DUGONG (DUGONG DUGON) ABUNDANCE ALONG THE ANDAMAN COAST OF THAILAND

ELLEN M. HINES
Department of Geography and Human Environmental Studies, San Francisco State University, 1600 Holloway Avenue, San Francisco, California 94132, U.S.A.
E-mail: ehines@sfsu.edu

KANJANA ADULYANUKOSOL
Phuket Marine Biological Center, P. O. Box 60, Phuket 83000 Thailand

DAVID A. DUFFUS
Whale Research Lab, Department of Geography, University of Victoria, Victoria, British Columbia V8W 3P5, Canada

ABSTRACT

In 2000 and 2001, dugong abundance was estimated using aerial surveys in three provinces along the Andaman coast of Thailand. A microlite aircraft was used to fly aerial transects over seagrass areas. All surveys were done during rising tides as the dugongs came to the seagrass beds to feed. The largest population was found in Trang province. In Trang, the total number of sightings during 22 surveys was 264, out of which 31.5% were single dugongs. The largest group seen in 2000 was 30, and in 2001, 53. The maximum number of calves seen in one day was 13. The best minimum estimate of population abundance is 123 animals (CV = 60.8%) in Trang province. Higher numbers of dugong sightings and group sizes corresponded with higher tides until water turbidity impeded sightings after the highest spring tide. In other areas the number of animals seen was too small for population estimates.

Key words: dugong, Dugong dugon, population assessment, Thailand, Andaman Sea.

The dugong (Dugong dugon) is critically endangered. Outside of Australia, the country with the largest estimated dugong population, dugongs only survive in fragmented populations in the Eastern hemisphere. Neither the number of dugongs remaining in these populations nor its range is known beyond incidental sightings and the reports of fishermen (Marsh et al. 1999, 2002). In Thailand the dugong has been under Federal protection since 1947 (Humphrey and Bain 1990). Our study along the Andaman coast is the first systematic dugong population survey in Thailand (also see Hines 2002a, b).

There are five population centers along the Andaman coast: Ranong, Phuket, Krabi, Trang, and Satun (Fig. 1). Aerial surveys were flown near Phuket, Krabi, and Trang. Many of the seagrass beds surrounding the island of Phuket have been
degraded by coastal development (Poochaviranon 2000). Krabi, on the eastern coast of Phang-nga Bay, has seagrass beds on Yao Noi and Yao Yai Islands in the Bay, also at Sriboya, Pu, and Hang Islands (hereafter referred to as the Three Islands), and on the eastern coast of Phang-nga Bay (Fig. 1). The largest seagrass beds along this
coast are in Trang province. There are two beds equaling 7 km$^2$ at Libong Island, and 6.36 km$^2$ in Had Chao Mai National Park (Chansang and Poovachiranon 1994) (Fig. 1). In this area is also the largest known remnant population of dugongs in Thailand (Adulyanukosol et al. 1997).

Our overall objective was to estimate dugong abundance and distribution along the Andaman coast of Thailand. Our second objective was to develop practical field protocols for future monitoring of dugong populations with appropriate spatial scale, and sensitive to local budgetary constraints and logistical support (Aragones et al. 1997).

**Methods**

The only practical method to directly count dugongs is from the air (Hudson 1981, Marsh 1995a). Aerial surveys have been widely used in other parts of the species range (Rathbun et al. 1988, Chambers et al. 1989, de Jongh 1995, Marsh 1995b).

We first used a helicopter to perform extended area surveys along the entire coast to determine the overall distribution and obtain a qualitative estimate of the abundance of dugongs and seagrass (Lefebvre et al. 1995, Aragones et al. 1997). Results of the helicopter surveys can be found in Hines (2002a). A microlite fixed-wing aircraft was then used for more detailed surveys in areas that either had sightings in the helicopter surveys, or were reported to have groups of dugongs by interview respondents or Thai researchers (Aragones et al. 1997).

We used transect surveys to sample representative areas and estimate abundance and densities of dugongs for the total area (Burnham et al. 1980). While line-transect sampling is recommended for cetaceans (Barlow 1988, Forney et al. 1991), dugongs are more difficult to sight because they are often solitary or in cow-calf pairs, and as their surfacing time is from 1 to 2 s, are difficult to locate in turbid water (Marsh 1995a; Pollack et al., in press). Strip, or fixed-width transect techniques are recommended for dugong aerial surveys, and for other marine mammal aerial surveys where the aircraft is moving rapidly. At the speeds required to safely fly an open aircraft it is difficult to correctly assess perpendicular distances from the aircraft while searching the field of view and counting animals (Marsh 1995a, Miller et al. 1998).

The microlite aircraft was used to fly predetermined fixed transects to estimate population distributions and counts in Trang province in both 2000 and 2001 and in the Three Islands area in Krabi in 2000. In 2001 we flew transects along the northeast coast of Phuket Island in Phuket province, and the Yao Islands in Phang-nga Bay. Transects were perpendicular to shore and took advantage of visible endpoints both on land and in the water (e.g., buoys, limestone outcroppings).

Transect lines should ideally be placed parallel to the density gradient of the distribution of the group of animals (Yoshida et al. 1997). Dugongs are generally found in shallow waters. While feeding they are mostly in sea grass beds 11–12 m deep (Reynolds and Odell 1991). Therefore, the density gradient is most probably perpendicular to the shoreline, and we placed the transect lines accordingly. We used a zigzag pattern to equalize the effort on all parts of the transect line (Dahlheim et al. 2000, Buckland et al. 2001). In each survey area we estimated the time it took to turn the microlite from one transect to another, and subtracted that time from effort calculations. In 2001 we added a small area and four more transect
Figure 2. Transects and strata used for microlite surveys in Trang Province. The estuary sampling block was added in 2001.

In Trang we flew 45 transects in 2000 and 49 transects in 2001 (Fig. 2). In the Three Islands area, we flew 20 zigzag transects (Fig. 3). In Phuket, we flew 9 transects, and in the Yao Islands, 36 transects (Fig. 4). To calculate differences in density, we created sampling strata around groups of transects (Table 1) (Bayliss 1986, Marsh 1995a).

The transects were flown at between 400 and 500 m apart, starting from 1.5 to 2.5 h before high tide (Tide Tables, Hydrographic Department, Royal Thai Navy 2000). Transects were flown at an average height of 152 m and an average speed of
Fig. 3. Transects and strata used for microlite surveys in the Three Islands area, Krabi Province.

46 km (85 km/h). Visibility from the microlite was 200 m on each side. We established this measurement by marking an area of the beach using a measuring tape and then placing markers on the sand at 400 m as could be seen from the microlite at survey altitude. We then marked the struts of the microlite corresponding with that distance.

Two hundred meter visibility from an aircraft has been calculated for 137 m of altitude by Marsh et al. (1996). This altitude is considered sufficiently low to prevent repeated sightings while allowing adequate visibility (Marsh and Saalfeld 1990, Marsh 1995a). The higher altitude flown in our study was necessary for safety in the microlite.
Figure 4. Transects and strata used for microlite surveys in Ban Pak Lok (Phuket Province) and the Yao Islands (Phang-nga Province).

Due to the maneuverability and relative quietness of the aircraft, when an animal or group of animals was seen, it was easy to circle at lower altitude to gather further information. Species, number of calves, group size, and behavior were documented before returning to the transect line.

Latitude and longitude of all sightings and routes were recorded using a global positioning system (GPS). We also recorded the time, weather, tidal level, and Beaufort sea state (see Hines 2002a).

We used the program DISTANCE for estimation of population abundance and density (Thomas et al. 1998, Buckland et al. 2001). To analyze strip transects in DISTANCE, we used a uniform detection function model with 0 adjustments terms (Buckland et al. 2001). A detection function is $g(x)$, or the probability of detecting
Table 1. Sampling strata and lengths of strip transects by area.

<table>
<thead>
<tr>
<th>Area</th>
<th>Year</th>
<th>Strata number</th>
<th>Area (km²)</th>
<th>Length of transect (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trang</td>
<td>2000/2001</td>
<td>1</td>
<td>29.24</td>
<td>59.11</td>
</tr>
<tr>
<td>Trang</td>
<td>2000/2001</td>
<td>2</td>
<td>3.25</td>
<td>6.73</td>
</tr>
<tr>
<td>Trang</td>
<td>2001</td>
<td>3</td>
<td>1.68</td>
<td>6.02</td>
</tr>
<tr>
<td>Trang</td>
<td>2000/2001</td>
<td>4</td>
<td>29.29</td>
<td>42.77</td>
</tr>
<tr>
<td>Trang</td>
<td>2000/2001</td>
<td>5</td>
<td>31.43</td>
<td>53.58</td>
</tr>
<tr>
<td>Three Islands</td>
<td>2000</td>
<td>1</td>
<td>60.28</td>
<td>105.19</td>
</tr>
<tr>
<td>Phuket</td>
<td>2001</td>
<td>1</td>
<td>58.56</td>
<td>55.13</td>
</tr>
<tr>
<td>Yao Islands</td>
<td>2001</td>
<td>1</td>
<td>20.01</td>
<td>29.40</td>
</tr>
<tr>
<td>Yao Islands</td>
<td>2001</td>
<td>2</td>
<td>8.82</td>
<td>15.10</td>
</tr>
<tr>
<td>Yao Islands</td>
<td>2001</td>
<td>3</td>
<td>2.95</td>
<td>14.62</td>
</tr>
</tbody>
</table>

an object, given that it is at a distance \(x\) from the random point or line (Thomas et al. 1998). Under these model definitions, the program assumes a probability of detection of 1 between 0 distance from the observer and the truncation distance. In sample sizes approaching 1, a probability density function for the width of the transect \(f(0)\) cannot be calculated, and density and abundance cannot be estimated reliably (Jefferson 2000, Buckland et al. 2001).

Strip transects are a strip or strata of length \(L\) and width \(2w\). In a formal strip transect the assumption is made that all objects within the census area are detected (Buckland et al. 2001). The uniform detection function is the only model that fits for strip transects as \(g(x)\) does not change over a set distance, and no adjustment terms are needed.\(^1\)

DISTANCE estimates \(D\), or the number of animals per unit area as

\[
D = \frac{n}{2wL}
\]  

(1)

Therefore, we set the truncation distance at 200 m, or half the estimated width of the strip.\(^1\) We interpreted the maximum value of \(n\) as given in DISTANCE, or estimate of animals in a specified area, as a minimum estimate of population abundance (Jefferson 2000).

To examine the affects of tide level on our ability to see dugongs, we separated the 2001 sightings into truncated tide level categories. We then ran abundance and density estimates on each category.

RESULTS

Trang Province

In 2000 we conducted aerial surveys in Trang Province for 10 d between 6 and 20 March. The average daily count of dugongs and calves was 38.2 (Table 2). All dugongs sighted were in \(\leq 5\)-m depth lowest low water (sea level) as measured by bathymetric maps from the Hydrographic Department of the Royal Thai Navy. We recorded a total of 52 calves, an average of 5.2 daily. A minimum of 2 and a maximum of 13 calves were located in one day with a standard deviation of 3.6. Adults

\(^1\) Personal communication from Stephen T. Buckland, CREEM, The Observatory, Buchanan Gardens, St Andrews KY16 9LZ, Scotland, 14 October 2004.
Table 2. Estimates of abundance, density, and other associated parameters for the microlite surveys in Trang province in 2000 and 2001. Symbols used: $k$, numbers of samples (the number of transect lines); $L$, total length of transects surveyed; # of animals seen, the actual count of dugongs including calves; $n$, number of on-effort sightings; average group size, average number of animals in group, $n/L$, encounter rate; $D$, estimate of density of animals; $N$, estimate of animals in specified area; SE, standard error; CV, coefficient of variation.

<table>
<thead>
<tr>
<th>Year</th>
<th>Day</th>
<th>Area (sq. km)</th>
<th>L (km)</th>
<th># of animals seen</th>
<th>Average group size</th>
<th>n/L</th>
<th>D</th>
<th>N</th>
<th>SE</th>
<th>CV (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>6 March</td>
<td>93.2</td>
<td>45</td>
<td>162.2</td>
<td>62</td>
<td>19</td>
<td>3.3</td>
<td>0.1</td>
<td>1.0</td>
<td>89</td>
</tr>
<tr>
<td></td>
<td>7 March</td>
<td></td>
<td>36</td>
<td>16</td>
<td>37</td>
<td>12</td>
<td>3.1</td>
<td>0.1</td>
<td>0.6</td>
<td>53</td>
</tr>
<tr>
<td></td>
<td>8 March</td>
<td></td>
<td>34</td>
<td>13</td>
<td>23</td>
<td>11</td>
<td>2.1</td>
<td>0.1</td>
<td>0.4</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>9 March</td>
<td></td>
<td>15</td>
<td>10</td>
<td>15</td>
<td>10</td>
<td>1.5</td>
<td>0.1</td>
<td>0.2</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>10 March</td>
<td></td>
<td>23</td>
<td>15</td>
<td>23</td>
<td>15</td>
<td>1.5</td>
<td>0.1</td>
<td>0.4</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>13 March</td>
<td></td>
<td>45</td>
<td>13</td>
<td>45</td>
<td>13</td>
<td>3.5</td>
<td>0.1</td>
<td>0.7</td>
<td>65</td>
</tr>
<tr>
<td></td>
<td>17 March</td>
<td></td>
<td>18</td>
<td>11</td>
<td>18</td>
<td>11</td>
<td>3.1</td>
<td>0.1</td>
<td>0.5</td>
<td>59</td>
</tr>
<tr>
<td></td>
<td>19 March</td>
<td></td>
<td>41</td>
<td>18</td>
<td>41</td>
<td>18</td>
<td>2.3</td>
<td>0.1</td>
<td>0.6</td>
<td>59</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>382</td>
<td>140</td>
<td>382</td>
<td>140</td>
<td>2.7</td>
<td>0.1</td>
<td>0.5</td>
<td>550</td>
</tr>
<tr>
<td>Average</td>
<td>2000</td>
<td></td>
<td>38.2</td>
<td>14.0</td>
<td>38.2</td>
<td>14.0</td>
<td>2.7</td>
<td>0.1</td>
<td>0.5</td>
<td>22.1</td>
</tr>
<tr>
<td>2001</td>
<td>31 March</td>
<td></td>
<td>94.9</td>
<td>49</td>
<td>169.5</td>
<td>10</td>
<td>8</td>
<td>1.3</td>
<td>0.0</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>1 April</td>
<td></td>
<td>11</td>
<td>9</td>
<td>12.2</td>
<td>1.2</td>
<td>0.1</td>
<td>0.2</td>
<td>15</td>
<td>4.7</td>
</tr>
<tr>
<td></td>
<td>2 April</td>
<td></td>
<td>5</td>
<td>5</td>
<td>1.0</td>
<td>0.0</td>
<td>0.1</td>
<td>7</td>
<td>2.8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3 April</td>
<td></td>
<td>7</td>
<td>6</td>
<td>1.2</td>
<td>0.0</td>
<td>0.0</td>
<td>10</td>
<td>4.8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4 April</td>
<td></td>
<td>6</td>
<td>6</td>
<td>1.0</td>
<td>0.0</td>
<td>0.1</td>
<td>8</td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5 April</td>
<td></td>
<td>42</td>
<td>20</td>
<td>2.1</td>
<td>0.1</td>
<td>0.6</td>
<td>59</td>
<td>13.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6 April</td>
<td></td>
<td>79</td>
<td>16</td>
<td>4.9</td>
<td>0.1</td>
<td>1.2</td>
<td>111</td>
<td>78.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>7 April</td>
<td></td>
<td>88</td>
<td>9</td>
<td>8.8</td>
<td>0.1</td>
<td>1.3</td>
<td>123</td>
<td>87.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>8 April</td>
<td></td>
<td>55</td>
<td>12</td>
<td>4.6</td>
<td>0.1</td>
<td>0.8</td>
<td>77</td>
<td>49.6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10 April</td>
<td></td>
<td>43</td>
<td>9</td>
<td>4.8</td>
<td>0.1</td>
<td>0.6</td>
<td>60</td>
<td>30.7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>11 April</td>
<td></td>
<td>35</td>
<td>13</td>
<td>2.7</td>
<td>0.1</td>
<td>0.5</td>
<td>49</td>
<td>20.4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>12 April</td>
<td></td>
<td>16</td>
<td>11</td>
<td>1.5</td>
<td>0.1</td>
<td>0.2</td>
<td>22</td>
<td>7.8</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>2001</td>
<td></td>
<td>397</td>
<td>124</td>
<td>397</td>
<td>124</td>
<td>2.9</td>
<td>0.1</td>
<td>0.5</td>
<td>555</td>
</tr>
<tr>
<td>Average</td>
<td>2001</td>
<td></td>
<td>33.1</td>
<td>10.3</td>
<td>33.1</td>
<td>10.3</td>
<td>2.9</td>
<td>0.1</td>
<td>0.5</td>
<td>46.3</td>
</tr>
<tr>
<td>Average</td>
<td>2000</td>
<td></td>
<td>35.4</td>
<td>12.0</td>
<td>35.4</td>
<td>12.0</td>
<td>2.8</td>
<td>0.1</td>
<td>0.5</td>
<td>50.2</td>
</tr>
<tr>
<td>Totals for both years</td>
<td></td>
<td></td>
<td>779</td>
<td>264</td>
<td>779</td>
<td>264</td>
<td>5.1</td>
<td>0.1</td>
<td>0.5</td>
<td>41.8</td>
</tr>
</tbody>
</table>

($n = 330$) comprised 86% of the counts, and calves 14%. We recorded 20.8 dugongs per surveying hour. Of 186 sightings, single animals accounted for 75%. Only three sightings (2%) were of groups over six (17, 26, and 30).

During the 2001 field season in Trang province, we completed 12 aerial surveys between 31 March and 12 April. We counted an average of 33.1 dugongs and calves per day (Table 2). All dugong sightings were again in ≤5-m depths. The spatial
Figure 5. Two examples of sighting locations in Trang province: (a) 6 April and (b) 7 April 2001.

distributions of sightings for two of the survey days are illustrated in Figure 5. We counted 46 calves in total, with mean sightings of 3.8 daily. Twelve percent of the dugongs seen were calves and 88% (n = 351) were adults. On average we sighted 18.9 dugongs per hour.

We made a total of 124 separate sightings, out of which 31.5% were of single animals. Groups of \( \leq 3 \) constituted 42.6% of all sightings, and 45.6% were of groups of six animals or larger. The largest group, 53, was seen on two consecutive days in a row. For both years, the minimum estimate (the largest \( n \) of
Table 3. Estimates of abundance, density, and other associated parameters for the different strata on the microlite surveys in Trang province in 2000 and 2001. Symbols used: \(k\), numbers of samples (the number of transect lines); \(L\), total length of transects surveyed; average \(n\), average number of on-effort sightings; average group size, average number of animals in a group, average \(n/L\), encounter rate; average \(D\), average estimate of density of animals; average \(N\), average estimate of animals in specified area; SE, standard error; CV, coefficient of variation.

<table>
<thead>
<tr>
<th>Years surveyed</th>
<th>Area (sq. km)</th>
<th>(k) (km)</th>
<th>(n)</th>
<th>Average group size</th>
<th>(n/L)</th>
<th>Average (D)</th>
<th>Average (N)</th>
<th>SE (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000 and 2001</td>
<td>1</td>
<td>29.2</td>
<td>14</td>
<td>59.1</td>
<td>4.0</td>
<td>1.1</td>
<td>4.8</td>
<td>0.2</td>
</tr>
<tr>
<td>2000</td>
<td>2</td>
<td>3.3</td>
<td>1</td>
<td>6.7</td>
<td>0.1</td>
<td>0.2</td>
<td>0.2</td>
<td>0.1</td>
</tr>
<tr>
<td>2000</td>
<td>3</td>
<td>1.7</td>
<td>4</td>
<td>7.3</td>
<td>0.3</td>
<td>0.4</td>
<td>0.5</td>
<td>0.2</td>
</tr>
<tr>
<td>2000 and 2001</td>
<td>4</td>
<td>29.3</td>
<td>17</td>
<td>42.8</td>
<td>3.6</td>
<td>5.1</td>
<td>20.4</td>
<td>1.2</td>
</tr>
<tr>
<td>2000 and 2001</td>
<td>5</td>
<td>31.4</td>
<td>13</td>
<td>53.6</td>
<td>4.4</td>
<td>1.9</td>
<td>9.8</td>
<td>0.4</td>
</tr>
</tbody>
</table>

the total population size in the area surveyed was 123 dugongs (Table 2). In the tide level analysis, the numbers of dugong sightings and group sizes rose to a peak level in the 3.0–3.4 medium tide level class, and fell at the highest spring tide level.

Of the five sampling strata, the average population abundance estimate was highest in stratum 4 (Table 3). The average group size and density of individual animals was also highest here. The highest \(n\) for any survey day and therefore the minimum population estimate for this sampling stratum was 98 animals.

Groups of dugongs gathered in the dense patches of sea grass, mostly *Halophila ovalis*, along the eastern end of Libong Island (Fig. 2). Smaller groups of dugongs regularly fed on the more patchy sea grass along the south coast of the island. This area, stratum 5, had an average group size of 1.9, and a minimum abundance estimate of 37 (from the survey day with the highest \(n\)). Between Muk Island and Laem Yong Lam, another area with patchy sea grass, sampling block 1, an estimated 12 dugongs foraged in average groups of 1.1 (Table 3) (see Hines 2002a).

**Krabi Province**

In Krabi province, within the Three Islands area, after five transects, the maximum sighting was of four adult dugongs, plus one calf. The total number of sightings over all five days was 12. Adults were 75% of the total, and calves, 25%. The average number of sightings was 2.4, the minimum 0, and the maximum 5, with a standard deviation of 2.5. The number of dugongs per hour in this area was 2.2. All dugongs were seen in ≤5-m depths. The sampling block area here was 60.3 km², and the transect length was 105.2 linear kilometers. The sample size in this area was not sufficient for a reliable estimate of population abundance and density.
Phuket and Phang-nga Provinces

We flew microlite surveys on the northeast coast of Phuket Island and around the Yao Islands in Phang-nga Bay between March 23 and 25 in 2001. In Phuket, we established one sampling block of 58.3 km², containing 55.1 linear kilometers of transect. Three sampling blocks in the Yao Islands totaled 31.8 km². The total linear kilometers of the three transect paths equaled 88.5.

We sighted three dugongs, one near Ban Pak Lok on Phuket, and two in the Yao Islands, none of which were calves. There were feeding trails in sea grass beds between Yao Noi and Yao Yai Islands, as well as in the sea grass in the sampling block at the south end of Yao Yai Island. As in the surveys in other areas, no dugongs were seen in waters ≥5-m depth. As in Krabi, the sample size was too low to perform statistical analysis.

Discussion

We estimate that the present population of dugongs along the Andaman coast is approximately 200 animals, with a minimum population abundance estimate of 123 animals in Trang province. Because we are, as of yet, unaware of the extent of movement along the coast, protecting only some of these habitats, even those with a larger population of dugongs, will not ensure the recovery of the entire population, even if local extinction is prevented. Both past and present habitat areas need to be considered for protection (Preen 1998).

In the Kuraburi area, we cannot at this time make a reasonable minimum population estimate. Based on trails that we saw, the animals seen by villagers and other researchers, and the extent and cover of the sea grass beds, the area can and most likely does support a small population of dugongs.

The Yao Islands have dense beds of sea grass in two areas, the first on the northeast coast of Yao Yai Island, and the second in a sheltered bay at the south end of Yao Yai Island. We have located feeding trails during boat-based sea grass sampling and aerial surveys at both these sites. There is sea grass in the middle of the west coast of the same island, but it has been damaged by monsoon storms, and is sparse. During the 2001 microlite survey, two dugongs were seen in the sea grass beds on the northeast coast of Yao Yai Island. In 1999 Adulyanukosol saw a group of eight dugongs between Yao Yai and Yao Noi Islands during a helicopter survey. Interview respondents in these areas have reported regularly seeing groups of between 1 and 10 dugongs. Fishermen in this area think that there are approximately 15 dugongs in the local sea grass beds. It is possible that a group of dugongs feed here regularly.

Adulyanukosol et al. (1997) found five dugongs in the Three Islands area. In the 2000 microlite surveys, we saw up to four adults and one calf in one day. Villagers told of seeing 10 dugongs in the past 3 yr. From the number of sightings, strandings, and the condition and extent of sea grass, the Three Islands area has sea grass beds that can support a small population of dugongs. We estimate that the minimum population here at this time is between 5 and 10 dugongs.

In Trang province, for all strata combined, the best minimum estimate of the population at this time is 123 dugongs. However, the coefficients of variation (CVs) of the population estimates are relatively high (Table 2). Transect sampling design and estimation of factors that control researchers' ability to detect dugongs should be further refined to reduce the CVs. In general, the highest levels of statistical precision are indicated by CVs of <20%. At these percentages, the estimates are
considered more reliable, and can be dependably utilized as the bases for trend analysis in the future (Jefferson 2000).

To reduce the coefficients of variation in the population abundance estimations, the aerial transect methodology should be refined. Marsh and Sinclair (1989a, b) and (Marsh 1995a) have defined perception bias as animals potentially visible that are overlooked by observers, and availability bias as the number of animals unseen by observers because of uncontrollable factors such as turbidity, sea state, depth, and animal behavior. Sighting availability along the Andaman coast was especially affected by turbidity at various tide levels causing differences in abundance and density estimates. At the highest spring tide levels, when the water depth was over 3.5 m, the level of turbidity of the water was too high to see animals that were not at the surface.

Pollack et al. (in press) have refined methods created by Marsh and Sinclair 1989a, b) to correct for these factors in survey conditions and have reported lowered CV estimates. We recommend that these methods be adapted for local conditions and implemented in future surveys. We also suggest that a larger aircraft be used with room for at least one independent observer on each side of the plane to minimize perception bias.

The transect methodology used here should be continued to increase the precision of estimates. It is also important to establish transects and conduct surveys in the secondary feeding sites. While a statistically powerful trend estimate is not currently possible, more and regular surveys will provide a more complete picture of dugong habitat and distribution along the Andaman coast (Taylor and Gerrodette 1993, Marsh 1995b).

ACKNOWLEDGMENTS

We would like to acknowledge Ocean Park Conservation Foundation and the International Development Research Centre for research funding. At the Phuket Marine Biological Center we have been generously supported by the Director, Oonchit Bhatiyasevi, as well as Supot Chantrapornsyl, Dr. Kongkiat Kittiwattanawong, and Sombat Poochaviranon. We thank Dr. Paul Wade, Dr. Samantha Strindberg, Amy Kirk, Stephanie Olsen, Heather Patterson, Monsiri Baird, Pitsit Charnsop, Suwan Pitaksintorn, Nimit Sittirod, Jim Enright, and two anonymous reviewers. Dr. Cherdag Virapat, Choomjet Karnjanakesorn, and Suriya Saikrachang from the Thai Department of Fisheries were instrumental in getting us support for our surveys.

LITERATURE CITED


Received: 29 November 2003
Accepted: 18 November 2004