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ABSTRACT

This study documents the presence of harbour porpoise (*Phocoena phocoena*, Linnaeus 1758) in the tidal Thames from strandings, dedicated surveys and opportunistic sightings. In March 2015, a visual and acoustic vessel survey for harbour porpoises was conducted; 17 sightings and 45 acoustic detections of porpoise groups were documented. A conservative acoustic encounter rate of 4.2 animals/100 km surveyed is estimated, comparable to results from acoustic surveys in other important European porpoise habitats. Presented with data from opportunistic sightings records, porpoises are reported in the tidal Thames during all months, with peak presence in spring and late summer. Results support the need for further studies in this significant habitat, and that harbour porpoises must be considered when planning future activities and developments within the estuary.

## INTRODUCTION

The presence of harbour porpoises (*Phocoena phocoena*, Linnaeus 1758) in the River Thames and Estuary, including central London, has been documented in scientific literature and Victorian etchings (e.g. Kemsey 1982, Plates Illustrative of Natural History, S.P.C.K, ca.1845). Since these early descriptions, there have been few reports of harbour porpoise within the Thames. However, despite an increase in the rate of incidental sightings by the public, fishermen and local groups in the last decade (Castello y Tickell & Barker 2015; Natural History Museum, 2018), harbour porpoises have received little study in the Thames and there are few published accounts.

This paper presents data from the first systematic survey of the tidal Thames for harbour porpoises, and collates previously disparate sighting and stranding data, providing an update on harbour porpoise presence and distribution in the tidal Thames and estuary.

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**Key words**: Harbour porpoise, distribution, Thames Estuary, conservation, visual & acoustic survey

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# METHODS

A simultaneous acoustic and visual survey was conducted between Felixstowe and Tower Bridge, London, from R/V *Song of the Whale*, between the 6th and 15th March 2015. Due to navigational constraints, a randomised, even-coverage design was not possible. Therefore, survey lines were designed to cover every major channel within the estuary.

Acoustic sampling was conducted continuously during the survey using an experimental hull-mounted hydrophone array consisting of two broadband elements (2 to 200 kHz bandwidth). This array, mounted ahead of the keel on the vessel's midline 1 m below the waterline, was able to collect data throughout the survey when towing a more traditional hydrophone was not possible due to navigational or safety considerations. In addition to the hull-mounted array, the towed array, containing a pair of broadband elements (2 to 200 kHz bandwidth), was towed 20 -100 m behind the vessel when possible. Surveys for harbour porpoises have been conducted using towed arrays on numerous occasions (see Gillespie & Chappell 2002; Gillespie et al. 2005; Cucknell et al. 2016) and may detect at least 10 times more individuals than equivalent visual techniques (e.g. 561 on-track acoustic detections vs. nine sightings, Cucknell et al. 2017). Signals from both arrays were passed to National Instruments 6251 data acquisition cards; for the bandwidths of interest for porpoises (115-160 kHz), the response of the system was approximately flat.

PAMGuard was used throughout the survey to automatically detect porpoise echolocation clicks. Stereo wav files from both arrays were recorded continuously at a sample rate of 500 kHz using PAMGuard (Gillespie et al. 2009).

In daylight hours and in sea states below four, two visual observers recorded marine mammal sightings from an elevated platform (eye height of 5.5 m above sea level). In sea states of four or higher, observers were positioned on deck (eye height of 3.5 m). Sightings, survey effort, environmental and GPS data were logged via Logger software (www.marineconservationresearch.org). Observers scanned to 90 degrees either side of the track-line between the vessel and the horizon with the naked eye, using binoculars for species confirmation. Estimated distances and relative angles (using an angle board) to sightings were recorded along with an estimate of group size.

## Data analysis

All harbour porpoise sightings and acoustic detections were mapped in QGIS (QGIS Development Team) using the World Geodetic System (WGS84) coordinate system. Porpoise click trains comprising four clicks or more and identified as 'certain' by two independent analysts, were included in analysis. Where possible, slant distances to vocalising animals were estimated using target motion analysis in PAMGuard. Click trains were considered to represent a unique encounter (i.e. not a detection of an animal previously seen or detected acoustically) if there was no corresponding sighting or click train within six minutes and 25 seconds. This time threshold was estimated by projecting a hypothetical radial area of porpoise movement over the trackline, corrected for maximum acoustic detection distance for porpoises (400 m; Villadsgaard et al. 2007). This was estimated using an average swimming speed of a porpoise (0.9 m $sec^{-1}$, Otani et al. 2000) relative to the survey speed of the vessel (5.8 knots).

The two separate hydrophone arrays provided independent detections of harbour porpoises. Due to hull vibrations and flow noise, the hull-mounted array had a lower detection range than the towed array. Combining the output from both arrays optimised the efficiency of surveying with challenging navigational constraints. To avoid duplication between arrays, any detections on the towed array within six minutes and 25 seconds of the hull-mounted array were removed from the dataset. The hull-mounted hydrophone array was used to estimate a relative acoustic encounter rate throughout the survey. As the towed hydrophone length had to be varied due to depth, navigation and logistical requirements, relative comparison between areas was not appropriate. As such, for this study, the towed array results were used only to provide presence/absence information.

The variance of the acoustic encounter rate *n*/100 km was calculated using days as sampling units (Buckland et al. 2001, pp78-80). The variance in the number of detections for each day was calculated as follows:

$$\hat{\mathrm{var}}(n) = L\sum_{i=1}^{k} l_i\left(\frac{n_i}{l_i} - \frac{n}{L}\right)^2 /(k-1)$$

where $i$ is the transect number from 1 to $k$, $l_i$ is the length of transect $i$ and $L$ is the sum of all transect lengths. The variance of the detection rate/100 km was then calculated by dividing $\hat{\mathrm{var}}(n)$ by $L^2$ and multiplying by 100. Encounter rates estimated from the hull-mounted hydrophone data were mapped across the tidal Thames survey area using a 0.05 degree grid in QGIS.

## Data from other organisations

Harbour porpoise sighting and stranding data collected between 1990 and 2015 were contributed by a number of local organisations (Table 1).

# RESULTS

Vessel surveys comprised 676 km of visual and acoustic effort between 6th and 15th March 2015 (no survey occurred in the daylight hours of 9th March 2015); of the acoustic effort, 570 km incorporated simultaneous effort with the hull-mounted array. The survey occurred in daylight hours when sea states were typically below four (sea state 1 = 16%, 2 = 32%, 3 = 32% and 4 = 19%). In addition, two acoustic-only night surveys were conducted between Tower Bridge and the Thames Barrier.

During the survey, 17 harbour porpoise sightings (of which eight were unique – i.e. not associated with an acoustic detection within 6 min 25 s), 36 grey seal sightings and 45 unique acoustic detections of harbour porpoise groups were reported ($n$ = 24 hull-mounted array, $n$ = 21 towed array; see Figure 1). Estimation of group size from the acoustic arrays was not possible; the average porpoise group size from sightings was 2.0 individuals.

The acoustic encounter rate of the tidal Thames for the survey period from 7th to the 12th March was 4.2 porpoise groups/100 km surveyed [vâr(*groups/100 km*) = 5.4] calculated from the hull-mounted hydrophone only (as noted, because the length of the towed array had to be varied, and therefore its likely detection characteristics were also variable, it is more appropriate to use the hull-mounted detections when considering the entire study area). Porpoise acoustic encounter rate was highest in the outer Thames Estuary (Figure 2). During those periods when it was possible to record with both arrays simultaneously, 58% of those animals detected with the towed array were also detected with the hull-mounted array. All of the hull-mounted detections were of animals within 250 m of the trackline. By contrast, 91% of the detections made with the towed array were within 250 m of the trackline, with the remaining 9% of detections being made at distances greater than 250 m.

## All sightings data from the tidal Thames

Data from dedicated shore watches, publicly reported sightings and strandings were collated from five organisations (Table 1). Between 1990 and 2015, over 2000 sightings, 161 strandings and 45 acoustic detections of harbour porpoise were documented throughout the tidal Thames (Figure 3). The group sizes for all sightings reported varied between one and 26 individuals. For the sightings presented in Figure 3, the range in group size was one to 15 with a mean group size of 1.79 and a SD of 1.57.
Records of porpoises are documented in all months, with peaks in April and August for sightings, and March and April for strandings (Figure 4).

**Table 1: Sightings, strandings and acoustic detections of harbour porpoise recorded in the tidal Thames. The sighting data were from both dedicated shore watches and publicly reported sightings from all seasons between 1990 and 2015.**

| Organisation | Type of data | Sightings | Strandings | Year |
|---|---|---|---|---|
| ZSL | Public sightings | 239 | 10 | 2002-2015 |
| Essex Wildlife Trust Biodiversity Records | Public sightings / strandings /shore watch | 103 | 35 | 2001-2015 |
| MARINElife | Sightings from ferry route | 11 | - | 2014 |
| Cetacean Stranding Investigation Programme (CSIP) | Strandings | - | 108 | 1990-2014 |
| Kent Wildlife Trust and Kent Mammal Group | Shore watches / public sightings / strandings | 13 (+1871 recorded without lat/long information) | 8 | 2008-2015 |
| Marine Conservation Research | Survey based sightings / acoustic detections | 17 (+45 acoustic detections) | - | This survey |
| **Total** | | **383 (+1871)** | **161** | **1990-2015** |

**Figure 1: A map of the River Thames & Estuary showing porpoise sightings (white triangles) and acoustic detections from the towed hydrophone (black circles) and hull-mounted hydrophone (white circles) arrays. Solid black lines represent the survey track-lines with the hull and towed hydrophones, grey line represents survey track-lines with the towed hydrophone only; NB dark grey polygons represent operational wind farms in the estuary in all maps.**

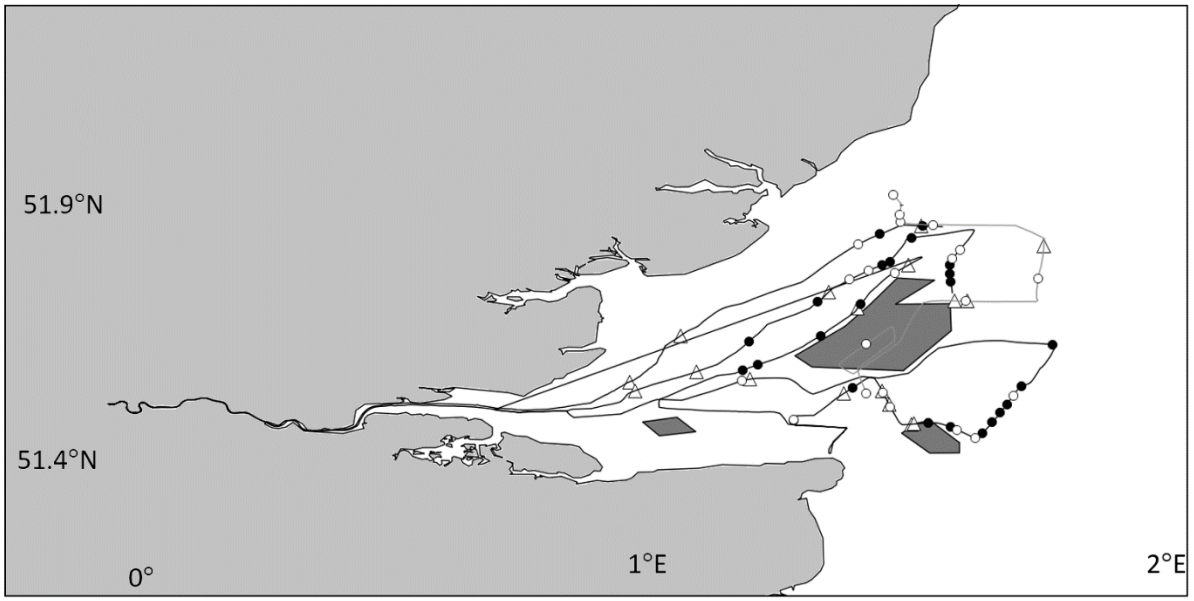



**Figure 2: Relative encounter rates presented in a 0.05° grid, based on hull-mounted acoustic detection data. The vessel's track while using the hull mounted hydrophone is marked as a black line.**

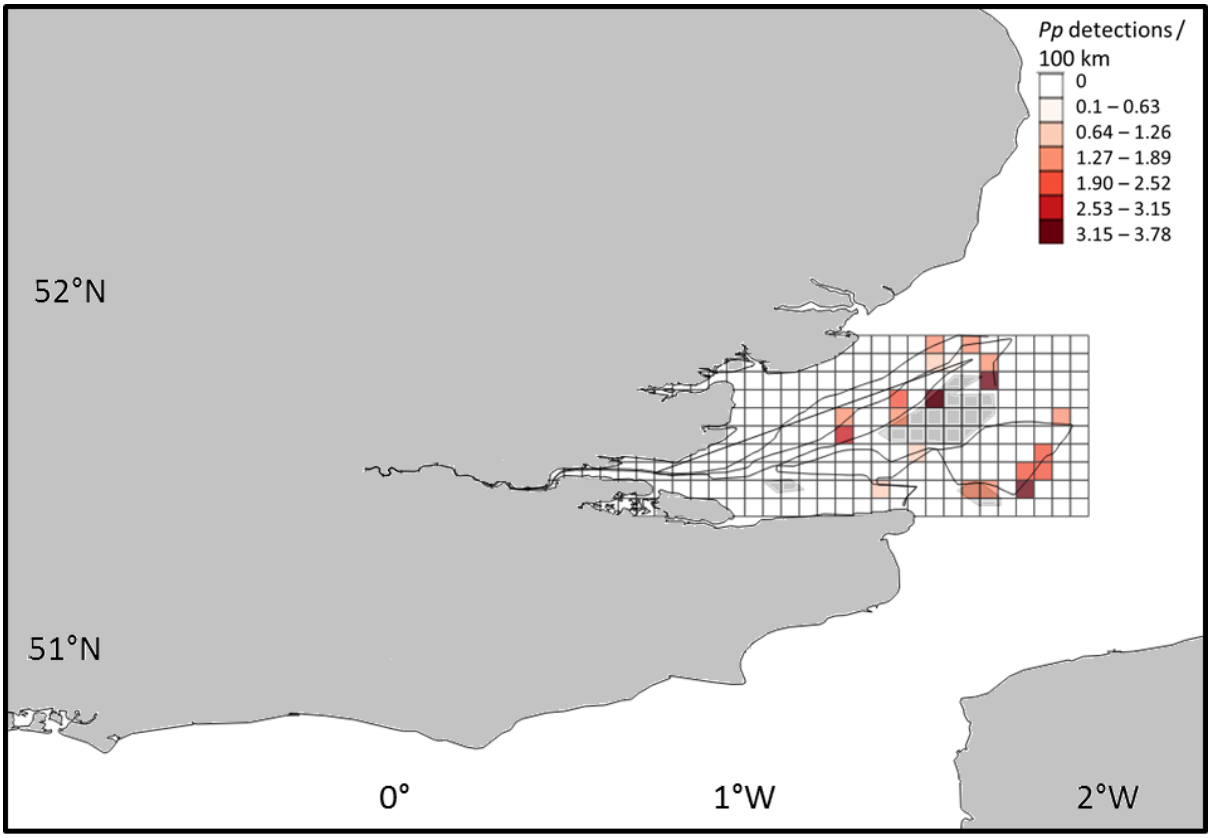


**Figure 3: A map of the River Thames and Estuary displaying public sightings from onshore and offshore effort (grey triangles) where latitude and longitude data were provided, strandings (white squares) and MCR sightings (white triangles), towed (black circles) and hull-mounted (white circles) acoustic detections.**

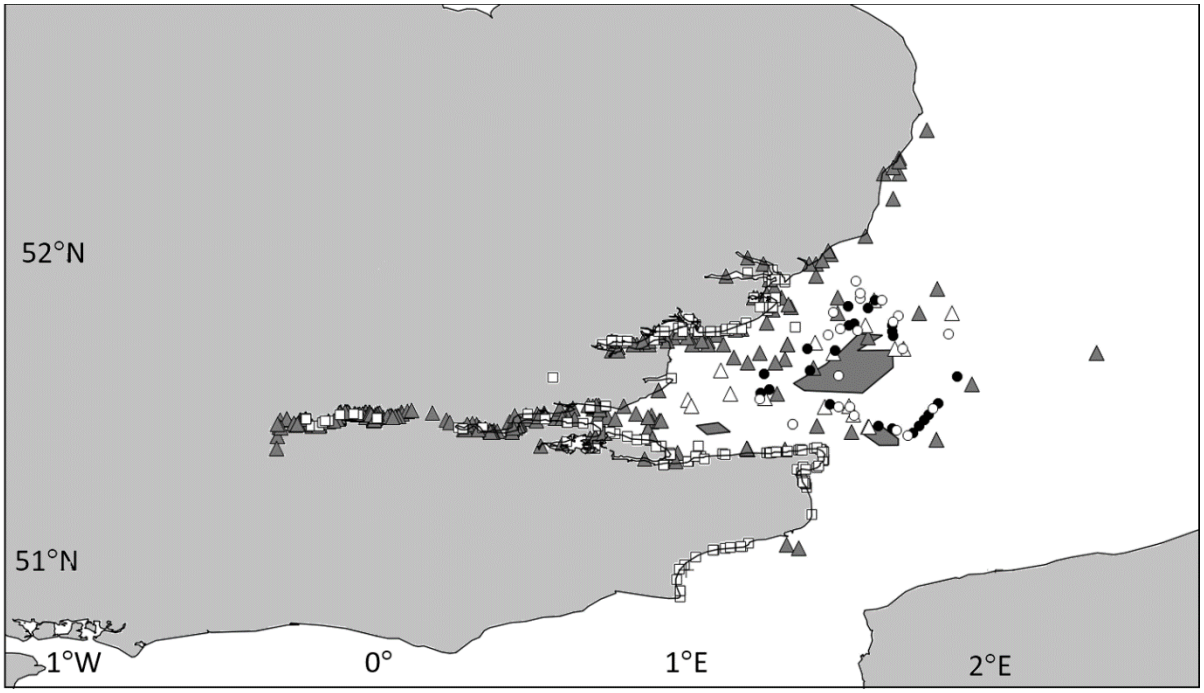
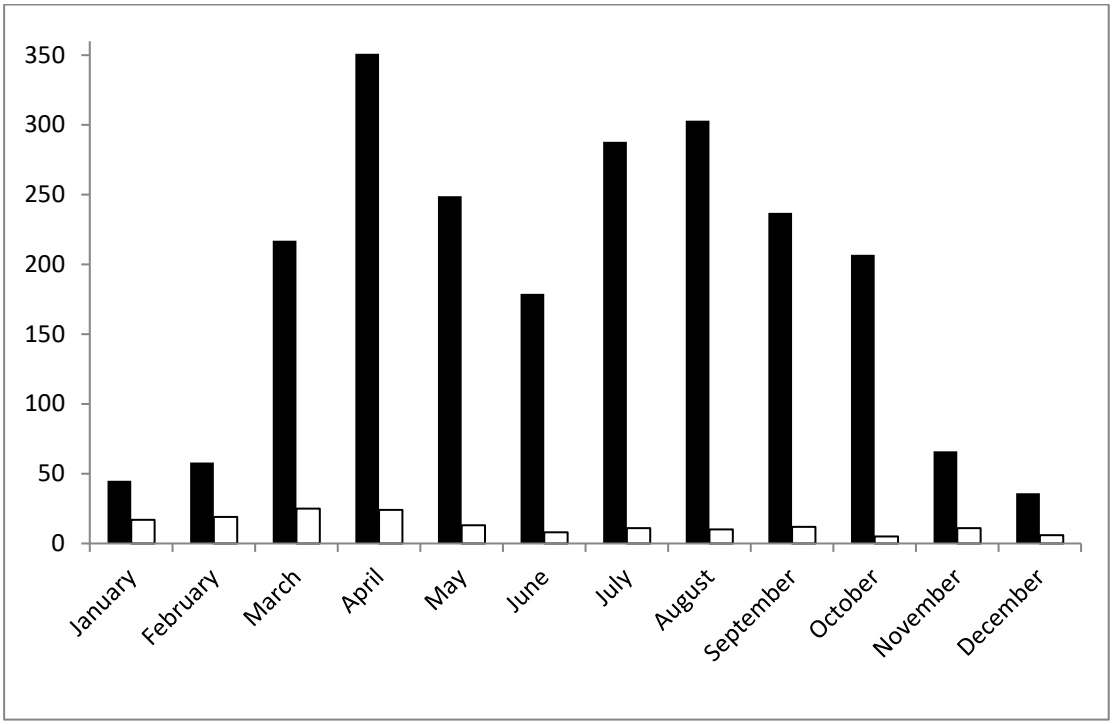



**Figure 4: The number of harbour porpoise sightings (black columns) and strandings (white columns) by month from collated and previously unpublished strandings and sightings data from 1990-2015 (MCR data not included).**




# DISCUSSION

It is clear that harbour porpoises live in and around the tidal Thames and Thames Estuary (Figure 3); over 2000 encounters have been opportunistically documented since 1990. The rate of sightings and strandings has increased over the last decade or so (see for example Castello y Tickell & Barker 2015), perhaps due to greater awareness of these animals and the establishment of schemes to collect data from the public, such as ZSL's Marine Mammal Survey, Sea Watch and the UK Cetacean Strandings Investigation Programme. Acoustic encounter rates of 4.2 (hull-mounted array) or 6.7 (towed array) harbour porpoise detections/100 km in March 2015 are noteworthy, and support modelling of harbour porpoise densities undertaken by Heinänen & Skov (2015) and Gilles et al. (2016); both predicted high density areas in the outer Thames Estuary. Studies in two Special Areas of Conservation (SAC) in Ireland reported 4 detections/100 km and 2 detections/100 km (Rockabill

to Dalkey Island SAC and Roaringwater Bay SAC respectively) (Berrow and O'Brian 2013), and an acoustic/visual survey in German and Dutch Dogger Bank zones reported an encounter rate of 4.8 animals/100 km surveyed (Gilles et al. 2011). At these sites, porpoises are a qualifying feature of their designation as protected areas. Caution should be used when comparing encounter rates estimated using different systems; however, the values estimated for the Thames are of a similar order of magnitude to these other studies. Furthermore, the acoustic encounter rates calculated from the Thames should be considered conservative; only the hull-mounted array was used consistently throughout the study area, and this had a reduced range (<250 m) when compared to a traditional towed array (<400 m). Despite limitations, this short study demonstrates the efficacy of a hull-mounted hydrophone array for use in confined waters.

During the survey, the highest encounter rates were recorded in the outer estuary (Figure 3). This is expected for a species largely limited to continental shelf waters, relatively shallow bays, estuaries, and tidal channels (Hammond et al. 2008). The datasets collated from other organisations also reveal a considerable density of sightings along the coastline, although this may reflect a shore-based observer bias within 1 km of the coast. Porpoise densities may also vary with season. Aerial surveys in Belgian and Dutch waters have shown that porpoises seem to move offshore in summer (Gilles et al. 2016; Geelhoed & Scheidat 2018). Heinänen & Skov (2015) identified the waters east of the outer Thames Estuary as a persistent high-density area in winter. Many of the data presented are not corrected for effort (such as the public reports of sightings and strandings) and so could not be incorporated into absolute abundance and density estimations. Furthermore, the lack of sightings in some areas does not necessarily reflect an absence of animals, it may be due to lack of observer effort. Despite these constraints, the data reveal a year–round presence of harbour porpoises in the estuary, with peaks in presence in spring (March-April) and late summer (July-August) (Figure 4). Further study is required to understand these peaks which may be related to effort, sighting conditions, improved prey availability and/or the presence of a seasonal breeding habitat (Gaskin 1977, Northridge et al. 1995, Read & Westgate 1997).

Over the last decade, there has been significant development within the tidal Thames, including the new Tideway Tunnel, offshore windfarms and the London Gateway "super port", in addition to increased levels of shipping. Harbour porpoises are threatened throughout their range by incidental bycatch in fishing gear (Donovan & Bjørge 1995), disturbance from shipping (Hermannsen et al. 2014; Dyndo et al. 2015) and pile-driving during construction, including for wind farms (Dähne et al. 2013; Brandt et al. 2011; Tougaard et al. 2009). The species is protected under UK and European legislation (including the Marine and Coastal Access Act 2009, Annex II of EU Habitats Directive, the Bonn Convention, UK Biodiversity Action Plan). It is hoped that by confirming both the year-round presence and significant densities of porpoises in the Thames, this study will help to improve the understanding and the conservation of this elusive cetacean and its coastal habitat.

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