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Inter-basin movements of Mediterranean sperm whales provide insight into their population structure and conservation

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ABSTRACT

The sperm whale is one of the very few deep diving mammal species in the Mediterranean Sea. Following a rare mass stranding of male sperm whales in the Adriatic Sea in December 2009, photo-identification methods were used in order to investigate previous sightings of the stranded whales in the region. Fluke photos of the stranded whales were compared with those of 153 and 128 free-ranging individuals photographed in the western and eastern Mediterranean basins, respectively. Three out of the seven stranded whales had been previously photo-identified and some of them more than once. To reach the stranding place, two of these re-identified whales performed long-range inter-basin movements of about 1600–2100 km (in a straight line) either through the Strait of Sicily or the Strait of Messina. In addition, comparisons among all whales photographed in the two Mediterranean basins revealed that one more individual first photographed in the western basin (1991) was re-identified 13 years later in the eastern basin (2004). These three cases provide the first conclusive evidence of inter-basin movement of sperm whales in the Mediterranean Sea. Inter-basin gene flow is important for the survival of the small and endangered Mediterranean sperm whale population. Mitigating the disturbance created by human activities in the straits area is crucial for its conservation.

1. Introduction

The sperm whale (*Physeter macrocephalus*) is one of the very few deep diving mammals in the Mediterranean Sea. Perpetual movement is crucial for this species as a response to highly variable resources in space and time (Jaquet et al., 2003). Both sexes are capable of performing long latitudinal and longitudinal migrations across oceanic basins, which can reach 5000 km for females (Kasuya and Miyashita, 1988) and 7400 km for males (Ivashin 1967 cited by Whitehead, 2003) in straight line distances. Sperm whales inhabiting semi-enclosed seas like the Mediterranean should be equally capable of performing such long migrations, even if they had to be limited within this restricted sea. Both genetic studies (Drouot et al., 2004a; Engelhaupt et al., 2009) and surveys in the area of the Strait of Gibraltar (de Stephanis et al., 2008b; Fernandez-Casado et al., 2001) indicate that there is minimal or no regular movement of sperm whales through the only natural connection of the Mediterranean Sea with the world's oceans.

The maximum dimensions of the Mediterranean Sea, about 3700 km longitudinally from the Strait of Gibraltar to the Levantine coasts and 1800 km latitudinally from the northern Adriatic to the Gulf of Sirte off Libya are well within the swimming capabilities of both sperm whale sexes, if not limited by geographical barriers. Two straits separate the western from the eastern Mediterranean basin and their characteristics might limit crossings in both senses. These are the Strait of Messina between the Italian mainland and Sicily, and the Strait of Sicily between Sicily and Tunisia (Fig. 1). The first is only 3 km wide with a maximum depth of 80 m at the middle of the narrowest part of the channel; however, it provides a connection between two deep-water basins that are very close to each other. The second is 140 km wide, and has a complicated bathymetry composed by a shallow plateau (depth <100 m in half of the strait's width) crossed by two near-parallel channels of maximum depths 360 and 430 m (Stansfield et al., 2003).

More than six decades ago Bolognari (1949, 1950, 1951, 1957) proposed a speculative scheme conjecturing the movement and routes of sperm whales across the region, assuming that the species visited the Mediterranean Sea from the Atlantic Ocean. This scheme included the crossing of both the straits of Messina and Sicily. Although he did not obtain enough data to support the

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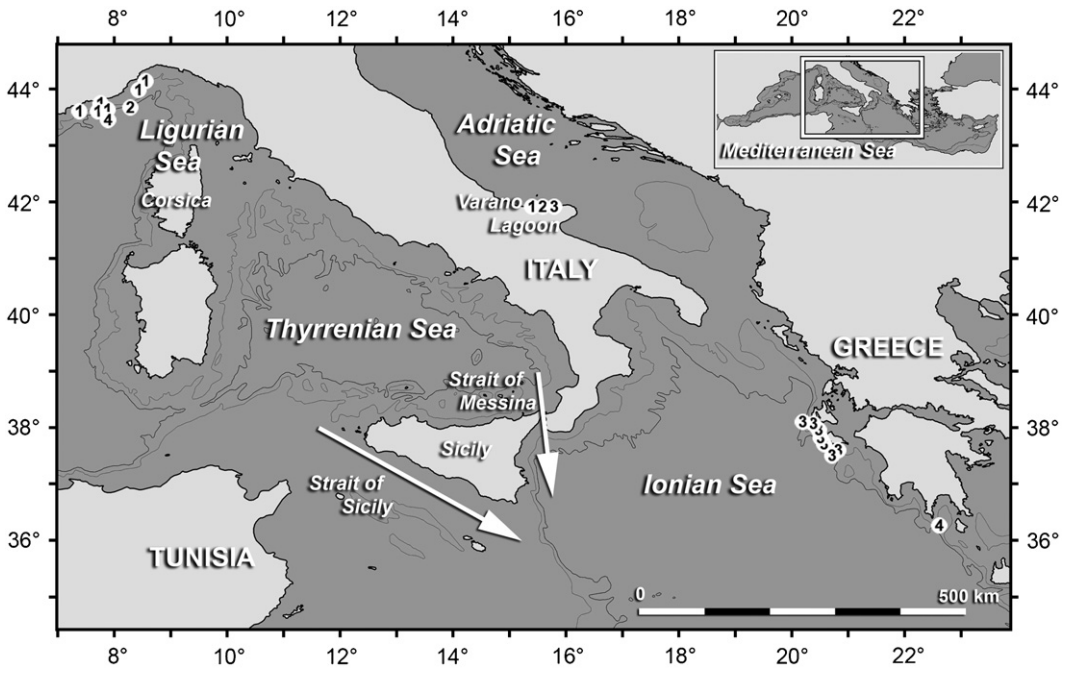

Fig. 1. Map of the central Mediterranean, west and east of the Straits of Messina and Sicily. The position of the area presented in the map within the limits of the Mediterranean Sea is shown at the top right frame. Depth contours correspond to 1000 m (light grey) and 2000 m (dark grey). All observations of the whales identified in both the western and eastern Mediterranean basins and/or identified in the mass stranding are shown by numbered white dots. 1: CLA, 2: POMO, 3: ZAK WHITEHEAD, 4: ODYSSEAS (see Table 1).

entire pathway of the proposed migrations, Bolognari (1949, 1950) reported one pair and one group of fifteen sperm whales at the narrower part the Strait of Messina, just before the exit towards the Tyrrhenian Sea. He also reported several other cases (mostly groups but single individuals as well) of whales heading north towards the narrowest part of the strait. There are no such observations in more recent times. A recent year-round survey, which involved spending a large amount of effort on both sides of the strait, recorded no sperm whale crossings, and few approaches of the Strait's southern area at 18 km or more from the narrows (Notarbartolo di Sciara et al., 2006b). Another dedicated sperm whale survey that covered large areas throughout the Mediterranean found no sperm whales in the Strait of Sicily (Lewis et al., 2007).

Comparisons made between sperm whale individuals photo-identified until 2003 in the two Mediterranean basins (NAMSC Catalogue compiled and produced by IFAW) failed to detect any matching. With the exception of Bolognari's works, no evidence of inter-basin movement was available until now, and this could lead to the idea that the Mediterranean sperm whale population might be further segregated into two more or less isolated sub-populations: eastern and western.

Stimulated by a rare mass stranding of sperm whales in the Adriatic Sea (Bearzi et al., in press), in this study we investigate the previous movement behaviour of the stranded whales and provide conclusive evidence of inter-basin movement of sperm whales in the Mediterranean Sea. We then discuss the resulting insight into the Mediterranean sperm whale population structure, with its relevant conservation implications.

2. Materials and methods

2.1. Field data collection

Between the late 10 and early 11 December 2009 seven sperm whales stranded north of the Varano Lagoon in the Gargano Promontory, Italy, Adriatic Sea. The animals were scattered along a stretch of approximately 3.8 km of beach. Most of (if not all) the whales were alive at the time of stranding, but all had died by the night of December 12. All stranded whales were males 15–21 years old (Cozzi, pers. comm.) and their sizes were 10.5 (#5), 11.2 (#7), 11.3 (#3), 11.4 (#4), 11.8 (#1), 12.1 (#6) and 12.2 (#2) m (numbering according to position of the stranded whales along the beach, increasing westwards). We used photo-identification methods to investigate previous sightings of the stranded whales. Before the whales were measured and sampled, several photos of the flukes of each whale were taken to record any available characteristic that could result in individual identification. These characteristics included marks (nicks, notches, scallops, irregularities, etc.) along the trailing edge of the flukes and/or pigmentation marks on the ventral or dorsal surface of the flukes. All whales had distinctive marks that made them recognizable. Additional photos of the dorsal fin and lower jaw area were taken in case they could provide assistance to the identification process.

2.2. Photo-identification analysis

The best photos of each of the seven stranded whales were compared with all the available photos of free ranging sperm whales from the Mediterranean Sea originating from the period 1990–2009. We opted for non-automatic comparisons performed by visual inspection of each photo, since the total number of known individuals in the Mediterranean Sea is relatively small (few hundreds). The photos of known sperm whales originated from three sperm whale photographic databases enriched with photos provided by several colleagues from various locations of the northern Mediterranean Sea. The three databases were: (1) GREPHYSC 2009 (Greek Physeter Catalogue) with photos from the Hellenic Trench and all Greek Seas, (2) the Mediterranean part of NAMSC 2004 (North Atlantic & Mediterranean Sperm Whale Catalogue) and (3) the Tethys sperm whale catalogue 2008 (TeSC). All photos of GREPHYSC are originating from the eastern Mediterranean. Photos of NAMSC originating from the eastern Mediterranean (duplicates of GREPHYSC photos), as well as low quality photos ($Q \leq 3$; Arnbom

Table 1
Data regarding all the observations of the three stranded whales that matched with previously observed free ranging sperm whales (CLA, POMO and ZAK WHITEHEAD) and the free ranging whale that was photo-identified in both Mediterranean basins (ODYSSEAS). Ages kindly provided by Prof. Bruno Cozzi who examined tooth sections of the stranded sperm whales.

Whale name	Sex	Age	Number of encounters	Date	Geographical area	Mediterranean basin	Encounter type	Number of individuals
CLA (#6)	Male	20–21	7	6 Jul 2002	W Ligurian Sea	Western	Solitary male	1
				5 Aug 2003	W Ligurian Sea	Western	Male aggregation	2
				21 Aug 2003	W Ligurian Sea	Western	Male aggregation	4
				27 Aug 2003	W Ligurian Sea	Western	Male aggregation	5
				6 Jul 2005	W Ligurian Sea	Western	Male aggregation	2
				12 Aug 2007	W Ligurian Sea	Western	Male aggregation	3
				11 Dec 2009	SW Adriatic Sea	Eastern	Male mass stranding	7
POMO (#2)	Male	19–20	2	30 Jul 2003	W Ligurian Sea	Western	Male aggregation	4
				11 Dec 2009	SW Adriatic Sea	Eastern	Male mass stranding	7
ZAK WHITEHEAD (#5)	Male	15	9	5 July 2000	SE Ionian Sea	Eastern	Social unit	≥ 5
				27 Aug 2002	SE Ionian Sea	Eastern	Social unit	12
				24 Jul 2005	SE Ionian Sea	Eastern	Social unit	7
				26 Jul 2005	SE Ionian Sea	Eastern	Social unit	7
				27 Jul 2005	SE Ionian Sea	Eastern	Social unit	7
				31 Jul 2005	SE Ionian Sea	Eastern	Social unit	7
				2 Aug 2005	SE Ionian Sea	Eastern	Social unit	7
				31 Aug 2005	SE Ionian Sea	Eastern	Social unit	7
				11 Dec 2009	SW Adriatic Sea	Eastern	Male mass stranding	7
ODYSSEAS	Male	n.a.	2	3 Aug 1991	W Ligurian Sea	Western	Solitary male	1
				6 Aug 2004	W Kythira Sea	Eastern	Solitary male	1
				7 Aug 2004	W Kythira Sea	Eastern	Solitary male	1

1987) were discarded. The remaining NAMSC photos were compared among them and duplicates of individuals appearing more than once were deleted. In the same way, the "cleared" NAMSC and TeSC were compiled into one catalogue, where each individual's ventral side of flukes appeared only once. After this process, and when considering only the ventral flukes, the NAMSC-TeSC catalogue contained 153 individuals from the western Mediterranean basin and the GREPHYSC contained 128 from the eastern.

While comparing the flukes of the seven stranded sperm whales with the flukes of free ranging sperm whales, three matchings were found (whales #6, #2, #5, see Appendix). According to NAMSC rules, when a matching was found with any of the available photos, the photo owner was invited to participate as a co-author in this paper.

2.3. Sperm whale encounter contexts

Encounters with sperm whale individuals or associations mentioned in the text are defined as follows. Solitary male: a single male with no other sperm whales visually or acoustically detectable during the encounter. Loose male aggregation: Two to five single males (or exceptionally more) spread in a radius of up to ten km (exceptionally up to fifteen km), following independent dive cycles. Social unit: group of four to twelve and rarely more adult females, immature whales and often calves with almost stable composition for several years.

Gender determination in fifteen and eight sperm whales that were not observed as members of social units in the eastern (Frantzis and Alexiadou, 2008) and western (Engelhaupt et al., 2009) Mediterranean basins, respectively, showed to be all males. When no gender determination was possible in the reported observations in the Ligurian Sea (Table 1), based on the above results we considered all whales as males, since they were not members of social units.

3. Results

The comparisons of all flukes from the western and eastern Mediterranean basins with each other revealed only one matching; the whale named "ODYSSEAS". Therefore, the total of available and individually identifiable sperm whales (known by their ventral flukes) was 280. Data regarding all the observations of the three stranded whales that matched with previously observed free ranging sperm whales (CLA, POMO, ZAK WHITEHEAD) and the whale that was photo-identified free ranging in both Mediterranean basins (ODYSSEAS) are presented in Table 1 (see also Appendix). The position of all observations is shown in Fig. 1.

The whale named CLA (#6) was a male first photo-identified in 2002 in the NW Ligurian Sea, where it was re-identified five more times in 2003, 2005 and 2007. Eventually, it was found among the stranded whales in the SW Adriatic Sea in 2009 (see Fig. A1 in Appendix), measured 12.1 m and was 20–21 years old. The maximum straight line distance between all observations in the W Ligurian Sea was 103 km. CLA was always observed as solitary individual or among males. The shortest straight line distance (while avoiding land) separating its two last observations made in different basins was 1800–2100 km depending on the four possible paths that the whale could have followed (west or east of Corsica and the Straits of Messina or Sicily).

The whale named POMO (#2) was a male first photo-identified in 2003 in the W Ligurian Sea. It was re-identified when found among the stranded whales in the SW Adriatic Sea in 2009 (see Fig. A4 in Appendix), measured 12.2 m and was 19–20 years old. In both cases POMO was observed in male aggregations. The shortest straight line distance (while avoiding land) separating its two last observations made in different basins was 1700–2100 km depending on the four possible paths that the whale could have followed (west or east of Corsica and the Straits of Messina or Sicily).

The whale named ZAK WHITEHEAD (#5) was a male first photo-identified in 2000 in the SE Ionian Sea (Hellenic Trench), where it was re-identified seven more times in 2002 and 2005. Eventually, it was found among the stranded whales in the SW Adriatic Sea in 2009 (see Figs. A2 and A3 in Appendix), measured 10.5 m and was 15 years old. ZAK WHITEHEAD was always observed as member of the same social unit, except in its last re-identification among the stranded males. The maximum straight line distance between all observations in the SE Ionian

Sea was 68 km. The shortest straight line distance (while avoiding land) separating its two last observations (both in the eastern Mediterranean basin) was 630 km.

The whale named ODYSSEAS is a male first photo-identified in 1991 in the W Ligurian Sea. It was re-identified more than 13 years later free ranging in W Kythira Sea (see Fig. A5 in Appendix). In both cases ODYSSEAS was observed as a solitary male. The shortest straight line distance (while avoiding land) separating these two observations made in different basins was 1600–1900 km depending on the four possible paths that the whale could have followed (west or east of Corsica and the Straits of Messina or Sicily).

4. Discussion

4.1. The mass stranding

Mass strandings of sperm whales are extremely rare in the Mediterranean Sea (Notarbartolo di Sciara et al., 2006a). They concern both male groups (e.g. 7 males in 1892 in Marsala, SW Sicily; Braschi et al., 2007) and groups of females with young animals (e.g. 5 females+3 more whales with lengths 4–9.8 m in 1956 in Gulf of Vlore, NW Albania; Bearzi et al., in press). In a review concerning the Adriatic Sea since 1555, Bearzi et al. (in press) found five mass strandings of sperm whales involving 3–8 animals before the one reported in this study. The recent mass stranding in December 2009 involved 7 animals originating from both the western and eastern Mediterranean basins. The exact type of association between these whales before they stranded is unknown, but as in a similar previous case (see above), their number is much larger than the group size of loose male aggregations in the Mediterranean. According to the studies conducted in both the western and eastern Mediterranean basins, such aggregations usually consist of 2–3 individuals and rarely can reach 4 or 5 (de Stephanis et al., 2008a; Drouot et al., 2004b; Frantzis et al., unpublished data; Notarbartolo di Sciara et al., 2006a; Pavan et al., 2000; for a possible exception see Pierantonio et al., 2008). This discrepancy may indicate that more than one loose male aggregation and/or several solitary individuals could have coalesced in a limited sea area in response to an irregular situation.

4.2. Male and female site-fidelity and long-range movements

Given the minimal movement of sperm whales through the Strait of Gibraltar (de Stephanis et al., 2008b; Drouot et al., 2004a; Engelhaupt et al., 2009; Fernandez-Casado et al., 2001), long-range migrations out of the Mediterranean seem unlikely or very rare. In the Mediterranean male sperm whales were found to travel from the Ligurian Sea – an area where females and social units occur rarely (Drouot et al., 2004b; Moulins and Würtz, 2005) – to the Balearic Islands, where they can meet with social units, and back (Drouot-Dulau and Gannier, 2007). The longest one-way straight line distance recorded for these movements was 490 km, and a two-way travel reached 856 km (Drouot-Dulau and Gannier, 2007). The longest one-way travel that we report in this study is 1800–2100 km depending on the path followed by the whale #6 (CLA). Two more male sperm whales (#2: POMO and ODYSSEAS) performed similarly long migrations (1600–2100 km), while moving from the western to the eastern Mediterranean basin. The west–east direction and a starting point in the Ligurian Sea were common in all three inter-basin movements. They are probably due to the higher research effort (number of photos) in the Ligurian Sea and a higher male abundance as well (Drouot et al., 2004b) than in other areas of the western Mediterranean. Whale #6 (CLA) was regularly observed as solitary male or in loose male aggregations in the Ligurian Sea (2002–2007), until it was found in the eastern basin. Inter-annual re-identifications of males in the Ligurian Sea (Drouot-Dulau and Gannier, 2007) and the area of the Strait of Gibraltar (de Stephanis et al., 2008a; Fernandez-Casado et al., 2001) are common and suggest site fidelity over periods of years. Seasonal return or year-round presence in male grounds could be the pattern for sub-adult males, until they reach a certain level of maturity to perform long-range or even inter-basin migrations.

In our comparisons between basins, we found no inter-basin matchings of female sperm whales. This may be due to the small sample of fluke photos from social units observed in the western basin (mainly the Balearic Islands). An alternative explanation could be the high fidelity of social units to their own grounds. Genetic analyses at the ocean level (N Atlantic and Mediterranean Sea) indicate fidelity of females to coastal basins (Engelhaupt et al., 2009), and this could be also the case in the smaller scale of the two Mediterranean basins. Along the Hellenic Trench (eastern Mediterranean, Greece) several females or entire social units are at least seasonally (summer) resident, since they have been regularly re-sighted during the period 1998–2009; some of them in 5 consecutive years or in sightings spread across a 15-year period (Frantzis et al., unpublished data). Such an example is also the natal social unit of whale #5 (ZAK WHITEHEAD), re-sighted several times in the Ionian Sea (Table 1) during the period 2000–2005, and composed by members that were still observed in 2009 (Frantzis et al., unpublished data). Opportunistic winter re-identifications indicate that these whales may be year-round resident. Considering the actual knowledge, it is tempting to hypothesize that several females and their social units never cross the straits and spend their entire life in one Mediterranean basin. This hypothesis is further supported by differences observed in coda (i.e. communication sounds) repertoires of social units between the western and eastern basin (Drouot et al., 2004c; Rendell et al., 2007). Such differences have been interpreted as indicative of cultural differences (Whitehead, 2003). One young female (7.7 m) and a calf (4.1 m) in 2002, and one calf (5 m) in 2004 are among the stranding records of sperm whales very close to or in the middle (Pantelleria Island) of the Strait of Sicily (Centro Studi Cetacei, 2004; Centro Studi Cetacei Onlus and Museo Civico di Storia Naturale di Milano, 2006), but it is impossible to know if these whales died and stranded while moving from one basin to the other. Inter-basin movements of social units seem less frequent than those of males, but their occurrence and exact frequency remain to be assessed.

4.3. Movement pattern and purpose in the life-history framework

In order to understand the patterns of inter- and intra-basin movements of the Mediterranean sperm whales, long-term (i.e., decadal) followings of particular individuals are necessary. There are currently two ways to achieve such followings: (a) the stable isotope analysis of the whale's accumulated history in their teeth (Mendes et al., 2007a, 2007b) and (b) a continuous, long-term photo-identification effort.

There are only two teeth of Mediterranean sperm whales examined so far for their isotopic profiles: one male 12.9 m-long, 42-year old, and one female 10.0 m-long, 24-year old, both originating from the Hellenic Trench (Mendes et al., 2007a). The isotopic profiles suggest that the female did not undertake large-scale movements, possibly remaining in the same region and feeding at a similar trophic level throughout life (Mendes et al., 2007a). The male had a marked shift in isotopic ratios around the age of 20 with values becoming close to those recorded in the female thereafter and until death at 42. According to the high regional heterogeneity of water characteristics and primary production between basins in the Mediterranean, this isotopic

change suggests a movement from the western to the eastern basin at the age of 20 (Mendes et al., 2007a); exactly the same age of both stranded males of this study that were found to have performed an inter-basin migration. Although preliminary, two independent studies using different methodologies (Mendes et al., 2007a; this study), both indicate that a micrography of the sperm whale population model proposed for the Atlantic ocean (Engelhaupt et al., 2009; Lyrholm et al., 1999) applies to the scale of a regional closed sea with two basins: female basin philopatry and long-range male-mediated genetic dispersal through inter-basin migration in the Mediterranean.

Sperm whale births have been observed in both Mediterranean basins (Drouot et al., 2004b; Johnson et al., 2010). However, the recorded individual history of photo-identified sperm whales born in the Mediterranean is still relatively short in time and covers only a small fraction of the actual total population. One of the whales of this study (#5; ZAK WHITEHEAD) was first observed in a social unit inhabiting the eastern basin as a four-year old juvenile. During the next five years this whale was repeatedly re-sighted in the same social unit, which was likely its natal social unit. According to the available data (Table 1), it left its social unit sometime between September 2005 and November 2009 at an age of 11–15. This is the first data of this kind regarding male sperm whales in the Mediterranean Sea. Male dispersal from their natal social unit is believed to occur at the age of ~6 years in the ocean (Whitehead, 2003). Male #5 left its social unit much later, at an age close to or after sexual maturity, which occurs at ~10 years in the ocean (Whitehead, 2003). These findings demonstrate the potential of photo-identification as a technique that can follow over decades the movements and various stages of the life-history of long-living mammals. Photo-identification catalogues and increased collaboration among research groups could provide indication on the origin (natal grounds) of male sperm whales that perform inter-basin movements, as well as a way to understand if their movements are casual, or represent a return to natal grounds, or correspond to a need to avoid inbreeding.

4.4. Conservation importance of straits

Despite the important gaps that remain, the findings of this study show that sperm whales migrate from one deep Mediterranean basin to the other through the Strait of Messina or through the Strait of Sicily. Sperm whales in the Mediterranean all compose one population, which is genetically different from the Atlantic (Drouot et al., 2004a; Engelhaupt et al., 2009), and likely to be small and isolated (Notarbartolo di Sciara et al., 2006a). Inter-basin movements are likely to be important for its viability, by maintaining a gene flow and mixing throughout its entire range. The straits constitute small sea areas that function as marine corridors for migratory species and therefore, are extremely important for the survival of these species' populations (Anonymous, 2003). Human activities that introduce permanent or regular disturbance in the area of the straits may rapidly result in local habitat degradation. Such activities that are known or likely threats for sperm whales (Notarbartolo di Sciara et al., 2006a) – e.g. noise pollution from marine traffic, seismic surveys, drilling, military exercise, etc., harmful fishing activities like the pelagic driftnets, significant interventions in the landscape like the construction of ports or bridges – already occur in the straits and their neighbourhood (e.g. the intensive drilling off Tunisia in the very middle of the Strait of Sicily; see news release of 3 August 2010 by Gulfsands Petroleum PLC, regarding the Lambouka prospect). All of them may contribute in creating anthropogenic barriers in the middle of an inter-basin migratory route of sperm whales. Such barriers may have already been raised in the strait of Messina, where sperm whale crossings are no longer observed (Notarbartolo di Sciara et al., 2006b) in contrast to what was reported in the past (Bolognari, 1949, 1950). The many captures, shootings and mass killings through explosives described by Bolognari (1949, 1950, 1951) during the years 1947–1949, have likely contributed to such extirpation. It is unknown if the flow of sperm whales through the Strait of Sicily has also decreased in comparison to the past. Such a scenario would result in an increasing degree of isolation between the two basins. Whether it is occurring already or will possibly arise in the near future, unsuitability of the central Mediterranean straits to sperm whales is a serious threat for a population that is proposed as Endangered in the IUCN Red List of Threatened Species (Notarbartolo di Sciara et al., 2006a). Considering the small size of the Mediterranean population, its isolation from the Atlantic and the potential importance of male mating in non-natal basins, its fragmentation in two isolated remnant populations could be from dangerous to catastrophic. Both future conservation actions and research effort should aim at avoiding the scenario of fragmentation by limiting or mitigating disturbing human activities in the area of the straits.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.dsr.2011.02.005.

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Appendix: Photo-identification matchings

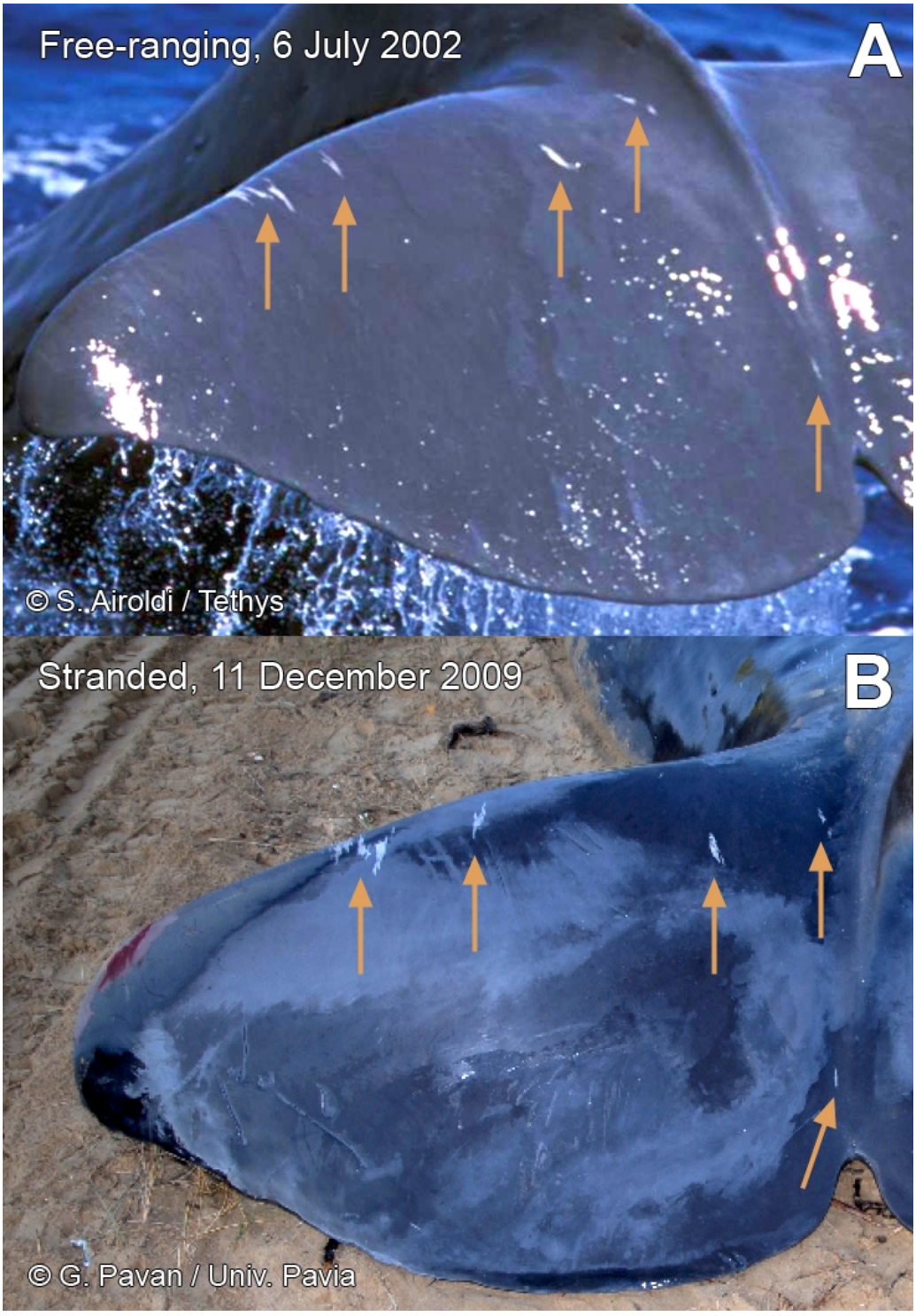

Figure A1. Dorsal side of the left fluke of the whale named "CLA" (#6 among the stranded whales). A: First photo-identification in the western Mediterranean Sea (western Ligurian Sea) in 2002. B: Re-identification in 2009 among the stranded whales in the Adriatic Sea (B). The arrows point to the most apparent characteristics of its flukes (white pigmentation patches) that remained unchanged between the two observations.

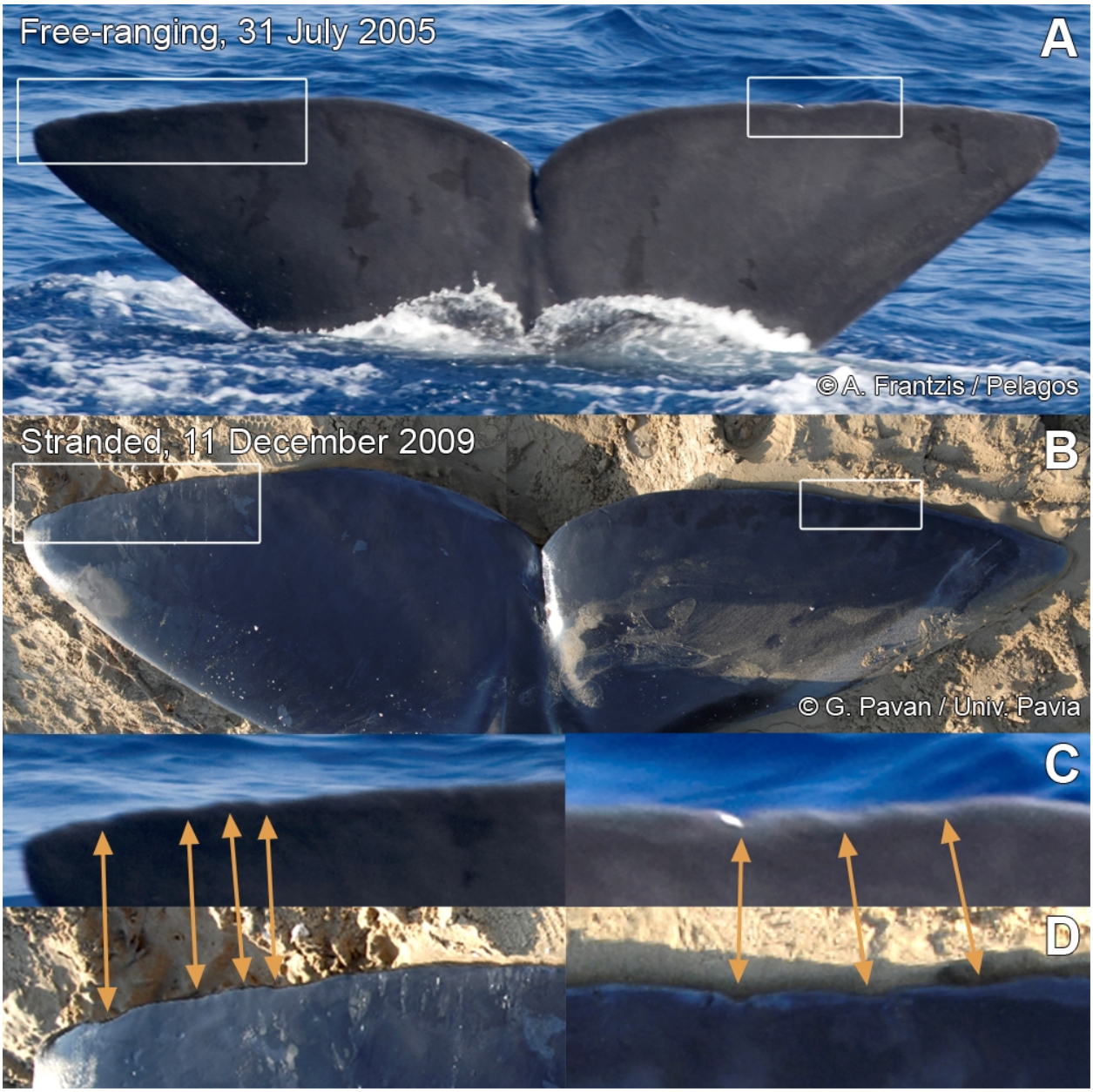

Figure A2. Flukes of the whale named "ZAK WHITEHEAD" (#5 among the stranded whales; see also Fig. 3). A: Photo-identification in the eastern Mediterranean Sea (eastern Ionian Sea) in 2005. The ventral side of the flukes is shown. B: Re-identification in 2009 among the stranded whales in the Adriatic Sea. Two photos (left and right fluke separately) have been joined to show the entire dorsal side of the flukes. The original photos have been flipped horizontally in order to allow for comparisons of the trailing edge of the flukes. C and D: Magnification of parts of photos A and B (rectangles), respectively, showing identical trailing edge characteristics in the left and right flukes (arrows).

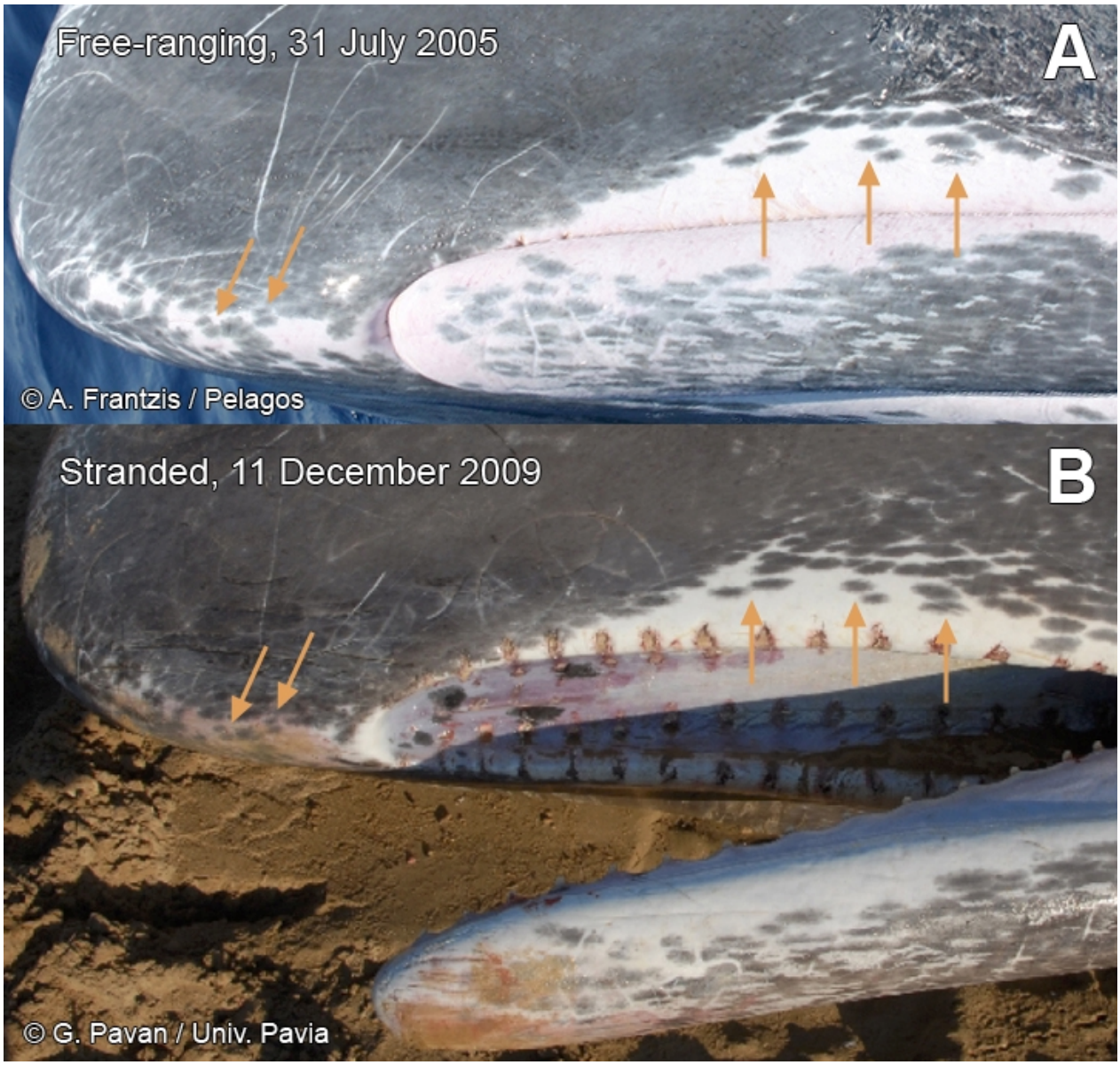

Figure A3. Mouth and lower jaw pigmentation of the whale named "ZAK WHITEHEAD" (same with Fig. 2; #5 among the stranded whales). A: Photo-identification in the eastern Mediterranean Sea (eastern Ionian Sea) in 2005. B: Re-identification in 2009 among the stranded whales in the Adriatic Sea. The arrows point to the most apparent white and grey pigmentation patterns around the mouth and on the lower jaw, which remained unchanged between the two observations.

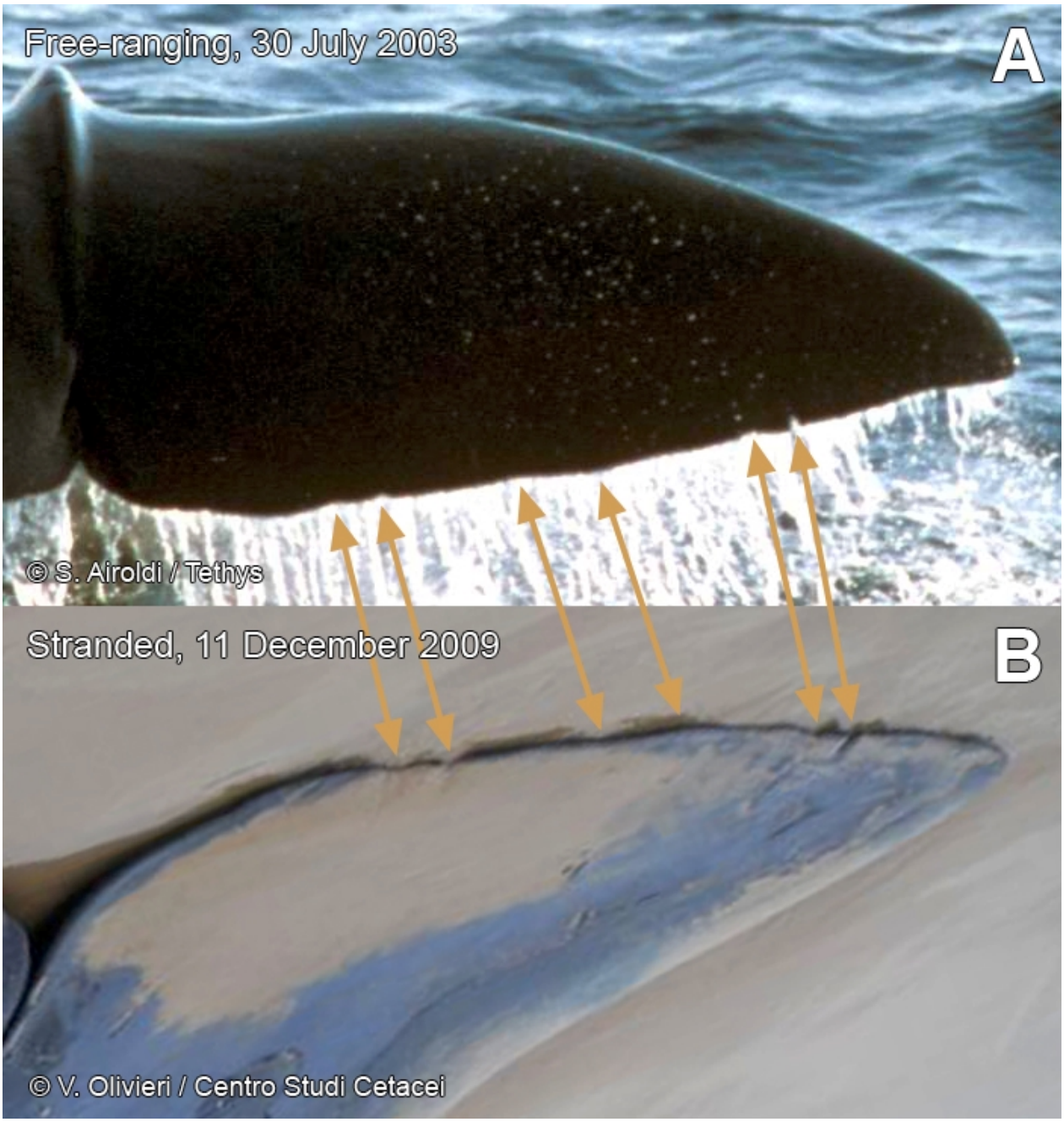

Figure A4. Right fluke of the whale named "POMO" (#2 among the stranded whales). A: First photo-identification in the western Mediterranean Sea (western Ligurian Sea) in 2003. The dorsal side of the flukes is shown. B: Re-identification in 2009 among the stranded whales in the Adriatic Sea. The arrows point to identical trailing edge characteristics (notches and other irregularities).

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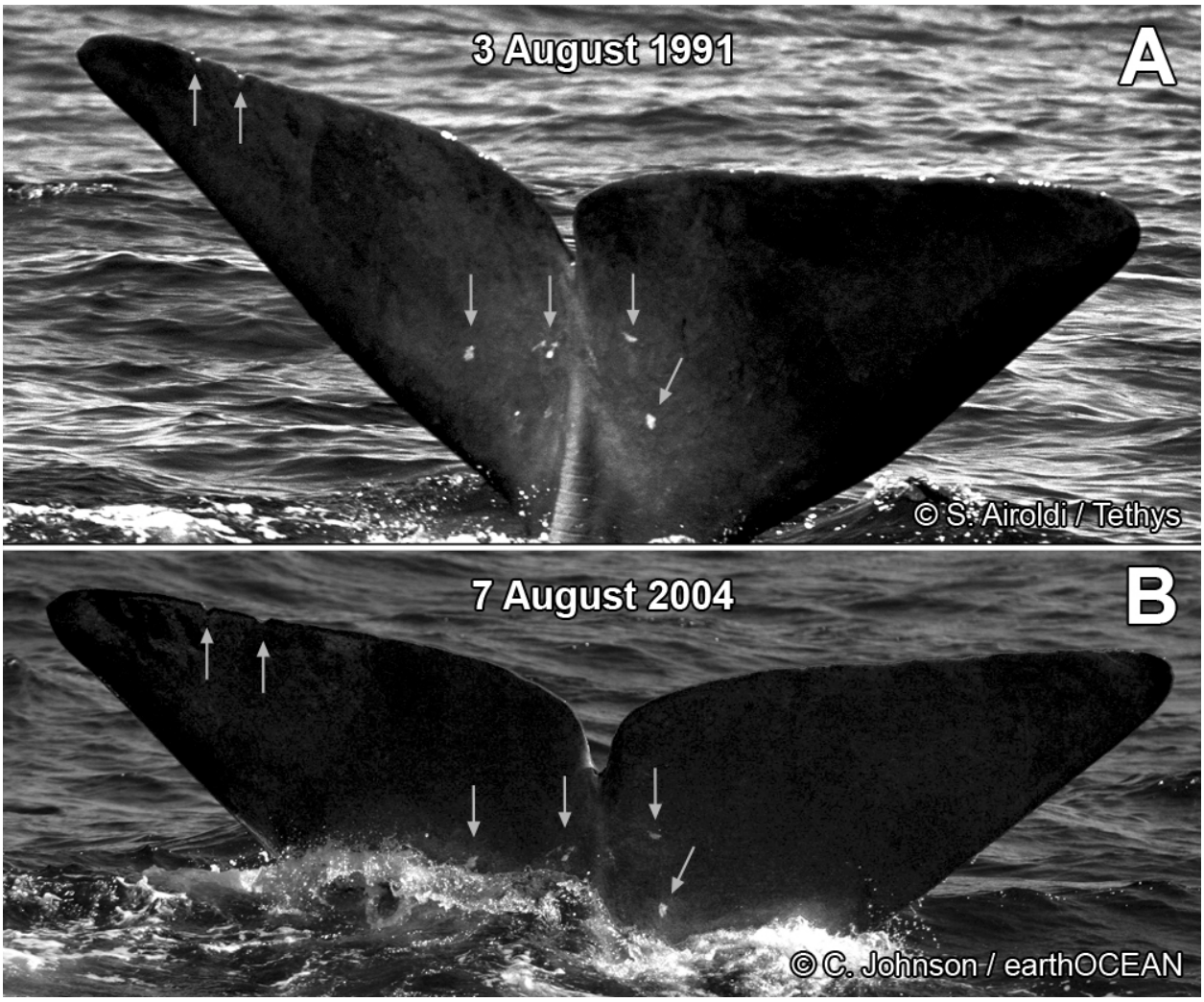

Figure A5. Ventral side of flukes of the male sperm whale named "ODYSSEAS". A: First photo-identified in the western Mediterranean Sea (western Ligurian Sea) in 1991. B: Re-identified thirteen years later in the eastern Mediterranean (SE Ionian Sea) in 2004. The arrows point to the most apparent characteristics of its flukes (two notches and four white pigmentation patches) that remained unchanged between the two observations.

Supplementary material for Frantzis et al., 2011. Inter-basin movements of Mediterranean sperm whales

Table A1: Origin of sperm whale photos that resulted in matchings. The catalogues in which each photo was found are given in the last column. TeSC 2008: Tethys Sperm Whale Catalogue, owned by Tethys Research Institute (Milano, Italy). NAMSC 2004: North Atlantic & Mediterranean Sperm Whale Catalogue, published by IFAW. GREPHYSC: Greek Physeter Catalogue, owned by Pelagos Cetacean Research Institute (Vouliagmeni, Greece). Ages kindly provided by Prof. Bruno Cozzi who examined tooth sections of the stranded sperm whales.

Whale name	Number of encounters	Date	Geographical area	Mediterranean basin	Photo-identification catalogue
CLA (#6)	7	6 Jul 2002	W Ligurian Sea	Western	TeSC 2008, NAMSC 2004
		5 Aug 2003	W Ligurian Sea	Western	TeSC 2008, NAMSC 2004
		21 Aug 2003	W Ligurian Sea	Western	TeSC 2008, NAMSC 2004
		27 Aug 2003	W Ligurian Sea	Western	TeSC 2008, NAMSC 2004
		6 Jul 2005	W Ligurian Sea	Western	TeSC 2008
		12 Aug 2007	W Ligurian Sea	Western	TeSC 2008
		11 Dec 2009	SW Adriatic Sea	Eastern	Mass stranding
POMO (#2)	2	30 Jul 2003	W Ligurian Sea	Western	TeSC 2008, NAMSC 2004
		11 Dec 2009	SW Adriatic Sea	Eastern	Mass stranding
ZAK WHITEHEAD (#5)	9	5 July 2000	SE Ionian Sea	Eastern	GREPHYSC 2009
		27 Aug 2002	SE Ionian Sea	Eastern	GREPHYSC 2009, NAMSC 2004
		24 Jul 2005	SE Ionian Sea	Eastern	GREPHYSC 2009
		26 Jul 2005	SE Ionian Sea	Eastern	GREPHYSC 2009
		27 Jul 2005	SE Ionian Sea	Eastern	GREPHYSC 2009
		31 Jul 2005	SE Ionian Sea	Eastern	GREPHYSC 2009
		2 Aug 2005	SE Ionian Sea	Eastern	GREPHYSC 2009
		31 Aug 2005	SE Ionian Sea	Eastern	GREPHYSC 2009
		11 Dec 2009	SW Adriatic Sea	Eastern	Mass stranding
ODYSSEAS	2	3 Aug 1991	W Ligurian Sea	Western	TeSC 2008, NAMSC 2004
		6 Aug 2004	W Kythira Sea	Eastern	GREPHYSC 2009
		7 Aug 2004	W Kythira Sea	Eastern	GREPHYSC 2009