

The Large-Scale Distribution of Humpback Whales (*Megaptera novaeangliae*) Wintering in French Polynesia During 1997-2002

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Abstract

The distribution of wintering humpback whales, *Megaptera novaeangliae*, was investigated during the 1997-2002 period with most data coming from dedicated small boat surveys. In complement, sightings were collected systematically during an opportunistic large vessel survey in 1999, and a sighting program was set up with the French Armed Forces in 2001 and 2002. Every year, dedicated surveys were organized on a 12-m sailboat during the September to November period: a three-observer standard sighting protocol was maintained, with systematic hydrophone sampling to detect singing males. Surveys took place in the Society Islands (the Societies) (1997-2002), Australes Islands (1999 and 2000), Marquesas Islands (2000), and Tuamotu Archipelago (2002). These surveys totaled 12,695 km of effective effort and 2,594 acoustic samples. A total of 129 on-effort sightings were collected, with groups numbering up to six animals, including a calf or juvenile, on 38 occasions. Singers were detected acoustically in three archipelagos, averaging 20.7% of hydrophone stations, with a maximum of 27.0% (Windward group of the Societies) and a minimum of 9.4% in the Tuamotu; no whale was heard in the Marquesas. Although survey effort included offshore waters, whales were mostly (83%) found less than 2 km from the shoreline. All surveyed islands sheltered at least one male humpback, and female/calf pairs were seen in three archipelagos, suggesting that mating occurs over a wide area. The extensive distribution range was confirmed by 29 complementary sightings from the Armed Forces and 17 sightings from the opportunistic survey vessel. The distribution range of whales embodies three archipelagos and a total area of nearly 2,000,000 km², but humpback whales are marginally present in the Marquesas. The sighting rate for individuals were estimated for inshore waters of different archipelagos from visual data: a maximum of 1.54 whale/100 km was found in the Windward Islands, 1.48 whale/

100 km in the Australes, 0.72 in the Tuamotu, and a minimum of 0.35 whale/100 km around the Leeward Islands. These results suggest that humpback whales winter around more than 84 islands in French Polynesia, mostly away from scientific monitoring.

Key Words: boat survey, humpback whale, distribution, acoustics, tropical Pacific, *Megaptera*

Introduction

Southern humpback whales (*Megaptera novaeangliae*) feed around Antarctica during the austral summer and winter in tropical latitudes (Dawbin, 1966, 1997; Patterson, 1991; Winn & Reichley, 1985), including the South Tropical Pacific Ocean (Reeves et al., 1999). Little is known about humpback distribution in the waters of French Polynesia, although their presence was reported by Poole (1993) and further documented mostly from study sites in the Society Islands (the Societies) (Gannier, 2000; Gannier & Gannier, 1998) and Rurutu, a whale-watching site in the Australes (Lefèvre et al., 1999; Poole & Darling, 1999). Humpback whales commonly are seen in French Polynesia from July to December, and an extended distribution range was suspected from preliminary survey results, even before data from the Marquesas and Tuamotu were obtained (Bourreau & Gannier, 2001; Gannier et al., 2000). On wintering grounds, soniferous whales are males (Darling & Bérubé, 2001; Darling et al., 1983) and quiet whales may be juveniles, subadults, or adults of both sexes. Hence, visual-only surveys are inadequate to detect male humpback whales because the dive time of male singers ranges from 12 to 25 min (Spitz et al., 2002), with surfacing periods of only 1 to 2 min. The aim of this study was to provide a reasonable picture of wintering humpback whale distribution in French Polynesia. French Polynesia consists of 118 islands in four archipelagos spread over 5,000,000 km², thus, determining the humpback whale distribution posed a strong

challenge. A series of small boat surveys was carried out from 1997 to 2002, combining visual and acoustic sampling, and covering 29 islands in the Societies, the Australes, the Marquesas, and the northern and central Tuamotu. They were complemented by records from an opportunistic large vessel survey held in 1999, and from a sighting program organized with the French Armed Forces in 2001-2002.

Materials and Methods

Area of Study

Islands in French Polynesia are grouped in four archipelagos (Figure 1): the Societies (centered at 17° S, 150° W), which have been divided for the study into the Leeward group (five islands covered) and the Windward group (Tahiti, Moorea, and Maiao); the Marquesas centered at 9° S, 140° W (ten islands); the Australes with six islands, five of which are lined 200 km apart between 22° S, 155° W (close to the southern Cook Islands) and 24° S, 148° W; and the Tuamotu-Gambier Archipelagos, a group of 75 atolls spread over 2,000,000 km² (between 14° S, 150° W and 24° S, 134° W). The two latter archipelagos were partially sampled, the dedicated survey covering three

of the Australes (Raivavae, Tubuai, and Rurutu) and nine of the northern and central Tuamotu-Gambier groups (Makatea, Tikehau, Rangiroa, Arutua, Apataki, Toau, Fakarava, Kauehi, and Aratika). The French Armed Forces covered all archipelagos.

Most islands are surrounded by a coral reef, including atolls where barrier reefs are the only emerging part of the island edifice. Continental shelves are absent in French Polynesia, with the exception of the Marquesas Archipelago, whose islands are surrounded by a 5-10 km and about a 50 m deep shelf. All islands are of volcanic origin with 10-20° steep slopes, hence depths of more than 500 m are reached within 2 km from the coast or reef line. Water masses in French Polynesia are generally oligotrophic (Rougerie & Rancher, 1994), with the exception of the Marquesas, which lie at the boundary of the equatorial belt (Signorini et al., 1999). Sea surface temperature of 22-27° C are found within the area of study during the humpback wintering season, though it is dependent on the El Niño Southern Oscillation (ENSO) situation.

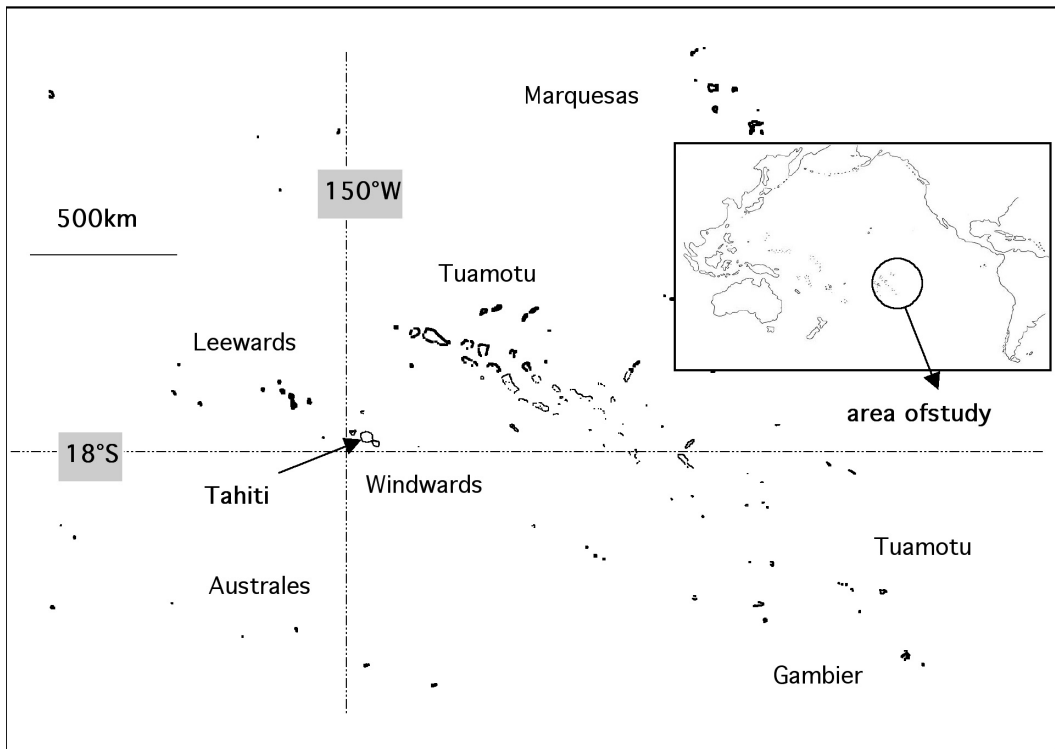


Figure 1. Area of humpback whale study in the southern tropical Pacific Ocean

Data Collection

Dedicated surveys were carried out from a 12-m auxiliary sloop during the September to November period from 1997 to 2002, except for the survey around the Marquesas (21 September to 9 November 2000), during which a 14-m catamaran was used. A total of 241 days were spent at sea to collect data: The Windward group of the Societies was sampled every year from 1997 to 2002; all other archipelagos (including the Leeward group of the Societies) were covered once or twice from 1997 to 2002 (Table 1). The same field protocol was applied along the survey period; visual searching was combined with systematic acoustic samples. The boat moved in zigzag tracks around the islands, mostly inshore and using diesel propulsion (speed 10 km/h). Surveys took place with wind speed less or equal to Beaufort 4. Offshore data were obtained during travel from one island to the next. Results from a six-week preliminary survey carried out in 1996 showed that humpbacks were concentrated close to the barrier reef, so from 1997 onwards we decided to sample a 3-km strip around the islands. Three observers shared the frontal sector, searching with naked eyes. Whales were positioned upon detection (i.e., radial distance and bearing were estimated) and approached. A single-channel towed hydrophone (Magrec Ltd, UK) was used throughout the study; the effective band width was 200 Hz-15 kHz. Acoustic listening was performed every 20 min. Whenever a singing whale was detected, it was tentatively located and approached using both acoustic and visual techniques.

The opportunistic vessel survey took place from 7 July to 5 August 1999 while the *R/V L'Atalante* was engaged in geophysical research

over a large area embodying much of the Australes Archipelago, located at about 23° S latitude, some 600 km south of Tahiti (Figure 1). One observer searched with naked-eye from the upper deck (15 m above the surface) while the vessel cruised at 18.5 km/h. The searching was interrupted when the wind speed exceeded Beaufort 5. This was a passing mode survey, and species identification was done with a pair of 10x50 binoculars.

Complementary data were collected from Armed Forces units in French Polynesia: the Gendarmerie Nationale, the Air Force helicopters and aircrafts, and the Navy patrol aircrafts and ships. After comprehensive training, sighting data were collected from June to November 2001 and 2002. This set of data was an opportunity to gain distribution knowledge for areas beyond our dedicated survey possibilities. The Armed Forces were not requested to report area coverage, but have been covering all areas in French Polynesia.

Data Processing

Oedipe geographical software (Massé & Cadiou, 1994) was used for mapping and effort calculations. Visual and acoustic data were used separately to quantify the whale presence. The distribution of whales was assessed by pooling data obtained over the whole period of survey (1997-2002). Only data collected within an archipelago were used to determine large-scale distribution; therefore, sampling segments from journeys between archipelagos were not included in the analysis. Acoustic data were mapped and a simple singing rate was computed to quantify singer presence in different archipelagos:

$$A\% = 100 \times (P / N+P)$$

Table 1. Humpback whale dedicated surveys in French Polynesia from 1997 to 2002

| Survey period | Archipelago | Survey duration (days) | Effective effort (km) | Number of sightings |
|-------------------------|------------------------|------------------------|-----------------------|---------------------|
| September-November 1997 | Windwards, Leewards | 25 | 1,168 | 14 |
| September-October 1998 | Windwards | 29 | 893 | 17 |
| September-October 1999 | Windwards | 23 | 1,165 | 24 |
| October 1999 | Australes | 9 | 624 | 6 |
| September-October 2000 | Windwards, Australes | 23 | 2,167 | 21 |
| October-November 2000 | Marquesas and offshore | 42 | 2,314 | 1 |
| September-November 2001 | Windwards, Leewards | 51 | 1,955 | 15 |
| September 2002 | Windwards | 19 | 957 | 23 |
| September-October 2002 | Tuamotu | 20 | 1,452 | 8 |

where, P is the number of positive listenings (i.e., when a whale song was heard during the station) and N the number of negative listenings.

Visual data were converted to a sighting rate for individuals (SRI), estimated for each archipelago by taking the daily effort as the sample unit:

$$\text{SRI} = (n.S) / (2L)$$

where, n is the number of on-effort sightings, S is the mean school size, and L is the effective sampling effort. Estimates were obtained by pooling inshore data from individual islands. This index was derived from the line-transect estimator formulated in Buckland et al. (1993) by taking the effective search width (ESW) as equal to unity (1 km), as in a strip transect approach. SRI may be assumed to be unbiased, provided that detection performance does not vary among surveys, which would be the case for a given survey protocol (i.e., same platform and number of observers) and if sighting conditions were constant on average. This assumption was realistic because only sampling effort obtained with sea state of Beaufort ≤ 4 was retained for the processing of SRI. Estimates were obtained with *Distance* 2.2 software (Laake et al., 1994) and SRI variances were estimated with component variances.

Confidence intervals were estimated on the basis of a log-normal distribution of the sighting rates for individuals as would be true for a density estimate (Buckland et al., 1993).

The same method was used to estimate the distribution from the large vessel opportunistic survey, whose results were kept separate from the small boat dedicated survey. French Armed Forces data were not effort-corrected and were used as complementary records to determine large-scale distribution range.

Results

Survey Effort

A total of 12,695 km was covered on-effort during dedicated surveys, including 9,276 km inshore. Because the Windward group in the Societies was monitored throughout the study period, other archipelagos received a less intense, but equivalent, effort (Figure 2): 6,912 km (5,336 km inshore) in the Windwards, 1,652 km in the Leewards (993 km inshore), 1,393 km in the Australes (674 km inshore), 1,452 km in the Tuamotu (972 km inshore), and 1,673 km in the Marquesas Islands (1,301 km inshore). The acoustic sampling effort consisted of a total of

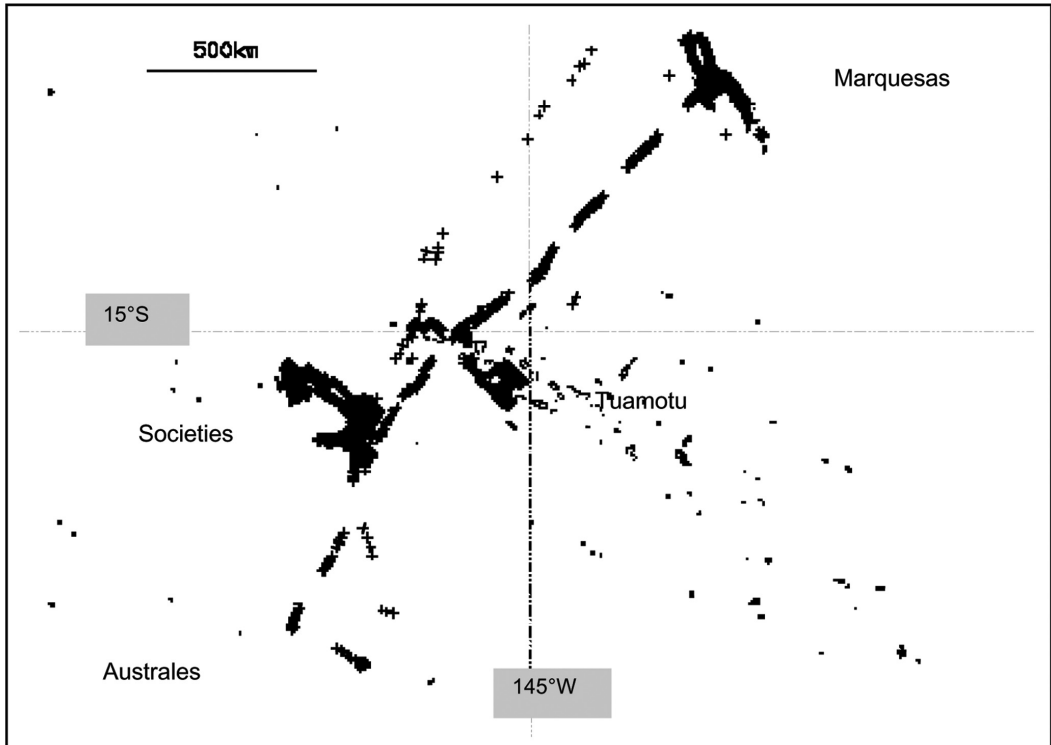


Figure 2. Sampling effort in French Polynesia, 1997-2002; cross marks the end of effective effort segment (Beaufort ≤ 4) and an acoustic sample.

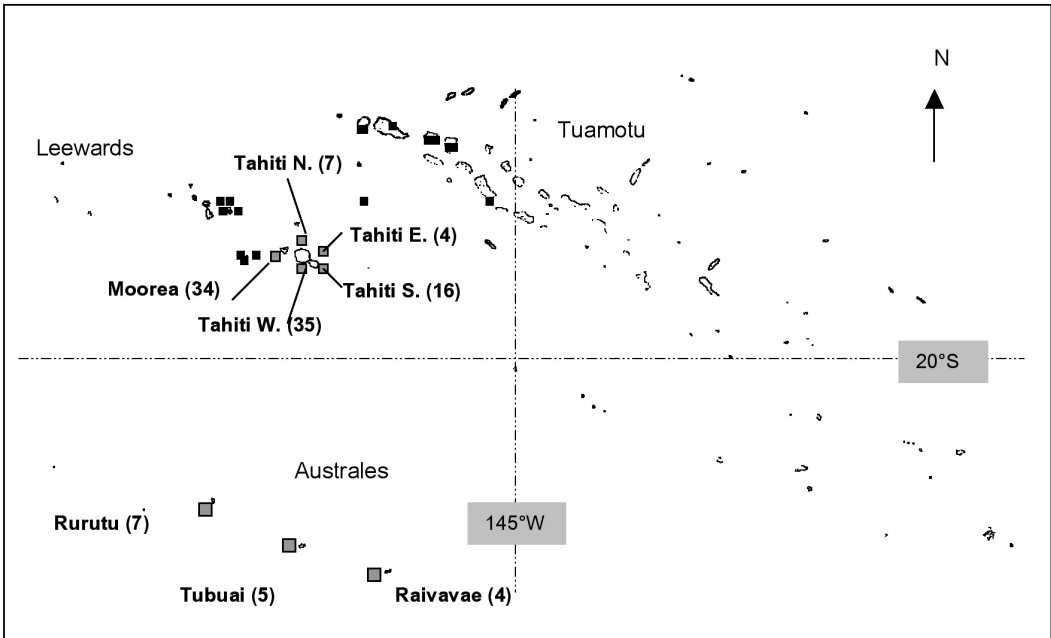


Figure 3. Humpback whale sightings in French Polynesia obtained from dedicated surveys, 1997-2002; where necessary, single sightings symbols are replaced by a number of sightings in a given area (grey squares).

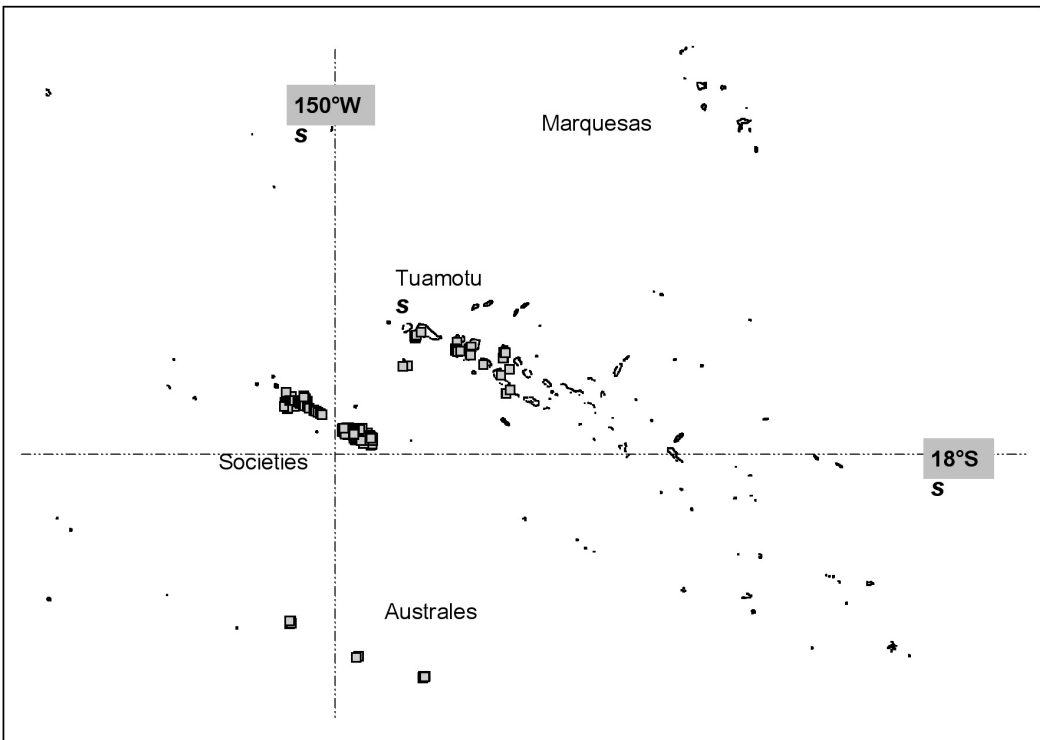
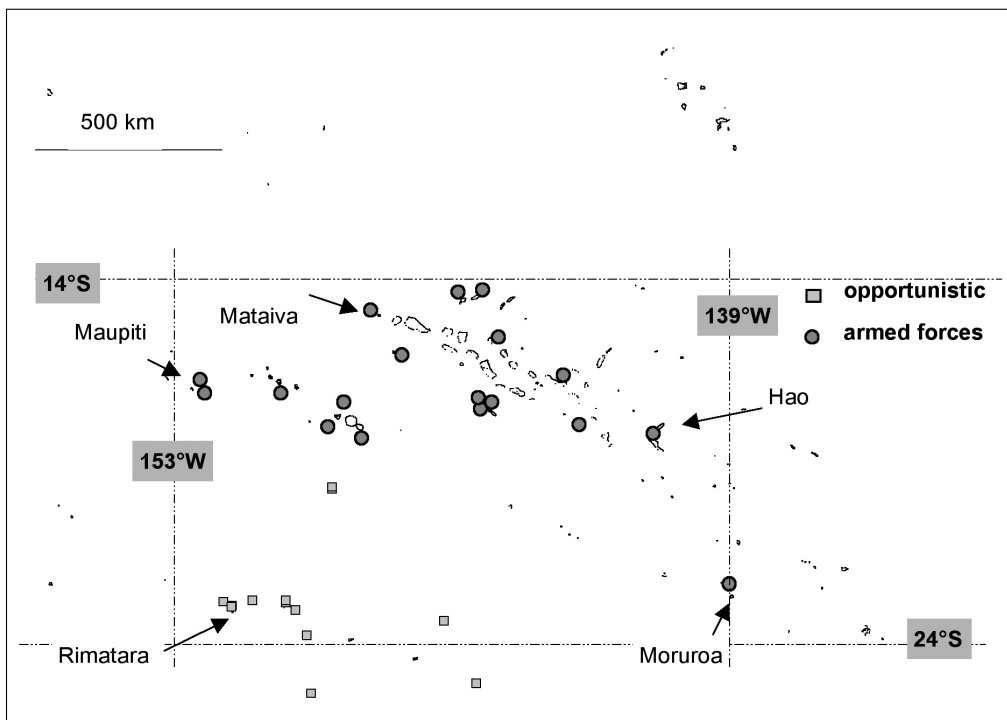


Figure 4. Humpback whale acoustic detections from dedicated surveys, 1997-2002, in French Polynesia

Table 2. Sighting rates of humpback whales for different archipelagos in French Polynesia

| Area | Windwards | Leewards | Australes | Tuamotu | Marquesas |
|--------------------------------------|---------------------|---------------------|---------------------|---------------------|-----------|
| Sighting rate n/L (CV%) | 8.53 E-03 (11.8) | 2.52 E-03 (46.1) | 1.04 E-02 (31.2) | 4.10 E-03 (40.1) | 0.0 |
| School size (CV%) | 1.80 (5.9) | 1.40 (17.5) | 1.43 (12.1) | 1.75 (9.3) | - |
| SRI ind./100 km (CV%) | 1.54 (13.2) | 0.35 (49.3) | 1.48 (33.5) | 0.72 (41.2) | 0.0 |
| Acoustic samples (total positive) | 1,458 391 | 323 53 | 254 67 | 288 27 | 271 0 |
| Acoustic rate (A%) | 27.0 | 16.4 | 26.4 | 9.40 | 0.0 |

**Figure 5.** Sightings of humpback whales from an opportunistic survey, 1999 (grey square), and from French Armed Forces surveys, 2001-2002 (black circles)

2,594 listening stations: 1,458 in the Windwards, 323 in the Leewards, 254 in the Australes, 288 in the Tuamotu, and 271 in the Marquesas. An effective effort of 4,438 km (3,605 km in the Australes area) was achieved during the R/V opportunistic survey, representing 239 hours of sighting effort.

Visual Detections

Humpback whales were observed in the Societies, Australes, and Tuamotu, but not in the Marquesas. A total of 129 groups of humpback whales were

observed on-effort during the sailboat surveys (Figure 3). Fourteen sightings were obtained in 1997, 17 in 1998, 30 in 1999, 22 in 2000, 15 in 2001, and 31 in 2002. Humpbacks mostly were observed in groups of one to four animals, with only one group of six individuals; 51% of sightings were single animals, 36% were pairs, 10% were groups of three animals, and 4% were groups of \geq four animals. Female/calf (a 4-6 m whale) pairs were sighted on 14 occasions, and female/juvenile (a 7-9 m whale) pairs on seven occasions; in addition,

Table 3. Complementary humpback whale data from the French Armed Forces sighting program

| Sighting ID | Date | Archipelago | Island | Group size | Calf | Position (°S, °W) |
|-------------|----------|-------------|-----------|------------|------|-------------------|
| 2001.01 | 07/08/01 | Tuamotu | Anaa | 2 | 1 | 145°29, 17°21 |
| 2001.02 | 24/08/01 | Societies | Tahiti | 1 | 0 | 149°35, 17°38 |
| 2001.03 | 30/08/01 | Tuamotu | Mururoa | 5 | 1 | 138°55, 22°10 |
| 2001.04 | 14/09/01 | Tuamotu | Reitoru | 2 | 0 | 143°05, 17°50 |
| 2001.05 | 20/09/01 | Tuamotu | Mataiva | 2 | 0 | 148°44, 14°43 |
| 2001.06 | 16/10/01 | Tuamotu | Anaa | 1 | 0 | 145°29, 17°21 |
| 2001.07 | 18/10/01 | Societies | Tahiti | 3 | 1 | 149°32, 17°31 |
| 2001.09 | 17/08/01 | Tuamotu | Hao | 2 | 0 | 141°00, 18°06 |
| 2001.10 | 09/08/01 | Societies | Tahiti | ? | ? | 149°37, 17°35 |
| 2001.11 | 01/11/01 | Societies | Maupiti | 2 | ? | 152°20, 16°30 |
| 2002.02 | 28/05/02 | Tuamotu | Ahe | 6 | 1 | 146°20, 14°30 |
| 2002.03 | 30/05/02 | Tuamotu | Ahe | 2 | 1 | 146°30, 14°53 |
| 2002.05 | 21/06/02 | Societies | Tetiaroa | 2 | 0 | 149°50, 16°59 |
| 2002.06 | 16/07/02 | Tuamotu | Anaa | 1 | 0 | 145°29, 17°21 |
| 2002.07 | 13/08/02 | Societies | Tahiti | 1 | 0 | 149°38, 17°02 |
| 2002.08 | 22/08/02 | Societies | Moorea | 1 | 0 | 149°53, 17°34 |
| 2002.10 | 22/08/02 | Societies | Moorea | 1 | 1 | 149°56, 17°37 |
| 2002.11 | 22/07/02 | Tuamotu | Makatea | 1 | 1 | 148°27, 16°03 |
| 2002.12 | 27/07/02 | open sea | | 1 | 1 | 145°38, 16°09 |
| 2002.13 | 19/06/02 | Societies | Tahaa | 2 | 1 | 151°30, 16°40 |
| 2002.14 | 03/07/02 | Australes | Rimatarua | 1 | 1 | 153°00, 22°00 |
| 2002.15 | 04/09/02 | Tuamotu | Anaa | 4 | 2 | 145°29, 17°21 |
| 2002.16 | 30/05/02 | Tuamotu | Aratika | 3 | ? | 145°40, 15°14 |
| 2002.17 | 22/09/02 | Societies | Tahiti | 1 | 0 | 149°41, 17°34 |
| 2002.19 | 19/10/02 | Societies | Bora | 1 | 0 | 151°45, 16°35 |
| 2002.20 | 11/10/02 | Societies | Tahiti | 2 | 1 | 149°30, 17°29 |
| 2002.22 | 06/10/02 | Societies | Tetiaroa | 3 | 1 | 149°30, 17°00 |
| 2002.23 | 15/10/02 | Societies | Moorea | 5 | 0 | 149°50, 17°33 |
| 2002.24 | 01/10/02 | Societies | Maupiti | 2 | 1 | 152°20, 16°30 |

either one calf or one juvenile was observed in 28 groups numbering ≥ 3 individuals.

Acoustic Distribution Results

We obtained 538 detections of singing males in all archipelagos, except the Marquesas, or 20.7% of the samples as a global average (Figure 4). We had a 27.0% singing rate in the Windwards, 26.4% in the Australes, 16.4% in the Leewards, and 9.4% in the Tuamotu. There was an indication of temporal variation in the Windwards, with a singing rate of 33% for the period 1997-1999 (723 samples) compared to 21% for 2000-2002 (735 samples).

Visual Distribution Results

The sighting rate varied from 1.04 groups/100 km in the Australes, 0.85 groups/100 km in the Windwards, 0.41 groups/100 km in the Tuamotu, and 0.25 groups/100 km in the Leewards (Table 2). Mean school sizes varied from 1.80 in the Windwards to 1.40 individual/group in the Leewards. The apparent group structures were

similar, with schools of three animals or more and the presence of mother/calf pairs in the three archipelagos where humpback whales were observed.

The SRI estimates indicated that whale distribution was denser in the Australes and Windward Islands, with respective indices of 1.48 whales/100 km (CV=33.5%) and 1.54 whales/100 km (CV=13.2%), than in the Tuamotu and Leewards (0.72 and 0.35 whales/100 km, respectively, with CV of 41.2% and 49.3%) (Table 2). We noted a marked contrast between the Leewards and Windwards, two groups of islands less than 150 km apart.

Opportunistic Survey and Armed Forces Sightings

The opportunistic survey delivered 17 sightings on 20 individuals. Due to the distance, three sightings were not identified with certitude; however, blows and surface behavior corresponded to those of humpback whales rather than to larger rorqual species or to sperm whales (*Physeter catodon*). Hence, these data were recorded and processed as

probable humpbacks (Figure 5). Whales were observed close to Rimatara and Rurutu Islands, as well as in open sea shallow waters, over sea mounts. From the opportunistic survey, a SRI estimate of 0.55 whales/100 km could be obtained. The Armed Forces reported 29 sightings of humpback whales (10 in 2001 and 19 in 2002), including in the northwestern (Mataiva atoll) and southern (Mururoa atoll) Tuamotu (Table 3).

In summary, dedicated survey results showed an extended humpback wintering area in French Polynesia, between longitudes of 145° W and 151° W, and latitudes of 15° S and 23° S. Data from the opportunistic survey in 1999 (17 sightings) and the Armed Forces program in 2001-2002 (29 sightings recorded close to 13 islands) further increased the controlled distribution range to an area of 1,725,000 km² between the positions 14° S, 153° W and 24° S, 139° W, extending southeast from Mururoa and northwest to Maupiti and Mataiva (Figure 5).

Discussion

For this study, 29 islands in four archipelagos were sampled. Armed Forces sightings accounted for nine additional islands (although the Armed Forces did not report coverage). Hence, the distribution of whales was directly determined for 38 islands, and humpback whales were observed close to 27 islands. In an earlier report, Poole & Darling (1999) stated from various data sources that humpback whales had occurred around 25 islands and four archipelagos during the 1988-1998 period. The large-scale distribution may be compared with information on the Hawaiian or Caribbean breeding grounds, where whales disperse over a large region while being concentrated in a core area such as the four-islands region in Hawaii (Darling et al., 1983; Swartz et al., 2001). Both visual and acoustic results showed that whale presence is more intense in the Australes and Windwards, with SRI estimates in the 1.5 whales/100 km range, than in the Leeward and Tuamotu Islands (SRI=0.35-0.7 range). Our "core" distribution area would be the region centered close to 150° W longitude and shared by the northern Australes, the Windwards, and the northwestern Tuamotu (Figure 4). In several oceanic regions, main wintering and breeding areas include shallow water sites (Smith et al., 1999; Winn & Reichley, 1985). Mobley et al. (1993) observed that humpback whales off Hawaii's main archipelago consistently favored waters less than 180 m deep, including the shallow Penguin bank. Among the archipelagos of French Polynesia, only the Marquesas include a shelf; however, shallow waters are found in the offshore banks

of the Australes and within the Tuamotu atolls. Tuamotu lagoons often communicate with the ocean, although passes include in many cases a very shallow sill, which makes the safe entrance of whales difficult. Physiography alone could not explain the distribution differences found in French Polynesia.

The acoustic rate in the Tuamotu (9.4%) was lower than in the Leewards (16.4%), as opposed to the visual SRI. Singing whales usually are not engaged in surface activity (Darling & Bérubé, 2001); thus, they are less likely to be visually detected. Singing is a reflection of social behavior at the time of the survey, and because acoustic and visual detection can vary locally over short time spans, our observed differences may also be due to a limited survey effort.

In the Societies, the islands of Mehetia (eastern Windwards) and Maupelia (western Leewards) were reported to shelter several whales (Joshua Rouger, pers. comm.) in 2001 and 2002. Consequently, from our sightings and available reports (Gannier, 2000; Poole, 1993; Poole & Darling, 1999), we consider that all 14 islands of the Leewards and Windwards groups shelter humpback whales, most of them throughout the wintering period.

In the Australes Archipelago, four islands (Raivavae, Tubuai, Rurutu, and Rimatara) shelter whales, including singers and mother/calf pairs, and the Maria atoll (located further west and then closer to the Cook Islands) undoubtedly hosts wintering whales. From the large vessel survey, we learned that whales also were located over shallow banks in the offshore part of this archipelago; however, due to the survey time (July 1999—early in the wintering season), it could not be determined if such remote sites were used throughout the wintering season or only by northbound migrating whales. The humpback whale normally is known to winter in shallow or inshore waters (Winn & Reichley, 1985), but there are examples of the offshore presence of animals (Swartz et al., 2001).

For the Tuamotu-Gambier Archipelago, our visual and acoustic results showed an extended distribution range, in particular for the northern and central Tuamotu Atolls, most of which sheltered at least one male singer. During the survey, sightings were reported regularly to us by local people and appeared to be common in Makemo (17° S, 144° W) and up to the northern atolls of Takaroa-Takapoto (14° S). The Armed Forces reported that observing a group of five whales, including a calf, in Mururoa (22° S, 139° W) was not exceptional, since whales were sighted in this much surveyed atoll as early as in 1991. In the Gambier Islands (a southern extension of the Tuamotu), located southeast at 136° W and 23° S,

humpback whales are seen regularly during July and August (Francis Sanford, pers. comm., 2001), as mentioned by Reeves et al. (1999), but not throughout the wintering season. In summary, a total of 65 atolls north of 22° S are within regular distribution range and may host humpback whales either permanently or frequently, possibly to the same extent as the northern and central Tuamotu, which were all shown (this study) to shelter whales. Therefore, the Tuamotu Archipelago potentially hosts the major portion of the wintering whales in French Polynesia.

We did not observe humpbacks during surveys between September and November 2000 in the Marquesas (Laran & Gannier, 2001). Nevertheless, a few humpback whales are observed there on a yearly basis, according to information gathered from local people during our two surveys and particularly mother-calf pairs (unpublished data, Gannier, 2002). This suggests that the winter presence of humpback whales in the Marquesas (10 islands) is marginal compared to the Societies, Australes, and Tuamotu, perhaps because this archipelago is located further north than the other ones. The documented presence of killer whales (*Orcinus orca*) in the Marquesas (Gannier, 2002; Gendarmerie de Ua Pou, pers. comm., 2002; Gendarmerie de Nuku Hiva, pers. comm., 2003) might also account for a lower occurrence near this archipelago.

Our survey work and accompanying sighting reports suggest the humpback's wintering range extends over an area of 1,745,000 km², covering 84 islands in the Australes, the Societies, and a major portion of the Tuamotu (Figure 5). This immense range extension has clear consequences in terms of monitoring. It also makes estimating abundance from photo-identification from a few islands (Tahiti, Moorea, and Rurutu) problematic. Poole & Darling (1999) identified 54 whales from fluke photographs in Moorea during the 1991-1998 period; however, this should not be considered a bottom-line abundance estimate of the wintering population in French Polynesia, which may amount to several hundred whales as suggested by the present study. Furthermore, the humpback population wintering in French Polynesia probably wanders into other archipelagos such as the Cook Islands (Hauser et al., 1999). The extent of migratory movement between nearby wintering sites in the southern hemisphere is still in question (Garrigue et al., 2000), with recent evidence that humpback songs from different "substocks" are very similar (Helweg et al., 1998). There is a continuum of known or possible breeding sites among archipelagos, ranging from the Tuamotu to eastern Australia (Figure 1). It is crucial to determine the population identity of humpback

whales wintering in French Polynesia and, in particular, if these whales belong to the Antarctic Area V stock, identified by early research (Dawbin, 1966), or to an eventual Antarctic Area VI stock, much less documented.

Conclusions

This study brought a new perception of the humpback whales distribution in French Polynesia. Compared to existing knowledge, we have shown that the Tuamotu Archipelago is an important area for wintering whales. The use of a combined acoustic and visual survey method enabled semi-quantitative distribution results. This extended distribution range is a key factor for any future study dealing with the conservation status of humpback whales wintering in French Polynesia, particularly if abundance or stock identity are concerned.

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Literature Cited

- Bourreau, S., & Gannier, A. (2001). First results on the distribution of wintering humpback whales (*Megaptera novaeangliae*) in French Polynesia 1997-2000. *European Research on Cetaceans*, 15, 374-377.
- Buckland, S. T., Anderson, D. R., Burnham, K. P., & Laake, J. L. (1993). *Distance sampling: Estimating abundance of biological populations*. London: Chapman and Hall. 446 pp.
- Darling, J. D., & Bérubé, M. (2001). Interactions of singing humpback whales with other males. *Marine Mammals Science*, 17, 570-584.
- Darling, J. D., Gibson, K. M., & Silber, G. K. (1983). Observations on the abundance and behavior of humpback whales (*Megaptera novaeangliae*) off West Maui, Hawaii, 1977-79. In R. S. Payne (Ed.), *Communication*

- and behavior of whales (pp. 201-222). Boulder, CO: Westview Press.
- Dawbin, W. H. (1966). The seasonal migratory cycle of humpback whales. In K. S. Norris (Ed.), *Whales, dolphins and porpoises* (pp. 145-170). Berkeley: University of California Press.
- Dawbin, W. H. (1997). Temporal segregation of humpback whales during migration in southern hemisphere waters. *Memoirs of the Queensland Museum*, 42(1), 105-138.
- Gannier, A. (2000). Distribution of cetaceans off the Society Islands (French Polynesia) as obtained from dedicated survey. *Aquatic Mammals*, 26, 111-126.
- Gannier, A. (2002). Distribution of cetaceans off the Marquesas Islands (French Polynesia) as obtained from a small boat dedicated survey. *Aquatic Mammals*, 28, 198-210.
- Gannier, A., Bourreau, S., & Casacci, C. (2000). *Preliminary results on the distribution of wintering humpback whales in French Polynesia 1997-1999* (Paper SC/52/IA9). Presented to the IWC Scientific Committee, May 2000. (Unpublished). 12 pp.
- Gannier, O., & Gannier, A. (1998). First results on the distribution of cetaceans in the Society Islands (French Polynesia). *European Research on Cetaceans*, 12, 54-58.
- Garrigue, C., Forestell, P., Greaves, J., Gill, P., Naessig, P., Patenaude, N. M., & Baker, S. C. (2000). Migratory movements of humpback whales (*Megaptera novaeangliae*) between New Caledonia, East Australia and New Zealand. *Journal of Cetacean Resource Management*, 2(2), 111-115.
- Hauser, N., Peckham, H., & Clapham, P. J. (1999). Humpback whales in the Cook Islands, south Pacific. *Abstract from the Thirteenth Biennial Conference on the Biology of Marine Mammals*, Maui, Hawaii.
- Helweg, D. A., Cato, D. H., Jenkins, P. F., Garrigue, C., & McCauley, R. D. (1998). Geographic variation in South Pacific humpback whales' songs. *Behaviour*, 135, 1-27.
- Laake, J. L., Buckland, S. T., Anderson, D. R., & Burnham, K. P. (1994). *Distance user's guide V2.2*. Fort Collins: Colorado Cooperative Fish and Wildlife Research Unit, Colorado State University. 72 pp.
- Laran, S., & Gannier, A. (2001). Distribution of cetaceans in the Marquesas Islands (French Polynesia). *European Research on Cetaceans*, 15, 426-430.
- Lefèvre, Y., Leborgne, E., & Gannier, A. (1999). An abnormal calf of humpback whale observed off Rurutu island (French Polynesia). *European Research on Cetaceans*, 13, 367-368.
- Massé, J., & Cadiou, Y. (1994). *Oedipe manuel utilisateur*. Nantes: Institut Français de Recherche sur le Mer (Ifremer). 38 pp.
- Mobley, J. R., Forestell, P. H., & Grotefendt, R. (1993). *Results of 1993 aerial surveys in Hawaiian waters*. (Unpublished). 24 pp.
- Patterson, R. A. (1991). The migration of humpback whales *Megaptera novaeangliae* in east Australian waters. *Memoirs of the Queensland Museum*, 30(2), 333-341.
- Poole, M. (1993). A sighting/stranding network in French Polynesia, 1988-1993. In *Abstract from the Tenth Biennial Conference on the Biology of Marine Mammals*, Galveston, Texas.
- Poole, M., & Darling J. (1999). Occurrence of humpback whales (*Megaptera novaeangliae*) in French Polynesia. *Abstract from the Thirteenth Biennial Conference on the Biology of Marine Mammals*, Maui, Hawaii.
- Reeves, R. R., Leatherwood, S., Stone, G. S., & Eldredge, L. G. (1999). *Marine mammals in the area served by the South Pacific Regional Environment Program*. Report of the South Pacific Regional Environment Program (P.O. Box 240, Apia, Samoa). 48 pp.
- Rougerie, F., & Rancher, R. (1994). The Polynesian South Ocean: Features and circulation. *Marine Pollution Bulletin*, 29, 14-25.
- Signorini, S. R., McClain, C. R., & Dandonneau, Y. (1999). Mixing and phytoplankton bloom in the wake of the Marquesas Islands. *Geophysical Research Letters*, 26, 3121-3124.
- Spitz, S. S., Herman, L. M., Pack, A. A., & Deakos, M. H. (2002). The relation of body size of male humpback whales to their social role on the Hawaiian breeding ground. *Canadian Journal of Zoology*, 80, 1938-1947.
- Swartz, S. L., Martinez, A., Cole, T., Clapham, P. J., McDonald, M. A., Hildebrand, J. A., Oleson, E. M., Burks, E. M., & Barlow, J. (2001). Visual and acoustic survey of humpback whales (*Megaptera novaeangliae*) in the eastern and southern Caribbean Sea: Preliminary findings. *NOAA Technical Memorandum* (NMFS-SEFSC-456). 45 pp.
- Winn, H. E., & Reichley, N. E. (1985). Humpback whales *Megaptera novaeangliae* (Borrowski, 1781). In S. H. Ridgway & R. J. Harrison (Eds.), *Handbook of marine mammals, Volume 3: The sirenian and baleen whales* (pp. 241-273). New York: Academic Press. 362 pp.