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APPLICATION OF A MARK-RECAPTURE METHOD FOR THE ABUNDANCE ESTIMATES OF *TURSIOPS TRUNCATUS* (DELPHINIDAE, MONTAGU, 1821) IN THE NORTHERN IONIAN SEA, CENTRAL MEDITERRANEAN SEA

APPLICAZIONE DI UN METODO DI MARCATURA-RICATTURA PER LE STIME DI ABBONDANZA DI *TURSIOPS TRUNCATUS* (DELPHINIDAE, MONTAGU, 1821) NEL MAR IONIO SETTENTRIONALE, MAR MEDITERRANEO CENTRALE

Abstract – Cetacean population abundance is a criterion for assessing D1-Biodiversity of the EU Marine Strategy Framework Directive to achieve Good Environmental Status. Abundance estimates should be consistent, robust and validated across different methodologies. The present study focuses on estimating the abundance of the common bottlenose dolphin in the Northern Ionian Sea, by applying a mark-recapture approach to photo-identification data collected from 2016 to 2021. The POPAN model was applied to encounter histories of 139 individuals classified as transients, visitors, and seasonal residents. The best-fitting model accounted for both varying survival and entry probabilities by groups as well as varying capture probability by effort. Super-population estimate is 304 individuals (95% CI=254-362), among which 51 seasonal residents (95% CI=41-65), 128 transients (95% CI=107-153), and 125 visitors (95% CI=106-146). This study contributes to a deeper understanding of the population demographic parameters and highlights the importance of establishing a long-time series of photo-identification data.

Keywords: abundance, mark-recapture, common bottlenose dolphin, Northern Ionian Sea

Introduction – Understanding populations abundance of different species and their dynamic is essential for developing effective and comprehensive management and conservation strategies (Tyne *et al.*, 2016), particularly for coastal species more exposed to anthropogenic activities. The Northern Ionian Sea shows complex geomorphological and hydrographic characters that support the occurrence of several cetacean species among which the common bottlenose dolphin, *Tursiops truncatus* (Montagu, 1821) (Carlucci *et al.*, 2021). However, human-induced pressures in the area pose significant threats to the long-term viability of populations by reducing habitat suitability and affecting the availability of their natural resources. Research efforts have long focused on *T. truncatus* population in this basin, with previous studies examining social structure, spatial distribution, and interactions with local fisheries (Cipriano *et al.*, 2022). Previous abundance estimates of *T. truncatus* in the Gulf of Taranto have been already provided by applying methods such as Conventional Distance Sampling and the Delta approach with Random Forest models (Carlucci *et al.*, 2018). However, the availability of a six-year photo-identification (photo-ID) data has enabled the use of a mark-recapture (MR) method, providing an opportunity to upgrade previous abundance estimates and assess other important population parameters. The photo-ID is a non-invasive technique which has long been applied for individual identification of cetaceans based on unique natural features or markers such as

nicks, notches, scars, and pigmentation patterns occurring on dorsal (small cetaceans) and caudal fin (large cetaceans) (Würsig and Würsig, 1977).

Materials and methods – Photo-ID data were collected between July 2016 and September 2021, during standardized vessel-based surveys carried out on board of a 12 m catamaran applying the Line Transect Sampling method (Buckland *et al.*, 2001). The MR approach was applied to estimate abundance of *T. truncatus* population using the open-population POPAN model. POPAN uses a specific parameterization of the Jolly–Seber model (Schwarz and Arnason, 1996) that, like other Jolly–Seber models, relies on a series of assumptions: 1) marks are permanent and correctly recognised on recapture; 2) individuals are released immediately after marking; 3) the study area remains constant throughout the study period; 4) homogeneity in survival probabilities among individuals between subsequent occasion; and 5) homogeneity of capture probabilities among individuals in a sampling occasion. This model provides estimates of the super-population size (N), the apparent survival rate (ϕ), the capture (p) and entry (β) probabilities, considering that N is the estimated total number of animals potentially available for capture in the study area over the course of the study, and β represents the likelihood of an individual from the super-population joining the population between two consecutive sampling occasions. To verify the condition of open population Closure tests (CloseTest software) were performed. To verify whether the data satisfied the assumptions and to detect any significant overdispersion in the data, goodness-of-fit (GOF) tests of the standard Cormack–Jolly–Seber (CJS) model were applied. To enhance the reliability of our estimates, site-fidelity information derived from a previous study (Cipriano *et al.*, 2022), which classifies individuals as transients, visitors, and seasonal residents, was incorporated as variable in the analysis. Models were built considering a constant (\cdot), time-variable (t), group-variable (group) structure for the parameters ϕ , β and considering a constant (\cdot), group-variable (group) and effort variable ($\log(\text{effort})$) for parameter p , resulting in 36 possible models. Over-dispersion in the data was accounted for by estimating the variance inflation factor (\hat{c}), and QAICc (quasi-likelihood Akaike’s information criterion) values were used for best model selection, with the lowest QAICc value as indication of the most parsimonious model. The abundance estimates based on the population marked (\hat{N}_m) were adjusted with mark rate (θ) to obtain the total population abundance estimate (\hat{N}_{tot}) as well as for each sampling occasion (\hat{N}_{occ}). All analyses were performed in RStudio using R2Ucare and RMark packages according to procedures followed in Pace *et al.* (2021) and Cipriano *et al.* (2022). A Pearson correlation analysis was conducted to examine whether there was a significant trend in abundance over the years.

Results – A total of 122 daily sampling occasion with useful photo-ID data were conducted over the study period, during which 139 adult individuals were photo-identified. The encounter histories were aggregated on a monthly basis, totaling 33 capture occasions. Tests of closure (Otis test, $p < 0.05$; Stanley and Burnham test $p < 0.05$) and discovery curve indicated that population is open. The GOF test was significant ($\chi^2 = 177.18$; $p < 0.05$; $df = 91$), so estimates were adjusted with the variation inflation factor ($\hat{c} = 1.95$). The best-fitting model accounted for both varying apparent survival (ϕ) and entry probabilities (β) by groups as well as varying capture probability by effort (p) (Tab. 1).

Tab. 1 - First three POPAN models ranked by lowest QAICc.
Primi tre modelli POPAN ordinati per QAICc più basso.

Models	Npar	QAICc	ΔQAICc	Weight	QDeviance
$\phi(\sim\text{group}) p(\sim\log(\text{effort})) \beta(\sim\text{group})$	9	1023.541	0	0.7507192	536.2365
$\phi(\sim\text{group}) p(\sim\text{group}) \beta(\sim\text{group})$	10	1025.747	2.206089	0.2491331	536.3484
$\phi(\sim\text{group})p(\sim\log(\text{effort})) \beta(.)$	7	1041.075	17.53467	17.5346670	557.9305

The best model estimated the apparent survival rate of 0.990 (95% CI=0.979–0.995) for seasonal residents, 0.896 (95% CI=0.830–0.938) for transient, and 0.989 (95% CI=0.980-0.994) for visitors. Average probability of capture resulted in 0.240 (95% CI=0.211–0.273). The probability of entering the superpopulation is 2.9% (95% CI=2.8-3.2) for transients and 2.1% (95% CI=1.6-2.7) for visitors. The estimated superpopulation (\hat{N}_{tot}) of common bottlenose dolphin over the six-year study period, adjusted for the mark rate ($\theta=0.579$), is 304 individuals (95% CI=254-362), among which 51 seasonal residents (95% CI=41-65), 128 transients (95% CI=107-153), and 125 visitors (95% CI=106-146) (Tab. 2).

Tab. 2 - Abundance estimates (95% CI) from the best model (N_m) and after correction with θ (\hat{N}_{tot}).
Stime di abbondanza (e 95% CI) derivanti dal miglior modello (N_m) e dopo correzione con θ (\hat{N}_{tot}).

Groups	N_m (95% CI)	\hat{N}_{tot} (95% CI)
Seasonal residents	30 (25-36)	51(41-65)
Transient	74 (66-82)	128 (107-153)
Visitors	72 (67-78)	125 (106-146)
Total	176 (158-196)	304 (254-362)

On each monthly sampling occasion, abundance estimates ranges from 98 (95% CI=65-149) to 106 (95% CI=72-156) in 2016, from 101 (95% CI=70-145) to 112 (95% CI=80-158) in 2017, from 110 (95% CI=84-142) to 132 (95% CI=104-169) in 2018, from 107 (95% CI=87-133) to 121 (95% CI=98-149) in 2019, from 94 (95% CI=71-124) to 97 (95% CI=74-128) in 2020 and from 80 (95% CI=64-100) to 87 (95% CI=70-108) in 2021 (Fig. 1). A negative trend in abundance ($r=-0.559$), although not significant, was detected during the investigated period.

Conclusions - The application of the open population MR model on *T. truncatus* in the Northern Ionian Sea allowed us to obtain baseline information on key population parameters, enhancing our knowledge of its demographic features and providing new abundance estimate of this putative population. Although the estimates provided in this study are not directly comparable to previous ones due to methodological differences, the average monthly abundance estimate for 2016 aligns with earlier estimates from 2009-2016 period (Carlucci *et al.*, 2018).

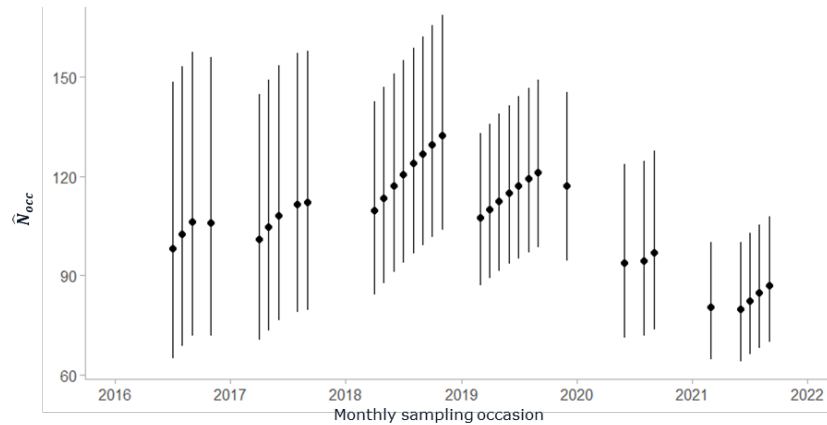


Fig. 1 – Monthly abundance estimates (95% CI) over the study period.

Stime di abbondanza mensili (e 95% CI) relative al periodo di studio.

Additionally, results highlighted that only a portion of the population is currently known, underlining the need to improve the monitoring effort in the area to better understand the structure and dynamics of this population. Expanding the systematic collection of photo-identification data over a wider area and a longer timescale is crucial to improve the accuracy of population parameter estimates and it is essential for better understanding the actual trend in abundance, which currently appears to be declining. This is a cornerstone for developing and implementing effective conservation and management strategies for this species in the Northern Ionian Sea.

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