



**Third Monitoring Report
Mangroves Raised by Coastal Forest Division
Sindh Forest Department, Govt: of Sindh
At Shah Bundar and Keti Bundar**



International Union For Conservation of Nature

**Sindh Coastal Community
Development Project
(SCCDP)
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I. INTRODUCTION

The Sindh Coastal Community Development Project (SCCDP) is being implemented by the Sindh Coastal Development Authority (SCDA) in coastal areas of Thatta and Badin through government agencies (Sindh Forest Dept., Sindh Fisheries Department, and District Governments) and non-government organizations (NRSP and IUCN) with different roles and responsibilities assigned to each of them. The objectives of the project are:

- i. Diversify household income generation options and access to service in ways sustainable to the fragile ecosystem
- ii. Improve coastal zone management by stabilising environmental degradation, protecting coastal areas from accelerated erosion
- iii. Strengthen institutional capabilities for coastal zone planning and development and management of fisheries resources

The complex nature of the project demands effective cooperation between organizations for successful implementation of the project in order to achieve the following outputs:

- i. Sustainable community managed income generating mangrove stands, pond/raft fisheries, and shell fisheries established
- ii. Transparent and accountable community driven mechanisms for identification, implementation and operations and maintenance of civil works and public services in place

Under the sub-component improved coastal management, IUCNP is tasked with the planning and implementation of community planting, management and environmental assessment of aquaculture in the coastal areas of the Thatta and Badin districts. IUCN Pakistan's key roles in the ADB funded 'Sindh Coastal Community Development Project are:

- i. To implement the Community Mangrove Planting component of the project – 350 ha on community owned property.
- ii. To monitor and evaluate both the 350 ha area and the planting of 6000 ha of mangrove by the Dept of Forestry on government owned land.
- iii. To monitor environmental impacts of the aquaculture related activities to be undertaken as part of the project.

In the role of consultant IUCNP has been working very closely with NRSP and Sindh Forest and Fisheries departments for the implementation of SCCDP.

II. SCOPE AND OBJECTIVES OF MONITORING

This monitoring and evaluation report pertains to reportedly 2800 ha of new mangrove plantation carried out in Shah Bundar (1500) and Keti Bundar (1300 ha) by Sindh Forest Department–Coastal Forest Division (SFD-CFD) during 2011 and the evaluation of mangrove plantations carried out by SFD-CFD at Keti Bundar and Shah Bundar during previous years i.e. 2009 and 2010, as per following details.

#	Name of Site	Year Wise Actual Area Planted (Ha)			Total Area (Ha)
		2011	2010	2009	
i.	Keti Bundar	1300	716.5	832.5	2849
ii.	Shah Bundar	1500	683.5	967.5	3151
	Grand Total	2800	1400	1800	6000

It may further be pointed out that during visit of Keti Bundar by ADB Mid-term Mission during the month of August 2011 IUCN was specifically asked to revise monitoring framework to assess natural regeneration within the planted areas which was emerging or surviving as a result of protection efforts by Sindh Forest Department.

Therefore, in accordance with para 55 of MoU of ADB Mid-term Review Mission (1-15 August 2011) the scope and monitoring methodology adopted under this report has been revised to include assessment of scale of natural regeneration in the planted area.

The objectives of this monitoring report are as follows:

- i. Assess quantity and quality of mangrove rehabilitation work undertaken by SFD-CFD under the project under the current and previous years and report the same to Project Executing agency.
- ii. Assess natural regeneration within the planted areas which was emerging or surviving as a result of protection efforts by Sindh Forest Department.
- iii. Provide positive technical feedback to the CFD on deficiencies in implementation of the mangrove rehabilitation component.
- iv. Enhance overall outcome of the mangrove rehabilitation sub-component.

III. METHODOLOGY

IUCN Pakistan has developed a monitoring framework for monitoring the process and approaches adopted in planting of 6000 ha under the project by the Sindh Forest Department. The methodology follows the guidelines and indicators identified in the monitoring framework. The monitoring approach involved several steps, as follows:

i. Pre-Planting Site Selection

The sites for mangrove plantation component were finalized by the ADB's appraisal mission. These sites were reconfirmed and intensively visited by IUCN staff jointly with the staff of Coastal Forestry Division (CFD) of Sindh Forest Department during the month of April 2011 to establish a baseline, GIS maps which were shared with the Project Director, SCCDP and DFO-CFD, Karachi.



ii. Post-Planting Monitoring

Monitoring of mangrove areas is a daunting task in terms of their inter-tidal characteristics, remoteness which are subject to tidal phenomenon which limits access to these areas. Hence, the choice to access and monitor planted areas becomes subject to suitable tide and weather conditions. Nevertheless, the post planting monitoring by IUCN remained continue through out the period during which several joint visits of planted sites in Shah Bundar and Keti Bundar were carried out.

These visits were carried out during the various phases of implementation of mangrove component of the project by the Sindh Forest Department including site selection, area mapping, visits of ADB Missions, joint visits with PMU staff and finally for the assessment of survival/success percentage in the planted areas. The purpose of these visits was to monitor mangrove plantation work, record GPS coordinates of planting sites for preparation of GIS maps of the planted areas and to ensure conformity of planted areas with the already identified sites. The GIS maps have also been used to assess



the quantum of planted areas.

The detailed field data collection was conducted from 17 to 19 November and 30–03 December 2011 and 13 December 2011 at both the sites by the two field teams constituted by IUCN Pakistan. During these visits, the staff of CFD accompanied the field teams.

iii. Assessment of Survival/Success Percentage of Mangrove Plantations

The assessment of survival percentage of mangrove planted areas is one of the important indicators identified in the monitoring framework. This assessment helps in evaluating effectiveness of planting approach, choice of species, protection measures, etc. adopted by CFD. It also provides a useful insight for subsequent corrective measures based on the lessons learnt.

In order to assess survival and success percentage of new and previously planted areas, a Simple Random Sampling (SRS) approach was adopted. SRS is a widely used sampling approach to make inference about population from data collected through the independently selected samples. Using SRS, randomly selected geographic locations were identified within the sites planted under the project at Shah Bundar and Keti Bundar. The randomization was undertaken on the basis of the extent of both East longitudinal and North latitudinal coordinates encompassing the entire planted areas.



The random sample locations were identified using quick random calculator which is available at <http://www.graphpad.com/quickcalcs/randomn2.cfm>. Based on this, sampling locations were identified for data collection in each of the project sites (Keti Bundar and Shah Bundar) separately for both newly planted areas and previous

years planted area. The sample plots were well distributed to represent the entire planted areas. The list of randomly selected coordinates is annexed (Annexure I).

The randomly selected sample plots were located in the field using GPS. At each sampling location, fixed area plots measuring 10 m x 10 m were laid out. The sample plots were laid using a systematic procedure measuring 10m from the point of origin towards north, then 10m towards east, then 10m towards west and finally measuring 10m towards west (point of origin) to complete the square grid. The same procedure was adopted to lay out sample plot on the opposite side.

At each sample plot, data pertaining to no. of surviving plants, no. of dead plants, type of species, height of plants, leaf count, etc. was recorded in datasheets developed for the purpose. In addition, natural regeneration and old naturally growing mangrove plants were also counted within each sample plot besides recording of general topographical and biological conditions, grazing, soil condition etc.

The field collected data was compiled using Microsoft Excel Spread Sheets and analysed for their statistical significance. The data was analysed to calculate various statistical parameters including, mean, variance, standard deviation to estimate statistical significance of the sample data and make inference about the population. The significance of sample data was analysed by applying t-test statistic using 0.05% significance level (95% confidence). Based on this analysis conclusions were drawn about the mean plant survival of new plantations and success percentage of previous year's plantations at both the project sites.



In all, data was recorded from 189 sample plots laid out at 104 randomly selected locations within the current and previous years' planting sites at Keti Bundar, and Shah Bundar, as per following details.

#	Site	No. of Sampling Locations/Year of Planting			Total
		2011	2010	2009	
1	Keti Bundar	31	16	13	60
2	Shah Bundar	19	13	12	44
Grand Total		50	29	25	104

iv. Assessment of Planting Process and Approach

This was undertaken through physical verification of planted sites and discussion with the field staff on planting approach, process and protection measures adopted to safeguard the planted areas. Photographs were also taken to know ground position of at various locations.

IV. FINDINGS OF MONITORING & EVALUATION

It may be kept in mind that the monitoring and evaluation is a continuous process, the data and findings in this report will keep evolving as the monitoring and evaluation process will remain continue throughout the project period. Therefore, the findings and analysis presented in this report pertain to the ground situation at the point in time when this M&E was undertaken i.e. Nov-Dec 2011. This situation may vary during the subsequent M&E of the same areas. The summary of findings covering the various important parameters is shown as follows:

#	Parameter	Findings
i.	Site Selection	The sites planted during 2011 confirm with the sites identified by IUCN jointly with staff of CFD at both sites (Keti Bundar and Shah Bundar). At both the sites, sparse natural mangrove vegetation exists on mudflats covered by grass.
ii.	Area Planted	<p>The planting has been done in the completely or partially blank mudflats and interspaces within the existing sparse natural vegetation of <i>Avicennia marina</i> at both the sites.</p> <p>Based on GIS maps, the net tackled area at Keti Bundar during 2010-11 has been estimated to be approximately 1348 ha against 1300 ha claimed by SFD-CFD. Whereas, net tackled area of monitored block at Shah Bundar has been estimated as 1485 ha against 1500 ha claimed by SFD-CFD.</p> <p>Whereas, the planted area during 2010 and 2009 at Keti Bundar is estimated to be 616 ha and 830 ha against 716.5 ha and 832.5 ha respectively as reported by SFD-CFD; and the planted area during 2010 and 2009 at Shah Bundar is estimated to be 671 ha and 946 ha against 683.5 ha and 967.5 ha respectively reported by SFD-CFD.</p> <p>Hence, the total area planted under the project comes to be 5896 ha against the reported area of 6000 ha planted by SFD-CFD, leaving a net difference of 104 ha which is yet to be planted to achieve the target fully.</p>
iii.	Choice of species	<p>During 2010-11, the species planted included mainly <i>Rhizophora</i> (89%) and <i>Avicennia</i> (11%) at Keti Bundar, and <i>Rhizophora</i> (37%), <i>Avicennia</i> (47%) and <i>Ceriops</i> (11%) at Shah Bundar.</p> <p>Initially the area was planted with <i>Rhizophora spp.</i> as its propagules were available for planting during May and June. Later on, other areas were planted with <i>Avicennia sp</i> including</p>

		<p>restocking of failure areas. Propagules of <i>Rhizophora</i> and seeds of <i>Avicennia</i> species have been used for planting and restocking of failures respectively.</p> <p>As far as previous years' mangrove plantations are concerned, the current species composition in the areas planted at Keti Bundar during 2010 includes <i>Avicennia</i> (53%), <i>Rhizophora</i> (47%), and the species composition planted during 2009 includes <i>Avicennia</i> (54%), <i>Rhizophora</i> (43%) and mixed specie (13%).</p> <p>Whereas, the current species composition in the areas planted at Shah Bundar during 2010 includes <i>Avicennia</i> (85%), <i>Rhizophora</i> (15%), and the species composition planted during 2009 includes <i>Avicennia</i> (83%), <i>Rhizophora</i> (17%).</p>
iv.	Planting Pattern	The planting pattern involved linear-block fashion with overall 10'x10' spacing between plants and rows. At a few places, close spacing of 8' x 8' was also observed. However, in most of the areas the planting distance was found to be consistent with the spacing prescribed in the project document.
v.	Survival Percentage	<p>Within the mangrove plantation raised during 2011 the estimated overall survival percentage of was estimated to be 81% at Shah Bundar with a margin of error $\pm 12\%$ and 87% at Keti Bundar with a margin of error $\pm 7\%$ at 0.05% significance level (95% confidence level).</p> <p>Good survival % of <i>Rhizophora</i> was observed in the areas surrounded by sparse natural vegetation of <i>Avicennia</i>.</p>
vi.	Success Percentage of previous years mangrove plantations (2010 & 2009)	<p>The existing success% of the mangrove plantation raised during 2010 was estimated to be 78% at Shah Bundar with a margin of error $\pm 10\%$ and 71% at Keti Bundar with a margin of error $\pm 11\%$ at 0.05% significance level (95% confidence level).</p> <p>Whereas, the existing success% of the mangrove plantation raised during 2009 was estimated to be 72% at Keti Bundar with a margin of error $\pm 11\%$ and a progressively lower 58% success was observed at Shah Bundar with a margin of error $\pm 8\%$ at 0.05% significance level (95% confidence level).</p>
vii.	Planting Process and Approach	The planting process followed by SFD-CFD appeared conventional approach, as community engagement in the process was

		found restricted to engaging community members as labourers and chowkidars (watchers). The indirect role of NRSP in community mobilization for mangrove planting component was observed, as the plantation watchers belonged to COs organized by NRSP. IUCN Pakistan organized trainings jointly with SFD before the start of planting season wherein the participating communities, field staff, labourers and plantation watchers were trained in different aspects of mangrove planting process including site selection, choice of species and nursery raising.
viii.	Adopted Protection Measures	<p>In Shah Bundar, five members of regular staff of CFD are involved in protection of the planted areas. In addition, fifty community members have been engaged as paid watchers to undertake regular patrolling of the area. In order to protect the area from camel grazing wire fencing has been done at potential camel crossings. The current protection measures were so far found effective as the previously grazed and stunted mangrove vegetation is showing signs of recovery. Natural recovery of such areas due to these protection measures may be considered as incremental benefits of the project interventions.</p> <p>At Keti Bundar, four members of regular forest staff and forty five watchers/chowkidars (on contractual basis) have been engaged for protection of the plantation. Besides, through negotiation with local Jat community a corridor has been left as passage for their camel movement to avoid damage to planted areas.</p>
Natural Regeneration		
	Estimation of NR	<p>Due to consistent protection of the planted areas a lot of natural regeneration of <i>Avicennia</i> has been observed in the planted areas. The natural regeneration is more profuse at Keti Bundar as compared to Shah Bundar. There is also observable increase in number of naturally regenerating saplings within the planted areas.</p> <p>The number of naturally regenerating saplings at Keti Bundar has been estimated to be 763, 1659 and 3619 saplings/ha within the planted areas during 2011, 2010 and 2009 respectively.</p> <p>Whereas, the number of naturally regenerating saplings within the planted areas at Shah Bundar has been estimated to be 258, 77 and 512 saplings/ha within the planted areas during 2011, 2010 and 2009</p>

		<p>respectively.</p> <p>If protected continually, the incremental benefits of natural regeneration may outweigh the number of plants actually planted under the project.</p>
Recovery of Old Natural Mangrove Vegetation		
	<p>Estimation of Old Natural Growth</p>	<p>A lot of natural old growth of <i>Avicennia</i> was also observed recovering within the planted areas due to consistent protection against animal grazing.</p> <p>The recovery of old natural mangrove vegetation was more in planted areas at Keti Bundar as compared to Shah Bundar.</p> <p>At Keti Bundar the number of recovering old naturally growing plants has been estimated to be 68, 325 and 250 plants/ha within the areas planted during 2011, 2010 and 2009, respectively. The height of these plants varied from 2'-3'.</p> <p>Whereas, at Shah Bundar, the number of recovering old naturally growing mangrove plants was estimated to be 63, 0 and 129 plants/ha within the planted areas during 2011, 2010 and 2009 respectively. The height of these plants varied from 1.5'-5'.</p> <p>If protected continually, these may be considered as incremental benefits of the project.</p>

V. DISCUSSION

Based on field visit, the following observations related to technical aspects and adopted planting approach have been recorded and are commented as follows. It is hoped that these comments would provide useful direction and guidance to the project executing agency and the staff of CFD for future interventions.

i. Technical Aspect of the Project

a. Estimated Survival Percentage

Based on statistical analysis of the field data the mean survival % in the mangrove areas planted under the project at Keti Bundar and Shah Bundar during various years is summarized in Table I. The survival estimates have been tested against 95% significance level.

Table I: Survival/success % of Mangrove Areas Planted under SCCDP

Site	Survival/Success %					
	2011		2010		2009	
	%	Margin of Error@ 95% level of confidence	%	Margin of Error@ 95% level of confidence	%	Margin of Error@ 95% level of confidence
Keti Bundar	87	(± 7%)	71	(± 11%)	72%	(± 11%)
Shah Bundar	81	(± 12%)	78	(± 10%)	58%	(± 8%)
Overall	84%	9.5	74.5	10.5	65%	9.5%

The detailed statistical analysis for Shah Bundar and Keti Bundar is shown as Annexure -II.

At Keti Bundar, the aggregate survival/success in the planted areas since 2009 was found to be 77% against the aggregate survival/success of 72% observed at Shah Bundar.



A much consistent level of survival/success was observed at Keti Bundar in different years, apparently due to consistent level of protection of the entire planted areas which fell adjacent to each other. A similar consistent level of survival/success was observed at Shah Bundar in the areas planted during 2011 and 2010.

However, a much lesser level of success (58%) was observed in area planted during 2009 at Shah Bundar. The most obvious reasons for a lower level of success appeared to be initial errors in selection of species for planting i.e. planting of *Rhizophora* in low-lying and barren mudflats, resulting in algal attack and flushing away of planted propagules due to fast receding tidal flows. Since, the selected site appeared too remote and isolated the subsequent measures for restocking of the failure area appeared inadequate to restock the entire area with *Avicennia* due to prohibitive costs and remoteness, resulting overall less success %.

b. Plant Growth

As far as plant growth is concerned, at Keti Bundar, good growth of *Rhizophora* was observed in the grassy mudflats covered with sparse natural vegetation of *Avicennia*. The height of *Rhizophora* plants varied from 10"-20" and leaf count 8-14 leaves in plantations raised in different years. The height of *Avicennia* plants varied from 4"-20" and leaf count 4-50 leaves in plantations raised in different years.



Similarly, at Shah Bundar, good growth of all mangrove species in the grassy mudflats covered with sparse natural vegetation of *Avicennia*. The height of *Rhizophora* plants varied from 11"-18" and leaf count 6-8 leaves in plantations raised during 2011. The height of *Avicennia* plants varied from 6"-18" and leaf count 6-46 leaves in the plantations raised during year 2010 and 2009.

Furthermore, the natural vegetation which has remained stunted due to previous overgrazing by camels was also found recovering at various places due to continued protection by the field staff. A continued protection of the planted areas would allow these grazed mangrove plants to grow vigorously.

c. Choice of Species and Planting Methodology

Under the technical features of the project, 'two main species of mangroves *Avicennia* and *Rhizophora* have to be planted in mixed and single species clusters and belts of 50 to 100 meters width, and at a density of approximately 1100 plants per ha'. However, the specific definition of "cluster" has not been prescribed in PC-I. Unless otherwise specified, the density of 1100 plants/ha prescribed in the PCI appears to reflect normal practice of raising mangrove plantation blocks at 10'x10' spacing i.e. one plant per nine square meters.



The field observations revealed that separate blocks of single species have been planted at both the sites. The *Avicennia* and *Ceriops* were planted through seeds and *Rhizophora* were sown through propagules directly.

At Keti Bundar, *Rhizophora* appeared to be the single most species planted during 2011 occupying almost 89% of the total planted area. The remaining 11% area was planted with *Avicennia*. This approach reflects a significant shift from a much balanced and diverse species composition followed during the previous years and as prescribed in PC-I. The most obvious reasons for this approach seem to be easier planting of *Rhizophora* propagules as compared to planting of other mangrove species.

As far as previous years' mangrove plantations are concerned, the current species composition in the areas planted at Keti Bundar during 2010 includes *Avicennia* (53%), *Rhizophora* (47%); whereas, the species composition planted during 2009 includes *Avicennia* (54%), *Rhizophora* (43%) and mixed specie (13%).

Conversely, a much balanced and diverse species composition was observed at Shah Bundar in the areas planted during 2011 which included *Avicennia* (47%), *Rhizophora* (37%) and *Ceriops* (11%). Whereas, the current species composition in the areas planted at Shah Bundar during 2010 included *Avicennia* (85%), *Rhizophora* (15%), and the species composition planted during 2009 includes *Avicennia* (83%), *Rhizophora* (17%).

A comparative species wise composition of planted area is shown in Table II & III.

Table II: Species-wise Survival/success % at Keti Bundar

#	Species	Year of Planting					
		2011		2010		2009	
		(%)	Est. Area (Ha)	(%)	Est. Area (Ha)	(%)	Est. Area (Ha)
1	<i>Avicennia</i>	11%	148	47%	290	54%	443
	<i>Rhizophora</i>	89%	1200	53%	326	33%	271
	<i>Ceriops</i>	-	-	-	-	-	-
	Mixed (<i>Avicennia</i> + <i>ceriops/ Rhizophora</i>)	-	-	-	-	13%	106
	Blank	-	-	-	-	-	-
	Total	100%	1348	100%	616	100%	820

Table III: Species-wise Survival/success % at Shah Bundar and Estimated Coverage

#	Species	Year of Planting					
		2011		2010		2009	
		(%)	Est. Area (Ha)	(%)	Est. Area (Ha)	(%)	Est. Area (Ha)
1	<i>Avicennia</i>	47%	698	85%	570	83%	785
	<i>Rhizophora</i>	37%	549	15%	101	-	-
	<i>Ceriops</i>	11%	163	-	-	-	-
	Blank	5%	74	-	-	17%	161
	Total	100%	1485	100%	671	100%	946

The higher survival percentage of all mangrove species was observed on grassy mudflats with scattered natural growth of *Avicennia*. Hence, it is advised to plant *Rhizophora* only in grassy mudflats. Completely barren and low-lying mudflats should be avoided for *Rhizophora* planting. In such areas direct seed sowing or wildlings of *Avicennia* may be preferred. Further, it is emphasized that wherever possible mixed plantation of mangrove species shall be preferred for better environmental benefits.

d. Area Planted

Based on GIS maps the actual area planted at Keti Bundar has been estimated to be 2794 ha against the reported area of 2849 ha. Whereas, the actual area planted at Shah Bundar was estimated to be 3102 ha against the reported area of 3151 ha. The net difference in actually planted area and reported area comes to be 104 ha against the total target of 6000 ha allocated to SFD-CFD under the project.

A comparative position of actual area planted under the project since 2009 and the area reported by SFD-CFD is shown in Table IV.

Table IV: Comparative Position of Actual and Reported Area Planted under SCCDP Since 2009

Site Year	Keti Bundar				Shah Bundar			
	2011	2010	2009	Total	2011	2010	2009	Total
Actual Area Planted (Ha)	1348	616	830	2794	1485	671	946	3102
SFD-CFD Reported (Ha)	1300	716.5	832.5	2849	1500	683.5	967.5	3151
Difference	+48	-100.5	-2.5	-55	-15	-12.5	-21.5	-49

e. Container Plant Nursery

Reportedly, SFD-CFD has established mangrove container plant nurseries of 475,000 saplings each at Keti Bundar and Shah Bundar during 2011.

Against the target, approximately, 90,000 saplings of *Rhizophora*, *Aviennia* and *Ceriops* were observed at Keti Bundar nursery, besides approximately 20,000 blank polythene bags available at the site, as shown in Table VI.



Table V: Container Plant Stock Position at Keti Bundar Nursery

#	Species	No of Beds	Saplings Per Bed	Total No of Saplings
1	<i>Rhizophora mucronata</i>	8	1280	10240
		38.5	1040	40040
		16.5	800	13200
			Sub-total	63480
2	<i>Avicennia marina</i>	4.5	1280	5760
3	<i>Ceriops tagal</i>	5	960	4800
		11	432	4752
		4.5	1560	7020
		6.5	800	5200
			Sub-total	21772
4	Blank polythene bags	15.5	1280	19840
			Grand Total	110,852

The review of nursery stock register (Table VII) revealed that new raising of **475,000** saplings of various mangrove species was carried out in Keti Bundar nursery since November 2010. Of these, approximately 350,000 saplings have been shown as consumed up to November 2011. This indicates that the saplings were raised and consumed during the same year. Moreover, it reveals that most of the stock was consumed during the period from April – Oct 2011 when the propgauls and seeds of different mangrove species were naturally available in abundance. Normally the practice is that the container plant stock is consumed before and after the seeding seasons of the mangrove species as well as for the restocking of the failures.

Table VI: Container Plants Raising as per Stock Register at Keti Bundar Nursery

#	Month	Species	Opening Balance	New Raising	Consumption	Closing Balance
1	Nov:2010	<i>Rhizophora</i>	-	25500	-	25500
		<i>Ceriops tagal</i>	5000	-	5000	-
2	Dec:2010	<i>Rhizophora</i>	25500	-	-	25500
3	Jan: 2011	<i>Rhizophora</i>	25500	140000	-	165500
		<i>Ceriops tagal</i>	0	10000	-	10000
4	Feb:2011	<i>Rhizophora</i>	165500	-	-	165500
		<i>Ceriops tagal</i>	10000	-	-	10000
5	Mar:2011	<i>Rhizophora</i>	165500	-	15500	150000
		<i>Ceriops tagal</i>	10000	-	-	10000
6	Apr: 2011	<i>Rhizophora</i>	150000	-	10000	140000
		<i>Ceriops tagal</i>	10000	-	-	10000
7	May: 2011	<i>Rhizophora</i>	140000	-	40000	100000
		<i>Ceriops tagal</i>	10000	-	-	10000
8	Jun: 2011	<i>Rhizophora</i>	100000	150000	30000	220000

		<i>Ceriops tagal</i>	10000	-	-	10000
9	Jul: 2011	<i>Rhizophora</i>	220000	-	40000	180000
		<i>Ceriops tagal</i>	10000	-	-	10000
10	Aug:2011	<i>Rhizophora</i>	180000	139000	15000	304000
		<i>Avicennia</i>	-	10500	-	10500
		<i>Ceriops tagal</i>	10000	-	-	10000
11	Sep:2011	<i>Rhizophora</i>	304000	-	15000	289000
		<i>Avicennia</i>	10500	-	-	10500
		<i>Ceriops tagal</i>	10000	-	-	10000
12	Oct: 2011	<i>Rhizophora</i>	289000	-	80000	209000
		<i>Avicennia</i>	10500	-	-	10500
		<i>Ceriops tagal</i>	10000	-	-	10000
13	Nov:2011	<i>Rhizophora</i>	209000	-	100000	109000
		<i>Avicennia</i>	10500	-	-	10500
		<i>Ceriops tagal</i>	10000	-	-	10000
		Total	-	475000	350500	129500

Similarly, at Shah Bundar, two mangrove nurseries were established during 2011. Approximately, 140,000 saplings of various mangrove species were observed in both nurseries during field monitoring in Nov. 2011 as indicated in Table VIII.

Table VII: Container Plant Stock Position at Shah Bundar Nursery

#	Species	No of Beds	Saplings Per Bed	Total No of Saplings
Nursery – I				
1	<i>Rhizophora mucronata</i>	5	1860	9300
2	<i>Avicennia marina</i>	7.5	1860	13950
		8	1305	10440
		24	1800	43200
			Sub-total	67590
3	<i>Ceriops tagal</i>	6	1860	11160
		12	1305	15660
			Sub-total	26820
4	<i>Aegicerus corniculatom</i>	18	1305	23490
			Total Nursery I	127200
Nursery – II				
1	<i>Avicennia marina</i>	18	560	10080
2	<i>Rhizophora mucronata</i>	5	560	2800
			Total Nursery II	12880
			Grand Total	140080

The review of nursery stock register (Table VII) revealed that new raising of **475,000** saplings of various mangrove species was carried out in Shah Bundar nurseries since November 2010, besides carrying forward previous year's stock of 80,500 saplings. Of these, approximately 405,500 saplings have been shown as consumed up to November 2011.

The consumption pattern of nursery saplings shows similar patterns of consumption in both areas i.e. Keti Bundar and Shah Bundar. The nursery saplings have been raised and consumed during the same year, and mostly during the period of year when plenty of propagules and seeds of different mangrove species were available

naturally. It seems that the presence of nursery played a positive role in influencing the survival rate regime; however, a more appropriate use of stock is recommended to avoid undue losses.

Table VIII: Container Plants Raising as per Stock Register at Shah Bundar Nursery

Month	Species	Opening Balance	New Raising	Consumption	Closing Balance
Nov: 2010	<i>Avicennia</i>	70500	25500	30000	66000
	<i>Ceriops tagal</i>	5000	-	-	5000
	<i>Aegicerus sp.</i>	5000	-	-	5000
Dec: 2010	<i>Avicennia</i>	66000	-	40000	26000
	<i>Ceriops tagal</i>	5000	-	-	5000
	<i>Aegicerus sp</i>	5000	-	-	5000
Jan: 2011	<i>Rhizophora</i>	-	100000	-	100000
	<i>Avicennia marina</i>	26000	-	-	26000
	<i>Ceriops tagal</i>	5000	30000	5000	30000
	<i>Aegicerus sp.</i>	5000	20000	5000	20000
Feb: 2011	<i>Rhizophora</i>	100000	-	-	100000
	<i>Avicennia</i>	26000	-	-	26000
	<i>Ceriops tagal</i>	30000	-	-	30000
	<i>Aegicerus</i>	20000	-	-	20000
Mar: 2011	<i>Rhizophora</i>	100000	-	-	100000
	<i>Avicennia</i>	26000	-	16000	10000
	<i>Ceriops tagal</i>	30000	-	-	30000
	<i>Aegicerus</i>	20000	-	-	20000
Apr: 2011	<i>Rhizophora</i>	100000	-	-	100000
	<i>Avicennia</i>	10000	-	-	10000
	<i>Ceriops tagal</i>	30000	-	-	30000
	<i>Aegicerus</i>	20000	-	-	20000
May: 2011	<i>Rhizophora</i>	100000	-	20000	80000
	<i>Avicennia</i>	10000	-	-	10000
	<i>Ceriops tagal</i>	30000	-	10000	20000
	<i>Aegicerus</i>	20000	-	5000	15000
Jun: 2011	<i>Rhizophora</i>	80000	20000	30000	70000
	<i>Avicennia</i>	10000	100000	10000	100000
	<i>Ceriops tagal</i>	20000	15000	5000	30000
	<i>Aegicerus</i>	15000	15000	5000	25000
Jul: 2011	<i>Rhizophora</i>	70000	-	30000	40000
	<i>Avicennia</i>	100000	-	-	100000
	<i>Ceriops tagal</i>	30000	-	5000	25000
	<i>Aegicerus</i>	25000	-	5000	20000
Aug: 2011	<i>Rhizophora</i>	40000	-	10000	30000
	<i>Avicennia</i>	100000	119500	-	219500
	<i>Ceriops tagal</i>	25000	15000	10000	30000
	<i>Aegicerus</i>	20000	15000	5000	30000
Sep: 2011	<i>Rhizophora</i>	30000	-	10000	20000
	<i>Avicennia</i>	219500	-	-	219500
	<i>Ceriops tagal</i>	30000	-	-	30000

	<i>Aegicerus</i>	30000	-	-	30000
Oct: 2011	<i>Rhizophora</i>	20000	-	10000	10000
	<i>Avicennia</i>	219500	-	69500	150000
	<i>Ceriops tagal</i>	30000	-	-	30000
	<i>Aegicerus</i>	30000	-	-	30000
Nov: 2011	<i>Rhizophora</i>	10000	-	10000	-
	<i>Avicennia</i>	150000	-	30000	120000
	<i>Ceriops tagal</i>	30000	-	15000	15000
	<i>Aegicerus</i>	30000	-	15000	15000
	Total	-	475000	405500	150000

ii. Planting Process and Approach

a. Community Engagement

The planting process followed by SFD-CFD represented a conventional approach, as community engagement in the process was found restricted to engaging community members as labourers and chowkidars (watchers). The indirect role of NRSP in community mobilization for mangrove planting component was observed, as the plantation watchers belonged to COs organized by NRSP. IUCN Pakistan organized trainings jointly with SFD before the start of planting season wherein the participating communities, field staff, labourers and plantation watchers were trained in different aspects of mangrove planting process including site selection, choice of species and nursery raising.

Furthermore, a lot of emphasis has been given by SFD-CFD to planting of *Rhizophora* in new plantations and nursery raising. A balanced approach needs to be followed to promote a mix of mangrove species in new plantations rather than following a monoculture approach.

b. Organisational Collaboration

As per project design, IUCN has been assigned role of continuous monitoring of mangrove component throughout the project life. This role could only be effectively discharged if both SFD-CFD and IUCN work closely in mangrove component implementation. However, there is a need to improve exchange of information by SFD-CFD on a regular basis for timely and effective monitoring and feedback.

VI. CONCLUSION AND RECOMMENDATIONS

Overall conclusion is that SFD-CFD has attempted the target of mangrove plantation over 6000 ha assigned to them under SCCDP with overall satisfactory level of survival or success. The net area so far planted under the project has been estimated to be 5896 ha against the reported area of 6000 ha by SFD-CFD.

The observed percentage of survival in 2011 mangrove plantation has been estimated to be 87% at Keti Bundar and 81% at Shah Bundar which may be considered as exceptionally good success. However, the real challenge is to sustain new plantations over the period of time.

Furthermore, except for a relatively lower success % in 2009 planted areas at Shah Bundar, the overall success % has been estimated to be more than 70% at both Keti Bundar and Shah Bundar in the areas planted during 2010 and 2009.

Since 2009, a gradual improvement has been noticed in selection of sites for new plantation, choice of species and protection measures, resulting in a relatively more survival/success % in the areas planted subsequently i.e. during 2010 and 2011.

A lot of naturally regenerating saplings and old scattered natural growth of *Avicinnia* continue to emerge with in the planted areas, most profusely at Keti Bundar. If protection is ensured through the project life, the natural regeneration within the planted areas would enhance present density of the planted sites and may outnumber the saplings actually planted under the project.

It is therefore, advised that in future interventions, SFD-CFD shall consider protection as a priority strategy than actual new planting in the areas where natural regeneration is expected to be more profuse. Any new mangrove plantation should only be considered as supplemental plantation in the leftover blank area during the subsequent years. This will result in a more efficient use of available financial resources.

Recommendations for follow-up:

- A balanced and diverse species composition shall be preferred in future plantations against establishing monoculture.
- *Avicennia* being more salinity tolerant mangrove species in the Indus Delta shall be preferred in planting activities. Its seed is available in large quantities during planting season and gives relatively good success even at difficult sites.
- The Rhizophora planting in the low lying mudflats near the fringes of the creeks should be avoided. It should only be planted in areas surrounded by sparse natural vegetation of *Avicennia* or in grassy mudflats covered with *Aleuopus* and *Arthrocnemum* grasses.
- In the areas where natural regeneration is expected to be more profuse, protection of area shall be given a priority than actually undertaking planting such areas. Any supplemental new mangrove plantation shall only be considered during the subsequent years to fill-in the leftover gaps.
- Silviculturally the container plant nurseries stock should be consumed before and after the seeding season of mangroves as well as for restocking/maintenance of the plantations.
- Regular and timely information exchange on field activities (such as, planting targets, progress reports, area maps/sketches, GPS coordinates, etc.) between CFD and IUCN needs to be ensured.
- Monitoring is a continuous process that would remain continuous through the project life. This needs to be appreciated at all the levels.

GIS Map Showing The Area Planted By Sindh Forest Department In The Year 2009, 2010 and 2011 Under SCCDP At Shah Bundar



GIS Map Showing The Area Planted By Sindh Forest Department Under SCCDP In The Year 2009, 2010 And 2011 At Keti Bundar



**Annexure I: List OF Randomly Selected Coordinates
Based on
<http://www.graphpad.com/quickcalcs/randomn2.cfm>**

Shah Bundar		
North Latitude (Extent 24 ⁰ 04' 27" to 24 ⁰ 11' 23") East longitude (Extent 67 ⁰ 46' 49" to 68 ⁰ 03' 56")		
#	North North Latitude	East Longitude

1	N 24 ⁰ 07' 39"	E 67 ⁰ 49' 26"
2	N 24 ⁰ 09' 49"	E 67 ⁰ 48' 31"
3	N 24 ⁰ 09' 33"	E 67 ⁰ 48' 40"
4	N 24 ⁰ 08' 11 "	E 67 ⁰ 48' 54"
5	N 24 ⁰ 09' 47"	E 67 ⁰ 49' 06"
6	N 24 ⁰ 09' 44"	E 67 ⁰ 48' 49"
7	N 24 ⁰ 07' 47"	E 67 ⁰ 48' 08"
8	N 24 ⁰ 09' 38"	E 67 ⁰ 47' 40"
9	N 24 ⁰ 08' 13 "	E 67 ⁰ 48' 24"
10	N 24 ⁰ 09' 31 "	E 67 ⁰ 49' 16"
11	N 24 ⁰ 10' 01 "	E 67 ⁰ 47' 42"
12	N 24 ⁰ 07' 49"	E 67 ⁰ 49' 01"
13	N 24 ⁰ 10' 00"	E 67 ⁰ 47' 52"
14	N 24 ⁰ 07' 51"	E 67 ⁰ 48' 04"
15	N 24 ⁰ 05' 11 "	E 67 ⁰ 49' 31"
16	N 24 ⁰ 05' 25"	E 67 ⁰ 50' 10"
17	N 24 ⁰ 05' 07"	E 67 ⁰ 49' 46"
18	N 24 ⁰ 05' 34"	E 67 ⁰ 50' 01"
19	N 24 ⁰ 04' 52"	E 67 ⁰ 49' 33"
20	N 24 ⁰ 10' 45 "	E 67 ⁰ 48' 15"

21	N 24 ⁰ 10' 54"	E 67 ⁰ 48' 24"
22	N 24 ⁰ 10' 02 "	E 67 ⁰ 48' 28"
23	N 24 ⁰ 10' 30 "	E 67 ⁰ 48' 41"
24	N 24 ⁰ 10' 11 "	E 67 ⁰ 48' 26"
25	N 24 ⁰ 10' 21 "	E 67 ⁰ 48' 36"
26	N 24 ⁰ 10' 26 "	E 67 ⁰ 48 '23"
27	N 24 ⁰ 10' 03 "	E 67 ⁰ 48' 42"
28	N 24 ⁰ 10' 18"	E 67 ⁰ 48' 27"
29	N 24 ⁰ 04' 48"	E 67 ⁰ 49' 56"
30	N 24 ⁰ 04' 44"	E 67 ⁰ 49' 35"
31	N 24 ⁰ 04' 50"	E 67 ⁰ 50' 17"
32	N 24 ⁰ 04' 40"	E 67 ⁰ 50' 01"
33	N 24 ⁰ 04' 24 "	E 68 ⁰ 01' 56"
34	N 24 ⁰ 04' 38 "	E 68 ⁰ 02' 37"
35	N 24 ⁰ 05' 04 "	E 68 ⁰ 02' 36"
36	N 24 ⁰ 05' 22"	E 68 ⁰ 02' 39"
37	N 24 ⁰ 04' 34"	E 68 ⁰ 01' 50"
38	N 24 ⁰ 05' 13"	E 68 ⁰ 03' 27"
39	N 24 ⁰ 03' 46"	E 68 ⁰ 03' 17"
40	N 24 ⁰ 04' 55"	E 68 ⁰ 03' 03"
41	N 24 ⁰ 05' 30 "	E 68 ⁰ 02' 16"
42	N 24 ⁰ 04' 27 "	E 68 ⁰ 03' 30"
43	N 24 ⁰ 05' 09 "	E 67 ⁰ 02' 07"
44	N 24 ⁰ 03' 59"	E 67 ⁰ 02' 38"

**Annexure I: List OF Randomly Selected Coordinates
Based on
<http://www.graphpad.com/quickcalcs/randomn2.cfm>**

Keti Bundar		
North Latitude (Extent 24 ⁰ 08' 19" to 24 ⁰ 11' 55") East longitude (Extent 67 ⁰ 22' 56" to 67 ⁰ 27' 60")		
#	North Latitude	East Longitude

1	N 24 ⁰ 10' 21"	E 67 ⁰ 24' 23"
2	N 24 ⁰ 09 '15 "	E 67 ⁰ 24' 47"
3	N 24 ⁰ 09' 20 "	E 67 ⁰ 24' 27"
4	N 24 ⁰ 10' 58 "	E 67 ⁰ 24' 36"
5	N 24 ⁰ 10' 02 "	E 67 ⁰ 23' 50"
6	N 24 ⁰ 10 '20 "	E 67 ⁰ 24' 35"
7	N 24 ⁰ 10' 12 "	E 67 ⁰ 24' 29"
8	N 24 ⁰ 10' 19 "	E 67 ⁰ 24' 43"
9	N 24 ⁰ 10' 29"	E 67 ⁰ 24' 55"
10	N 24 ⁰ 09' 18"	E 67 ⁰ 24' 49"
11	N 24 ⁰ 09' 23"	E 67 ⁰ 24' 11"
12	N 24 ⁰ 10' 49"	E 67 ⁰ 23' 09"
13	N 24 ⁰ 09' 44"	E 67 ⁰ 24' 19"
14	N 24 ⁰ 09' 45"	E 67 ⁰ 24' 51"
15	N 24 ⁰ 10' 23"	E 67 ⁰ 24' 09"
16	N 24 ⁰ 10' 48"	E 67 ⁰ 23' 17"
17	N 24 ⁰ 10' 33"	E 67 ⁰ 24' 25"
18	N 24 ⁰ 10' 05"	E 67 ⁰ 24' 03"
19	N 24 ⁰ 11' 03"	E 67 ⁰ 24' 13"
20	N 24 ⁰ 11' 02"	E 67 ⁰ 23' 04"
21	N 24 ⁰ 10' 55"	E 67 ⁰ 24' 28"

22	N 24 ⁰ 10' 51"	E 67 ⁰ 25' 03"
23	N 24 ⁰ 09' 34"	E 67 ⁰ 23' 54"
24	N 24 ⁰ 09' 33 "	E 67 ⁰ 23' 38"
25	N 24 ⁰ 09' 25 "	E 67 ⁰ 24' 43"
26	N 24 ⁰ 09' 25 "	E 67 ⁰ 25' 10"
27	N 24 ⁰ 08' 30 "	E 67 ⁰ 26' 03"
28	N 24 ⁰ 08' 57"	E 67 ⁰ 26' 25"
29	N 24 ⁰ 08' 48"	E 67 ⁰ 25' 58"
30	N 24 ⁰ 08' 59"	E 67 ⁰ 25' 34"
31	N 24 ⁰ 09' 17"	E 67 ⁰ 25' 22"
32	N 24 ⁰ 10' 36"	E 67 ⁰ 25' 25"
33	N 24 ⁰ 11 '16"	E 67 ⁰ 25' 36"
34	N 24 ⁰ 11 '04"	E 67 ⁰ 25' 24"
35	N 24 ⁰ 10' 53"	E 67 ⁰ 25' 13"
36	N 24 ⁰ 10' 55"	E 67 ⁰ 24' 53"
37	N 24 ⁰ 10' 53"	E 67 ⁰ 27' 24"
38	N 24 ⁰ 10' 53"	E 67 ⁰ 27' 24"
39	N 24 ⁰ 11' 30"	E 67 ⁰ 27' 11"
40	N 24 ⁰ 09' 56"	E 67 ⁰ 27' 42"
41	N 24 ⁰ 10' 28"	E 67 ⁰ 27' 20"
42	N 24 ⁰ 10' 23"	E 67 ⁰ 27' 00"
43	N 24 ⁰ 10' 04"	E 67 ⁰ 26' 41
44	N 24 ⁰ 09' 46"	E 67 ⁰ 27' 23"
45	N 24 ⁰ 09' 27"	E 67 ⁰ 26' 08"
46	N 24 ⁰ 10' 33"	E 67 ⁰ 26' 40"
47	N 2 ⁰ 4 09' 18"	E 67 ⁰ 26' 53"
48	N 2 ⁰ 4 09' 31"	E 67 ⁰ 25' 44"
49	N 2 ⁰ 4 09' 29"	E 67 ⁰ 27' 08"
50	N 24 ⁰ 09' 58"	E 67 ⁰ 26' 06"
52	N 24 ⁰ 10' 22"	E 67 ⁰ 26' 27"
53	N 24 ⁰ 09' 43"	E 67 ⁰ 26' 11"
54	N 24 ⁰ 10' 31"	E 67 ⁰ 25' 55"

ANNEXURE – II: Statistical Analysis

Shah Bundar 2011:

The sample variance and standard deviation could be calculated using the following formula:

Sample Variance = Sum (Σ) of squared deviations from mean divided by degree of freedom, is given by:

$$S^2 = \frac{\sum (X - \bar{X})^2}{n - 1}$$

Where X is sample value, and \bar{x} is sample mean, n-1 is degree of freedom.

Sample variance (S^2) for living plants could be calculated as follows:

$$S^2 = \frac{132.45 \text{ (from Excel sheet)}}{18}$$

$$S^2 = 7.358$$

Sample Standard Deviation (S) is square root of variance. Therefore, sample standard deviation (S) for living plants would be:

$$S = \sqrt{7.358} = 2.713$$

$$\text{Standard Error} = \frac{\text{Standard Deviation}}{\sqrt{\text{Number in the Sample}}} = \frac{\text{Standard Deviation (S)}}{\sqrt{n}}$$

$$\text{SE}(\text{surviving plants}) = \frac{2.713}{\sqrt{19}}$$

$$\text{SE} = 0.6224$$

The confidence interval for the population mean constructed at 0.05 significance level gives the following range of mean population survival:

$$\bar{x} \pm t_{\alpha/2} \frac{S}{\sqrt{n}}$$

$$t > \alpha/2, n-1 = t_{0.025, 18} = 2.101 \text{ (from t-table)}$$

$$\text{Therefore: } 8.842 \pm 2.101 \frac{2.713}{\sqrt{19}}$$

$$= 8.842 \pm 2.101 \times 0.6224$$

$$= 8.842 \pm 1.307$$

Hence, we are 95% confident that the mean population survival % (μ) in all transects lies between 10.149 plants/sample plot or 1015 plants/ha (93%) and 7.535 plants/sample plot or 753 plants/ha (69%). In other words, the mean population plant survival is 8.842 plants/sample plot or 884 plants/ha (81%) with a margin of error ± 1.307 (12%).

Shah Bundar 2010:

The sample variance and standard deviation could be calculated using the following formula:

Sample Variance = Sum (Σ) of squared deviations from mean divided by degree of freedom, is given by:

$$S^2 = \frac{\sum(X - \bar{X})^2}{n - 1}$$

Where X is sample value, and \bar{x} is sample mean, n-1 is degree of freedom.

Sample variance (S^2) for living plants could be calculated as follows:

$$S^2 = \frac{186.462 \text{ (from Excel sheet)}}{25}$$

$$S^2 = 7.458$$

Sample Standard Deviation (S) is square root of variance. Therefore, sample standard deviation (S) for living plants would be:

$$S = \sqrt{7.458} = 2.731$$

$$\text{Standard Error} = \frac{\text{Standard Deviation}}{\sqrt{\text{Number in the Sample}}} = \frac{\text{Standard Deviation (S)}}{\sqrt{n}}$$

$$SE(\text{surviving plants}) = \frac{2.731}{\sqrt{26}}$$

$$SE = 0.535$$

The confidence interval for the population mean constructed at 0.05 significance level gives the following range of mean population survival:

$$\bar{x} \pm t_{\alpha/2} \frac{s}{\sqrt{n}}$$

$$t > \alpha/2, n-1 = t_{0.025, 25} = 2.060 \text{ (from t-table)}$$

Therefore:

$$8.462 \pm 2.060 \frac{2.731}{\sqrt{26}}$$

$$= 8.462 \pm 2.060 \times 0.535$$

$$= 8.462 \pm 1.1021$$

Hence, we are 95% confident that the mean population survival % (μ) in all transacts lies between 9.564 plants/sample plot or 956 plants/ha (88%) and 7.359 plants/sample plot or 736 plants/ha (67%). In other words, the mean population plant survival is 8.462 (78%) with a margin of error ± 1.04 (10%).

Shah Bundar 2009:

The sample variance and standard deviation could be calculated using the following formula:

Sample Variance = Sum (Σ) of squared deviations from mean divided by degree of freedom, is given by:

$$S^2 = \frac{\sum(X - \bar{X})^2}{n - 1}$$

Where X is sample value, and \bar{x} is sample mean, n-1 is degree of freedom.

Sample variance (S^2) for living plants could be calculated as follows:

$$S^2 = \frac{467.59 \text{ (from Excel sheet)}}{23}$$

$$S^2 = 20.330$$

Sample Standard Deviation (S) is square root of variance. Therefore, sample standard deviation (S) for living plants would be:

$$S = \sqrt{4.508} = 2.123$$

$$\text{Standard Error} = \frac{\text{Standard Deviation}}{\sqrt{\text{Number in the Sample}}} = \frac{\text{Standard Deviation (S)}}{\sqrt{n}}$$

$$SE(\text{surviving plants}) = \frac{2.123}{\sqrt{24}}$$

$$SE = 0.433$$

The confidence interval for the population mean constructed at 0.05 significance level gives the following range of mean population survival:

$$\bar{x} \pm t_{\alpha/2} \frac{s}{\sqrt{n}}$$

$$t_{\alpha/2, n-1} = t_{0.025, 23} = 2.060 \text{ (from t-table)}$$

$$\text{Therefore: } 6.375 \pm 2.069 \frac{2.123}{\sqrt{24}}$$

$$= 6.375 \pm 2.069 \times 0.433$$

$$= 6.375 \pm 0.896$$

Hence, we are 95% confident that the mean population survival % (μ) in all sample plots lies between 7.271/sample plot or 727 plants/ha (67%) and 5.479/sample plot or 548 plants/ha (50%). In other words, the mean population plant success is 6.375/sample plot or 637 plants/ha (58%), with a margin of error ± 0.896 (8%).

Keti Bundar 2011:

The sample variance and standard deviation could be calculated using the following formula:

Sample Variance = Sum (Σ) of squared deviations from mean divided by degree of freedom, is given by:

$$S^2 = \frac{\sum(X - \bar{X})^2}{n - 1}$$

Where X is sample value, and \bar{x} is sample mean, n-1 is degree of freedom.

Sample variance (S^2) for living plants could be calculated as follows:

$$S^2 = \frac{553.48 \text{ (from Excel sheet)}}{61}$$

$$S^2 = 9.074$$

Sample Standard Deviation (S) is square root of variance. Therefore, sample standard deviation (S) for living plants would be:

$$S = \sqrt{9.074} = 3.012$$

$$\text{Standard Error} = \frac{\text{Standard Deviation}}{\sqrt{\text{Number in the Sample}}}$$

$$\text{SE (surviving plants)} = \frac{3.012}{\sqrt{62}}$$

$$\text{SE} = 0.382$$

The confidence interval for the population mean constructed at 0.05 significance level gives the following range of mean population survival:

$$\bar{x} \pm t_{\alpha/2} \frac{s}{\sqrt{n}}$$

$t_{\alpha/2, n-1} = t_{0.025, 61} \approx t_{0.025, 60} = 2.000$ (from t-table)

$$\text{Therefore: } 9.484 \pm 2.000 \frac{3.012}{\sqrt{62}}$$

$$= 9.484 \pm 2.000 \times 0.382$$

$$= 9.484 \pm 0.764$$

Hence, we are 95% confident that the mean population survival % (μ) in all sample plots lies between 10.248 plants/sample plot or 1025 plants/ha (94%) and 8.72 plants/sample plot or 872 plants/ha (80%). In other words, the mean population plant survival is 9.484/sample plot or 948 plants/ha (87%) with a margin of error ± 0.764 (7%).

Keti Bundar 2010:

The sample variance and standard deviation could be calculated using the following formula:

Sample Variance = Sum (Σ) of squared deviations from mean divided by degree of freedom, is given by:

$$S^2 = \frac{\sum(X - \bar{X})^2}{n - 1}$$

Where X is sample value, and \bar{x} is sample mean, n-1 is degree of freedom.

Sample variance (S^2) for living plants could be calculated as follows:

$$S^2 = \frac{480 \text{ (from Excel sheet)}}{31}$$

$$S^2 = 15.484$$

Sample Standard Deviation (S) is square root of variance. Therefore, sample standard deviation (S) for living plants would be:

$$S = \sqrt{15.484} = 3.935$$

$$\text{Standard Error} = \frac{\text{Standard Deviation}}{\sqrt{\text{Number in the Sample}}}$$

$$\text{SE (surviving plants)} = \frac{3.935}{\sqrt{32}}$$

$$\text{SE} = 0.695$$

The confidence interval for the population mean constructed at 0.05 significance level gives the following range of mean population survival:

$$\bar{x} \pm t_{\alpha/2} \frac{s}{\sqrt{n}}$$

$$t > \alpha/2, n-1 = t_{0.025, 31} = t_{0.025, 30} = 1.697 \text{ (from t-table)}$$

$$\text{Therefore: } 7.750 \pm 1.697 \frac{3.935}{\sqrt{32}}$$

$$= 7.750 \pm 1.697 \times 0.695$$

$$= 7.750 \pm 1.180$$

Hence, we are 95% confident that the mean population survival % (μ) in all sample plots lies between 8.93 plants/sample plot or 893 plants/ha (82%) and 6.57 plants/sample plot or 657 plants/ha (60%). In other words, the mean population plant survival is 7.75 plants/sample plot or 775 plants/ha (71%) with a margin of error ± 1.180 (11%).

Keti Bundar 2009:

The sample variance and standard deviation could be calculated using the following formula:

Sample Variance = Sum (Σ) of squared deviations from mean divided by degree of freedom, is given by:

$$S^2 = \frac{\sum(X - \bar{X})^2}{n - 1}$$

Where X is sample value, and \bar{x} is sample mean, n-1 is degree of freedom.

Sample variance (S^2) for living plants could be calculated as follows:

$$S^2 = \frac{226.65 \text{ (from Excel sheet)}}{25}$$

$$S^2 = 9.066$$

Sample Standard Deviation (S) is square root of variance. Therefore, sample standard deviation (S) for living plants would be:

$$S = \sqrt{9.066} = 3.011$$

$$\text{Standard Error} = \frac{\text{Standard Deviation}}{\sqrt{\text{Number in the Sample}}}$$

$$\text{SE (surviving plants)} = \frac{3.011}{\sqrt{26}}$$

$$\text{SE} = 0.590$$

The confidence interval for the population mean constructed at 0.05 significance level gives the following range of mean population survival:

$$\bar{x} \pm t_{\alpha/2} \frac{s}{\sqrt{n}}$$

$$t > \alpha/2, n-1 = t_{0.025, 25} = 2.060 \text{ (from t-table)}$$

$$\text{Therefore: } 7.885 \pm 2.060 \frac{3.011}{\sqrt{26}}$$

$$= 7.885 \pm 2.060 \times 0.590$$

$$= 7.885 \pm 1.215$$

Hence, we are 95% confident that the mean population survival % (μ) in all sample plots lies between 9.10 plants/sample plot or 910 plants/ha (83%) and 6.670 plants/sample plot or 667 plants/ha (61%). In other words, the mean population plant survival is 7.885/sample plot or 788 plants/ha (72%) with a margin of error ± 1.215 (11%).