IMPACT ASSESSMENT OF PROSPECTING EXPLORATION ACTIVITIES THROUGH 3D SEISMIC DATA ACQUISITION BY OIL INDIA LTD, ON MANGROVE FAUNA AT KAKINADA, ANDHRA PRADESH

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1. INTRODUCTION

Increasing human population and its corresponding resource requirements has led to an increase in the extraction of natural resources such as wood, oil and minerals. Several of the nations, especially the developed and developing countries across the globe are facing an energy crisis situation due to the shortage of energy sources and supply systems. This has resulted in intensive explorations for energy sources, both conventional and non-conventional. The fossil fuels continue to be among the priority areas in this global quest for energy driven primarily by economic reasons. The seismic explorations involve the process of locating natural hydrocarbon (oil and gas) deposits located deep underground. . The diverse economic sector of the India is highly dependent on the energy sector which is dominated by the fossil fuels imported from other regions of the world. About 55% of the energy in the country is produced from coal and 34 % from oil and currently 35% of the commercial energy needs of the country are imported (Arun et al. 2010).

These seismic survey process consists of a series of activities such as mapping of the potential resource field with the help of controlled seismic energy signals recorded by a network of receivers (geophones) that are placed along transects. Gelatin explosions are used to generate underground seismic waves within seismic shoot holes ie: 15-20 meter deep holes. The waves reflected back from underground layers will be detected by the geophone networks and will be used to map the potential hydrocarbon resource of the area in varying depth profiles underground. The exact impacts of terrestrial seismic exploration activities on local environment are little understood, however the overall influence of oil and gas development on terrestrial wildlife is reasonably well known (Cameron et al. 1992; Lyon and Anderson 2003; Sawyer et al. 2006).

2. ORIGIN OF THE STUDY

The Ministry of environment and Forests (MoEF), Government of India has implemented various policies, laws and directives to ensure proper maintenance of ecology and environment of the country. As part of these rules, it is mandatory to procure the

Environmental clearance through a due Environmental Impact Assessment (EIA) process for all major developmental projects. This monitoring study originated from the recommendations of an earlier study in 2011titled "Impacts of Proposed Seismic Survey Operations on the Avifauna and Wildlife of Reserve Forest Areas of KG Basin Project of OIL India Ltd" done by Sálim Ali Centre for Ornithology and Natural History (SACON). The 3D Seismic survey causes disturbances to the ecosystem mainly through the movements of people and materials during the laying of Geophone, Shoot Hole Drilling and the Shooting Process.

SACON in its 2011 study had recommended certain management and mitigatory measures for the proposed 3D seismic surveys in East Godavari mangrove areas targeted at minimizing the disturbances to the Mangroves, Avifauna and to the potential breeding sites of endangered Olive Ridley Turtle (*Lepidochelys olivacea*) along the coast line, etc. It also had identified three rare species of mangroves namely 1) *Scyphiphora hydrophyllacea (*Narathanduga*),* 2) *Xylocarpus granatum (*Senuga*)* and3) *Senneratia alba (*PeddaKaliga*).*Considering the lack of data availability from the country pertaining to the impacts of seismic surveys on the wildlife and ecology, SACON study had further recommended a monitoring study to be conducted during the seismic surveys in order to generate relevant data on the response of local fauna to the seismic exploration activities. Further to the report submitted by Sálim Ali Centre for Ornithology and Natural History (SACON), Oil India Limited (OIL) again approached Sálim Ali Centre for Ornithology and Natural History (SACON) to carry out the Monitoring study of 3D seismic survey in East Godavari Mangrove area. Thus SACON undertook the present monitoring study to document the response of select faunal groups to the seismic exploration activities by OIL during the six months duration of July to December 2013. As part of the monitoring study, a full time researcher was engaged throughout in the field along with the 3D seismic survey team to collect data systematically through appropriate field protocols on the response of faunal elements to the seismic survey.

2.1 IMPACT OF SEISMIC SURVEYS

Oil and Gas exploration and developmental activities have rapidly expanded during the past few decades. The issue of impacts on environment and living organisms that have potentially been affected by these Oil and Gas exploration process has been a serious ecological concern. There are many studies available on the impacts of seismic surveys on marine life especially marine fauna (Larson 1985; Gordon et al. 2003). The search of marine oil and gas deposits includes the use of seismic survey techniques, which employ high level, low frequency sounds in the analysis of sea bed structure. The most common sound source used in marine geophysical surveys is air gun arrays (Turnpenny & Nedwell 1994). However in terrestrial areas, most common sound source used is gelatin (small quantity) based explosion and this kind of gelatin based seismic explosion is commonly used in seismic surveys in India (Sharma 1986).

There have been many potentially significant impacts of seismic surveys identified worldwide. These include: Noise generation from 3D seismic operations (airgun/ gelatin explosion); Effect of seismic waves and vibrations on living organisms; disturbances to natural habitat due to physical presence of survey team; and disposal of synthetic materials from labors or as a result of seismic explosions. According to Gordon et al. (2003), potential biological effects of sound from seismic shoot include physical, physiological and/or psychological effects, behavioural disruption, and indirect effects associated with altered habitat and prey availability. Physiological effects could include hearing threshold shifts and auditory damage as well as non-auditory disruption, and can be directly caused by sound exposure or the result of behavioural changes in response to sounds (Gorden et al 2003; Di Iorio & Clark 2010). As Blanc et al. (2006) pointed out, common definition of disturbance on wildlife which provide by European Commission is “any phenomenon that may cause a significant change in the dynamics of a population or the eco-ethological characteristics of populations”. According to Cline et al. (2007), Human-wildlife conflict can be categorized into two; 1) Wildlife conflicting with human goals, 2) human behavioural conflict with wildlife safety and well-being. Wildlife disturbances from seismic survey can be treated as the first type of disturbance.

Movements of seismic survey team in the forest area can potentially cause notable impacts on habitat and associated faunal elements.

The expected distribution of measured sound levels in the forest areas are varying from 2dB -5dB. The shot holes fired at a depth of 20 meters using small charge size varying form 1.5-2 kg.

According to the experts at OIL, during the shooting process, the expected mean intensity of the waves generated and its rate of transmission loss during propagation on ground is as below. No systematic measurement on this aspect has been conducted in this regard.

Table 1: Approximate Noise levels generated during the seismic shoots

No	Distance	Mean noise level received (dB)
1	0 km (Close to Origin)	8 - 10 db
2	1 km	5 dB
3	3 Km	3 dB
4	5 Km	<1 dB

Many of the organisms are directly related to flora of the particular area. Studies on fish population elsewhere showed that, well planned seismic survey can minimize impacts on spawning of fish (Payne 2004). Unlike marine animals birds face lesser impact from seismic sound. Stemp (1985) reported that, seismic air gun sound emissions caused no death and no variation in water bird abundance in Green Land. Some studies showed that, seismic surveys did not make any mass death of fishes; however some fish mortality records especially from close to seismic shot holes have also been reported (Payne 2004). Seismic survey is likely to disturb birds rafting on the sea surface especially in the direct vicinity of air gun (Stemp 1985). Scientific studies of seismic survey on fish population has revealed that, egg and larval mortality was limited to within a few meters of the seismic array, physical injury to fish is limited to tens of meters while auditory damage is potentially extend to hundreds of metres (Kostyuchenko 1973; Turnpenny and Nedwell 1994; Saetre and Ona 1996; Kenchington et al. 2001).

Scientific studies showed that, seismic exploration survey has the potential to affect wildlife either by increasing noise and human activity around them, or seismic shooting process. The seismic activities can even lead to long-term habitat alteration. Though the exploration activities is often a short term process, extending over a few months, the footprint of exploration activities especially in the high wildlife sensitive area can be quite large (Jorgenson et al. 2010). Seismic exploration can alter plant community structure, directly affecting fauna of that area on a long-term basis (Jorgenson et al. 2010). The long-term seismic explorations in the arctic have been shown to affect bird distribution and nest success (Ashenhurst and Hannon 2008). There is evidence to suggest wildlife may react to seismic activity with elevated metabolic rates (Bradshaw et al. 1998), and the cumulative effects of repeated disturbance of individuals may affect population reproductive rates if exploration is widespread (Bradshaw et al. 1998).

3-D seismic methods can have a larger surface footprint than 2-D surveys, as a denser grid of trails is used (Jorgenson and Cater, 1996). Impact studies of seismic survey in forest area showed that the animals those who avoided area because of seismic shot return to the area within one to four weeks after the disturbance (Russell 1977). Though not alarming, minimizing these impacts is very important. Potential ecological effects of roads and/or paths in the wildlife areas include physical disturbance, habitat loss, reduction in population of proximal species, dispersal of wildlife and even mortality of wildlife. Although to a lesser degree, the habitat fragmentation may be a result, which intern would impact biological diversity (Spellerberg and Morrison 1998). Minimization and mitigation of negative impacts can be accomplished with appropriate safeguard during the seismic explorations.

3. OBJECTIVES

The present study was aimed at monitoring the impact of prospecting exploration activities by OIL through 3D seismic data acquisition on the fauna of mangrove forests at Kakinada, East Godavari district of Andhra Pradesh on the fauna

4. STUDY AREA

The present study covered the Reserve forest areas proposed for seismic hydrocarbon exploration by OIL in the Krishna Godavari delta in the East Godavari District of Andhra Pradesh (around 16^0 37’ N and 82^0 17’ E). East Godavari District had its name from River Godavari and is dominated by a human habitations and agricultural lands.

The study covered the reserved forest areas covered under 3D seismic survey acquisition survey by Oil India Ltd. in the Krishna Godavari Delta in the East Godavari District of Andhra Pradesh (16^0 37’ N and 82^0 17’ E) during July- December 2014. The study area is located along the coastal zone of the East Godavari district that includes mainly Mangrove forests and patchily distributed settlements. The entire stretch of coastal belt (of about 25km long and 1.5 km wide) along the margins of the present study area is devoid of natural forests and is dominated by Casuarina plantations in different growth stages. The people inhabiting the study area are mostly dependent on fishing and aquaculture farms for their livelihoods.

The Andhra Pradesh is influenced by both Southwest and Northeast monsoons, but coastal areas of the Andhra Pradesh mainly influenced by Northeast monsoon. The East Godavari has comparatively high in rainfall and has tropical humid climate during monsoon and winter season. Temperature increases from 22^OC to hottest in May. The East Godavari has little variation in temperature because of the low relief and the moderating effect of the sea. The weather is mainly dry from February and there is a steady progression in heat till the summer months.

The area of 4,866 Sq.km is under mangrove forest in India. Of these, 397 Sq.km area is under Andhra Pradesh (Ravishanker et al. 2004). Mangroves of Andhra Pradesh distributed mainly along the Krishna (156 sq.km) and Godavari river (241 sq.km). The majorities of mangrove patches of Godavari mangrove forests are located in East of Godavari District and apart from these small portions are also distributed along the coasts of Vishakhapatnam, West Godavari, Guntur and Prakasam Districts (Ravishanker et al. 2004).

According to Department of Forest and Environment, Government of Andhra Pradesh, this area has 80.3 sq.km of Mangroves as Reserved Forests (Reserved forests of Kothapalem, Kandikuppa, Ratikaluva, Masanitippa, Matlathippa and Balusutippa). The major river channels such as Gautami - Godavari and Nilarava and a large number of associated channels and tributaries criss-cross the study area. Main Godavari and its distributaries have formed many patches of Mangroves in the Godavari estuary in the East Coast of India. Along the eastern boundary of the east Godavari district, mangroves interspersed with human habitations dominate the landscape. Plantations and aquaculture tanks dominated the area around human habitation, while, large patches of luxuriant mangrove forests under six different Reserved Forests (RF) namely, Balusutippa Reserve forest, Matlatippa Reserve forest, Masanitippa Reserve forest, Rathikaluva Reserve forest, Kandikuppa Reserve forest and Kothapalem Reserve forest formed the rest of the land area.

5. METHODOLOGY

Field surveys were conducted from August to December 2013 along with the 3D seismic data acquisition survey activities by M/s Oil India Ltd. Basic information about field and possible impacts were also collated from the earlier report (Arun et al. 2011). Specific faunal taxa of the area were selected to study the impacts of 3D seismic survey in East Godavari mangrove forests. Data was collected through systematic field study and analyzed with appropriate statistical tools to understand the major impacts of 3D seismic acquisition survey in the reserved forest areas. The study was conducted from 9.00am to 4.00pm. Due to the transient nature of the disturbance from subsurface explosions used for the seismic surveys and associated tangible disturbances to the local fauna, the data on the response of different animal taxa was collected synchronously with shooting activities of the seismic survey. Specific field methods were used for sampling different representative taxa. The birds and insects were the major groups selected for the purpose of the present study Details of selected field methods used in this study are given below.

5.1 POINT COUNT SURVEY

This widely used method recommended for bird monitoring surveys (Bibby et al. 2000) was used for collecting the bird abundance data. In this method, the observer records the bird species seen within a fixed radius. Point counts are essentially strip transects of zero length in which the observer performs the count in a 360º arc around a fixed point survey station (Whitworth et al. 2007). This method was used to estimate the abundance of birds at selected shooting points monitored. Point survey stations were located few meters away from each seismic shoot hole. Birds were monitored systematically at 3 minute intervals from within a fixed radius of around 30 m from the observer. Each point was scanned systematically at 3 minutes intervals so that disturbances from workers movements and shooting could be monitored.

5.2 TOTAL COUNT SURVEY

The goal of a total count is to conduct a complete count of all the birds present over a specified area to obtain an unbiased estimate of abundance without statistical inferences or underlying assumptions (Bibby et al. 2000; Whitworth et al. 2007). This method is generally used in wetlands to count wetland birds. During the present study the total count method was used to document and monitor the birds in a wetland during the seismic surveys. The available open wetland for the total count was minimum 100m from the shooting area. Five minutes interval total counts method was used to monitor birds to study the impacts of 3D seismic survey on migratory birds. All birds were identified from the field itself using a field guide (Kazmierczak 2000).

5.3 ALL- OCCURRENCES SAMPLING

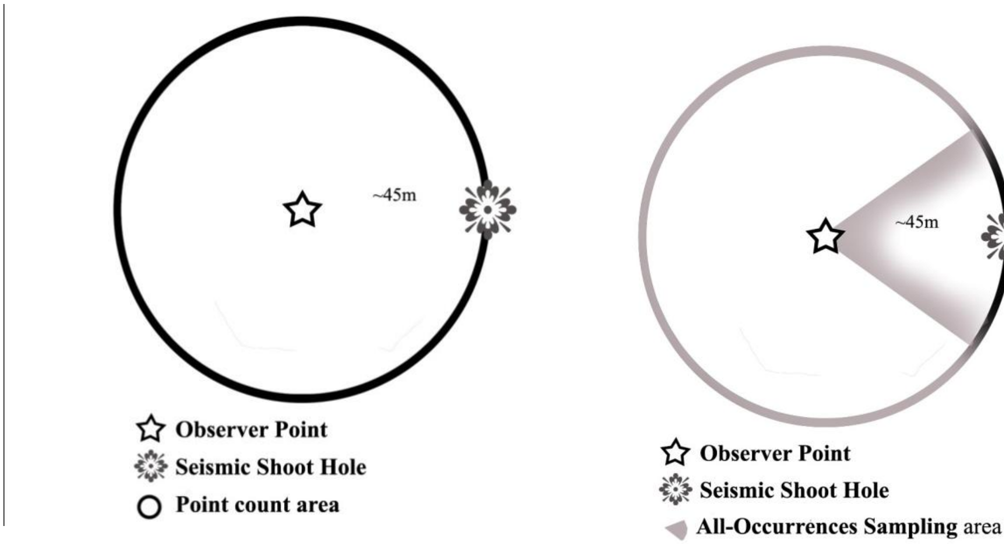
To quantify the animal behaviour and their activities appropriate methods needs to be chosen. It is impossible to observe the behaviour of all animals together in a large group. Therefore, to observe the activities of an individual in a group, All- Occurrences Sampling technique was adopted. In this method only one animal is selected at a time and observations were made on their major activities such as resting, feeding and flying activities of insects especially Honey-Bees in the mangrove forest close to 3D seismic survey activities. This technique is especially useful in determining the rate, frequency, or synchrony of occurrence of specific activities. All-Occurrences Sampling was performed from within 40m of the shot holes while shooting was on.

5.4 OPPORTUNISTIC OBSERVATIONS

It is often difficult to quantify the impacts through field observations and surveys. Since the present impact monitoring study on the 3D seismic surveys was to monitor mangrove fauna, it was not feasible to systematically monitor all the faunal taxa of the area within this stipulated time. Hence some of the other taxa were monitored through opportunistic observations. There are many reports regarding the impacts of 3D seismic survey that have opportunistically recorded from the field. We walked randomly in the seismic survey zone in the mangroves of Kakinada and opportunistically observed (visual) various faunal taxa encountered and recorded their behavioural response during the 3D seismic surveys.

Seismic waves are known to be used by many arthropods, fishes, reptiles, amphibian and small mammals in species specific communication, prey detection and navigation (Hill 2001). Any kind of extra seismic waves can disturb these species' normal communication and related activities. It is necessary to do some long term monitoring study with systematic sampling efforts to quantify the impacts on various faunal taxa from such waves that can interfere with their communication and sensory mechanisms.

Point count, All-Occurrences and Total count data were utilized to quantify the impact of 3D seismic survey on selected taxa.



Point count All-Occurrences sampling

Figure 1: Survey technique adopted in field

6. RESULTS

The present study monitored the direct and indirect Impacts of seismic surveys on fauna of the mangrove using Birds Insects, Crabs, Reptiles and fishes as representative taxa.

During the 3D seismic survey, tools, labour and machineries were used inside the mangrove forests. Major sources of faunal impacts observed during the seismic survey operations were from, 1) Physical presence and movement of the labour and machinery within the forest and 2) Noise and vibration generated from shooting (underground explosions). There are four major steps involved in the seismic surveys, that result in disturbances to the system, namely,

- Initial survey of the area
- Laying of Cables and geophones
- Shot hole drilling
- Seismic wave generation through underground explosion (shooting)

Faunal impacts of prospecting exploration activities through 3D seismic data acquisition can be categorized broadly into two; direct and indirect impacts. Direct impacts include changes in activity patterns of mangrove fauna especially birds and crabs in response to the 3D seismic survey activity. Indirect impacts to the fauna involve destruction of faunal habitats, which in turn can affect the mangrove fauna in multiple ways. Generally, the 3D seismic data acquisition surveys does not cause impacts beyond short-term reversible changes to the system if the activities follow a strict scientifically developed plan.

6.1 IMPACTS ON FAUNA

There are many direct short-term impacts on mangrove fauna from 3D seismic survey as observed in the field. These temporary effects had mostly short-term impacts since the survey normally lasted only for few days in any given area.

6.2 DISTURBANCES FROM HUMAN INTERFERENCE

Direct impacts of seismic surveys on wild fauna are caused through direct disturbances especially on their normal activities. Besides direct disturbances to mangrove fauna, several studies have identified numerous indirect impacts associated with noise and pollution from motor use, transportation of seismic equipments/materials. Ultimately all these activities cause the degradation of mangrove habitat. Many elements of mangrove fauna were observed to be disturbed due to the cable laying and Geophones placing, Shot hole drilling, Seismic explosions and frequent movements of the people in the mangrove.

The response of birds and insects to the sound and vibrations caused by the shooting process was systematically recorded in the field during the present study

6.3 DISTURBANCE TO AVIFAUNA

Kakinada mangrove forest provides good feeding ground for many bird species'. 79 species of birds have been reported by SACON from the study area. Near threatened species Black-headed Ibis (*Threskiornis melanocephalus*) also observed from the study area. 52 bird species were recorded during the present study (Table 2). During this study period, Grey-headed Lapwing (*Vanellus cinereus*) was observed twice in the shooting area. This species is a rare species in India and rarely distributed along the east coast.

Table 2:Bird species recorded during the present study from the seismic survey areas

No	Species Name	Scientific Name	IUCN Status
1	Grey Francolin	*Francolinus pondicerianus*	LC
2	Black-headed Ibis	*Threskiornis melanocephalus*	NT
3	Asian Openbill	*Anastomus oscitans*	LC
4	Indian Pond-heron	*Ardeola grayii*	LC
5	Cattle Egret	*Bubulcus ibis*	LC
6	Purple Heron	*Ardea purpurea*	LC
7	Great Egret	*Casmerodius albus*	LC
8	Intermediate Egret	*Mesophoyx intermedia*	LC
9	Little Egret	*Egretta garzetta*	LC
10	Western Reef-egret	*Egretta gularis*	LC
11	Black Kite	*Milvus migrans*	LC
12	Brahminy Kite	*Haliastur indus*	LC
13	White-breasted Waterhen	*Amaurornis phoenicurus*	LC
14	Black-winged Stilt	*Himantopus himantopus*	LC
15	Red-wattled Lapwing	*Vanellus indicus*	LC
16	Grey-headed Lapwing	*Vanellus cinereus*	LC
17	Pacific Golden Plover	*Pluvialis fulva*	LC
18	Grey Plover	*Pluvialis squatarola*	LC
19	Little Ringed Plover	*Charadrius dubius*	LC
20	Kentish Plover	*Charadrius alexandrinus*	LC
21	Greater Sand Plover	*Charadrius leschenaultii*	LC
22	Common Snipe	*Gallinago gallinago*	LC
23	Spotted Redshank	*Tringa erythropus*	LC
24	Common Redshank	*Tringa totanus*	LC
25	Common Greenshank	*Tringa nebularia*	LC
26	Marsh Sandpiper	*Tringa stagnatilis*	LC
27	Wood Sandpiper	*Tringa glareola*	LC
28	Terek Sandpiper	*Xenus cinereus*	LC
29	Common Sandpiper	*Actitis hypoleucos*	LC
30	Little Stint	*Calidris minuta*	LC
31	Long-toed Stint	*Calidris subminuta*	LC

32	Rock Pigeon	*Columba livia*	LC
33	Yellow-footed Green-pigeon	*Treron phoenicopterus*	LC
34	Eurasian Collared-dove	*Streptopelia decaocto*	LC
35	Spotted Dove	*Stigmatopelia chinensis*	LC
36	Rose-ringed Parakeet	*Psittacula krameri*	LC
37	Greater Coucal	*Centropus sinensis*	LC
38	Stork-billed Kingfisher	*Pelargopsis capensis*	LC
39	White-throated Kingfisher	*Halcyon smyrnensis*	LC
40	Black-capped Kingfisher	*Halcyon pileata*	LC
41	Pied Kingfisher	*Ceryle rudis*	LC
42	Little Green Bee-eater	*Merops orientalis*	LC
43	Blue-tailed Bee-eater	*Merops philippinus*	LC
44	Oriental Skylark	*Alauda gulgula*	LC
45	Ashy Prinia	*Prinia socialis*	LC
46	Hill Myna	*Gracula religiosa*	LC
47	Common Myna	*Acridotheres tristis*	LC
48	Jungle Myna	*Acridotheres fuscus*	LC
49	Asian Pied Starling	*Sturnus contra*	LC
50	House Sparrow	*Passer domesticus*	LC
51	Baya Weaver	*Ploceus philippinus*	LC
52	Scaly-breasted Munia	*Lonchura punctulata*	LC

Birds are one of the major components of Kakinada mangrove biodiversity and there are many species of birds associated with mangrove forest. Many of them are resident bird species such as Lesser Sand Plover *Charadrius mongolus*, Little Stint *Calidris minuta*, and Ashy Prinia *Prinia socialis* are very abundant (Figure 2). Among the highly abundant bird species, Lesser Sand Plover was observed in large groups. All these migratory waders were observed along the edges of mangroves where mud flats were present, whereas resident species like Ashy Prinias, Pied Starlings, Egrets and Sunbirds were observed inside the mangrove forest where seismic survey work was being conducted (Figure 3). Less migratory waders were observed in Kandikuppa Reserved forest possibly due to the absence of large mudflats in the edges of these mangrove forests, whereas Masinatippa reserved forest had vast stretch of wetlands associated with mangrove forest.

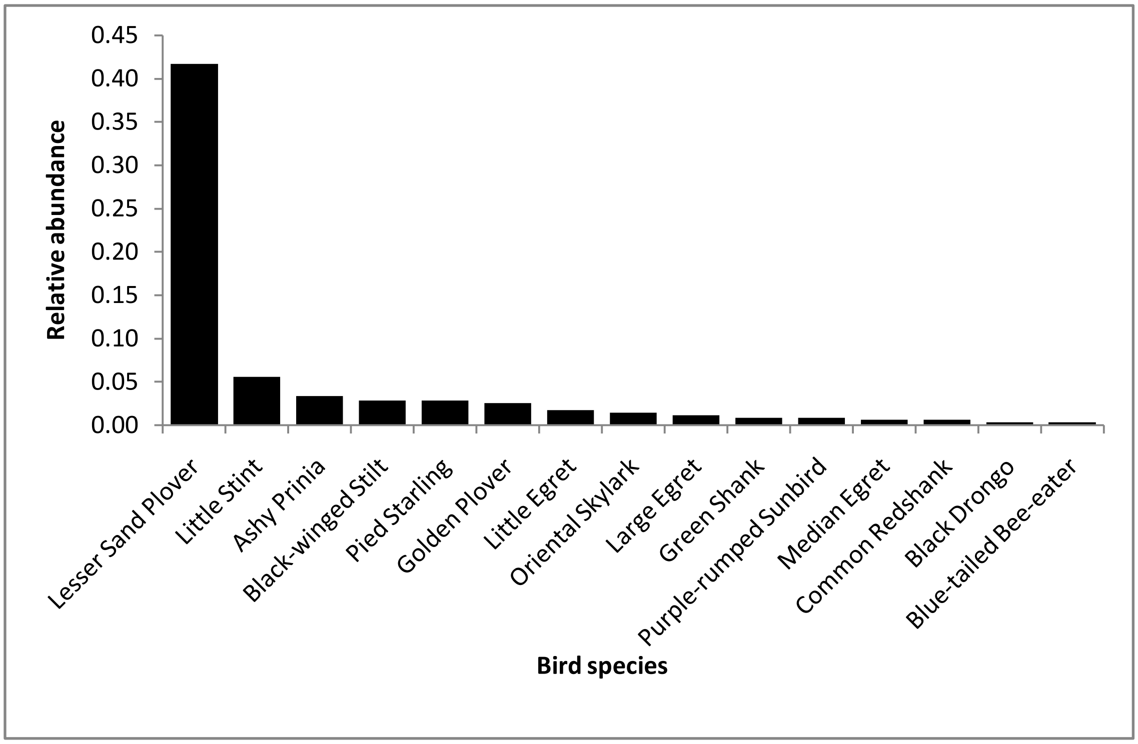


Figure 2: Relative abundance of bird species observed during 3D seismic shots

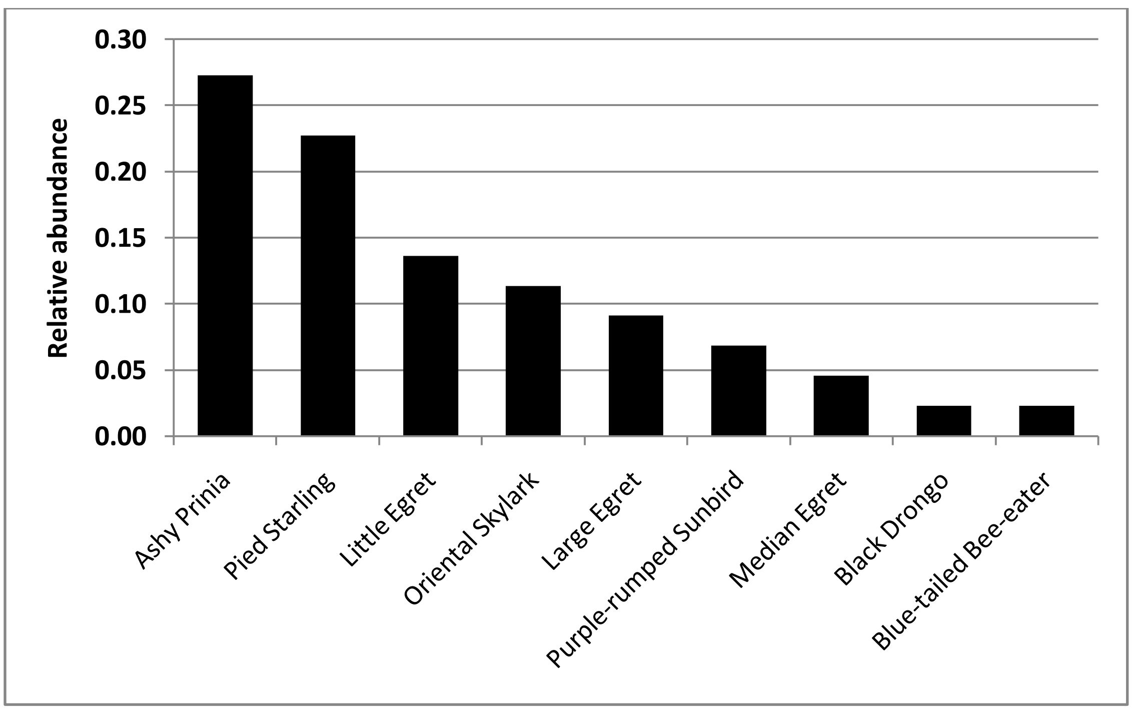


Figure 3: Relative abundance of common resident bird species during the seismic shots.

Results showed that, seismic survey activities in Kakinada reserved forest disturbed both migratory and resident birds' normal activities. Most of the birds flew off from their perches during the shooting time due to sound (Figure 4). People's movements in and around mangrove for shooting purpose like shot hole drilling, shooting material transportation also disturbed birds as well as other mangrove fauna. Ashy Prinias were widely distributed in these mangrove forests, at the time of shooting; they used to fly off their perches and/or stop singing/ calling. The seismic explosion is transient in nature and the disturbances caused to birds were temporary. There is no permanent impact expected during the process of seismic exploration activities.

From the data on birds collected from the area around seismic signal receiver station (ie. 3D seismic observers' station located more than 100m away from the nearest shot hole), it was evident that there was no perceivable change in the behaviour or activity pattern of birds in response to the seismic shoots at this distance.

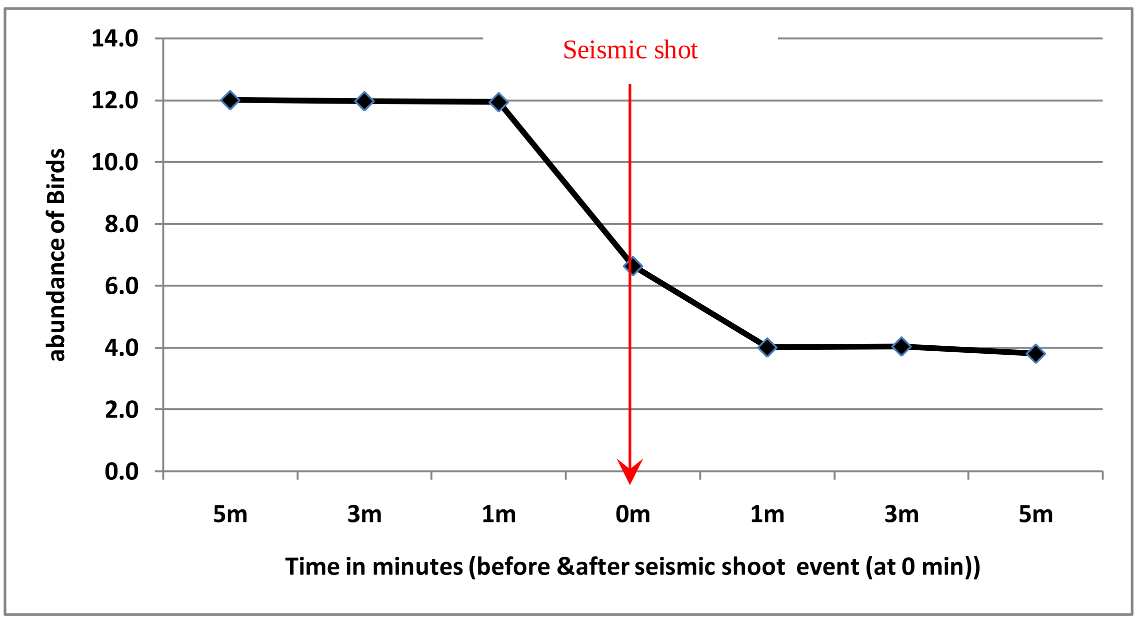
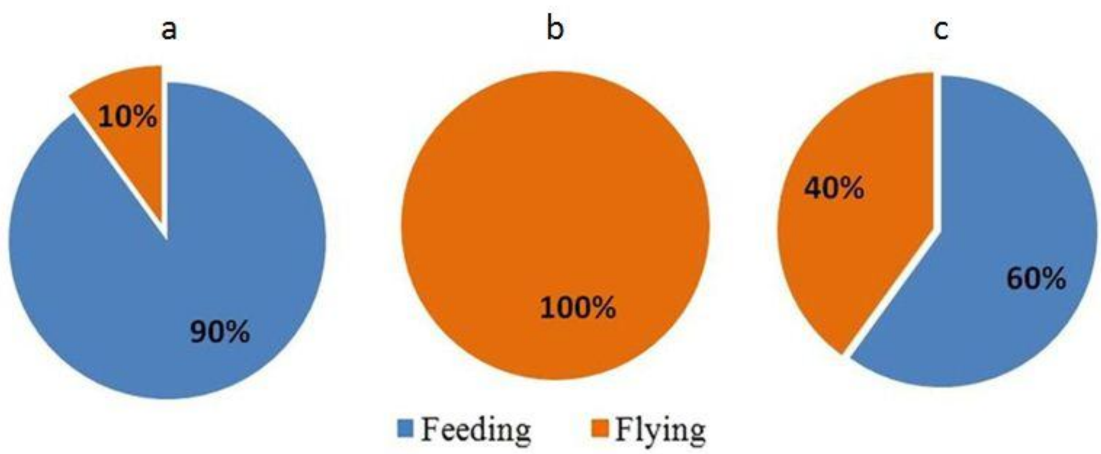


Figure 4 Changes in abundance of birds during the seismic shots

6.4 DISTURBANCE TO INSECTS' ACTIVITIES

Insects were the other major taxa selected to observe the impacts of 3D seismic survey. Most of the insect species in the forest are part of complex food webs and ecosystem processes and these processes are often poorly understood (Liebhold and Bentz 2011). This study tried to study the response/ impacts of 3D seismic survey on the insects, especially Honey Bees. Honey bees were very abundant in the area during seismic survey process were very active throughout the day. Results of this study showed that, insects were disturbed for a minute, but these disturbances were momentary. As a representative group, Honey Bees' activities were observed carefully to study the disturbances caused. We have observed flying and feeding behaviour and their abundance during shooting period. During seismic shooting time, all insects stopped their activities and were airborne. After a few minutes their feeding activities resumed (Figure5). Butterflies also were found to be disturbed and flying off during shooting time possibly due to the vibrations and after few minute they restarted their normal activities whereas some moths were observed shifting their position from upper side of the leaf to lower side but they did not fly. The observations generally indicated that, there are short-term and reversible impacts as disturbances to activities of insects caused by the seismic survey activities especially, the vibrations from subsurface explosions.



a) before 5 minutes of shoot, b) during shoot, c) after 5m of shoot

Insects' feeding and flying activities during seismic shots

Honey Bee (*Apis dorsata*) Tawny Coster Butterfly (*Acraea terpsicore*)

Some common insect species (bees and butterflies) of the area.

6.5 Opportunistic Observations from Field

6.5.1 Crabs

Activity changes in Response to seismic shooting by the Crab species such as Mangrove crab (*Perisesarma bidens)* and Fiddler Crab (*Uca spp*) were observed carefully in the field. Fiddler Crabs were abundant in the mangrove forest especially in muddy areas near to seismic shooting points. We observed fiddler crab behaviour carefully wherever they were abundant. Distribution of Fiddler crabs and abundance patterns varied across sites. Fiddler crabs (*Uca spp*) were not observed in many of the shooting points. Studies have shown that, crabs use seismic signals to communicate within groups, especially for mate finding, spacing, warning, etc (Hill 2009).

Fiddler Crab(*Uca spp*) Mangrove crab (*Perisesarma bidens)*

Behavioural changes of crabs were observed during the seismic shots.

Fiddler crabs were observed carefully to understand their behaviour during seismic shoot. During seismic shooting time, most of the Fiddler Crabs stopped their activities for few minutes and resumed after few minutes. Some crabs were observed climbing on to mangrove trees after the seismic shoot. This study could not find any prominent impacts except one death incident and the above mentioned behavioural changes mostly in fiddler crabs.

6.5.2 Snakes

Snakes also showed some temporary behavioural changes. There were many Dog-faced Water Snake (*Cerberus rhynchops*) snakes observed in the field around seismic shoot holes. Initially these snakes were observed to be highly active in search of food, But after the seismic shoot, snakes were observed to slowdown their activities and finally going to resting position. Snakes also communicate mainly through seismic vibrations (Carpenter 1977). Seismic waves produced from shoot can be the reason for changes in behaviour of snakes. Still we need detailed long-term scientific studies to see whether there are any permanent behavioural changes or fecundity of organisms caused by seismic surveys.

Dog-faced Water Snake (*Cerberus rhynchops*)

6.5.3 Fishes

There are many studies that have been conducted on impacts of seismic survey on fishes around the World (Persadie 2011; Kostyuchenko 1973; Turnpenny and Nedwell 1994; Saetre and Ona 1996; Kenchington et al. 2001). Fish will only sustain direct impact if they are very near to shoot hole and it may cause significant physiological effects, it may cause even death of certain fishes, especially fishes with air filled swim bladders

(Persadie 2011). Seismic waves can also reportedly cause short term hearing damage to fish (Persadie 2011). The 3D seismic survey may have short-term effects on fishes' behaviour, communication and their movements. There are two incidents of observed fish mortality during 3D seismic shoots in Kandikuppa reserved mangrove forest in East Godavari. These two shoot holes were on mangrove edge (2meter away from water). According to McCauley et al. (2000), adult and juvenile fish are rarely affected by seismic operations because they are able to detect and physically avoid the seismic source. The physical damage effects are most pronounced on fish with a swim bladder because the organ is unable to adapt quickly enough to the high intensity seismic pressure waves (McCauley et al. 2000). Observations of two dead fishes of *Acanthopagrus latus* after the shooting in the Kandikuppa reserved mangrove forest might be due to sudden seismic waves of vibrations. If the received seismic wave vibrations are powerful enough to damage the air bladders (possible when the shooting point is close to the water), the fish can become stunned and disorientated, or trauma can occur to fish hearing (McCauley et al. 2000). The two instances of fish mortality observations indicate that the fishes are the most susceptible to get impacted from the seismic surveys especially when the shot holes are close to the water bodies. As evident from the literature that, such fish death incidents could be due to air sac rupture caused by seismic waves generated during the 3D seismic surveys (Turnpenny and Nedwell 1994; Saetre and Ona 1996; Kenchington et al. 2001).

Dead fish-*Acanthopagrus latus*at Kandikuppa reserved mangrove forest.

6.6 IMPACT ON MANGROVE HABITAT

It has been observed that some of the mangrove trees and branches had to be chopped during the seismic survey process especially around the shot hole areas and during the laying of geophone cables. Direct impacts on habitat is caused by clearing of mangrove vegetation during the laying of geophones and cable lines as well as shot hole drilling for 3D seismic explorations. As Studies elsewhere have shown, some bird species will respond to the "edge effect" around these new gaps in the habitat created from seismic lines in the forests (Bayne and Dale 2011).

Damages to vegetation during 3D seismic surveys in Kandikuppa RF

The process of laying of geophones cables and shoot hole drilling for 3D seismic exploration was performed manually with the help of many labors (Survey group has 3-5 labors; geophone placing group has 15-20 labors; 5-6 groups of shot hole drilling each contain 5-6 labors; 6 shooting group contains 5-7 labors in each group). The movement of these labourers also played a major role in disturbing mangrove habitat. These destructions of Mangroves have significant impacts on life cycles and food chains of the organisms that inhabit these areas.

7. CONCLUSION

Except in the case of fishes, no major direct impacts could be observed on the monitored faunal species from various aquatic and terrestrial faunal groups such as Birds Reptiles, insects and crustaceans during the survey, however few incidents of mortality observed (2 fishes) after the shooting activity during the seismic survey. It is inferred that, the sudden seismic shock can affect mostly fishes and crabs close to the shot hole area. It has been observed that some of the mangrove trees were damage during the clearance of the path for geophone laying and this mangrove destruction can negatively impact the local mangrove ecosystem. Activities of birds, butterflies, and snakes near shooting area were disturbed by peoples' movements, seismic shooting sound and seismic vibrations. There weren't any impacts found on fauna beyond 100 meters from shooting holes.

The earlier study by SACON had recommended the following four specific safeguards to be followed for minimizing the impact of Seismic surveys on Avifauna and wildlife of the area. 1) No cutting or destruction of natural mangroves may be done during the seismic survey operations. Appropriate adjustments may be made in the locations of shot holes and geophones in order to avoid damage to mangroves; 2) The seismic survey activity may preferably be restricted to the period between May to November; 3) More specifically, no activity should be undertaken during December to February in the mangrove areas&4) The survey may be avoided along the 1km wide stretch along the beaches during February to April, which is the reported breeding season of Olive Ridley Turtles (*Lepidochelys olivacea*) in this area. It was observed that, although the OIL has adhered to most of the recommendations, there was some minor cutting of mangrove branches in certain areas. Adequate instructions to the field staff and labourers on this aspect should be ensured to avoid such damages in the future.

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PLATE 1:Seismic survey activities inside the Reserved Mangrove Forest.

View of water gushing out from the shot hole during the Seismic blast inside the Mangrove forest

Movement of men and Machineries inside the forest

PLATE 2: Selected photos of Avifauna from the study area

Lesser Sand Plover (*Charadrius mongolus*)

Grey-headed Lapwing (*Vanellus cinereus*)

Oriental Skylark (*Alauda gulgula*)

Marsh Sand piper (*Tringa stagnatilis*)

Common Snipe (Gallinago gallinago)


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