Accord créant le Sanctuaire
pour les mammifères marins
en Méditerranée

Accordo per la costituzione
del Santuario per i mammiferi marini
nel Mediterraneo

« Absolute abundance of Risso's dolphin (*Grampus griseus*) in the north-western part of the Pelagos Sanctuary »

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14 September 2015

Final report

Study required and financed by:
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Reference of the project:

Convention No 03/2014

Image credit:

Istituto Tethys onlus

This report should be quoted as:

Sabina Airoldi, Arianna Azzellino, Léa David, Frank Dhermain, Nathalie Di-Meglio, Viridiana Jimenez, Julie Jourdan, Hélène Labach, Caterina Lanfredi, Elisa Remonato, Massimiliano Rosso, Marine Roul, Alessia Scuderi. 14 September 2015. Absolute abundance of Risso's dolphin (*Grampus griseus*) in the north western part of the Pelagos Sanctuary. Pelagos Sanctuary Convention No. 03/2014, 59 pages. Istituto Tethys /EcoOcean Institut/GECEM/Fondazione CIMA/GIS3M.

Contents

1. Introduction

Risso’s dolphin *Grampus griseus* (Fig. 1) has been studied in several locations around the world but information on this cetacean species remains relatively scant. In the Mediterranean Sea, they are relatively widespread (Gaspari & Natoli 2006) but not abundant and their occurrence can be unpredictable, possibly due to wide-ranging movements.

Fig. 1. Risso's dolphin (drawing by Massimo Demma).

Order: Cetacea
Suborder: Odontoceti
Family: Delphinidae
Genus: *Grampus*
Species: Grampus griseus (G. Cuvier, 1812)

This factor, together with generally low densities, has prevented consistent, focussed investigations into their ecology and behaviour. Even within the few Mediterranean areas where Risso’s dolphins are known to be consistently present, however, only limited information has been obtained. The distribution, ecology, status and trends of this species in the Mediterranean therefore remain somewhat mysterious. Hence, the Risso’s dolphin remains one of the least-known cetacean species in the region and it has been the subject of few dedicated studies (Bearzi *et al.*, 2010). A regional IUCN Red List workshop in March 2006 concluded that the Mediterranean subpopulation is Data Deficient (Gaspari & Natoli 2006).

Little is known about the abundance of Risso’s dolphins in the Mediterranean Sea, although most observations have occurred in the Ligurian-Corso-Provençal basin during the summer. However, in all surveyed Mediterranean areas with a suitable habitat, encounter rates for Risso’s dolphins have been low compared with rates for other more common delphinids, such as striped dolphins, with an order of magnitude higher than that of Risso's dolphins (Bearzi *et al.,* 2010). In the MEDACES and Italian stranding databases, only a small proportion of total strandings have been of Risso’s dolphins: 2.5% of all records in the MEDACES database (N = 7796; Universitat de València 2009) and 3.6% of all records or 3.7% of all animals in the Italian database (N = 3695 records, 3805 animals; http://mammiferimarini.unipv.it/ as of 4 January 2010) (Bearzi *et al.,* 2010).

The only abundance estimate based on line-transect methods was conducted in a 32 270 km^2 area east of Spain, where aerial surveys in 2001-2003 yielded an estimate of 493 individuals (CV = 60.6%; Gómez de Segura *et al*., 2006). That estimate was not corrected for visibility bias and therefore likely underestimates the true abundance in the sampled area (Gómez de Segura *et al*., 2006). Ship surveys in the western Mediterranean (Forcada 1998) as well as aerial and ship surveys in the Pelagos Sanctuary (Panigada *et al*., 2009, 2010) did not result in sufficient numbers of sightings to make meaningful estimates of abundance for Risso’s dolphins.
As there are no estimates of abundance for the entire Mediterranean it is impossible to define the current status of the Mediterranean subpopulation and its trends over time. This is more relevant in view of the fact that the Mediterranean subpopulation is considered genetically different from the North-East Atlantic one, with limited gene flow between the two areas (Gaspari *et al*., 2007).

Abundance estimates are fundamental for the implementation and assessment of the effectiveness of conservation measures, in accordance with Resolution 5.9 of the 5th Meeting of the Parties to ACCOBAMS, which reaffirms the priority of obtaining more recent estimates of abundance of the different species of cetaceans, and the Marine Strategy Framework Directive (MSFD) which requires regular reports on population dynamics, range and status of cetacean species in European waters.

A preliminary estimate of absolute abundance for the Pelagos Sanctuary, based on photographic capture-recapture (“mark-recapture”) procedures and limited to a portion of about 24,000 km^2, suggested that there were less than 300 individuals in the period ranging from 1998 to 2004 (Airoldi *et al*., 2005). However the small sample size which characterized this preliminary analysis was too small to provide robust estimates. More recently, an aerial survey has been conducted over the northwestern portion of the Mediterranean basin

(PACOMM) and an estimate of Risso's dolphin population has been provided both for the winter and the summer period. Such a study concerning a much wider area (little less than 200,000 km^2) provided a winter estimate of 2550 individuals (95%CI: 849-7658) and a summer estimate of 1783 individuals (95%CI: 849-7658), being the highest Risso's dolphin desinties identified out of the Pelagos Sanctuary borders (see Fig. 2).

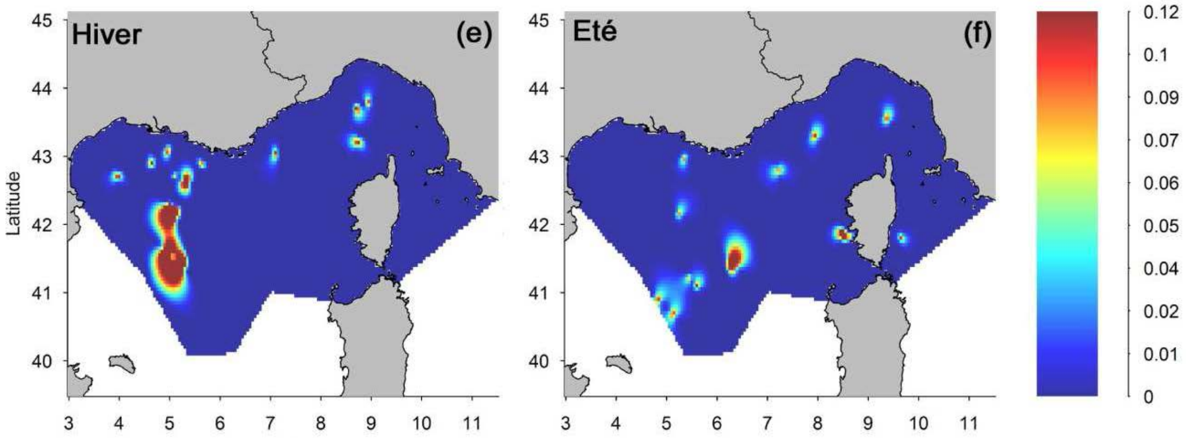


Fig. 2. The areas of highest Risso's dolphin densities outlined from the PACOMM aereial survey during winter (left chart) and summer (right chart).

The PACOMM study outlines how patchy must be the distribution of Risso's dolphin and suggests that a significant portion of Risso's dolphin populations in the area might be external to the Pelagos borders.

The combination and sharing of each of the three Partners' photo-identification catalogues - who have collected data on Risso's dolphins within the Sanctuary - provide the most robust dataset to support mark-recapture analysis therefore producing more reliable abundance estimates for the entire north-western portion of the Sanctuary.

2. Study area

The datasets provided by the four Institutes (Istituto Tethys, Fondazione CIMA, EcoOcean - EOI, GECEM) taking part in this project are the most consistent in size and study period among those available in the area of the Sanctuary. Their union ensures a coverage of approximately 50% of the Sanctuary, encompassing coastal, slope and deep pelagic waters (Fig. 3).

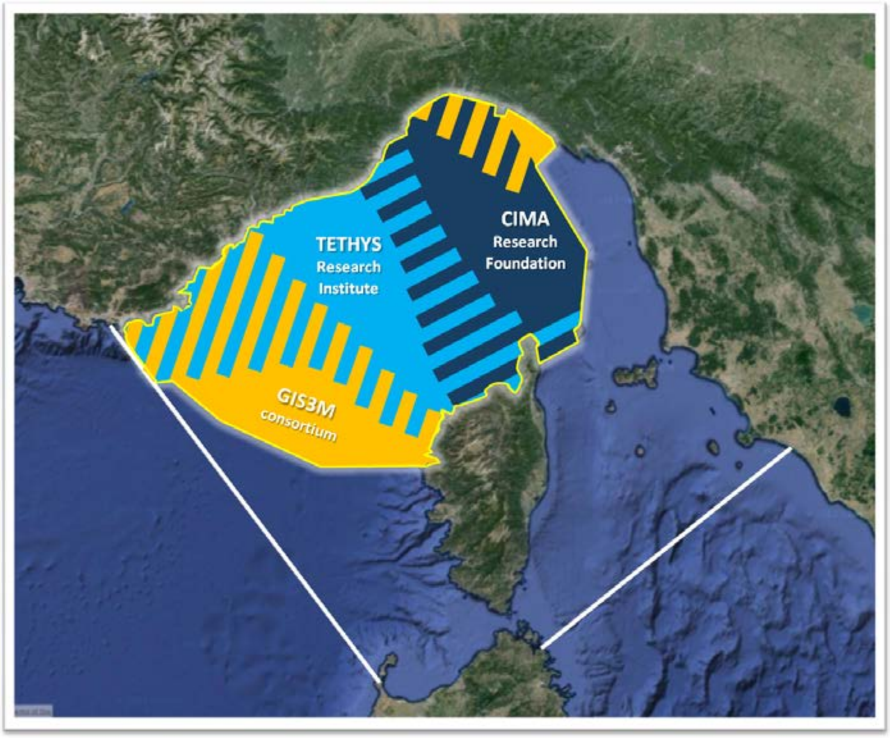


Fig. 3. Study areas of the three Partners within the Pelagos Sanctuary

Data were collected from 1989 through to 2014 during dedicated and opportunistic boat-based surveys, conducted from different platforms (Fig. 4).

Fig. 4. Two of the platforms used for the dedicated surveys

Most fieldwork effort took place during the summer season (May–Sept), with a minimum of two observers at a time (one on each side of the boat), searching for dolphins by naked eye and binoculars. A total of 268 sightings were recorded (Table 1).

Table 1. Study periods and type of survey of the different Partners.

Partner	Survey	Number of sightings	Study period
Istituto Tethys	*Ad libitum*	177	1989 - 2014
CIMA Foundation	*Ad libitum*	33	2004 - 2013
EcoOcéan Institut	Mainly line transect, photo-ID as side project	45	1994 - 2014
GECEM	*Ad libitum*	13	1993 - 2012

Once a dolphin pod was sighted, it was slowly approached in order to record its location, identify the species, estimate the pod size, assess the age composition of the pod, and take photographs of individual animals for photo-identification. In order to define the age composition of a pod, three age classes were distinguished based on visual assessment using the average adult size as a reference: (1) adults: individuals of about 3–4m long; (2) juveniles: individuals approximately 2/3 the length of an adult, usually swimming in association with an adult, but sometimes swimming independently; (3) calves: individuals 1/2 the length of an adult, in close association with an adult, and swimming regularly besides or slightly behind an adult.Attempts to photograph all Risso's dolphins encountered were made from a close distance, both on the left- and right-side, independently of age/sex class and dorsal fin distinctiveness. During all types of surveys, sighting data included location, time of encounter, best estimate of group size and composition. Time constraints have limited full photographic coverage of some encounters during systematic and opportunistic surveys.
Photographs of individuals were taken as perpendicularly to the dolphin’s body axis as possible and concentrated mainly on the dorsal fin.

The initial number of sightings and photo-identified individuals provided for this study increased slightly, because EcoOcéan Institut and Tethys Institute included 2014 photo-identification data in their catalogues. Tethys also included images provided by a whale-watching boat (from 1996 through to 2000, from June to September) and Tethys and CIMA improved their catalogues with data provided by other opportunistic platforms. Experienced observers (at least one trained biologist) guaranteed the reliability of the data collection (Table 2).

Table 2. Sightings during which Risso's dolphins were identified, and number of photo-identified individuals for each side.

Partner	Sightings with individuals photo-identified	Photo-identified individuals	Study period
Istituto Tethys	146	272 right side - 263 left side	1989 - 2014
CIMA Foundation	33	125 right side - 129 left side	2004 - 2013
EcoOcéan Institut	23	76 right side - 73 left side	1994 - 2014
GECEM	13	75 right side - 97 left side	1993 - 2012

A total of 215 sightings during which Risso's dolphins were identified were reported by the Partners, distributed in the study area as shown in Fig. 5.

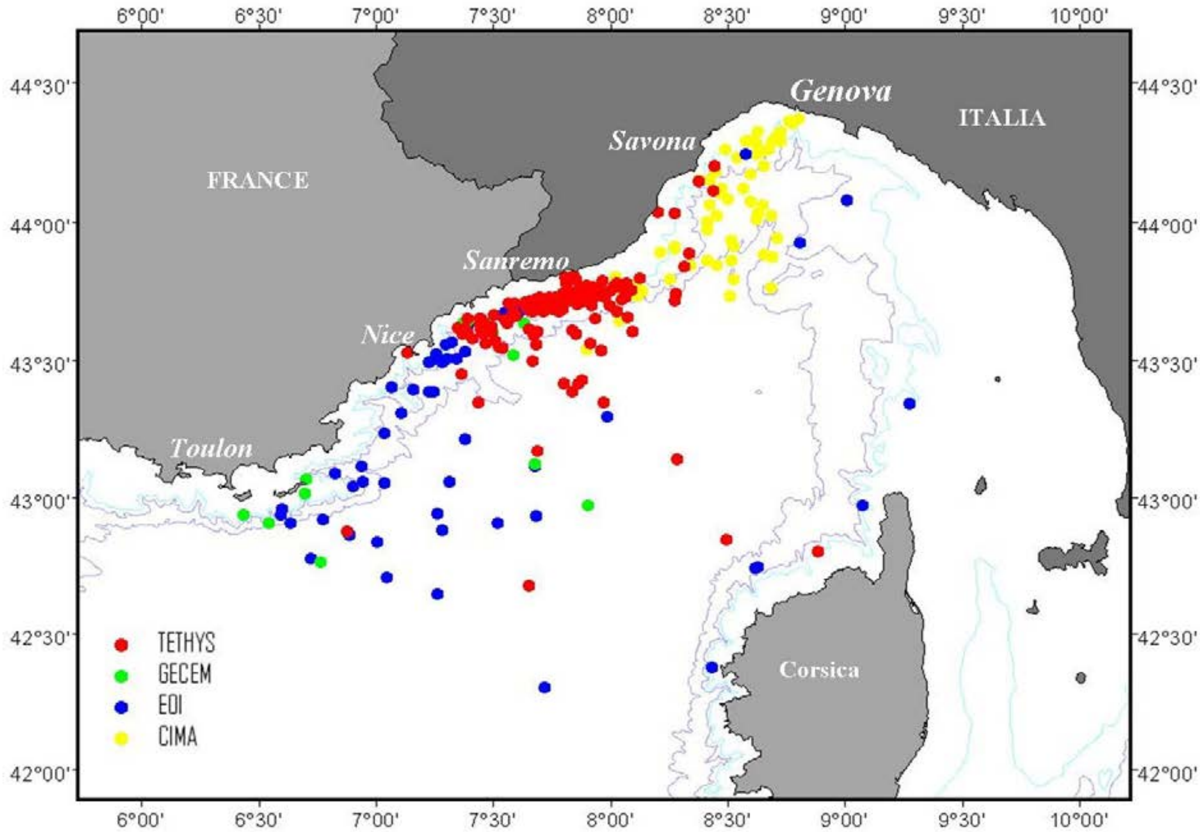


Fig. 5. Sightings of Risso’s dolphins reported by the four Institutes

3. Products obtained

The Table 3 summarizes the timing of the different activities under the Project in relation to the actual start of the Convention (October 2014).

	Task	Trimester		
		First phase	Second phase	Third phase
Task 1	**Preparation of protocol**			
Task.1.1.	Protocol preparation and distribution to all Partners			
Task 2	**Preparation and upload of images on INTERCET**			
Task.2.1.	Preparation of the images, sighting and effort data			
Task.2.2.	Images, sighting and effort data uploaded onto INTERCET			
Task.2.3.	Image validation			
Task.2.4.	Comparison of the Partner photo-ID catalogues			
Task.2.5.	Implementation of the *Med. Grampus Catalogue*			
Task 3	**Absolute abundance estimate**			
Task.3.1.	Assigning quality rate to the images			
Task.3.2.	Selection of the images			
Task.3.3.	Preparation of the matrices			
Task.3.4.	*Mark-recapture* analyses			
Task 4	**Report**			
Task.4.1.	Preparation of the intermediate report			
Task.4.2.	Preparation of the final report			
Task 5	**Project coordination**			
Task.5.1.	Project coordination			

Table 3. GANTT chart of the activities.

3.1. A photo-id database for the north-western part of the Pelagos Sanctuary, based on common protocols and standardised procedures

One of the aims of this study was to create a new photo-identification database, derived from the union of the catalogues of the three Partners of this project.

Photo-identification consists of finding a character that is sufficiently variable within a species so that each individual has its own characteristics. The character has to be as stable as possible over time (at least for a few years and during the entire study period) and should be easily photographed (Verborgh 2005).

Descriptions of life history patterns and empirical measures of population dynamics can be facilitated by individual identification (Hammond *et al*., 1990). Photo-identification of naturally marked cetaceans helps obtain information on group structure, site fidelity, movement patterns and population size. In conjunction with other studies, long-term photo-identification can also enhance descriptions of life history parameters such as age at sexual maturity, calving intervals and reproductive and total life span (Würsig and Jefferson 1990). Confirmation of the validity of photo-identification by natural markings has come from studies that combine this technique with various sorts of tagging (Irvine *et al.*, 1982, Scott *et al*., 1990).

Cetaceans exhibit a variety of individually distinctive natural features. In most cases, features appearing above the surface of the water during the respiratory cycle are most useful. In particular, heads, backs, dorsal fins and flukes are used most frequently for individual identification, with variations occurring in colour patterns, skin patches, body scarring, and nicks/notches along fin edges (Hammond *et al*. 1990).

Adult Risso's dolphins are heavily scarred, mostly from superficial wounds caused by the teeth of conspecifics (MacLeod, 1998, Hartman *et al*., 2008, Bearzi *et al*., 2010). These scratches persist for a long time so they can be individually identified not only by the usual features of the dorsal fin (shape, notches and amputations) but also by the unique scarification patterns on the dorsal fin and the body (Fadda & Airoldi, 2000, Hartman *et al*., 2008).

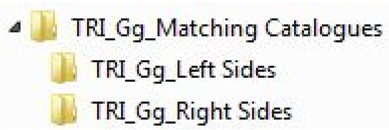
3.1.1. Common protocol

In order to obtain a unified catalogue that complies with the common criteria, a protocol with specific guidelines was prepared and provided to the Partners. The protocol includes detailed descriptions on how to manage the photo-id images collected by the different Partners and how to standardise their catalogues before comparing their photos with those of the other Partners catalogues.

The standardisation procedures followed by all Partners in the preparation of the images, the selection of those to be included in its catalogues of photo-identification, those relating to the assignation of the pictures' quality criteria and the distinctiveness of the marks of the individuals are shown in the protocol below.

PHOTO-ID AND MATCHING CATALOGUES

Photo-id Matching Catalogues of well-marked individuals: there are two matching catalogues, one for the right side and another one for the left side of the dorsal fins. The catalogues contain only the <u>most recent and best picture</u> (matching picture) of each side per individual. Generally this picture will be from the last sighting of the individual to date. However, in the event that the picture from a previous sighting is of better quality than the most recent one, it is recommended to keep the best quality picture instead of the last one in the matching catalogue, as long as the fin in question does not display major evolution that would otherwise not be detectable.



✱ The pictures to be included in the catalogues must have a photographic Quality value of Q1 or Q2, and an Individual Distinctiveness value of D1 or D2. See section "Pictures Management and Selection".

✱ In the Med Grampus Project, the participating Institutes will only share their Matching Catalogues.

The requirements that are mandatory for the standardisation of the catalogues have been marked with an asterisk ✱.

PICTURE MANAGEMENT and SELECTION

a) First Selection

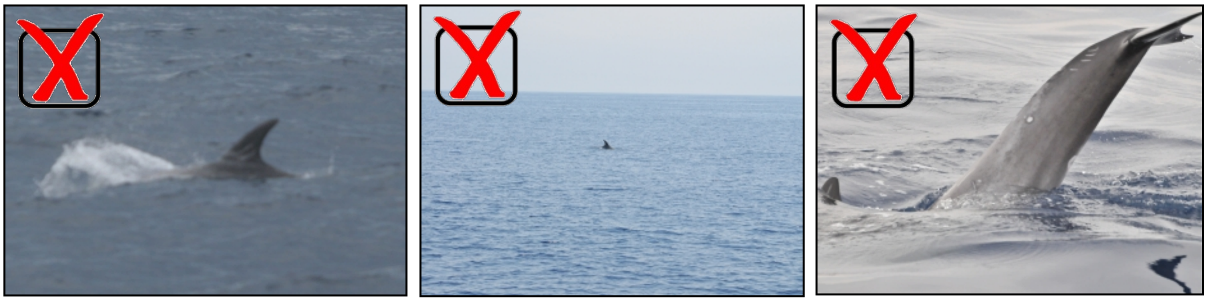
All the original pictures of a Risso's dolphin sighting go into a **Master folder**. TRI renames the master folders as follows:

Master_Gg_20110712_01

The file name is made up of 4 fields, separated by "_" (*underscore*), corresponding to:

- The word "Master"
- 2 letter code of the species: **Gg** = **G**rampus **g**riseus
- Date: yyyymmdd
- Sighting number: 2 digits

It is recommended to start with a preliminary selection of pictures in the Master folder by discarding any unwanted pictures that may be out of focus, too dark, where the animals are too far away, or not displaying any useful photo-identification features (see examples below). Doing so will save time and energy later.



A copy of the Master folder should be made in the same location, so as to find yourself with duplicates of the Master folder. One of them will be compressed and archived, the second will serve for cropping and analysis of the pictures, and renamed Cropped_Gg_20110712_01.

b) Renaming the pictures

TRI renames the pictures in the master folders as follows:

CSR_Gg_20110712_01 _###0_SAIR

The file name is made of 6 fields, separated by "_" (*underscore*), corresponding to:

- Study area ID code: 3 capital letters, Eg. **CSR**: **C**etacean **S**actuary **R**esearch
- 2 letter code of the species: **Gg** = **G**rampus **g**riseus, **Tt** = **T**ursiop **t**runcatus, …
- Date: yyyymmdd
- Sighting number: 2 digits
- Picture number: 4 digits, last digit is a zero (Eg: 00**1**0, 00**2**0, 00**3**0, 00**4**0, ..., 0**23**0, 0**24**0, ...);
- Photographer ID code: 4 capital letters = first letter of the name + first 3 letters of the surname

In case a picture features more than one 'useful' (identifiable) animal, duplicate the picture as many times as needed according to the number of photo-identifiable animals present in the frame, so as to attribute a photograph to each individual.

TRI renames the pictures featuring more than one individual as follows:

E.g.: picture featuring 3 individuals (all three of them being considered ‘useful’; meaning all three individuals are in focus, fully visible/without interference)
CSR_Gg_20110712_01 **_0120**_SAIR → original, can be removed
CSR_Gg_20110712_01 _012**1**_SAIR → 1st individual
CSR_Gg_20110712_01 _012**2**_SAIR → 2nd individual
CSR_Gg_20110712_01 _012**3**_SAIR → 3rd individual

Each data supplier can rename the pictures according to the protocol of their own project, although some key information must be present in the name of all the pictures or associated. This information is:

- Name or code of the individual, must be the same for the right and the left hand side (if known)
- Side of the dorsal fin: L (left) or R (right)
- Institute ID-Code or Study area/Project ID code. Eg. **CSR**: **C**etacean **S**anctuary **R**esearch, the same you used in the Annex No. 2_Data Suppliers and Study Areas/Project.

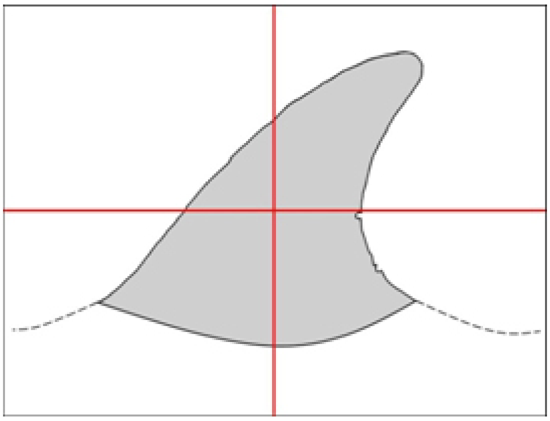
Examples from the TRI Catalogues:

Adam_L_CSR_Gg_20100530_01_0050
Gio_L_CSR_Gg_20060814_05_0032

Adam_R_CSR_ Gg_20090716_04_0990
Gio_R_CSR_Gg_20080923_09_0541

c) Cropping the pictures

The cropping of the pictures is usually done on a copy of the Master folder that can be renamed so as to be distinguishable from the archived original. Before starting with the matching procedure, crop all the pictures in order to include each part of the body or, if you prefer, to focus on the dorsal fin.



For pictures featuring more than one animal, crop each of the copies focusing on each of the animals in turn, in order to obtain a picture as the one shown above. If the animals are far away, it is necessary to zoom in and crop the pictures following the same instructions.

✱ **The pictures contained in the catalogues provided by the data suppliers should conform to these two formats.**

d) Preliminary matching

Advice: TRI proceeds to a preliminary matching within the pictures of a single sighting (grouping all the pictures that belong to a certain individual), in order to identify both sides of the individuals and to select the best matching picture for each side of each animal. The matching picture of each individual is renamed with a provisional code, same for both sides of the fin, as follows:

***001*_L**_CSR_Gg_20110712_01 _0120_SAIR
***001*_R**_CSR_Gg_20110712_01 _0440_SAIR

After matching the sighting (matching) pictures with the main Matching Catalogues, the provisional code will be replaced with the name of the animal if the match is positive and the individual is already present in the catalogue. If the photograph has no match in the Matching Catalogues, meaning that the individual has been sighted and photo-identified for the first time, it will be given a new name.

In order to determine if a matching slide can be included in the "Well Marked Individuals Catalogue" it is necessary to assess its photographic quality and the individual distinctiveness.

✱ **The assessment of the photographic quality and the individual distinctiveness is then done only on the matching pictures.**

✱ **Data suppliers will create an Excel file list of all the pictures contained in the left sides and right sides catalogues. The list will be used to value the photographic quality (PQ) and the individual distinctiveness (D) of each picture and each individual.**

Side	ID	Filename	Date	Photographic quality (PQ)				Total value	Overall PQ	Ind. Distinct. value
				FC	CO	AN	EI			
L	Enri	Enri_L_CSR_Gg_20050806_07_0180_APRO	06/08/05							
L	Febo	Febo_L_CSR_Gg_20050806_07_1270_APRO	06/08/05							
L	Giotto	Giotto_L_CSR_Gg_20050806_07_1080_APRO	06/08/05							
L	Matti	Marti_L_CSR_Gg_20050806_07_1070_APRO	06/08/05							
L	Nero	Nero_L_CSR_Gg_20090807_04_0490_EPIR	06/08/05							
R	Freud	Freud_R_CSR_Gg_20040904_012_3040_VFAD	04/09/04							
R	Guy	Guy_R_CSR_Gg_20040904_012_3070_VFAD	04/09/04							
R	Macchia	Macchia_R_CSR_Gg_20040904_012_0310_VFAD	04/09/04							
R	Will	Will_R_CSR_Gg_20040904_012_3260_VFAD	04/09/04							

e) Assessing the PHOTOGRAPHIC QUALITY of the pictures

The quality value of a picture is based on the quality of the photograph, independently of the distinctiveness of the dorsal fin.

There are four variables to be considered, each one of those is given a score of 1 or 3 or 5. The overall photographic quality results from the sum of these scores.

➲ ✱ **Pictures in which at least one of the four values is 5 are immediately classified as PQ3: Poor quality and must be therefore excluded from Well Marked Photo-Id catalogues and abundance analysis.**

1) FOCUS/CLARITY (FC): crispness or sharpness of the image. It may also include pixelation (digital images).

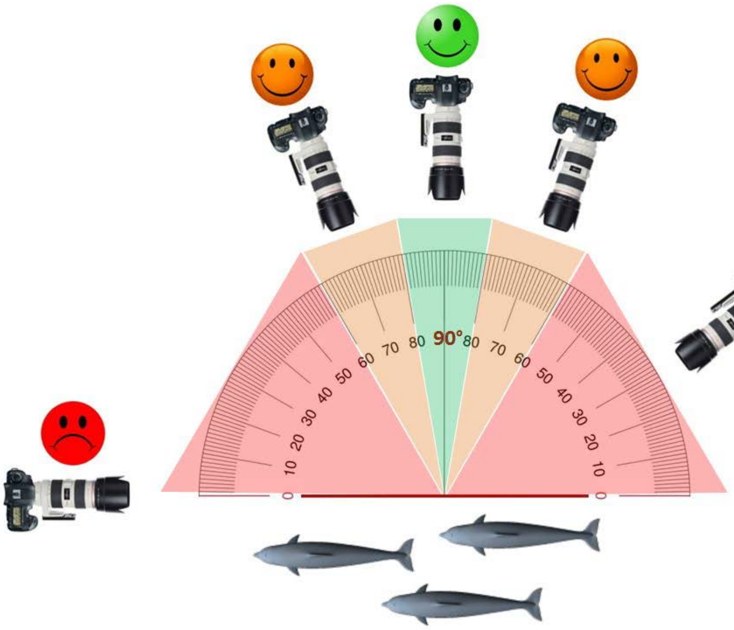
Value	**Quality**	**Examples**
1	**Excellent** **Scarring and notches perfectly visible**	 
3	**Moderate** **Scarring and notches still visible**	 
5	**Poor** **Scarring and notches indistinguishable**	 

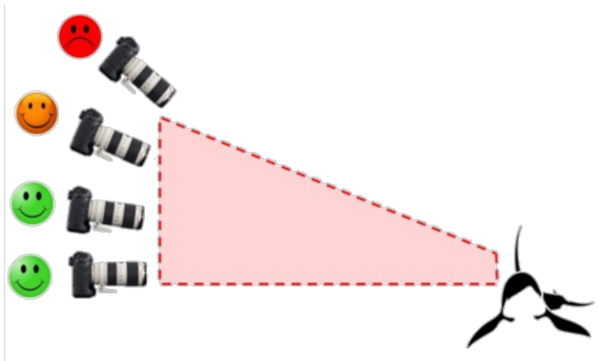
2) CONTRAST (CO): difference in coloration between the dorsal fin and the surrounding environment. Photographs with too much contrast lose details as small features wash out to white. Images with too little contrast lose the fin into the background and features lack definition.

Sometimes the contrast of a digital picture can be improved by increasing the brightness of the picture and changing the contrast. It is recommended to try this procedure before releasing a picture.

Value	Quality	Examples
1	**Excellent** Ideal contrast	 
3	**Moderate** Small features wash out and big ones, if present, still visible.	  Example of picture that have been retrieved by using a software  
5	**Poor** Scarring not visible	 

3) ANGLE (AN): angle of the fin to the camera. The fin must be as perpendicular to the camera as possible. Bear in mind that the camera must also be as level as possible with the animal, pictures taken from too high above can alter the view of the markings.





Value	Quality	Examples
1	**Excellent** 80°-90°	 
3	**Moderate** 60°-80°	 

5	**Poor** 0°-60°	 

4) ENVIRONMENTAL INTERFERENCE (EI): obstruction to the view of the dorsal fin by environmental factors (waves, water splashes, other dolphins, etc..)

Value	Quality	Examples
1	**Excellent** Dorsal fin visible in its entirety	 
3	**Moderate** Dorsal fin about 80% visible with back edge completely visible	 
5	**Poor** 60% or less visible, back edge not visible	 

***OVERALL PHOTOGRAPHIC QUALITY**: sum of the scores for the characteristics described above.*

➲ **Remember: Pictures in which at least one of the four values is 5 are immediately classified as Q3: Poor quality and must be therefore excluded from Well Marked Photo-Id catalogues and abundance analysis.**

Pictures with values 1 and 3 and overall values between 4 and 12 are to be classified as follows:

<u>PQ1</u>: 4-6. Good quality
<u>PQ2</u>: 8. Moderate Quality
<u>PQ3</u>: 10-12. Poor quality

➲ ✱ **Only pictures classified as PQ1 and PQ2 can be used in the second phase: assessing the individual distinctiveness of the animal (see paragraph e).**

Examples of how to assess the PHOTOGRAPHIC QUALITY of a picture

FC	**3**
CO	**1**
AN	**1**
EI	**3**
Tot	**8**

Q2: MODERATE QUALITY

FC	**3**
CO	**1**
AN	**1**
EI	**1**
Tot	**6**

Q1: GOOD QUALITY

FC	3
CO	3
AN	1
EI	3
Tot	10

Q3: POOR QUALITY

f) Assessing the INDIVIDUAL DISTINCTIVENESS

Overall individual distinctiveness is based on the amount of information present on the dorsal fin, namely:

- notches on the trailing and/or leading edge
- coloration and scarring
- fin shape

D1: **Very distinctive**, three or more evident and well visible features. The matching can be confirmed by a single expert researcher (an expert researcher is considered to be someone who has at least two years experience in the photo-identification of various species of dolphins).

D2: **Moderately distinctive**, at least one evident and permanent and well visible feature. The matching must be confirmed by at least two expert researchers.

D3: **Non distinctive**, none or poor feature content.

➲ **Only the individuals with distinctiveness D1 and D2 can be included in the Well Marked Photo-Id catalogues and be used for abundance analysis.**

Examples of how to assess the DISTINCTIVENESS of an individual Risso's dolphin

D1: very distinctive

D2: moderately distinctive

D3: not distinctive




Example of a filled-in Excel Form only with images to be incorporated into the Well Marked Catalogue

Side	ID	Filename	Date	Photographic quality (PQ)				Total value	Overall PQ	Ind. Distinct value
				FC	CO	AN	EI			
L	Enri	Enri_L_CSR_Gg_20050806_07_0180_APRO	06/08/05	1	1	3	1	6	Q1	D1
L	Febo	Febo_L_CSR_Gg_20050806_07_1270_APRO	06/08/05	3	3	1	1	8	Q2	D1
L	Giotto	Giotto_L_CSR_Gg_20050806_07_1080_APRO	06/08/05	1	1	3	1	6	Q1	D2
L	Matti	Marti_L_CSR_Gg_20050806_07_1070_APRO	06/08/05	1	3	3	1	8	Q2	D2
L	Nero	Nero_L_CSR_Gg_20090807_04_0490_EPIR	06/08/05	1	1	3	3	8	Q2	D2
R	Freud	Freud_R_CSR_Gg_20040904_012_3040_VFAD	04/09/04	1	1	3	1	6	Q1	D2
R	Guy	Guy_R_CSR_Gg_20040904_012_3070_VFAD	04/09/04	1	1	1	3	6	Q1	D1
R	Macchia	Macchia_R_CSR_Gg_20040904_012_0310_VFAD	04/09/04	1	3	1	3	8	Q2	D1
R	Will	Will_R_CSR_Gg_20040904_012_3260_VFAD	04/09/04	1	1	3	1	6	Q1	D1

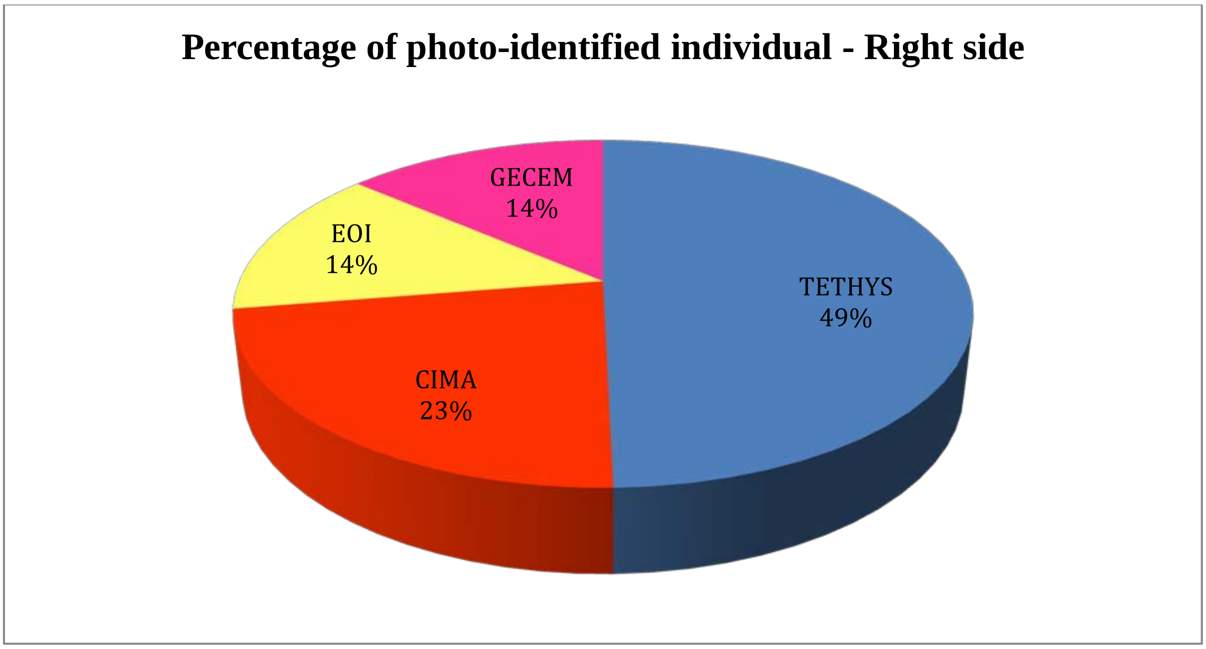
3.1.2. Images and data preparation

The Partners made proceeded to a revision of their digital photographic dataset, in accordance with the protocol above, selecting the best pictures of both sides of each individual. The contribution of the Partners resulted in a total of **548** photo-identified individuals for the right side and **562** for the left side (Table 4).

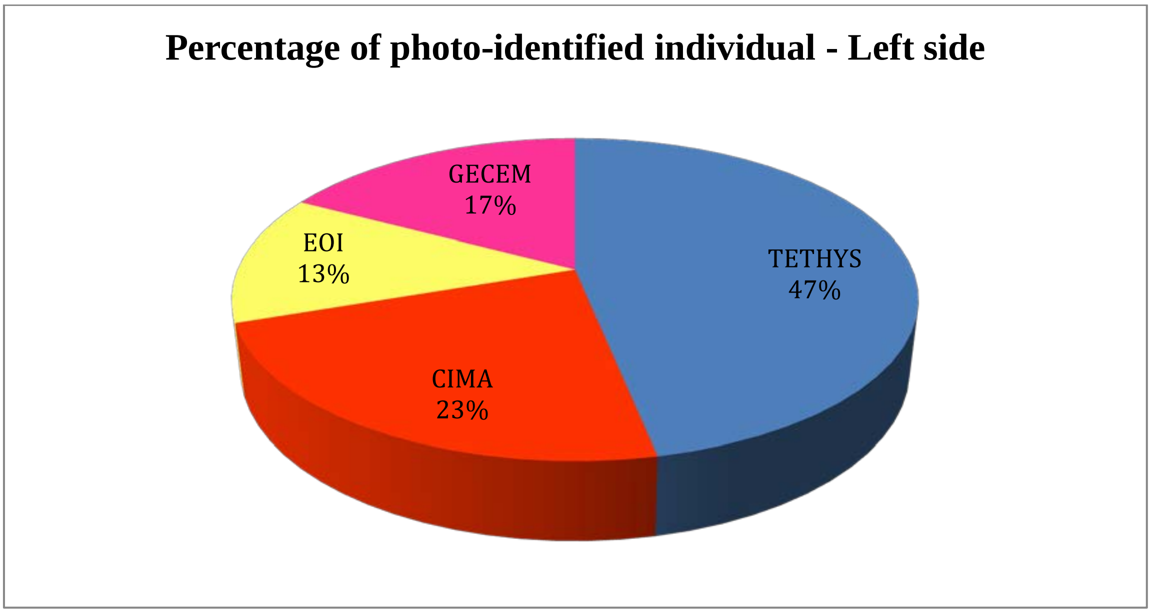
Table 4. Number of Right and Left side images of the four catalogues.

Partner	Number of right side photo-identified individual	Number of left side photo-identified individual
TETHYS	272	263
CIMA	125	129
EOI	76	73
GECEM	75	97
Total	**548**	**562**

The individual catalogues varied in their percentage of Left and Right dorsal fin sides: Tethys 49%, Cima 23%, EOI 14%, GECEM 14% (Fig. 6 a); for the left side Tethys 47%, Cima 23%, EOI 13%, GECEM 17% (Fig. 6 b).



a)



b)

Fig. 6. Percentage of photo-identified animal by Partners. a) Right side; b) Left side.

3.1.3. Comparison of the catalogues (matching analysis) and creation of a unique, common catalogue

The comparison between the four catalogues was carried out by all Institutes (except Fondazione CIMA). In the end, all matches were crosschecked and all individuals compared in order to avoid false-positives and false-negatives. Every picture of each catalogue was compared with all the images of the other catalogues. At the end of the matching procedure, the results of the Partners were merged into a single table and compared. When all the Partners agreed on the different results, two summary tables were prepared, one for each side.

The comparison of all catalogues yielded many matches, resulting in a total of **405** different individuals for the right side and **402** for the left side. For **261** of these individuals, the correspondence between the two sides of the body was also found. Some individuals were photographically captured only by one Partner, others by more Institutes (Table 5; Fig. 7).

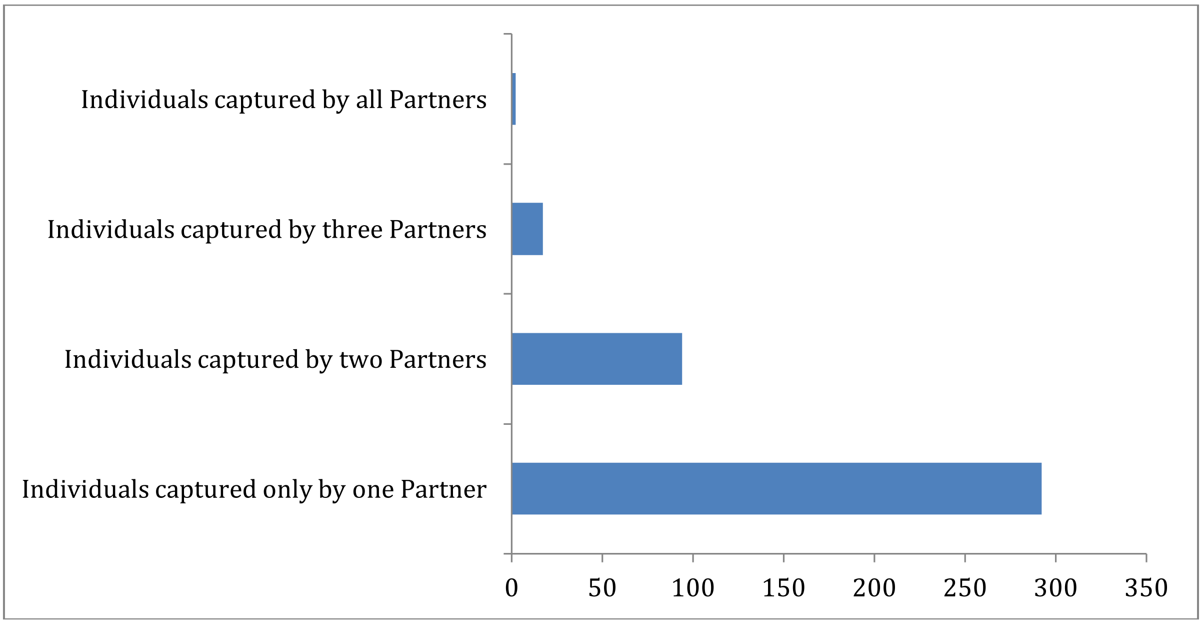
Table 5. Number of individuals captured by one or more Partners. a) Right side; b) Left side

	Right side
Number of individuals captured only by one Partner	292
Number of individuals captured by two Partners	94
Number of individuals captured by three Partners	17
Number of captured by all Partners	2

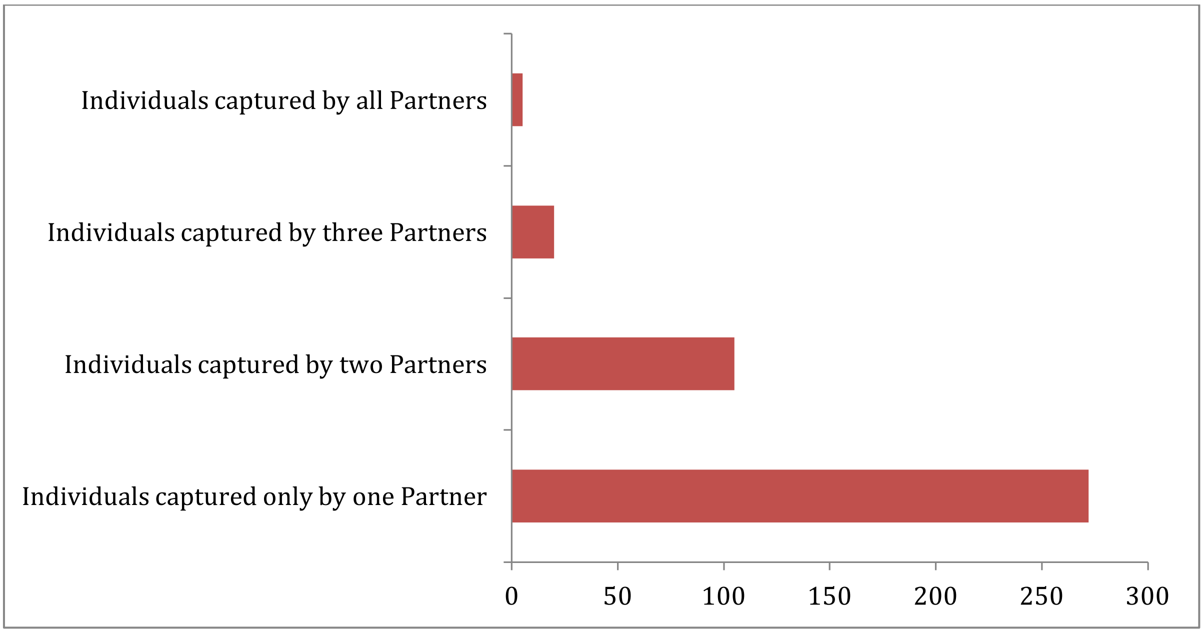
a)

	Left side
Number of individuals captured only by one Partner	272
Number of individuals captured by two Partners	105
Number of individuals captured by three Partners	20
Number of captured by all Partners	5

b)



a)



b)

Fig. 7. Number of animals captured by one or more Partners. a) Right side; b) Left side

3.1.4. Implementation of the Mediterranean Grampus Catalogue

In order to improve the biological knowledge of the Mediterranean population of Risso's dolphins and therefore its conservation, it is crucial to gather more information about abundance, movement patterns, social structure and habitat use at a basin level by gathering available data collected in past years by other Mediterranean organisations. The outputs of this study represent an important contribution to the implementation of the Mediterranean Grampus Catalogue.

3.2. Effort, sighting and photo-id data and validated images available onto the online INTERCET platform

In accordance with the instructions contained in the Conservation Action 4b, Resolution 5.2 Work Programme 2014 -2016, adopted at the 5th Meeting of the Parties to ACCOBAMS, all the Partners uploaded their effort data collected in positive conditions, the sighting data and the images of both sides of the photo-identified individuals onto the INTERCET platform.
The INTERCET platform (http://www.intercet.it) is the operational tool of the European project GIONHA (Governance and Integrated Observation of marine Natural Habitat) used by all the Partners to upload the data collected relating to the Risso’s dolphin in the northern Tyrrhenian Sea. The web platform allows Partners to easily share and compare collected data, and to geo-reference them using Geographical Information Systems (GIS) technology.
All Partners uploaded the following data: research platform “tracks”, “sightings”, photo-identified “individuals”, “association photo-individuals”, and “matching the catalogues”. Several variables were uploaded into the “track” section: the track identification code, the location of the visual station above sea level, the number of marine mammal observers, the average speed of the platform, tracking mode (acoustical or visual), type of research platform, start and end of the track, sea state and total number of sightings. The second section relates to “sighting” data, and includes sighting code, target species, visual or acoustical detection, total number of individuals, total number of calves, human activities, track code, associated species, photos, start and end of sightings. The third is the photo-identified “individuals” section, including individual code, species, INTERCET code, sex (and sex detection mode), and whether the individual is dead. In the “association photo-individuals” section, the un-associated photos (grouped by sighting) are linked with the individual selected in the list in the photo-identified “individuals” section. The photos of both sides of the photo-identified individuals are correlated to the sighting catalogue. Finally, in the “matching the catalogues” section, all Partners can match the photo-identified individuals of their own catalogue with that of the other Partners. Furthermore, INTERCET has a dedicated section for research and

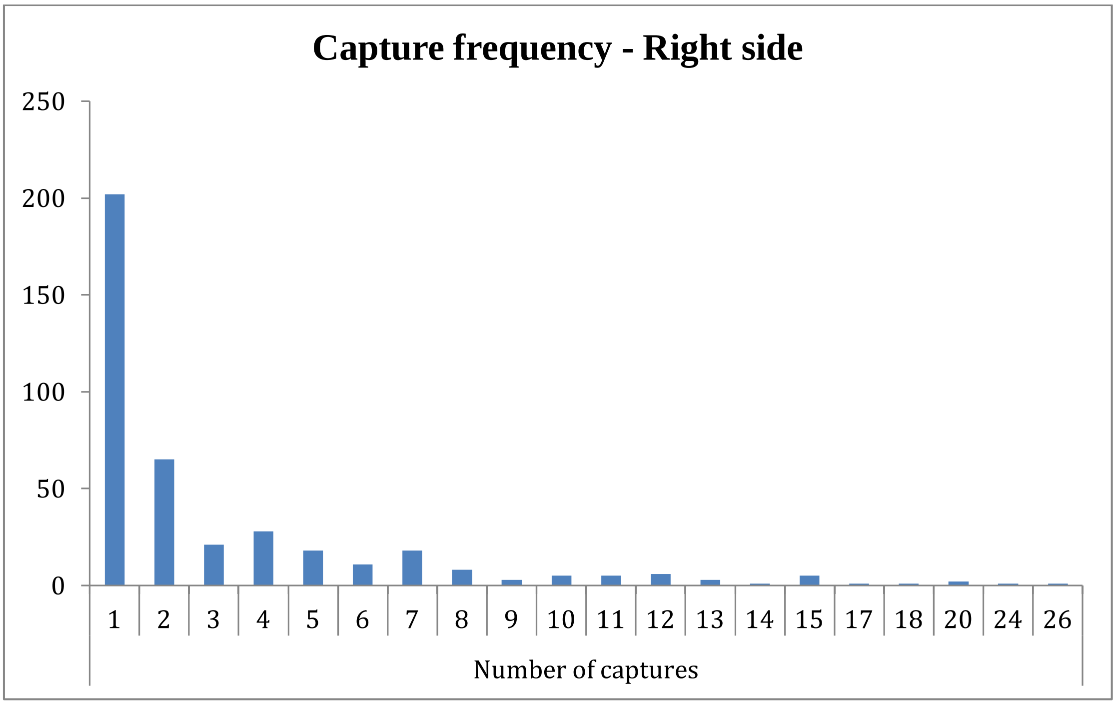
visualising all data uploaded on the platform (track, sightings, individuals and photos). INTERCET platform allows Partners to aggregate, visualise and analyse data and geo-reference photos. This tool aims to obtain habitat, home range and abundance information for the target species: Risso's dolphin.
All the images uploaded on INTERCET platform were validated.

3.3. Mark recapture matrices

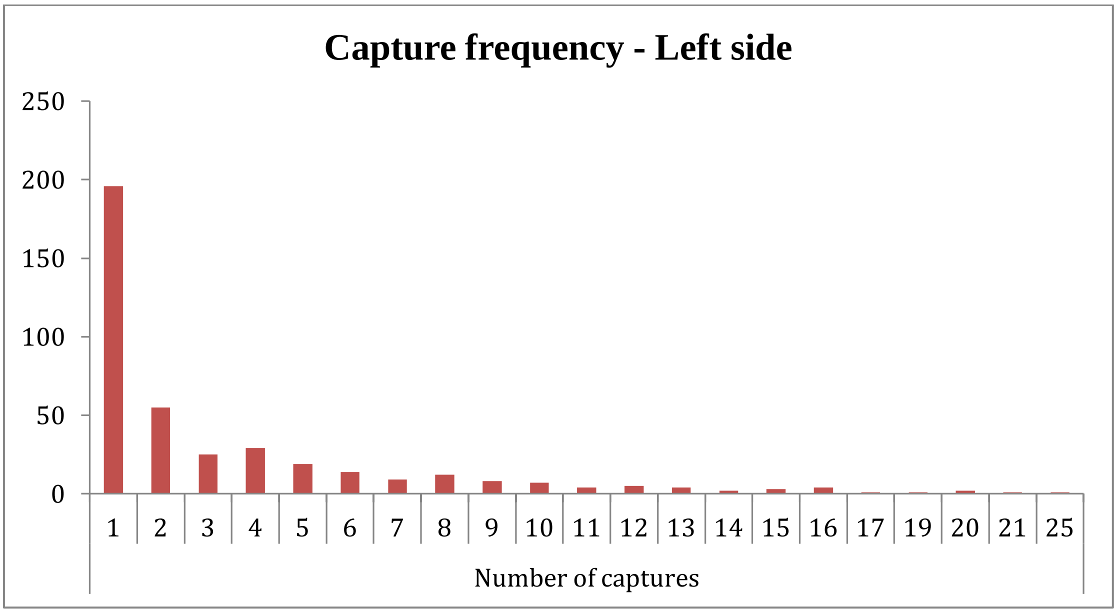
3.3.1. Historical captures dataset

A dataset of capture histories per encounter was created using the individual identification photographs (Würsig & Jefferson 1990). A capture was defined as an individual identification within an encounter. All the capture events were merged toghether, creating a big unique dataset.

The capture frequency histograms (Fig. 8) show that the right side and the left side dataset present the same pattern in terms of individuals captured only once or repeatedly.



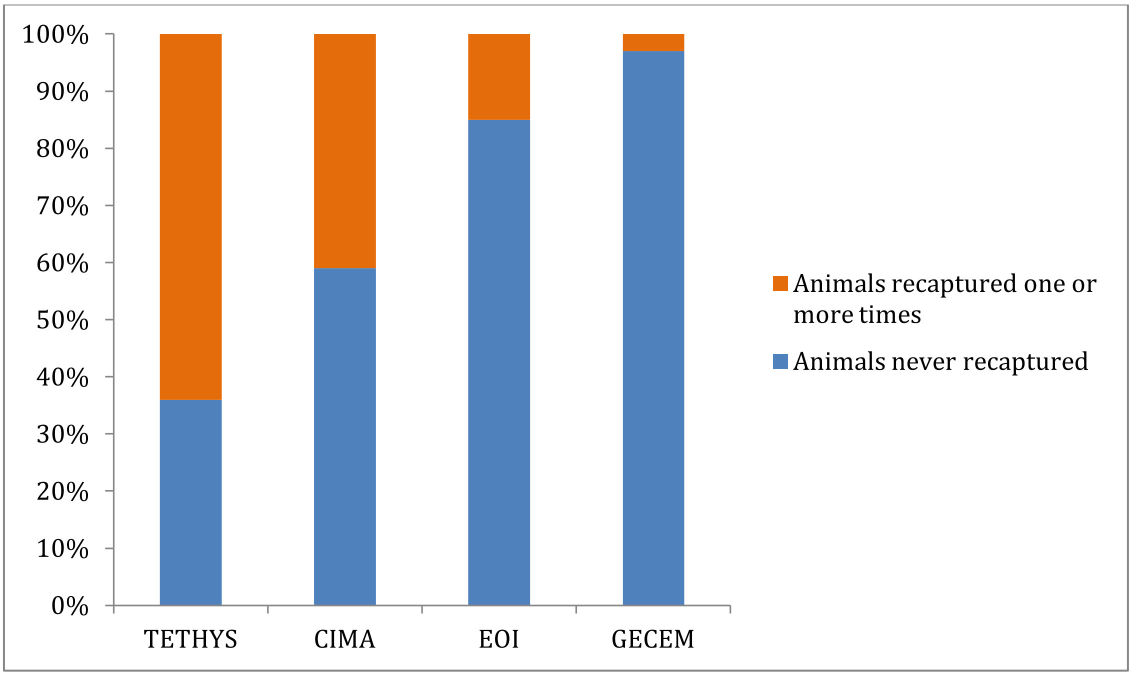
a)



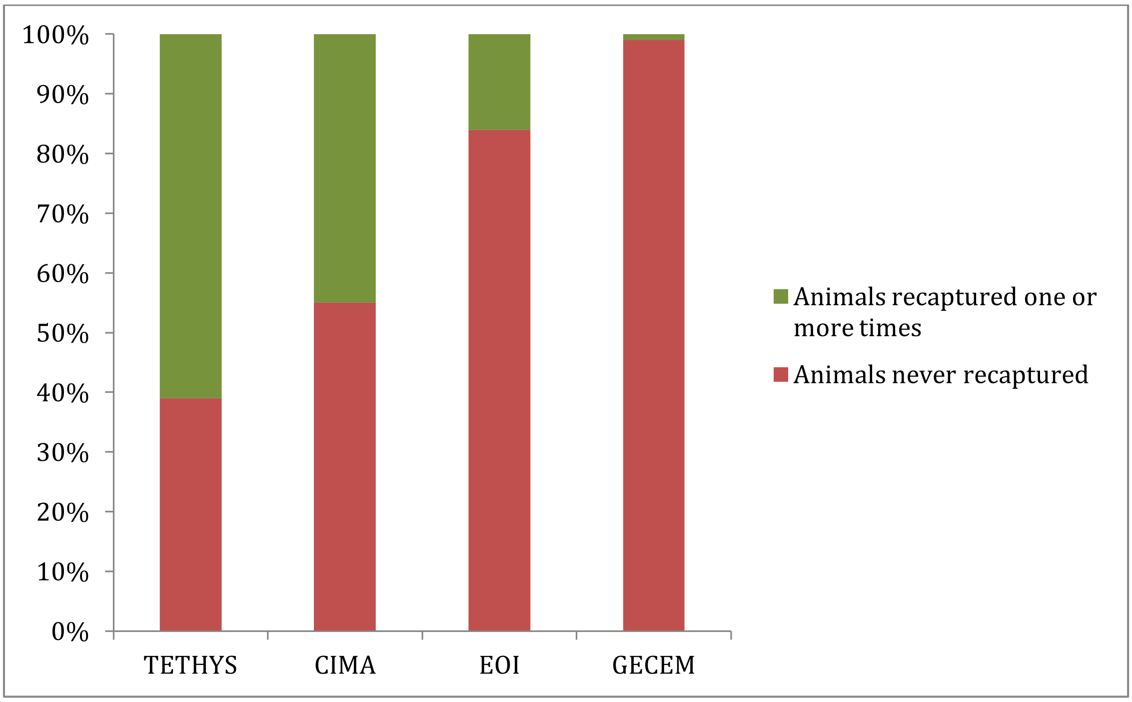
b)

Fig 8. Capture frequency histogram for photo-identified individuals from right side (a) and left side (b).

The percentage of recaptures were extremely different among the Institutions (Fig. 9), depending on the different size of their photo-identification catalogues.



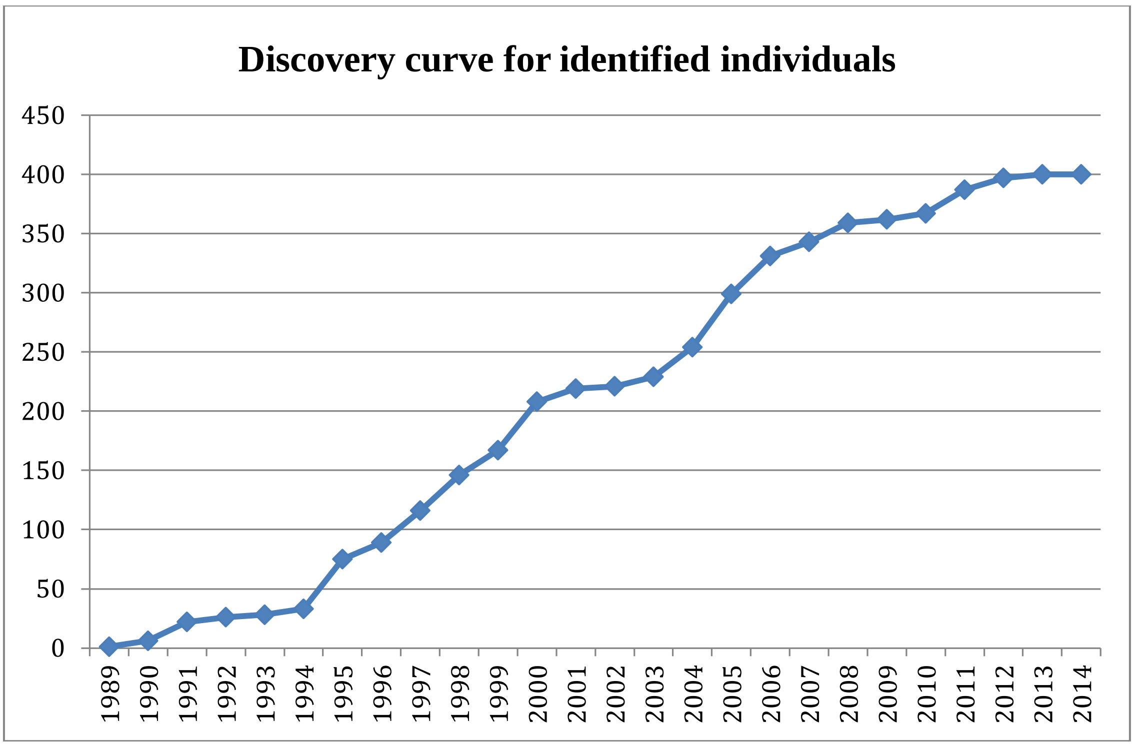
a)



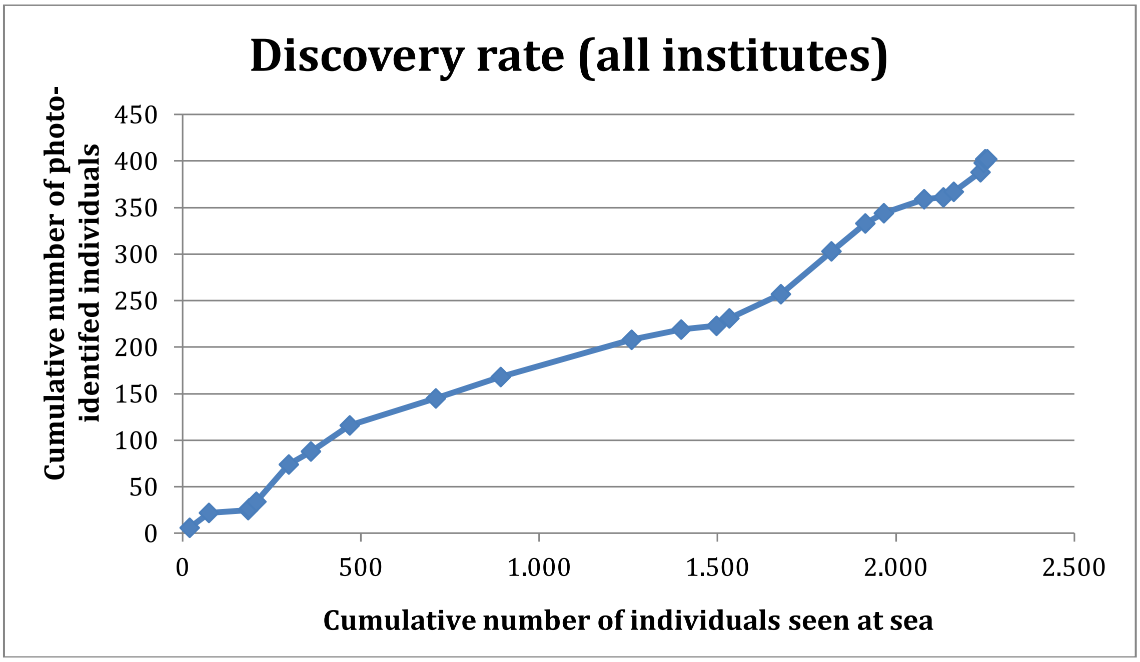
b)

Fig . 9 Percentage of recaptures of the different Partners. a) Right side; b) Left side.

The two discovery curves of the individuals captured, based on the right side catalogue, show still a monotonic increasing trend, suggesting that not all individuals using the area have been captured (Fig. 10 a) and b)).



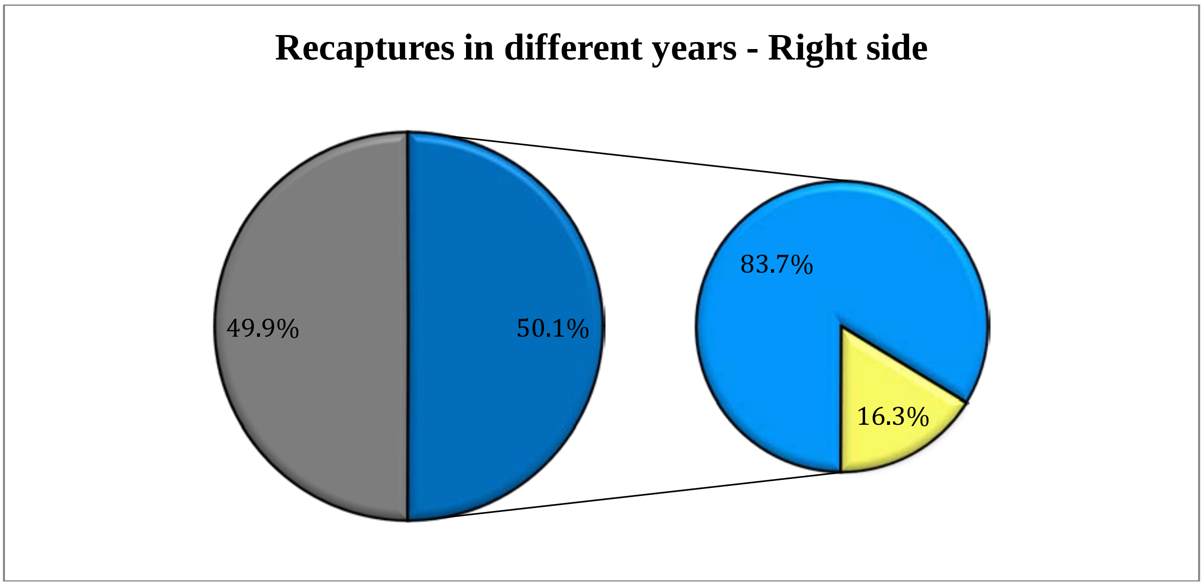
a)



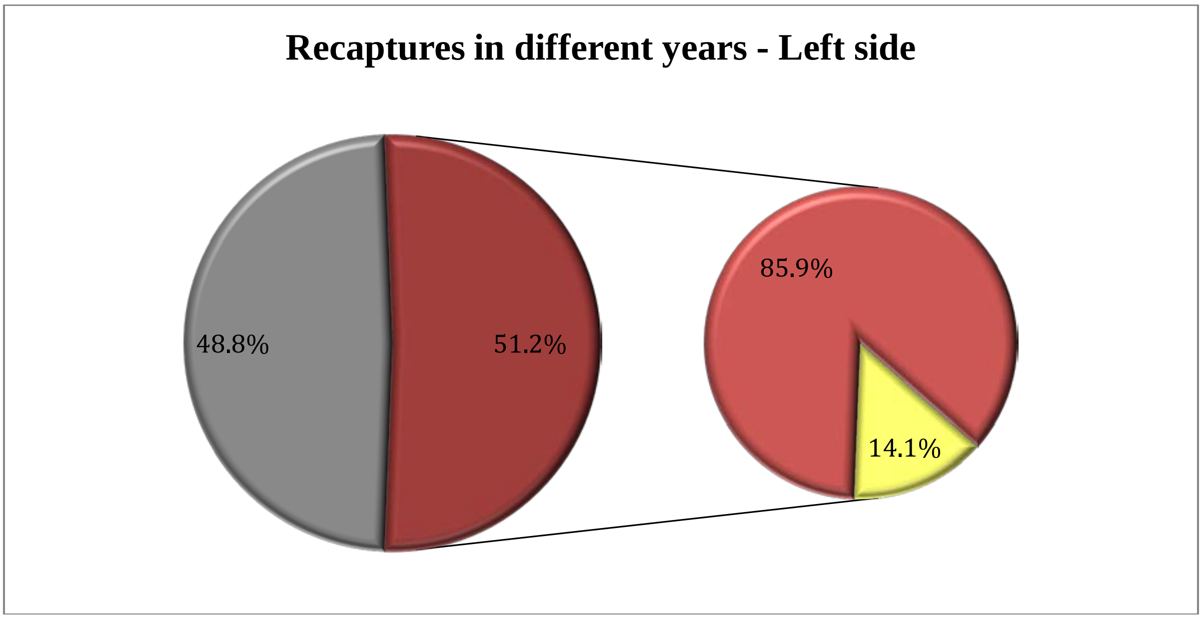
b)

Fig. 10 a) and b). Discovery curves based on individuals (right side) captured between 1989-2014.

Concerning the right side dataset, the 50.1% of the 405 individuals, (203 individuals) were recaptured. The 83.7% (170) of the recaptured individuals were captured in different years (Fig. 11 a). Concerning the left side dataset the 51.2% (206 individuals) of the 402 individuals, were recaptured and the 85.9% (177) of these were captured in different years years (Fig. 11 b).



a)



b)

Fig. 11. Percentage of recaptures and percentage of animals recaptured in different years. a) Right side; b) Left side.

3.3.2. Q-rating and image selection

In order to create the matrices for the mark-recapture analysis, a subset of data was prepared. Only individuals with sufficiently distinctive marks to allow future recognition were included in the dataset and only good quality photographs were used (Hammond 1986, Stevick *et al.*, 2001).

Photographs were graded (Q-rate) according to the common protocol. Each of the best images for each capture was independently assigned a quality rating from 1-3 (respectively good, moderate and poor); and each catalogued dolphin was assigned a distinctiveness category, ranging from very distinctive, moderately distinctive, and non-distinctive. The photo quality rate was based on focus, clarity and contrast of the image, and on the angle and size of the dorsal fin relative to the frame (Friday *et al.*, 2000). Captures featuring photo quality 1-2 were defined as high-quality (HQ) images. Non-distinctive individuals were based only on none or poor visible features or on atypical fin shapes, moderately distinctive individuals had at least one evident and permanent and well visible feature, distinctive individuals had three or more evident and well visible features. Individuals with distinctiveness 1-2 were defined as well-marked (WM). This study used only WM-individuals and HQ-images, thus increasing the certainty of matches.

3.3.3. Creation of the mark-recapture matrices

Fig. 12 shows the total number of individuals captured in each fieldwork season. As it can be observed the number of photographic captures varied greatly season after season. It has to be also observed that the right side and left side data set, as it was reasonably to expect, show the same pattern. Given this situation and the wide time frame encompassed by this integrated data set, it wouldn't be appropriate trying to apply mark-recapture methods on the whole data set. Data need to be pooled based on the homogeneity of the photographic effort (e.g. 2005 and 2006 data are consistent concerning the number of captures so they can be pooled).

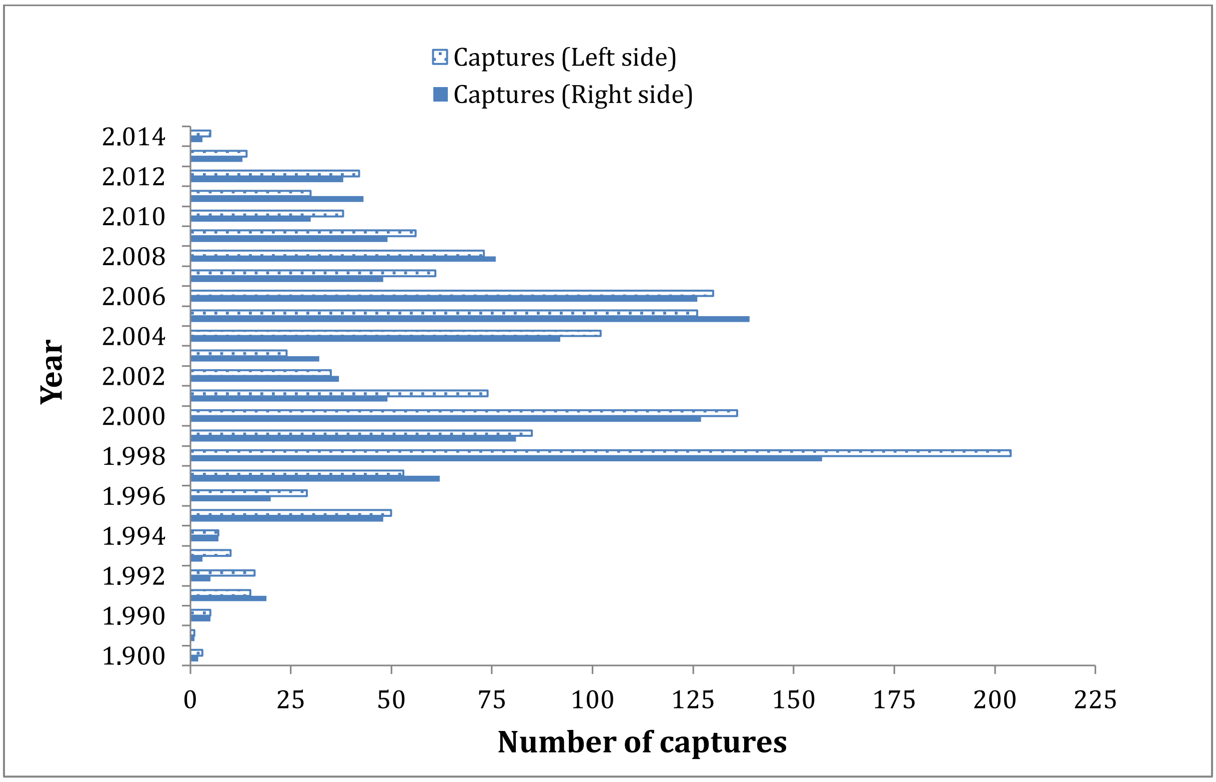


Fig. 12. Number of captures of photo-identified individuals by year.

Besides photographic effort homogeneity, another concern when using mark-recapture methods is sample size both in terms of total captures and recaptures. Therefore the time interval between capture occasions need to be set in order to have appropriate sample sizes. Fig. 13 shows the number of total captures and recaptures by year (i.e. fieldwork season).

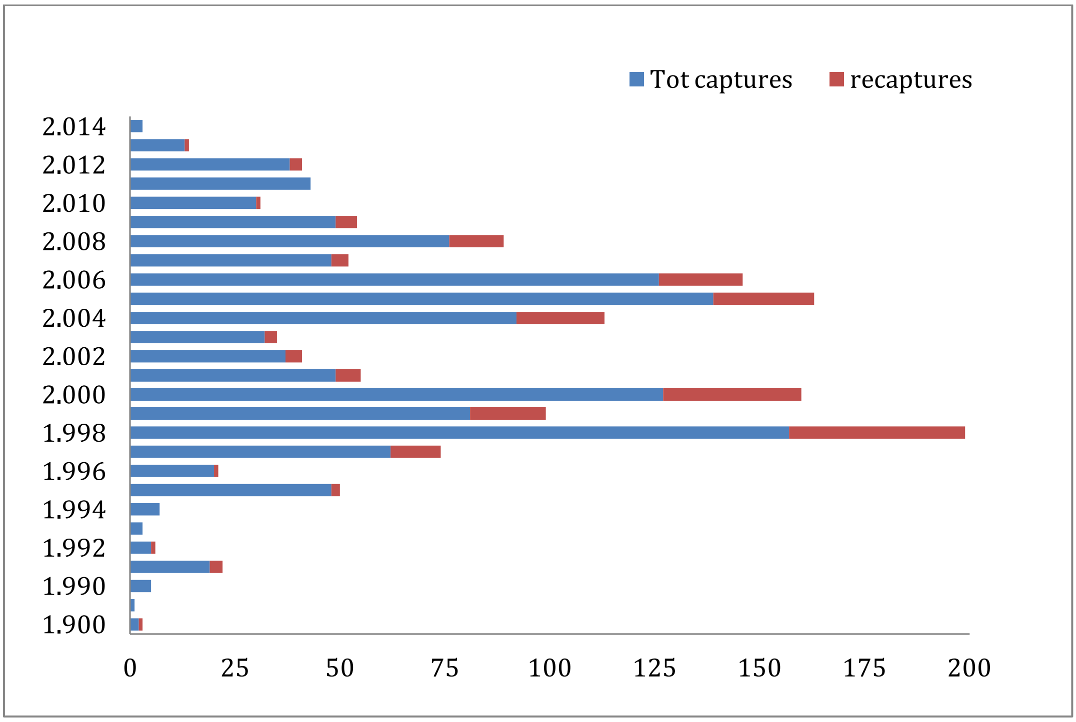


Fig. 13. Number of total captures and recaptures of photo-identified individuals by year.

It clearly appears that only few seasons have enough recaptures to allow robust abundance estimates through mark recapture methods. Time interval spanning over different seasons will be also evaluated. Fig. 14 indicates the number of total captures and recaptures when pooling the data deriving from two following seasons (2-year interval).

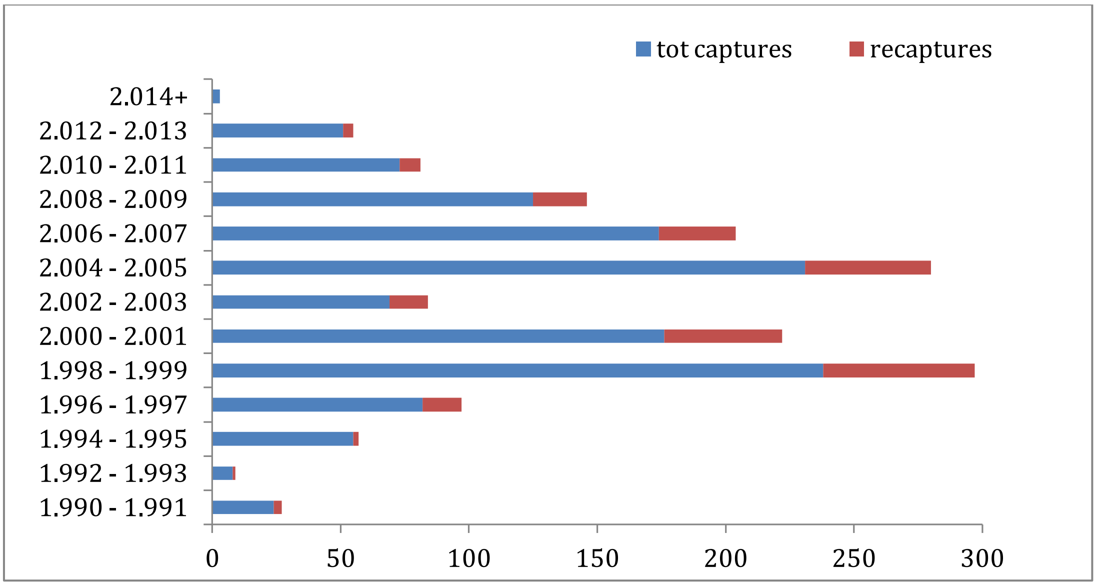


Fig. 14. Ratio between total captures and recaptures pooling the data deriving from two following seasons

Estimates of abundance were calculated using the software MARK, assuming both closed and open population models. Time dependent and heterogeneity models were tested with closed population models.

3.4. Mark-recapture analyses

The study of life history parameters is of fundamental importance to understanding the dynamics of animal populations. Individual-based information forms the basis of capture-recapture studies, in which animals are captured, marked in some way and then released into the population. The initial marking is followed by one or several capture occasions where live animals are recaptured or resighted, and/or dead animals are recovered. The combination of these multiple recapture occasions results in individual capture histories: a record denoting whether each individual was observed or not in each sampling occasion (White & Burnham, 1999). Capture-recapture models developed to analyse the information contained in these capture histories have been used extensively to estimate demographic parameters of biological populations, such as population size, survival probability, population growth rates and recruitment (Schwarz & Seber, 1999). Moreover, statistical developments in some of these models offer a way of assessing the influence of specific factors on the patterns of variation of population parameters (Schwarz & Seber, 1999).

In cetacean populations, capture-recapture studies are generally based on the use of natural markings like nicks and notches on dorsal fins, pigmentation and saddle patch patterns, markings on tail flukes and callosity patterns on rostrum (Hammond et al., 1990).

To avoid violation of one of the key assumptions of capture-recapture analysis, these distinctive features must be sufficiently long lasting, slow changing and unique to be recognized in subsequent sightings (Hammond, 1986). Risso's dolphins show a range of colouration patterns. Individuals can be recognized by the distinctive scarification patterns (long lasting features), as well as by the shape and notches of their dorsal fin (Fadda & Airoldi, 2000; Hartman et al., 2008)

3.4.1. Capture-recapture models

Capture-recapture models include closed models, where the population is assumed to remain unchanged for the duration of the study, open models, where the population may change through additions (births or immigration) and deletions (deaths or emigration), and combinations of both open and closed models (Schwarz & Seber, 1999), often referred to as Pollock’s robust design (Pollock, 1982). The Jolly–Seber (JS) model (Jolly, 1965; Seber,

1965) enables to estimate the apparent individual survival and capture probabilities, and the abundance providing also estimates of entries into (“births” and “immigrations”) and losses from (“deaths” and “emigrations”) the population (Pollock et al., 1990).

An important assumption of capture-recapture models is the homogeneity of capture probabilities among individuals; i.e., the model assumes that all animals have the same probability of being captured given that they are alive and in the population (Lebreton et al., 1992). This assumption is often unrealistic in biological populations: some animals may have home ranges that extend beyond the study area and may, therefore, be unavailable to sampling during a specific sampling occasion; the study area may be traversed by migratory animals; and individual animals may differ in the extent of their movements, with some individuals being permanently present in the study area, whereas other individuals may temporarily move out of the area. Additionally, animals may show different behaviours that ultimately affect their capture probability, and this may result from inherent individual differences or be induced by previous sampling efforts.

Unless it is specifically associated with static group covariates (e.g., sex, age), heterogeneity in capture probabilities cannot be adequately modelled using open models (Pradel et al., 1997). While survival estimates from open models are relatively unaffected by heterogeneity in capture probabilities, estimates of population size and recruitment rates may suffer from serious bias (Carothers, 1973). Alternatively, closed population models that allow for heterogeneity in catchability among animals (Otis et al., 1978; Pledger, 2000) can be employed to generate unbiased estimates of population size. However, these models assume geographic and demographic closure of the population and cannot be used to estimate survival or recruitment rates. When the consecutive primary periods of sampling are not sufficiently separated in time to allow the population to change through gains (birth and immigration) or losses (death or emigration) and, the time interval between consecutive secondary sampling occasions is sufficiently short the population can be assumed closed. With this design, data from secondary samples within each primary period can be analysed using standard closed models to derive estimates of population size.

3.4.2 Methods

Considerations on data set characteristics

As discussed in the previous paragraphs, the integrated dataset of photographic data is highly heterogeneous as highly heterogeneous is the effort which has been dedicated to photo-identification during the whole study period. Heterogeneity can be easily evaluated from the charts showed below (Fig. 15 and 16), summarizing the number of photographed individuals per year (i.e. number of captures) and showing in different color the repeated sighting of single individuals (i.e. number of recaptures).

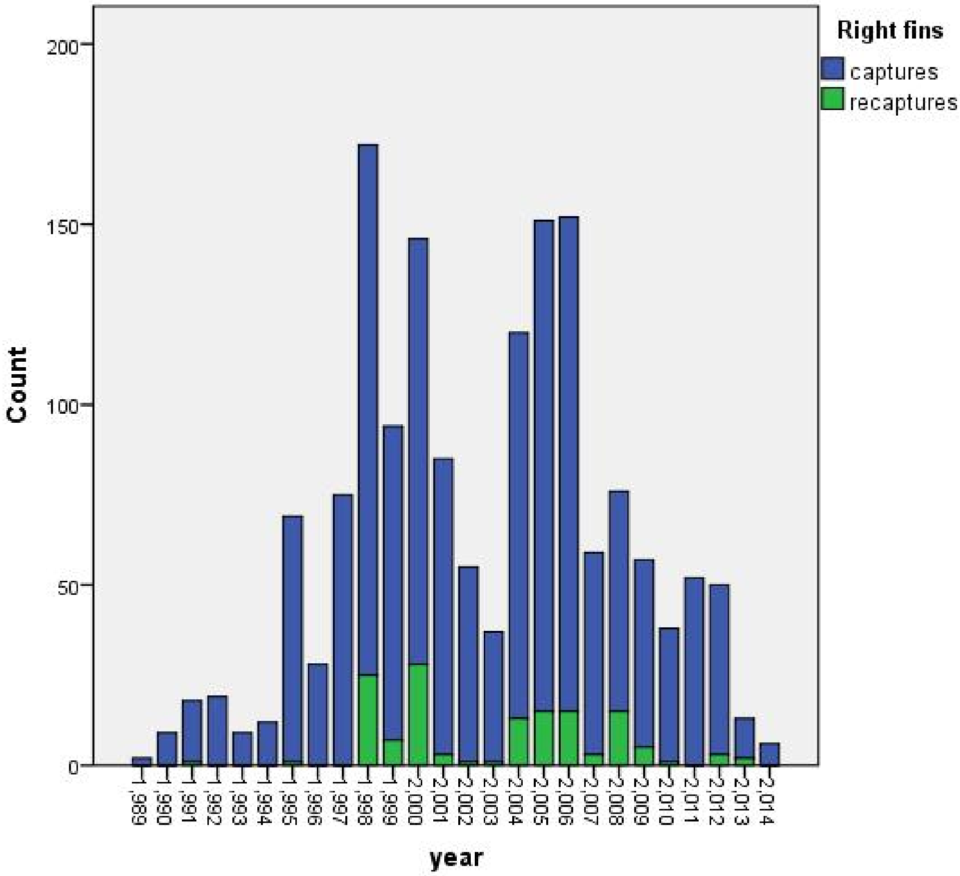


Fig. 15. Right fins **-** Number of captures and recaptures per field season (year)

The charts clearly show that only few field seasons can be used as samples for mark-recapture analysis having an appropriate number of recaptures. Fig. 17 and 18 show the monthly distribution of the photographic captures for both the Right and the Left fin data set. It can be observed that there is a huge amount of variability even in the monthly pattern of the captures. Although, it can be concluded that June, July and August are generally the months with highest number of captures there have been several exceptions to this general rule in different field seasons (e.g. in the 2000 right fin dataset the highest captures occurred in October).

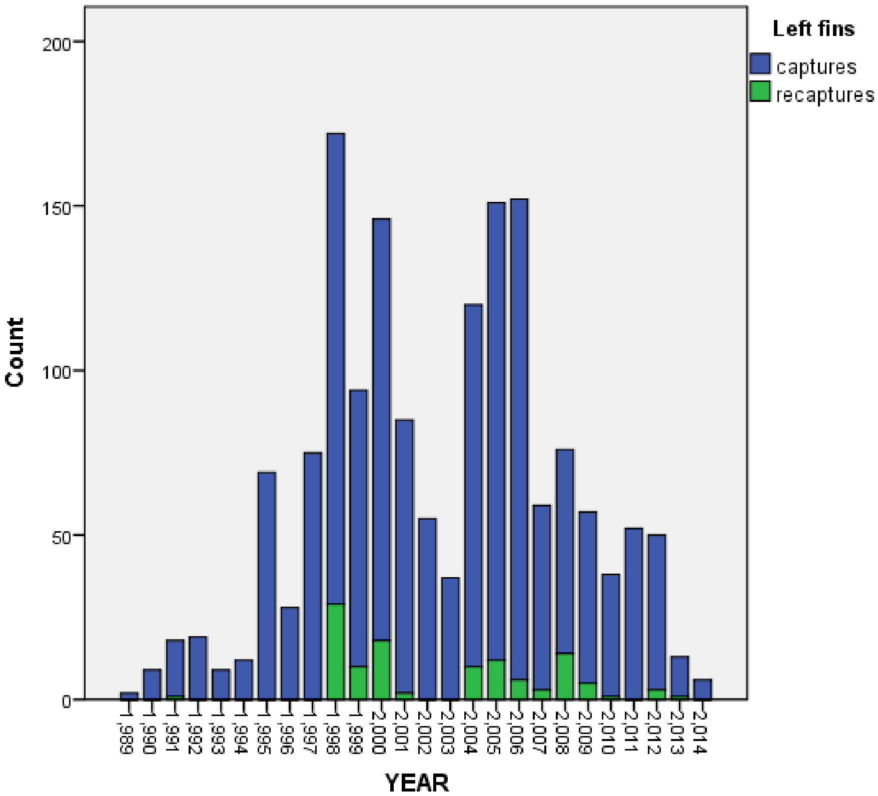


Fig. 16. Left fins - Number of captures and recaptures per field season (year)

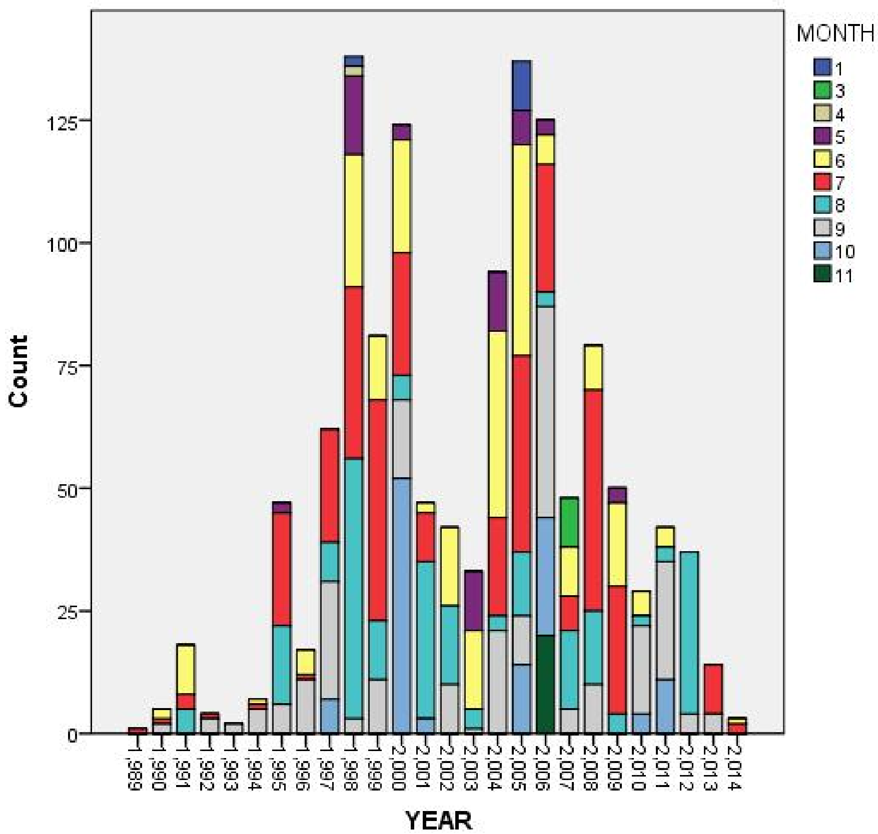


Fig. 17. Right fins - Monthly distribution of captures per field season (year)

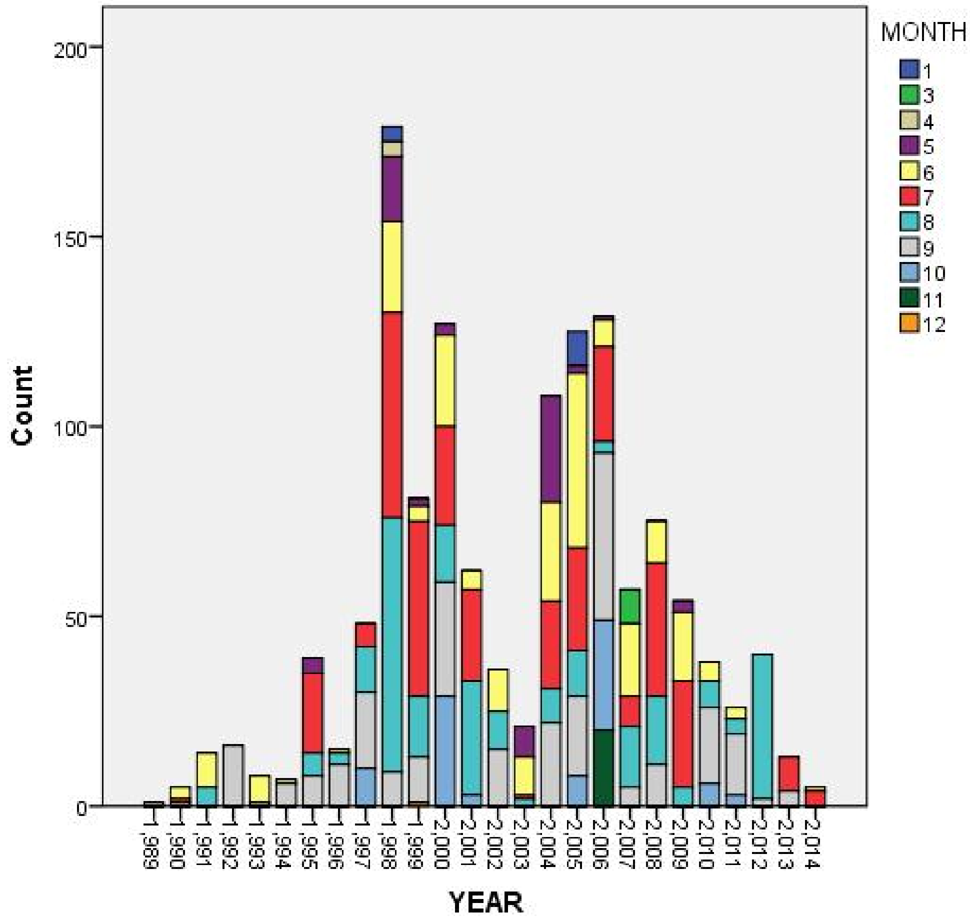


Fig. 18. Left fins **-** Monthly distribution of captures per field season (year).

Fig. 19 shows the number of photographic captures subdivided by the number of encounters of the same animal during the field season for both the right and left fin data set.

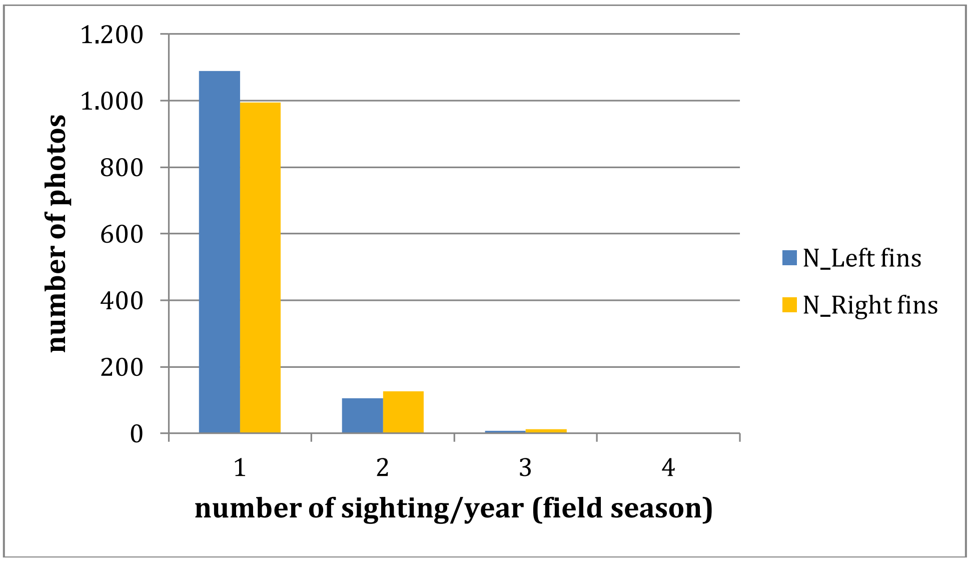


Fig. 19. Number of photographed individuals by right and left fin and number of captures per field season (year)

Fig. 20 shows the same Fig. in terms of percentages. It can be observed that if there is a slightly higher number of photographed left fins for the individuals seen only once during the field season (i.e. 52.2 vs 47.7), the pattern is inverted for the individuals seen more than once during the field season (i.e. 54% and 62% of right fins respectively for the individuals seen 2 and 3 times during the field season). There is only one individual seen 4 times during the study season and the 4 sightings concerns only the left fin data set.

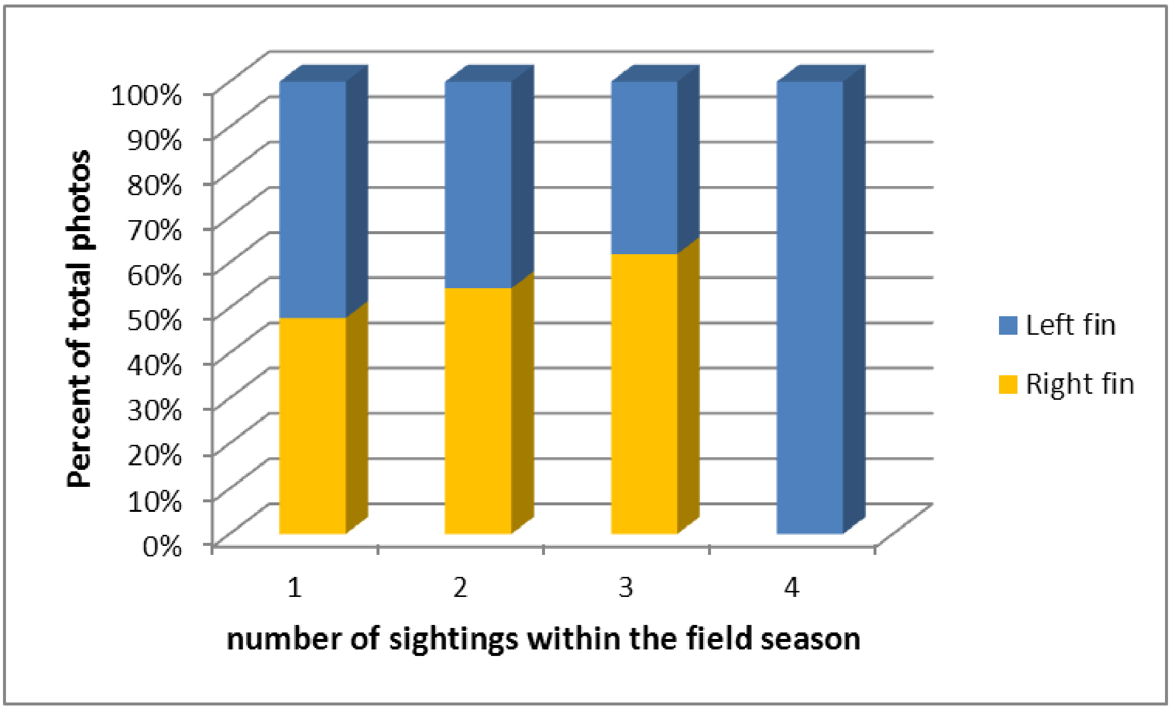


Fig. 20. Percentage of right and left fin photographed individuals subdivided by number of captures per field season (year)

The statistical association among the right and left fin data set was also tested and it was found highly significant (chi-square: 371.6; df:1 $P<0.001$) suggesting that the two dataset contain the same information and will produce similar estimates. Given that, the fact that the right fin database has slightly more cases concerning the resightings (i.e. individual seen 2 or 3 times during the same field season) there might be reason to choose the right fin dataset as the main dataset for mark recapture analysis.

Selection of sampling unit for mark-recapture analysis

In the light of the mentioned heterogeneity, the safest time unit for mark-recapture analysis, in order to minimize the assumptions violations of the standard mark-recapture models, seems to be the field season and the monthly unit the most appropriate sampling occasion. **Assuming**

as primary period the fieldwork season, and the monthly basis the time interval between consecutive secondary sampling occasions, the time frame may be considered sufficiently short to assume the population closed. Under this choice of sampling unit only some field seasons (i.e. 1998, 1999, 2000, 2004, 2005, 2006, 2007, 2008 and 2009) have been chosen to produce robust abundance estimates thanks to their appropriate number of captures and recaptures and many field seasons with insufficient sample size to support the mark recapture analysis based on this sampling unit. Using a larger sampling unit may solve the problem but it would certainly require more complex analytical methods, resulting in a loss of precision of the estimates and a loss of resolution for the temporal pattern of the estimate abundance. For this reason we chose to produce the most robust abundance estimates based on the field seasons with the highest number of captures and recaptures and to evaluate whether to consider also the low sample size field seasons under different sampling units to produce also same historical estimates although less accurate.

Choice of mark-recapture models

Estimates of abundance were calculated using the FORTRAN program MARK (Mark and Recapture Parameter Estimation) v.8.0 developed by the Department of Fishery and Wildlife, Colorado State University, assuming both closed and open population models. In order to analyze the data in this program, the encounter histories for the marked animals selected need to be transcribed into binary: the number ‘1’ indicating that an animal had been sighted, and ‘0’ indicating that the animal had not been sighted. This data preparation was done for all the chosen sampling unit and interval.

It is worthwhile to remind that a closed population remains constant in size and composition during the study, while an open population is subject to animals leaving and entering the population through births, deaths, emigration and immigration. Although all populations are subject to these processes, it is possible to have closure by conducting a study over a short time frame, and this is often desirable since as we will see later the assumptions for running an open population model are much more difficult to satisfy.

The field season sampling unit seems roughly coherent with the closed population model assumptions.

Closed population mark-recapture studies are used to estimate the number of animals in a population; i.e. to provide an estimate of absolute abundance. The simplest case involves two capture sessions. In the first capture session, a group of animals is caught, marked and released. The population is then re-sampled on one subsequent occasion. This method was developed independently by Peterson in the 1890s to estimate the size of fish populations and by Lincoln in the 1920s to estimate wildlife populations. It is therefore called the Peterson-Lincoln estimate (Seber 1982).

The general assumption of the standard closed population mark-recapture models are:

1. There are no births, deaths, immigration or emigration during the study;
2. All animals have the same probability of being caught;
3. Marks are not lost.

The first of these assumptions is often referred to as the assumption of closure in the literature and can be relaxed in some cases (Pollock et al. 1990). The second assumption, often called the "assumption of equal catchability", is unlikely to be true for many wild animal populations. This has led to the development of more appropriate population models that specifically address this issue, and these will be covered below. The third assumption applies to any mark-recapture model.

To estimate the size of the population, with two sampling occasions the following equation is used:

$\check{N}_i = n_1 n_2 / m_2$

Where

$\check{N}_i$ = estimated population size

n_1 = number of animals caught in the first capture session
n_2 = number of animals caught in the second capture session
m_2 = number of animals caught in both sessions (recaptures)

Closed population mark-recapture studies can have multiple capture sessions, and this has advantages over conducting just two sessions. As well as providing more data, allowing more precise estimates, it also allows us to address the second assumption above, that all animals have the same probability of being caught.
The behaviour of animals may change after initial capture, causing them to be captured more frequently ("trap happy") or less frequently ("trap shy"). Individuals may also be inherently different in their probability of capture. If ignored, these effects could cause abundance to be biased.

Otis et al. (1978) showed how these effects can be detected using mark recapture data, and developed theory for estimating abundance with these effects operating. They also showed how changes in capture probability between sessions, which can also bias estimates, can be accounted for. They developed Program CAPTURE, which allows the user to compare alternative models to assess which effects are operating, then estimate population size using the most appropriate model. Program MARK which incorporates most of the CAPTURE models (White & Burnham 1999) allows a similar model selection procedure.

As far as closed population models are concerned, time dependent and heterogeneity models were tested. The encounter histories were analyzed using the CAPTURE application run within program MARK, which has 11 available models that test for three sources of variation in sightings probabilities; that of (i) a time response, which considers that a sighting probability varies from sampling period to sampling period but that all animals within each sampling period have the same probability of being sighted (i.e. model Mt), (ii) a behavioural response, where animals become either 'trap happy' or 'trap shy' after their first capture (Mb) and (iii) individual heterogeneity, where individuals vary in their capture probability (Mh). The 11 models were all based on these principles and/or combinations of the three (for example, Mbh, Mth, Mtb), plus one additional model where probability of capture remains constant (M0). **The time model (Mt) was selected as reference for modelling this population, because variations in capture between sampling periods are strongly evident in the present data set.** In addition, the time heterogeneity model (Mth) was applied to test whether the capture probabilities of individuals also varied over time.
If populations are subject to births, death, immigration and emigration during a study, then open population mark-recapture methods should be used. Analyzing data from mark-recapture studies of open populations is more complicated theoretically, because births, deaths, immigration or emigration may be confounded by the ability to detect these processes. The key to open population theory is estimating survival probability (φ) and capture probability (p). Once capture probability is known, population sizes for each capture occasion (denoted as i) can be estimated by the equation:

$\check{N}_i = n_i/\acute{p}_i$

Where

$\check{N}_i$ = population size for capture occasion i
n_i = number of animals captured on occasion i
$\acute{p}_i$ = capture probability on occasion i

Recruitment between capture sessions is estimated according to the equation:

$\dot{B} = \check{N}_i - \phi_i \check{N}_{i-1}$

where

$\dot{B}$ = recruitment for occasion i

$\check{N}_i$ = population size for capture occasion i

ϕ_i = survival probability on occasion i

The animals in any session can be divided into three categories: (1) live animals that are seen, (2) live animals that are not seen, and (3) dead animals. The model needs estimating the relative proportions in categories 2 and 3. The mathematics for doing this is again beyond the scope of this report, but the underlying concepts are not too difficult to understand. If individuals tend to be captured in most sessions, then disappear, we would naturally think that capture probability was high and that most disappearances were due to mortality (or emigration). Conversely, if individuals tend to be captured intermittently, we would think that capture probability was lower and that many of the individuals missing at any time were alive. The Jolly-Seber model (JS) does this formally (Seber 1982).

Standard open population mark-recapture models require four assumptions to be met:

1. All individuals have the same survival probability
2. All individuals have the same capture probability
3. Marks are not lost or overlooked
4. The duration of each capture occasion is instantaneous in relation to the intervals between sessions

The original open population models required all animals to have the same survival and capture probabilities, but subsequent developments have allowed this to be relaxed to "animals of the *same type* have the same survival and capture probability". So it is now possible to divide animals into different groups (e.g. unmarked vs long-lasting marks, females vs males etc.).

Some estimates based on open population models were produced to add support for the closed population estimates and to provide some estimates for the field seasons (e.g. 2011 and 2012) with a number of captures too low to support estimates based on the field season time unit.
We did not apply any correction on the obtained abundance estimates based on the proportion of poorly marked and well-marked individuals, as described by Williams et al., 1993, since the poorly marked individuals in Risso's dolphins are about the 10-20% of the total (see Table 6), so a minor fraction of the population, and we have used the photographic dataset based on the whole catalogue to produce the abundance estimates.

Table 6. Percentage of the poorly and unmarked individuals in the four different datasets.

Dataset	Percentage Right side poorly ad unmarked individuals	Percentage Left side poorly and unmarked individuals
Istituto Tethys	22%	21%
CIMA Foundation	8%	13%
EcoOcéan Institut	19%	23%
GECEM	13%	10%

3.4.3 Results

Right side catalogue

As explained in the previous paragraph the right side catalogue, including the majority of resightings, was assumed as the main catalogue for producing the abundance estimates. Closed population M(t) models after Darroch and Chao were selected, because variations in capture between sampling periods are strongly evident in the present data set (chi-square: 104.5, df: 11, $P < 0.001$). On the other hand, being the ratio between recaptures and captures not significantly different from 20% in all the considered field season (one-sample t-test vs 0.2, $P > 0.80$) it can be assumed that although sighting probabilities vary from sampling period to sampling period, all animals within each sampling period have the same probability of being sighted and resighted. In these models the primary sampling interval is the year (i.e. the fieldwork season) and the secondary sampling unit is the monthly interval within the fieldwork season. Table 7 summarises the abundance estimates obtained by means of closed population models assuming that a sighting probabilities vary from sampling period to sampling period (i.e. model M(t) according to Darroch and Chao formulations). Abundance estimates are provided for both the datasets including all photographed animals (*all*) and only the well-marked individuals (*wm*). It can be observed that the estimates obtained by the two dataset are extremely similar confirming that the low proportion of poorly marked individuals present in the *all* dataset does not affect the robustness of the estimates or challenge the assumption about the equality of the individual capture probabilities.

Table 7. Abundance estimates (N) obtained by MR models applied on the Right side catalogue. Standard Error (SE) and lower (N-lower) and upper (N-upper) confidence interval limits, capture and recapture numbers are shown. Abundance estimates are provided for both the datasets, including all photographed animals (all) and only the well-marked individuals (wm).

Year	Dataset	Model	Capture occasions	N	SE	N-lower	N-upper	Captures	Recaptures	CR ratio°
1998	all	M(t) Darroch	4	90	8.23	79	112	68	27	0.40
1998	all	M(t) Chao	4	95	11.67	80	128	68	27	0.40
1998	wm	M(t) Darroch	4	84	10.19	71	112	58	20	0.34
1998	wm	M(t) Chao	4	88	13.49	72	127	58	20	0.34
1999	all	M(t) Darroch	4	98	16.1	77	143	58	13	0.22
1999	all	M(t) Chao	4	105	21.95	78	170	58	13	0.22
2000	all	M(t) Darroch	5	240	57.8	161	397	79	11	0.14
2000	all	M(t) Chao	5	223	57.34	147	334	79	11	0.14
2000	wm	M(t) Darroch	5	154	37.3	105	258	59	10	0.17
2000	wm	M(t) Chao	5	141	36.57	95	248	59	10	0.17
2001	all	M(t) Darroch	3	115	51.1	62	289	38	3	0.08
2001	all	M(t) Chao	3	94	36.82	56	219	38	3	0.08
2002	all	M(t) Darroch	4	128	52.8	69	298	37	4	0.11
2002	all	M(t) Chao	4	108	41.3	62	241	37	4	0.11
2003	all	M(t) Darroch	5	73	27.6	43	164	28	4	0.14
2003	all	M(t) Chao	5	63	21.9	40	135	28	4	0.14
2004	all	M(t) Darroch	5	99	14.24	80	137	60	15	0.25
2004	all	M(t) Chao	5	129	31.25	90	220	60	15	0.25
2004	wm	M(t) Darroch	5	97	16.08	76	141	55	12	0.22
2004	wm	M(t) Chao	5	133	37.65	87	246	55	12	0.22
2005	all	M(t) Darroch	7	252	43.16	189	362	101	19	0.19
2005	all	M(t) Chao	7	250	48.63	181	378	101	19	0.19
2005	wm	M(t) Darroch	7	240	46.17	174	360	91	18	0.20
2005	wm	M(t) Chao	7	208	40.03	153	315	91	18	0.20
2006	all	M(t) Darroch	7	174	26.5	136	242	86	21	0.24
2006	all	M(t) Chao	7	203	41.59	146	316	86	21	0.24
2006	wm	M(t) Darroch	7	184	34.03	136	274	79	15	0.19
2006	wm	M(t) Chao	7	201	47.17	139	332	79	15	0.19
2007	all	M(t) Darroch	6	168	73.07	85	401	39	4	0.10
2007	all	M(t) Chao	6	135	54.65	73	310	39	4	0.10
2008	all	M(t) Darroch	4	89	17.94	66	140	47	11	0.23
2008	all	M(t) Chao	4	87	19.22	64	144	47	11	0.23
2008	wm	M(t) Darroch	4	84	21.57	58	149	40	7	0.18
2008	wm	M(t) Chao	4	89	26.73	59	173	40	7	0.18
2009	all	M(t) Darroch	4	57	11.03	44	90	35	9	0.26
2009	all	M(t) Chao	4	57	12.59	43	97	35	9	0.26
2009	wm	M(t) Darroch	4	59	16.71	40	112	29	6	0.21
2009	wm	M(t) Chao	4	51	13.19	37	94	29	6	0.21

° CR ratio: recaptures/captures ratio

Estimates based on open population models were added as support for the estimates based on closed population models and to provide estimates for the field seasons with a sample size too low to support the field season time unit. Three different type of models were used: the standard Jolly-Seber (Model A), the Jolly-Seber Model B, assuming constant survival rate per unit time and time-specific capture probabilities and Jolly-Seber Model D, assuming constant survival rate per unit time and constant capture probability. In this type of models the primary sampling period is a three-years (i.e. fieldwork seasons) interval and the secondary sampling unit is the single year (field season). Table 8 shows the abundance estimates based on open population models.

Table 8. Abundance estimates (N) obtained by Jolly-Seber models. Standard Error (SE) and lower (N-lower) and upper (N-upper) confidence interval limits, capture and recapture numbers are shown. Abundance estimates, where possible, are provided for both the dataset including all photographed animals (all) and only the well-marked individuals (wm).

Model-Period		Capture occasions	N	SE	N-lower	N-upper	Captures	Recaptures
Model A - Jolly-Seber capture-recapture model with both death and immigration								
1997-99	**all**	**3**	**119.75**	**22.66**	**75.35**	**164.16**	**121**	**45**
Model D - Constant survival rate per unit time, constant capture probability.								
1997-99	**all**	**3**	**123.96**	**30.31**	**64.55**	**183.37**	**121**	**45**
1997-98	all	3	131.69	22.27	88.04	175.35	121	45
1998-99	all	3	116.22	22.86	71.41	161.03	121	45
Model B - Constant survival rate per unit time, time-specific capture probabilities.								
1997-99	**all**	**3**	**140.5**	**42.51**	**57.18**	**223.83**	**121**	**45**
1997-98	all	3	124.29	22.42	80.35	168.24	121	45
1998-99	all	3	156.72	40.23	77.86	235.57	121	45
Model D - Constant survival rate per unit time, constant capture probability.								
2001-03	**all**	**3**	**70.93**	**23.86**	**24.17**	**117.69**	**80**	**24**
2001-02	all	3	81.25	19.56	42.91	119.6	80	24
2002-03	all	3	60.61	16.22	28.82	92.4	80	24
2001-03	**wm**	**3**	**59.56**	**25.17**	**10.22**	**108.89**	**66**	**16**
2001-02	wm	3	59.24	18.1	23.77	94.71	66	16
2002-03	wm	3	59.88	19.49	21.69	98.07	66	16
Model A -- Jolly-Seber capture-recapture model with both death and immigration								
2011-2013	**all**	**3**	**77.45**	**11.33**	**55.23**	**99.66**	**72**	**14**
Model D - Constant survival rate per unit time, constant capture probability.								
2011-13	**all**	**3**	**55.62**	**9.54**	**36.91**	**74.32**	**72**	**14**
2011-12	all	3	78.95	9.06	61.19	96.72	72	14
2012-13	all	3	32.28	5.44	21.63	42.94	72	14

Model B - Constant survival rate per unit time, time-specific capture probabilities.								
2011-13	**all**	**3**	**67.18**	**16.27**	**35.29**	**99.07**	**72**	**14**
2011-12	all	3	79.25	10.65	58.37	100.14	72	14
2012-13	all	3	55.11	13.48	28.69	81.52	72	14

As shown in Table 8, the abundance estimates based on open population models confirm the estimates based on closed population (see Fig. 21) and allow to provide estimates also for time interval where captures and recaptures numbers were too low to apply closed population models (i.e. 2012-2013).

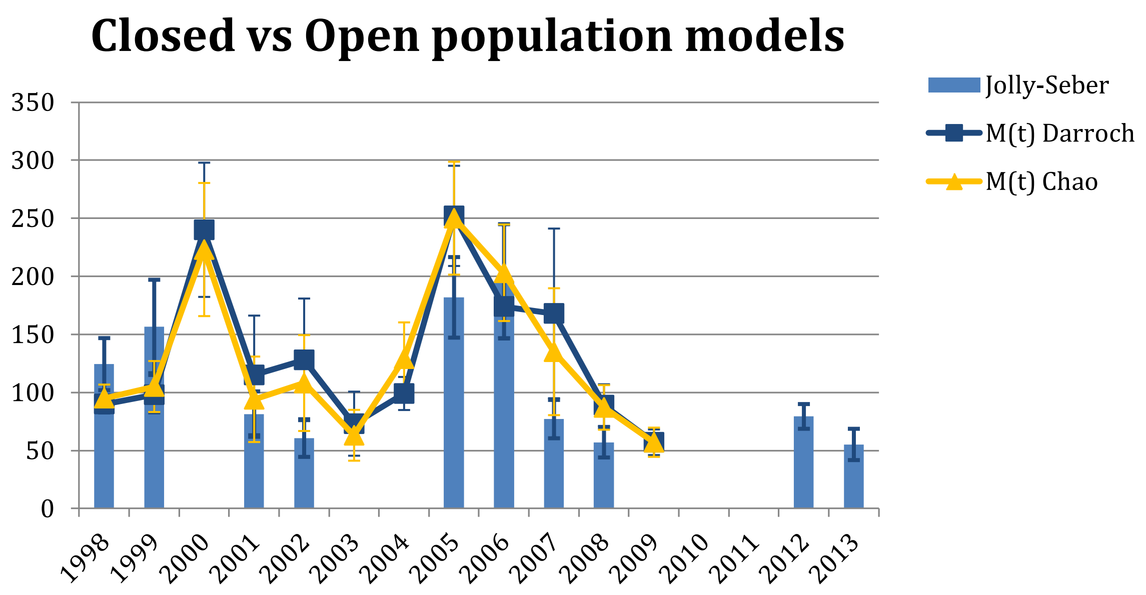


Fig. 21. Comparison between abundance estimates based on closed population (M(t) after Darroch and Chao) and open population models (Jolly-Seber). The error bars are the standard error (SE) of the estimates.

Left side catalogue

Although the right side was assumed as the reference catalogue for producing the abundance estimates, some estimates were provided also based on the Left side catalogue for the years where the number of captures and recaptures were high enough. Also in this case, closed population M(t) models after Darroch and Chao were used assuming as sampling period the year (i.e. the fieldwork season) and the monthly interval as sampling unit. Table 8 summarises the abundance estimates obtained by means of closed population models assuming that a sighting probabilities vary from sampling period to sampling period (i.e. model M(t) according to Darroch and Chao formulations). Abundance estimates are provided only for the dataset including all photographed animals (*all*). It can be observed that the estimates obtained by the Right and Left side dataset are similar, although the Left side estimates tend to be lower due to the lower number of captures (see Fig. 22).

Table 9. Abundance estimates (N) obtained by MR models applied on the Left side catalogue. Standard Error (SE) and lower (N-lower) and upper (N-upper) confidence interval limits, capture and recapture numbers and CR ratio are shown.

Year	Model	Capture occasions	N	SE	N-lower	N-upper	Captures	Recaptures	CR ratio°
1999	M(t)	5	84	12.81	68	120	54	10	0.19
1999	M(t) Chao	5	147	53.6	87	319	54	10	0.19
2000	M(t)	6	166	25.16	129	231	83	21	0.25
2000	M(t) Chao	6	160	27.85	122	236	83	21	0.25
2001	M(t)	3	87	18.16	64	140	47	9	0.19
2001	M(t) Chao	3	88	20.25	64	149	47	9	0.19
2005	M(t)	5	154	23.86	120	216	79	19	0.24
2005	M(t) Chao	5	159	29.8	119	241	79	19	0.24
2008	M(t)	4	82	14.84	63	123	46	12	0.26
2008	M(t) Chao	4	85	18.69	62	140	46	12	0.26
2009	M(t)	4	68	14.04	51	110	39	10	0.26
2009	M(t) Chao	4	62	12.18	48	99	39	10	0.26

° CR ratio: recaptures/captures ratio

As shown in Table 8, the abundance estimates based on open population models confirm the estimates based on closed population (see Fig. 21) and allow to provide estimates also for time interval where captures and recaptures numbers were too low to apply closed population models (i.e. 2012-2013).

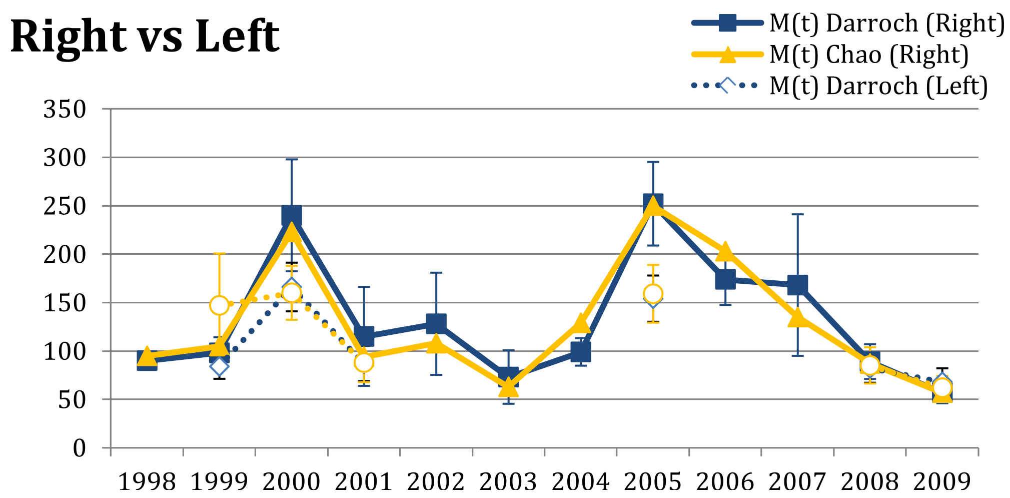
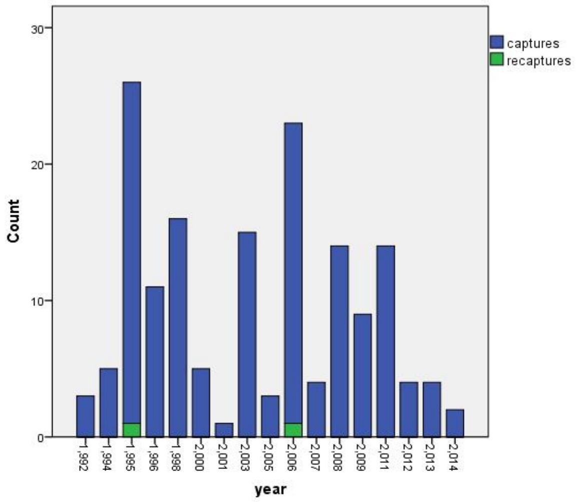


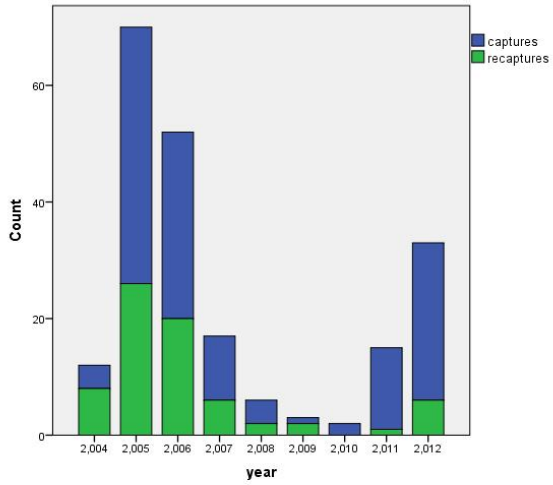
Fig. 22. Comparison between Right and Left abundance estimates based on closed population models (M(t) after Darroch and Chao). The error bars are the standard error (SE) of the estimates.

Abundance estimates per subareas

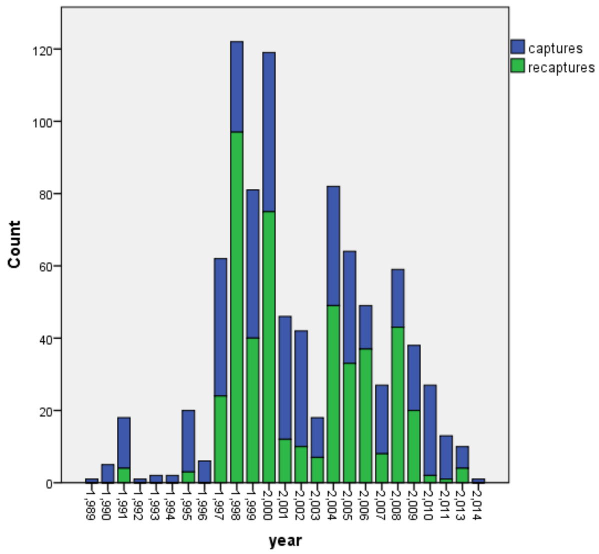
To complete the investigation, abundance estimates were also produced based on the single data provider dataset (i.e. EOI-GECEM, TRI and CIMA). No estimate was obtained for the EOI-GECEM area due to the low number of recapture of this dataset. On the other hand, the abundance peak years (i.e. 2005 and 2006) were used in both the TRI and CIMA dataset to provide area-specific abundance estimates. In both cases the abundance estimates remained of the same order of magnitude (i.e. 100-130 individuals, ranging from 80-250) confirming how strongly these two areas are connected. Further surveys are certainly needed to complete the coverage of the western portion of the study area.



EOI-GECEM



CIMA



TRI

Fig. 23. Right fins - Number of captures and recaptures per field season (year) disaggregated per dataset.

3.4.4 Conclusions

- The applied closed population models (M(t) after Darroch and Chao) allowed to obtain abundance estimates concerning 12 years (fieldwork season) providing similar results.

- **The abundance ranged in average around 130 individuals with a 95% CI of 90 – 230 individuals.**

- The estimates show the existence of a temporal pattern in Risso’s dolphin abundances, particularly there were peaks in 2000 and 2005, followed by a subsequent decreasing trend.

- **The lowest and highest limits of the obtained abundance estimates span respectively around 40 and 400 individuals.**

- Open population models confirmed the results of closed population models and allowed to provide an estimates also for the last years of the time series, where the number of captures and recaptures were too low to sustain closed population models based on the single field season. It can be observed that **there is a decreasing trend in the Risso’s dolphin encounters in the study area and the 2012-13 estimates suggest that the number of Risso’s dolphins occurring in the areas has recently turned into half of the average values referring to the whole time series (60-70 individuals).**

- The abundance estimates provided per subareas revealed various heterogeneity due to the low sample size of the capture-recapture dataset, especially concerning the western portion of the study area, confirming the need to improve the effort in this sector.

4. Summary

An integrated photographic archive has been created by combining the datasets provided by the four Institutes (Istituto Tethys, Fondazione CIMA, EcoOcean - EOI, GECEM) taking part in this project. The used datasets are the most consistent in size and study period among those available in the area of the Sanctuary. Their union ensured a coverage of approximately 50% of the Sanctuary, encompassing coastal, slope and deep pelagic waters. Data were collected from 1989 through to 2014 during dedicated and opportunistic boat-based surveys, conducted from different platforms, mostly during the summer season. A total of 268 sightings was recorded and 215 are the sightings during which Risso's dolphins were identified. A protocol with specific guidelines was prepared on how to manage the photo-id images collected by the different Partners, in order to standardize their catalogues before proceeding with the matching. Images, tracks and sighting data of the Partners have been uploaded on INTERCET platform, the operational tool of the European project GIONHA (Governance and Integrated Observation of marine Natural Habitat), allowing Partners to aggregate, visualise and analyse data. The comparison of all catalogues yielded many matches, resulting in a total of 405 different individuals identified based on the right side of the dorsal fin, and 402 individuals based on the left side. Only 261 individuals were identified by both sides. About the 50% of the individuals were recaptured, although the majority (> 80%) of the recaptures referred to different years. The number of captures varied greatly among the years. Because of the observed capture variability and considering the wide time frame encompassed by the integrated dataset, it did not appear meaningful to apply mark-recapture methods on the whole data set and data were pooled based on the homogeneity of the photographic effort. Estimates of abundance were calculated using the FORTRAN program MARK (Mark and Recapture Parameter Estimation) v.8.0 developed by the Department of Fishery and Wildlife, Colorado State University, assuming both closed and open population models.

The field season and the monthly unit were chosen as the most appropriate primary and secondary sampling intervals, in order to assume a time frame sufficiently short to assume the population closed. In addition, some abundance estimates based on open population models were also produced to confirm the estimates assuming the closed population and to provide abundance estimates for the field seasons (e.g. 2011 and 2012) with a number of captures too low to support estimates based on the field season time unit.

Risso’s dolphin abundance ranged in average around 130 individuals with a 95% CI of 90 – 230 individuals. Mark-recapture estimates highlighted also a temporal pattern in Risso’s dolphin abundances, particularly there were abundance peaks in 2000 and 2005 (peaking 240-250 individuals with a 95%CI of about 190 – 370), followed by a subsequent decreasing trend. The lowest and highest limits of the obtained abundance estimates span respectively around 40 and 400 individuals. Open population models confirmed the results of closed population models and allowed to provide an estimate also for the last years of the time series, where the number of captures and recaptures are too low to sustain closed population models based on the single field season. The 2012-13 estimates suggest that the number of Risso's dolphin individuals occurring in the areas has recently turned into half of the average values referring to the whole time series (60-70 individuals).

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