ABSTRACT

This study analyzes data on the biology of sperm whales, *Physeter macrocephalus* Linnaeus, 1758, obtained between 1965 and 1980 by the COPESBRA at the Costinha Whaling Station, Paraíba, Brazil. The data come from the log books of the whaling ships and from the spreadsheets containing biological information filled out by employees of the SUDEPE at the flensing plan of the whaling station. The catches occurred from June to December, in an area delimited by 06º22'-07º52'S and 33º26'-34º58'W. A total of 641 sperm whales were killed in this period. The average sex ratio was 2.05 females to each male. The mean largest frequency of females was recorded in the first and the last months of the season, and that of males in July/August. The mean total length (TL) of males was 11.4 m (minimum 7.2 m, maximum 17.6 m). The females had a mean TL of 10.1 m (minimum 8.6 m, maximum 12.9 m). A decrease was observed in the TL of females along the years. Fetuses were observed in 8.3% of the catches. They had TL between 0.24 and 4.3 m. All sperm whales had food in their stomachs, showing that they feed in the area. As in other places north to the 40ºS, there was a higher frequency of females than males. The difference between the time of maximum catch of males and females may reflect a temporal segregation in the arrival of sperm whales in the area. The reproductive activity of sperm whales in these tropical waters occurs year-round.

Key words: Biological data; Costinha Whaling Station; sperm whale.
MATERIAL AND METHODS

The present study is based on data gathered during the commercial catches of sperm whales made by COPESBRA between 1965 and 1980. Comparative data was taken from the International Whaling Statistic (IWS), the papers by SINGARAJAH (1985), KISHIWADA (2007), PAIVA & GRANGEIRO (1965, 1970), ROCHA (1980a, b) WILLIAMSON (1975) and internal reports to SUDEPE by the Brazilian delegation to the 27th, 28th, and 30th annual meetings of the IWC.

The whaling station of Costinha (6°57'45"S, 34°51'28"W), municipal district of Lucena, was located on the left margin of Rio Paraíba's estuary, on the opposite side of Cabedelo's harbor.

The whaling season lasted from June to December. Back then, whaling ships set off to sea daily, leaving Cabedelo between 03:30-04:00 AM and returning to the factory no later than 11:00 PM (GRANGEIRO 1962, KISHIWADA 2007). The information on whales was recorded in the whaler's log books and in spreadsheets of biological data filled out by employees of the former Superintendência do Desenvolvimento da Pesca (SUDEPE) at the flensing plan of the whaling station. In the log books the following data was registered: date and hour of departure from harbor and arrival at the whaling station; numbers of shots fired and of successful shots; name of the ship; port of registration (RGP) of the ship; the gunner's name; sequential number of the animal killed; whale species; date, hour, geographic position and number of whales sighted in the group; conditions of the sea, sky, rain, wind, temperature and barometric pressure.

In the spreadsheets of biological data the whales were identified with the same number attributed to them at the time of capture in the log book. The former contained the date, sex and total length (in meters and feet) of the whale, thickness of the blubber, presence of food in the stomach, size of the testes (males), sex and total length of the fetus (when present) and a field for other observations.

In this study, we defined a group as two or more animals moving together and in a coordinate way. To determine the state of sexual maturation, the classification of WHITEHEAD et al. (1997) was adopted, as follows: mature males > 13 m; females and immature individuals between 7 and 12 m (mature females > 9 m); first year of life between 5 and 6 m; and calves < 4.5 m. We based our estimates of the age of the fetuses, on the criteria used by RICE (1989), where the pregnancy period from 14 to 15 months is divided into two phases: the phase of embryonic growth (60 days) and in the phase of linear growth (1 to 1.1 cm/day⁻¹).

The information on date, catch position, sex, total length, stomach content, sex and size of the fetus and number of individuals sighted in the group was tabulated in electronic spreadsheets and the basic statistics were calculated.

RESULTS

The whaling area extended over the 200 n.miles of exclusive economical zone of Brazil (UNITED NATIONS 1980), constituting a small part of the sperm whale IWC Division I of the Southern Hemisphere. This division was defined by the IWC as the area between longitudes 60° and 30°W (DONOVAN 1980). The catches of sperm whales occurred in a zone delimited by the latitudes 06°22' and 07°52'S and longitudes 33°26' and 34°58'W (Fig. 1). In that area, the continental shelf extends about 20 miles off the coast and at its border the depth increases abruptly from 60 to 4000 m. The substratum in the shelf area is irregular and rocky.

The most important oceanographic feature of the area is the proximity to the equatorial current system. The trade winds from southeast drive the waters to the west, forming the South-equatorial Current. A large part of this current goes to the south and follows a longitudinal N-S direction, until about 40º S, where the direction changes to the east. It is called Current of Brazil, and because it comes from the equatorial and tropical areas (PEREIRA & SOARES-GOMES 2002), it is characterized by warm and more saline waters.

The average superficial water temperature in the whaling area was 27°C, remaining practically constant during the year. The speed of the current fell from 1.04 knots in June to 0.60 in December (SINGARAJAH 1984).

Between 1952 and 1980, 686 sperm whales were killed off the coast of Paraíba (KISHIWADA 2007); of these, 641 catches took place between 1965 and 1980. Table I shows the number of annual catches by COPESBRA compared with catches by the Sociedade de Pesca Taiyo Limitada (SPTL), in Cabo Frio, Rio de Janeiro.
The mean total length (TL) of the males caught was 11.4 m, with a minimum of 7.2 m and a maximum of 17.6 m. Of these, 18% were considered sexually mature because they were more than 13 m long. The females had a mean TL of 10.1 m with minimum and maximum lengths of 8.6 and 12.9 m, respectively. Five females (1%) measured between 8.6 and 8.9 m, a size considered immature by WHITEHEAD et al. (1997).

There were no records of captured calves of less than one year of age accompanied by their mothers.

A decrease of mean TL was observed among females with the passing years (Fig. 2). Among males there were strong oscillations of TL in the studied period. Monthly analyses showed a higher frequency of smaller individuals of both sexes at the beginning and the end of the season (Fig. 3).

Out of the 641 individuals caught in the studied period, 431 were females and 210 were males. Figure 4 shows the annual number of sperm whales hunted between 1965 and 1980. Notice that the number of animals killed varied from year to year. However, with a few exceptions, females were in larger numbers, especially in 1969 (59 females), 1973 (53 females) and 1970 (45 females). Males were more frequently caught in the seasons of 1970, 1972 and 1973, with 31, 24 and 22 animals, respectively.
The average sex ratio for the studied period was 2.05 females for each male, with largest values in 1975 (4.4), in 1969 (3.68) and in 1971 (3.23). Only in 1967, 1976 and 1977 the number of males was almost the same as that of females, with rates of respectively 1:1, 0.8:1 and 0.9:1. Apart from these years males did not outnumber females (Tab. II).

The monthly records of catches (Fig. 5) revealed a higher frequency of females at the beginning and the end of the season, while the higher frequency of males was in July and August. The curve of females is "U" shaped, indicating a higher rate of captures in June (149 individuals) and December (125 individuals) with an abrupt decrease in September (4 individuals). Catches of males showed a progressive increase, with a maximum in August (82 specimens), followed by a decline in October (17 animals), and a
Thirty six cases of pregnant females were recorded, totaling 8.3% of the total females caught between 1965 and 1980. The fetuses were in different stages of development, with TL varying between 0.2 and 4.6 m. Of these, 14 were males, 20 were females and one had unrecorded sex. One male fetus (UFPB-5965) (Fig. 6) has been kept in the Marine Mammal Collection of the Departamento de Sistemática e Ecologia of Universidade Federal da Paraíba. Measuring 24 cm it is approximately 85 days old according to RICE (1989). The pregnant females showed a mean length of 10.1 m, with a minimum of 8.6 m and a maximum of 11.2 m. They were caught between 06º33'-07º50'S and 33º38'-34º32'W (Fig. 1). Catches of 26 lactating females were also recorded, approximately 6% of all captured females. The monthly variation of pregnant females is shown in figure 7.

Table III shows fetus size, date of capture of the mother and projected estimates of the possible date of birth of sperm whale fetuses caught by COPESBRA.

According to the spreadsheets of biological data, all sperm whales caught by COPESBRA showed rests of food in the stomach. However, no identification of the stomach content was made at the time.

DISCUSSION

The number of sperm whales exploited by COPESBRA since its beginning up to 1980 (686 animals) is not very significant when compared with catches in Antarctica. Between the seasons of 1949-1950 and 1967-1968, a total of 89,544 animals were caught in Antarctic whaling grounds with a mean number of 4,712.8 individuals per season. This represents, just in one season, 6.8 times more than the total number of sperm whales exploited off the coast of Paraíba since 1911. This number is also much smaller than the number of catches reported from other tropical areas (Tab. IV).

In the four seasons of activity of the whaling station of Cabo Frio, the number of sperm whale catches was considerably larger than that of the COPESBRA in the same period (see Tab. I). However, at Costinha, the captures increased from 1965 on, when a significant change occurred in the number of catches and target species. The sperm whale and minke whale captures increased, the sei whale catches declined and the humpback whale disappeared from the records (Fig. 8 and Tab. V). The COPESBRA always prioritized the catch of baleen whales over the sperm whales. Initially, humpback whales were preferred; soon thereafter, the preference shifted to sei whales; finally, the focus was on the catch of minke whales.
The positions recorded by the whaling ship between 1965 and 1980 reveal that the area of sperm whale hunting off the coast of Paraíba remained the same. According to SINGARAJAH (1985) the whaling ground of the COPESBRA covered an area of about 15,000 n. miles$^2$, while the area of SPTL in Cabo Frio was 42,000 n.miles$^2$. This made the coastal whaling operations from Cabo Frio more difficult and more expensive, probably contributing to the closing of the activities of that company. The spatial distribution of sperm whale catches off the coast of Paraíba (Fig. 1) is almost the same for males and females. However, while the distribution of males tended to concentrate in one area, females had a more homogeneous distribution.

JAQUET (1996) indicates that the Brazilian coast from states of Rio Grande do Norte to Rio Grande do Sul, with the exception of a small strip in the mouth of the San Francisco river, is one of the areas of larger concentration of sperm whales in the globe. The mean total length of the animals caught was within the general pattern described for the species (RICE 1989). However, in the catches made by COPESBRA, we noticed a decrease of size in the course of time, especially in females (Fig. 2). WHITEHEAD (2003) indicated the large mature males as the main target of whalers in the world, therefore KASUYA (1991) showed that, as exploitation progressed in the North Pacific, the average length of males diminished but not that of females. However, in our study, we verified a higher number of females in the catches, probably because larger whales were not consistently selected by the gunner. These numbers may be responsible for the decrease in mean TL from 11.4 m in 1965 to 9.3 m in 1980 (Fig. 2).

Only 18% of the males caught were larger than 13 m; in other words, 82% were not sexually mature. In agreement with WHITEHEAD (2003), in low latitudes the large males wander among groups of females for a period of a few months, tending to live a solitary life for the remaining of the year. The monthly analysis showed that smaller individuals were caught more frequently in the beginning and in the end of the season. This temporal segregation pattern was also observed by ROCHA (1980b) and LUCENA (2006) for the minke whales, *Balaenoptera bonaerensis* Cuvier, 1829, *Balaenopteridae*, hunted in the same area by COPESBRA. ROCHA (1980b) considers this pattern as a reproductive strategy of the species.

The mean size of the sperm whales caught off the coast of Paraíba was lower than that of animals from other waters (Tab. VI). This may be related to a higher percentage of females captured off Paraíba coupled with a more intensive selection of large males at other whaling grounds.

| Year | Sperm whales | Sól whales | Minko whales | Humpback whales | Total |
|------|--------------|------------|--------------|-----------------|-------|
| 1955 | 1            | 198        | 6            |                 | 205   |
| 1956 | 3            | 196        | 14           |                 | 213   |
| 1957 | 2            | 115        |              |                 | 117   |
| 1958 | 4            | 118        | 5            |                 | 127   |
| 1959 | 11           | 294        | 2            |                 | 315   |
| 1960 | 1            | 500        | 10           |                 | 511   |
| 1961 | 5            | 504        | 11           |                 | 520   |
| 1962 | 4            | 272        | 8            |                 | 284   |
| 1963 | 7            | 253        | 2            |                 | 272   |
| 1964 | 4            | 256        | 44           |                 | 304   |
| 1965 | 13           | 149        | 68           |                 | 230   |
| 1966 | 24           | 72         | 352          |                 | 448   |
| 1967 | 20           | 49         | 488          |                 | 557   |
| 1968 | 39           | 58         | 456          |                 | 553   |
| 1969 | 75           | 56         | 617          |                 | 748   |
| 1970 | 76           | 23         | 701          |                 | 800   |
| 1971 | 55           | 18         | 900          |                 | 973   |
| 1972 | 66           | 5          | 702          |                 | 773   |
| 1973 | 75           | 6          | 650          |                 | 731   |
| 1974 | 29           | 2          | 765          |                 | 796   |
| 1975 | 54           | 3          | 1,039        |                 | 1,096 |
| 1976 | 9            | 3          | 776          |                 | 788   |
| 1977 | 25           | 5          | 1,000        |                 | 1,030 |
| 1978 | 24           | 690        |              |                 | 714   |
| 1979 | 27           | 739        |              |                 | 766   |
| 1980 | 30           | 902        |              |                 | 932   |
| 1981 | 74           | 749        |              |                 | 749   |
| 1982 | 854          | 854        |              |                 | 1,708 |
| 1983 | 625          | 625        |              |                 | 1,250 |
| 1984 | 600          | 600        |              |                 | 1,200 |
| 1985 | 598          | 598        |              |                 | 1,196 |
| Total| 683          | 3,155      | 1,4319       | 72              | 18,229|
It is interesting to notice the similarity between the monthly curves of capture of mature females and pregnant females (BEST et al., 1997). Consequently, pairing is expected to have taken place 14 months earlier. This agrees with data of several authors, reported by WHITEHEAD (2003) that the distribution of sperm whales in some areas, particularly in low latitudes, has large mensal and annual variations.

As seen in table III, estimates of birth time based on fetus length showed higher frequencies between September-December. This may explain the higher frequency of females in catches. Among single sighted animals, the frequency of large males was higher.

The sex ratio of two females for each male had been already observed by GRANGEIRO (1962) in the first years of sperm whaling off the coast of Paraíba. KAHN et al. (1993) mention that during the last 40 years of sperm whaling the preference for catching mature males ended up changing the adult sex ratio in some areas (CLARKE et al., 1980). It has been suggested that this change resulted in a disruption of the sperm whale’s mating system, leading to a reduction in pregnancy rates, thus lessening the potential of the population for recovery (CLARKE et al., 1980, MAY & BEDDINGTON 1980, WHITEHEAD 1987). However, during whaling off the coast of Paraíba there was no selection for size, and the sex ratio found in our study may reflect the real situation of the sperm whales’ population in the area.

From 1976 on, the IWC recommended a minimum size of 9.2 m and maximum size of 13.7 m for the capture of sperm whales in the Southern Hemisphere (RICE 1989). This measure was intended to avoid the capture of sexually immature animals and also of large, sexually mature males. Our data shows that 25 females and six males smaller than 9.2 m and seven males above 13.7 m were killed after 1976. These numbers represent 33% of the sperm whales caught after 1976. It may be considered, however, that the estimate of size of a live sperm whale at sea may have such a margin of error.

Five of the 25 females captured (between 1978 and 1980) measured between 8.6 and 8.9 m. Even though this size range was considered by WHITEHEAD et al. (1997) to correspond to immature individuals, one of the females, measuring 8.6 m, was pregnant.

The sex ratio is near one at birth for sperm whales. However, during whaling off the coast of Paraíba, WHITEHEAD (2003) to correspond to immature individuals, one of the females, measuring 8.6 m, was pregnant.

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Table VI. Average TL (in meters) of sperm whales caught in different whaling grounds, for the years 1977-1980. Source: IWS.

| Whaling ground | 1977 | 1978 | 1979 | 1980 |
|----------------|------|------|------|------|
| Brazil         | 9.7  | 9.2  | 9.2  | 9.3  |
| Antarctica     | 13.7 | 14.2 | 14.5 |     |
| Iceland        | 14.3 | 14.6 | 14.7 | 14.3 |
| Spain          |      | 11.3 |      |      |
| Japan, pelagic | 12.1 | 11.5 | 11.5 | 11.5 |
| Japan, coastal | 10.9 | 11.3 | 11.5 | 11.7 |
| Ex-URSS, pelagic | 11.7 | 13.7 | 13.0 |      |
| South Atlantic | 12.6 | 12.4 | 12.7 |      |
| South Pacific Ocean | 10.5 | 11.0 | 10.7 |      |
| Indian Ocean, pelagic | 12.1 | 11.8 | 11.4 |      |
| Australia      | 12.5 | 12.2 | 12.4 |      |

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It is interesting to notice the similarity between the monthly curves of capture of mature females and pregnant females (Fig. 7). This
Our findings agree with more recent data on Brazilian sperm whale stranding (RAMOS et al. 2001) showing that most calf stranding occur in beaches of Brazilian Northeast between 5ºS and 11ºS in summer and autumn. Further, on January 11, 1998 we recorded a stranded male calf measuring 3.3 m in Praia de Oitero (6º50'S), Paraíba. The specimen is preserved in the collection of the UFPB, number 3556. On May 7, 2006 another 4 m calf stranded alive near the city of Cabedelo, Paraíba, being thereafter returned to sea. Thus, sperm whales dwelling in waters off Paraíba may be at any stage of their reproductive cycles, from conception to birth. This data confirm the hypothesis that sperm whales reproduce in tropical waters (REEVES et al. 2002).

Since all animals killed showed food remains in the stomach we believe that sperm whales feed normally in the area. There is no data from COPESBRA on what kind of food was eaten, but a male stranded at Praia de Campina, Mamanguape, Paraíba state had beaks of squid of different sizes in the stomach. GURJÃO et al. (2003) examined the stomach contents of three sperm whales stranded in the coast of Ceará, (~5ºS) Brazil and found 20 species of squid, most of them (76%) belonging in the family Histiotethiidae. Preference for species of this family was also observed in sperm whales of the North Pacific Ocean, but variations may occur in different areas (CLARKE 1987).

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two major historical phases of sperm whaling occurred—the open boat hunt conducted under sail by whalers from the United States, Britain, France and offshore areas of the world's oceans and were hunted extensively across all oceans for two centuries (Whitehead, 2002). Off the Western Australian coast, of Ameland (the Netherlands); three of these had food remains in the stomach. Sperm whales (Physeter macrocephalus) inhabit and forage in deep animal was stranded on 27 November 1997 near Wassenaar (the Netherlands). Four became stranded the following day, 28 November 1997, on the island The stomach contents of seven male sperm whales Physeter macrocephalus (Odontoceti: Physeteridae) from the north-east Atlantic were examined. One animal was stranded on 27 November 1997 near Wassenaar (the Netherlands), Four became stranded the following day, 28 November 1997, on the island of Ameland (the Netherlands); three of these had food remains in the stomach. Sperm whales (Physeter macrocephalus) inhabit and forage in deep offshore areas of the world's oceans and were hunted extensively across all oceans for two centuries (Whitehead, 2002). Off the Western Australian coast, two major historical phases of sperm whaling occurred—the open boat hunt conducted under sail by whalers from the United States, Britain, France and...
Germany (1712–1920) (Bannister et al., 2008), and the commercial, mechanized hunt (1904–1999), primarily off the continental shelf near Albany and in the New Holland grounds off Carnarvon (Figure. The modern sperm whales Kogia and Physeter (superfamily Physeteroidea) represent highly disparate, relict members of a group of odontocetes that peaked in diversity during the middle to late Miocene. Based on a highly informative specimen (including the cranium with ear bones, mandibles, teeth and some postcranial elements) from the lower Miocene (early Burdigalian, 19–18 Ma) of the Chilcatay Formation (Pisco Basin, Peru), we describe here a new genus and species of physeteroid, Rhaphicetus valenciae gen. et sp. nov. 2020. A New Longirostrine Sperm Whale (Cetacea, Physeteroidea) from the lower Miocene of the Pisco Basin (southern coast of Peru). Journal of Systematic Palaeontology. 18(20); 1707-1742. The Coastal Paleontologist, atlantic edition.