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# TAPHONOMY OF STRANDED SMALL CETACEANS: GENERAL ASPECTS AND IMPACT OF THE COAST

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We provide the first summarizing report of preservation rates of carcasses of stranded harbour porpoises, bottlenose and common dolphins on the beaches of the Sea of Azov and the Black Sea in 2000–2013. Remains are preserved on a coastline during a warm season (with daily maximum air temperatures 10–36°C) from 3–102 days (harbour porpoises) to 7 years (bottlenose dolphins). Interspecies differences in preservation rate are generally explained by body size. However, neonates rapidly decompose independent of their species and body size. The main factor of coastal geography affecting the preservation rate is the type (origin) of the beach, i.e. dominating abrasion or accumulative process, rather than its geographical position, orientation or relation to wind or current directions. 50% preservation rate for carcasses of harbour porpoises on abrasion or mixed abrasion and accumulative beaches is attained at 34–58 days, and on accumulative beaches it is attained at 16–17 days. Another factor is the seasonal wave activity washing off or burying carcasses in autumn and winter. Unusual weather conditions can produce favourable environments for mummification and extraordinarily long carcass preservation.
***Keywords:*** cetaceans, harbour porpoise, bottlenose dolphin, taphonomy, strandings, carcass decomposition, beach, abrasion, accumulation.

## INTRODUCTION

Analysis of strandings is a useful tool in monitoring of cetacean populations. However, this method has some limitations [1, 2]. First of all, the number of reported strandings (reporting rate) is only indirectly associated with the population state, and it can be presented as the function of

Abundance x Mortality rate x Buoyancy x Drift conditions x Discovery rate

For example, the stranding rate can rise when a population increases or a mass mortality event occurs, or in winter (when buoyancy increases due to enlarged blubber layer), or under favourable weather conditions. However, the discovery rate is at least as important, as the other listed factors, and in its turn, it is determined by

Recovery effort x Preservation rate

The latter factor depends on human activities (removal or burial) and on natural processes of burial and decomposition, i.e. early stages of taphonomic transition.

Assessment of this factor is important in planning an adequate recovery effort, which is necessary for effective discovery of stranded carcasses.

Another application of taphonomy is paleontological research including reconstruction of circumstances of fossil deposition and preservation. Such a historical reconstruction often has to be grounded on comparison with observed modern processes, and the deficit of this kind of data is felt [3, 4, 5].

Here we report some results of taphonomic study of small cetaceans stranded on the coastline of the Sea of Azov and the Black Sea. In particular, we examined general time frames of carcass decomposition and the impact of stranding location (geography and type of the beach) on the taphonomic process.

**MATERIALS AND METHODS**

Data were collected from field excursions along the coastline of the Sea of Azov and the Black Sea in 2000–2013 (Fig. 1).

The data are available from four coastal areas on the southern coast of the Sea of Azov:

(1A) Chokrak Lake bar, mixed accumulative and abrasion coast, sandy and shell beach, 30–50 m wide, north orientation;

(2A) Rifov Bay, an accumulative coast, sandy beach, 10–40 m wide, north-east orientation;

(3A) Tarkhan Cape, an abrasion coast, stone and pebble beach, 0–25 m wide, north and north-east orientation;

(4A) Barzovka, mixed abrasion and accumulative coast, sandy and pebble beach, 5–30 m wide, north and north-east orientation.

In addition, occasional observations were made in the Bulganak Bay, mixed abrasion and accumulative coast, sandy and pebble beach, 0–25 m wide, north and north-west orientation.

The data were obtained from four coastal areas on the Black Sea coast:

(1B) Coast of the Kalamita Gulf between Novofyodorovka and Nikolaevka: a mixed accumulative and abrasion coast (described in a number of studies [6, 7, 8]), sandy and pebble beach, 0–50 m wide, west orientation;

(2B) Coast of the Feodosiya Gulf, central part: an abrasion and accumulative coast, sandy and pebble beach, 0–40 m wide, south orientation;

(3B) Chauda Cape: an abrasion coast, pebble beach, 0–10 m wide, west orientation;

(4B) Coast of the Kerch Peninsula near Yakovenkovo: an abrasion and accumulative coast, sandy beach, 10–50 m wide, south orientation.

Exact locality (geographical coordinates), date, geographical orientation of the coast, beach type, weather conditions (water and air temperature, wind force and direction, wave activity, precipitation), species, body size, age and sex category, body condition and stage of decomposition were recorded. Marking of selected carcasses was conducted.

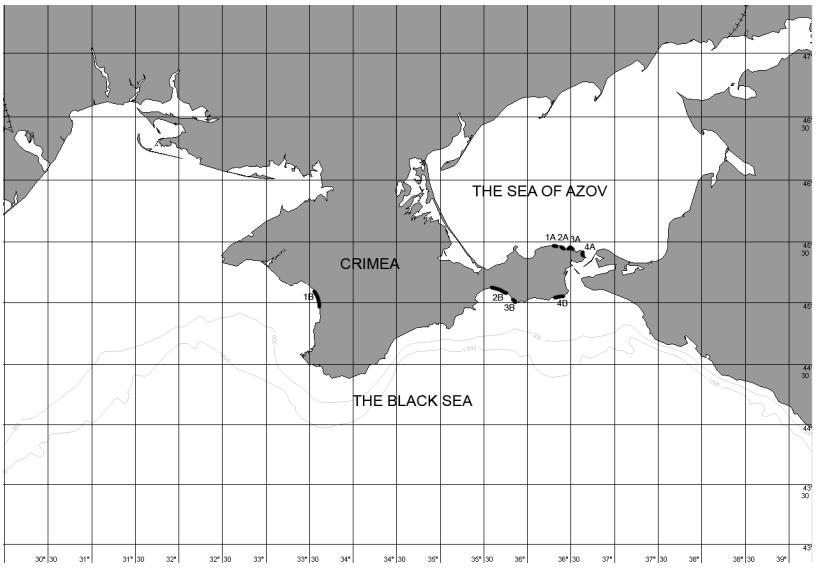


Figure 1. The region of study. Codes for coastal areas are indicated in the Material and Methods section.

Neonates were considered as specimens with healing umbilicus and non-erupted teeth; current year born animals not matching these criteria were considered as calves. Stages of decomposition were identified as following: (1) live stranding; (2) fresh carcass, no visible decomposition marks; (3) early decomposition; (4) advanced decomposition; (5) mummification or skeletonizing. Beach types were identified following Zenkovich (1958) [6]. Harbour porpoise carcasses were traced during warm season only ("summer" in a broader sense), at maximum daily air temperatures 10–36°C, to avoid biases associated with temperature and humidity regimes.

Statistical comparison of mean values was calculated using Chi-square test. Preservation rates were estimated from linear regressions.

## RESULTS AND DISCUSSION

### Harbour porpoise

In total, data on the fate of 380 carcasses were encountered during this study, 205 (including 40 neonates) from the Sea of Azov and 175 (including 9 neonates) from the Black Sea. The stranded animals were 0–20 years old; body length range was within 50–160 cm; body weight range was within 2–70 kg. Thus, our sample included all age and size classes typical for the Black Sea porpoises *Phocoena phocoena relicta* [9].

The Sea of Azov. The maximum period of carcass preservation was recorded as 102 days (Bulganak Bay, 2011). Time intervals of 76 and 70 days were also recorded; however, the most of carcasses were recorded on the beach no longer than for 50 days (Table 1).

No neonates have been recorded as preserved for more than 7 days. Transition of a neonate carcass from the stage 2 to the stage 4 was within 36 hours; body and skeleton parts have being lost for this time interval due to wave activity and scavenging. On the contrary, calf carcasses decomposed at the same rate as older animals. No age (excluding neonate) or sex differences in preservation rate were discovered.

No carcasses have been preserved on a beach as long as September. While some of them were being observed during summer, classified as stage 4 or 5, with no or little marks of further decomposition, none of them has remained by October.

Data from 2011 significantly differed from the other years: better preservation was recorded on all beaches, regardless the type or orientation.

The most consistent data on the preservation rate were obtained from the multi-year series of observations made on the beach of the Tarkhan Cape (fig. 2), which includes 90 traced carcass fates (excluding neonates) during 2000–2011. This area was chosen as a model because it was an unpopulated coast with almost no visitors. This is an example of a relatively high preservation rate: as linear regression predicts, 50% of carcasses are preserved on 34 days.

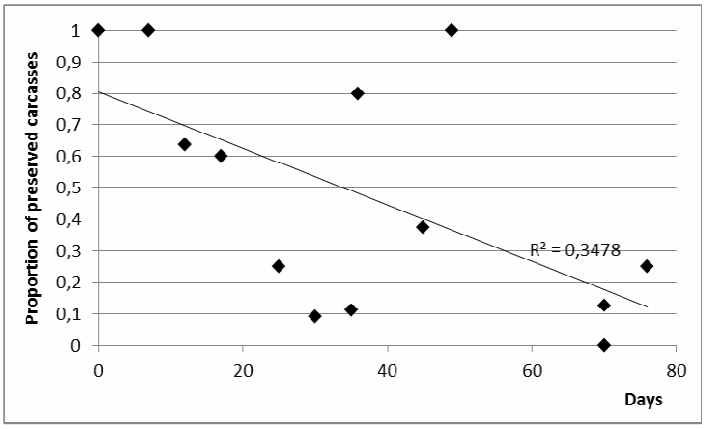


Figure 2. Preservation rates of carcasses of harbour porpoises on a beach on the Tarkhan Cape, the Sea of Azov. The linear regression line is shown.

The areas with dominating accumulative processes, Rifov Bay and Chokrak bar, were characterized by rapid burial of carcasses: the most of them were recorded once only. The longest preservation period, as recorded, was 36 days. The exception was the sample of porpoises stranded in 2011 when an unusually high preservation rate (0.82) was recorded on 49 days in the Rifov Bay.

Transition of partly submerged or floating carcasses from the stage 2 to the stage 3 was observed as lasting within 24 to 48 hours in summer, at water temperature of 25°C. Body mass was dropping by nearly 40% during this time interval (body mass of a live animal was estimated from linear measurements of a stranded carcass [10]). When a carcass was on the open air, this process lasted less than 24 hours. So the decomposition rate of harbour porpoises at initial stages is generally similar to that of human carcasses [11].

Interestingly, the preservation rates of cetacean carcasses perfectly match the earlier reported pattern of preservation of marine litter at the coasts of the Kerch Peninsula [12], so they reflect general regularities of material transfer.

**Table 1.**

**Preservation rates of carcasses of harbour porpoises *Phocoena phocoena* (excluding neonates) on beaches of different origin.**

| Region | Type of the coast | Number of traced fates of carcasses | Estimated time interval for 50% preservation, days | Estimated time interval for 10% preservation, days | The longest recorded preservation, days |
|---|---|---|---|---|---|
| The Sea of Azov (3A): Tarkhan Cape | Abrasion | 90 | 34 | 78 | 76 |
| The Sea of Azov (1A, 2A, 4A): Chokrak bar, Rifov Bay, Barzovka | Accumulative and abrasion | 75 | 17 | 37 | 50 |
| The Black Sea (1B): Kalamita Gulf | Accumulative and abrasion | 41 | 16 | 42 | 53 |
| The Black Sea (2B): Feodosiya Gulf | Abrasion and accumulative | 78 | 39 | 70 | 57 |
| The Black Sea (3B): Chauda Cape | Abrasion | 27 | 44 | 80 | 80 |
| The Black Sea (4B): Yakovenkovo (2011 only) | Abrasion and accumulative | 20 | 58 | 102 | 93 |

The Black Sea.

The maximum period of carcass preservation was recorded as 93 days (Yakovenkovo, 2011). Like at the Sea of Azov, 2011 was the year when the preservation rate was especially high, and during other years preservation intervals were within 60 days (Table 1).

Notably short preservation intervals were found at the coast of the Kalamita Gulf known by active processes of accumulation and transport of sand and detritus [6–8]: they were extremely similar to those at accumulative Azov coasts. Abrasion coasts of Chauda and Kyz-Aul capes showed the highest preservation rates, slightly exceeding those of the Tarkhan Cape.

As in the Sea of Azov, no carcasses have been preserved on a beach as long as September: none of the summer strandings has remained by October.

**Bottlenose dolphin and common dolphin**

Data on fates of 26 bottlenose dolphins (including 5 neonates) and 7 common dolphins were summarized in this study (Table 2). Neonate and calf bottlenose dolphins at the age less than 1 year old, up to 140 cm long and ca.30 kg weight, are rapidly decomposed, and none of them was recorded later than a month after the finding. So these carcasses are more similar in their decomposition rates to neonate porpoises, which are 4–10 times lighter, than to adult porpoises of the same size category: a similar decay pattern has been reported for pigs [13]. The carcasses of older bottlenose dolphins were robust to environmental conditions. Most of them were preserved during all the warm season (from March to October), many of them without visible changes. However, almost all carcasses were swept off during the period from October to February. The only specimen left for more than a year was a dolphin stranded on the Tarkhan Cape in May 2007: its vertebral column has been observed by the end of the study in August 2013. Carcasses of common dolphins well preserved during two months, similar to bottlenose dolphins, but none of them was observed during the whole warm season (Table 2).

**Table 2.**

**Preservation rates of carcasses of dolphins (excluding neonates).**

| Species | Number of traced fates of carcasses | Estimated time interval for 50% preservation, days | Estimated time interval for 10% preservation, days | The longest recorded preservation, days |
|---|---|---|---|---|
| Bottlenose dolphin *Tursiops truncatus* | 21 | 152 | 263 | 2645 |
| Common dolphin *Delphinus delphis* | 7 | 75 | 115 | 89 |

**General regularities**

Strong interspecies variation in carcass preservation rates is clearly explained by differences in mean body weight (see also [14]) and can be described by a linear regression (fig. 3). However, this trend does not include neonates, which are rapidly decomposed regardless the species and body size, and it obscures fine-scale within-species variation due to environmental factors.

The main physical factors contributing to carcass preservations were the type of the coast and the season. Porpoise carcasses better preserved on the coasts with dominating abrasion process and rapidly buried on accumulative coastlines. The carcasses well preserved during the spring and summer season and were quickly destroyed by autumn and winter storms. In the course of this study, we found no significant differences in preservation rates, which could be caused by coast orientation and dominating wind or

current directions, on the contrary to our earlier research summarizing data from a small part of this sample [16].

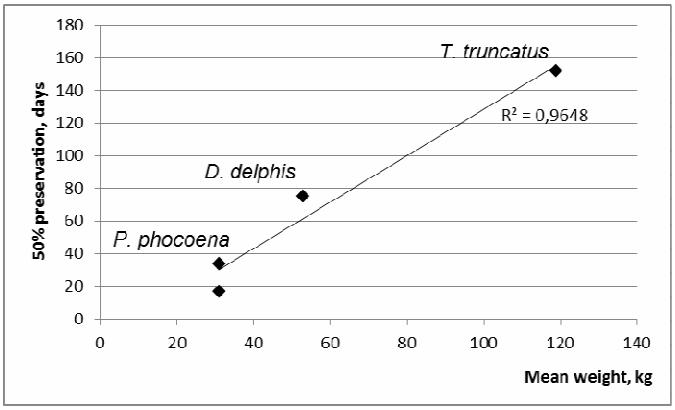


Fig. 3. Interspecies variation of carcass preservation rate, mean weight vs. 50% preservation in days. Mean weights follow Kleinenberg (1956) [15], preservation values follow the Tables 1 and 2.

A time-dependent taphonomic anomaly was identified: in 2011 preservation rates were unusually high on all coastlines regardless other factors. It is explained by high stranding rate in May and June [17] combined with weather conditions favouring mummification, namely high air temperature and low humidity. It caused rapid decay and dehydration of soft tissues independent of species, body size or age category and transition to a mummy phase (fig. 4).

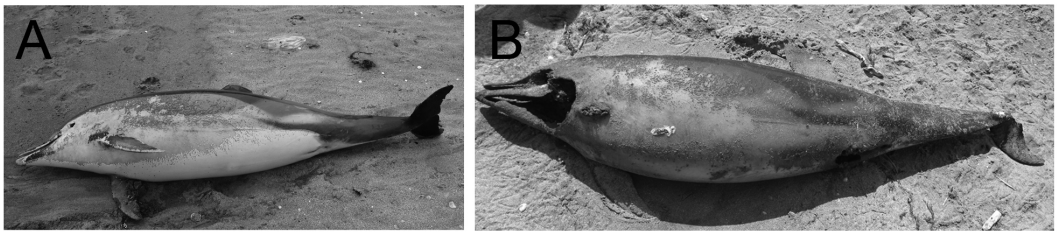


Fig. 4. Rapid decomposition of a common dolphin in May 2011: A, fresh carcass with early decomposition marks, May 4, photo by O. V. Kukushkin and P. A. Moroz; B, the carcass with advance decomposition marks (putrefaction, decay of skin and internal organs) and scavenging marks, May 7, photo by P. E. Gol'din.

We did not found any association between the preservation rate and the stage of decomposition by the moment of stranding. Fresh and strongly decomposed carcasses showed similar preservation rates. Little difference is quite expectable, given a rapid transition to the stage 4 of carcasses stranded during the warm season.

**CONCLUSIONS**

Remains of stranded cetaceans are preserved on a coastline during a warm season (with daily maximum air temperatures 10–36°C) from 3–102 days (harbour porpoises) to 7 years (bottlenose dolphins). Interspecies differences in preservation rate are generally explained by body size. However, neonates of any species rapidly decompose independent of their size, and normally neonate strandings would be underestimated during routine monitoring operations. The main factor of coastal geography affecting the preservation rate is the type of the beach, i.e. dominating abrasion or accumulative process, rather than its geographical position, orientation, wind or current directions. 50% preservation rate for carcasses of harbour porpoises on abrasion or abrasion and accumulative beaches is attained at 34–58 days, and on accumulative beaches it is attained at 16–17 days, so only the abrasion-dominating coasts fit routine stranding monitoring schedules based on 21–30 day interval operations. Another factor is the seasonal wave activity washing off or burying most of the carcasses in autumn and winter. Unusual arid weather conditions can produce favourable environments for mummification and extraordinarily long carcass preservation.

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**Гольдин П. Е. Тафономия малых китообразных, выброшенных морем: общие особенности и влияние берега / П.Е. Гольдин, К.А. Вишнякова, Е.В. Гладилина //** Ученые записки Таврического национального университета им. В.И. Вернадского. Серия «Биология, химия». – 2013. – Т. 26 (65), № 3. – С.45-53.
Приведены первые систематические данные о сохранности выброшенных на побережье трупов морской свиньи, афалины и обыкновенного дельфина на пляжах Азовского и Черного морей в 2000–2013 годах. Останки сохраняются на берегу в течение теплого сезона (при максимальных дневных температурах воздуха 10–36°С) от 3–102 дней (морские свиньи) до 7 лет (афалины). Межвидовые различия в сохранности в целом объясняются размерами тела. При этом новорожденные быстро разлагаются независимо от вида и размеров. Главный фактор географии побережья, влияющий на сохранность тел, – тип пляжа (абразионный или аккумулятивный), – а не его географическое положение, экспозиция или направление господствующих ветров и течений. 50% сохранность трупов морской свиньи достигается на абразионных и абразионно-аккумулятивных берегах в течение 34–58 дней, а на аккумулятивных – на 16–17 день. Другой фактор, влияющий на сохранность, – сезонные штормы, смывающие или погребающие останки осенью и зимой. Необычные аридные погодные условия могут создавать благоприятную среду для мумификации и нетипично долгого сохранения останков.
***Ключевые слова:*** китообразные, морская свинья, афалина, тафономия, выбросы, разложение трупа, пляж, абразия, аккумуляция.

**Гольдін П.Є. Тафономія малих китоподібних, що викинуті морем: загальні аспекти і вплив берегу / П.Є. Гольдін, К.О. Вишнякова, О.В. Гладіліна //** Вчені записки Таврійського національного університету ім. В.І. Вернадського. Серія „Біологія, хімія". – 2013. – Т. 26 (65), № 3. – С. 45-53.
Наведено перші систематичні дані про збереження викинутих на узбережжі трупів морської свині, афаліни і звичайного дельфіна на пляжах Азовського і Чорного морів в 2000–2013 роках. Останки зберігаються на березі протягом теплого сезону (при максимальних денних температурах повітря 10-36°С) від 3-102 днів (морські свині) до 7 років ( афаліни). Міжвидові відмінності в схоронності в цілому пояснюються розмірами тіла. При цьому новонароджені швидко розкладаються незалежно від виду і розмірів. Головний фактор географії узбережжя, що впливає на збереження тіл, - тип пляжу (абразійний або акумулятивний), - а не його географічне положення, експозиція або напрямок пануючих вітрів і течій. 50% збереження трупів морської свині досягається на абразійних і абразійно-акумулятивних берегах протягом 34-58 днів , а на акумулятивних - на 16-17 день. Інший фактор, що впливає на збереження, - сезонні шторми, що змивають або ховають останки восени і взимку. Незвичайні арідні погодні умови можуть створювати сприятливе середовище для муміфікації і нетипово довгого збереження останків.
***Ключові слова:*** китоподібні, морська свиня, афаліна, тафономія, викиди, розтин трупа, пляж, абразія, акумуляція.

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