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Population Size and Habitat Characteristics of the Indo-Pacific Humpback Dolphin (*Sousa chinensis*) Off Donsak, Surat Thani, Thailand

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Abstract

Investigations on the distribution, population size, and habitat characteristics of animal populations provide the baselines for sound conservation management. Southeast Asia is considered an important habitat for the Indo-Pacific humpback dolphin (*Sousa chinensis*), but information regarding their population size and habitat characteristics is limited. The present study investigated the distribution and habitat characteristics of humpback dolphins off Donsak, Thailand, and estimated the population size based on photo-identification records. Using the POPAN model, the minimum population size of the humpback dolphins off Donsak was estimated to be 193 (167 to 249; 95% confidence interval), with 36 calves, 58 juveniles, 40 subadults, and 59 adults. The progressively ascending cumulative sighting curve implied that the actual humpback dolphin population size in the investigated area is likely higher than this estimate. Principal components analysis of the environmental characteristics indicated that the adult dolphins tend to occur in deeper and clearer waters relative to the younger age classes. Alterations of the coast environment and coastal anthropogenic activities may be particularly deleterious for younger dolphins. Findings from this study contribute significantly to our understanding of the humpback dolphins in Thailand and provide valuable insight for future conservation management.

Key Words: Indo-Pacific humpback dolphin, *Sousa chinensis*, distribution tendency, habitat characteristic, photo-ID, population size, Thailand

Introduction

Studies on the distribution, population size, and habitat characteristics of animals produce baseline data for assessing their population status (International Union for Conservation of Nature [IUCN], 2001), extent of occurrence (Hung & Jefferson, 2004; Rayment et al., 2009; Frère et al., 2010), and distribution tendency (Parra, 2006; Panigada et al., 2008; Anadón et al., 2009; Smith et al., 2009; Embling et al., 2010), which are components essential for sound conservation management (IUCN, 2001; Whitehead et al., 2004; Huntington, 2009; Jefferson et al., 2009; Dolman & Simmonds, 2010; Wade et al., 2010). Conservation actions may become ineffective in terms of mitigating threats to population survival and habitat integrity when baseline data on population attributes are lacking (Thompson et al., 2000, 2010; Williams et al., 2006; Jefferson et al., 2009; Huang et al., 2012). These data are particularly sparse in the coastal habitats of developing countries such as in Southeast Asia, where rapid economic development in recent decades and large human populations along the coast have had a marked deleterious impact on the environment (MacKinnon et al., 2012).

The Indo-Pacific humpback dolphin (*Sousa chinensis*) is widely distributed in coastal waters from the western Indian Ocean to the western Pacific Ocean (Jefferson & Karczmarski, 2001; Jefferson & Rosenbaum, 2014). Although exact micro-habitat use might differ among populations (Jefferson & Karczmarski, 2001; Parra & Jedensjö, 2009; Ross et al., 2010), humpback dolphins generally occur in shallow and coastal waters where the depth seldom exceeds 20 m (Karczmarski et al., 2000; Jefferson & Karczmarski, 2001; Jaroensutasinee et al., 2010). In such nearshore habitats, anthropogenic activities often have substantial impacts on population survival and habitat integrity (Jefferson et al., 2009; Ross et al., 2010; Huang et al., 2013; Huang & Karczmarski, 2014). Investigations on the distribution and population size/abundance estimate of humpback dolphins have received increasing attention in the past decade, but most of the surveys were geographically limited to some well-known populations (Jefferson & Karczmarski, 2001; Reeves et al., 2008; Huang & Karczmarski, 2014). Relevant information on the population baselines of humpback dolphins in coastal Thailand is rare, even though this area is considered an important habitat of these dolphins (Reeves et al., 2008).

In Thailand, Indo-Pacific humpback dolphins are known to reside in the northeast Gulf of Thailand (Beasley & Davidson, 2007) and Donsak–Khanom waters (Jaroensutasinee et al., 2010). Systematic surveys, however, were implemented exclusively in Khanom waters (Jaroensutasinee et al., 2010). Potential anthropogenic impacts in the coastal habitats of humpback dolphins have been increasing continuously as the coastal development projects to accommodate ferry piers, resorts/hotels, factories, and dolphin-watching tourism are gradually expanding to Donsak waters from the nearby Khanom waters. Thus, an urgent need exists to obtain baseline data on the population size, distribution, and habitat characteristics of humpback

(a)

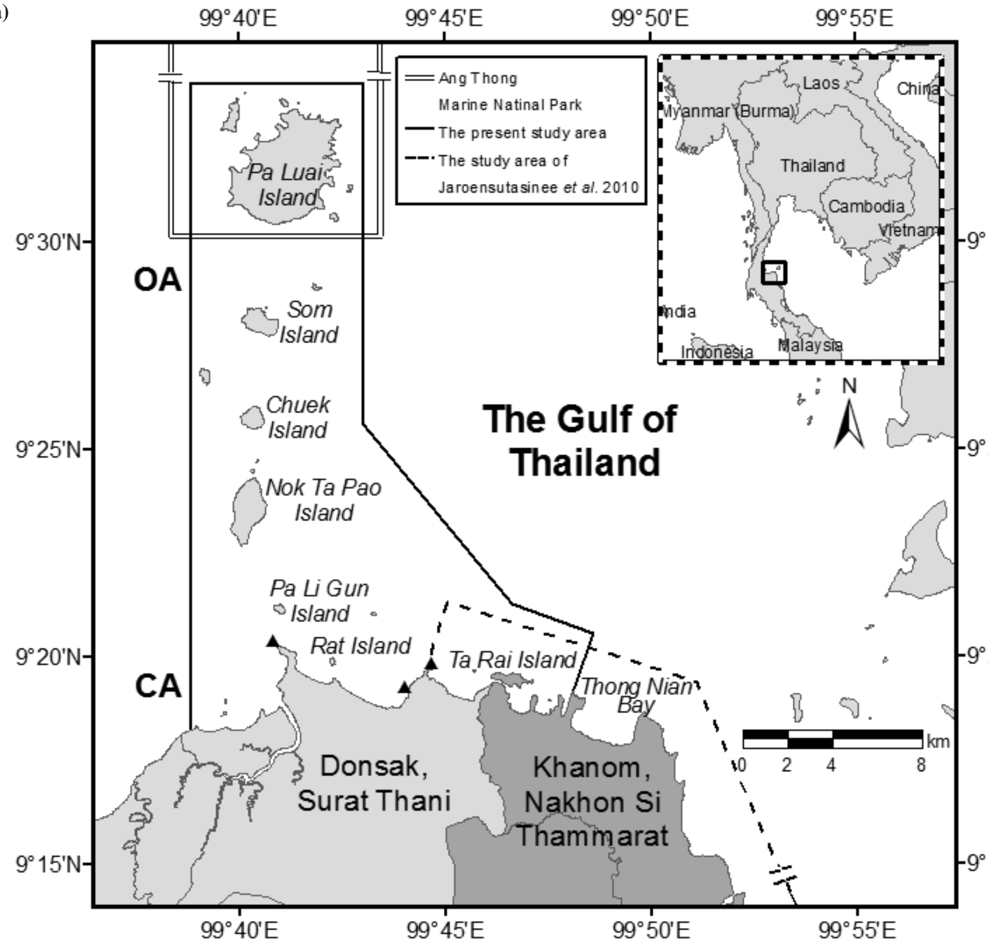

Figure 1a. Study area for this study; the southern part of Ang Thong Marine National Park is included here. The black triangles (▲) indicate the ferry transportation piers (from left, Somserm Ferry, Sea Tran Ferry, and Raja Ferry). The survey area in Jaroensutasinee et al. (2010) is outlined by the dashed line.

dolphins in this area so that the impacts of anthropogenic activities can be assessed and proper mitigation actions can be proposed. In this study, we investigated the distribution and habitat characteristics of the humpback dolphins off Donsak and estimated the population size based on photo-identification (photo-ID) records. The baseline data from this study will provide information important for dolphin conservation planning in the area.

Methods

Study Site

The study area included the coastline area (CA) close to Donsak, where the water depth range is between 1 and 5 m, and the offshore area (OA) around the small islands, where the water depth ranges from 2 to 18 m (Figure 1a). The eastern portion of the survey area overlaps the survey area described by Jaroensutasinee et al. (2010; Figure 1a). In the CA, habitat features include rocky shores/cliffs, sand beaches, mud flats, mangroves, and seagrasses. Major anthropogenic activities originate from ferries transporting tourists to Samui and Phangan islands, small-scale and industrial fishing, dolphin-watching boats, and industrial factories along the coast. In the OA, sand beaches, rocky shores, and cliffs comprise the major habitat features. Small-scale fishing is the primary human activity in this habitat. Pa Luai Island, which is at the northernmost edge of the survey area, is located within the Ang Thong Marine National Park (9.517 N, 99.683 E) established in 1980. The annual air temperature ranges from 22.0 to 29.9° C in winter (mid-October to mid-February), 23.2 to 32.8° C in summer (mid-February to mid-May), and 23.7 to 32.1° C in the rainy season (mid-May to mid-October).

(b)

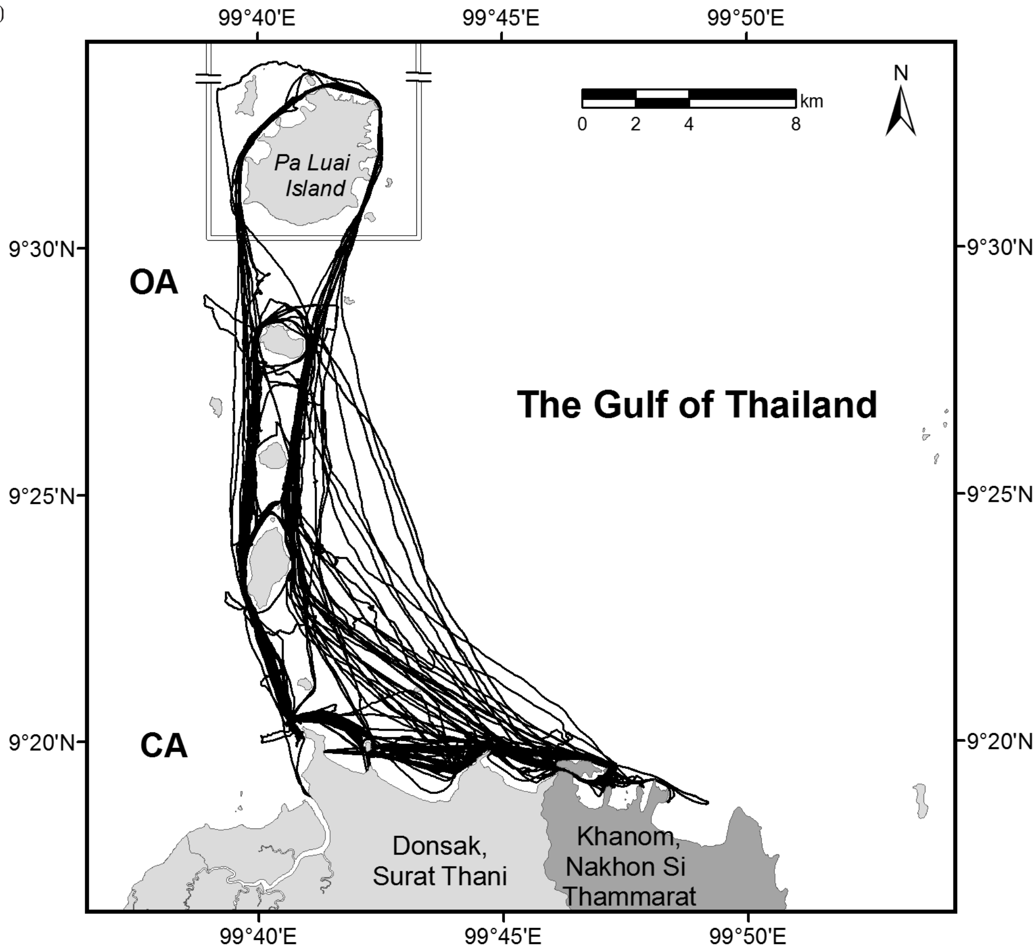

Figure 1b. Survey routes for this study; the southern part of Ang Thong Marine National Park is included here.

(c)

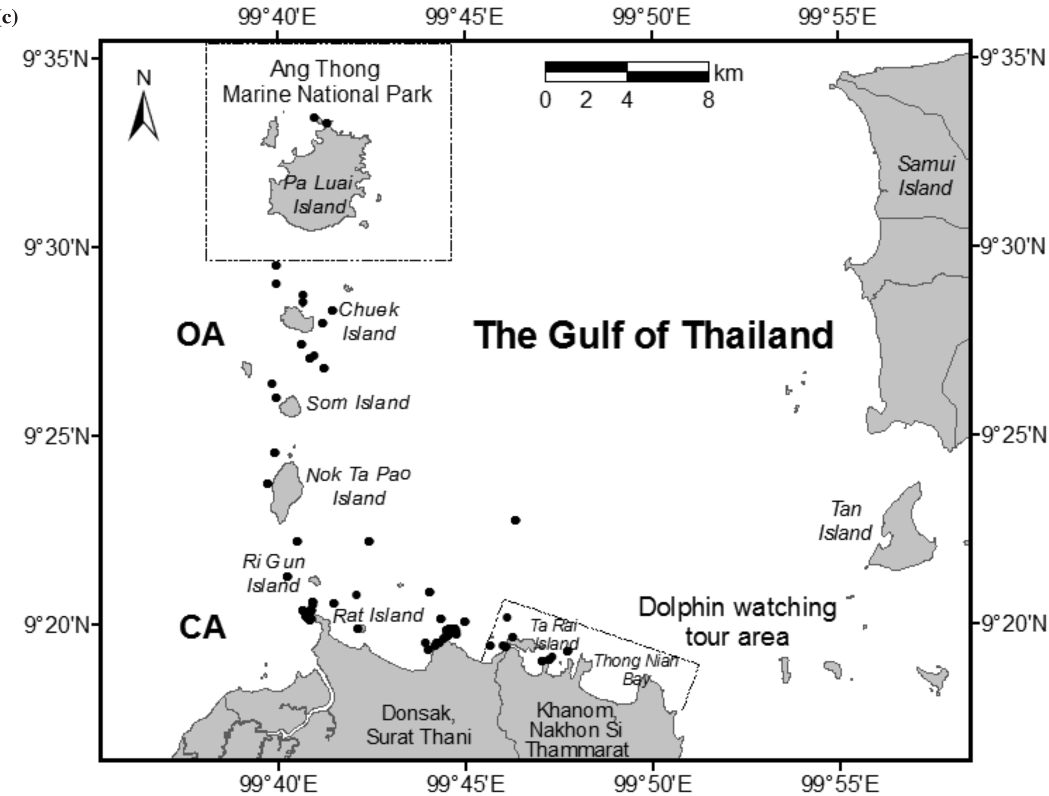

Figure 1c. Positions of humpback dolphin sightings in this study; the southern part of Ang Thong Marine National Park is included here.

Data Collection

The field surveys were conducted from 0800 to 1400 h during December 2011 through April 2013 on a survey vessel under a Beaufort (BF) sea state of 0 to 2 and clear weather with at least ~1 km sea-surface visibility. The survey vessel was a long-tailed fishing boat equipped with an outboard 175-hp engine cruising at a maximum speed of 15 km/h. On each survey day, the survey tracks started from Rat Island to either Ta Rai Island on the east or the Somserm Ferry on the west (CA area), then headed to the islands around the OA up until Pa Luai Island, and finally back to Rat Island (Figure 1b). At least two surveys were performed in each month. All the survey routes were tracked and recorded using a Garmin eTrex30 global positioning system (GPS). Each time humpback dolphins were sighted, the location was marked on the GPS; the boat speed was reduced; and then the water depth (WD), turbidity (TB), pH, sea-surface temperature (SST), and salinity (SN) were measured as well as other nonparametric environmental characteristics (see Table 1). Photographs of the humpback dolphins were taken using DSLR D80, D90, and D7000 Nikon digital cameras with 70- to 300-mm lenses. Habitat characteristics were defined as rocky shores, artificial structures, mud flats, sand beaches, and seagrasses based on direct observations. Finally, the distance offshore (DS) for each sighting was determined by measuring the closest distance between the sighting location and the coastline using the geographic information systems (GIS) application.

Photo-ID Records

Photographs of dorsal fins, taken perpendicular to the body axis of the humpback dolphins, were used for photo-ID records. Individual animals were identified based on the dorsal fin figure and/or distinctive, persistent marks such as nicks, notches, pigmentation pattern, color, and scars as described by Fearnbach et al. (2012). All photo-IDs were implemented by the same individual scientist to ensure the quality and consistency of identification. Age classes of the dolphins were classified primarily based on the pigmentation pattern of body color described by Jefferson (2000): calves (UC) – very young dolphins with

Table 1. The scales of nonparametric environmental characteristics, including the tidal phase, % cloud cover, wind power, rain, and sunlight conditions

Environmental parameters	Conditions	Scale
Tidal (TD)	Low tidal	0
	High tidal	1
% cloud cover (CC)	< 20 cloud	0
	20-50% cloud	1
	> 50% cloud	2
Wind power (WP)	No wind	0
	Little wind	1
	Strong wind	2
Rain (RN)	No rain	0
	Drizzle	1
	Raining	2
Sunlight (SL)	Cloudy	0
	Light	1
	Strong	2

smooth gray skin often observed to be paired with adults; juveniles (SJ) – individuals with white spots on gray skin and some nicks on the dorsal fin; subadults (SA) – dolphins with less than 50% white on gray skin, starting white from the tip of the dorsal fin; and adults (UA) – dolphins with more than 50% of their body skin almost white or pink with small gray spots (Figure 2).

Data and Statistical Analysis

The population size of the Indo-Pacific humpback dolphins in the study area was estimated using POPAN in *MARK* software (White & Burnham, 1999) based on individual sighting histories. In the POPAN model, the population size estimate, N, denotes the size of a super-population, either the total number of animals occurring in the survey area or the total number of animals available for capture at any time during the survey period (Nichols, 2005). Three parameters, Φ, P, and b, which represent the apparent survival rate, probabilities of capture, and probabilities of entry (Reisinger & Karczmarski, 2010), respectively, describe the histories of animal sightings. Each parameter was described by either time $\{t\}$, age classes $\{g\}$, both time and age-classes $\{g \times t\}$, or being unaffected by both t and g $\{.\}$. The best-fitted model of the $\Phi\{\} \cdot P\{\} \cdot b\{\}$ combination was selected with a minimal Akaike information criterion (AIC) value (Burnham & Anderson, 1998).

The Kruskal-Wallis test was first used to test for differences in habitat characteristics among dolphins of different age classes. A principal components analysis (PCA) was applied to transform environmental characteristics related to dolphin sightings into independent components. A discriminant analysis was employed to determine the variable that significantly distinguishes different age classes and tests the differences among the age classes.

Results

In total, 46 boat survey days covering 2,618.4-km survey distance and 205 survey hours were conducted (Table 2; Figure 1b). During the survey period, 89 sightings were gathered (Figure 1c), and over 45,000 images were taken, from which 142 individuals with clear and perpendicular dorsal fin photos on both sides were identified (Figure 3). The average sighting rate/unit effort

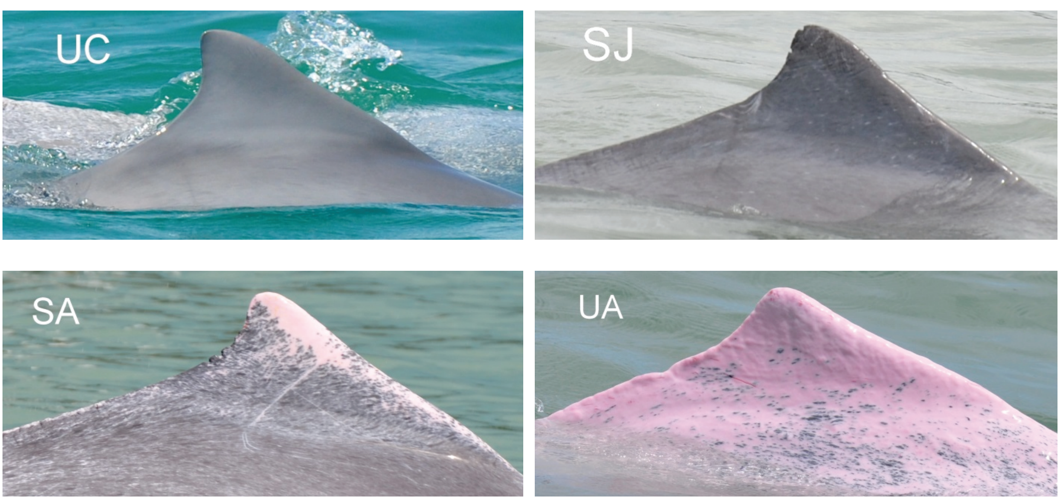

Figure 2. The four age classes of the Indo-Pacific humpback dolphin discriminated by their body color pattern based primarily on Jefferson (2000): calves (UC), juveniles (SJ), subadults (SA), and adults (UA)

was 0.038 group/km. Group size of humpback dolphins ranged from 1 to 18 (mean = 4.7 ± 3.4 [SD]) dolphins. Among the 142 identified individuals, 15 individuals had been identified previously by Jaroensutasinee et al. (2010). The numbers of UC, SJ, SA, and UA dolphins in the 142 identified individuals were 33, 37, 31, and 41, respectively.

N-estimate

The N-estimate (N, 95% confidence interval [CI]) of the humpback dolphins using POPAN models in *MARK* software is presented in Table 3. Of the POPAN model tested, $N\{g\}{\cdot}\Phi\{.\}{\cdot}P\{.\}{\cdot}b\{.\}$, $N\{g\}{\cdot}\Phi\{t\}{\cdot}P\{t\}{\cdot}b\{g\}$, and $N\{g\}{\cdot}\Phi\{g{\times}t\}{\cdot}P\{g{\times}t\}{\cdot}b\{g{\times}t\}$ did not reach numerical convergence. $N\{g\}{\cdot}\Phi\{g\}{\cdot}P\{g\}{\cdot}b\{g\}$ was selected as the best-fitted model (Table 3). The N (95% CI) estimated for different age classes based on this model was 36 (34 to 44), 58 (48 to 77), 40 (35 to 52), and 59 (51 to 75) for UC, SJ, SA, and UA, respectively. The total estimated number of dolphins was 193 with a 95% CI of 167 to 249.

Environmental Characteristics

Table 3 summarizes the environmental characteristics recorded during the sightings for different age classes. The environmental characteristics in six of the 89 total sightings were not measured and thus were excluded from the analysis because of bad weather conditions (BF > 2) during those sightings. Of the 11 examined environmental characteristics, four were significantly different among the four age classes: DS (Kruskal-Wallis, $KW = 11.20, p < 0.05$), TB ($KW = 16.17, p < 0.01$), SST ($KW = 16.17, p < 0.1$), and pH ($KW = 16.17, p < 0.1$; Table 4).

The PCA transforms environmental characteristics measured into three independent components: PC1, PC2, and PC3 (Table 5). The component loadings (Table 5) indicate that PC1 and PC2 can be related to weather (PC1) and sea-surface (PC2) conditions, while PC3 relates to habitat conditions.

Stepwise discriminant analysis revealed that only PC3 ($F = 3.459, p < 0.05$) was significantly different among the four age classes (Wilk's $\lambda = 0.977, p < 0.05$), while the other two were not ($F = 1.734$ and 0.864, $p = 0.16$ and 0.46, respectively). UA dolphins have a significantly higher PC3, which is primarily determined by DS, TB, and WD (Table 5), than the dolphins of the other three age classes (generalized linear model [GLM], ANOVA: $F = 3.459, p < 0.05$; Figure 4). The differences in PC3 among UC, SJ, and SA were not statistically significant (Table 6).

Discussion

Events of tag-loss and tag-induced mortality are usually assumed to be absent in traditional capture–mark–recapture experiments to estimate population size. Violation of the above assumptions often leads to severe bias and lower precision in population size estimates (Arnason & Mills, 1981; Seber & Felton, 1981; McDonald

Table 2. Survey efforts (days, distance), sightings, and numbers of animals sighted from December 2011 to April 2013

Date	Days	Distance (km)	Sightings	Animals sighted
2011				
December	3	124.8	3	3
2012				
January	3	218.19	9	40
February	2	131.27	5	36
March	3	237.97	8	61
April	3	192.67	1	8
May	2	181.93	2	3
June	3	112.39	2	10
July	3	197.09	1	6
August	3	222.93	4	7
September	3	199.47	5	40
October	2	150.52	6	27
November	3	54.52	3	28
December	2	28.56	2	1
2013				
January	2	64.4	5	22
February	3	160.74	9	35
March	3	165.64	10	59
April	3	175.34	14	56
Total	46	2,618.43	89	442

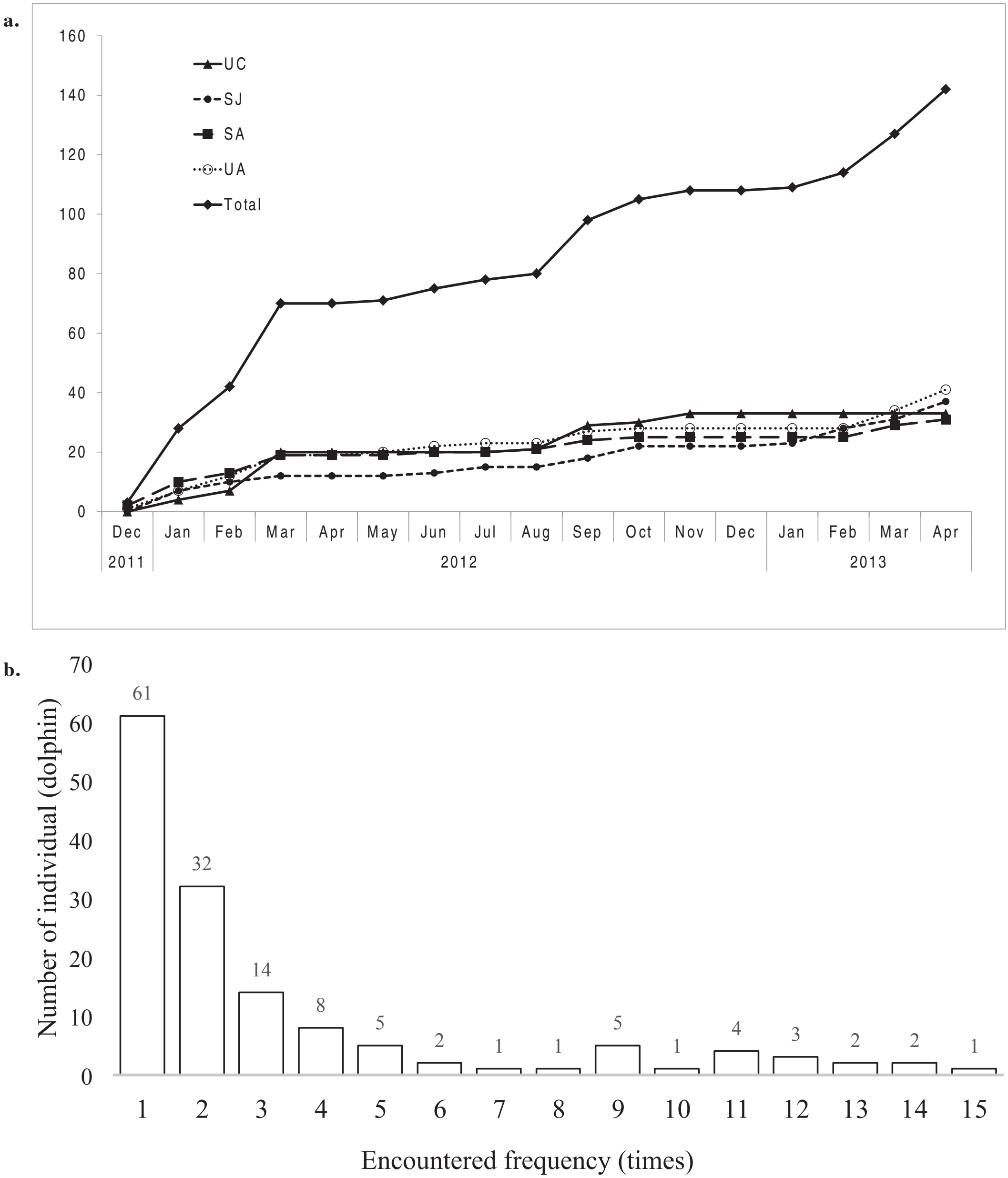

Figure 3. (a) Cumulative number of identified individuals during the survey period, and (b) number of animals at different sighting frequencies

et al., 2003; Cowen & Schwarz, 2006). The photo-ID technique, which is frequently used in cetacean censuses (Wilson et al., 1999; Currey et al., 2009; Verborgh et al., 2009; Reisinger & Karczmarski, 2010), is based on distinguishable marks on animals rather than artificial tagging, and is accomplished without the need for animals to be physically captured or recaptured by investigators. Tag-induced mortality is not relevant in the photo-ID process since the animals are not physically tagged. However, "tag-loss" events could occur during photo-ID studies due to individual growth. Evolving notched marks on the dorsal fin and progressively changing body color among different age classes in some species, such as humpback dolphins, could mistakenly

Table 3. Population size (N, 95% CI) of the humpback dolphins off Donsak estimated using the POPAN model in *MARK* software; UC = unspotted calves, SJ = spotted juveniles, SA = subadults, and UA = unsubadults.

Model	AICc	ΔAICc	N (95% CI)	UC	SJ	SA	UA
$\Phi\{g\}\cdot p\{g\}\cdot b\{g\}\cdot N\{g\}$	48533	0	193 (167-249)	36 (34-44)	58 (48-77)	40 (35-52)	59 (51-75)
$\Phi\{t\}\cdot p\{g\}\cdot b\{g\}\cdot N\{g\}$	58363	9830	1,178 (513-3036)	194 (92-474)	427 (184-1070)	203 (84-585)	354 (153-907)
$\Phi\{t\}\cdot p\{.\}\cdot b\{t\}\cdot N\{g\}$	58369	9836	914 (431-2215)	214 (101-520)	240 (113-580)	194 (91-475)	266 (126-640)
$\Phi\{.\}\cdot p\{g\}\cdot b\{t\}\cdot N\{g\}$	58419	9886	344 (235-578)	70 (52-105)	124 (76-231)	51 (40-75)	99 (68-167)
$\Phi\{g\}\cdot p\{g\}\cdot b\{t\}\cdot N\{g\}$	58420	9887	318 (224-520)	66 (50-99)	111 (71-202)	51 (40-75)	90 (64-144)
$\Phi\{.\}\cdot p\{.\}\cdot b\{t\}\cdot N\{g\}$	58421	9888	282 (218-398)	66 (51-95)	74 (57-104)	60 (46-86)	82 (64-114)
$\Phi\{g\}\cdot p\{.\}\cdot b\{t\}\cdot N\{g\}$	58423	9890	275 (213-386)	65 (50-93)	71 (56-99)	60 (46-86)	79 (62-108)
$\Phi\{.\}\cdot p\{.\}\cdot b\{.\}\cdot N\{g\}$	58453	9919	198 (171-249)	46 (40-59)	52 (45-65)	42 (36-54)	58 (50-71)
$\Phi\{g\}\cdot p\{.\}\cdot b\{g\}\cdot N\{g\}$	58454	9921	196 (170-246)	46 (40-58)	51 (44-63)	42 (36-54)	57 (50-70)
$\Phi\{g\}\cdot p\{g\}\cdot b\{.\}\cdot N\{g\}$	58456	9923	203 (172-263)	46 (39-58)	58 (48-77)	40 (35-52)	59 (51-75)
$\Phi\{.\}\cdot p\{g\}\cdot b\{.\}\cdot N\{g\}$	58457	9924	201 (172-258)	46 (39-58)	56 (47-72)	41 (35-54)	58 (50-73)
$\Phi\{.\}\cdot p\{g\}\cdot b\{g\}\cdot N\{g\}$	58457	9924	201 (172-259)	46 (39-59)	56 (47-73)	41 (35-55)	58 (50-74)

Table 4. Age classes (*n*), range, mean (± SD), and Kruskal-Wallis test (χ^2) results of environmental characteristics among the age classes; BF = Beaufort Sea State, CC = cloud cover, DS = distance offshore, RN = rain, SL = sunlight, SD = Secchi disk (turbidity), TD = tidal, WD = water depth, WP = wind power, and WT = water temperature.

	Age classes (N)								
	UC (101)		SJ (103)		SA (137)		UA (98)		
Parameters	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range	χ^2
BF	0.27 ± 0.46	0.00-2.00	0.35 ± 0.52	0.00-2.00	0.34 ± 0.50	0.00-2.00	0.32 ± 0.47	0.00-1.00	1.51
CC	0.11 ± 0.31	0.00-1.00	0.08 ± 0.27	0.00-1.00	0.12 ± 0.32	0.00-1.00	0.05 ± 0.22	0.00-1.00	3.83
DS	501.80 ± 559.46	17.00-2,976.73	438.19 ± 553.32	17.00-2,556.00	527.8 ± 589.16	28.45-2,976.73	597.86 ± 618.21	53.00-2,556.00	11.20*
RN	0.03 ±0.17	0.00-1.00	0.02 ± 0.14	0.00-1.00	0.03 ± 0.17	0.00-1.00	0.01 ± 0.10	0.00-1.00	1.29
SL	1.56 ± 0.65	0.00-2.00	1.66 ± 0.58	0.00-2.00	1.55 ± 0.67	0.00-2.00	1.72 ± 0.51	0.00-2.00	5.76
SD	1.33 ± 0.57	0.50-3.00	1.29 ± 0.56	0.50-3.00	1.18 ± 0.54	0.50-3.00	1.43 ± 0.63	0.5-3.0	16.17**
TD	0.59 ± 0.49	0.00-1.00	0.69 ± 0.46	0.00-1.00	0.66 ± 0.47	0.00-1.00	0.69 ± 0.46	0.00-1.00	3.52
WD	4.58 ± 1.99	1.90-12.70	4.73 ± 2.41	1.70-16.40	4.75 ± 2.78	1.70-16.40	5.42 ± 3.12	1.70-16.40	3.99
WP	0.30 ± 0.46	0.00-1.00	0.39 ± 0.49	0.00-1.00	0.39 ± 0.49	0.00-1.00	0.34 ± 0.47	0.00-1.00	2.82
WT	29.91 ± 1.31	27.30-32.60	30.22 ± 1.33	27.30-32.60	29.82 ± 1.36	26.60-32.60	30.22 ± 1.24	27.30-32.60	9.65*
pH	3.19 ± 0.28	7.15-9.07	8.20 ± 0.27	7.15-9.05	8.18 ± 0.29	7.15-9.07	8.20 ± 0.25	7.89-9.06	9.68*

Table 5. Component loadings of environmental characteristics at the sighting points based on principal components analysis (PCA); variables with a high influence on the determination of components are shown in bold.

Environmental characteristics	PC1	PC2	PC3
BF	0.1121	**0.8185**	-0.1876
CC	**-0.8546**	0.1042	-0.1631
DS	0.0623	0.0507	**0.7303**
RN	**-0.7490**	-0.1164	0.0304
SL	**0.8188**	-0.0853	0.1510
SST	0.4669	-0.2706	0.4120
TB	0.1923	-0.2536	**0.7835**
TD	-0.1623	0.6142	0.2931
WD	0.0531	0.2079	**0.7542**
WP	0.0693	**0.8855**	-0.1444
pH	0.3333	-0.5819	-0.1832
eigenvalue	2.3783	2.3849	2.1114
% variance explained	21.62	21.68	19.19

Note: BF = Beaufort Sea State, CC = cloud cover, DS = distance offshore, RN = rain, SL = sunlight, SST = sea-surface temperature, TB = turbidity, TD = tidal, WD = water depth, and WP = wind power

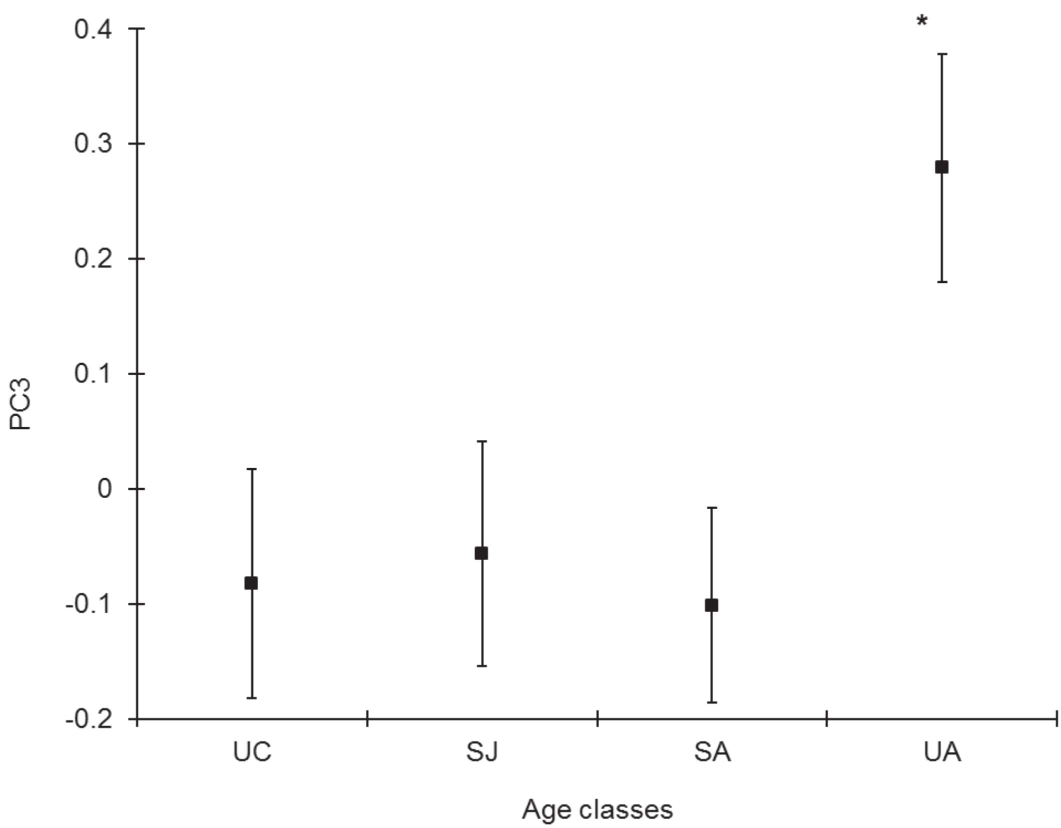

Figure 4. Mean (± SE) of PC3 (primarily determined by DS, TB, and WD) according to age class in humpback dolphins; UA dolphins had a significantly higher PC3 than the UC, SJ, and SA dolphins (GLM, ANOVA: $F = 3.459$, $p < 0.05$).

Table 6. Difference (*F*-matrix) in PC3 among age classes (tested by discriminant analysis)

	UC	SJ	SA
SJ	0.034		
SA	0.022	0.122	
UA	6.605*	5.814*	8.523*

* $p < 0.05$

duplicate identifications of the same individual. The probability of such "tag-loss" bias, however, should be very low in this study as the temporal scale (17 mo) may not be long enough for the emergence of new, unidentified marks on the identified individuals. Photo-ID experiments on humpback dolphins with a longer temporal scale, however, should be viewed with caution regarding bias from the evolving marks.

Population Size and Distribution Tendency

This study estimated that 193 (95% CI: 167 to 249) humpback dolphins occur in the survey area. This estimate is much higher than that in the neighboring Khanom waters previously estimated by Jaroensutasinee et al. (2010). The difference in the accumulative sighting curve among surveys in waters off Donsak (this study) and Khanom (Jaroensutasinee et al., 2010) suggests different distribution patterns between the humpback dolphins in Donsak and Khanom waters. In Khanom waters, humpback dolphins may have been fully identified according to the asymptotic sighting curve (Jaroensutasinee et al., 2010). The distribution of these humpback dolphins may be confined to the surveyed Khanom and surrounding waters, or alternatively, the dolphins may have a wider distribution range, periodically moving between Khanom waters and neighboring habitats. Based on the monthly sampling frequency (Jaroensutasinee et al., 2010) and very rare observations/reports of humpback dolphin occurrence on the southern Khanom coast, we prefer the hypothesis that the distribution of the humpback dolphins off Khanom may be confined to the waters surrounding Khanom, although this remains to be confirmed through future surveys.

In contrast, the humpback dolphins near Donsak waters may have a wider distribution than the survey area. The progressively increasing accumulative sighting (Figure 3a) indicates that unidentified humpback dolphins continuously and periodically enter this region. Some of the unidentified humpback dolphins might come from nearby Khanom waters; the eastern part of the present survey area partially involves this zone (Figure 1). As most of the humpback dolphins off Khanom are thought to have been identified, cross-matching between Jaroensutasinee et al. (2010) and this study can resolve the question as to how many humpback dolphins routinely move between Donsak and Khanom waters. Besides the Khanom waters, the coastal waters to the west of Donsak can provide other potential habitats for the humpback dolphins where they may move across a relatively long temporal scale. Unfortunately, neither the spatial nor temporal scale of this study could provide answers to this matter. Successive surveys to disclose the site fidelity of the humpback dolphins in the survey area are needed.

Habitat Characteristics

Within the survey area, the humpback dolphins were observed to be primarily distributed in shallow and inshore waters, similar to the distributions of humpback dolphins investigated elsewhere (Ross et al., 1994; Karczmarski et al., 1999; Hung & Jefferson, 2004; Wang et al., 2004, 2007). Multivariate statistics indicate a subtle difference in the distribution tendency among different age classes in this study, however. According to our analysis, the distance offshore (DS), water depth (WD), and turbidity (TB; higher TB value represents clearer water) are the most influential variables. Our analysis also indicated that UA dolphins have a greater tendency to be distributed further offshore (DS > 518 m) and in clearer water (TB > 1.29 m). Off the Donsak waters, the UA dolphins frequently occur on rocky shores, sand beaches, and artificial structures; generally, these areas are deeper and clearer than seagrass and mud flat areas where the UC, SJ, and SA dolphins are sighted more commonly.

Implication for Conservation

On the *IUCN Red List of Threatened Species* (Reeves et al., 2008), the Indo-Pacific humpback dolphin is classified as near threatened (NT), which implies a declining trend on a global scale (IUCN, 2001); however, baseline data regarding the extent of occurrence, population size, and population trend are still rare and are often lacking across most of Southeast Asia. Results of this study partially fill the information gap of humpback dolphin occurrence in Southeast Asia. More than 200 humpback dolphins are found in the coastal waters off Donsak and Khanom in the central west Gulf of Thailand (Figure 1), with a tendency for differing habitat characteristics between younger (the UC, SJ, and SA) and older (the UA) dolphins (Figure 4). Although the POPAN model provides an estimate of the apparent survival rate (Φ), which is critical to project a population trend (Currey et al., 2009; Huang & Karczmarski, 2014; Huang et al., 2014), individual immigration/emigration could play an important role in estimating

Φ as the accumulative sighting curve does not reach an asymptote in this study. Therefore, the application of Φ to population trend projections should be treated cautiously. Given the numerically small N-estimate of humpback dolphins off the Donsak–Khanom coast, which is potentially prone to the effects of diverse anthropogenic activities, precautionary acts are needed immediately to mitigate and minimize the threats likely to endanger the population survival and integrity of coastal habitats.

Off the Donsak–Khanom coast, various anthropogenic activities directly and indirectly impact the survival of humpback dolphins (Figure 5). The humpback dolphins are frequently sighted very close to fishing nets (Figure 5a), suggesting a direct and lethal risk of incidental mortality due to net entanglement (Figure 5b), and indirect but prolonged influence from biomass removal and, hence, prey depletion (Bearzi et al., 2008, 2010; Piroddi et al., 2011). Many humpback dolphins present scars from propeller cuts (Figure 5c). Local dolphin-watching boats frequently access humpback dolphins at an extremely close proximity (Figure 5d). Other threats, such as water pollution and coast modification/alteration, may also weaken the humpback dolphin viability off the Donsak and Khanom waters in an implicit but chronic manner. As our analyses indicate a higher tendency toward inshore and shallow water for the younger humpback dolphins than the adult dolphins of the Donsak–Khanom habitat, coastal alteration following escalating land utilization along the coast might impact younger dolphins in particular and, hence, the long-term survival of this population.

Designation of marine mammal protected areas (MMPAs) is traditionally considered an ultimate resolution for mitigating anthropogenic impacts at an integrative perspective (Hoyt, 2005; Slooten et al., 2006; Slooten, 2007; Ross et al., 2010; Gormley et al., 2012). Extending the existing Ang Thong Marine National Park southward (Figure 1a) to encompass the distribution range of the investigated humpback dolphins may provide a framework for humpback dolphin conservation off the Donsak and Khanom waters. The actual implementation and enforcement of management, however, is more complicated in practice because of the humpback dolphins' close proximity to waters where human activities are intensive. The primary conservation strategies that should

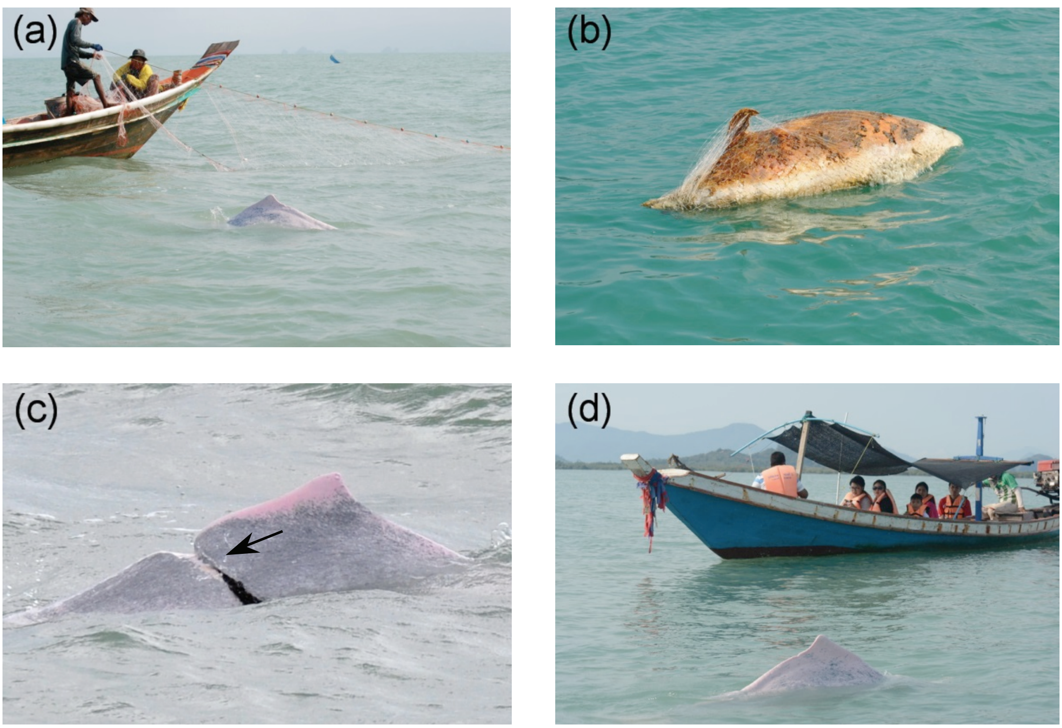

Figure 5. Anthropogenic activities likely to impact the survival and habitat integrity of humpback dolphins off Donsak waters: (a) extreme proximity to fishery vessels, (b) fish-net entanglement, (c) propeller cutting (arrow), and (d) proximity from dolphin-watching tour boats.

be integrated into current management strategies can include, but should not be limited to, increasing local awareness, introducing alternative fishing gears reinforced by constant and adequate enforcement, and defining boat-traffic and dolphin-watching regulations in dolphin distribution areas (Flores & Bazzalo, 2004; Kreb, 2005).

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