Parameters for Coconut Rhinoceros Beetle Modeling

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Abstract

This document represents an attempt to extract parameters for modeling coconut rhinoceros beetle (CRB) population dynamics from the literature. A couple of review articles provided a good starting point: Bedford 1980 and Pallipparambil 2015. The only published journal article on modeling CRB population dynamics, Hochberg and Waage 1991, was also a useful reference.

1 Parameters used in the Hochberg and Waage model

Table from Hochberg and Waage 1991:

TABLE 1. Biological interpretations, numerical values, sensitivities, and sources of the parameters used in the simulation model†

	Biological Interpretation	Value	Units	Sen‡	Ref¶§
a	Eggs laid per healthy breeder	5·60	10 days^{-1}	***	a,d
b	Eggs laid per infected breeder	0·64	10 days^{-1}	*	b
c_j	Development: juveniles	0·0595	10 days^{-1}	***	c
c_f	Development: feeders	0·0649	10 days^{-1}	**	d
c_b	Development: breeders	0·187	10 days^{-1}	**	d
m_j	DI mortality: juveniles	0·0474	10 days^{-1}	*	c
m_f	DI mortality: feeders	0·0152	10 days^{-1}	*	e
m_b	DI mortality: breeders	0·0152	10 days^{-1}	*	e
α_j	Virus mortality: juveniles	0·556	10 days^{-1}	*	f
α_f	Virus mortality: feeders	0·260	10 days^{-1}	**	b
α_b	Virus mortality: breeders	0·260	10 days^{-1}	*	b
β_{bj}	Trans: breeders ⇒ juveniles	0·0869	i^{-1} 10 days^{-1}	*	g
β_{jj}	Trans: juveniles ⇒ juveniles	0·0019	i^{-1} 10 days^{-1}	*	g
β_{ff}	Trans: feeders ⇒ feeders	0·1501	i^{-1} 10 days^{-1}	***	g
β_{bf}	Trans: breeders ⇒ feeders	0·0330	i^{-1} 10 days^{-1}	*	g
β_{fb}	Trans: feeders ⇒ breeders	0·0070	i^{-1} 10 days^{-1}	*	g
β_{jb}	Trans: juveniles ⇒ breeders	0·0024	i^{-1} 10 days^{-1}	*	g
ν	DD mortality: juveniles	0·005	j^{-1} 10 days^{-1}	***	g

† Abbreviations: DI=density-independent; DD=density-dependent; Trans=transmission; i=infected donor; j=juvenile competitor.

‡ Sensitivity, or relative importance in the accuracy of parameter estimation according to sensitivity analysis: *** very important; ** important; * unimportant. Underline indicates that parameter estimates are based on least squares estimation (see text for explanation).

§ References: (a) Hurpin & Fresneau 1973; (b) Zelazny 1973a; (c) Zelazny & Alfiler 1986; (d) Zelazny & Lolong 1988; (e) Zelazny 1977; (f) Zelazny 1972; (g) see text for estimation procedure.

2 Life cycle

Table from Bedford 1980. Note that the column for CRB, *Oryctes rhinoceros*, was compiled using data from 4 sources:

Table 1 Duration in days of immature stages of some palm rhinoceros beetles

Stage	*Oryctes rhinoceros*	*Oryctes boas*	*Oryctes monoceros*	*Oryctes elegans*	*Scapanes australis*	*Strategus aloeus*
	(13, 20, 62, 80)	(75)	(82)	(81) mean	(13)	(84)
Egg	8–12	7	14	10	32	21
First instar larva	10–21	10	13	14	35	14
Second instar larva	12–21	14	12	21	45	21
Third instar larva	60–165	70	56	56	190	210
Prepupa	8–13	8	9	10	21	14
Pupa	17–28	15	17	14	45	42

3 Life table data

"A lab study by Indiravathi (2001) reported that approximately 63% of eggs and 87% of larvae successfully developed into adults." [Pallipparambil 2015]

"Small improvements in the average survival of larvae would explain the post-typhoon increases in Rhinoceros Beetle populations so often observed on Pacific islands. Assuming survival from oviposition to adult emergence is near 2 percent in a stable pop- ulation: a posttyphoon generation might increase 2.5 times with an average 5 percent survival in the numerous palm logs felled by the storm. A population decline would be expected only when preadult mortality exceeds 98 percent." [Hinckley 1973]

4 Life span and generation time

"The total life span in Palau may range from 150 to about 270 days, and I assume the average under normal conditions to be about 200 days. The pre-incubation period is about 12 to 20 days. The period from the of an egg to first egg of the next generation may be as little as 115 days. Thus, given favorable conditions, more than 3 generations my develop in one year." [Gressitt 1953]

"Unfavorable environmental conditions reduces larval size and prolongs development up to 420 d (Catley, 1969)." [Pallipparambil 2015]

5 Larval food conversion

"The minimum volumes per grub were 400 cc in a coconut log; 5000 cc in a kapok log; 7000 cc in a breadfruit log; 7000 cc in sawdust; and 9000 cc in grass compost." [Hinckley 1973]

6 Fecundity

"A female lays 70 to more than 100 eggs in its lifetime. Taking 90 as the average number of eggs laid by one female and assuming the sex ratio to be one female to one male, with an average life-cycle of 4 months to middle of egg-layng period for each female), the theoretical figure of 186,390 progeny per original female during one year (16,995,293,890 by the end of two years) is obtained." [Gressitt 1953]

"Both sexes mate several times and from studies of spermatophore residues in the bursa copulatrix of field collected females Hoyt (undated) estimated that there is a maximum of eight matings. However, field collected females have produced fertile eggs up to 130 days after being confined singly in cans of rotting sawdust which suggests that multiple matings are not essential. Egg production varies considerably depending on the longevity of the beetle and the suitability of the oviposition medium. Menon and Pandalai (1958) recorded up to 152 eggs per female although 90 - 100 would be more usual." [Catley 1969]

7 Sex ratio

"Of 282 specimens examined from Palau and Samoa, 142 were males and 140 were females. This suggests a ratio of 1.014 males to one female." [Gressitt 1953]

8 Flight distances

"The beetle is thought to prefer short flights, but is capable of long flights if local conditions are unfavorable (Catley, 1969). A lab study demonstrated that palm-fed tethered adult beetles had a flight potential of 2-3 h, covering the equivalent of 2-4 km (Hinckley, 1973). Reports of long distance flight by *O. rhinoceros* include adults flying toward light on a ship anchored 700 m from shore (Catley, 1969), marked adults recaptured at 900 m within 3d and approximately 1600 m within a month (Cumber, 1957). Kamarudin and Wahid (2004) used mark-release-recapture studies to determine the flight range of *O. rhinoceros* in oil palm replanting regions in Malaysia; their results suggested that the adults moved at the rate of 10-23 m/day and up to 1.3 km/week." [Pallipparambil 2015]

9 Number of adult feeding events (=attacks)

Vander Meer 1987 indicates that adult CRB feed 6 times between days 30 and 150 after eclosion from the pupa (see figure 4 in the article).

10 Probability of palm death from an attack

11 Detection level for economic damage

Hinckley 1973:

"The final goal should be a population reduction below the level at which economic damage[3] can be detected (Hinckley 1966).

[3]About 7.5 beetles/hectare (3/acre) on plantations in Western Samaoa."

12 Density of coconut palms on Guam

Estimated number of *Cocos nucifera* with DBH $>$ 5 inches growing on forested land on Guam (63,383 acres) is 1,162,494. [Donnegon et al. 2004]

This is 18.21 coconut palms per acre ($=$ 45.00 per ha).

13 References

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