American Journal of Agricultural and Biological Sciences 3 (3): 610-616, 2008
ISSN 1557-4989

Pattern of Survival and Mortality of Mangrove Populations Grown at Al-Jubail Area (Saudi Arabia) of the Arabian Gulf

[1]Akram Ali, [1]Ahmed Alfarhan, [2]Ernest Robinson and [3]Ibrahim Aldjain
[1]Department of Botany and Microbiology,
College of Science, King Saud University, Riyadh 11451, P.O. Box: 2455, KSA
[2]King Khalid Wildlife Research Centre, Thumamah,
C/o. National Commission for Wildlife Conservation and Development,
P.O. Box: 61681, Riyadh 11575, KSA
[3]Department of Gardens and landscape,
Riyadh Municipality, P.O. Box: 156444 Riyadh 11778, KSA

Abstract: The life table and fecundity schedule were produced for [*Avicennia marina* (Forsk.) Vierh] populations of four habitat types at Al-Jubail area, KSA. These types are sand mounds, salt flats, shoreline and intertidal sites. Survivorship (l_x) was least in sand mounds and similar in all other sites. Age-specific-mortality rates (q_x) where parallel in the flower bud, flower, fruiting and seedling stages in all sites, while demonstrated site-specific variations in adult stages with highest values in the shoreline and salt flat sites. The killing power (k_x) values were parallel in all sites except for the sand mounds. The expectations of future life (e_x) were variable at different age classes and sites with highest values attained in the intertidal and shoreline sites. Plants in the sand mounds and salt flats showed lower expectations for future life than in the other habitats. The reproductive values were close to zero in all age classes of the salt flats site. The net reproduction rate (R_0) ranged from 0.023 to 0.4 with negative or close to zero intrinsic rate of increase per capita (r). The generation time (T) ranged from 25.6 years in the sand flats to 53.75 years in the sand mounds. This study supported that the conservation of *Avicennia marina* may allow for continued dynamic adaptation to different habitat types in the Arabian Gulf coast.

Key words: Mangrove habitats, growth stages, life rate, killing rate

INTRODUCTION

The mangrove forests of the Red sea coast grow on soft-bottom and hard-bottomed substrates. Mangrove trees may reach 5-7 m height in the southern Red Sea, where the continental shelf is wider and the intertidal slopes more gradual, allowing development of better sedimentary conditions. Establishment of mangrove species depends on seedling recruitment during regeneration[17]. Therefore, survival of seedlings directly affects species distribution and abundance[9]. Seedling establishment is a critical phase in the life cycle of all seed plants, but it is particularly crucial for mangroves forests due to the unstable substrates and the influence of tidal inundation within the mangrove[5,17]. The processes before and after the establishment of mangrove plants, such as flowering, fruiting, dispersal, predation, competition and other factors may influence the initial pattern of distribution and abundance across intertidal forest zone[9,10, 16].

Individual performance of plant populations can be characterized in terms of age classes, life-history stages or some closely related proxy variables (i.e., size), such an approach is easily generalizable to many different populations of different demographic classes[7]. Life table and fecundity schedule analysis are more phonological than process oriented[3] because at some spatial scale, environments are comprised of habitats of different quality that exert significant influence on the individual performance[11].

In KSA (Asia), no previous studies explicitly compared the dynamics of an age-with site variations of *Avicennia marina* populations. Field observations showed that *Avicennia marina* in Gulf of Aquaba, occuping different habitat types survive and reproduce at different rates among the different age classes. Survival and dynamics of mangrove plants have been examined in gaps and undestroyed habitats[2,4,7,9,11,14,17]. Studies by Osunkoya and Creese[11] revealed that

Corresponding Author: Akram Ali, Department of Botany, Faculty of Science, Zagazig University, Zagazig, Egypt
Tel: 00966557554020 Fax: 0096614675833

survival and growth of *Avicennia marina* seedlings was greater in gaps than under closed canopy, irrespective of tidal position. Smith[16] found that survival of several mangrove seedlings including *Avicennia marina* was higher in gaps than under the forest canopy. For *Avicennia marina* in Gulf of Aqaba the population dynamics in different habitat types is crucial to understanding the apecies performing in its most northern limit in Egypt (Africa).

The main objective of this study is to analyze the life table and fecundity schedule of A. marina growing naturally in different habitat types in the coastal area of the Arabian Gulf, an important asset to understanding the site and age-dependent performance.

MATERIAL AND METHODS

Study area: The Arabian Gulf region extends from Shatt Al-Arab and the coastal lowlands in the north to the Strait of Hormus and the high mountains of Oman in the south. It is a semi enclosed shallow continental water body measuring 1000 km in the length and varying in width from a maximum of 340 to a minimum of 60 kms. The average depth is about 35 m and maximum is 100 m. The Gulf is subjected to wide climatic fluctuations, with surface water temperatures generally ranging from 12°C in winter to > 35°C in summer and salinity from 28 to 60 ppt. The Gulf is home to one of the world's largest dugong populations, found off the coasts of Saudi Arabia.

Al-Jubail area is part of the coast of Saudi Arabia in the Arabian Gulf. It encompasses extensive mangroves, mudflats, and a diverse array of benthic habitats including reefs and sea grasses. There are reefs which mostly appear as small pinnacles or outcrops, and as patch reefs between Ras Almishab Saffaniyah and Abu Ali, and between Abu Ali and Ras Tanura. These reefs support coral growth at their extreme northern distribution, which are remarkable as they withstand the major shifts in temperature and salinity occurring in the Gulf. The area is also, an important avifaunal wintering site and migratory pathway, with extensive shallow water bodies.

Demography and phenology: Individual plants were located, mapped and censuses at intervals in four quadrates (10×10 m) pre site for two years (2006-2007). The age of juvenile and adult individuals was determined according to number of branches into five age classes: seedling and adult plants with age 1-15, 15-25, 25-50 and 50-75 years. A conventional cohort life table was constructed based on sexual reproduction. The life table summarizes the probability of survival of different stages (flower, fruit, seed, seedling, juvenile, and adult plants). Fecundity schedules were constructed based on average seed production.

Life table and fecundity schedule: A time-specific life table was calculated based on survival data obtained from the different cohorts of *Avicennia marina*. It was assumed that the investigated population was in a stable demographic stage with constant input and stable age distribution, i.e., the year-to-year variation in the population averages out by dealing with different stages recruited from flower bud to adults of different age classes. Having made this assumption, the life table and fecundity schedule were constructed following Pastor[12].

The first column of the life table sets out the various stages (cohorts) of the life cycle that have been distinguished. The second and third columns list the estimated age in years (x) and its corresponding numbers per cohort (N_x). The data have been standardized in the fourth column. Starting with a value of 1.0, the proportion of original cohort surviving to the start of each stage (L_x) was obtained as:

$$L_X = \frac{N_X}{N_0}.1 \quad (1)$$

The proportion of original cohort dying during each age (d_x) was calculated as:

$$d_x = l_x - l_{x+1} \quad (2)$$

Then the stage-specific mortality rate (q_x) was calculated as:

$$q_x = d_x / l_x = 1 - \frac{l_{x+1}}{l_x} \quad (3)$$

The rate or intensity of mortality during any cohort, which reflects the killing-power (k_x) was computed from the N_x values as:

$$k_x = \log_{10} N_x - \log_{10} N_{x+1} \quad (4)$$

Like the L_xs the k_xs are standardized, but unlike the q_xs summing k_xs is a legitimate procedure[1].

The expectation of future life (e_x) in age units was estimated as:

$$e_x = \sum_0^n l_x / l_0 \quad (5)$$

A fecundity schedule was constructed from the seed output. The number of seeds per individual plant per cohort and, accordingly, the percentage contribution of each cohort to the total population seed output was estimated. If b_x is the average number of seeds per individual per cohort, the net reproductive rate (R_o) was given by:

$$R_0 = \sum l_x b_x \quad (6)$$

The reproductive value (V_x) or the average contribution of future generation was given by:

$$V_x = \sum_{t=x}^{\infty} \frac{l_t}{l_x} . b_t \quad (7)$$

The term L_t/L_x represents the probability of living from age x to age t and b_t is the average reproductive success of an individual at age t.

The generation time (T) was estimated as:

$$T = \frac{\sum x l_x b_x}{\sum l_x b_x} \quad (8)$$

The intrinsic rate of increase (r) was calculated as the natural logarithm of net reproductive rate divided by the generation time:

$$r = \frac{\ln R_0}{T} \quad (9)$$

RESULTS AND DISCUSSION

The survival curve (L_x) of *Avicennia marina* showed a gradual decline in survival from flower bud stage to fruiting stage, i.e., the age of 0.083-0.416 year old stages of the life table, then sharp decline in seedling stages, i.e., of age 0.5 year old in all locations (Table 1-4). This is followed by a plateau of low values in juvenile and adult stages, i.e. from 0.5 to 75 year old plants in all locations except for the salt flats where plants attained at maximum 75 years old (Table 1-4). For sand mound habitat, individuals from seedling stage to adults of age 15 years old were not represented in the population (Table 1).

The values of the age-specific mortality rate (q_x) increased from below 0.5 until reached the value of one in the flower and fruit stages (Table 1-4). The (q_x) value fluctuated between increase and decrease in the seedling and adult stages in all sites (Table 1-4). The values in juvenile and adult stages showed high level at shoreline sites where it reach maximum of 2.083 at 25 years old individuals and value of one in 50 years old individuals in salt flats site (Table 2). For sand mounds values reaches zero at seedling and adult stages (Table 1) and at 15 and 50 years old stages in the intertidal site (Table 4).

The killing power (k_x) showed sharp increase during the fruiting stage in all sites except in Sand mounds (Table 1), where values slightly increased in the flowering stage then decreased to zero in the remaining stages (Table 1-4). The remaining sites showed sharply decrease from fruiting to seedling stages followed by irregular gradual cycles of decrease and increase until age 75 years old (Table 2-4). The maximum values of killing power (5.27) were attained in the fruiting stage especially in the intertidal site (Table 4).

Table 1: Life table and fecundity schedule calculated for [*Avicennia marina* (Forsk.) Vierh] population growing naturally in sand mounds at Al-Jubail area, KSA

Stages	X	N_x	L_x	d_x	$\log_{10} N_x$	q_x	K_x	e_x	b_x	$l_x b_x$	$x l_x b_x$	V_x
Flower bud	0.4160	8717994	1	0.279616	6.94	0.279	0.15	1.76	-	-	-	-
Flower	0.5000	6280303	0.72038400	0.678629	6.79	0.942	1.23	1.06	-	-	-	-
Fruit	0.0830	364020	0.04175500	0.041748	5.56	0.999	3.80	1.00	-	-	-	-
Seedling	0.2500	58	0.00000660	0.00000620	1.76	0.939	1.29	1.11	-	-	-	-
Age class												
(1)	15.000	3	0.00000034	0.00000011	0.47	0.323	0.17	2.32	21300	0.0072	0.108	89049
(2)	25.000	2	0.00000023	0.00000012	0.30	0.522	0.30	1.95	35260	0.0081	0.202	100152
(3)	50.000	1	0.00000011	-	0.00	-	-	2.00	64180	0.007	0.35	132685
(4)	75.000	1	0.00000011	-	0.00	-	-	-	71505	0.0079	0.592	71505
										∑0.030	∑1.252	

$R_0 = 0.04$, $T = 37.75$, $r = -0.085$

X = Estimated age in years, N_x = Number per stage, L_x = Proportion of original cohort surviving to start of each stage, d_x = Proportion of original cohort dying during each stage, q_x = Stage-specific mortality rate, K_x = Killing power, e_x = Expectation of future life, b_x = Average number of seeds per individual, V_x = Reproductive rate, R_0 = Net reproductive rate, T = Generation time, and r = Intrinsic rate of increase

Table 2: Life table and fecundity schedule calculated for [*Avicennia marina* (Forsk.) Vierh] population growing naturally in salt flat at Al-Jubail area, KSA

Stages	X	N_x	L_x	d_x	$\log_{10} N_x$	q_x	K_x	e_x	b_x	$l_x b_x$	$x l_x b_x$	V_x
Flower bud	0.4160	2787316	1	0.54772600	6.44	0.547	0.34	1.49	-	-	-	-
Flower	0.5000	1260630	0.4522740000	0.41268500	6.10	0.912	1.06	1.09	-	-	-	-
Fruit	0.0830	110348	0.0395890000	0.03958400	5.04	0.999	3.9	1.00	-	-	-	-
Seedling	0.2500	14	0.0000050000	0.00000070	1.14	0.14	0.06	2.62	-	-	-	-
Age class												
(1)	15.000	12	0.0000004300	0.00000150	1.08	0.349	0.18	1.88	1520	0.0065	0.097	5489
(2)	25.000	8	0.0000002800	0.00000180	0.90	0.643	0.42	1.36	5115	0.0143	0.357	6097
(3)	50.000	3	0.0000010000	0.00000100	0.48	1.000	0.00	1.00	2750	0.0027	0.135	2750
(4)	75.000	-	0.0000000001	-	-	-	-	-	-	-	-	-
										∑0.023	∑0.589	

$R_0 = 0.023$, $T = 25.6$, $r = -0.147$

Table 3: Life table and fecundity schedule calculated for [*Avicennia marina* (Forsk.) Vierh] population growing naturally in shoreline at Al-Jubail area, KSA

Stages	X	N_x	L_x	d_x	$\log_{10} N_x$	q_x	K_x	e_x	b_x	$l_x b_x$	$x l_x b_x$	V_x
Flower bud	0.4160	8010413	1	0.47549500	6.90	0.475	0.28	1.56	-	-	-	-
Flower	0.5000	4201508	0.5245050	0.49076800	6.62	0.935	1.19	1.06	-	-	-	-
Fruit	0.0830	270253	0.0337370	0.03373500	5.43	0.999	4.25	1.00	-	-	-	-
Seedling	0.2500	15	0.0000018	0.00000014	1.17	0.077	0.69	1.62	-	-	-	-
Age class												
(1)	15.000	3	0.00000037	0.00000025	0.47	0.675	0.47	3.00	16120	0.0059	0.0885	74972
(2)	25.000	1	0.00000012	0.00000025	0.00	2.083	0.00	6.17	32050	0.0038	0.095	181464
(3)	50.000	3	0.00000037	0.00000012	0.47	0.324	0.17	1.67	30175	0.0112	0.56	48458
(4)	75.000	2	0.00000025	-	0.30	-	-	-	27060	0.0067	0.502	27060
										∑0.027	∑1.245	

$R_0 = 0.027$, $T = 46.11$, $r = -0.078$

Table 4: Life table and fecundity schedule calculated for [*Avicennia marina* (Forsk.) Vierh] population growing naturally in intertidal site at Al-Jubail area, KSA.

Stages	X	N_x	L_x	d_x	$\log_{10} N_x$	q_x	K_x	e_x	b_x	$l_x b_x$	$x l_x b_x$	V_x
Flower bud	0.4160	11601445	1	0.26800900	7.06	0.268	0.13	1.8	-	-	-	-
Flower	0.5000	8492157	0.731991	0.65137900	6.93	0.889	0.96	1.1	-	-	-	-
Fruit	0.0830	935220	0.080612	0.08061100	5.97	0.999	5.27	1.0	-	-	-	-
Seedling	0.2500	5	0.00000043	0.00000026	0.69	0.604	0.39	3.3	-	-	-	-
Age class												
(1)	15.000	2	0.00000017	0.00000017	0.30	0.000	0.00	6.0	35110	0.0059	0.0885	132965
(2)	25.000	4	0.00000034	0.00000017	0.60	0.500	0.30	2.5	60315	0.0205	0.512	124737
(3)	50.000	2	0.00000017	0.00000017	0.30	0.000	0.00	3.0	41605	0.0071	0.355	52510
(4)	75.000	4	0.00000034	-	0.60	-	-	-	21810	0.0074	0.555	21810
										∑0.040	∑1.51	

$R_0 = 0.04$, $T = 37.75$, $r = -0.085$

The mean expectation of future life (e_x) for the different cohorts showed slight decrease from flower bud stage until reached the value of one at fruiting stage in all sites (Table 1-4), the maximum values of 6 and 6.17 were attained by 15 years old individuals in the intertidal site (Table 4) and 25 years old individuals in the shoreline (Table 3). At salt flats, the values slightly increased in seedling stage then gradually decreased towards 75 years old individuals (Table 2). In the sand mounds individuals of 25 years old age the e_x value decreased from 3.03 to 1.21 at age of 50 years old (Table 1).

The reproductive rate ($I_x b_x$) showed high values in 25 years old individuals of salt flats and intertidal sites (Table 2 and 4) and 75 years old individuals for sand mounds (Table 1). In the salt flats, 50 years old plants attained its highest reproductive rate (Table 2). Table 1-4 show that $I_x b_x$ of *Avicennia marina* in the shoreline, intertidal, while salt flats and sand mounds attained the lowest values. The maximum reproductive value attained by 25 years old individuals reached 181464 in the shoreline site and 56370 in the sand mounds (Table 3 and 1). In intertidal site 15 years old individuals attained the highest value (Table 4). The reproductive values (v_x) in the salt flats were nearly similar in all ages and relatively low, but it ranged from 2750 to 5498 (Table 2).

The net reproductive rate (R_0) in different sites ranged from 0.023 to 0.4 indicating slight seed production over generations (Table 1-4). The intrinsic rate of increase per capita per year was negative or close to zero value and amounted from -2.8 to -0.085. The generation time (T) gives the highest estimation of 53.75 years at the sand mounds while the lowest value was 25.6 years for the salt flats (Table 1 and 2).

This current population analysis homogenizes plant demography across different habitat types, an approach that is prove to give some representation of population dynamics in heterogeneous habitats. The survival curves exhibit a combination of type I, II and III curves[4]. The high mortality of seed and seedlings coincides with the type III curve. The values of the age-specific mortality rates fluctuated between increase and decrease in the seedling and adult stages in different habitat types. The values in juvenile and adult stages showed high level at the shoreline site where it reach maximum of 2.083 at 25 years old individuals and value of one in 50 years old individuals in salt flat habitat.

The age-specific survival curve exhibits high mortality of flowers, seeds and seedlings. This is followed by low mortality of juvenile and adults. The average mortality rate per year (q_x) and killing power (k_x) increases steadily to the germinable seed and seedling stages, then fall towards juvenile stage. This reflects the fact that early reproductive stages starting from flower bud to seedlings are at mortality risk relative to juvenile and adult individuals. According to Harper and White[9], this survival pattern as stage follows stage means that selectional forces in the habitat are acting on the weakest stages of the life cycle. As for *Avicennia marina*, from the age of 0.083-0.416 year old stages gradually decline in survival from flower bud to fruits and of age 0.5 year old in all locations sharp decline in seedling stages, meanwhile, mortality rate and killing power are increasing, and mean expectation of future life falls to its minimum.

The high mortality rate of reproductive organs (flowers and fruits) and seedlings in sand dune and salt flat habitats decreases the possibility of population existence in the future. Alternatively, successful regeneration in the other habitats ensures population existence, recovery and demographic diversity that cover different age classes. This variation among populations seems to occur in response to combination of factors related to population age-structure (demographic events) and habitat suitability[6]. As pointed out by Bowers[3], populations may attempt to widen the range of their fitness in a heterogeneous environment through selection of different habitat types, and that selection has site-dependant demographic and dynamic consequences.

The estimation of mean expectation of future life (e_x) for the various cohorts surviving to successive years showed that it was slight decrease from flower bud stage until reached the value of one at fruiting stage in all sites, the maximum values of 6 and 6.17 were attained by 15 years old individuals in the intertidal site and 25 years old individuals in the shore line. This is due to the high losses during seed, seedling and juvenile stages. The combination of low expectation of future life (e_x), low reproductive value (v_x) of old individuals, and negative intrinsic rate of increase (r) per annum indicates that the major contribution to the population is made by adults within the age range of about 7-20 years. Similar results were obtained on other polycarpic species in the sequence of plant's life stages[5,15]. The reason for the high expectation of life of *Avicennia marina* in the flower bud stage is not easy to elucidate, but it may relate to the relatively low mortality rate (q_x) and killing power (k_x).

The reproductive value (v_x) in the salt flat habitat was nearly close in all ages and was relatively low, where it ranged from 2750 to 5498. The maximum reproductive value attained by 25 years old individuals reaches 181464 in the shoreline site and 56370 in the sand mounds. In intertidal site, the 15 years old individuals attained the highest value. The net reproductive rate (R_0) in different sites ranged from 0.023 to 0.4 indicating slight increase in seed production over generations. The intrinsic rate of increase per capita per year was negative and amounted from -2.8 to -0.085. The R_0 of the whole population describes its growth potential. This means failure of the population to attain 'positive' growth, indicating a future decrease in adult population size that survived to the stage of seed production. An interesting aspect of reproductive value (v_x) is that, although the population has maintained relatively high values, it exhibited a 'negative' intrinsic rate of increase. This indicates that high fecundity of adult individuals does not ensure the maintenance of the population. This behavior has been proved true for other plant species[2].

Variation in population demography and reproductive ecology is largely inseparable from variation in habitat types. A central premise is that *Avicennia marina* occupying habitats of different quality and survives and reproduces at various rates. Performance of populations demonstrated high mortality and low reproductive values in sand mound and salt flat habitats. The survivorship and fecundity varied among different age classes of the adult individuals. The preferred habitats are the intertidal and shoreline sites.

As demonstrated by Pulliam and Danielson[13], the quality of one habitat type to produce and the other to absorb new individual is crucial to understanding population dynamics. For *Avicennia marina*, since population dynamics varies according to age, habitat and age by habitat interaction, one may point out: (1) juvenile and adult individuals have the potential of occupying habitats of different quality, and (2) the differential occupancy of habitats by individuals within a population creates a spatial and temporal variation over which demographic rates vary widely[8].

CONCLUSION

This present study has demonstrated that reproductive behavior of *Avicennia marina* is in the Arabian Gulf west coast likely to be important in determining its ability to survival in different habitats. Treatment of population dynamics in different habitats may assume that the dynamics are partially determined by fecundity and survivorship. This reflects the situation of *Avicennia marina* and the spatial heterogeneity in population demography.

ACKNOWLEDGEMENT

This study is part of the research activities of the Center of Excellence of Biodiversity Research program, developed and funded by the Ministry of Higher Education, KSA. Thanks are expressed to Center of Excellence and anonymous referees for their constructive comments on the first draft of this study.

REFERENCES

1. Begon, M., M. Mortimer and D. Thompson, 1996. Population ecology: A Unified study of animals and plants. 3rd Edn. Wiley-Blackwell Publishing. ISBN:978-0-632-03478-9 http://eu.wiley.com/WileyCDA/WileyTitle/productCd-0632034785.htm
2. Blasco, F., P. Saenger and E. Janodet, 1996. Mangroves as indicators of coastal change. Catena, 27(3-4): 167-178. DOI: 10.1016/0341-8162(96)00013-6 http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6VCG-3WDC4XS-2&_user=10&_rdoc=1&_fmt=&_orig=search&_sort=d&view=c&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=bb7fb27b36354b36932b49f76d0a57c8
3. Bowers, M.A., 1994. Dynamics of age-and habitat-structured populations. OIKOS, 69: 327-333. http://www.jstor.org/pss/3546154
4. Clarke, P.J. and W.G. Allaway, 1993. The regeneration niche of the grey mangrove (*Avicennia marina*): Effect of salinity, light and sediments factors on establishment, growth and survival in the field. Oecologia, 93: 548-556. DOI: 10.1007/BF00328964 http://www.springerlink.com/content/mxm083482m751600/
5. Deevey, E.S., 1947. Life tables for natural populations of animals. Q. Rev. Biol., 22: 283-314. http://links.jstor.org/sici?sici=0033-5770%28194712%2922%3A4%3C283%3ALTFNPO%3E2.0.CO%3B2-S
6. Doyle, R.W., 1975. Settlement of phytoplankton: A theory of habitat selection in varying environments**.** Am Nat., 109(966): 113-118. DOI: 10.1086/282980 http://www.journals.uchicago.edu/doi/abs/10.1086/282980
7. Ellison, A.M. and E.J. Farnsworth, 1993. Seedling survivorship, growth and response to disturbance in Belizean Mangal. Am. J. Bot., 80 (10): 1137-1145. http://cat.inist.fr/?aModele=afficheN&cpsidt=3931914
8. Feller, I. C. and K. L. McKee, 1999. Small Gap Creation in Belizean Mangrove Forests by a Wood-Boring Insect. Biotropica, 31(4): 607-617. http://www.jstor.org/pss/2663901
9. Harper, J.L. and J. White, 1974. The demography of plants. Annu. Rev. Ecol. Syst., 5: 419-463. DOI:10.1146/annurev.es.05.110174.002223 http://arjournals.annualreviews.org/ DOI: /abs/10.1146/annurev.es.05.110174.002223
10. McGuinness, K.A., 1996. Dispersal, establishment and survival of *ceriops tagal* propagules in a north Australia mangrove forest. Oecologia, 109(1): 80-87. DOI: 10.1007/s004420050061 http://www.springerlink.com/content/tbb7m1xf0xmbty1d/
11. Osunkoya, O.O. and R.G. Creese, 1997. Population structure, spatial pattern and seedling establishment of the grey mangrove, *Avicennia marina* var. Australasica, in New Zealand. Aust. J. Bot., 45(4): 707-725. DOI:10.1071/BT96070 http://www.publish.csiro.au/paper/BT96070.htm
12. Pastor, J., 2008. Mathematical ecology of populations and ecosystems. Wiley-Blackwell Publishing. ISBN:978-1-4051-8811-1 http://eu.wiley.com/WileyCDA/WileyTitle/productCd-1405188111.htm

13. Pulliam, H.R. and B.J. Danielson, 1991. Sources, sinks and habitat selection: A landscape perspective on population dynamics. Am. Nat., 137: 550-566.
DOI: 10.1086/285139
http://www.journals.uchicago.edu/doi/abs/10.1086/285139
14. Sherman, R. E., T. J. Fahey and J. J. Battles, 1999. Small-scale disturbance and regeneration dynamics in a neotropical mangrove forest. Journal of Ecology, 88(1): 165-178.
DOI:10.1046/j.1365-2745.2000.00439.x
http://www3.interscience.wiley.com/journal/119035870/abstract?CRETRY=1&SRETRY=0
15. Silvertown, J.W., 1987. Introduction to plant population ecology. Essex, England, Longman Scientific & Technical.
ISBN number:6AB1-048-7-0507.
http://www.antiqbook.com/boox/masstr/6AB1-048-7-0507.shtml.
16. Smith, T.J. III, 1987. Seed predation in relation to tree dominance and distribution in mangrove forest. Ecology, 68(2): 266-273.
Serial ID – ISSN: 0012-9658
http://www.fao.org/agris/search/display.do?f=./1987/v1313/US8726074.xml;US8726074
17. Tomlinson, P.B., 1995.The Botany of Mangroves. Cambridge, United Kingdom Cambridge University Press.
ISBN Number: 052146675x / 9780521466752
http://www.ffbooks.net/?page=shop/flypage&product_id=9513&CLSN_616=1216220805616f22e239a3e4447b1853