ОКЕАНОГРАФІЯ ТА БІОЛОГІЧНІ РЕСУРСИ

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RESULTS TAGGINGS OF ANTARCTIC WHALES

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Реферат. Способи мічення китів описано в історичній послідовності. Дано опис міток різного типу й показано їх ефективність. Наведено карти міграцій промислових видів китів в Антарктиці та прилеглих водах, складених за результатами повернення міток. Визначено перспективи використання фотоідентифікації китів і радіоміток із супутниковим зв'язком, а також аналізу ДНК на основі біопсії.

Реферат. Способы мечения китов описаны в исторической последовательности. Дано описание меток разного типа и показана их эффективность. Приведены карты миграций промысловых видов китов в Антарктике и прилежащих водах, построенные по результатам возврата меток. Указаны перспективы использования фотоидентификации китов и радиометок со спутниковой связью, а также анализа ДНК на основе биопсии.

Abstract. Methods of whale marking are described in historical order. Marks of different types are described, and their effectiveness is analyzed. Commercial whale migration maps in the Antarctic and nearby waters, based on mark return, are given. Perspectives of use of photo identification of whales, satellite radio marks and biopsy DNA analysis are given.
Key words: whale, marking, whale marks, satellite radio, photo identification, biopsy.

1. Introduction

During whaling period, the analysis of taken whales allowed, to some extent, making conclusions about their *moves* to feeding areas and back, and about population areas. But it was impossible, without marking, to determine migration routes, population structure, *life span* and many other issues of whale biology. So, in 1924 a program of large scale whale marking started by joint efforts of the interested parties. Information about the returned marks was submitted to the Scientific Committee of International Whaling Commission (IWC). After abolition of whaling, non-lethal research methods were developed. Up to present time, significant data were accumulated, and it is time to summarize them.

2. Material and method

This paper analyses hand harpoons discovered in taken whales, which acted as marks. While analyzing modern marks, we used the data of international whaling statistics, supplemented and corrected by marking results by Soviet whaling fleets "Slava", "Sovetskaya Ukraina", "Sovetskaya Rossia" and "Yuri Dolgoruky", which had been hidden from scientific community. Satellite radio marking results and different ways of whale identification are described as well.

3. Results and discussion

On the basis of maps of movements, we analyze the characteristics of tagged whales migration to the feeding fields and back into the areas of winter distribution.

3.1. The debris handheld harpoons as whale tags

Until the middle of the second half of the 19th century, the whales all over the world were extracted only with hand harpoons. Natives of Chukotka and Aleutian Islands continued to use hand-held harpoons till 1920-1930s. Sometimes the wounded whale with a harpoon stuck in its body (usually a fragment of a harpoon (fig. 1)), went from prosecution. If later the whale was caugth, and the harpoon had any distinguishing features, then it was possible to judge how much time passed since the hunting of whales (and in some cases, estimate its age), and tentatively identify the migration path of the animal. I.e., such findings sometimes functioned as markers (Fig. 1–10 see the color paste between pages 140 and 141).

In 17-18th centuries some whales, which had been harpooned in Davis strait, were later taken near Spitsbergen Island. And vice versa, some whales, wounded near Spitsbergen, wre found in two days in Davis strait (Scoresby, 1820; Scoresby, 1825; Tomilin, 1957). Such findings have shownthat two populations of Northern Atlantic Greenland whales – Western Greenland and Spitsbergen ones – are not isolated.

European harpoons were found in whales taken in the Kamchatka Sea, long time before whaling started in the Pacific Ocean. Some harpoons were marked by Latin letters. In one case it was possible to determine the whaler's name: harpoon extracted from a right whale taken near Sakhalin Island (Tatarian Strait) had letters "WB", which belonged to Holland whaler Wilhelm Bostian, who whaled near Spitsbergen Island (Zordraguer, 1723, according to Tomilin, 1957). It is difficult to imagine, but the facts pointed to the link of right whales from Northern Pacific Ocean with that of Northern Atlantic Ocean via Arctic Ocean. We can only assume how they migrated: in eastern or western direction.

3.1.1. Attempts to estimate life span of whales based on found hand harpoons debris. As M. Vasiliev reported in 1891 (according to Tomilin, 1957), harpoon debris was found in a sperm whale (not old one, according to his estimate), which remained in the body for 40 years. Not long ago there were reports about finding of harpoon debris in *fat* of 5 killed bowhead whales. Let's examine these cases.

In 1981, an ivory harpoon head with a metal point was recovered from the blubber of a whale (81WW2; 17.7 m) taken in Wainwright, Alaska, between Chukchi Sea and Beaufort Sea (Philo et al. 1993). A triangular metal blade (about 3 × 3 cm) similar to a walrus harpoon point was recovered from an unknown whale taken in Wainwright in either 1992 or 1993 (it was found in some blubber stored in an ice cellar). A slate whale point was recovered from whale 92B2 (a 15.7-m female) taken in Barrow, Alaska (closer to Beaufort Sea, to the east of the place where whale 81WW2 was taken), in May 1992 and two stone points were recovered from whale 93WW5 (a 16.7-m male) taken at Wainwright on 27 May 1993. In 1997, a 16.1-m male (97WW3) also taken at Wainwright carried a triangular slat e harpoon tip similar to that found in whales 92B2 and 93WW5. In all cases, the points were recovered from the blubber in the dorsal thoracic region.

Researchers at the University of Alaska museum evaluated the ivory–metal point recovered from 81WW2. They suggested that points with this manufacture style were similar to some collected on the St. Lawrence Island in the 1920s and may have been made as late as the 1970s (walrus harpoons) (Philo et al. 1993). We should note that ivory tips with metal blades were used in Chukchi Sea for whaling as early as 1791 (Krupnik, 1998).

The researchers noted that none of the recovered traditional points were associated with any modern whaling equipment (Yankee harpoons or projectiles) suggesting that the strike was made with entirely traditional gear. But they report (and it is very important!) that after 1880s, when most hunters made the transition to Yankee weaponry, they may have still used traditional tools (for religious

reasons) to strike the animal and then kill it using firearms. There was a report that European whalers aboard the Beluga recovered a whaling iron embedded in the blubber of a bowhead whale in 1890 that was very likely placed by the crew of the Montezuma, which last cruised in 1854 (Dall, 1899, according to Tomilin, 1957). Thus, this whale carried the iron for a minimum of 36 years.

By matching these points with collections at the Smithsonian Institute, researchers suggested that these points may have been placed by Eskimo whale hunters 100–130 years ago (Weintraub, 1996), which means whales lives more than 100 years. The conclusion seems to be supported by biochemical analysis via aspartic acid racemization (George, at al., 1999).

However from our point of view the reliability of the conclusion is too low. The conclusion about so long life span of whales (at least bowhead ones) contradicts age estimate based on registration structures: baleen plates and ear plugs, as well as teeth of toothed whales (Ruud, 1940; Tomilin, 1945; Nishiwaki, 1950; Berzin, 1961; Gambell, Grzegorzewska, 1967; Mikhalev, 1977, 1982; Klevezal, 1988; Mikhalev, 1971, 1973, 1975, 2002). Also the conclusion is not confirmed by results of marking by special whale marks, which will be discussed below.

3.2. Special-purpose Whaling marks

Analysis of harpoon debris gave little information about whale distribution and migrations. It was necessary to start marking using special whaling marks. First marks were designed and implemented in Great Britain, ordered by Discovery Committee. They were tested near Iceland in 1924 by English scientist Hardy and Norwegian A. Yort (Hardy, 1940; Jonsgard, 1968). The marks look like a pin with disk diameter 4.45cm. Also a wooden stick with diameter 0.8cm with line was connected to the pin. To connect to whale body the pin had point 6.35cm long with 3 barbs. It was made of iron covered by silver. On the inner side of its disk there was serial number and the following text: “Reward for return to Discovery Committee Colonial Office London”. Wooden stick with line and cartridge were inserted into barrel of smoothbore gun. Nevertheless despite of massive marking during several years and good reward (1 British Pound), there were no returns. Perhaps the marks were not connected well to the animal skin and got lost. So it was necessary to change their construction.

New marks were made of stainless tube with diameter 1.5cm, length 25cm and weight 150g. The tube had lead point on front end, and rear end was used to insert power cartridge. Along the tube its serial number and the text above was engraved. The shots were made from havy smoothbore guns of 12 caliber. After a good shot the marks broke through thick layer of fat and got stuck in it or muscle. Massive whale marking started in 1932 in the Antarctica near South Georgia Islands. Till 1938 more than 5000 whales were marked, most of them fin whales (*Balaenoptera physalus*). Nevertheless despite of active whaling of this s pecies, the mark recovery was low – 5-7%. During whale splicing it was difficult to find the marks even in the case, when a shot was made at body of taken whale. Some marks were found in pots after fat boiling.

The Second World War stopped the whale marking. After the war whaling and marking were resumed. In addition to Great Britain marks of type “Discovery” were produced in Japan. During the third cruise of fleet “Slava” the members of its scientific group V.A. Arseniev, V.A. Zemsky and N.E. Salnikov performed test mark shots, and starting from cruise 1952/53 massive marking was started, initially by “Discovery” marks, then by marks made in USSR: the marks had text in Russian “СССР МОСКВА МИНРЫБПРОМ ВНИРО” (USSR Moscow MinRybProm VNIRO) and in English “Kindly return to Moscow USSR”, also they had serial numbers (fig. 2, top).

In 1953 in addition to Great Britain, Japan and the Soviet Union, Norway and Holland started whale marking. The marking was performed not only from whaling vessels. Especially for the marking Norway vessel “Enern” was sent to the Antarctica. Several scientists from different countries were in the expedition, which was leaded by Norway scientist J.T. Ruud (Ruud et al., 1953; Clark and Ruud, 1954). During two years the expedition marked 395 whales. At the end of 1950-s all countries in total marked more than 13000 whales.

After a while the mark “Discovery” changed. It became lighter, because it was made of duralumin. Also text on the mark was changed: "Reward for to Discovery British museum (Nat. History) London". The text on Soviet marks became shorter: “СССР МОСКВА ВНИРО” (“USSR MOSCOW VNIRO”) (Arseniev, 1959). We (Mikhalev, 1978) used these marks in cruise 1973/74 in Indian and Pacific Oceans on scientific-search vessel “Bodry-25” to mark whales: 34 sperm whales (*Physeter makpocephalus*); 11 seiwhales (*B. borealis*); 4 killer whales (*Orcinus orca*); 2 humpback whales (*Megaptera novaeangliae*); 1 fin whale (*B. physalus*); 1 minke (*B. acutorostrata*) и 1 Cuvier's beaked whale (*Ziphius cavirostris*). In the next cruise (1974/75 гг.) we managed to mark another 75 китов: 46 sperm whales, 11 minke, 3 fin whales, 3 seiwhales, 2 humpback wgales, 1 Bryde whale (*B. edeni*), 1 pilot whale (*Globicephala melaena*) and 8 killer whales.

Before the Second World War all countries marked more than 13000 whales in the Southern Hemisphere, including 4988 whales in the Antarctica. After the war and till 1975 they managed to mark another 4470 whales – 2040 fin whales, 1090 humpback whales, 400 sei whales (including Bryde’s whales), 551 sperm whales, 290 blue whales, 68 right whales (*Eubalaena glacialis*) and 31 minkes. In the Northern Hemisphere after the war 7444 whales were marked, including 6480 in the northern Pacific Ocean and 964 in the northern Atlantic Ocean.

More than 1500 whales were marked during whaling period by the Soviet Union. In total, according to incomplete data, 20573 whales were marked. Unfortunately, as we noted above, mark return was only about 5-7%. And most of returned marks have no scientific value, because the whales were caught right after marking.

The Discovery marks didn’t help to determine whale’s life span, because the age of the whales was unknown. According to S.G. Brown (Brown, 1995) in the Southern Hemisphere the marks remained the longest period in the body of a fin whale – 37 years (its age was determined by registering structures as 42 years); in humpback whale – 17 years (age 30 years); blue whale – 14 years (age 32 years); sei whale – 11 years (age 42 years); in sperm whale – 22 years (based by teeth its age was determined as 40 years).

In 1970-s the number of large whales significantly decreased (Yablokov, 1994; Zemsky et al., 1995; Zemsky, Mikhalev end Berzin, 1996; Mikhalev, 1997a; 1997b; 1998; Tormosov, et al., 1998; Data of Soviet Whaling [1949-1979], 2000), and most of the caught whales were small species, first of all minkes. Unfortunately the marks often deadly wounded these whales.

That’s why for small species a new mark was designed in Great Britain ordered by Discovery Committee and Scientific Committee of International Whaling Commission (IWC). It was a metal tube with lead tip as well, but it was just 16cm long with 0.8cm diameter (fig. 2, bottom).

The mark return is very important. One of the methods to determine whale *abundance* is based on ratio of *fired* and returned marks. But its precision is reduced by two factors. First of all it is unknown how many marks got stuck in whale body. The second, whalers didn’t report about all returned marks, hiding whaling regions and number of killed whales. At least that’s how it was on Soviet whaling fleets.

3.2.1. Results of marking by Discovery marks. We give maps of migrations of the Southern Hemisphere whales, based on corrected marking results on Soviet whaling fleets (Mikhalev, 1998, 2000; Mikhalev, Tormosov, 1997).

A. Blue whales. Largest animal of our planet - the Antarctic blue whale – practically does not *occur* north of 50º S.

The map (fig. 3) includes recovery of 44 marks of 571 marked Antarctic (real) blue whales. These blue whales were never seen to the north of 40º S.

The marking results show moving of blue whales from region of South Georgia Islands to the Weddell Sea and the Collaboration Sea, and from the Bellingshausen Sea to the Ross Sea.

As for pygmy blue whales (Balaenoptera musculus brevicauda) which like warmer waters, we have just one returned mark: the whale was marked on 12/1/1962 at 56º S 48º E, and taken on 4/4/1963 at 44º S 49º E. Using whaling results we can make conclusion that pygmy blue whales

from western Australian population move to Big Australian Bay, and those from eastern Australia to the Bass Strait and the Cook Strait.

B. Fin whales. This is the second largest whale. Was actively caught until the complete moratorium.

Their area in the Southern Hemisphere is wide – from 20º S to the Antarctic ice edge. Most of fin whales were marked (3684 whales) in period between October and May in zone from 20º S to 70º S. 329 marks were recovered.

The marking revealed (fig. 4) that fin whales of Chili population migrate through Drake Strait to the Weddell Sea. Fin whales from waters near South Africa move to Bouvet, Crozet, Kerguelen and Amsterdam Islands. Whales from coastal regions near New Zealand go to feeding areas off Balleny Islands and Ross Sea. Also one marked fin whale moved from Fiji Island to Collaboration Sea. In the middle of summer fin whales move to the south, in March and April reverse migration is noticeable.

C. Sei whales. This is the third largest whale of the genus *Balaenoptera*. Average size of adults reaches 15-16 meters.

Sei whales and fin whales occupy the same areas, and their migrations are similar. But unlike fin whales, sei whales move later to sub-Antarctic wahters. Perhaps this explains low competion between these two species. The map is created based on 77 recovered marks of 1395 whales (fig. 5).

The map requires one comment: the whales marked near Guinea and Liberia coast of Africa were most likely not sei whales, but Bryde's whales (Balaenoptera edeni). These whales are similar to sei whales, but a smaller. It is a relatively not numerous thermophilic species. In the Southern Hemisphere it can be found near isotherm 20° C. The Bryde whales can be met near Brasilian coast and western coast of South America, near western southern and eastern coasts of Africa (two strains), and near Indonesia. The whales were caught mainly as by product. That's why Bryde whales are less studied. From 577 marked Bryde's whales, only one mark was returned: the whale was marked and killed in the same region.

D. Minke whales. The smallest whale of the genus *Balaenoptera*. Average size of adults reaches 8–10 meters.

6531 whales were marked mostly during whaling period in high latitudes near Antarctica. The map shows coordinates of 112 recovered marks (fig.6).

As we see (fig. 11), the whales migrate to Ross Sea from Bellinsghausen Sea, as well as from Cook Balleny Islands. It is clear that Minke whales from Brasilian population migrate to Weddell Sea. The analysis of distribution of taken whales shows that not all Minke whales migrate each year to Antarctics feeding areas. At summer time they can be met in worm as well as in cold waters.

E. Humpback whales. The only representative of baleen whales from the genus Megaptera.

3944 humpback whales were marked. In period between June and October they were marked near western and eastern coasts of Australia, near New Zealand and to the south of New Caledonia. 165 marks were recovered. The most active whaling took part in the 5th and 6th sectors of Antarctic's waters, that is to the south of Australia, New Zealand and near Ross Sea. That's why most of marks were recovered in this area (fig. 7).

Our analysis showed that humpback whales from Brazilian waters migrate to the feeding areas in Bellingshausen Sea. Western African whales migrate to the region of Gough Island and more to the south of it. Western Australian whales migrate to Collaboration Sea. Eastern Australian population moves to Balleny Island, Collaboration Sea and Ross Sea. New Caledonian population migrates to the feeding areas near Balleny Island and Bellingshausen Sea.

F. Right whales. The whales of this species first suffered the most from fishing, If fishing is not stopped, they could disappear as a species. Recently, a noticeable trend towards recovery of its population.

Of the 173 marked in the Southern Hemisphere right whales have been discovered and mapped (Fig. 8), only 10 tags.

One mark was found in the whale killed on 3/27/1970 to the south of Tasmania Island at 48ºS and 146ºE. The whale was marked in the Big Australian Bay on 11/26/1969 at 41ºS and 122ºE. 9 other marks were recovered in the same region where the whales were marked – near Argentinean coast about 40ºS. Some of the Argentinean whales remain in this region during summer, and others move to Falkland Islands and more to the south-east in the region of South Georgia Island. According to monthly catch data right whales from the region of Tristan da Cunha Islands migrate to the region of Gough Island and more to the south-east.

G. Sperm whales. This is the largest representatives of the suborder *Odontoceti*. Males reach 12 m, females considerably smaller - up to 12 m.

Only sperm whales had commercial value from all teethed whales in the Southern Hemisphere. 4579 whales were marked, and 62 marks were recovered (fig. 9).

According to the mark ages, sperm whales from Chilean coast migrate to Bellingshausen Sea. Sperm whales from Argentinean population move to the south of Crozet and Kerguelen Islands. The whales (mostly females) from Australian coast migrate to Tasmania Island, and males from Eastern coast of Australia move to Balleny Islands.

3.3. Radio marks and satellite tracking

During the last twenty years radio marks were created and tested. The first experiments revealed the following. It is absolutely necessary to mark whale in the area of dorsal fin. It is this whale body part that is out of water longer than others when whale is breathing, so the mark can send 3-5 radio signals to allow track the whale. Due to small effective radius of transmitter and short term of action in the beginning of the experiments whales were lost soon.

Currently more inspiring results were received by marks with more reliable batteries and satellite connection. For example, migration of 4 marked pygmy blue whales.

Pygmy blue whale in its water element. Was monitored for more than 2 weeks (fig. 10).

A sperm whale, marked near Kuril Islands last August, has been sending signal for 6 months. The improvement of such marks is very promising.

3.4. Whale identification methods

Each whale has a specific shape and body coloration. Also, during their lives, bodies of the animals get marks due to different reasons: scars, scratches, traces of bites, bio fouling, etc. (Yablokov, 1963, 1966; Shevchenko, 1970, 1971, 1975; Mikhalev, 2000).

Photographs allow for identification of the whales to get information about moving of each individual, to determine population size, whale migration, to estimate their state and ability of reproduction. Modern technology (digital photo cameras with telescopic lens) allows accumulating of huge data. The whale catalogs are created for each region of world ocean. The data are entered into computers, which have programs to recognize the whales. This method doesn't require great expense, and its perspectives are difficult to overestimate.

DNA analysis can be attributed to the methods of identification. Usually, to get sample of whale for biopsy, an arrow with a tube in form of it is shot at whale from a crossbow. Based on the DNA analysis it is possible to determine, which whale meat and fat is sold on different markets, was the whale killed legally, which help to fight poaching.

4. Conclusion

Summing up the results of Antarctic whales marking, we can admit that at present, general scheme/routes of their migrations can be regarded as established, both to the feeding fields, and to the wintering areas. In the feeding period blue whales move from the area of South Georgia and Sandwich Islands to the Weddell Sea and Sea of the Commonwealth and from the Bellingshausen

Sea to the Ross Sea. Chilean fin whales migrate through the accumulation of the Drake Passage in the Weddell Sea. And from the coastal waters of Southern Africa - to Bouvet, Crozet, Kerguelen and Amsterdam islands. Fin whales coastal waters of New Zealand have put on weight on a Balleny islands and in the Ross Sea. In the middle of the *austral* summer herds of fin whales displace to the south, and in March and April *roam* back. Similar is the general scheme of migrations of sei whales. But unlike fin whale, sei whale aggregations later shift to the sub-Antarctic waters, thus reducing competition between species. *Marked* as sei whales, Guinean and Liberian coast whales are likely to be more heat-loving Bryde whales, which are difficult to be distinguished from the sei whale.

As to humpback whales, judging by marking results, their herds from the waters of Brazil migrate to feeding fields in the Bellingshausen Sea. West African ones feed in the same area by *Gough* island and in the southerly direction. West Australian humpback whales migrate to the Commonwealth sea, East-Australian - to Balleny islands, the Commonwealth and Ross Seas. Caledonian ones fatten in the waters from the Balleny islands to the Bellingshausen Sea.

Because of the small number of returned tags, migration of southern right whales can be judged only by results of fishing. Apparently, some whales of Argentine cluster shift to the Falkland Islands and then to the southeast in the area of South Georgia. The other part remains in the area for the summer period. *From/In/By* the analysis of monthly catch we can say that southern right whales from the area of the Islands of Tristan da Cuhna migrate into the region of Goff Island, and further to the south-east.

Sperm whales of Chilean herd migrate to feeding fields in the Bellingshausen Sea, and Argentine congestion shift to the waters south of Crozet and Kerguelen. Sperm whales (mostly females) from waters of the west coast of Australia migrate to Tasmania, and from the east coast of Australia (mostly males) – to the Balleny islands .

Marking by tags with strong batteries and satellite communication started giving encouraging results, enabling long-term tracking of *labeled/marked* whales. Development of this method promises *big* prospects. So does the method of photo-identification and biopsy sampling and identification of whales based on DNA This method also allows to determine the whale production being sold at different markets and whether the whale was legally taken, which contributes to the fight against poaching.

Present technical advance promises attractive prospects. Satellite tracking and identification of individuals in the next few decades will help determine the population structure of whale aggregations, identify feeding and reproductive areas. It will enable to determine more accurately the movement over time of individual biological groups – males, females, *barren* and pregnant animals, whales of various age groups, to judge the reproductive ability of populations. Overall all this will give a sound scientific basis for the assessment of whale stocks.

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Fig. 1. Debris hand-held harpoons found in the whale body

Fig. 2. Whale tags like "Discovery" (top - for large species; bottom - for small species)

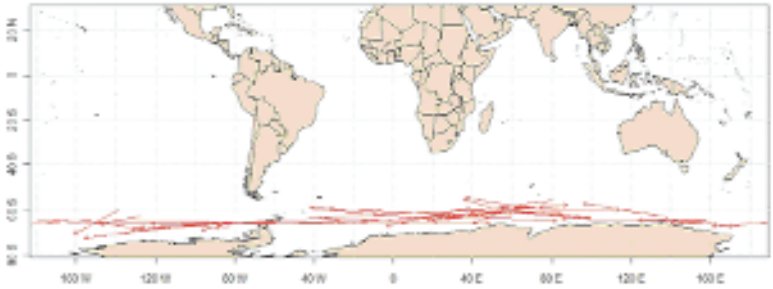

Fig. 3. Migrations of Antarctic blue whales according to marking data

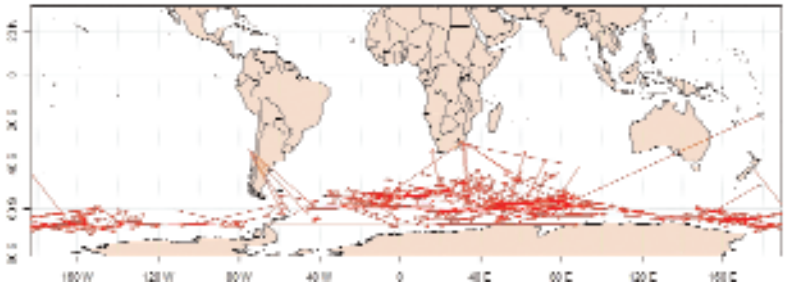

Fig. 4. Migration of fin whales according to marking data.

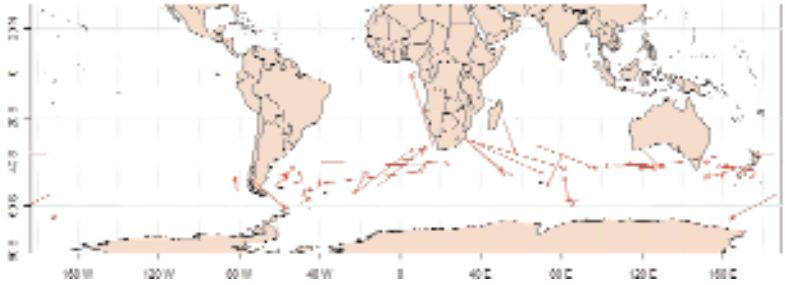

Fig. 5. Migration of Sei whales according to marking data

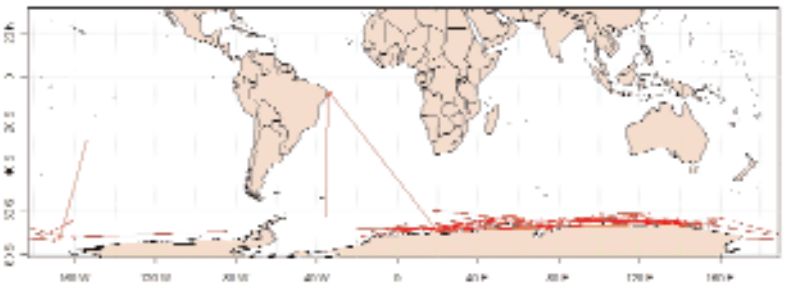

Fig. 6. Migration of Minke whales according to marking data

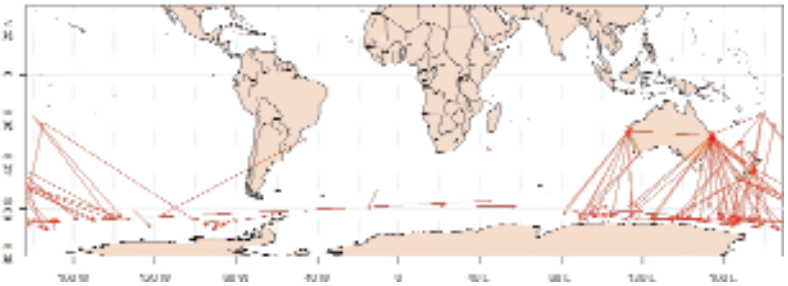

Fig. 7. Migration of Humpback whales according to marking data

Fig. 8. Migration of Right whales according to marking data

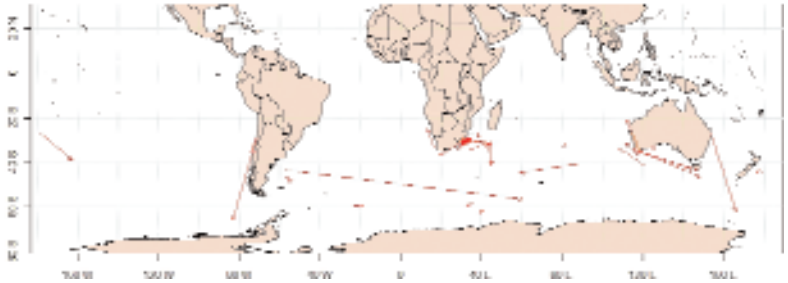

Fig. 9. Migration of sperm whales according to marking data

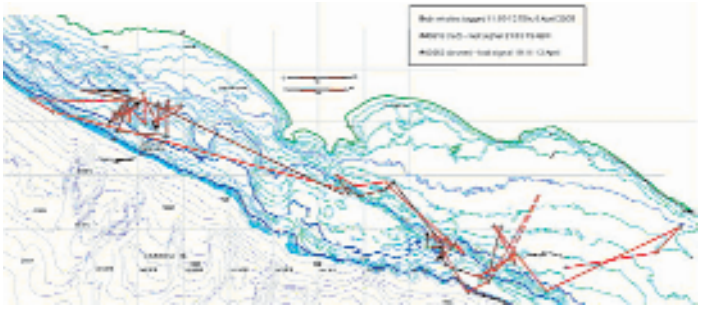

Fig. 10. Migration of pygmy blue whales marked by satellite marks