Postdispersal seed predation by eastern turtle dove:  
An experimental study in an urban botanical garden

Motoharu OKAMOTO*

キジバトによる散布後種子食害
—都市緑地植物園における実験的研究—

岡本素治*

抄録：ヒヨドリ等により散布された種子や核のキジバトによる食害の程度を見積る実験を都市内に孤立した緑地である長居植物園で行った。実験は、①種子（核）にマークをつけて地面に固定し、食べられるまでの日数を観察する方法と、②ヒヨドリ等がよく訪れる木の下にシードトラップを設置し、その内容とその周囲の林床の種子（核）数を比較する方法で行った。マーキング法により、ホルトノキの核、エンジュの種子、クスノキの核は食べられないことが分かった。クスノキの核がよく食べられ、ナンキンハゼの種子は時に無視され、硫黄ノモチの核はあまり食べられなかった。クスノキとナンキンハゼに対する好みの差は、可食部と保護器官の比率の違いによるエネルギー獲得効率の差に由来すると思われる。ヒヨドリ等がよく訪れる木の下では、キジバトに集中して探索される傾向があるように思われたが、今回の実験では十分に証明はできなかった。シードトラップの内容とその周囲の林床の種子（核）の比較により、クスノキやホルトノキの核では、散布されたクスノキ核のほぼ100％がキジバトにより捕食されることが推定された。

Abstract: The intensity of postdispersal seed predation by eastern turtle dove (Streptopelia orientalis) was estimated in an urban botanical garden using two methods, i.e., marked-seeds experiments and comparison of seed trap contents with seeds in the litter around. The marked-seeds experiment revealed the specific preference by the turtle dove to seeds or putamina. It preferred Cinnamomum to Sapium and Ligustrum perhaps for efficiency of energy gain. It did not eat putamina of Elaeocarpus, seeds of Sophora and fruits of Cinnamomum. More intensive searching efforts may have been paid by the turtle dove around the fruiting trees that frugivorous birds frequently visited during the experiment. However, this was not finally cleared in this experiment. The comparison of seed trap contents with seeds/putamina in the litter around showed that nearly 100 percent Cinnamomum putamina defecated beneath the Cinnamomum and Elaeocarpus tree were eaten by eastern turtle dove.

Key Words: Frugivorous birds; granivorous birds; postdispersal seed predation; seed dispersal; seed trap; Streptopelia orientalis.

Postdispersal seed predation is one of the most important factors that thin and trim the primary seed shadow made by dispersal agents (Janzen, 1983; 1986). Predation intensity is to be different among sites, and density-dependent seed mortality would be expected. This is believed to be a main reason why escape from the parents should be favoured for seeds (Janzen, 1970; Connell, 1971), along with competition with the parent tree (Harper et al., 1970). Empirical studies, however, that indicate actual intensities of predation pressure are few

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Among bird fauna in Nagai Botanical Garden in winter, eastern turtle dove and feral pigeon eat seeds/putamina once dispersed by birds such as brown-eared bulbul or grey starling, thus act as postdispersal seed predators (Okamoto and Kitajima, 1992). In this study I intend to estimate the intensity of postdispersal predation mainly by eastern turtle dove through marked-seed experiments and comparison of seed trap contents with seeds/putamina in the litter around. A crude estimation of the predation intensity under the parent tree will be presented.

**Materials and Methods**

**Study site**

Experiments were carried out in Nagai Botanical Garden, an urban botanical garden situated in the southern part of Osaka City (Okamoto and Kitajima, 1992). Nine species of birds are observed as common or seasonally important frugivores. Among them, brown-eared bulbul (*Hypsipetes amaurotis*: Pycnonotidae), grey starling (*Sturnus cineraceus*: Sturnidae) and dusky thrush (*Turdus naumanni*: Muscicapidae) are dispersal agents for fleshy fruited plant species. Eastern turtle dove (*Streptopelia orientalis*: Columbidae) and feral pigeon (*Columba livia*: Columbidae) are granivorous ground feeders and act as predators on once dispersed seeds. Effects of mammals (except men) on seeds are almost negligible in the botanical garden (Okamoto and Kitajima, 1992).

**Experiments**

Seed traps, 50cm × 50cm × 14cm (depth), were set beneath a crown (ca. 100m²) of *Cinnamomum camphora* (L.) Presl (two traps) and a crown (ca. 100m²) of *Elaeocarpus sylvestris* (Lour.) Poir. var. *ellipticus* (Thunb.) Hara (three traps). They were set on Nov. 20, 1992, when the consumption by birds of these species had just begun, and the contents of seed traps were gathered with two to four days intervals.

To estimate the intensity of postdispersal seed predation, two experiments were planned. First, a marked-seed experiment was carried out; seeds/putamina of *Cinnamomum camphora*, *Sapium sebiferum* (L.) Roxb. (introduced from China, common in urban environment of SW Japan), *Sophora japonica* L. (introduced from China, commonly planted in Japan), *Elaeocarpus sylvestris* var. *ellipticus*, and fruits of *C. camphora* were placed on the ground of some different conditions; beneath trees of fruiting bird-dispersed species (parent species and others), beneath trees of other dispersal categories, and open place. Each seed or putamen was put on an edge of an inconspicuous thread with adhesive material, and the other edge of the thread was fixed on the ground with an inconspicuous mark. The marked-seeds were set on Dec. 9, 11, 1992 and checked every one to three days for about a half month. To check whether turtle doves eat putamina of *Ligustrum lucidum* Ait. (introduced from China, common in urban environment of SW Japan) or not, a marked-seed experiment was carried out in early March, 1993.

In every experiment seeds/putamina were set together with those of other species,
particularly with *Cinnamomum* putamina, within circles of one meter diameter. This method makes it possible to reveal to some extent that some seeds/putamina were not eaten despite doves had searched around them.

Seeds and putamina for marked-seeds experiment were collected directly from trees, not from bird's droppings. Preliminary experiments showed that eastern turtle dove and feral pigion eat seeds or putamina from bird's droppings.

At nearly the end of the fruiting season, for the second experiment, several quadrats (50cm×50cm) were set beneath the same tree as the seed traps were set, and all fruits, putamina and seeds in the litter were collected and counted. The comparison of seeds/putamina numbers in the seed traps with those in the litter around is expected to illustrate the intensity of postdispersal seed predation.

**Results and Discussion**

*Phenological sketch of fruits and birds of the season*

During the marked-seed experiment in December, the fruits of *Cinnamomum* and *Elaeocarpus* were eagerly consumed by brown-eared bulbuls. Many seeds/putamina of conspecific and/or other bird-dispersed fruits were found in the seed traps beneath these trees. Fruits of *Sophora* and *Ligustrum* were eaten eagerly in mid-January.

*Predation intensities—Marked-seeds experiment*

The results of the marked-seed experiments were shown in Figs. 1 and 2.

Eastern turtle doves were frequently seen around the experiment sites. Feral pigeons were usually seen at open habitats and never seen around the experiment sites at least at my examining time. They do not appear to search forest floors that are separated by thicket from open habitat. Eastern turtle doves thus were the most influential seed predators in this experiment. Some seeds or putamina set at open habitats may have been eaten by feral pigeons, though these open sites were surrounded by thickets.

Several feeding habits of eastern turtle doves were clarified by these experiments. They do not eat seeds (putamina) of *Sophora japonica* nor *Elaeocarpus sylvestris*. They eat putamina of *Cinnamomum camphora* eagerly, but they ignore fruits of this species. The disappearance of some marked fruits of *Cinnamomum* seems to be caused by dusky thrushes, which sometimes seek fruits on the ground. Feeding experiments with feral pigeons also showed that they never eat fruit flesh nor whole fruit of *Cinnamomum* (Okamoto, pers. obs.) They know the presence of a putamen in it, because they peck out and eat the putamen when they were fed with half-broken *Cinnamomum* fruits.

Eastern turtle doves ate putamina (or seeds) of *Cinnamomum, Sapium* and *Ligustrum*, but there was a tendency of preferences (Fig. 1). The first was much preferred than the latter two. Seeds of *Sapium sebiferum* with white waxy seed coat layer, predispersal condition, were eaten as eagerly as *Cinnamomum* putamina. This difference in bird's preference seems to be dependent upon the efficiency of energy gain per effort for digesting. Average dry weight of endocarp of a *Cinnamomum* putamen (N=20) is 0.044 gr and that of embryo is
0.076 gr. In *Sapium* (N=20), that of endocarp is 0.059 gr and that of endosperm plus embryo is 0.049 gr. The ratios of digestible part to the whole are 0.64 in *Cinnamomum* and 0.41 in *Sapium*. Average dry weight of the waxy layer of a *Sapium* seed is 0.044 gr, thus the ratio of digestible part (waxy layer + endosperm and embryo) is 0.59, near to that of *Cinnamomum*. All of these edible parts are lipid-rich in these species. Eastern turtle doves sometimes might have ignored scraped seeds of *Sapium* in the experiment, because these seeds were always set along with *Cinnamomum* putamina within one meter apart.

The putamina of *Elaeocarpus* seemed to be ignored because of their tough coats with woody fibrous endocarp. The seeds of *Sophora* might have been ignored for some other reasons, because their coats are not so tough as those of *Elaeocarpus*. A feral pigeon artificially fed a scraped seed of *Sophora* picked up, taste and ignored it. Some poisonous substances would be expected, or pigeons and doves do not prefer the tough layer of albumen in the seed of *Sophora*. It is notable that a considerable part of *Sophora* seeds dispersed were eaten by masked hawfinches in the late winter.

Differential searching efforts by turtle doves might have been paid for various ground habitats. To exclude the effects of factors other than habitat conditions of setting place I select only the experiments with *Cinnamomum* putamina in December for analysis (Fig. 2).

In these days fruits of *Cinnamomum* and *Elaeocarpus* were eagerly consumed by brown-eared bulbuls. Fruit consumption of *Sophora* was mainly in mid-January and just fragmental during this experiment. Eastern turtle doves appeared usually to search forest floors in flocks of five to ten birds, and to be seen frequently beneath *Cinnamomum* trees.

![Figure 1](image-url)  
Fig. 1. Postdispersal seed predation mainly by turtle doves. Bar indicates days to disappearance for each marked-seed/putamen set at various environments. Possible maximum number of days, viz. postulated that disappearance occurs just before examining time, are shown for each seed/putamen, except those remained until the end of each experiment (15 days). A, putamen of *Cinnamomum camphora*; B, fruit of *C. camphora*; C, dispersed seed of *Sapium sebiferum*; D, pre-dispersed seed of *S. sebiferum*; E, putamen of *Elaeocarpus sylvestris* var. *ellipticus*; F, putamen of *Ligustrum lucidum*; G, seed of *Sophora japonica*. 
Most putamina of *Cinnamomum* set on Dec. 9 beneath a *Cinnamomum* and an *Elaeocarpus* tree, both of which were frequently visited bird-dispersed trees were eaten within two days. On the other hand, those set beneath trees that frugivorous birds did not frequently visit at the time of experiment and those set at open place seem to have received less severe searching. When the maximum number of days to disappear for each putamen are compared, *i.e.* postulate that putamina disappeared were eaten just before the time of examination, a significant difference (P < 0.05) is seen in Mann–Whitney's U-test, which is applied for the different checking intervals. However, these data remain still ambiguous.

All the putamina of *Cinnamomum* set beneath the *Cinnamomum* tree on Dec. 9 were eaten within three days, while those set beneath the same tree on Dec. 11 disappeared more slowly. Even when the possible maximum number of days are selected for the former experiment and the minimum for the latter, a significant difference (P < 0.01) are seen in Mann–Whitney's U-test. This suggests that more eastern turtle doves visited the *Cinnamomum* sites during Dec. 9 to 11 than the later days. Turtle doves might have searched this site in a large flock in those days, although some turtle doves visited the site in later days also. There is no significant difference in U-test (P > 0.1) between the experiments set on Dec. 11 beneath the *Cinnamomum* tree and in a stand of *Castanopsis cuspidata* (Thunb.) Schottky.

Ground conditions also seem to be very important. *Zelkova serrata* (Thunb.) Makino is

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**Fig. 2.** Postdispersal seed predation to *Cinnamomum* putamina set at various environments. Open bars indicate day of disappearance for each marked-putamen. a, *Cinnamomum* site; b, *Elaeocarpus* site; c, *Sophora* site; d, *Zelkova* site; e, *Castanopsis* site; f, open ground.
a deciduous tree and its floor was thickly covered with new fallen leaves. It was difficult even for me to find the marked putamina. This may be reflected in the pattern of disappearance at the Zelkova site.

It may be said, on the whole, that the searching efforts by turtle doves are not paid randomly. In particular, they frequently search forest floors in rather large flocks perhaps for security; they frequently showed chain-reacting flights from the experiment sites. This flocks may pay differential searching efforts to various environments for efficiency, although not cleared out in this experiment.

No difference was found in the intensity of predation pressure for putamina of a species between beneath parent trees and beneath other fruiting bird-dispersed trees; compare the results at the Cinnamomum site and the Elaeocarpus site. This may strongly reflect particular feeding habit of turtle doves, rather intelligent, diurnal searchers having keen visual sense and strong locomotive ability.

Preparation intensities—Comparison of seed trap contents with seeds in the litter

An estimation of the total intensity of seed predation at one site is given by this method. Results are shown in Table 1.

It is clear from the table that putamina of Cinnamomum received very severe predation

<table>
<thead>
<tr>
<th>Cinnamomum site</th>
<th>2 traps total</th>
<th>average 2 quadrats</th>
<th>Q-1</th>
<th>Q-2</th>
<th>Q-3</th>
<th>Q-4</th>
<th>Q-5</th>
</tr>
</thead>
<tbody>
<tr>
<td>C. camphora putamina</td>
<td>111</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>empty putamina(1)</td>
<td>9</td>
<td>68.4</td>
<td>36</td>
<td>15</td>
<td>8</td>
<td>33</td>
<td>79</td>
</tr>
<tr>
<td>fruits</td>
<td>45</td>
<td>16.8</td>
<td>10</td>
<td>9</td>
<td>1</td>
<td>18</td>
<td>4</td>
</tr>
<tr>
<td>Ligustrum lucidum</td>
<td>27</td>
<td>2.8</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>Sophora japonica</td>
<td>32</td>
<td>10.4</td>
<td>5</td>
<td>8</td>
<td>3</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>Elaeocarpus sylvestris</td>
<td>1</td>
<td>2.4</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>1</td>
</tr>
</tbody>
</table>

Others: 8 spp. 14 seeds/putamina were collected by 2 seed traps, 6 spp. 15 seeds/putamina by 5 quadrats.

<table>
<thead>
<tr>
<th>Elaeocarpus site</th>
<th>3 traps total</th>
<th>average 3 quadrats</th>
<th>Q-1</th>
<th>Q-2</th>
<th>Q-3</th>
<th>Q-4</th>
<th>Q-5(2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>E. sylvestris putamina</td>
<td>52</td>
<td>60.6</td>
<td>13</td>
<td>16</td>
<td>24</td>
<td>12</td>
<td>36</td>
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<tr>
<td>fruits</td>
<td>70</td>
<td>32.4</td>
<td>11</td>
<td>0</td>
<td>23</td>
<td>8</td>
<td>12</td>
</tr>
<tr>
<td>old putamina</td>
<td>52</td>
<td>31.2</td>
<td>4</td>
<td>10</td>
<td>33</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>C. camphora putamina</td>
<td>71</td>
<td>2.4</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>empty putamina(1)</td>
<td>17</td>
<td>19.8</td>
<td>5</td>
<td>2</td>
<td>5</td>
<td>5</td>
<td>16</td>
</tr>
<tr>
<td>fruits</td>
<td>4</td>
<td>3.0</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Ligustrum lucidum</td>
<td>100</td>
<td>31.8</td>
<td>4</td>
<td>20</td>
<td>2</td>
<td>13</td>
<td>14</td>
</tr>
<tr>
<td>Sophora japonica</td>
<td>13</td>
<td>33.0</td>
<td>6</td>
<td>22</td>
<td>5</td>
<td>15</td>
<td>7</td>
</tr>
</tbody>
</table>

Others: 14 spp. 30 seeds/putamina by 3 seed traps, 9 spp. 27 seeds/putamina by 5 quadrats

(1) including old ones. (2) This quadrate is set beneath an adjacent Cinnamomum tree.
at both the experiment sites. No living putamen was found in the litter (1250cm²) beneath a parent tree. But a considerable number of old or empty putamina were found in the litter. These had been caused by two reasons. First, turtle doves do not eat fruits of Cinnamomum, thus the ignored fallen fruits of the preceding years had been decayed and only the putamina remained. Some putamina had fragments of decayed fruit skins, indeed. Second, some fruits of Cinnamomum contain empty putamina (such fruits usually ripen much later). Turtle doves are likely to have ability to distinguish these putamina from normal ones. Specific gravity of normal putamina (dried in room condition in one month) is 0.870 ± 0.082 (N = 10), and a fresh putamen sinks in water. On the other hand, that of empty ones is 0.347 ± 0.026 (N = 4). It is not difficult for dove-size animals to distinguish these two putamina simply by weight or specific gravity, when they pick up.

At the floor of the Elaeocarpus-tree, a few putamina of Cinnamomum remained alive until the experiment time (mid-February), but it was observed that flocks of turtle doves were insistently searching the floor for several days after that. It is likely that much less putamina remain alive until spring.

Less severe predation pressure was observed for Ligustrum lucidum at the time of experiment, but the final survival rate of this species also will be much reduced at the Elaeocarpus floor. Seeds of Sophora were not eaten in the marked-seed experiment. Distribution of the seeds of Sophora were much concentrated to some particular quadrates. Birds may rest at some particular perching sites when they eat fruits of Sophora because of difficulty of ingestion.

It is shown from this experiment, too, that putamina of Elaeocarpus had received no predation by turtle doves. In a more natural environment, however, they also must have postdispersal seed predators such as rodents. They may have different feeding habits (Janzen, 1986). Searching area of a rodent, for instance, must be more restricted than that of a turtle dove. Dispersal from the parent trees even to the other bird-dispersed trees may be favoured in this case.

Comparison of the content of a seed trap with seeds in the litter around it must be a handy and useful method. In natural environments, it will illustrate the frequency of secondary dispersal by terrestrial animals as well as the intensity of postdispersal seed predation.

Acknowledgment

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Literature Cited