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Striped dolphins and short-beaked common dolphins in the Gulf of Corinth, Greece: Abundance estimates from dorsal fin photographs

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ABSTRACT

Capture-recapture methods relying on dorsal fin natural markings have never been applied successfully to striped dolphins, *Stenella coeruleoalba,* and were rarely used to assess abundance of short-beaked common dolphins, *Delphinus delphis*. We used digital photo-identification to obtain abundance estimates of striped and common dolphins living in mixed groups in the Gulf of Corinth, Greece. The proportion of either species was calculated based on the relative number of photographs of adult animals showing relevant portions of their body during conspicuous surfacings. Striped dolphins and common dolphins averaged 95.0% and 3.2% of all individuals, respectively. Animals showing intermediate pigmentation accounted for another 1.8%. Striped dolphin numbers were relatively high, with a point estimate of 835 animals (95% CI = 631–1,106). Common dolphins numbers were low (point estimate 28 animals; 95% CI = 11–73) and individuals were scattered within striped dolphin groups, indicating that this common dolphin population may be nonviable. Within a semiclosed Gulf exposed to considerable anthropogenic impact, the future of both dolphin species is of concern due to their suspected geographic isolation and restricted extent of occurrence. Information provided here can be used to inform timely conservation efforts.

Key words: striped dolphin, *Stenella coeruleoalba*, short-beaked common dolphin, *Delphinus delphis*, abundance, photo-identification, mixed groups, Mediterranean Sea, Gulf of Corinth, Greece.

The striped dolphin *Stenella coeruleoalba*—one of the most abundant cetacean species worldwide—is a small delphinid living in temperate to tropical waters around the world (Perrin *et al.* 1994*,* Archer 2002). Striped dolphins are the most common cetacean species inhabiting the Mediterranean Sea (Notarbartolo di Sciara *et al.* 1993; Aguilar 2000, 2006; Gannier 2005), but their total abundance in the whole Mediterranean basin is unknown. Striped dolphin abundance in parts of the western Mediterranean Sea was estimated at 117,880 individuals (95% CI = 68,379–214,800; Forcada *et al.* 1994). Surveys of striped dolphin abundance in the Ligurian-Provençal Basin (NW Mediterranean) yielded an estimate of 25,614 individuals (95% CI = 15,377–42,658; Forcada *et al.* 1995). Similar figures of striped dolphin abundance in the area of the Pelagos Sanctuary (Fig. 1) were obtained by Gannier (1998, 2006). In the Mediterranean coastal waters of Spain striped dolphin numbers averaged 15,778 (95% CI = 10,940–22,756; Gòmez de Segura *et al.* 2006). Another study in the southern Tyrrhenian Sea yielded 4,030 (95% CI = 2,239–7,253; Fortuna *et al.* 2007). No rigorous estimates of abundance exist in the eastern Mediterranean Sea (Fig. 1). Sighting reports indicate striped dolphins are the most abundant cetacean species in the Ionian Sea and in the waters of Greece (Notarbartolo di Sciara *et al.* 1993, Frantzis *et al.* 2003, Gannier 2005).

Striped dolphins in the Mediterranean Sea are generally boat-friendly, they often bow-ride (Würsig 2002) and their daily surface behavior and surfacing pattern makes them relatively easy to photograph. In the region, photographs have been used to investigate color patterns and pigmentation variability (Rosso *et al.* 2008) and to discriminate among small numbers of individuals in the context of opportunistic observations (*e.g.*, Francese *et al.* 2007). No systematic study, however, has been published on the abundance, movements, social organization, or other aspects of striped dolphin ecology and behavior based on individual photo-identification (Hammond *et al.* 1990), a research method successfully applied to a number of small Delphinidae since the 1970s (Würsig and Würsig 1977). Photo-id of individual striped dolphins may be hampered by reasons including: (1) large population sizes, making it difficult to catalogue and match large numbers of individuals; (2) poor dorsal fin markings; and (3) low chances of photographic recapture, due to the aforementioned reasons. The wide distribution of striped dolphins and their preference for offshore waters may also have played a role in some areas.

The short-beaked common dolphin *Delphinus delphis* (hereafter "common dolphin") is a small delphinid with a wide distribution characterized by a series of geographically separate populations (Perrin 2002). Common dolphins were once one of the most common cetacean species in the Mediterranean Sea, but during the last few decades they have declined throughout the region and have recently been classified as Endangered in the IUCN Red List (Bearzi *et al.* 2003). Today, common dolphins remain relatively abundant in the westernmost portion of the basin, the Alboràn Sea, but in the rest of the region they have become rare, with only a few hotspots of occurrence (Bearzi *et al.* 2003). There is no basin-wide estimate of abundance for common dolphins in the Mediterranean Sea. Line-transect ship surveys of the Alboràn Sea in 1991–1992 produced an estimate of 14,736 (95% CI = 6,923–31,366; Forcada and Hammond 1998), but attempts to produce reliable estimates elsewhere in the region were hampered by low sighting numbers. Photo-id has been used to study common dolphins in only a few areas around the world, where researchers have relied on long-term natural markings on the animals' dorsal fins (Neumann *et al.* 2002, Bearzi *et al.* 2005). Extensive photo-id conducted since 1994 in a coastal area of Greece—the Inner Ionian Sea Archipelago—showed that common dolphin numbers decreased from approximately 150 to 15 in only 10 yr (Bearzi *et al.* 2008*b*).

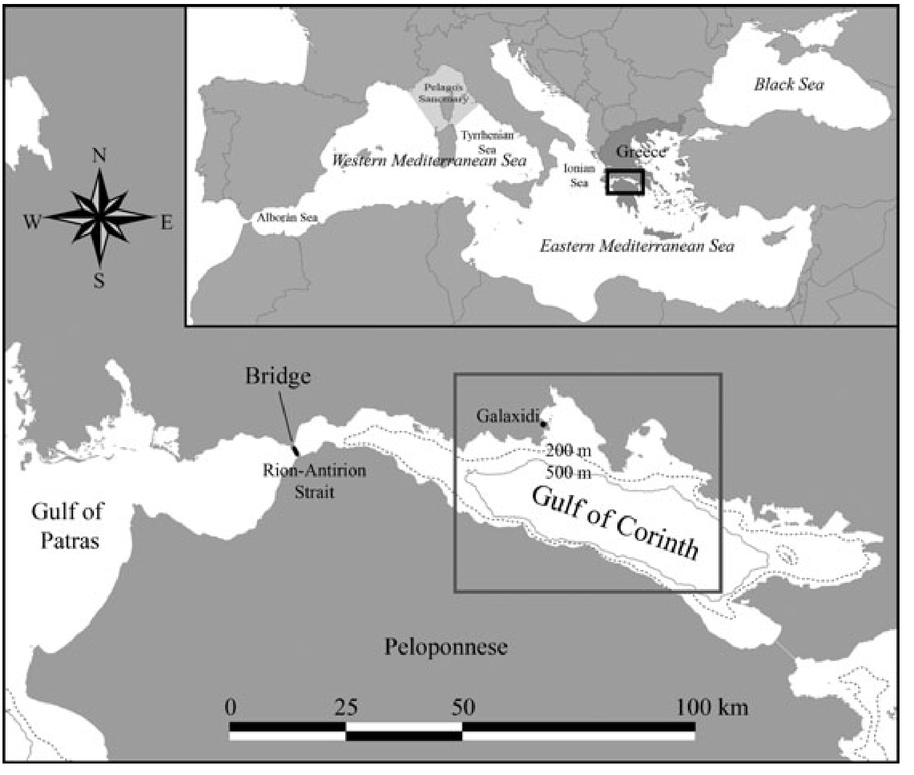

Figure 1. The study area (delimited by a gray line) situated in the central part of the Gulf of Corinth, Greece, including 200 and 500 m isobaths and some of the location cited in the text.

We applied photographic capture-recapture methods to estimate abundance of striped dolphins and common dolphins in the Gulf of Corinth, Greece. While work in this area was complicated by the presence of both species in mixed groups, the results of the study suggest that photo-id can be applied successfully to at least some populations of striped dolphins, therefore encouraging the testing of this method in other areas. Capture-recapture analyses based on photo-id data yielded estimates of relative and total abundance of both striped and common dolphins, useful for management and conservation planning.

Methods

Study Area

The Gulf of Corinth (surface area of approximately 2,400 km^2) is a deep, semiclosed basin separating the Peloponnese from mainland Greece (Fig. 1). The 1.9-km-wide Rion-Antirion strait, which separates the Gulf of Corinth from the outer Gulf of Patras, is crossed by a four-pylon bridge, the construction of which started in 2000 and was completed in 2004. The waters of the Gulf of Corinth are oligotrophic and transparent. Secchi disk readings of 10–33 m were recorded during the course of this study (mean = 22, SD = 6.1, $n = 45$). The Gulf does not have significant river runoffs, but it is exposed to anthropogenic pressures including discharge of toxic contaminants from coastal industries and of sewage from coastal cities. Intensive fishing, particularly by bottom trawlers, may represent another threat. While the western part of the Gulf is relatively shallow (the maximum depth under the Rion-Antirion bridge is about 70 m), its central portion has waters 500–900 m deep, offering a suitable albeit restricted habitat for a deep-water species such as the striped dolphin. This study focuses on dolphins inhabiting the central part of the Gulf, within a study area of approximately 1,400 km^2 (Fig. 1).

Survey and Photo-id Effort

Surveys were conducted from a 5.8 m inflatable craft with rigid hull powered by a 100 HP four-stroke outboard engine, from May to September 2009, totaling 6,318 km of navigation on 86 survey days. Navigation to search for dolphins was carried out under the following conditions: (1) daylight and long-distance visibility, (2) Douglas sea state $\leq$2, (3) at least two experienced observers scanning the sea surface, (4) eye elevation of approximately 1.6–1.8 m for both observers, and (5) survey speeds between 26 and 30 km/h. Binoculars were not used during navigation. All surveys started and ended at the port of Galaxidi (Fig. 1). A survey was interrupted if dolphins were sighted, sea or weather conditions deteriorated, or other factors forced the crew to return to the port (*e.g.*, late hour, low levels of fuel). Survey routes varied depending primarily on sea conditions, but attempts were made to attain an even coverage of the study area (Fig. 2). On each encounter with a group of dolphins, a large number of high-quality photographs were taken of all individuals present, irrespective of fin markings. Photo-id was performed following Würsig and Jefferson (1990), using 15 megapixel digital cameras equipped with 70–200 mm f2.8 AF zoom lenses. Visual analyses were eased by using a high-resolution 27 in. monitor, which allowed investigation of dorsal fin features at appropriately large scales (*i.e.*, exceeding actual dorsal fin size). Color photographs suitable for individual identification were obtained on 24 d. Of a total of 6,216 digital photos taken, 4,022 were selected based on recommendations provided by Read *et al*. (2003). These photos were cropped around the dorsal fin and any visible part of the body, and further selected using consistent criteria (*i.e.*, high sharpness and resolution, entire dorsal fin visible, fin perpendicular to camera, no water spray masking fin profile), independent of fin markings, resulting in 1,495 high-quality, high-resolution photographs portraying single dorsal fins. Images were then matched based on dorsal fin markings. Strict selection criteria and exclusive use of large-size, high-quality images in the analyses helped in meeting the "mark recognition assumption" in capture-recapture analyses (Wilson *et al.* 1999). Dorsal fin photos were subdivided into categories according to kind and relative size of natural markings. Only markings that could allow recognition from both sides of the fin were used. Physical anomalies of the dorsal portion visible from both sides during a regular surfacing, such as humps or abnormal fins, were also considered. Animals with no natural markings on the trailing edge of their dorsal fin were considered "unidentified," a category that also included calves.

Considering that mark changes occurring over time are a well-known complication during matching procedures, and they may result in identification errors (Carlson *et al.* 1990, Wilson *et al.* 1999, Gowans and Whitehead 2001), the relatively short

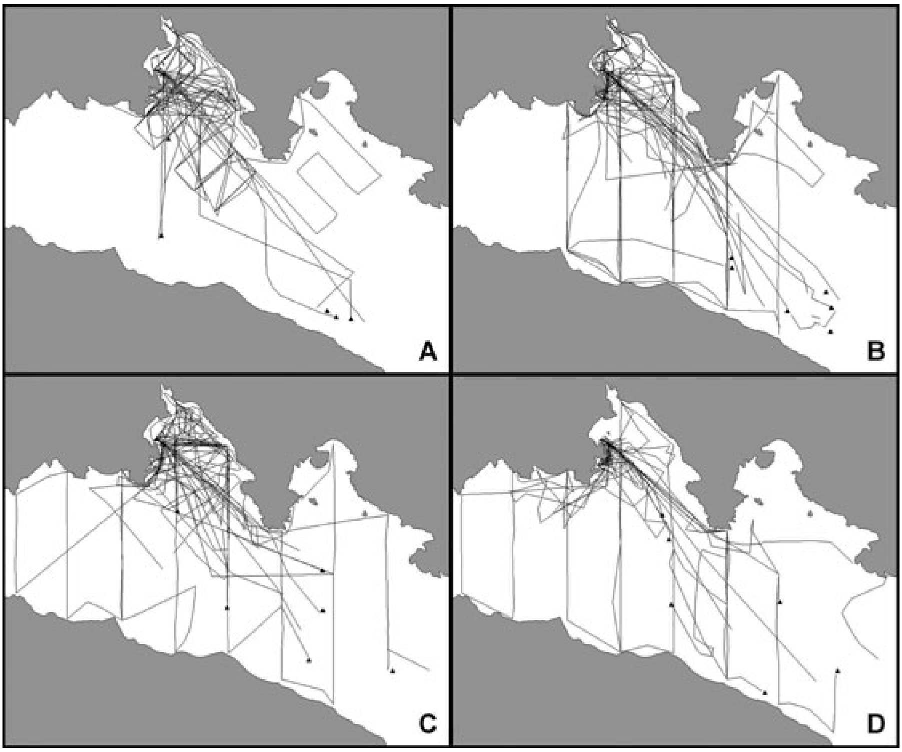

Figure 2. Survey effort (tracklines) in the four 30 d sampling intervals used for capture-recapture analyses: (A) 25 May–24 June, (B) 25 June–25 July, (C) 26 July–25 August, (D) 26 August–25 September. Triangles indicate encounters ($n = 24$) with striped dolphins and common dolphins.

duration of this study (<5 mo) contributed to increasing the reliability of dorsal fin identifications by reducing the likelihood of the addition of new markings. All phases of the matching process were rechecked several times by an experienced matcher assisted by a supervisor. Once the work was completed, two other experienced matchers took a subset of 500 photos through the catalog again to assess the magnitude of any matching bias. An estimated bias of 0.02 was found. Errors were then corrected and further matching bias was considered absent or insignificant.

Mixed Groups

In the Gulf of Corinth, striped dolphins and common dolphins were often found in mixed groups (Frantzis and Herzing 2002, Frantzis *et al.* 2003; Fig. 3). Mixed groups complicated the photo-id analyses presented here, because the similar size and morphology of the two species prevented reliable species identification based on dorsal fin photos that did not include flank patterns. Presence of a "white patch" on the dorsal fin was not considered a reliable species identification feature, since not all common dolphins display this sort of natural marking (Neumann *et al.* 2002, Bearzi *et al.* 2003, Stockin and Visser 2005). Some striped dolphins also can display a "white patch"

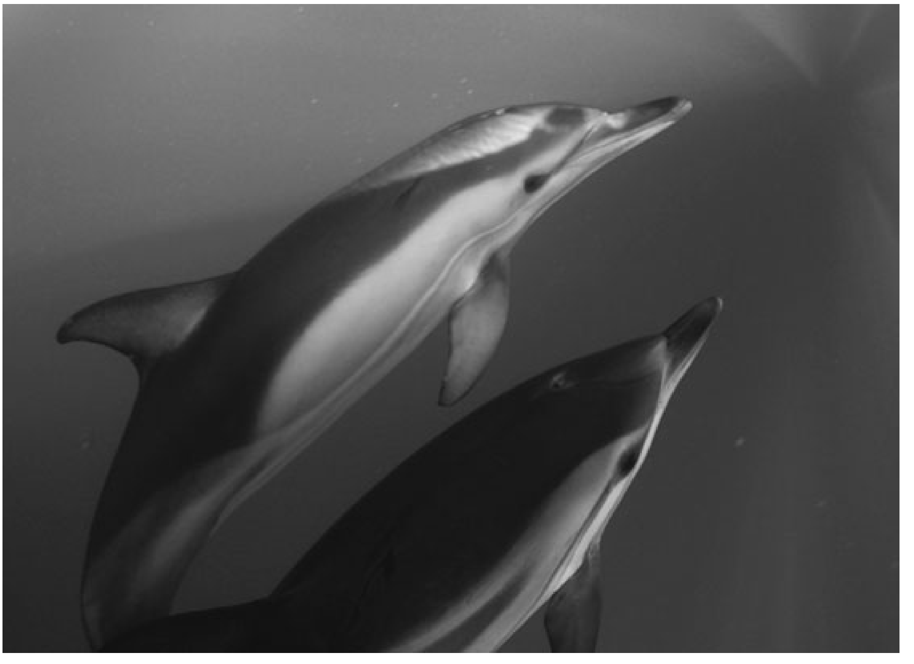

Figure 3. A striped dolphin and a short-beaked common dolphin swim near the research boat in the Gulf of Corinth (photo: Silvia Bonizzoni/Tethys Research Institute).

(Rosso *et al.* 2008), adding to the challenge of species identification. In addition, some individuals had intermediate pigmentation suggestive of hybridization, as noted by Frantzis and Herzing (2002). A considerable variation in the pigmentation of Mediterranean striped dolphins (Rosso *et al.* 2008), which occasionally includes a faded crisscross pattern (Podestà 1986), further contributed to the uncertainty. Because it was impossible to discriminate between the two species based on dorsal fin photographs, striped and common dolphins were considered together in capture-recapture analyses. This choice may have introduced some degree of bias in our abundance estimates, as discussed later.

The proportion of striped and common dolphins was estimated based on a subset of photographs of adult animals showing relevant portions of their body during aerial behavior, or performing other conspicuous surfacings. Photographs of individuals bow-riding or swimming under the research boat were excluded to avoid over-representation of either species resulting from a different species-specific attitude towards bow-riding (Würsig 2002). Multiframe sequences of single surfacing events were also discarded, using only one photo per sequence. The abundance of each species was then estimated by correcting the final abundance estimate for the proportion of photographs of each species.

In order to take into account the proportion of each species, and the proportion of individuals within species that are distinctive, the coefficient of variation for the abundance estimation for each species was calculated based on the following formula:

$$\mathbf{CV} = \sqrt{\mathbf{Proportion}}\,\mathbf{species}\,\mathbf{CV}^2 + \mathbf{Distinctiveness}\,\mathbf{CV}^2 + N\,\mathbf{CV}^2$$

where Proportion species CV is the coefficient of variation of the proportion of the different species; Distinctiveness CV is the coefficient of variation of the proportion of individuals within species that are distinctive (marked *vs.* unmarked), and *N* CV is the coefficient of variation of total population estimation. Because we used the multiple days of observation to estimate species composition or mark rate and SE factors in the effort in terms of numbers of days, SE (rather than SD) was used to obtain the final CV value.

Capture-Recapture Analyses

For the analysis the data were pooled in four 30 d intervals (if an individual was photographed at least once during each 30 d interval it was considered captured for that period). The choice of the most suitable model for capture-recapture analysis is often challenging, due to the large number of models and estimators available (Burnham *et al.* 1995). Program CloseTest (Stanley and Richards 2005) was used to investigate population closure. Two closure tests were run: (1) the Stanley and Burnham (1999) Test, developed under a null model allowing for time-specific variation in capture probabilities under closure, and (2) the Otis *et al.* (1978) Test, developed under a null model allowing for heterogeneity in capture probabilities under closure (Stanley and Richards 2005). The hypothesis of closure was rejected by both tests (Stanley and Burnham Closure Test $\chi^2 = 63.72763$, df = 29, $P = 0.00021$; Otis Closure Test z-value $= -3.10227$, $P = 0.00096$), indicating that closed models were inappropriate to estimate dolphin abundance in this study.

Capture-recapture estimates were based on Schwarz and Arnason's parameterization of the Jolly-Seber open population model (Schwarz and Arnason 1996, 2006), which includes the parameter *N*, denoting the size of a superpopulation. *N* can be considered as either the total number of animals available for capture at any time during the study or, alternatively, as the total number of animals ever in the sampled area between the first and last occasion of the study (Nichols 2005, Reisinger and Karczmarski 2009). This model provides abundance estimates while allowing entries (birth, immigration) and losses (death, permanent emigration) in the population under investigation. Open models make several assumptions: (1) marks are not lost or missed, (2) individuals are immediately released after being sampled and samples are instantaneous, (3) all marked individuals present on a given sampling occasion have the same probability of capture, (4) all marked individuals in the population that are alive on a given sampling occasion have the same probability of surviving to the next sampling occasion, and (5) there are no trap responses. In the present study, the assumptions under which mark-recapture models operate were addressed as follows: for assumption (1), we used only high-quality photographs to identify individuals; we used only individuals bearing marks suitable for reliable identification of either side of the fin across the duration of the study for capture-recapture analyses; only one experienced person was responsible for cataloguing photographs ensuring consistency in the recognition of individuals and grading of photographs; for assumption (2), we used sampling occasions that were short in comparison with the lifespan of the animals (Parra *et al.* 2006); for assumptions (3 and 4) the pooled χ^2 statistics (Test 2 + Test 3) indicated that the assumptions of homogeneous capture and survival probabilities were not violated ($\chi^2 = 2.4639$, df = 4, $P = 0.65111$), and the average capture probability in this study was 0.63, *i.e.*, greater than 0.5, indicating that heterogeneous capture probabilities were relatively unimportant (Pollock *et al.*

1990); for assumption (5), use of individual photo-id means that the animals are not subject to stress induced by capture, handling, or physical marking (Parra *et al.* 2006), and a Pradel's Test for trap-dependence (Pradel 1993) showed no indication of "trap-happy" or "trap-shy" behavior by marked individuals ($Z = -1.3192$, $P = 0.1871$). The pooled χ^2 statistics (Test 2 + Test 3) for homogeneity in capture and survival probabilities, and the Pradel's Test were carried out using Program U-Care (Choquet *et al.* 2009). Abundance estimates were obtained through Program MARK 5.1 (White and Burnham 1999).

Overdispersion is common in cetacean capture-recapture data because the fate (seen *vs.* not seen) of each individual within the school is not independent on the fate of the others (Anderson *et al*. 1994, Silva *et al.* 2009). Data were examined for overdispersion by calculating the variance inflation factor ($\hat{c}$), obtained by dividing the chi-square statistics of GOF tests by the number of degrees of freedom (Lebreton *et al*. 1992, Silva *et al*. 2009). The variance inflation factor of the best fitting model was 1.74 (*i.e.*, <3 and therefore not substantially different from 1, the model with perfect fit; Lebreton *et al*. 1992).

Four conditional forms of the Jolly-Seber model were fitted to the data, and the appropriate model for inference was selected using the Akaike Information Criterion corrected for small-sample sizes (AICc; Burnham and Anderson, 1998).

As capture-recapture estimates relied on natural markings to identify individuals, they refer exclusively to the population of marked animals. To include the unmarked portion and estimate total abundance, the proportion of unmarked individuals (which also included calves) was calculated based on the number of photographs of marked and unmarked dorsal fins obtained daily (Williams *et al.* 1993, Bearzi *et al.* 2008*a*, *b*). The variance of the abundance estimates was calculated following Wilson *et al.* (1999) as:

$$\mathrm{Var}(N_{\mathrm{tot}}) = N_{\mathrm{tot}}^2 \left(\frac{\mathrm{var}\ N}{N^2} + \frac{1-\theta}{n\theta} \right)$$

where n = number of animals captured, N = estimate of number of marked animals, θ = proportion of identifiable animals, N_{tot} = estimate of total population size after correcting for proportion of identifiable individuals, var N = variance of marked animals.

Results

Individual Photo-id

A total of 221 marked individuals were photographically identified. The number and proportion of dorsal fins ascribed to either category, as well as the number and proportion of photos are shown in Table 1. Figure 4 shows the rate of discovery of dolphins photo-identified in the Gulf of Corinth.

The dorsal fins of three individuals in the photo-id catalogue that could be clearly identified as common dolphins (species identification based on body pigmentation) belonged to the categories D4 and D6 (Table 1), while all other photos of common dolphins were of unmarked animals.

Table 1. Kinds and proportion of dorsal fins for striped dolphins and common dolphins photographed in the Gulf of Corinth.

	D1 Dorsal deformities	D2 One or more large notches	D3 Multiple nicks	D4 One nick	D5 Multiple small nicks or irregular trailing edge	D6 One small nick	U Unmarked	Total
n photos	29	195	239	110	167	76	679	1,495
% photos	1.9	13.0	16.0	7.4	11.2	5.1	45.4	100.0
n identified	4	39	73	27	53	25		221
% identified	1.81	17.65	33.03	12.22	23.98	11.31		100.0

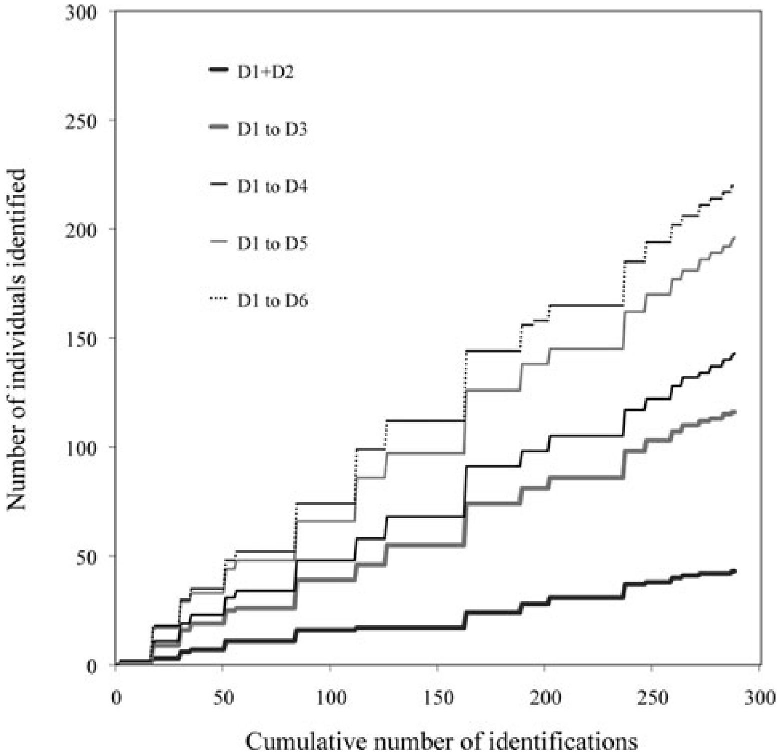

Figure 4. Rate of discovery curve by dorsal fin kind (Table 1) for striped dolphins, common dolphins and intermediate individuals photo-identified in the Gulf of Corinth.

Capture-Recapture and Proportion of Unmarked Animals

Table 2 shows the 30 d sampling intervals chosen for this study and other information relevant for capture-recapture analyses. The model that best fitted the data was model p(.)phi(t)pent(t) in which capture probabilities are constant and survival probabilities vary over time (Table 3). Because models p(t)phi(t)pent(t) and p(t)phi(.)pent(t) also provided a good description of the data (Table 3), model-averaged estimates were used, following Anderson (2008). Capture-recapture analyses resulted in point estimates of 457 marked animals (95% CI = 358–584). Based on 1,495 high-quality dorsal fin photos, the mean proportion of unmarked dolphins was 0.48 (95% CI = 0.37–0.58). By applying this mean proportion of unmarked individuals to the capture-recapture estimate, we obtained total abundance estimates of 879 animals (95% CI = 734–1,052; Table 4).

Proportion of Striped Dolphins and Common Dolphins in Mixed Groups

Common dolphins were found exclusively in mixed groups with striped dolphins and never in single species groups. Some of the groups were composed exclusively of striped dolphins, although in most cases the possibility that one or more common dolphins were present (even if not seen or photographed) could not be ruled out.

Table 2. Sampling intervals and other information relevant for capture-recapture analyses.

30 d sampling interval	No. of survey days	Days with dolphin encounters	No. of dolphin groups encountered	Km of navigation on effort	Total duration of encounters (min)	No. of individuals identified photographically (total per sampling interval)	No. of individuals identified photographically (cumulative)
25 May–24 June	18	May: 26 June: 10, 16, 17, 24	5	1,226	381	35	35
25 June–25 July	22	July: 1, 9, 16, 17, 22, 24	6	1,533	621	123	109
26 July–25 August	21	July: 31 August: 3, 12, 14, 19, 25	6	1,375	624	87	58
26 August–25 September	20	August: 27, 28, 31 September: 15, 17, 23	6	1,003	446	28	19
Total	81		23	5,137	2,072	273	221

Table 3. Parameter estimation and selection of appropriate open-population model using the Akaike Information Criterion (AICc) corrected for small sample sizes. p = capture probability, phi = survival probability, pent = probability of entry, SE = standard error, ΔAICc = difference between AICc and minimum AICc obtained, AICc weight = relative weight or strength of the model used for model averaging if models are very similar in weight, *n*p = number of parameters in the model, na = not available; (t) and (.) represent time-dependent and constant parameters, respectively.

Model	Sampling interval	p	SE	phi	SE	pent	SE	AICc	ΔAICc	AICc weight	*n*p
p(.)phi(t)pent(t)	25 May–24 June	0.54	0.132	na	na	na	na	297.977	0.00	0.579	8
	25 June–25 July	0.54	0.132	0.75	0.180	0.52	0.050				
	26 July–25 August	0.54	0.132	0.40	0.097	0.21	0.053				
	26 August–25 September	0.54	0.132	0.15	0.053	0.08	0.024				
p(t)phi(t)pent(t)	25 May–24 June	0.999998	0.005	na	na	na	na	299.989	2.01	0.212	9
	25 June–25 July	0.54	0.166	0.75	0.204	0.63	0.130				
	26 July–25 August	0.56	0.201	0.39	0.140	0.21	0.121				
	26 August–25 September	0.999945	0.030	0.08	0.029	0.05	0.019				
p(t)phi(.)pent(t)	25 May–24 June	0.999854	0.105	na	na	na	na	300.029	2.05	0.208	8
	25 June–25 July	0.61	0.150	0.63	0.143	0.40	0.096				
	26 July–25 August	0.35	0.108	0.63	0.143	0.27	0.097				
	26 August–25 September	0.10	0.052	0.63	0.143	0.25	0.130				
p(.)phi(.)pent(t)	25 May–24 June	0.55	0.132	na	na	na	na	315.140	17.16	0.00001	6
	25 June–25 July	0.55	0.132	0.35	0.071	0.55	0.052				
	26 July–25 August	0.55	0.132	0.35	0.071	0.22	0.047				
	26 August–25 September	0.55	0.132	0.35	0.071	0.05	0.030				

Table 4. Abundance estimates for marked animals and for the total population. n = number of animals captured, N = estimate of number of marked animals, θ = proportion of identifiable animals, N_{tot} = estimate of total population size after correcting for proportion of identifiable individuals.

	Marked animals				Total population			
Model	n	N	SE	95% CI	θ	N_{tot}	SE	95% CI
p(.)phi(t)pent(t)	221	439	49.06	353–547	0.52	845	73.42	713–1,002
p(t)phi(t)pent(t)	221	414	40.39	342–501	0.52	796	65.38	677–934
p(t)phi(.)pent(t)	221	550	97.31	390–776	0.52	1,058	118.94	849–1,318
p(.)phi(.)pent(t)	221	512	61.16	406–647	0.52	985	88.29	827–1,174
model-averaged	221	457	57.25	358–584	0.52	879	80.64	734–1,052

Table 5. Number of photos showing relevant portions of dolphin body areas, and percentage of agreement between judges in attributing these photos to striped dolphins, common dolphins, or intermediate individuals.

Visible body area	Number of photos	% of agreement between judges
Whole body	32	100
Fore section	10	100
Dorsal portion of fore section	25	96
Flank portion below dorsal fin ($\geq$1 dorsal fin height)	164	93
Rear section	79	86
Total	310	92

A total of 310 photographs taken during 23 observation days (one of 24 photo-id days yielded no suitable photos of conspicuous surfacings) were used for species identification. Photos were stratified according to extension of visible body area (Table 5), and blindly scored by two experienced researchers. Photos showing whole body, fore section, and dorsal portion of the fore section had a 93% or higher agreement between researchers, and were therefore deemed appropriate for this analysis. Photos showing the rear section had 86% agreement and were discarded. The proportion of animals of the two species was then calculated based on the relative number of photographs suitable for species identification obtained daily (Williams *et al.* 1993, Bearzi *et al.* 2008*a*, *b*), considering 218 photos on which there was no disagreement (Table 6). Striped dolphins were estimated to average 94.95% of individuals, while common dolphins represented 3.21% of individuals. Animals showing intermediate or otherwise anomalous pigmentation leading to uncertain identification accounted for another 1.84% (Table 6).

Applying these proportions to the abundance estimate obtained through photographic capture-recapture analyses, and taking into account all the associated uncertainties (see Methods) yielded point estimates of 835 striped dolphins (95% CI = 631–1,106), 28 common dolphins (95% CI = 11–73), and 16 "intermediate" individuals (95% CI = 5–54).

Table 6. Number of photos attributed to striped dolphins, common dolphins and intermediate individuals, based on 23 d with photos suitable for species identification (see Methods). Sampling intervals used for capture-recapture analyses are also shown. *Sc* = *Stenella coeruleoalba*, *Dd* = *Delphinus delphis*.

Sampling interval	25 May–24 June					25 June–25 July						26 July–25 August						26 August–25 September							
Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Total	%
Sc	2	31	6	8	5	22	10	2	21	7	12	13	18	8	3	10	7	6	6	6	2	1	1	207	94.95
Dd	0	0	0	2	0	2	0	0	0	0	0	2	0	0	0	1	0	0	0	0	0	0	0	7	3.21
Intermediate	0	0	0	0	0	0	0	0	0	0	0	1	1	2	0	0	0	0	0	0	0	0	0	4	1.84
Total	2	31	6	10	5	24	10	2	21	7	12	16	19	10	3	11	7	6	6	6	2	1	1	218	100.00

Discussion

The results of this study suggest that capture-recapture methods taking advantage of digital photography (Markowitz *et al.* 2003) can be applied to at least some striped dolphin populations and be used to obtain estimates of abundance. Nearshore presence of striped dolphins in the Gulf of Corinth and limited population size allowed us to overcome some of the factors potentially hampering photo-id of striped dolphins elsewhere (see above). This particular study, however, was challenged by a high proportion of unmarked animals and, even more importantly, by the regular occurrence of mixed-species groups including striped dolphins, common dolphins, and animals with intermediate pigmentation.

Notwithstanding about 90% of unmarked individuals, abundance estimates of Hector's dolphins (*Cephalorhynchus hectori*) off New Zealand were obtained based on photographic capture-recapture (Gormley *et al*. 2005). Such estimates were consistent with those obtained through line transect methods (Gormley *et al*. 2005), indicating mark recapture methods can be robust even with low percentages of marked animals. High proportions of inconspicuous dorsal fin markings, however, may increase false positive or false negative errors (*i.e.*, falsely identifying two sightings of different individuals as the same, or of the same individual as different; Stevick *et al.* 2001). The proportion of unmarked animals in our study (about 48%) may result in errors greater than those obtained with delphinid species or populations characterized by lower proportions of unmarked or poorly marked dorsal fins (*e.g.*, common bottlenose dolphins, *Tursiops truncatus*: 34% considered unmarked; Bearzi *et al.* 2008*a*). Owing to the kind and proportion of dorsal fin markings (Table 1), it is particularly important that analyses of markings relied on large, high-resolution digital photographs of entirely visible dorsal fins, strictly selected based on image quality and independent of the distinctiveness of the animal (Stevick *et al.* 2001, Read *et al.* 2003). In our study such an extended selection process resulted in over 77% of the photos taken in the field being discarded. While this procedure substantially reduced the sample size, it ensured assumptions of capture-recapture models were met. Comparisons of the occurrence of natural markings and proportion of marked animals obtained elsewhere will clarify whether striped dolphins in the Gulf of Corinth have unique dorsal fin marking patterns, or other populations are similarly marked and therefore amenable to photo-id studies.

The intermixing within striped dolphin groups of a small percentage (estimate: 5%) of common dolphins and "intermediate" individuals represented a technical difficulty. Dorsal fins of striped and common dolphins could not be reliably discriminated, therefore preventing separate treatment. Merging the two species in capture-recapture analyses may have introduced an unknown level of bias in our abundance estimates. Movements of the few common dolphins, found exclusively within large groups of striped dolphins, resembled those of striped dolphins and the two species seemed to behave as one. The hypothesis that capture-recapture probabilities varied significantly between the two species would not be supported based on present knowledge. Nevertheless, the alternative hypothesis that capture-recapture probabilities did not vary will need to be tested in future work. An additional difficulty was posed by the presence of animals showing intermediate pigmentation—possibly hybrids, for which capture probabilities may be particularly hard to assess.

Methods used to obtain separate estimates of total abundance for each species might generate additional bias if the proportion of marked and unmarked dorsal fins differed among striped dolphins, common dolphins, and individuals with intermediate pigmentation. Because the estimated proportion of striped dolphins (95.0%) was much greater than that of common dolphins (3.2%) and intermediate individuals (1.8%), the proportion of marked and unmarked animals in this study concerned primarily striped dolphins. Consequently, the average proportion of marked and unmarked fins introduced a negligible bias in the total estimate of striped dolphin numbers. Such bias, however, may be more relevant in total estimates of common dolphins, due to their low numbers.

The results of this study are consistent with previous observations that common dolphins in the Gulf of Corinth are found exclusively in mixed groups with striped dolphins, and never in single species groups (Frantzis and Herzing 2002, Frantzis *et al.* 2003). While some degree of inbreeding between the two species may occur, the actual occurrence of hybrids, as well as their fertility, remains to be conclusively established by genetic analyses. In the future, such analyses may be performed on samples obtained through skin swabbing (a benign and relatively noninvasive method; Harlin *et al.* 1999), as suggested by Frantzis and Herzing (2002), ideally by sampling bow-riding animals whose pigmentation pattern may be verified through simultaneous photo and video documentation, and compared with genetic results. The proportion of animals scored as intermediate in this study provides a figure of either variability in pigmentation patterns or occurrence of hybrids. Based on direct observations made in 1995 and 1997 by Frantzis and Herzing (2002), the average ratio of common *vs.* striped dolphins was 1:4.5–11. These figures seem to differ from our study, where common dolphins were estimated to represent only 3.2% of the total population and intermediate animals accounted for another 1.8%. While this apparent discrepancy may reflect potential changes that occurred during the time that separates the two studies, suggesting a possible decline of common dolphins, the alternative hypothesis of inconsistent methodology cannot be ruled out. In our study, estimates of the proportion of striped dolphins and common dolphins based on photographs of animals showing their flanks (bow-riding excluded) rely on the assumption that there was no difference in the occurrence of aerial behaviors or conspicuous surfacings between the two species.

Striped dolphins and common dolphins living in the Gulf of Corinth have been suggested to represent geographically isolated populations (Frantzis and Herzing 2002, Frantzis *et al.* 2003). While both species can be predictably found in the central and eastern portions of the Gulf, there are no records in its western area and in the adjacent Gulf of Patras, west of the Rion-Antirion Strait (Frantzis *et al.* 2003; Fig. 1). Although this study could not confirm the hypothesis of geographic isolation, movement patterns indicated by GPS recordings while dolphin groups were being followed to perform photo-identification suggested a flow of individuals across the eastern side of the study area (Fig. 1), whereas no movements were observed across its western side. While it is known that striped and common dolphins can occur east of our study area (Frantzis *et al.* 2003), capture-recapture methods do not require sampling of the entire range of a population to estimate its abundance (Williams *et al.* 2002). The only requirement is that all individuals in the population have an equal likelihood of being captured within the study area.

Applying photo-id methods to poorly marked and morphologically similar dolphin species that live together in mixed groups is inherently challenging. Figures of total and relative abundance such as those provided here, however, have important implications for the conservation and management of protected species. This study shows that a relatively large population of striped dolphins inhabits the Gulf of Corinth—a semiclosed area exposed to high anthropogenic impacts. Conversely, there are no more than a few tens of common dolphins and these individuals are scattered within striped dolphin groups. Such low numbers indicate this local population of common dolphins may be nonviable (Traill *et al.* 2010), with the possibility of additional issues posed by hybridization (Levin 2002). Investigation of population dynamics and trends of common dolphins in the Gulf of Corinth, as well as identification and timely mitigation of any threat posed by human activities, is a management priority. Appropriately extensive, longer-term photo-id studies may help overcome some of the methodological difficulties reported here, and contribute accurate abundance estimates as well as information regarding movements and life-history parameters such as reproductive success and survival rates. Such an approach, however, requires significant effort. Aerial surveys taking advantage of methods including distance sampling and aerial photogrammetry (Scott and Perryman 1991, Buckland *et al.* 1993) may also contribute reliable abundance estimates for the two species combined, although they may not allow a precise assessment of the proportion of either species in mixed groups. It appears that line-transect sampling combined with a species-identification study using photography may be the most economical approach for the long-term monitoring of striped dolphins and common dolphins in the area.

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