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Peak Mating and Breeding Period of the Humpback Whale

—(*Megaptera novaeangliae*) in Okinawa Island, Japan

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Abstract

Although detailed knowledge on breeding ecology of humpback whales is required for developing effective and sustainable whale watching programs in breeding areas, the breeding ecology of this species is still poorly understood. Hence, we examine the migratory timing of humpback whales in Okinawa that is one of their breeding ground, distinguishing the reproductive status (male, female, or female with a calf), group compositions (singleton, pair, or whales more than three) and group types (singer or competitive group) in order to assess the peak period of breeding activities. A total of 1192 days of photo-identification surveys were conducted from 1991 to 2012 and a total of 7366 humpback whales were sighted during the surveys. Among them, 1284 whales were sex-determined (848 males, 147 females and 289 females with a calf), 1138 singletons, 1416 pairs and 710 groups of more than three whales were observed. Females without calves tended to occur from late January to late February, which was the beginning of the breeding season and male-female pairs were observed most frequently during this period. The peak occurrence of competitive group which was considered a mating-related behavior group, formed by females and males, was also observed during this period. These results indicated that humpback whales peak mating period in Okinawa occurred between late January and late February. Females with a calf tended to increase from mid-February toward the end of the breeding season maintaining a high sighting per unit effort (SPUE) value in late March. We, therefore, suggested that the peak time of birthing and newborn care was probably that period in Okinawa. These findings extended our knowledge on the reproductive ecology of humpback whales in Okinawan waters.

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Keywords

Humpback Whale, Mating, Birthing, Reproductive Status, Okinawa

1. Introduction

Humpback whales (*Megaptera novaeangliae*) are found in oceans globally and annually migrating between the high-latitude polar waters for feeding and the low-latitude tropical and subtropical waters for breeding [1]-[3]. In the North Pacific, summer feeding aggregation of humpback whales occurs in the Bering Sea, as well as near Alaska, British Colombia, and California [4]. Winter mating and nurturing, on the other hand, occur around the islands or continental coastlines [5] of Mexico and the Revillagigedo Archipelago [6], Hawaiian Islands [7], and Japan and Philippines [7]-[12].

Commercial whaling conducted in the North Pacific in 1960s caused a significant decrease in the population of humpback whales inhabiting this area; Johnson and Wolman (1984) [13] reported that, from 1905 to 1960, approximately 23,000 individuals were caught in feeding and breeding areas. Rice (1978) [14] inferred that by 1966, when the International Whaling Commission (IWC) prohibited the commercial hunting of humpback whales, the population in the North Pacific was reduced to as few as 1000 individuals. However, this population has increased in recent years [15] and in 2008, its status was down-listed from Vulnerable to Least Concern on the Red List of threatened species produced by the International Union for Conservation of Nature and Natural Resources (IUCN).

In 1975, after commercial whaling on humpback whales was prohibited, whale watching tours begun in New England and in Hawaii [16], and this had been one of the fastest growing tourism products worldwide [17]. As the whale watching industry developed, the concern over its negative impacts on the whales increased [18]-[20]. Previous reports indicated the whales being watched presented behavioral changes, which were confirmed by close approaches of the whale watching vessels [21]-[23]. Berrow (2003) [17] suggested that, in order to reduce the impact on whales by whale watching tours and to develop sustainable whale watching management, it was essential to obtain basic information on cetaceans, including information on their breeding ecology and behaviors.

In the North Pacific, studies on breeding ecology and behavior of humpback whales had been conducted for many years in breeding areas such as Mexico, Hawaii, and Okinawa [6] [8]-[10] [24] [25]. In all these studies, males, females, and females with a calf were observed in the breeding areas every winter. Based on whaling data, previous studies suggested that the timing of migration between feeding and breeding areas varied according to the reproductive status of the whales [1] [8] [26]. In addition, certain behaviors (e.g., complex sounds emitted by males) and group types (e.g., competitive groups), considered to be related to the breeding activities of humpback whales, were only observed in breeding areas. The complex sounds emitted by male humpback whales (song) mainly in breeding areas were considered related to the male's mating display and to the intrasexual competition among males [27]-[31]. Competitive groups were considered as mixed groups of females and males in which males competed for the chance to mate with group females [32]. Nevertheless, there was no direct observation of mating or birth of humpback whales and therefore the breeding ecology of this species was still poorly understood.

In the present study, we analyzed data collected during the winter breeding season of humpback whales in Okinawan waters for 22 years (1991-2012) in order to assess the peak periods of mating and birth behaviors, contributing to the development of a sustainable whale watching plan as well as an effective species conservation plan.

2. Materials and Methods

2.1. Boat Surveys

Surveys of humpback whales occurred during the winter breeding season (January-March), off the coast of Kerama Islands (1991-2012) and Ie (2006-2012) Island in Okinawa, Japan (**Figure 1**). Study sites in Kerama (26˚03'38"N, 127˚06'25"E, 26˚24'14"N, 127˚31'10"E) and Ie (26˚33'12"N, 127˚34'22"E, 26˚48'37"N, 127˚56'11"E) Island were surveyed using small vessels (3.2 - 4.9 t) with at least two observers on board, one at the each side of the vessel.

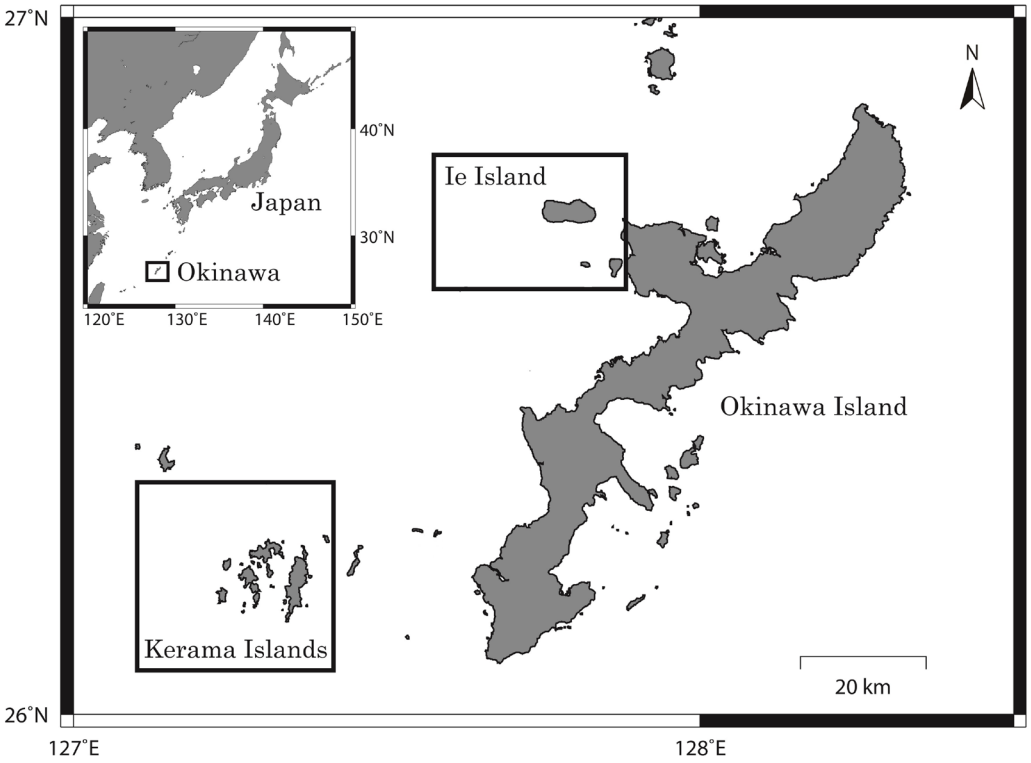

Figure 1. Ie and Kerama Islands in Okinawa, Japan. Study areas are indicated within boxes.

2.2. Data Collection

When whales were sighted, their tail flukes were photographed for identification [33] by comparing photos with those cataloged for whales previously identified in both study areas. Photographed individuals identified in each year that did not match the whales identified in previous years were assigned a new identification number and added to the catalogs. The sighting location (latitude and longitude), day, time and group composition, as well as the behavior of the whales, were recorded.

2.3. Definitions

Based on the definitions provided by Payne and MacVay (1971) [27], Winn *et al*. (1973) [34], Glockner (1983) [24], and Rasumussen (2011) [34], whales' reproductive status and group characteristics were classified in to eight classes as follows:

Category 1: Reproductive status

Male (M)—An individual observed as an escort during the surveys, or that has been previously observed as a singer and/or as an escort [24] [34].

Female (F)—An individual previously observed with a calf [24].

Female with a calf (Fc)—An individual observed with a calf during the surveys [24].

Category 2: Group composition

Singleton—Only one individual was observed.

Pair-Two individuals were observed but without a calf.

More than three—More than three individuals were observed but without a calf.

Category 3: Group type

Singer (Ms)—A male observed singing during the surveys [24] [27]. When singers were located, we stopped the engine of the vessel and heard the song through the hull of the boat without using a hydrophone, at the exact position where the whale dove, in order to ensure that this was the singing individual. Consequently, its song was recorded with a hydrophone for more than 10 min to confirm it singing by checking repeated phrases and themes [27].

Competitive group (CG)—A group formed by more than three adults exhibiting aggressive behavior toward each other [35].

2.4. Data Analysis

To examine temporal changes in humpback whale occurrence in the Okinawa Island region, we defined the three 10-days periods within each month (early, middle, and late), and calculated whale sighting per unit effort (SPUE) as follows:

$$SPUE = ni/si$$

where:

ni = number of sights during each period.

si = number of days that the survey was conducted during each period.

To assess humpback whales' peak period of reproductive activities in Okinawan waters, we calculated SPUE categorizing by types of eight classes described above and compared the SPUEs between classes. All the statistical analyses were conducted using Microsoft Excel (Microsoft Corp., Redmond, WA, USA), and differences were evaluated for statistical significance using the Kolmogorov-Smirnov test and $P < 0.05$.

3. Results

3.1. Survey Effort and Observations

Table 1 summarizes the survey effort, number of whales sighted and the SPUE calculated for each monthly period from January to March, from 1991 to 2012. Although the largest number of survey days were counted in mid-March (205), the largest values of number of sighted whales and SPUE. **Figure 2** shows SPUE temporal trends during the first and second halves of the survey period (first: 1991-2001, second: 2002-2012). No significant differences in occurrence trends were found between the two decades (Kolmogorov-Smirnov test; $P = 0.55$). The mode of SPUE for humpback whales in Okinawa was observed in mid-and late February.

3.2. SPUE Temporal Trends in Categories

Figure 3 shows the temporal trend of SPUE in each reproductive status of whales. Significant differences in SPUE temporal trends were found between M and F and between F and Fc (Kolmogorov-Smirnov test; M, F: $P < 0.01$; F, Fc: $P < 0.01$), but not between M and Fc (Kolmogorov-Smirnov test; $P = 1.54$). M and Fc SPUE tended to increase from mid-February toward the end of the breeding season, whereas F SPUE tended to be increase in late January, and decreasing from early March toward the end of the breeding season.

3.3. SPUE Temporal Trend in Group Composition

The numbers and ratio of occurrence according to group size are summarized in **Table 2**. Pairs, followed by singletons, were observed more frequently than groups with more than three whales. However, whale sex was determined more frequently in singletons than in pairs.

Table 1. Humpback whale sighting per unit effort (SPUE) within each ten days period during winter breeding seasons from 1991-2012.

Period		Number of whales sighted	Number of days of surveys	SPUE	%
January	Middle (11 to 20)	211	50	4.22	8.7
	Late (21 to 30)	556	88	6.31	13
February	Early (1 to 10)	995	145	6.86	14.1
	Middle (11 to 20)	1283	168	7.63	15.7
	Late (21 to 29)	1329	171	7.77	16
March	Early (1 to 10)	1226	177	6.92	14.2
	Middle (11 to 20)	1115	205	5.43	11.2
	Late (21 to 30)	651	188	3.46	7.1
Total		7366	1192	-	100

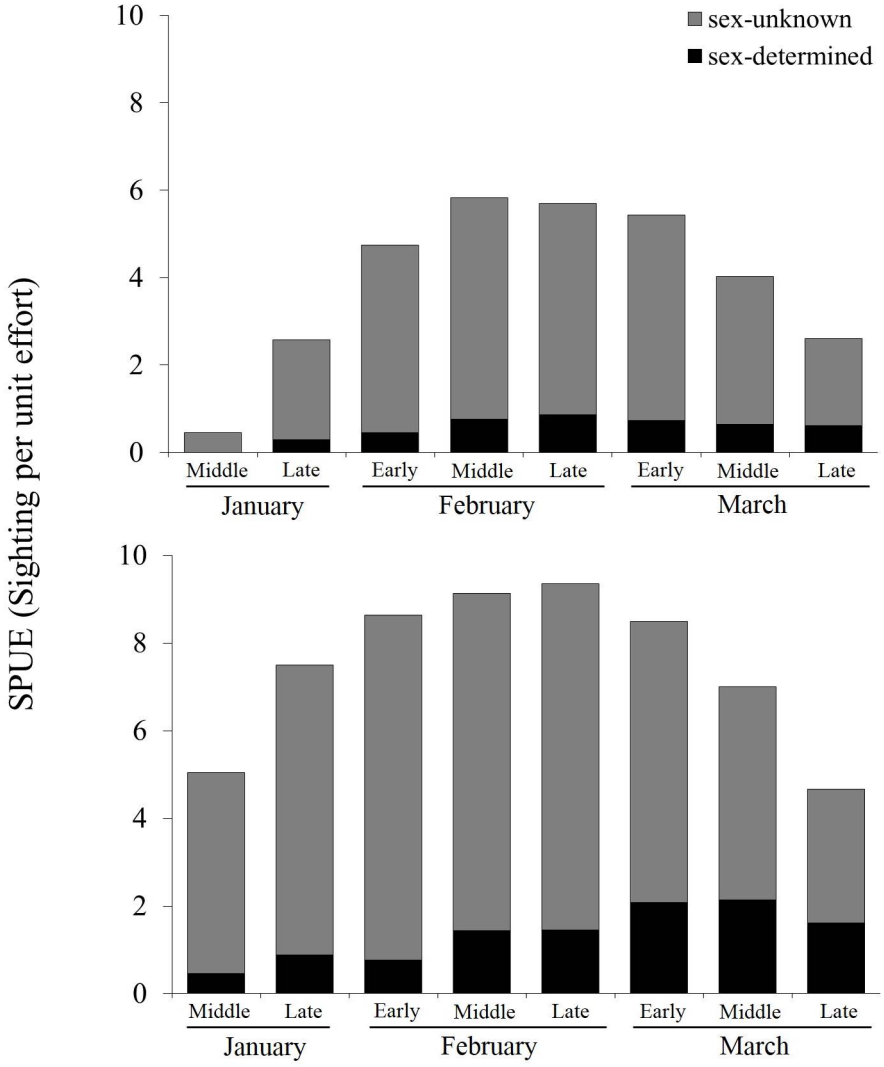

Figure 2. Humpback whales SPUE during the two decades of the survey: (a) first decade, 1991-2001 (sex-unknown: n = 2104, sex-determined: n = 362), and (b) second decade, 2002-2012 (sex-unknown: n = 3978, sex-determined: n = 922).

Figure 4 shows the temporal trend of SPUE in singletons and pairs where the sex of all individuals was determined. Significant difference was found between the SPUE temporal trends in singletons and pairs (Kolmogorov-Smirnov test; $P < 0.01$); singletons tended to occur at the end of the breeding season, whereas pairs tended to occur in the beginning of the season. Among the 227 sex-determined singletons, 215 (94.7%) were M and 12 (5.3%) were F; Of the 55 sex-determined pairs, 22 (40%) were male dyads (MM), 32 (58.2%) were male-female pairs (MF), and only one was a female–female pair (FF = 1.8%). Both results revealed male predominance in Okinawa. A significant difference was found between MM and MF SPUE temporal trends (Kolmogorov-Smirnov test; $P < 0.01$), with MM tending to occur at the end of the breeding season and MF tending to occur in the beginning of the season; FF were rarely found throughout the breeding season (**Figure 4**).

3.4. SPUE Temporal Trend in Group Type

One hundred thirty-three singers were observed (**Figure 5(a)**), and the SPUE increased sharply in early March and then slowly decreased toward the end of the breeding season. A total of 234 competitive groups occurred with increased SPUE from early to late February and decreased SPUE from early March toward the end of the breeding season (**Figure 5(b)**).

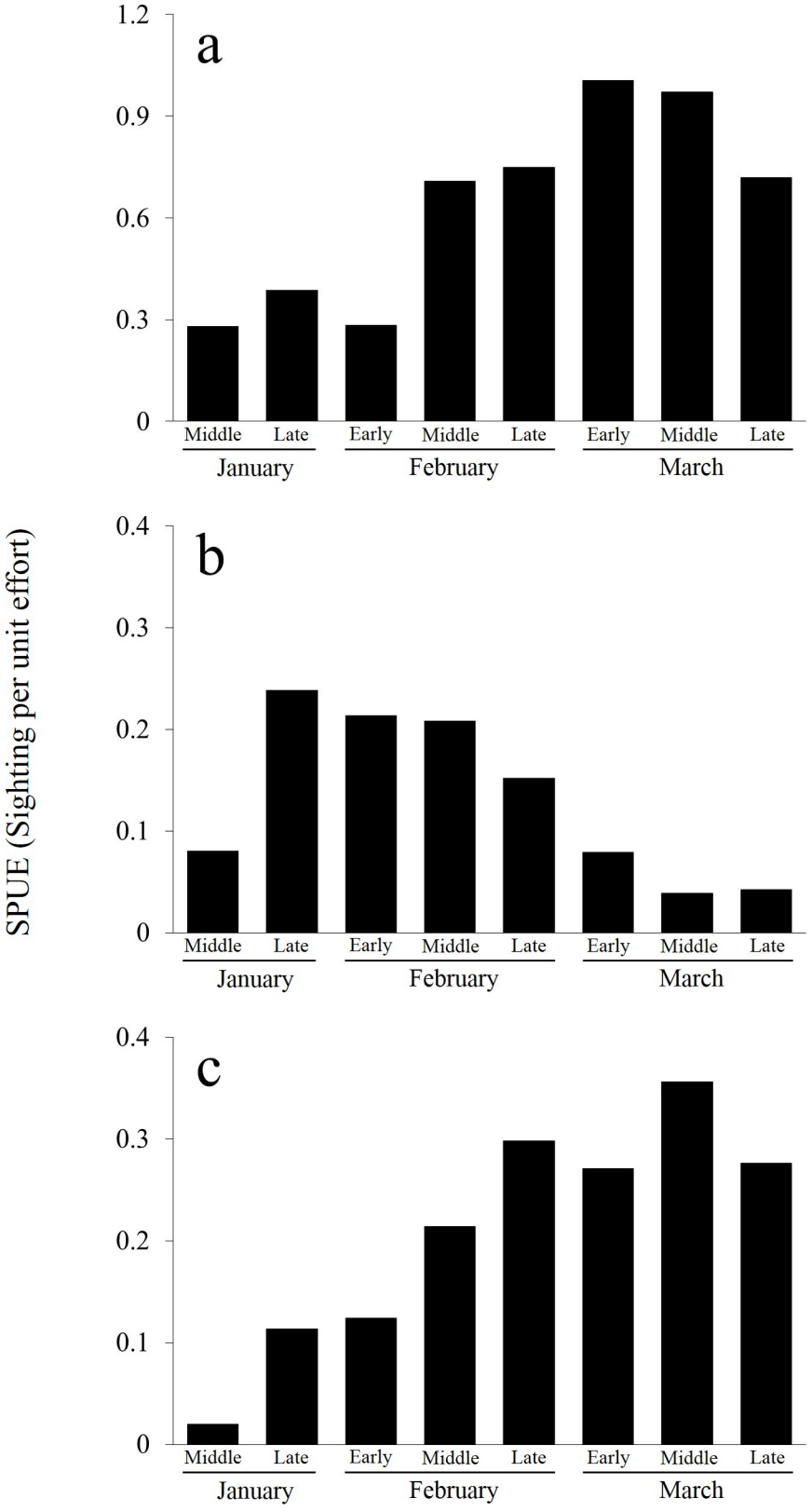

Figure 3. SPUE temporal trends according to humpback whale reproductive status: (a) male (n = 848), (b) female (n = 147) and (c) female with a calf (n = 289).

Table 2. Number, ratio and SPUE of each group observed in humpback whale surveys. Numbers in parentheses refer to the numbers of groups without females with a calf in which the sex of all whales was determined.

Group compositions	Number of groups (sex-determined)	%	SPUE
Singleton	1138 (227)	34.9	0.955
Pair	1416 (55)	43.4	1.188
More than three whales	710 (2)	21.8	0.596
Total	3264 (284)	100	-

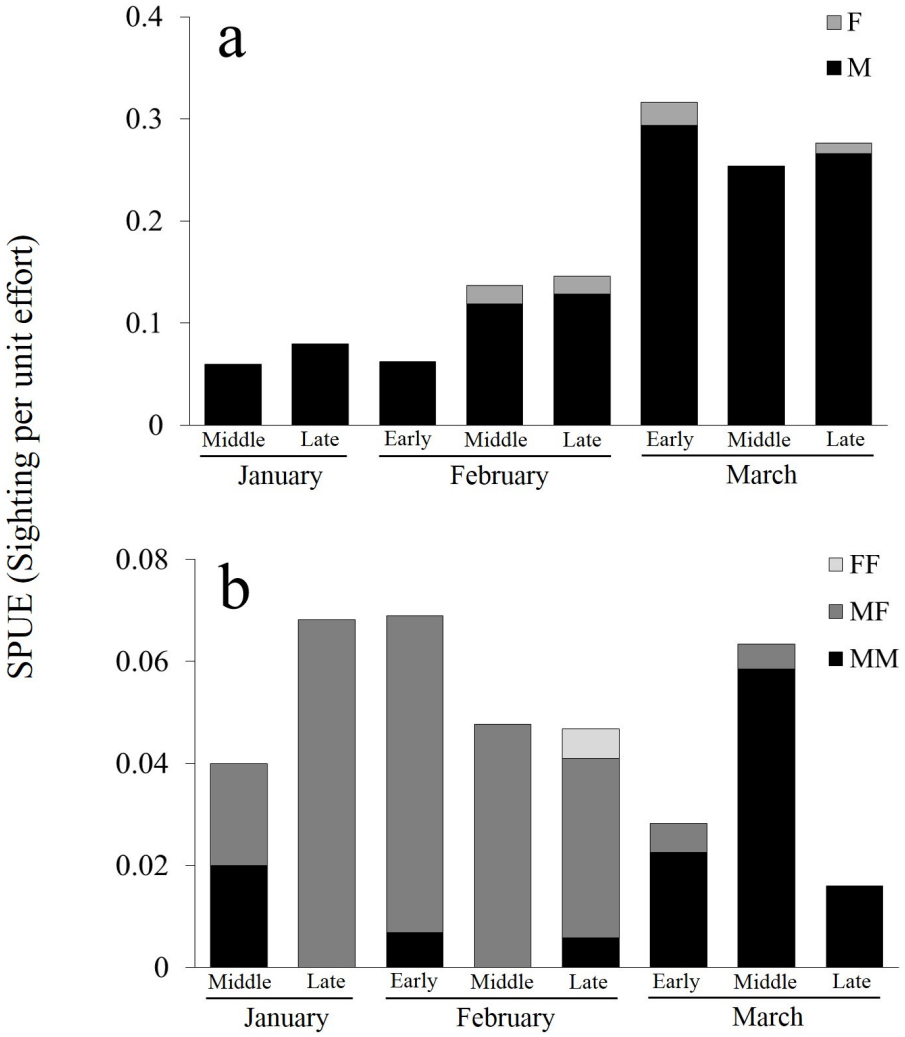

Figure 4. SPUE temporal trends in singletons and pairs where the sex of all group members was determined: (a) singletons (M: n = 215, F: N = 12) and (b) pairs (FF: n = 1, MF: n = 32, MM: n = 22).

4. Discussion

4.1. Occurrence of Humpback Whales in Okinawa

In the past 22 years, humpback whale occurrence in Okinawa has tended to increase from January to February, starting to decrease in early March. No significant differences were found between the trends observed during the two halves of the survey period (first: 1991-2001, second: 2002-2012), suggesting this trend is universal for the humpback whales breeding in Okinawan water.

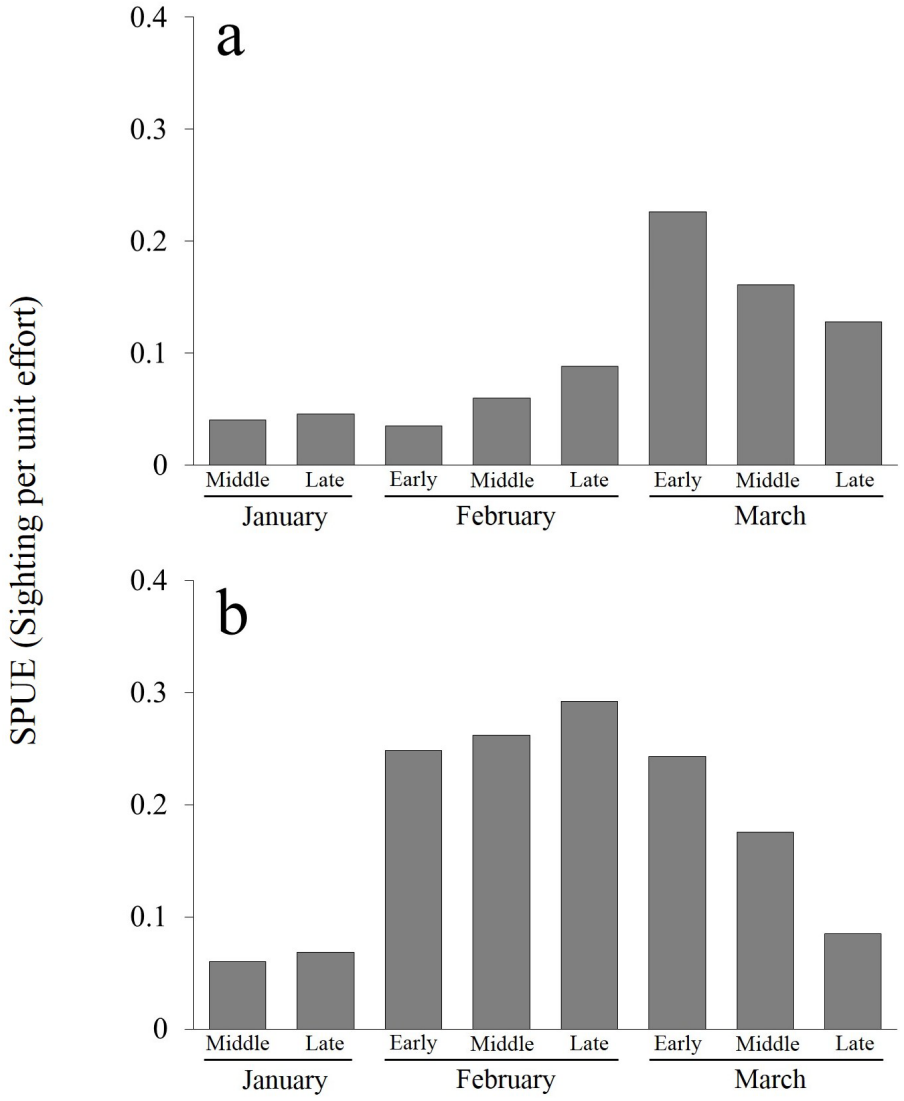

Figure 5. SPUE temporal trends according to group types: (a) singer (n = 133) and (b) competitive group (n = 234).

4.2. Peak Mating Period

Analyses of the temporal trends according to the reproductive status that F tended to occur from late January to late February, which is the beginning of the breeding season. Previous reports suggested that mating and lactating females tend to arrive early in the season [36] [37], being the first to leave the breeding area [38]. Hence, most females in Okinawan waters would already have mated between late January and late February. Supporting this hypothesis, most male-female pairs were observed during this period; the peak occurrence of CG which is considered a mating-related behavior group, formed by females and males, was also observed during this period. Overall, these results indicated that humpback whales peak mating period in Okinawa occurred between late January and late February.

Male occurrence tended to increase from mid-February, maintaining a high value in late February when females were rarely found, resulting in the high male proportion in Okinawa after late February. In fact, this might explain the fact that 90% of singletons and pairs of whales observed in this area were M (singleton) and MM (pair). Ms (singing male individuals) also tended to increase in early March. Therefore, males are probably long-staying to increase mating opportunities with females remaining in the ground, exacerbating their mating display by singing behavior under heated intra-sexual competition.

4.3. Peak Birthing and Nurturing Period

Results showed females with a calf tended to increase from mid-February toward the end of the breeding season, maintaining a high SPUE value in late March, whereas M and F tended to decrease during this period. These results are in agreement with the observation that females with a calf are the last to reach the breeding area from the feeding area and are the last to leave the breeding area [1]. Previous reports also suggested that pregnant females appear to spend a prolonged time in feeding areas, and they spend a prolonged period in breeding ground after giving birth to a calf, they spend a prolonged period in breeding areas to reduce the time spent in cold waters [39]. Thus, pregnant females might give birth after mid-February and they nurse their calves toward the end of the breeding season in Okinawa.

4.4. Conclusion

Our data on temporal trends of humpback whale occurrence in Okinawan waters indicated that there were peak periods of mating, birthing, and nurturing, during a breeding season. These findings represent valuable information on the breeding ecology of humpback whales, which is still poorly understood. Moreover, this information will contribute to the development of effective and sustainable whale watching tours, reducing the negative impact on the whales watched in breeding areas. For example, watching whale pairs should be avoided, especially in the hypothesized peak mating period, in order to reduce the possibility of disturbing their mating behavior. Tour vessels should also avoid approaching females with a calf during the peak birthing period in order to reduce the negative impacts on newly born calves. However, the peak mating, birthing, and nurturing periods suggested in this study still need support from direct observations of mating, birthing, and nurturing behaviors during those periods to validate them. Furthermore, the role of competitive groups and male's singing behavior still needs to be clarified, as no clear evidence of their association with mating behaviors has been provided yet. Therefore, further research on the behavior of humpback whales in their breeding grounds is essential for clarifying the breeding ecology of this species.

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