Abundance estimates for sperm whales in the Mediterranean Sea from passive acoustic line-transect surveys.

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Introduction

- Sub-population of sperm whales essentially isolated from Atlantic population
- Impacted by a variety of anthropogenic threats especially drift-netting
- Evidence for population decline
- Classified as Endangered by IUCN

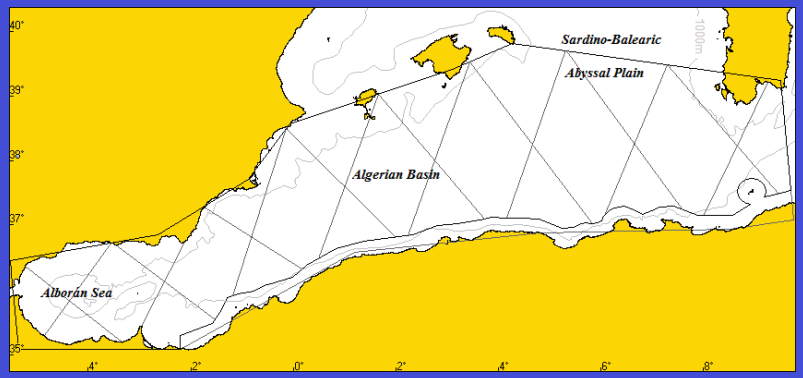
- Need data to assess population distribution and size to inform conservation actions
- ACCOBAMS 1st Meeting of Parties - resolution to conduct survey of Med for sperm whales
- Invitation from ACCOBAMS to develop method and conduct pilot survey in Ionian 2003.
- Further surveys in 2004 (SW) & 2007 (E)

- Sperm whales uniquely suited for survey by passive acoustics

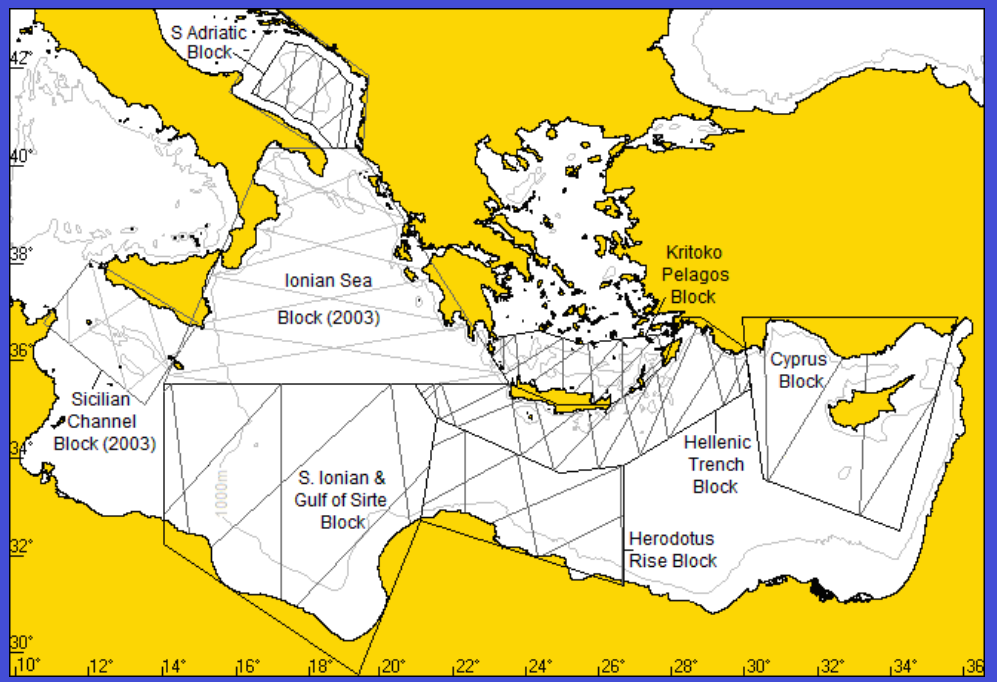
Loud regular clicks while dived => high detection range, low availability bias - unlikely to be missed, located before responsive movement, sharp click => precise angle.

Survey Design

- Subdivision in to strata – based on anticipated density and design practicalities
- Equal-spaced zigzag – efficient and near even coverage probability
- Random start
- Complimentary sets of transect
- Perpendicular to bathymetry – across anticipated density gradients



SW Med : 4,279 km



E Med : 16,816 km

Field protocol

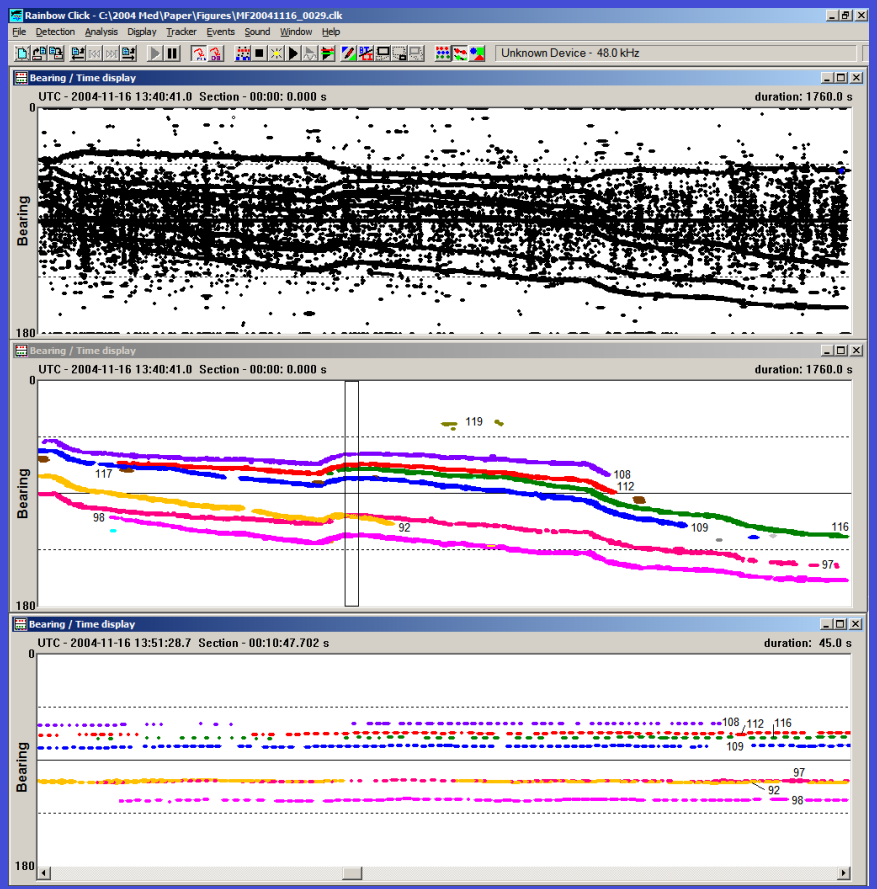
- Survey speed 7 knots (≈ 3 x speed of sperm whale)
- 24 hours a day
- Only break from survey track when last whale >6.5 km behind vessel
- 10° zigzags when whales detected

Acoustic data collection

- Quiet vessel (▲range, ▼disturbance)
- Two-element towed hydrophone
- Continuous WAV recordings
- Real time detections for zigzagging

Acoustic data analysis

- WAV files => Rainbow Click => CLK files
- Manually assign SW clicks => click trains (using bearing, ICI, spectral characteristics, etc)
- Link trains => whales
- Gaps = surfacing, recycling air, falling below detection threshold e.g. change in orientation



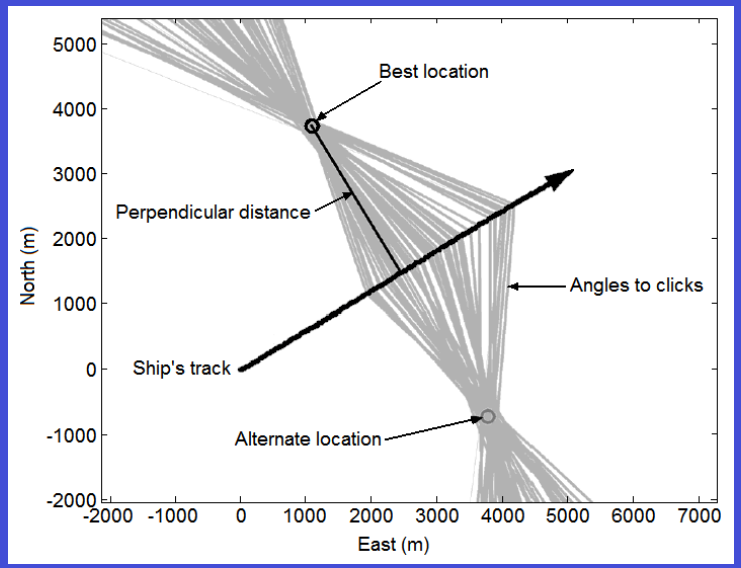
Candidate SW clicks in time bearing space for 30 mins

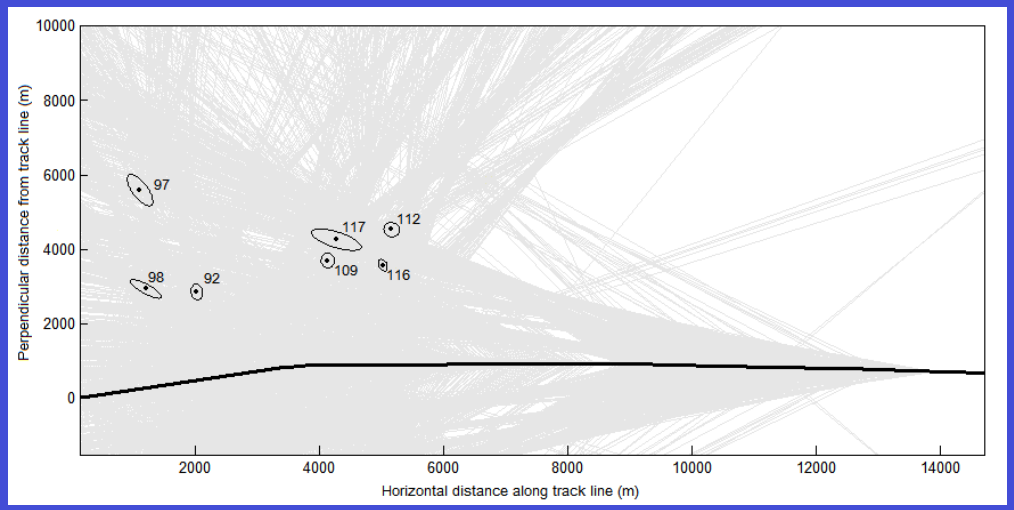
Assignment SW clicks to click trains and whales – 9 whales

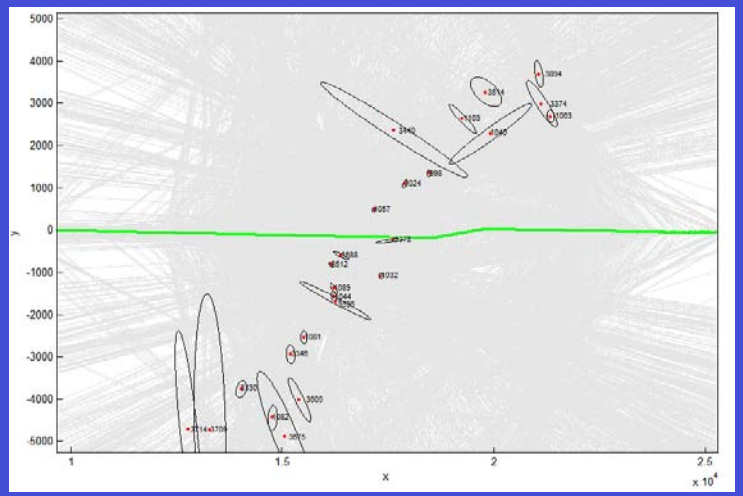
Zoomed – showing coincident whales

Perpendicular Distances

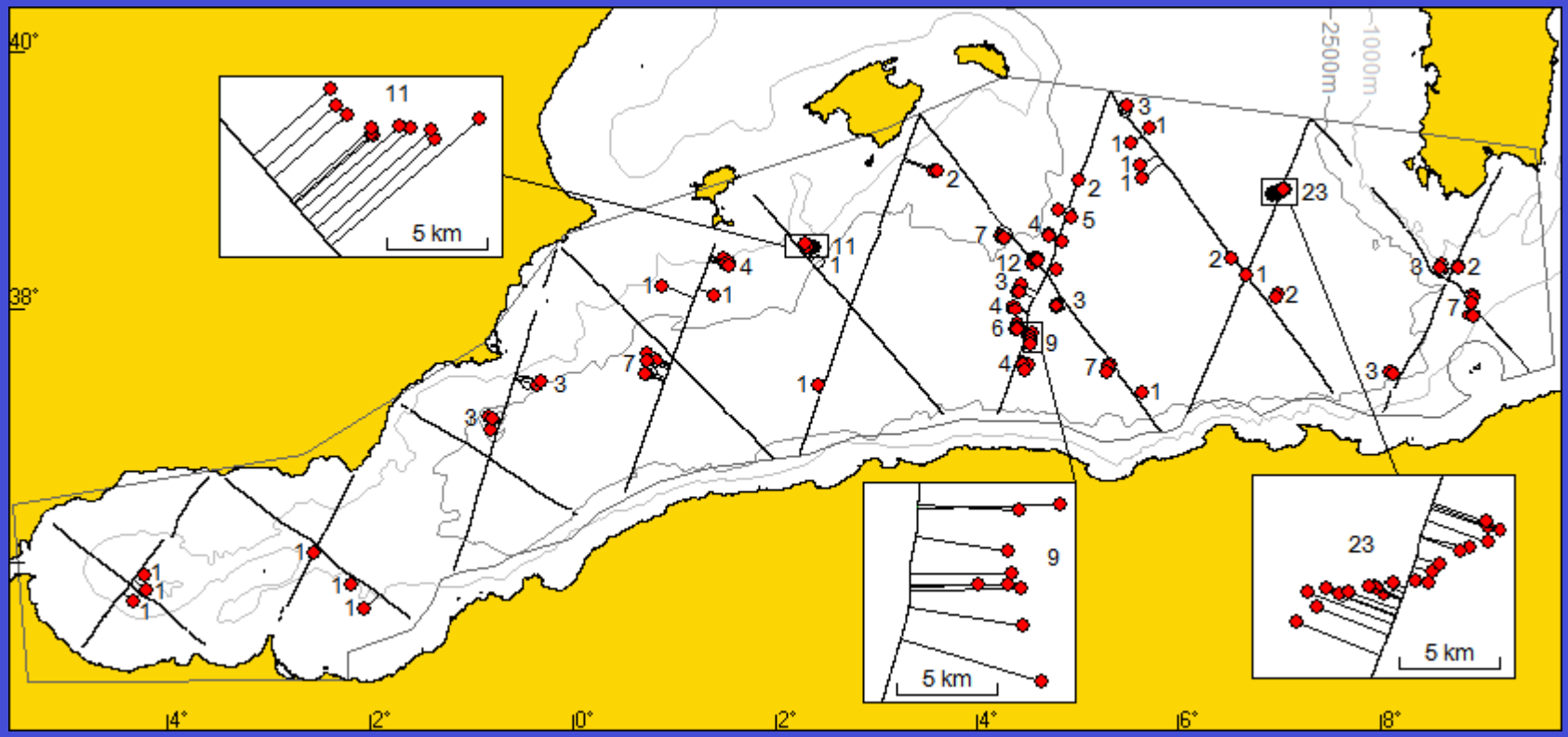
- Time of arrival differences => angle
- Maximum-likelihood estimation routine => distance of each animal from track at surface
- Select side with highest likelihood
- Calculate error ellipse 95% Conf. Limits
- Use error measure to reject animals





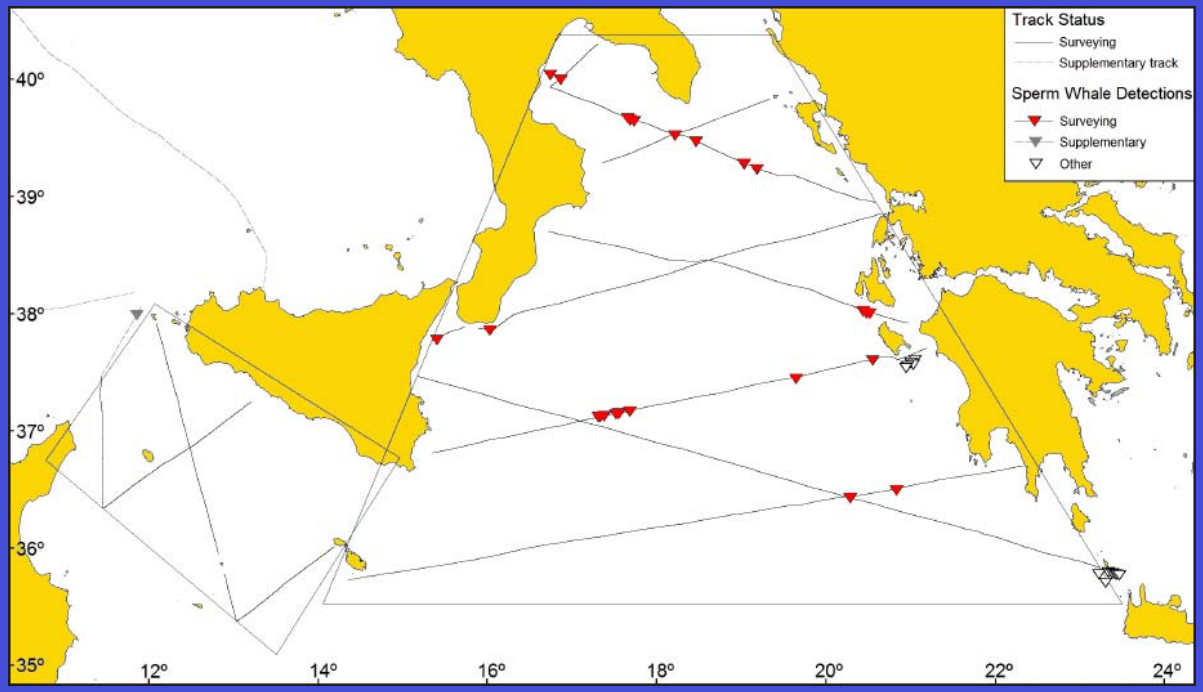


SW Mediterranean



- 159 detected whales
- Concentration of animals in central abyssal waters
- Locations associated with the continental slope
- Aggregations, some linear, large ≥ 23 animals

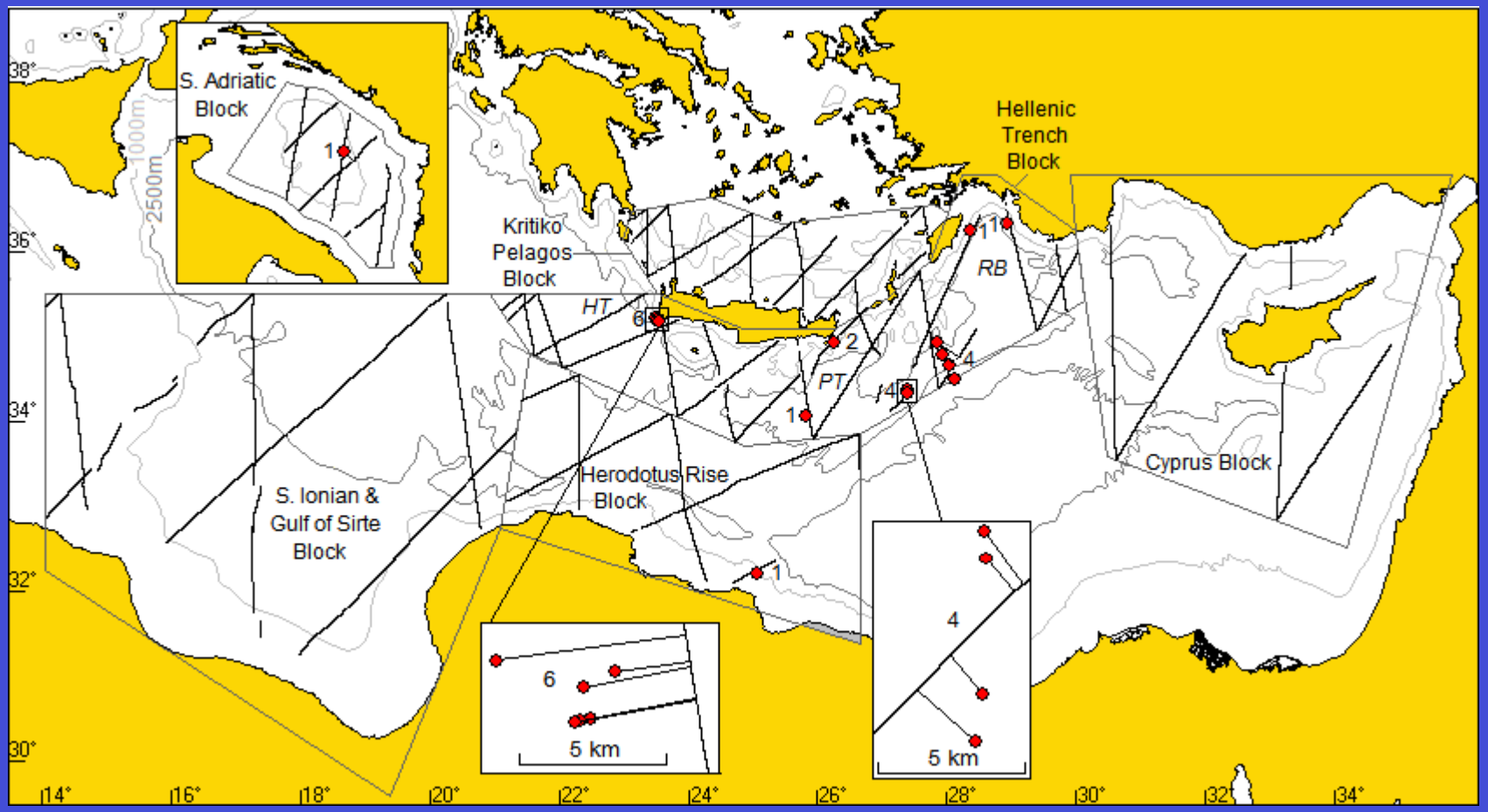
Ionian Sea and Sicilian Channel



17 animals as singles or small groups

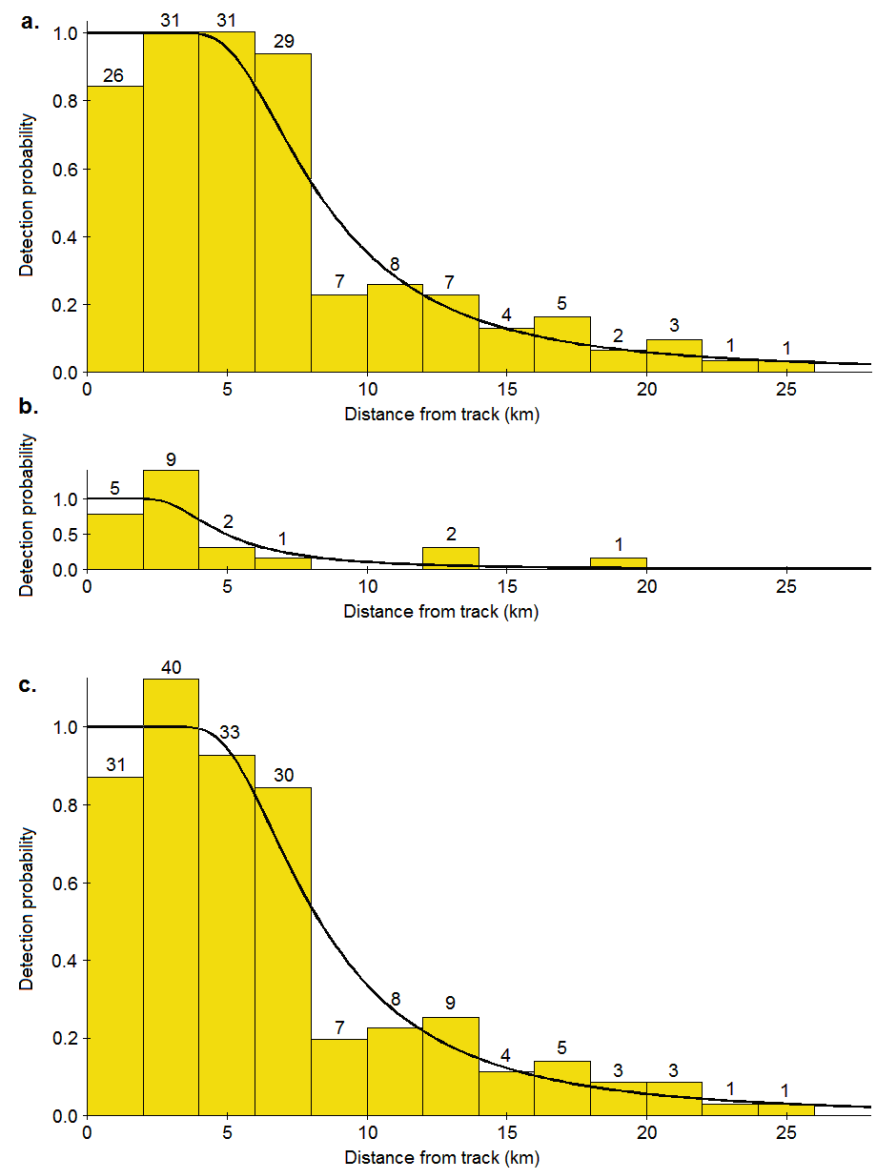
Larger groups detected on passage along W Greece

Eastern Mediterranean and S Adriatic



- Hellenic Trench = 19
- Herodutus Rise Block = 1
- Southern Adriatic = 1
- All others = 0

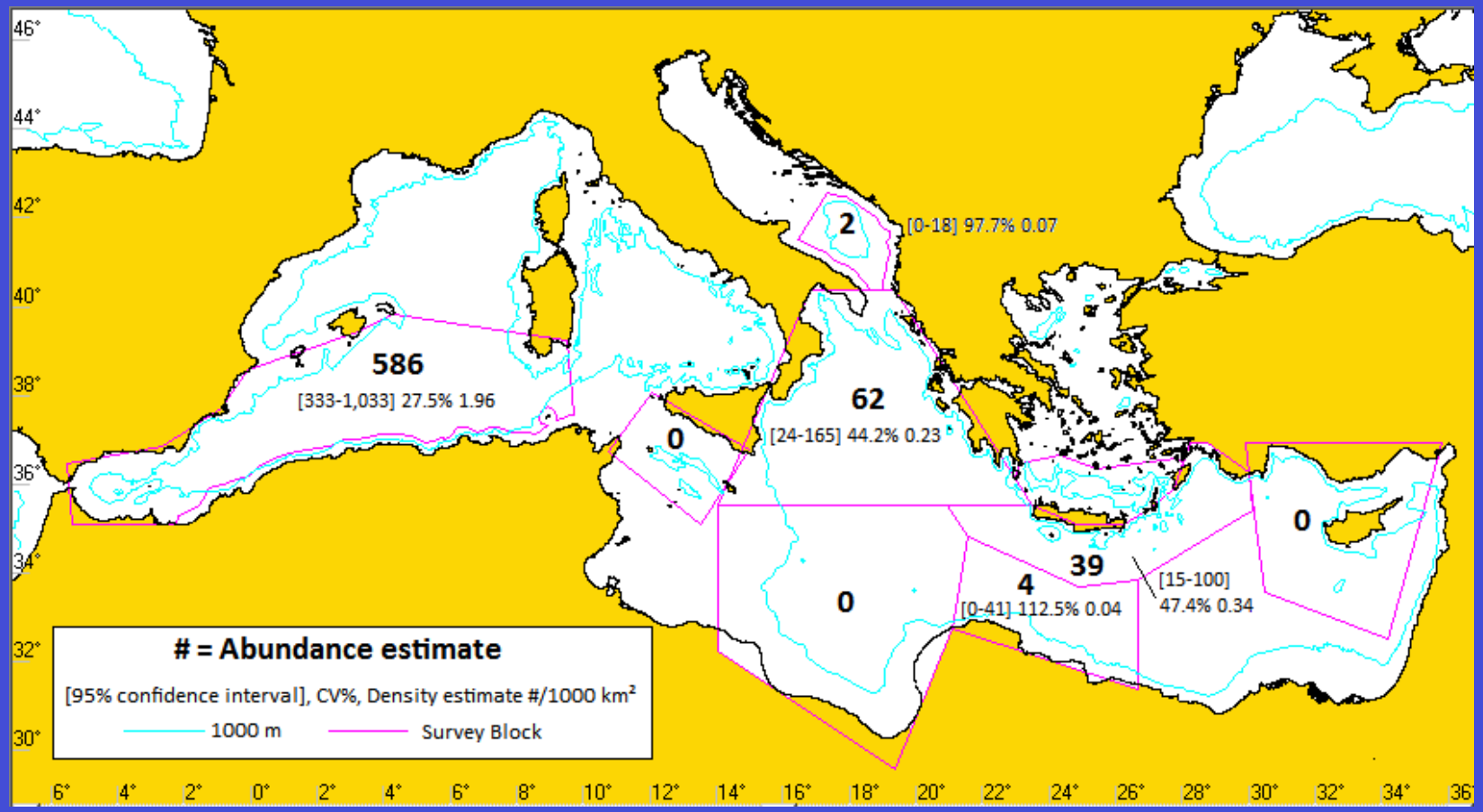
Detection function determination



- Individuals used rather than clusters
- Truncation distance 28 km
- Hazard Rate with no adjustments terms
- E Med low numbers => High ESW CV
- Pooled with SW Med for Detection Function

Region	Number of whales (after truncation)	Effective strip half-width (ESW) (km)	ESW coefficient of variation	ESW 95% confidence interval (km)
SW Mediterranean	155	10.0	8.5%	8.5 - 11.8
E Mediterranean (pooled)	20	6.2	28.2%	3.5 - 11.1
SW & E Mediterranean (pooled)	175	9.8	8.0%	8.4 - 11.5

- Function shape



Abundance estimates for surveyed areas:	
SW Basin:	586
E Basin:	107
Total surveyed area	**691**

Summary

- SW Med : 1.96 whales per 1,000 km²
- E Med : 0.10 whales per 1,000 km²
- SW Med 20x density of E Med
- Hellenic Trench block: densest 0.34 whales per 1,000 km²
- Ionian Sea block: with 0.23 whales per 1,000 km²
- Virtually none outside these two areas

Thanks

- Support of ACCOBAMS especially Marie-Christine Grillo-Compulsione & Giuseppe Notarbartolo di Sciara
- Advice from many fellow researchers especially Ana Cañadas, Alexandros Frantzis and Jonathan Gordon.
- Thanks to countries for providing permits.
- Thanks to numerous fieldworkers & organisations:

  Marta Azzolin (University of Torino, Italy), Myriam Ben Abid (Institut National des Sciences et Technologies de la Mer, Tunisia), Duncan Borg (Malta Environment and Planning Authority, Malta), Carlo Della Libera (Tethys Research Institute, Italy), Paul Dolder (Department of Environment, Food and Rural Affairs, UK), Najib Elouamari (Institut National de Recherche Halieutique, Morocco), Ruth Esteban (CIRCÉ, Spain), Mahmoud Fouad (Nature Conservation Sector, Egypt), Christina Francia (Tethys Research Institute, Italy), Veronica Frank (IFAW EU Office, Belgium), Popi Gikopoulou (Pelagos Research Institute, Greece), Gudjon Andri Gylfason (University of Iceland, Iceland), Mark Hadley (IFAW & University of Southampton, UK), Hildur Harðar (North Sailing, Iceland), Andrew Howard (IFAW, UK), Aliki Kaltsidou (Pelagos Research Institute, Greece), Pilar Marcos (Alnitak Project, Spain), Géraldine Montpelier (IFAW EU Office, Belgium), Hanna Nuutilla (Bangor University, UK), Evelyn Philpott (IFAW & University College Cork, Ireland), Alessia Scuderi (Tethys Research Institute, Italy), Arda Tonay (Turkish Marine Foundation, Turkey), Eda Topcu (Turkish Marine Foundation, Turkey), Joseph Vella (The Biological Conservation Research Foundation, Malta), Masha Vorontsova (IFAW, Russia), Ursula Woodburn (IFAW EU Office, Belgium).

Issues: g(0) = 1 ?

- Many joint visual & acoustic surveys - detections precede all sightings
- Med tags => 97% of time in normal dive cycles
- ≈75% of normal dive cycle clicking
- For 8 km range, male travelling at 4.6 km/hr would need to be quiet for 74 mins stationary or for 55 mins travelling in opposite direction

- However, some evidence of longer quiet surface periods & quiet drift-dives.

- => g(0) = 1 or close to 1

Slant angle

- Slant distance rotated to surface > actual perpendicular distance, worst close to track
- Gives notch and heaping
- Bias is negligible as Hazard rate model smoothes distortion
- Methods to avoid:
  - Alternate 'floor' or depth distribution function
  - Enhanced target-motion analysis
  - 3D array
  - Enhance analysis theory (line-transect / point survey)

Linking click trains

- Gaps to link across:
  1. Recycling air - short
  2. Surfaced – using trajectory, gap, click characteristics, etc – ↑ subjectivity ↑ numbers & ↑ distance
  3. Drops below detection – depends on length – tend to be distant animals

- Gaps of type 2 lend self to a probabilistic approach – where dive behaviour is modelled - Matthews
- Data here uses manual approach

Absolute Abundance Guestimate

- W Med: 1,092,000 km² x 1.96 ≈ 2140?
- E Med: 107?
- Gulf of Cadiz 47?
- Total ≈ 2294

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Issues

- $g(0) = 1$?
- Slant angle
- Linking click trains