We measured containment rates for four types of netting. Only one type of fish net (14 mesh 0.25 mm nylon monofilament), with a containment rate of 67% (an escape rate of 33%), proved useful as a barrier for adult CRB. This fish net is more than a physical barrier because beetles become permanently entangled. Most of the beetles escaping from the fish net were small. A higher mesh (smaller hole size) may reduce the high escape rate for smaller beetles.

1 Introduction

Use of netting as a physical barrier has been suggested as a tactic to prevent adult CRB from entering or leaving active and potential breeding sites. We previously tested plastic bird netting and found a high escape rate (ref). In this experiment, we tested bird netting plus three types of fish netting.
2 Materials and Methods

2.1 Beetles
We used field collected beetles. Prior to being used in the experiment, beetles were flight tested in the lab. Beetles which passed the flight test were marked with a unique number, measured, and weighed. Equal numbers of beetles were randomly selected and placed in plastic containers filled with moist peat moss.

2.2 Netting
Four types of netting were tested in this experiment.

2.2.1 Bird Net
Easy Gardner birdBlock STI-602. (Figure 1, 6)

2.2.2 Green Net 1
Half-inch mesh netting, PA206, ordered from www.leevalley.com. (Figure 2)

2.2.3 Green Net 2
Procured from Mari Marutani, Triton Farm (Figure 3)

2.2.4 Fish Net
Nylon, high tenacity, 14 mesh. Manufactured by Fortune Net and Twine, Quezon City, Philippines. (Figure 4, 5)

2.3 Experimental Setup
The experiment was performed during the nights of August 20, 22, and 28, 2014. Containers were placed inside inside bags constructed from netting and these were put on the ground at the center of a field at the Yigo Ag Expt Stn. At 7:00 PM, lids were removed from the containers. At 7:00 AM the following morning, the containers were picked up and the number of beetles remaining or entangled were counted (Figure 7). A trail cam equipped with an IR flash and mounted on a post was used to make time lapse videos of the experiment between 7:00 and 10:00 PM each evening (Figure 8).

2.4 Analysis
Analysis was performed using an iPython notebook (Program listing 2). ImageJ was used to make time lapse videos (AVI format; JPEG compression; 20 FPS; 5 s between frames).
3 Results and Discussion

The escape rate observed for the fish net is a function of beetle size (Figure 10). The escape rate for beetles with an elytral width of less than 18 mm was 76% (16 of 21 escaped), whereas the escape rate for beetles with an elytral width of greater than 18 mm was only 4% (1 out of 28).

Time lapse videos for escape tests performed on 2014-08-22 and 2014-08-28 are published on YouTube at http://youtu.be/C5C0Q-txYow and http://youtu.be/mnxAf-7K_dU. These videos clearly show that beetles become permanently entangled in the fish net, but are able to pass through other net types after a few minutes. The beetles become entangled in much the same way fish are caught in a gill net. When trying to escape, the 0.25 mm nylon monofilament from which the net is made gets lodged in the crack between the beetle’s head and thorax, preventing escape (Figure 11). We expect that a fish net with a slightly higher mesh (smaller holes) will prevent the high escape rate observed for smaller beetles. However, if the mesh becomes too high we expect that beetles will be able to escape by bringing their powerful front legs into play to stretch and break the monofilament. We have seen this behavior with the very heavy nylon screening from which our large field cages are made. Beetles are able to use their legs to bore holes through this.

Use of fish netting may become an important tactic for preventing adult CRB from entering or leaving piles of potential breeding material. Note that fish net is more than a physical barrier because beetles become permanently entangled.
Figure 2: Green net 1. Circular object is a U.S. penny (diameter = 19.05 mm). Distance between nots = 14.2 mm.

Figure 3: Green net 2. Circular object is a U.S. penny (diameter = 19.05 mm). Distance between nots = 9.9 mm.
Figure 4: Fish net. Circular object is a U.S. penny (diameter = 19.05 mm). Distance between nots = 13.0 mm.

Figure 5: Fish net label.
Figure 6: Bird net label.

Figure 7: Test containers when picked up on the morning following the 2014-08-28 escape test.
Figure 8: Tripod holding the trail cam used for time lapse video.

Figure 9: Proportion of adult coconut rhinoceros beetles remaining in containers or entangled. Error bars are 95% confidence intervals.
Figure 10: Sizes of beetles escaping from the fish net. Black circles indicate beetles which escaped. White circles are those which remained.

Figure 11: Entangled beetles cut out of fish net.
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2298, 08/22/14 12:00 AM, 08/22/14 12:00 AM, m, 24.91, 19.89, 4.983, Field, Container C, fish
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Listing 2: IPython notebook

# coding: utf-8

# In [1]:

# General syntax to import specific functions in a library:
###from (library) import (specific library function)
from pandas import DataFrame, read_csv

# General syntax to import a library but no functions:
###import (library) as (give the library a nickname/alias)
import matplotlib.pyplot as plt
import numpy as np
import pandas as pd #only needed to determine version number
import sys #only needed to determine Python version number

# Enable inline plotting
get_ipython().magic(u'matplotlib inline ')

# Enable rmagic
get_ipython().magic(u'load_ext rmagic ')

# A good reference for pandas dataframe manipulation is

# In [2]:
data = read_csv('escapeTest2.csv')
data.head()

# In [3]:

15
n = data.groupby('treatment').size()

# In [4]:
escaped = data[data['result'] == 'escaped'].groupby('treatment').size()
escaped

# In [5]:
df = DataFrame({'n':n, 'escaped':escaped})
df['contained'] = df['n'] - df['escaped']
df['pcontained'] = df['contained']/df['n']
df = df.sort('pcontained')
df

# In [6]:
import astropy.stats
ciContained = astropy.stats.binom_conf_interval(df['contained'], df['n'])

# In [7]:
df['lcl'] = ciContained[0]
df['ucl'] = ciContained[1]
df['lbar'] = df['pcontained'] - df['lcl']
df['ubar'] = df['ucl'] - df['pcontained']
df

# In [8]:
# The following 2 lines fix a problem with labels being clipped at bottom of figure.
from matplotlib import rcParams
rcParams.update({'figure.autolayout': True})
df.plot(y='pcontained', kind='bar', grid=False, color='lightgray', ylim=(0,1), yerr = [df['lbar'], df['ubar']])
plt.ylabel('proportion of beetles contained')
plt.savefig('containedBars2.pdf')

# In [9]:
d = data[data['treatment'] == 'fish net']
c = []
for result in d['result']:
    if result == 'escaped':
c.append('black')
else:
c.append('white')
d.plot(x='elytraLength', y='elytraWidth', kind='scatter', c=c)
plt.savefig('escapeSizes.pdf')

# In [9]: