of the island. Therefore, consumption of the coconut crab is forbidden in all the villages of Little Nicobar Island, which is close to Menchal Island. In Camorta Island the number of individuals was reduced to 8 crabs in the present study. Moreover, previously Patankar and D'Souza (2012) reported 17 individuals of crabs from this locality. There is also traditional belief in Camorta Island that hunting and consumption of the coconut crabs could bring bad fluke and also result in sickness. Nevertheless, the hunting is permitted in some villages of Camorta Island. Hence, the population of coconut crab is decreasing due to predation by human beings. The consumption of the coconut crab is rapidly increasing in the localities like Katchal and Teressa Islands. Female crabs are more targeted for consumption. With the exception, most of the people are unmindful about world's most engrossing largest terrestrial crab and its legislation. Previous study by Fletcher and Amos (1994) revealed that the long-life span and the slow growth rate incorporate with high levels of exploitation and habitat degradation lead the species vulnerable to overexploitation.

Conclusion

During this study period, a total of 103 coconut crab individuals were estimated from transect survey as well as bait survey. In this study, male coconut crab dominates in size as well as in population in Andaman and Nicobar Islands. There was no record of carrying egg mass by the female from the present study. The sex ratio of the coconut crab population is observed as 1: 0.6 in the study area. Globally, the coconut crab population in several areas

are becoming locally extinct or rapidly decreasing due to the anthropogenic activities such as habitat destruction and human predation (Brown & Fielder 1991, Fletcher, 1993; Schiller 1992, Lavery *et al*., 1996). The population of coconut crabs is also declining in Nicobar group of Islands except Menchal due to human predation. In Great Nicobar Island, the coconut crab is nearly extinct. Hence, it is an essential to measure conservation and develop regulations about this coconut crab resource in Andaman and Nicobar Islands with better perspectives. A large-scale habitat protection should be enhanced for this species. And, the public awareness activities should be introduced. Patankar and D'souza (2012) encouraged and mentioned the coconut crab as flagship species for raising ecological perception. Indeed, broader research should be focussed on region and season wise morphometric variation of coconut crabs. The Passive Integrated Transponder (PIT) tags should be applied to scrutinize the seasonally growth variability in both male and female crabs. This assessment can be applied as an indicator to evaluate the stock population size of Andaman and Nicobar Islands. The catch can be monitored throughout the year from different regions. And it will provide the indication of temporal and spatial patterns of exploitation and evaluate the resource.

In 1981, it was listed as a vulnerable species by the IUCN Red List. But later it was downgraded to 'Data Deficient' due to lack of biological data (Eldredge, 1996). Our findings revealed that the coconut crab populations are threatened with extinction in the Nicobar group of Islands except for Menchal Island due to human predatory practices, natural threats, and habitat degradation. Although the species is listed as Schedule- I under Wildlife Protection Act, 1972, still the population of this species is speedily declining in our country. To this end, we recommend providing more priority to conservation efforts to conserve this scheduled species in India.

Management Recommendations

The coconut crab is considered deeply exploited in Nicobar group of Islands. The anthropogenic threat such as cultivation, hunting and predation has been growing. Hence, it is an essential to conserve and develop regulations about this coconut crab resource in Andaman and Nicobar Islands with better perspectives. The major action is to be prohibited.

- the catching coconut crabs less than 50 mm TL
- disturbing the female coconut crabs carrying eggs
- disturbing the coconut crabs while estimating the length and sex

The following initiative of developing the regulations should be encouraged and recommended.

- Improving the public education and awareness regarding coconut crab biology, life cycle, vulnerability, stock status and unsustainable and sustainable exploitation practices
- Expand the existing system of protected areas to encompass wider tracts of coastal forest on Great Nicobar, the Nancowry group of Islands and Little Nicobar.
- Improving protection of Coconut crab breeding habitat.
- Monitoring the breeding population of this species.
- Establishing a seasonal boundary to protect the crabs during the period of the greatest reproductive action.
- Banning or controlling the coconut crab export
- Controlling the predators of crabs. The coconut crab is an important food resource for the Nicobarese, the community of Nicobar group of Islands.
- Establishing and implementing a programme to monitor the quantity and size of crabs' season wise and to assess periodically the Coconut crab population status.

Future Research

The following key areas of research are required on the following aspects:

- The future surveys should be done to agree with the present study to make sure the information collected can be comparable.
- Assess the density of coconut crabs in various localities to build an estimate of up-to-date distribution and population.
- Understanding the foraging and moulting behaviour of coconut crabs
- Developing a method for indexing in an area of known coconut crab population size that can be used for future monitoring purpose.
- Understanding the temporal and spatial patterns of exploitation
- Developing the logbook or hunter survey through which the information can be gathered and quantified

of threats to the juvenile crabs as well as the female crabs that carrying the eggs throughout year.
- Selecting and developing the permanent stations through which the annual monitoring can be achieved.
- DNA-based genetic study of the coconut crabs is required.

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