SUMMER DISTRIBUTION OF FIN WHALES (*BALAENOPTERA PHYSALUS*) IN THE NORTHWESTERN MEDITERRANEAN MARINE MAMMALS SANCTUARY

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RÉSUMÉ

Nous avons étudié la distribution du Rorqual commun dans la région du Sanctuaire des Mammifères marins de Méditerranée nord-occidentale en conduisant une série de prospections estivales entre 1991-2000. Les campagnes en mer se sont déroulées à bord de bateaux de 10-12 mètres en juillet et août et ont consisté en des échantillonnages aléatoires à une vitesse de 5 nœuds (1991-94) puis 6 nœuds en moyenne. Trois observateurs étaient à poste en permanence et toutes les 20-30 minutes les conditions environnementales et la position du bateau étaient consignées. Un total de 12 755 kilomètres d'échantillonnage effectif a ainsi été réalisé, au cours duquel 274 observations de Rorquals ont été enregistrées. La distribution moyenne montre une préférence pour les eaux de plus de 2 000 m de profondeur et une distance à la côte de 30 à 60 km, avec un taux d'observation moyen de 3,0 baleines/100 km, qui est maximal (3 à 6 baleines/100 km) dans une zone annulaire en mer Ligure. Le taux moyen annuel peut atteindre des valeurs faibles de l'ordre de 0,61-1,08 baleine/100 km ou fortes de 6,46-9,01 baleines/100 km certaines années. Cette variabilité inter-annuelle se retrouve dans l'effectif moyen des groupes qui oscille autour de 1,55 individus mais qui, certaines années, est plus bas et, d'autres années, atteint des valeurs de 1,8 à 2,2. À moyenne échelle et au cours d'une saison, on observe que les Rorquals communs ont tendance à étendre leur distribution vers les profondeurs moindres de juillet à août, probablement à la recherche de nourriture. La variabilité de la distribution à grande échelle (tout le bassin), à moyenne échelle (dans la région du Sanctuaire) et petite échelle (organisation spatiale de la population) peut s'expliquer par les fluctuations de l'abondance ou de la disponibilité de la proie préférentielle supposée de *B. physalus* en Méditerranée : l'euphausiacé *Meganyctiphanes norvegica*.

SUMMARY

The summer distribution of fin whales in the northwestern Mediterranean Sea was investigated with sighting surveys during the period 1991-2000 in 10-12 m boats cruising at a mean speed of 5-6 knots on random sampling lines. The effective visual effort totalled 12,755 km in the course of 18 surveys during which 274 on-effort fin whale sightings were obtained. Fin whales showed preference for waters deeper than 2 000 m (mean depth 2 295 m) and for offshore waters, with a mean distance to shore of 45.3 km. A global mean sighting rate of 3.0 whales/100 km was computed for the whole period of study, and

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successive survey sighting rates varied from lower values of 0.61-1.08 whale /100 km to higher values of 6.46-9.01 whales/100 km, suggesting inter-annual variability in large scale distribution. At medium scale, fin whales were shown to expand their distribution range from July to August, being more frequently found inshore of the 2 000 m isobath late in summer. At small scale, the mean school size in successive years varied around the global average of 1.55 whales/sighting, but it was found consistently either low, medium or high during a given year, whenever surveys were available for both July and August. The present findings are consistent with existing knowledge on the ecology of the fin whale main prey, the krill *Meganyctiphanes norvegica*, particularly as far as distribution and reproductive cycle are concerned.

INTRODUCTION

In December 1999, an International Sanctuary for Marine Mammals was formally created in the liguro-provençal basin and the northern Tyrrhenian Sea after a trinational ministerial meeting held in Rome. The creation of this marine protected area was greatly influenced by the summer abundance of cetaceans, particularly of fin whales, *Balaenoptera physalus*, and striped dolphins, *Stenella coeruleoalba* (Forcada *et al.*, 1995; Gannier, 1997 and 1998a). The fin whale is the only common mysticete in the Mediterranean Sea (Duguy *et al.*, 1983). Viale (1985) hypothesized that population exchanges occurred with the Atlantic Ocean but recent genetic results suggest the Mediterranean population may be significantly separated from fin whale stock inhabiting adjacent waters in the Atlantic Ocean (Bérubé *et al.*, 1998). Cetaceans surveys in the Mediterranean Sea have mainly focused on the western basin and the immediate surroundings of Italy: a basin-wide study in western Mediterranean Sea, excluding the Tyrrhenian Sea, enabled summer distribution and abundance estimates for the fin whale to be released (Forcada *et al.,* 1996): 3,583 individuals (95 % CI: 2130-6027) were believed to inhabit the western Mediterranean in 1991. Recent research on the fin whale focused on the liguro-provençal basin (eastern part of the northwestern basin) where summer densities estimates reach consistent values of 0.015 whale/km^2 (Forcada *et al.,* 1996; Gannier 1997) to 0.017 whale/km^2 (Gannier, 1998b) or 0.019 whale/km^2 (Gannier, 1999a), depending on the year of the survey. Until very recently, the species remained poorly known in terms of year-round and global distribution in the whole Mediterranean Sea, because parts of its range, such as the Tyrrhenian Sea (Marini *et al.*, 1996; Gannier, 1999b) and the Ionian Sea (Notarbartolo di Sciara *et al.,* 1993), were not regularly covered by dedicated surveys. Although, some sightings have been reported recently in the Ionian Sea (Politi *et al.*, 1994; Nascetti & Notarbartolo di Sciara, 1996), the southern Tyrrhenian Sea (Mussi *et al.,* 1998) and the eastern Alboran Sea (Canadas *et al.*, 1999), extensive field studies confirmed that fin whales are mainly distributed in the northwestern Mediterranean Sea during summer (Gannier *et al.*, submitted).

This summer distribution seems justified by hydrobiological studies showing different seasonal and primary production patterns to exist in the northwestern and southwestern areas; an ecotone is clearly apparent in climatological analysis of satellite imagery (Morel & André, 1991), the North Balearic Front being frequently located close to latitude 41°N (Le Vourch *et al.,* 1992). The summer distribution range of fin whales mainly covers all northern areas of the western Mediterranean and the International Sanctuary is only a part of it, encompassing a surface of 88,000 km^2, from which only 33,400 km^2 belong to the oceanic domain (depth > 2 000 m), propice to the presence of *B. physalus* (Notarbartolo di

Sciara *et al.*, 1993; Gannier, 1998c). It is generally inferred from survey results that fin whales favour waters deeper than 2 000 m in the Mediterranean, although this opinion largely derives from summer observations in the Ligurian Sea. Actually, recent results obtained in the Tyrrhenian Sea (Marini *et al.*, 1992) or Gulf of Lion (Gannier & Bourreau, 1999; Gannier, 1999b) show that waters shallower than 1 500 m and even 1 000 m are routinely frequented by this balenopterid elsewhere in the Mediterranean Sea.

Variations of the summer distribution are observed within the Sanctuary, both on a year-to-year basis and within a feeding season; they are probably due to ecological factors such as fluctuations in prey abundance or accessibility. Regular survey data and opportunistic sightings for the summer 1997 and 2000 suggested an increased variability in fin whale distribution and abundance in recent years (Beaubrun *et al.*, 1999; *pers. data*, 2000). The spring to autumn period is favourable to the fin whale feeding in the northwestern Mediterranean (Gannier, 1998c; 1999b), the main prey species being probably the euphausiid *Meganyctiphanes norvegica*, as stated from stomach content and faeces studies (Orsi Relini & Giordano, 1992; Astruc & Beaubrun, 2001), and assumed from the correlation of fin whale presence and *M. norvegica* concentration (Relini *et al.*, 1992; Orsi-Relini *et al.*, 1994). This euphausiid species is found in abundance in the northwestern Mediterranean (Casanova, 1974), where reproduction occurs from late winter to late spring (Cuzin-Roudy, 1993; Labat & Cuzin-Roudy, 1996).

Our research attempted to assess the summer average distribution of *B. physalus* and its variability at various scales in the Northwestern Mediterranean Marine Mammals Sanctuary and adjacent waters. This was carried on by analysing sighting data from a series of summer surveys held in the area from 1991 to 2000.

MATERIAL AND METHODS

STUDY AREA

The study area encompasses the Northwestern Mediterranean Marine Mammals Sanctuary and waters immediately adjacent, from 5° E to 11° 30 E longitude and north of 40°50 latitude. Large oceanic areas (water deeper than 2 000 m) are found in the liguro-provençal basin, but not in the northern Tyrrhenian Sea, whose open sea waters are of intermediate depth (1 000 m to 2 000 m). Continental slopes (200 m to 2 000 m) are very steep off Provence, northwestern Sardinia and Corsica and less steep in eastern Ligurian Sea and northern Tyrrhenian Sea (Fig. 1). The Ligurian Front and the associated water circulation form one of the most productive areas in the Mediterranean Sea, with a superficial primary biomass peaking in March-April (Jacques *et al.*, 1973; Nival *et al.*, 1975) and a summer primary production maximum located close to the pycnocline, 30 to 60 m deep (Jacques *et al.*, 1976). The most productive areas are generally found 20-35 milles offshore in the central Ligurian Sea, in water deeper than 2 000 m and are characterized by mesoscale spatial and temporal heterogeneity (Ibanez & Boucher, 1987).

SAMPLING STRATEGY

Our dedicated small boat surveys began in 1988, but only data collected from July 1991 to August 2000 were considered here to ensure a good consistency in

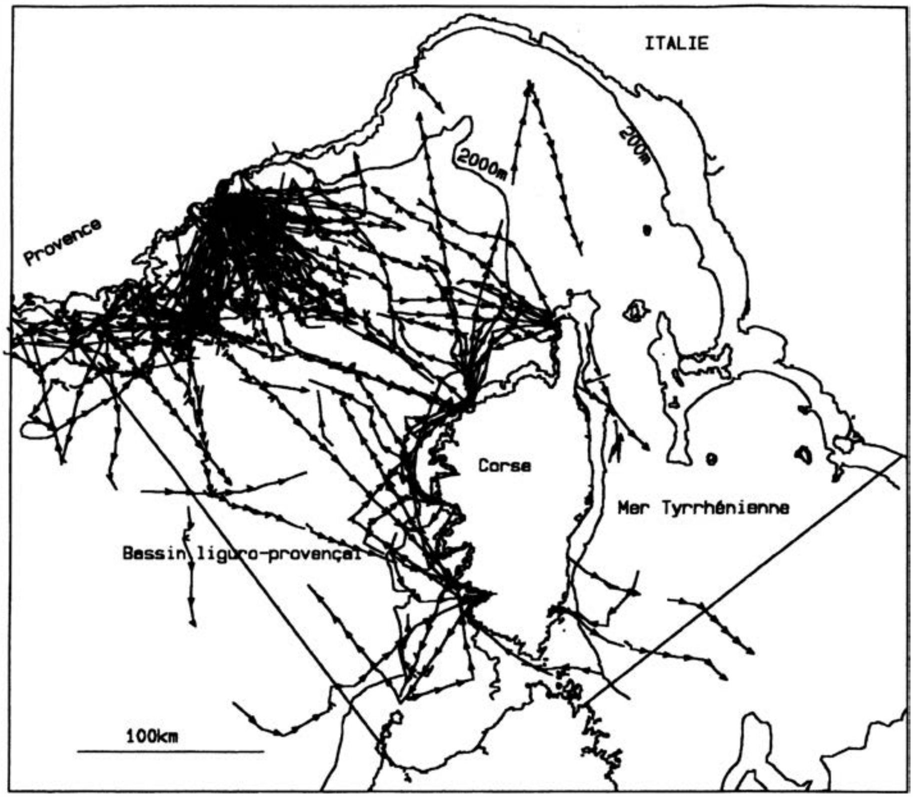

Figure 1. — Study area and sampling routes. (200 and 2 000 m isobath are drawn).

field protocoles, particularly in such aspects as the use of satellite positioning devices, the number of on-duty observers. A 9.50 m sloop was used up until 1994 and surveys were carried on with a 12.0 m motor-sailer boat from 1995 onwards. The sampling strategy was essentially similar throughout the survey period, involving random sampling (*i.e.* area coverage was not influenced by previous knowledge of sites of supposed high abundance) when the sighting conditions were good to excellent (basically Beaufort 0-3). Visual searching took place from half an hour after sunrise to half an hour before sunset. However, the survey was partly influenced by the vessel type, the 12 meter boat being fitted with an 80hp diesel engine allowing to sustain a mean speed of 11 km/h in straight line, whichever the sea conditions were, when the smaller vessel could only cruise at a mean speed of 9 km/h with variable heading when sea state built up and got close to Beaufort 4.

Field protocol combined visual searching with systematic discrete acoustic sampling from 1994 onwards, in order to detect sperm whales as well as delphinids (Gannier, 1998a). The visual survey consisted of continuous, naked eye observation by shifts of three observers rotating every two hours. One observer stood in front of the mast searching the ± 45° sector ahead, two other observers scanned the

30° to 90° and – 30° to – 90° sectors either side of the line. An index of sighting conditions was recorded every 20 minutes: the index varied from 0 (null) to 6 (excellent) and was derived from wind speed, sea-state, residual swell and light conditions (Gannier 1997, 1998a). With wind speed equal to Beaufort 3, good light conditions and no conspicuous swell the sighting conditions index was given a value of 4 (good). The 20 minutes period defined an unit sample, with corresponding effort (distance covered during the period) and sighting data (number of observations and associated school sizes).

SIGHTINGS

When cetaceans were detected various sighting parameters were recorded (bearing and radial distance to the boat, position, sea state) and fin whales were usually approached at a distance of 100-200 m to determine the school size and structure and to record various behaviour parameters. Sighting duration was variable, ranging from one minute to over 2 hours, however in 60 % of the cases it was comprised between 5 and 60 minutes.

DATA ANALYSIS

Effort

Data was loaded into a database and then exported to the geographic software *Oedipe* (Massé & Cadiou, 1994), which was used for mapping of the sampling track and sightings and computing sighting rates over determined areas or periods. Effective effort distribution in all regions in both continental slope (200-2 000 m depth) and open sea (> 2 000 m depth) strata was also determined with this software. A global effort distribution was obtained by calculating effort amount in every square of 10 × 10 n.m. Then a mosaic map was produced by considering a five level scale for effective effort: effort less than 5 nautical miles (9.2 km), effort between 5 and 20 n.m. (9.2 and 37 km), effort between 20 and 50 n.m. (37 and 92 km), between 50 and 200 n.m. (92 and 370 km) and over 200 n.m. (370 km).

Average distribution at medium scale

Sightings were plotted on nautical charts (*Service Hydrographique et Océanographique de la Marine*) from which accurate water depth (in metres) and distance to the shore could be determined. A mean distance to shore and a mean water depth were calculated and histograms relating to both variables were traced. An average distribution map was obtained by estimating mean sighting rates (number of individuals sighted per 100 km of effort) for every square of 10 × 10 n.m. Mean sighting rates $\mathbf{r_p}$ for every 10x10 square were computed with *Oedipe*:

$$r_p = \Sigma_{1,k}(N_i / L_i)$$

where **k** is the number of samples in square **p**, $\mathbf{N_i}$ is the number of whales seen during sample **i**, $\mathbf{L_i}$ is the effort during sample **i**. Then a mosaic was produced on the 10×10 grid by considering a five level scale for sighting rate r_p: r_p less than 0.5 whale/100 km, r_p between 0.5 and 1 whale/100 km, r_p between 1 and 3 whales/100 km; r_p between 3 and 6 whales/100 km and over 6 whales/100 km. A global mean sighting rate $\mathbf{R_p}$ was calculated for the whole area during the entire study period as well as standard errors SE for every estimate. The average distribution map, mean depth and mean distance of sightings to shore enabled to determine the medium scale distribution within the area of study.

Distribution variability at different scales

Beside the average situation and medium scale distribution, small and large scale distribution were obtained by producing results from successive surveys from 1991 to 2000. For constituting suitable data sets, surveys periods had to be shorter than 14 days duration (based on empirical experience) and samplings to cover a part of the study area (the Northwestern Mediterranean Marine Mammals Sanctuary). For every survey, five parameters were controlled: the survey mean sighting rate $\mathbf{R_{ps}}$, the mean school size, the evenness or patchiness of sightings along the sampling route, the "2 000 m bottom depth" criterion (whether there were sightings inshore of the 2 000 m isobath or not), and the distribution pattern (were sightings spread over all the domain, well off the 2 000 m isobath, or grouped along the 2 000 m isobath). These five parameters were compared for all distribution surveys with a particular attention paid to temporal aspects, both intra-seasonal (*i.e.* to compare situations obtained in July and August of the same year) and interannual (*i.e.* to compare distribution obtained in successive years).

Mean school sizes and distribution evenness were used to discuss small scale distribution: how individual whales or clusters were spatially organized.

The distribution pattern and "2 000 m criterion" were used to discuss temporal trends in medium scale distribution: how whales distribution departed from the average situation within the study area.

The survey mean sighting rate R_{ps} was to give an indication on this large scale distribution of fin whales, by comparison with the global mean sighting rate R_p. This was done on the assumption that sighting rates fluctuations in the area of study should reflect large scale distribution pattern, a lower R_{ps} indicating that fin whales might favour another area (than the Sanctuary) in their whole western Mediterranean distribution range, and vice-versa.

RESULTS

SURVEY EFFORT AND SIGHTINGS

The effective visual effort amounts to a total of 12,755 km (6,887 n.m.) during the survey period. The global effective effort distribution favoured the open sea area, with 55.5 % of effort against 37.4 % for the continental slope and 7.1 % for neritic waters. The sampling effort is intense in the central part of the Sanctuary (more than 100 km of effort per 10×10 square) and in the 50 km strip off the French continental coast (Fig. 2). The coverage is less intense in the southwestern offshore area and in the northeastern part of the Sanctuary, closer to the Italian continental coast.

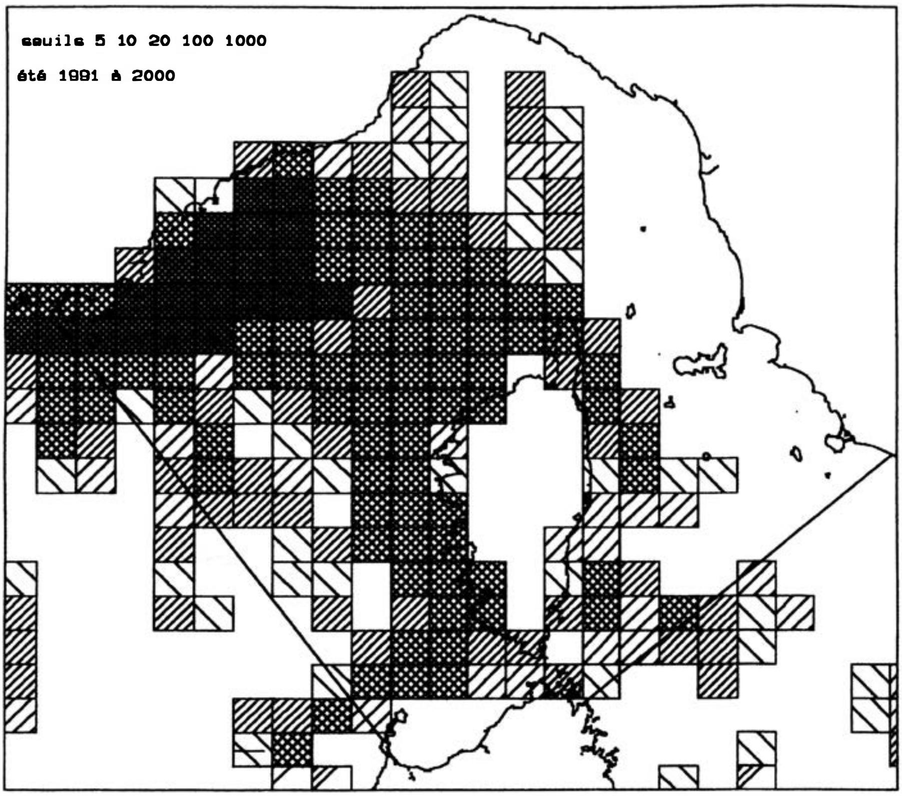

Figure 2. — Distribution of sampling effort.

A total of 274 fin whale sightings were obtained on-effort with Beaufort 3 or less sea-conditions (Fig. 3). School sizes varied between unity (61.2 % of sightings) and 7 individuals (one sighting), with 28.8 % of pair of whales and 6.0 % of sightings on schools of 3 individuals. A mean school size of 1.55 ind./group was obtained (SE = 0.87).

Medium scale average distribution

Sightings were obtained in water 70 m to 3 100 m deep, with a mean depth of 2 295 meter. Fin whales were shown to inhabit mainly oceanic waters of the northwestern Mediterranean: 86.8 % of the sightings were obtained in water deeper than 2 000 m, and 7.5 % in water shallower than 1 500 m, only 3 sightings being recorded in water less than 500 m deep.

The average distance from sighting to shore was 45.3 km, with a minimum of 2.8 km and a maximum of 133 km. When related to distance from shore, the sighting frequency showed an unimodal distribution centered around the 40 to

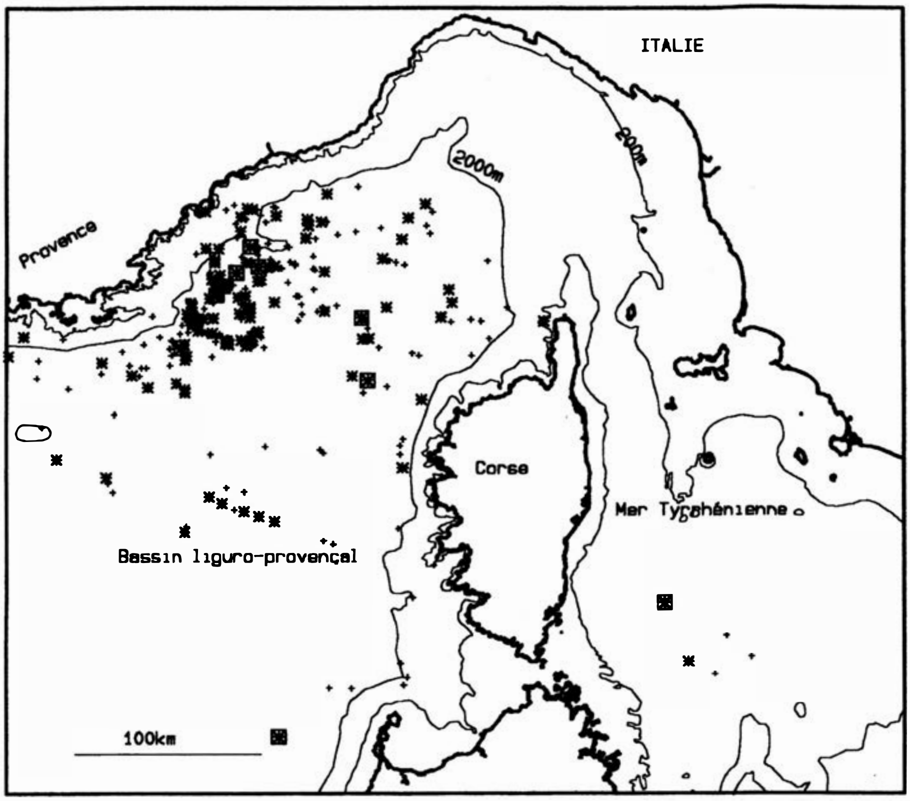

Figure 3. — Sightings of fin whales (on-effort only). Cross = 1 individual, star = 2-3 ind., square = 4-7 ind. (200 and 2 000 m isobath are drawn).

50 km from shore, with only 1.8 % of sightings recorded less than 10 km from shore and 2.1 % farther than 100 km (Fig. 4). Remarkably, 50.9 % of the sightings were recorded between 30 and 60 km from shore.

At medium scale, the fin whale distribution appeared to favour offshore waters. A global sighting rate $\mathbf{R_p}$ of 3.01 whale per 100 km (SE = 0.75) was obtained in the area of study for the whole 1991-2000 period. In inshore waters,

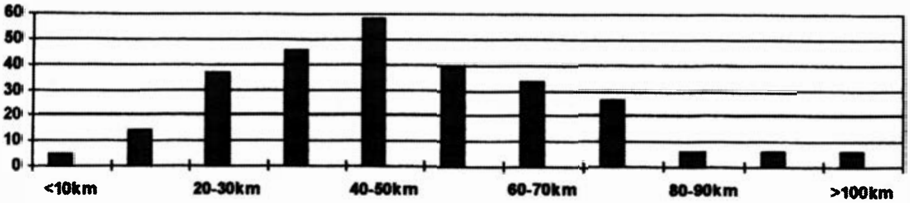

Figure 4. — Distribution of sightings relative to the distance-to-shore.

a sighting rate lesser than 0.5 w./100 km was found, when values close to the average were generally obtained in oceanic waters of the Sanctuary. Whales appeared to be quite evenly distributed in the central part of Ligurian Sea, but globally less common in southern offshore waters, although this trend would have to be confirmed by a more intense sampling in these waters. The fin whale sighting rate was higher than average (3 to 6 w./100 km) in an area 25-40 km off the continental coast, more or less off the 2 000 m isobath (Fig. 5). This area was more or less ring-shaped, as the fin whale distribution appeared to be less favourable in the most central part of the Ligurian Sea. A small area of concentration was also found in shallower waters of the northern Tyrrhenian Sea, some 70 km east of the Strait of Bonifacio. The western approaches of Corsica were comparatively less favoured than areas off the continental coast, whales seeming to be distributed slightly more offshore, farther than 35-50 km off northwest Corsica (Fig. 5).

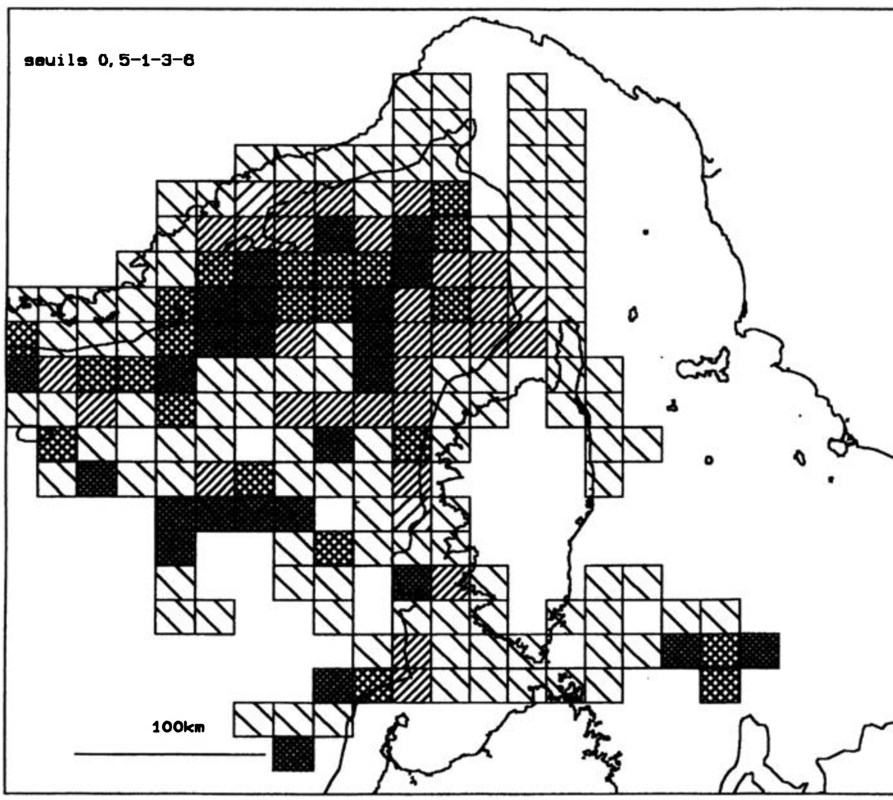

Figure 5. — Distribution of fin whale on a 10 × 10 miles grid.

DISTRIBUTION VARIABILITY

At large scale

We performed 18 distribution surveys during the study period, from which 15 were considered for analysis, including more than 500 km of effective effort

(Table I). Ten survey sighting rates $\mathbf{R}_{ps}$ were within 2.0 and 4.0 w./100 km, close to the global average found for the whole period, three were much lesser (in August 1997, 1998 and 2000) with minimal values of 1.08 w./100 km in August 1997 and 0.61 w./100 km in August 2000, and two were higher (July and August 1995) with a maximum of 9.01 w./100 km obtained in July 1995. Thus, if the large scale distribution of fin whales appeared to be quite regular in a majority of cases, in five cases whales were unusually rare or frequent in a region of the Sanctuary.

TABLE I

Summary of surveys from 1991 to 2000 with main distribution results.

Survey	Effort (km)	Sigh-tings	2 000 m criterion	Evenness	Distribu-tion pattern	Mean school size	Sighting rate (SE) wh./100 km
07/91	231	3	yes	yes	open sea	1.33	1.13 (0.35)
08/91	823	20	no	yes	both	1.35	3.33 (0.71)
07/92	919	16	yes	no	slope	1.5	2.69 (0.67)
08/92	381	22	no	yes	slope	1.5	8.49 (1.23)
07/93	546	8	yes	yes	both	2.25	2.49 (0.89)
08/93	1269	20	no	no	both	1.7	2.85 (0.76)
07/94	751	17	yes	yes	open sea	1.53	3.79 (0.79)
08/94	881	12	no	yes	both	1.5	2.30 (0.58)
07/95	686	33	yes	no	both	1.76	9.01 (1.35)
08/95	553	24	yes	no	both	1.83	6.46 (1.16)
07/96	540	9	yes	yes	open sea	1.13	1.40 (0.42)
08/96	827	32	no	no	both	1.04	3.48 (0.67)
08/97	960	11	no	yes	both	1.09	1.08 (0.34)
08/98	995	15	yes	no	both	1.47	1.50 (0.51)
07/99	893	12	yes	no	open sea	2.00	3.02 (0.84)
08/99	535	10	yes	yes	both	1.60	3.44 (0.88)
06/2000	361	11	yes	yes	open sea	1.45	3.87 (0.89)
08/2000	886	4	yes	yes	open sea	1.00	0.61 (0.30)

At medium scale

When considering the distributions obtained in July, whales were distributed far offshore on 3 occasions: in July 1994 (Fig. 6a), 1996 (Fig. 6b) and 1999. Two cases showed no clear tendency and in one case the distribution favoured waters close to the continental slope (July 1992). Out of nine distribution pictures in August (Table I), one was inshore, one favoured the open sea, and seven were recorded as neutral (neither inshore nor offshore), including in August 1995 (Fig. 6c) and in August 2000, when whales were outstandingly rare (Fig. 6d). A trend was apparent when considering the "2 000 m criterion": whales were frequently found inshore of the 2 000 meter isobath in August (1991-92-93-94-96-97) and never in July. Therefore, whales showed a slight tendency to expand their distribution range towards inshore areas from July to August.

At small scale

The comparison of mean school sizes across different surveys is very interesting: values between 1.00 (Aug. 2000) and 2.25 (July 1993) were obtained. When surveys have been achieved both in July and August, mean school sizes were consistently found either low, medium or high for both periods of the same year (Table I): school sizes were low in 1991 (poor sample size in July), medium in 1992, high in 1993, medium in 1994, high in 1995, low in 1996, low in August 1997, medium in August 1998, high in 1999 and low in August 2000. High mean school sizes were often linked to high sighting rates, although in July 1993 a mean school size of 2.25 was associated to a moderately low sighting rate (2.49 w./100 km). Similarly, the reverse case (low/low) was not systematically true: in August 1996, a mean school size of only 1.04 was found with a sighting rate of 3.48 w./100 km (Table I). Distribution was found patchy in seven cases, including six cases with medium or high mean school size: distribution patchiness seemed to be logically related to higher school sizes. However the reverse trend failed to be observed in two out of eight surveys when distribution evenness was high and mean school size was medium to high (July 1993, August 1999) (Table I). Thus, the small scale distribution as indicated by mean school sizes seemed to be rather constant throughout a given summer, but highly variable from one year to the next.

DISCUSSION

LARGE SCALE DISTRIBUTION

The large scale distribution of Mediterranean fin whales was recently better understood as it was confirmed that whales were mostly distributed north of the 40° parallel in the western Mediterranean (Gannier *et al.*, submitted), as first shown by Forcada *et al.* (1996) for the western basin only. Our survey sighting rates mostly fluctuated around the average values of 3.0 w./100 km, but much higher figures were reached in 1995 (9.0 and 6.4 w./100 km), indicating that fin whale favoured the area of study, and much lower sighting rates in August 1997

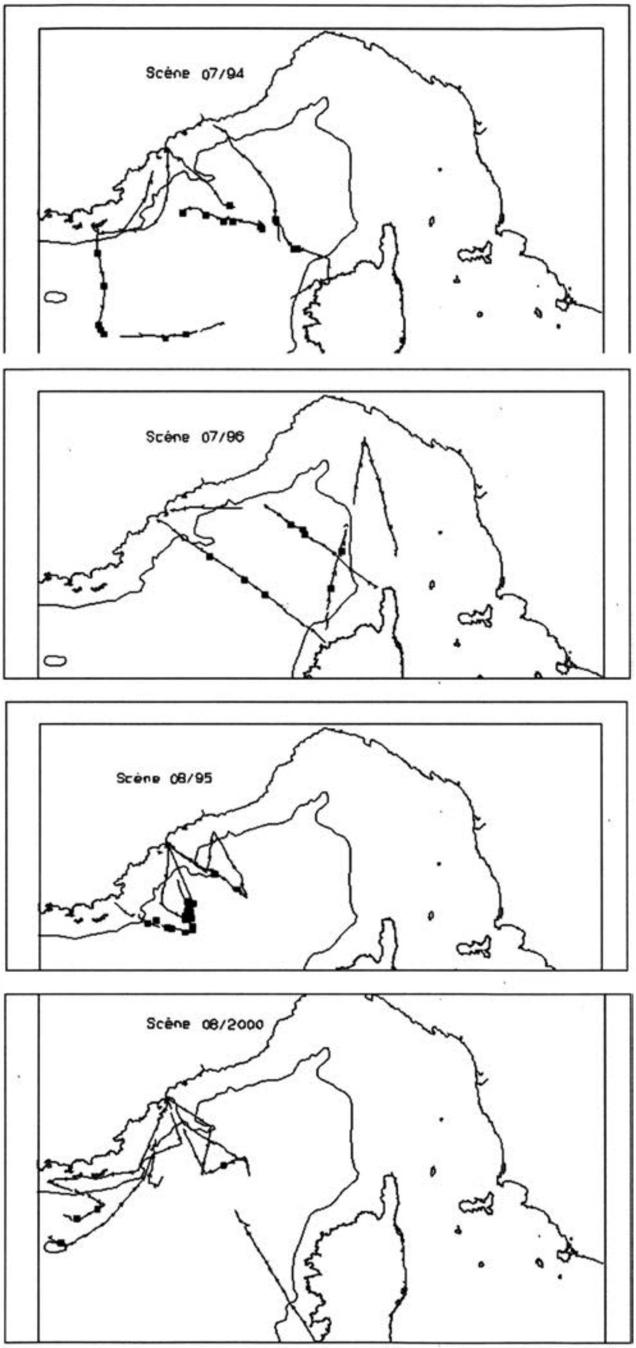

Figure 6. — Illustrative examples of distribution surveys. From top to bottom: 6a: 13-27 July 1994; 6b: 16-20 July 1996; 6c: 16-24 August 1995; 6d: 4-10 August 2000.

(1.08 w./100 km) and 2000 (0.6 w./100 km), indicating that whales were probably favouring another area than the Sanctuary within their whole distribution range in the northwestern Mediterranean. During summer 1997, 33 fin whale sightings were recorded in the Alboran Sea, a number much higher than usual in this southern region of the Mediterranean (Canadas *et al.*, 1999). This event is probably correlated to our corresponding very low sighting rate in the liguro-provençal basin. The Ligurian Sea is often considered as the favourite summering ground for fin whales (Notarbartolo di Sciara *et al.*, 1993; Gannier, 1999b), but the western part of the basin is likely to offer better prey availability at certain periods, particularly if small pelagic fishes are considered (Fischer *et al.*, 1987). Furthermore, large parts of the northwestern basin are not regularly covered by surveys, particularly between 40°30 and 41°30 of latitude, and may shelter a good proportion of the fin whale Mediterranean population, at a given time.

MEDIUM SCALE DISTRIBUTION

Our average distribution picture confirmed that fin whales favour waters deeper than 2 000 m in the Ligurian Sea, as already mentionned by Notarbartolo di Sciara *et al.* (1993) and Gannier (1998c). The amount of survey data enabled us to show that a ring-shaped peripheric region (25-40 km offshore) was in average more favoured than the most central part of the Ligurian sea. This is in agreement with results on summer primary and secondary production showing higher biomass close to the Ligurian Front 40 to 60 km offshore (Ibanez & Boucher, 1987). The highest biomass of krill *Meganyctiphanes norvegica* was also found some 40 km off the continental Ligurian coast rather than in the most central part of the basin during summer surveys (Orsi-Relini *et al.*, 1994). Distribution surveys showed that whales seemed to expand the distribution range towards inshore waters in August, as shown by the non-respect of the "2 000 m criterion", though they rarely wandered into areas shallower than 1 000 m. However during the summer 1997, when we obtained a sighting area of only 1.08 w./100 km in August, fin whales displayed very uncommon feeding and distribution patterns in the northwestern basin, frequently wandering into coastal waters (Beaubrun *et al.*, 1999). The above arguments tied together possibly indicate that fin whales may expand their distribution range as the summer season advances in order to meet suitable trophic conditions, and may also feed on a wide range of preys if their supposed main prey item, the krill *M. norvegica* (Orsi Relini & Giordano, 1992; Astruc & Beaubrun, 2001), is not abundant enough.

SMALL SCALE DISTRIBUTION

The small scale spatial distribution of fin whales is indicated by the mean school sizes, which we have shown to vary greatly from one year to the other, but not within the same summer feeding season: values as high as 2.25 (1993) or 1.83 w./group (1995) or as low as 1.04 w./group (1996) could be reached. Distribution patchiness or evenness was also observed on survey pictures. It is generally recognized that school size of baleen whales on feeding ground is linked to prey availability, although it is not known whether fin whales agregate following an active or a passive process (Gambell, 1985; Kawamura, 1994). The fin whales and *M. norvegica* respective distributions have been shown to be significantly correlated in the Ligurian Sea (Relini *et al.*, 1992) even if *M. norvegica* has itself a poorly known distribution. These organisms undertake extensive daily vertical migrations betwen their diurnal residence level, at depths of 500-1 000 m, and the superficial layers where they spend night time (Andersen *et al.*, 1992; Sardou & Andersen, 1993). Recently, Giard *et al.* (2001) derived fin whale dispersion patterns from whale watching systematic data and related them to measured krill biomass in the St Lawrence estuary. Krill biomass showed a high interannual variability and whales were more grouped when krill biomass was low: the authors hypothesized that whales agregated around capelin schools during krill poor seasons.

The consistency of mean school sizes throughout a given summer season might take sense if one considers the reproductive cycle of *M. norvegica* in the northwestern Mediterranean Sea (Cuzin-Roudy, 1993; Labat & Cuzin-Roudy, 1996): egg hatching usually occurs from February to May, two months before the survey period. *M. norvegica* biomass and availability in July and in August depends heavily on this reproductive cycle. If the school structure of fin whales owed much to prey availability, it would reflect strongly the earlier krill reproductive success whenever our whale distribution is determined, either in July or in August.

Thus, in the absence of other known factors, the prey availability would largely explain the fin whale distribution variability, at various scales, during the summer season.

CONCLUSION

Results from a large amount of survey effort showed the main features of the fin whale summer distribution in the region of the Northwestern Mediterranean Marine Mammal Sanctuary: a more or less ring-shaped maximal occurrence area located some 30-50 km off the continental coast and 40-60 km off the northwestern coast of Corsica. Some degree of inter-annual variability was noted for large scale distribution meaning the liguro-provençal basin was not always the principal concentration site of fin whales in the western Mediterranean. Medium scale variability was also shown within a summer season, the whales tending to expand their distribution range towards more inshore waters from July to August. Mean school sizes seemed to remain consistent within a given feeding season and to vary from one year to the next. The present set of results suggests that fin whales in the Mediterranean react to presently unknown variations in the distribution and availability of their preys. Current knowledge on the northwestern Mediterranean ecosystem may be unsufficient for understanding the population dynamics of predators such as fin whales.

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