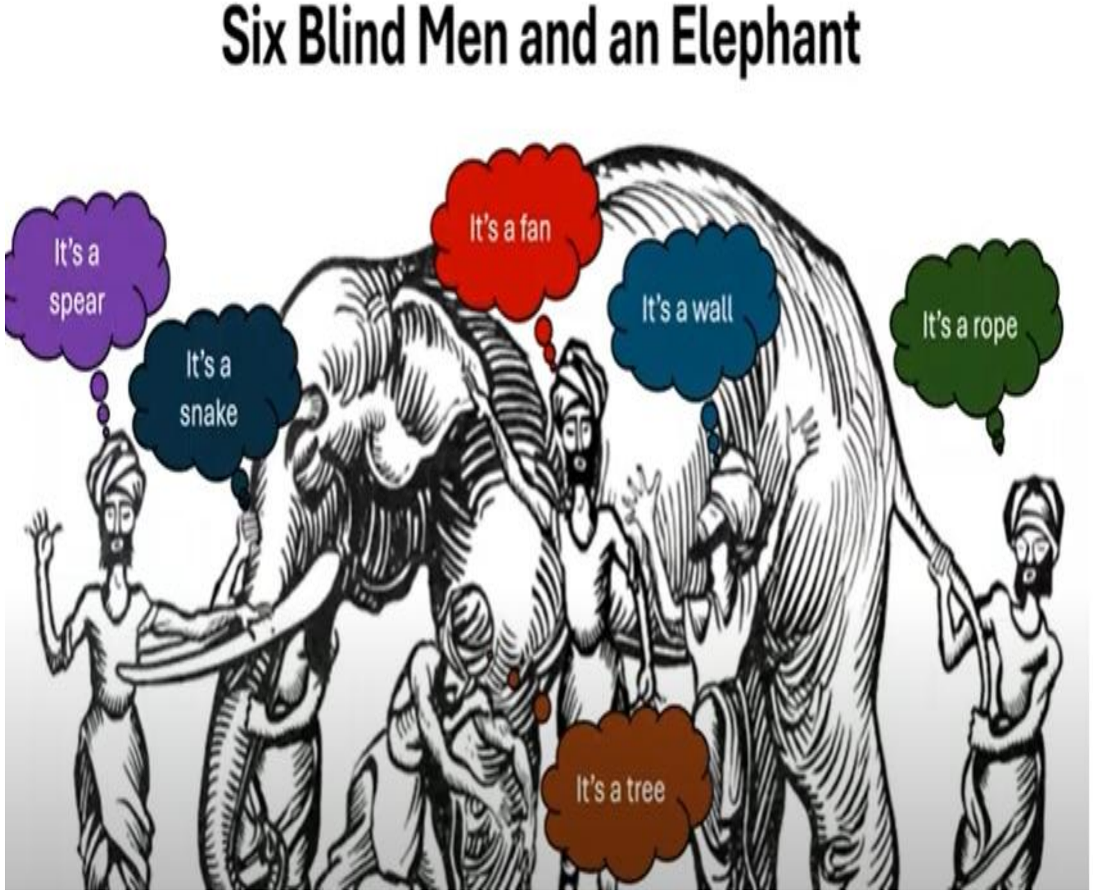
Unit Stock Identification & Fisheries Management



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15 th WPNT , 2025

Eden Bleu

Seychelles

The Stock concept

- When describing the dynamics of an exploited aquatic resource , a fundamental concept is that of the “stock”.
- A stock is a sub set of a species ,which is generally considered as the basic taxonomic unit.
- A prerequisite for the identification of stocks is the ability to distinguish between different species.

The Stock concept

- Cushing defines a fish stock as one that has a single spawning ground to which the adults return year after year.

- Larkin defines a stock as “ a population of organisms which , sharing a common gene pool , is sufficiently discrete to warrant consideration as a self- perpetuating system which can be managed.

The Stock concept

- Ihsen et al.(1981) define a stock as “ an intraspecific group of randomly mating individuals with temporal or spatial integrity.
- Ricker defines a fish stock as the “part of a fish population which is under consideration from the point of view or potential utilization.This definition reflects a completely different approach to the stock concept.

Gulland definition

- The most suitable definition in the context of fish stock assessment was given by Gulland (1983) who stated that for fisheries management purposes the definition of a "unit stock" is an operational matter. A sub-group of a species can be treated as a stock, if possible, differences within the group and interchanges with other groups can be ignored without making the conclusions reached invalid.

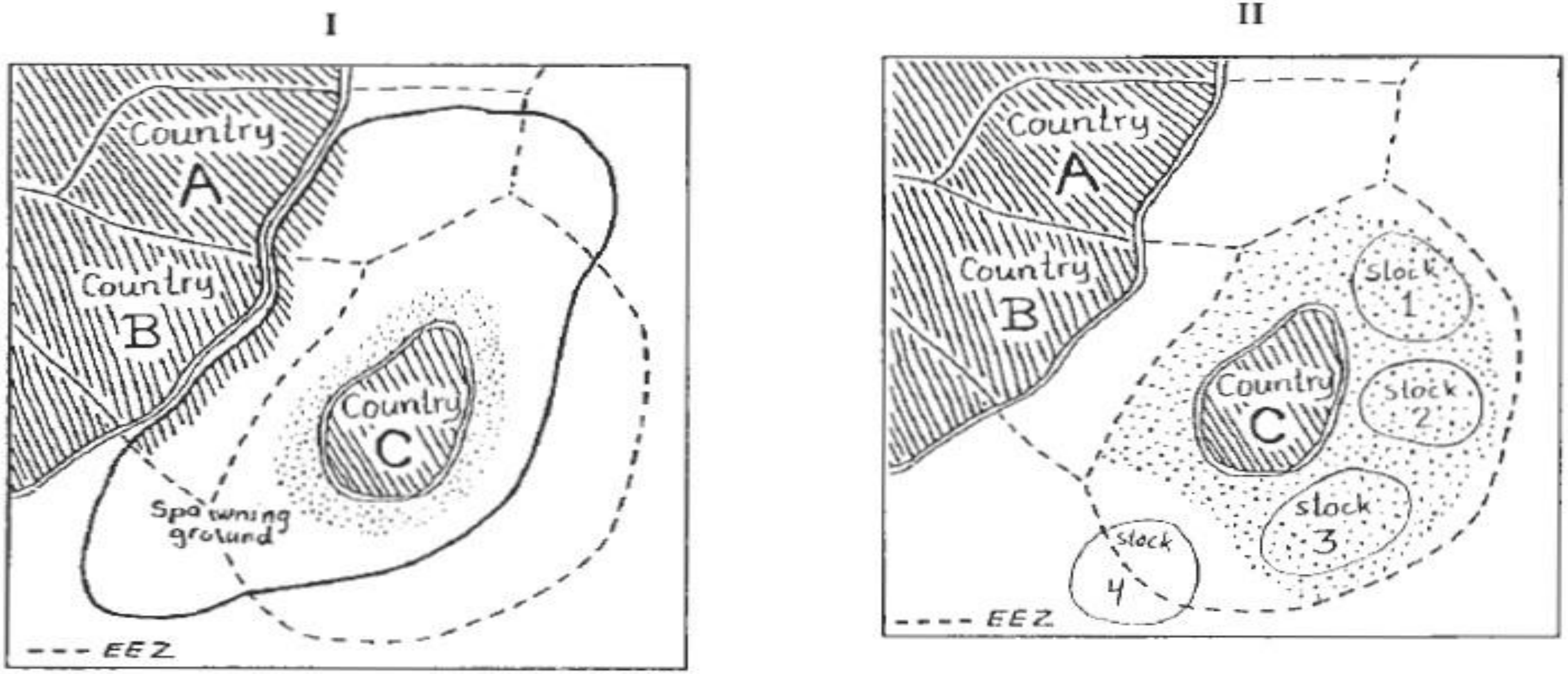
Gulland definition

- This means to start by making stock assessment over the entire area of distribution of a species , as long as there are no indications that separate unit stocks exist in that area. The identification of separate stocks is a complex matter , which usually requires many years of data collection and analysis.

What is a population?
Hilborn & Walters , 1992

- Much fisheries management is based on the presumption that the most important biological entity or element or unit of monitoring and regulation is the single species unit stock. A unit stock is an arbitrary collection of populations of fish that is large enough to be essentially self-reproducing (abundance changes are not dominated by immigration and emigration), with members of the collection showing similar patterns of growth, migration, and dispersal.

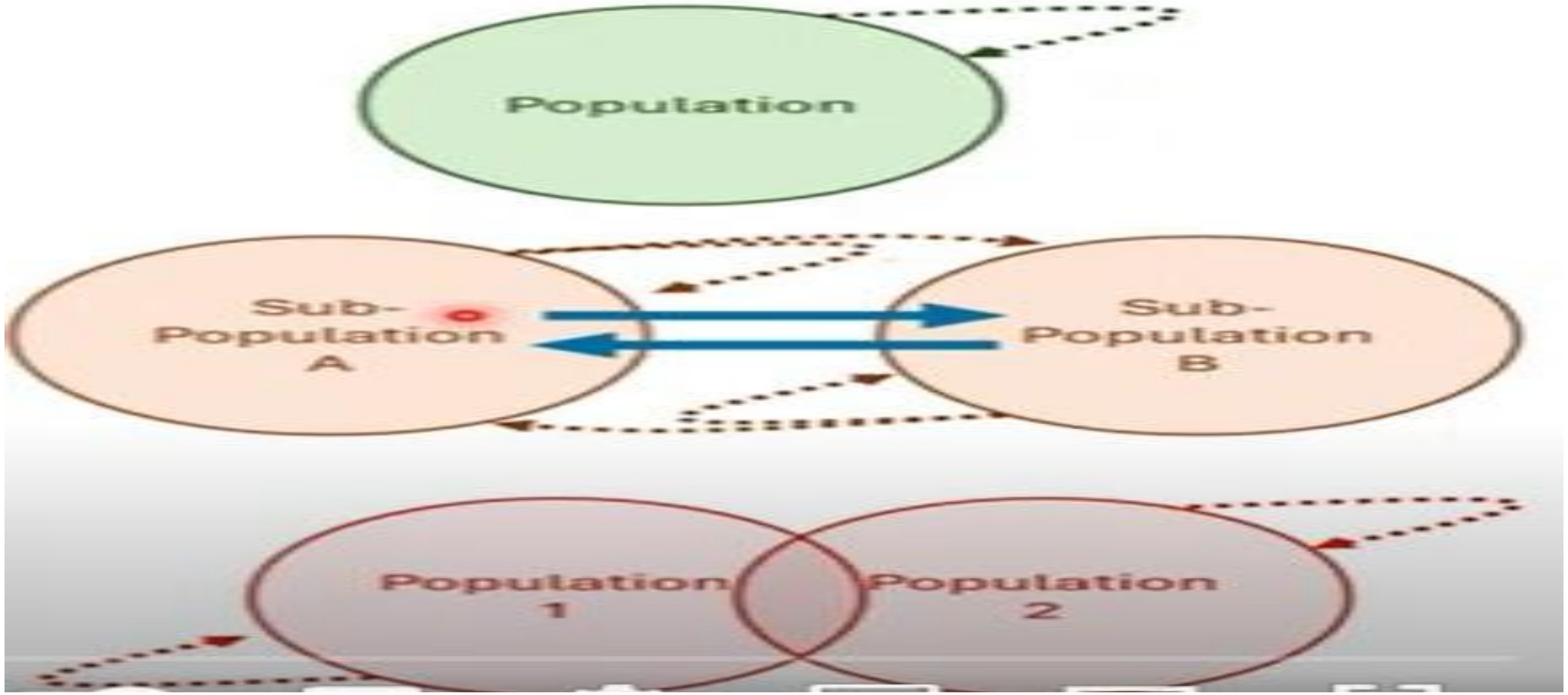
Fig : Distribution of stocks related of management problems



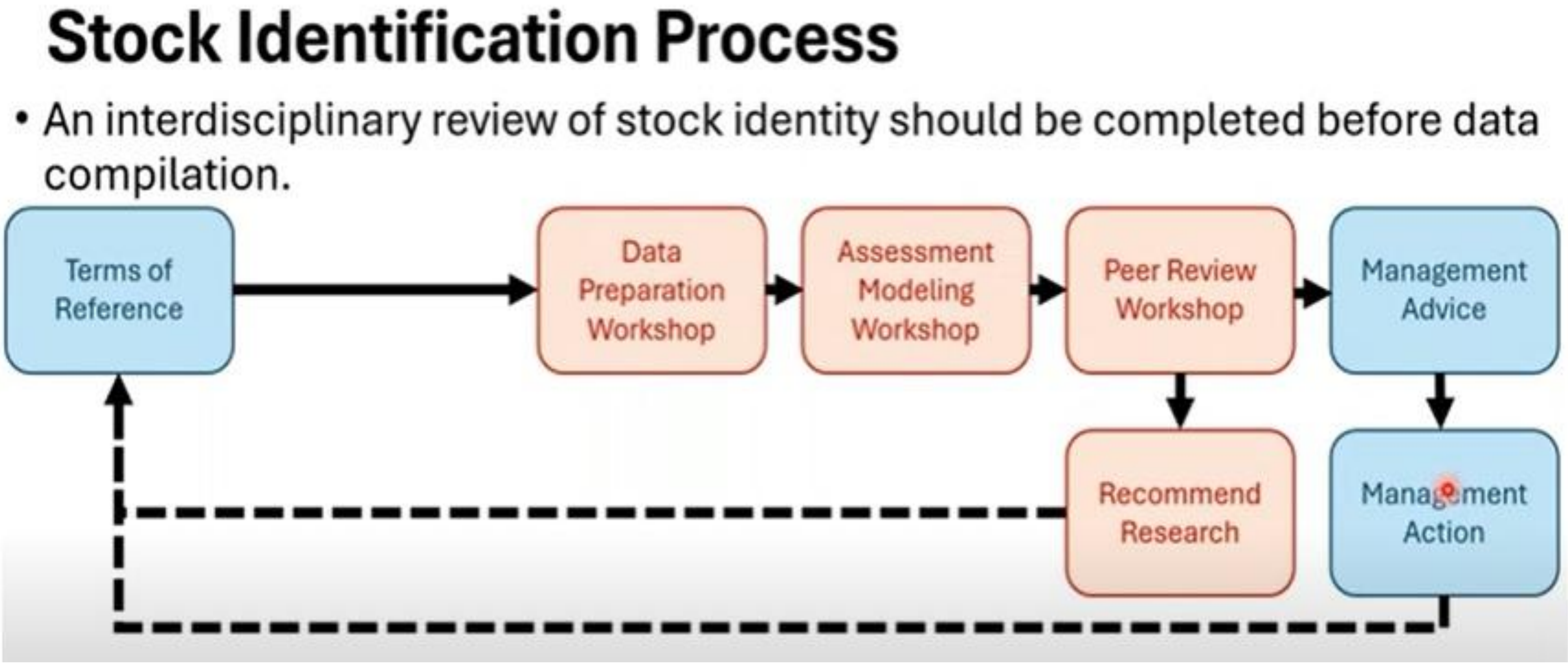
Distribution of stocks related of management problems

- From a fisheries assessment and management viewpoint, it is important to determine whether two adjacent stocks are either sufficiently interactive to be regarded as a single unit stock, or independent enough to be treated as separate unit stocks.

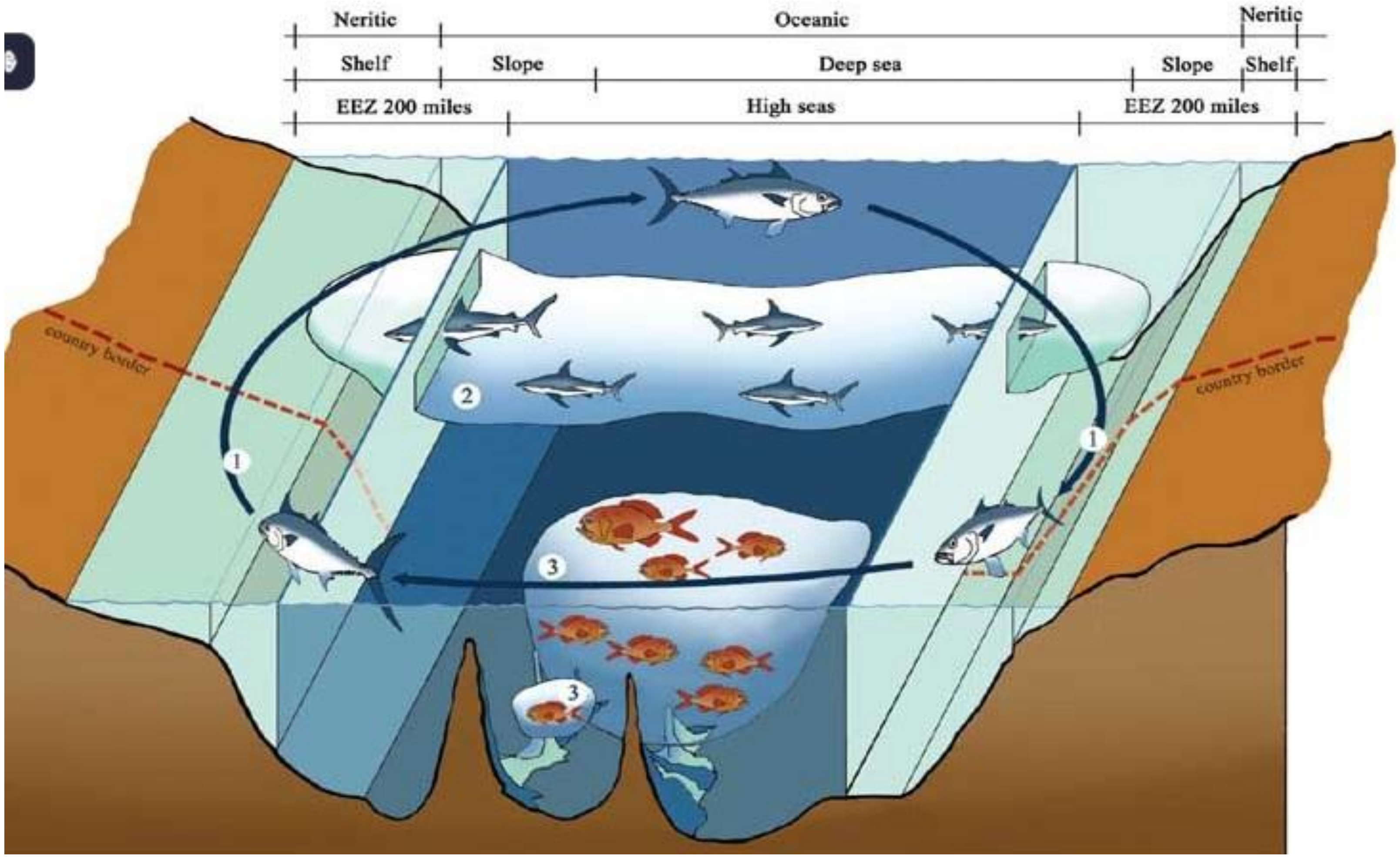
Population & Sub - Population



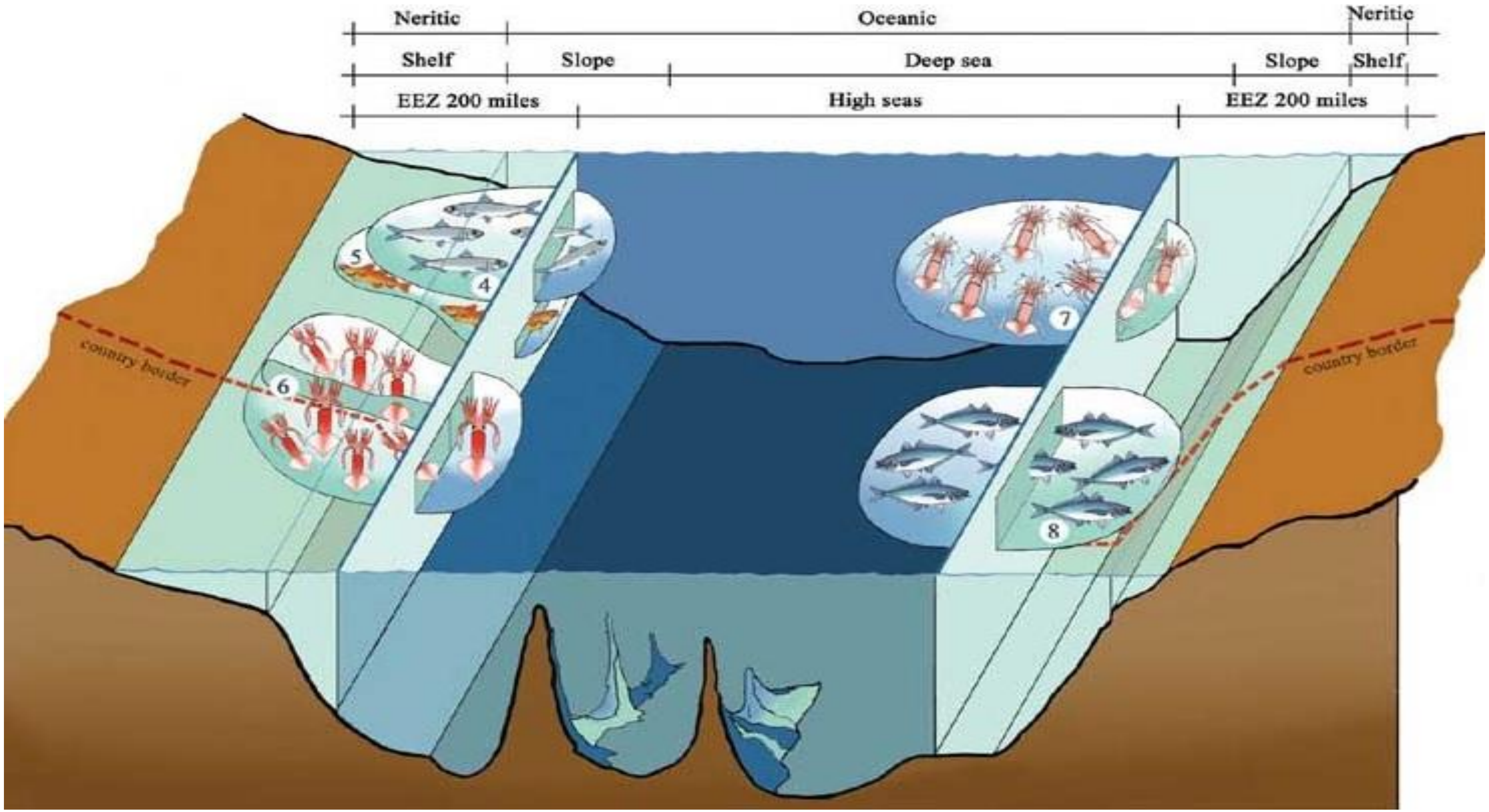
Stock Identification Process



Types of stocks occurring partially or entirely in the high seas. Top panel: 1. Highly migratory; 2. Straddling (extensive distribution); 3. High seas. Bottom panel



4. Pelagic straddling (mostly within EEZ); 5. Demersal straddling (mostly within EEZ); 6. Straddling (transboundary); 7. Straddling (mostly in high seas); 8. Straddling (evenly distributed)



Stock identification methods working group SIMWG , 2022

INTERNATIONAL COUNCIL FOR THE EXPLORATION OF THE SEA

- Genetics
- Growth marks in calcified structures
- Life history parameters
- Morphometrics/ meristics (Geometric morphometrics (GMM)
- Tagging
- Otolith shape
- Otolith chemistry
- Parasites
- Simulation approaches
- Interdisciplinary approaches
- Emerging issues

Genetic Studies

Fisheries studies and management are concerned with a unit stock, which may be defined as a discrete group of individuals that has the same gene pool, is self-perpetuating, and has little connection with adjacent groups of the same species.

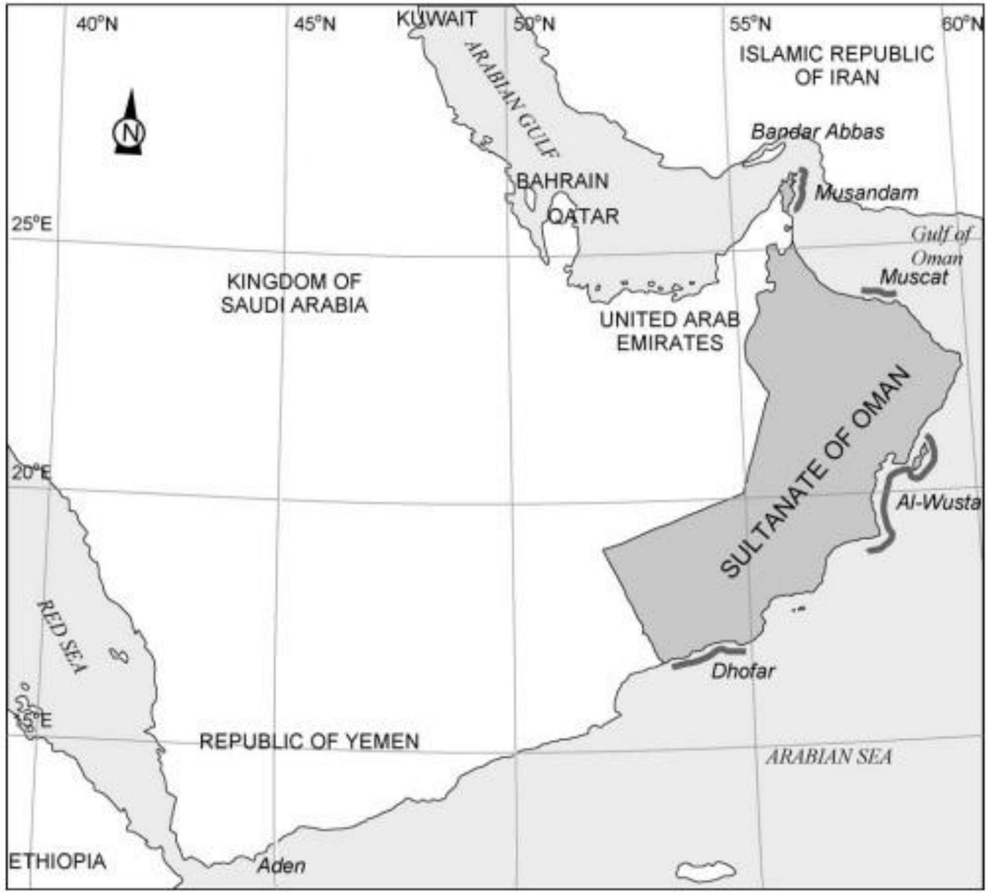
Population genetic studies

- Development and application of microsatellite markers for *Scomberomorus commerson* (Perciformes; Teleostei) to a population genetic study of Arabian Peninsula stocks

van Herwerden et al., 2006

Sampling area
van Herwerden et al., 2006

- Map of the Arabian Peninsula indicating the six sites in each of the four geographic locations within Oman, Iran and Yemen, where samples of *S.commerson* were taken for the population genetics study.



Abstract
van Herwerden et al., 2006

- We developed microsatellite markers for *Scomberomorus commerson*, and use these in a population genetic study of this species from the Arabian Peninsula. Samples were taken from six sites within four geographic regions: Iran (Persian Gulf), two sites in northern Oman (Gulf of Oman), two sites in southern Oman (Arabian Sea) and Yemen (Gulf of Aden). A total of 26 markers were developed. Of these, five produced polymorphic PCR products which amplified all six populations. These five markers were used to assess genetic differentiation from 50 individuals at each site. Genetic differentiation, as measured by the fixation index, Fst or Φst, was determined to estimate stock structure.

Abstract
van Herwerden et al., 2006

- The results identified two genetic stocks, one restricted to one locality (Dhofar) in the Arabian Sea, the other widespread with sufficient gene flow between all four regions to prevent regional genetic differentiation from occurring. Almost 99% of the genetic variation was within populations ($p < 0.001$). It is however advisable to consider additional, more conventional stock structure methods to determine management strategies as conventional measures of stock structure operate at ecological rather than evolutionary time scales, unlike genetic methods based on neutral markers and genetic drift.

Genetic studies

- Patterns of genetic isolation in a widely distributed pelagic fish, the narrow-barred Spanish mackerel (*Scomberomorus commerson*)

Fauvelot & Borsa , 2011

Fauvelot & Borsa , 2011

- Although migratory pelagic fishes generally exhibit little geographic differentiation across oceans, as expected from their life-history (broadcast spawning, pelagic larval life, swimming ability of adults) and the assumed homogeneity of the pelagic habitat, exceptions to the rule deserve scrutiny. One such exception is the narrow-barred Spanish mackerel (*Scomberomorus commerson*), where strong genetic heterogeneity at the regional scale has been previously reported. We investigated the genetic composition of *S. commerson* across the Indo-West Pacific range using control-region sequences (including previously published datasets), cytochrome-b gene partial sequences, and eight microsatellite loci, to further explore its phylogeographic structure.

Abstract
Fauvelot & Borsa , 2011

- All haplotypes sampled from the Indo-Malay-Papua archipelago (IMPA) and the southwestern Pacific coalesced into a clade (Clade II) that was deeply separated (14.5% nucleotide divergence) from a clade grouping all haplotypes from the Persian Gulf and Oman Sea (Clade I). Such a high level of genetic divergence suggested the occurrence of two sister-species. Further phylogeographic partition was evident between the western IMPA and the regions sampled east and south of it, i.e. northern Australia, West Papua, and the Coral Sea.

Abstract
Fauvelot & Borsa , 2011

- Strong allele-frequency differences were found between local populations in the southwestern Pacific, both at the mitochondrial locus (ΦST=0.282-0.609) and at microsatellite loci (^θ=0.202-0.313). Clade II consisted of four deeply divergent subclades (9.0-11.8% nucleotide divergence for the control region; 0.3-2.5% divergence at the cytochrome b locus).

Abstract
Fauvelot & Borsa , 2011

- Mitochondrial sub-clades within Clade II generally had narrow geographic distribution, demonstrating further genetic isolation. However, one particular haplogroup within Clade II was present throughout the central Indo-West Pacific; that haplogroup was found to be sister-group to an haplogroup restricted to West Papua and the Coral Sea, yielding evidence of recent secondary westward colonization. Such a complex structure is in sharp contrast with the generally weak phylogeographic patterns uncovered to date in other widely distributed, large pelagic fishes with pelagic eggs and larvae. We hypothesize that in *S. commerson* and possibly other Scomberomorus species, philopatric migration may play a role in maintaining the geographic isolation of populations by annihilating the potential consequences of passive dispersal.

Molecular analysis

Stock identification of frigate tuna (*Auxis thazard*) and bullet tuna (*Auxis rochei*) populations of Sri Lankan waters

IOTC-2024-WPNT14-20

Herath et al.,2024

Herath et al.,2024

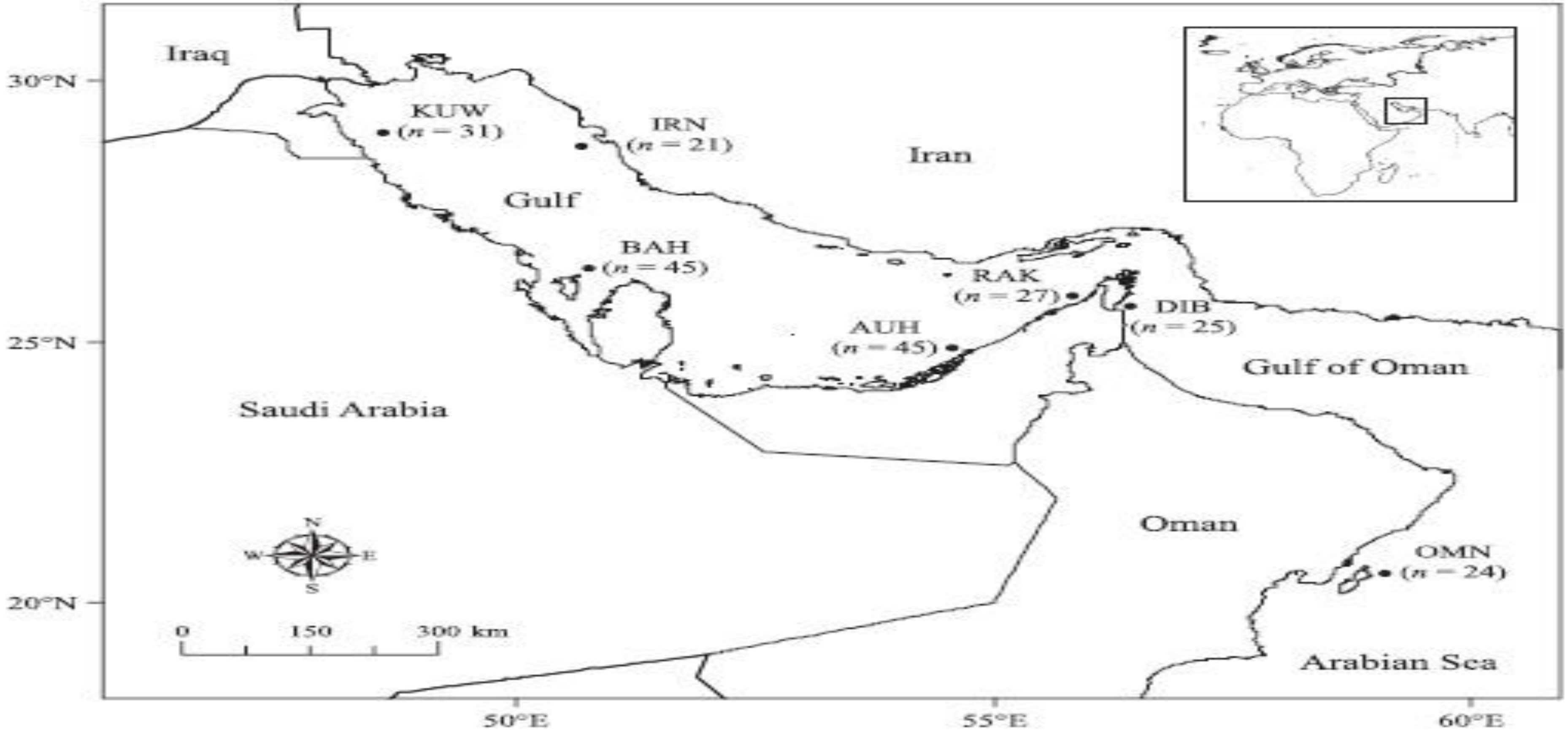
- The stock structure analysis using molecular markers involved the sequencing of the mitochondrial COI gene and the mitochondrial D-loop region. The phylogenetic analysis for both species showed that between populations, the haplotype diversity was high while the nucleotide diversity was low.

Mitochondrial DNA analyses

Mitochondrial DNA analyses of narrow-barred Spanish mackerel (*Scomberomorus commerson*) suggest a single genetic stock in the ROPME sea area (Persian Gulf, Gulf of Oman, and Arabian Sea)

Hoolihan et al.,2006

Hoolihan et al.,2006



Hoolihan et al.,2006

- We studied the genetic stock structure of *Scomberomorus commerson* (locally called kingfish) using restriction fragment length polymorphism (RFLP) and direct sequencing analyses of mtDNA samples from seven locations within the ROPME sea area (Persian Gulf, Gulf of Oman, and Arabian Sea).

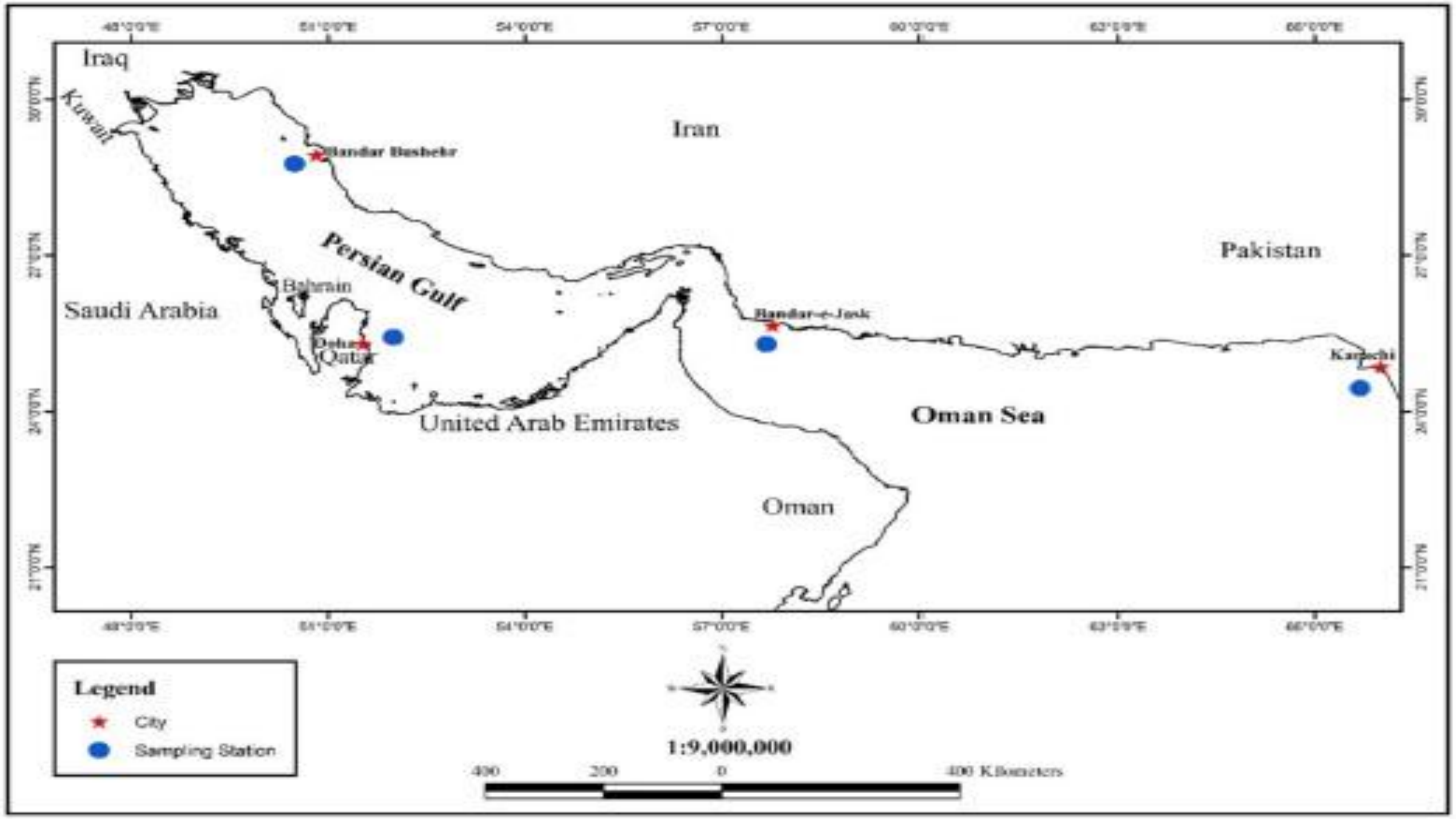
Hoolihan et al.,2006

- The results cautiously suggest that adopting a single-stock model and regional shared management are appropriate for sustainable long-term use of this important resource. More rigorous genetic testing using additional neutral markers, and mark-recapture experiments to detect spatial movement patterns, are recommended to further elucidate any stock substructure.

Mansour Kiai et al., 2016

- Phylogenetic relationships of *S. commerson* using sequence analysis of the mt DNA D-loop region in the Persian Gulf , Oman Sea & Arabian Sea

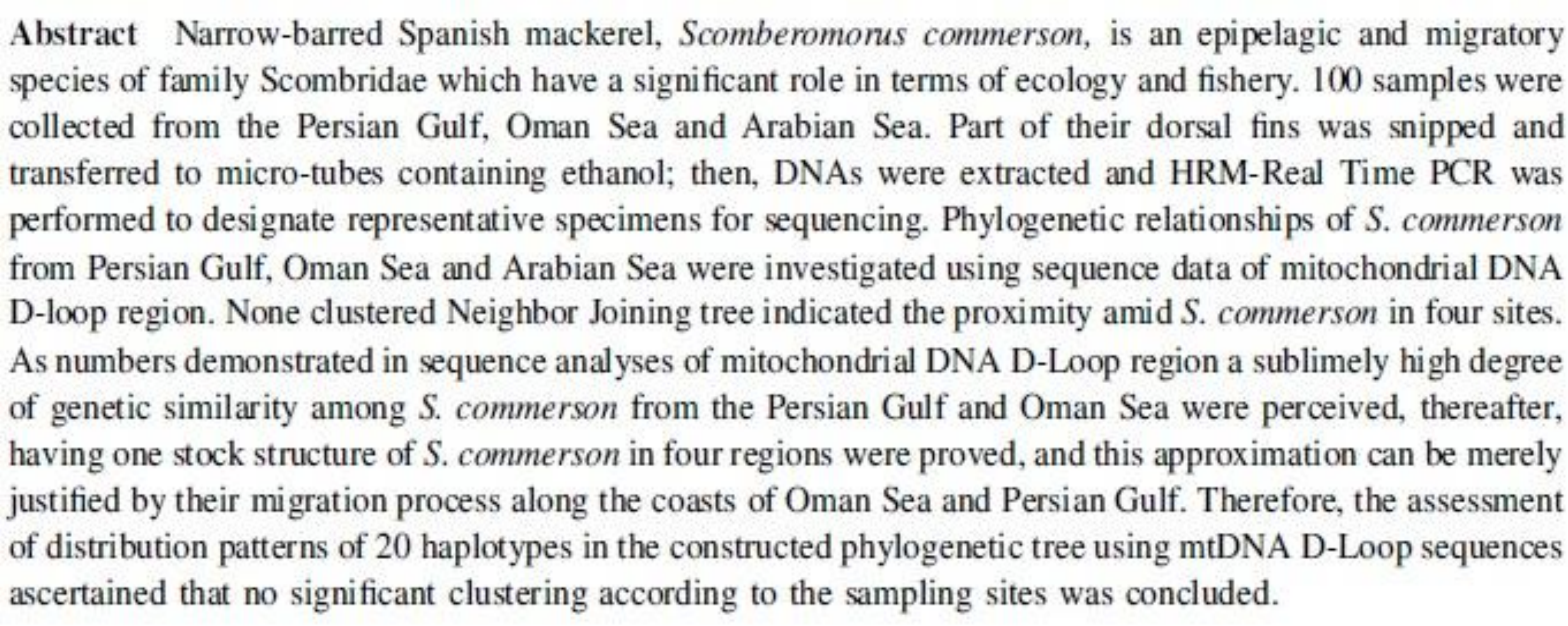
Four sampling sites in the Persian Gulf , Oman Sea & Arabian Sea
(Blue points: sampling sites)



Mansour Kiai et al., 2016

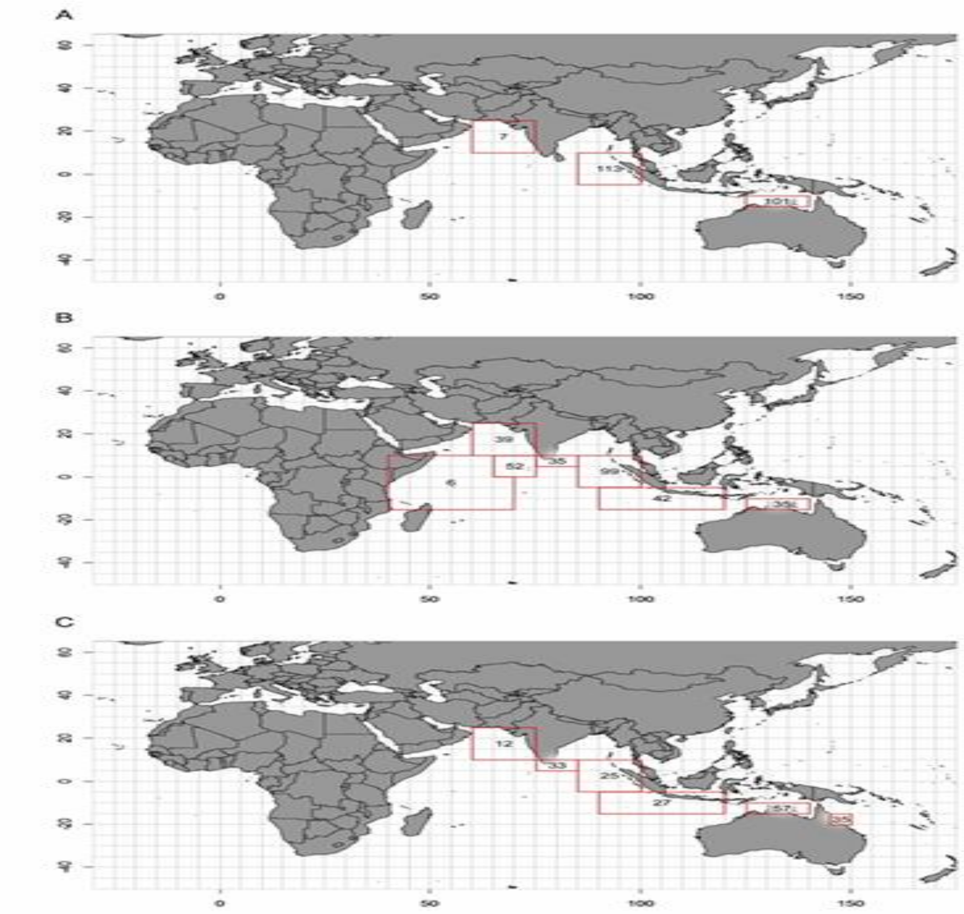
- A total of 100 *S.commerson* specimens were collected by gillnet at four sampling sites: northern Persian Gulf , Doha in southern part , Jask northern part of the Oman Sea and Karachi in the Arabian Sea. Part of the dorsal fin was snipped , preserved in ethanol and stored -20 degree centigrade (Menezes et al.,2012).

Mansour Kiai et al., 2016


Abstract Narrow-barred Spanish mackerel, *Scomberomorus commerson*, is an epipelagic and migratory species of family Scombridae which have a significant role in terms of ecology and fishery. 100 samples were collected from the Persian Gulf, Oman Sea and Arabian Sea. Part of their dorsal fins was snipped and transferred to micro-tubes containing ethanol; then, DNAs were extracted and HRM-Real Time PCR was performed to designate representative specimens for sequencing. Phylogenetic relationships of *S. commerson* from Persian Gulf, Oman Sea and Arabian Sea were investigated using sequence data of mitochondrial DNA D-loop region. None clustered Neighbor Joining tree indicated the proximity amid *S. commerson* in four sites. As numbers demonstrated in sequence analyses of mitochondrial DNA D-Loop region a sublimely high degree of genetic similarity among *S. commerson* from the Persian Gulf and Oman Sea were perceived, thereafter, having one stock structure of *S. commerson* in four regions were proved, and this approximation can be merely justified by their migration process along the coasts of Oman Sea and Persian Gulf. Therefore, the assessment of distribution patterns of 20 haplotypes in the constructed phylogenetic tree using mtDNA D-Loop sequences ascertained that no significant clustering according to the sampling sites was concluded.

Stock identification

Sampling locations of (A) longtail tuna (*T.tonggol*), (B) kawakawa (*E.affinis*) and (C) narrow-barred Spanish mackerel (*S .commerson*).
(IOTC-2020-WPNT10-10)



- A : Three sampling locations
- B : Seven sampling locations
- C : Six sampling locations

Summary of tissue samples used from several locations within the Indian Ocean between 2017 and 2019

Species	No. tissue samples	No. selected for sequencing	No. analysed (past quality control)	Size range analysed (mean) (cm)
LOT	316	298	221	43-103 (75)
KAW	546	362	308	21-68 (40)
COM	256	210	189	18-120 (59)

Stock identification
(IOTC-2020-WPNT10-10)

- Investigation of the genetic population structure of the narrow-barred Spanish mackerel over the last two decades, using either mitochondrial DNA or microsatellite nuclear markers, had already showed evidence of limited connectivity. These studies generally found strong genetic population structure at the regional scale.
- In the Indian Ocean samples from the Persian Gulf and the Oman Sea differ from those found in the Timor Sea (Fauvelot & Borsa, 2011).
- Using microsatellite markers Abedi et al. 2012 did not find any genetic differentiation inside the Persian Gulf, but two different stocks were identified around the Arabian Peninsula (van Herwerden et al., 2006).

Longtail tuna

- Our stockR approach revealed that each of the three sampling locations in the Indian ocean hosts a distinct genetic group, therefore providing the first evidence of population structure of longtail tunas in this region.

- The results of the present study both demonstrate the high detection power of our genotyping approach and highlight the need for further investigation of fine-scale population structure for this species across its full range in the Indian Ocean.

Kawakawa

- The stockR analysis detected the presence of at least two distinct genetic groups amongstthe seven sampling locations. The barrier to gene flow is located between the NEI and the ECI sampling locations. Possible explanations for the higher proportion of individuals with uncertain assignment in these two sampling locations includes: i) ongoing mixing between the two genetic groups still occurs or ii) the divergence is fairly recent and there is incomplete lineage sorting. This also shows that the gene pool is not completely homogeneous on each side of the genetic break.

Narrow-barred Spanish mackerel

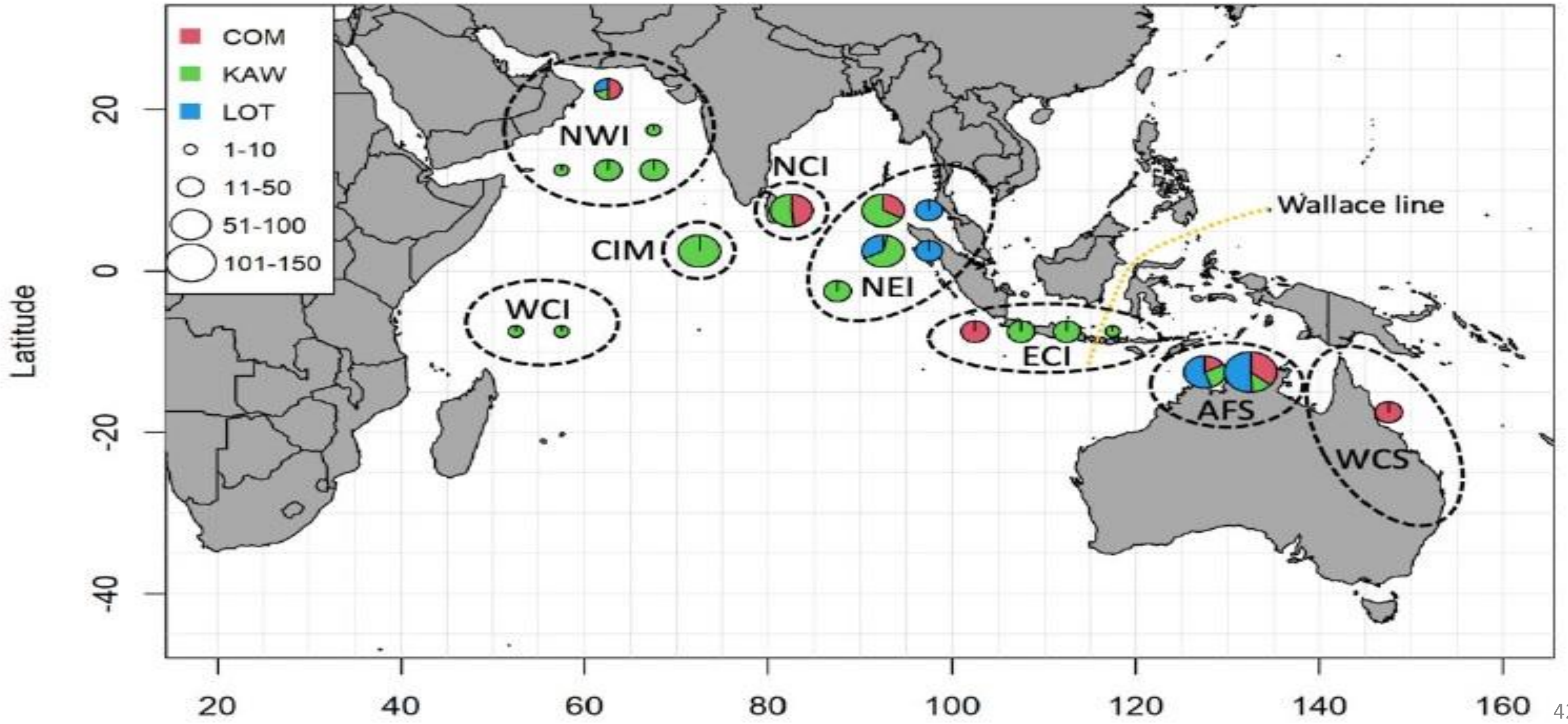
- This study detected a total of four genetic groups amongst five sampling locations within the Indian Ocean, taking the understanding of the narrow-barred Spanish mackerel to a new level, from regional to local.

Population genetic studies

- Genome scans reveal extensive population structure in three neritic tuna (COM , LOT & KAW) in the Indian Ocean

Feutry et al., 2024

Sampling locations and sample sizes of three neritic tuna species



Feutry et al., 2024
Abstract

Neritic tunas and tuna-like species are an important resource for many coastal nations[1] worldwide supporting both commercial and artisanal fisheries, but little is known about their population structure at a spatial scale required for effective fisheries management. In this study, we use Next Generation Sequencing methods to investigate the genetic connectivity of three major neritic tuna and tuna-like species in the Indian Ocean: Longtail Tuna (*Thunnus tonggol)*, Kawakawa (*Euthynnus affinis*), and narrow-barred Spanish mackerel (*Scomberomorus commerson)*. We sampled 293 Longtail Tuna from three locations, 362 Kawakawa from seven locations, and 210 narrow-barred Spanish mackerel from six locations. Genetic data showed clear evidence of heterogeneity in all three species, and patterns of isolation-by-distance were detected in Kawakawa and narrow-barred Spanish mackerel. Pairwise F_{ST} estimates of population differentiation and model-based grouping (mixture models) revealed that (i) individuals of Longtail Tuna from each sampling location belonged to a distinct genetic group, (ii) at least two different groups of Kawakawa were identified, and (iii) at least four groups of narrow-barred Spanish mackerel were identified across the sampled range within the north and eastern Indian Ocean. These results demonstrate that neritic tunas exhibit genetic structuring at small to medium spatial scales that need to be considered in the design of monitoring and assessment systems for fisheries management purposes in the northern and eastern parts of their range in the Indian Ocean. Further sampling, at a finer spatial resolution within the range of the current study, and across the north-western and western parts of their range of the Indian Ocean that were not covered in the current study, is required to provide a comprehensive understanding of the number of populations present and the spatial extent of individual populations in the Indian Ocean and adjacent seas.

Hard part
Otolith Studies

- Otolith chemistry analysis for fish identification relies on understanding how trace elements are incorporated into the otoliths (ear stones) during growth, as these elements reflect the fish's environment and life history. Key requirements include proper otolith preparation, understanding elemental incorporation, and establishing baseline data for comparison.

Otolith

- In addition, the shape and morphometry of the otoliths are valuable for identifying fish species and discriminating fish stocks (Tuset et al., 2008). Otolith morphometry has recently been extensively utilized with the advancements in computing power and image processing. Digital pictures replaced hand-drawn graphics in the 1980s, and image analysis techniques utilizing harmonic expansion and Fourier transform have been employed (Campana and Casselman, 1993; Nikiforidou et al., 2023).

- For otolith microchemistry studies aimed at identification and tracing, key instruments include those for sample preparation, elemental analysis, and data analysis. These typically involve micro milling for precise otolith sampling, laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) for elemental analysis, and various statistical software for data processing.

Breakdown of the instrument requirements

- 1. Sample Preparation

- 2. Elemental Analysis

- 3. Data Analysis

Sample Preparation

- Micromill: This device, like the one from New Wave Research, is used to extract specific portions of the otolith (powder, core, or discrete depths) for analysis. It typically includes a microscope, high-resolution camera, motorized stages, and a milling chuck.
- Polishing Equipment: Otoliths are often polished using lapping film (e.g., 3 µm) to prepare them for analysis.
- Sonicator: Used for detaching otoliths from microscope slides.
- Laminar Flow Cabinet: For drying otoliths after cleaning.
- Microscope Slides and Double-sided Tape: For mounting otoliths for analysis.

Elemental Analysis

- Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS): This is a widely used technique to determine elemental concentrations within the otolith.

- Solution Inductively Coupled Plasma Mass Spectrometry (SO-ICPMS): Another method for elemental analysis, particularly useful for analyzing whole otolith dissolution or specific regions.

- Multi-collector Inductively Coupled Plasma Mass Spectrometry (MC-ICP-MS): Suitable for high-precision isotopic analysis.

Data Analysis

- Statistical Software:

Packages like R, SPSS, or others are used for statistical analysis of the elemental data, including univariate and multivariate techniques.

- Geographic Information System (GIS) Software:

For spatial analysis of otolith data, especially when relating elemental signatures to geographic locations.

- Software for Image Analysis:

If otolith shape analysis is part of the study, software for Elliptical Fourier Descriptors (EFD) or other shape analysis techniques is needed.

Growth marks in calcified structures

- Characteristics of fish ear bones (otoliths) such as weight, dimension, shape, optical density and chemical composition may be stock or species specific. The mean values of such characteristics often differ when samples of fish from different stocks are compared, but the measurements rarely allow individuals to be assigned to specific stocks.

Growth marks in calcified structures
Otolith

- Recently, the application of otolith morphometry, such as geometric morphometry, has been developed to facilitate the determination of breeding grounds and fish stocks, as well as the migratory pathways of various commercially valuable species (de Carvalho et al., 2020). Because the shape and size of otoliths vary among fish species, otolith morphometrics can be used to differentiate individual fish populations and determine the impact of environmental factors on their growth (Begg et al., 2001).

Procedures for otolith shape and size indices calculation

- Otolith size indices, including otolith length (OL; mm), otolith width (OH; mm), otolith perimeter (OP; mm), and otolith area (OA; mm2), were automatically estimated using the ShapeR package. The otoliths were weighed using an Ohaus SPX223 Scout analytical balance. In addition, otolith shape-related indices, including form factor (FF), aspect ratio (AR), ellipticity (E), circularity (C), roundness (RO), rectangularity (RE), and squareness (SQ), were estimated using the equations presented in Table 1 (Tuset et al., 2003; Moore et al., 2022).

Morphological shape indices calculated from otolith size indices

Shape Indices	Formula
Circularity	OP^2/OA
Rectangularity	$OA/(OL \times OH)$
Roundness	$(4OA)/(\pi OL^2)$
Aspect Ratio	OL/OH
Form-Factor	$(4\pi OA)/OP^2$
Ellipticity	$(OL - OH)/(OL + OH)$
Squareness	$OA/(OL \times OW)$

OP, otolith parameter; OA, otolith area; OL, otolith length; OH, otolith height/width; OW, otolith weight.

Chemical otolith composition

- The chemical composition of fish otoliths (i.e. earbones) can be an effective tool to identify nursery areas and thus provide information on stock structure, which is important for determining the appropriate spatial scale at which a species should be managed (Campana 1999, Kerr et al. 2020). This technique has proved to be useful to study the origin and connectivity of yellowfin tuna in other oceans (Wells et al. 2012, Rooker et al. 2016, Kitchens et al. 2018).

Otolith chemistry

- Spatiotemporal structure of narrow-barred Spanish mackerel (*Scomberomorus commerson*) from the Red Sea and Western Indian Ocean based on otolith micro-chemistry

Sougueh et al., 2023

Number , sampling period , size range and estimated ages of fish for all sampling locations

Sampling location	Sampling event code	Number analyzed	Sampling period	Sampling season	Size range (cm)	Number of individuals of size class 70-90 cm	Estimated age (years)*
Egypt (North-RS)	Egy-S	10	May 2019	Summer	70–90	10	1–2
Djibouti-North (South-RS)	Dji-N-W	7	December 2018	Winter	160–180	0	12–14
Djibouti-North (South-RS)	Dji-N-S	9	June 2020	Summer	70–90	9	1–2
Djibouti-South (NW-IO)	Dji-S-W	23	March –Deccember2018	Winter	35–90	17	0.5–2
Somalia (NW-IO)	Som-S	13	August 2020	Summer	50–85	9	0.5–2
Mozambique (South-IO)	Moz-W	20	October 2011	Winter	60–100	13	0.5–3
South Africa (South-IO)	Sa-W	9	May 2011	Winter	60–130	2	0.5–10

* For fish sampled in Egypt, Djibouti and Somalia, the age estimates for males and females refer to the work carried out by Govender et al. (2006) in Oman and for fish caught in Mozambique and South Africa age estimates relate to the paper by Lee and Mann (2017) in the South West Indian Ocean (Mozambique).

Abstract
Sougueh et al., 2023

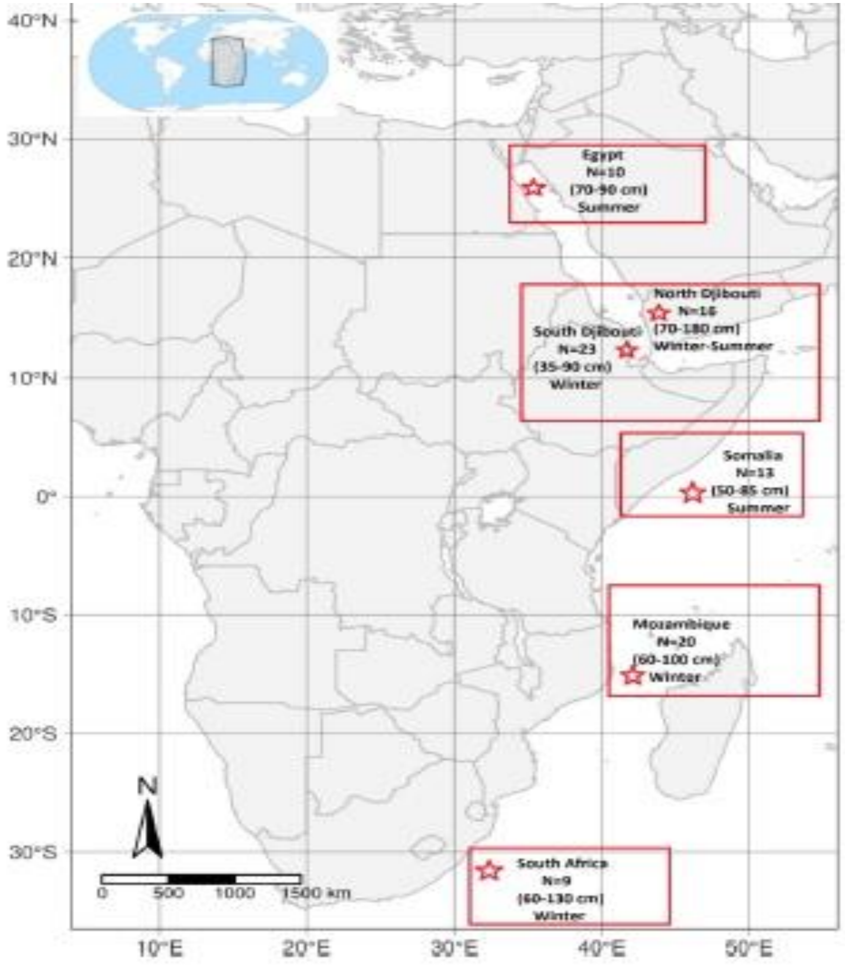
- As the population structure and connectivity between sub-populations are poorly understood for this species, we examined the spatio-temporal dynamics of narrow-barred Spanish mackerel via elemental concentrations (P, Mg, Sr and Ba) along otolith transects using LA-ICPMS for samples from 6 sites: Egypt, Djibouti North and South, Somalia, Mozambique and South Africa. For homogeneous size class samples (70–90 cm), otolith chemical signatures immediately preceding capture were used to accurately group individuals sharing a spatial proximity and/or season of capture.

Abstract
Sougueh et al., 2023

- Otolith core chemistry identified *two spawning chemical compositions*. The first common composition was characterized by relatively high concentrations of Sr and lower concentrations of P, Ba and Mg. The second less common spawning chemical composition was particularly rich in P, Ba and Mg and corresponded primarily to individuals caught off Mozambique, Somalia and Djibouti. These results are broadly consistent on one hand with patterns of water mass circulation in the Red Sea and western Indian Ocean and on the other hand with the observed spawning seasons.

Number of N.B.S.M otoliths analyzed the sampling season and the size distribution of sampled individuals from each sampling locations Sougueh et al., 2023

- Though further research using, for example, archival tagging is needed to clarify the mechanisms behind these patterns, these results reveal the potential of otolith chemistry to provide insights into the spatio-temporal dynamics of narrow-barred Spanish mackerel.



Otolith stable oxygen isotope analysis

- Early-life migrations of narrow-barred Spanish mackerel (*Scomberomorus commerson*) in the northwestern Pacific determined through otolith stable oxygen isotope analysis

Cheng et al.,2025

Cheng et al.,2025

- In this study, we reconstructed the early-life migration patterns of narrow-barred Spanish mackerel in the northwestern Pacific by using time-series otolith $\delta^{18}O$ analysis. Specimens collected from Taiwanese waters between 2013 and 2023 were analysed, and over 75% showed no significant seasonal variation in $\delta^{18}O$ values. However, specimens from 2016 to 2017 and from 2020 to 2021 had lower $\delta^{18}O$ values in autumn than in summer. Two distinct migration patterns were identified. The first pattern involved movement along the coasts of China, western Taiwan, and the Taiwan Strait from late spring to summer, followed by southward migration to southwestern Taiwan, southeastern China, the southern Taiwan Strait, and the northern South China Sea in winter, with a return northward by early spring.

Cheng et al.,2025

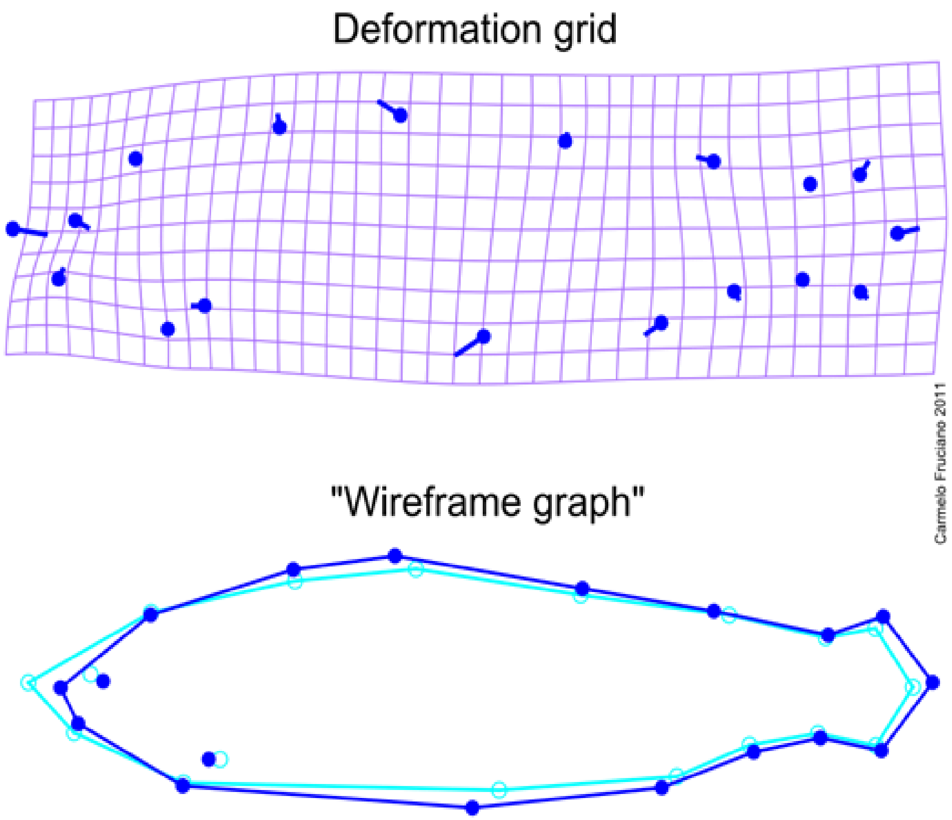
- The second pattern was similar but included a northward expansion into the East China Sea by mid-to-late summer, followed by a southward return in late autumn and winter. Both patterns closely corresponded to seasonal isotherms: 15°C–26°C in spring, 21°C–30°C in summer, 19°C–29°C in autumn, and 14°C–26°C in winter. These findings advance our understanding of the migratory behavior and environmental preferences of *S. commerson*, offering valuable insights for sustainable fishery management in the region.

Life history parameters

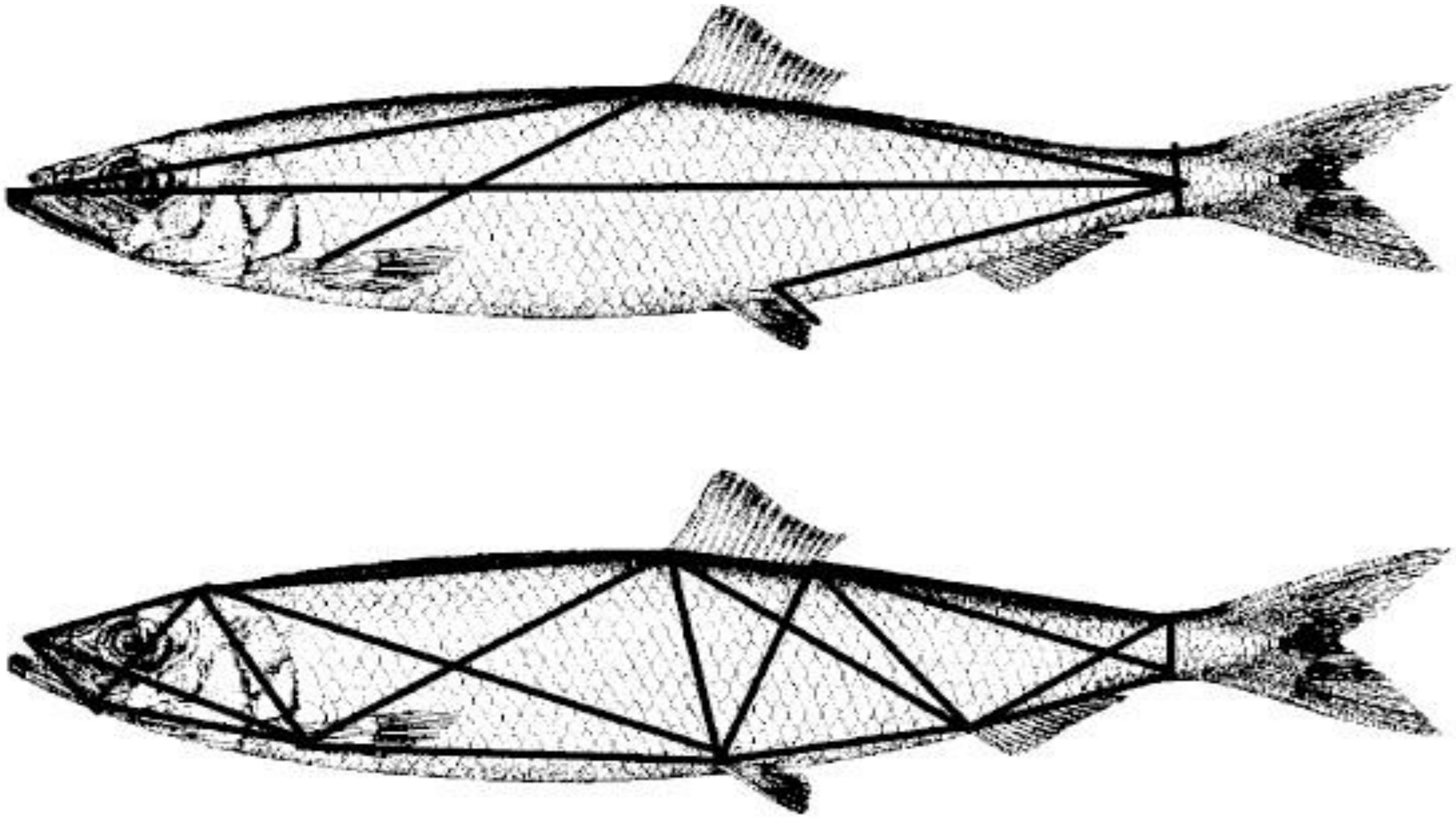
- Individual traits such as growth rate or maximum size can be described parametrically , and provide a basis for discriminating stocks. Studies of differences in life-history parameters are most useful for identifying tentative stock units that can be confirmed using methods such as tagging. This is because data on life-history parameters such as growth rate or age at maturity are relatively easy and inexpensive to collect , while tagging is expensive and time consuming.

Geometric morphometrics (GM)

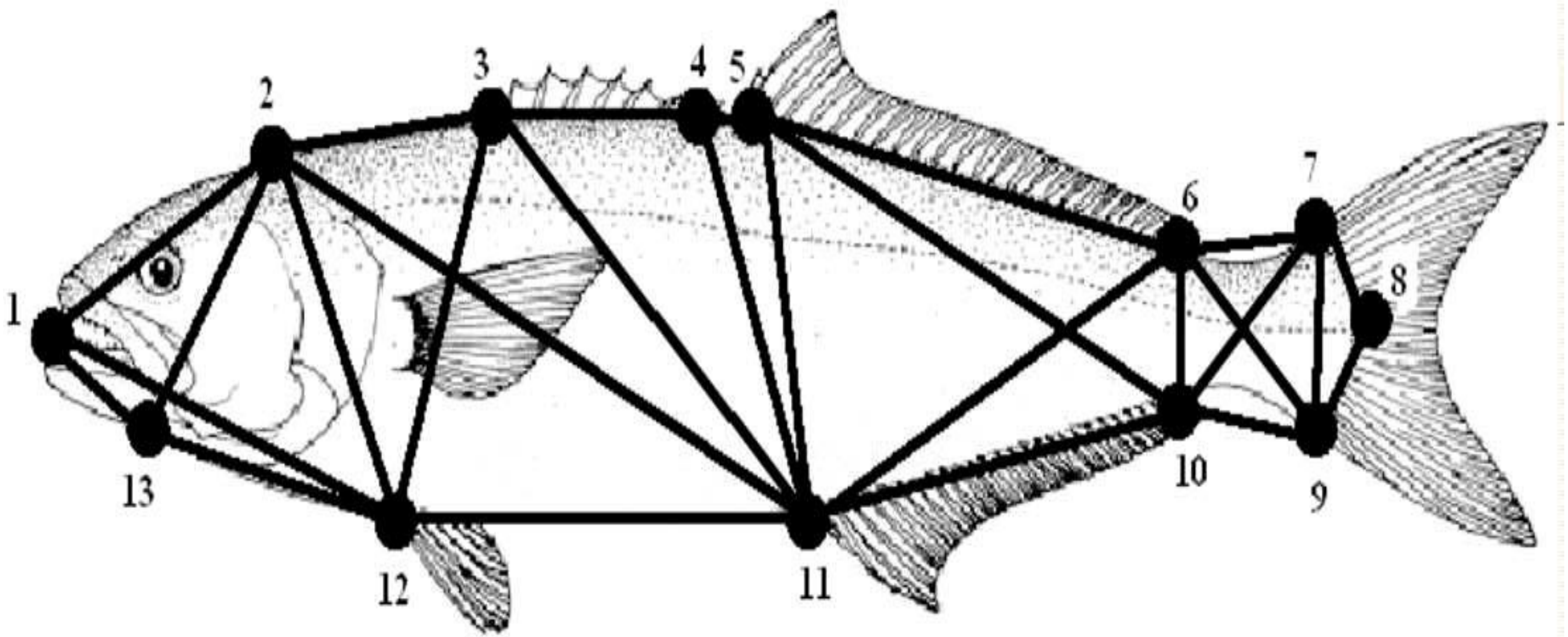
- Geometric morphometrics (GM) is a technique used to analyze shape variation in marine organisms, particularly for stock identification, taxonomy, and understanding the impact of environmental factors on shape. By focusing on shape, rather than just size, GM can help differentiate between closely related species or stocks that might otherwise be difficult to distinguish.



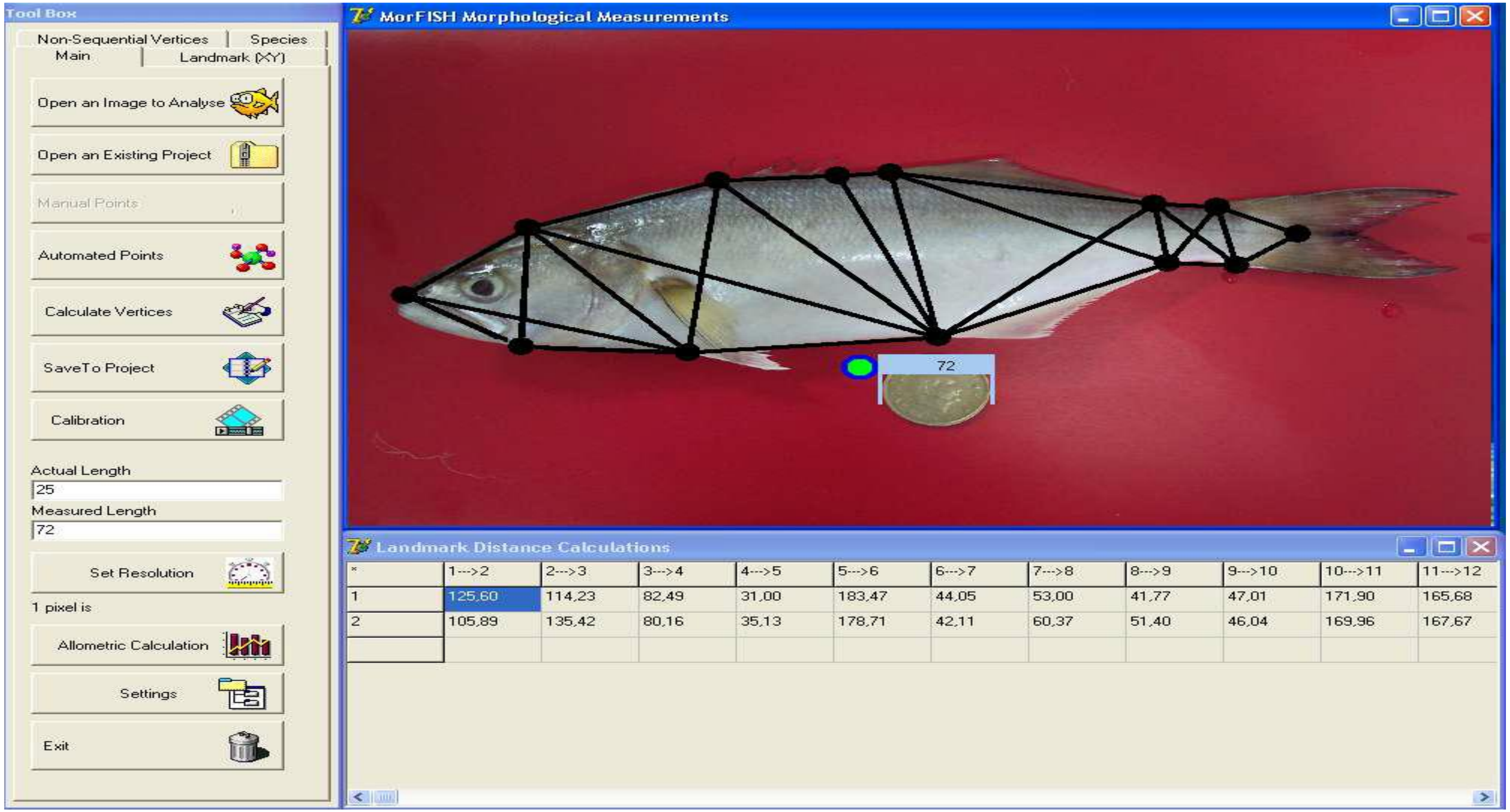
Traditional morphometric distances of finfish (above) and a network of box-truss network (below)



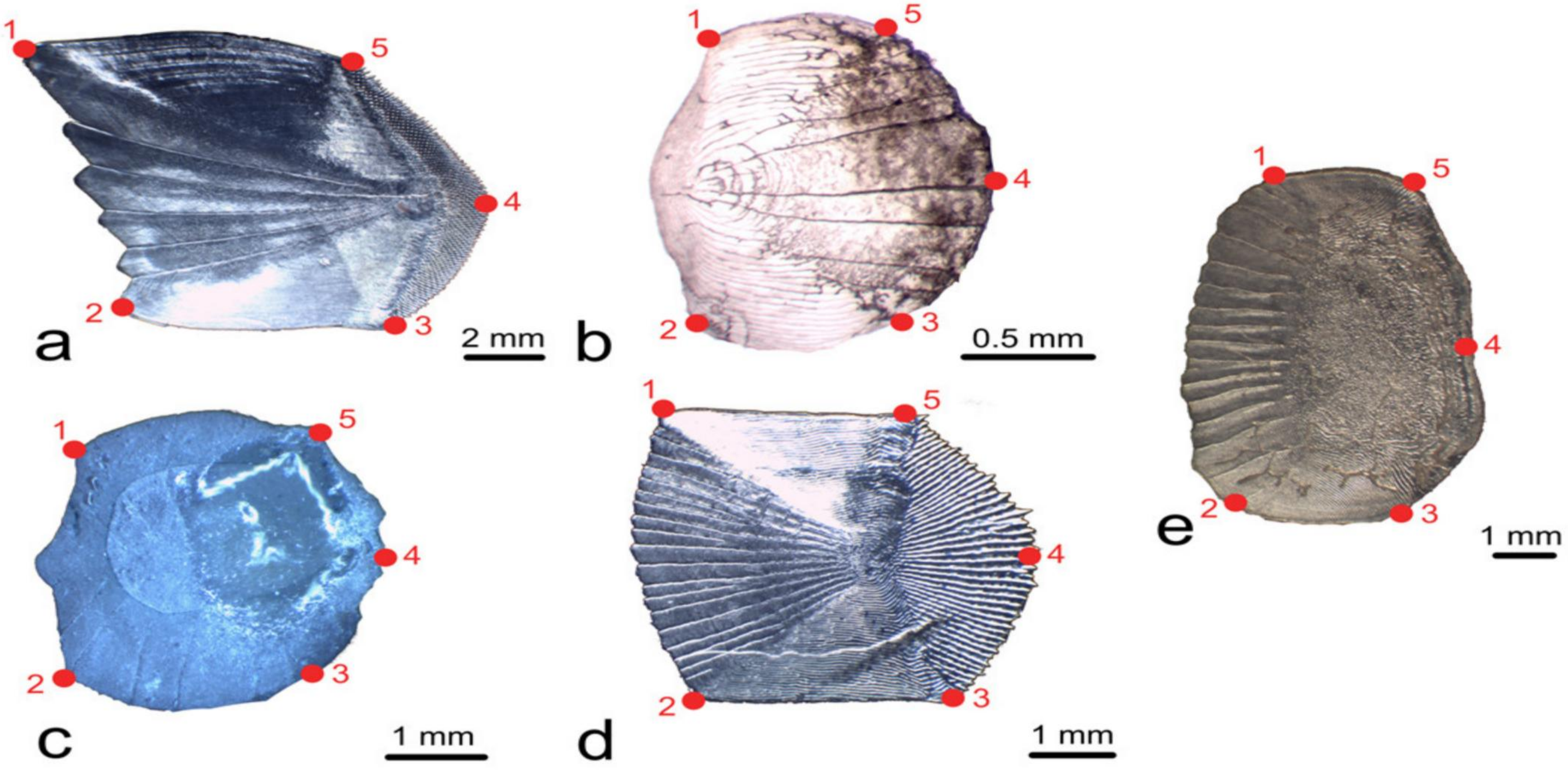
Locations of the 13 landmarks for constructing the truss network on *Pomatomus Saltatrix* illustrated as dark circles and morphometric distance measures between circles as lines.



Screen snapshot of MorFISH.



The red numbered dots show the position of the five landmarks for all the scales belonging to the five species considered: *Mullus surmuletus* (a), *Danio rerio* (b), *Sardina pilchardus* (c), *Dicentrarchus labrax* (d), and *Sparus aurata* (e)



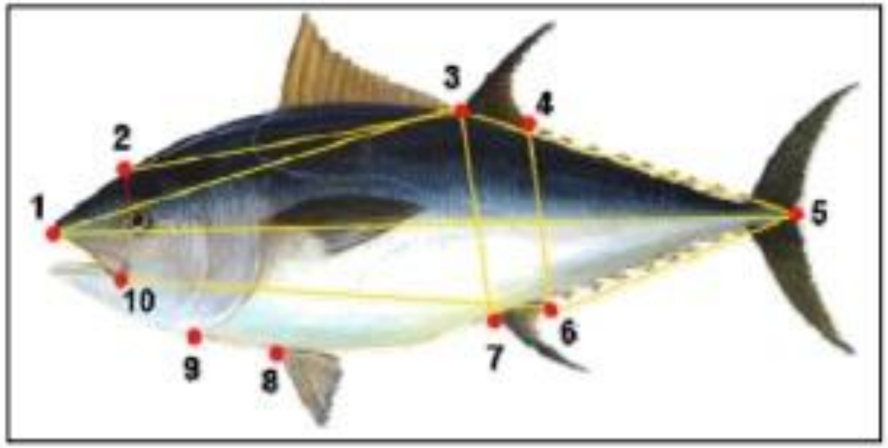
Geometric morphometrics

A morphometric approach for the analysis of body shape in Bluefin tuna :preliminary results

Truss network

landmarks and geometric distances used for the analysis

(Collect. Vol. Sci. Pap. ICCAT, 65(3): 982-987 (2010))

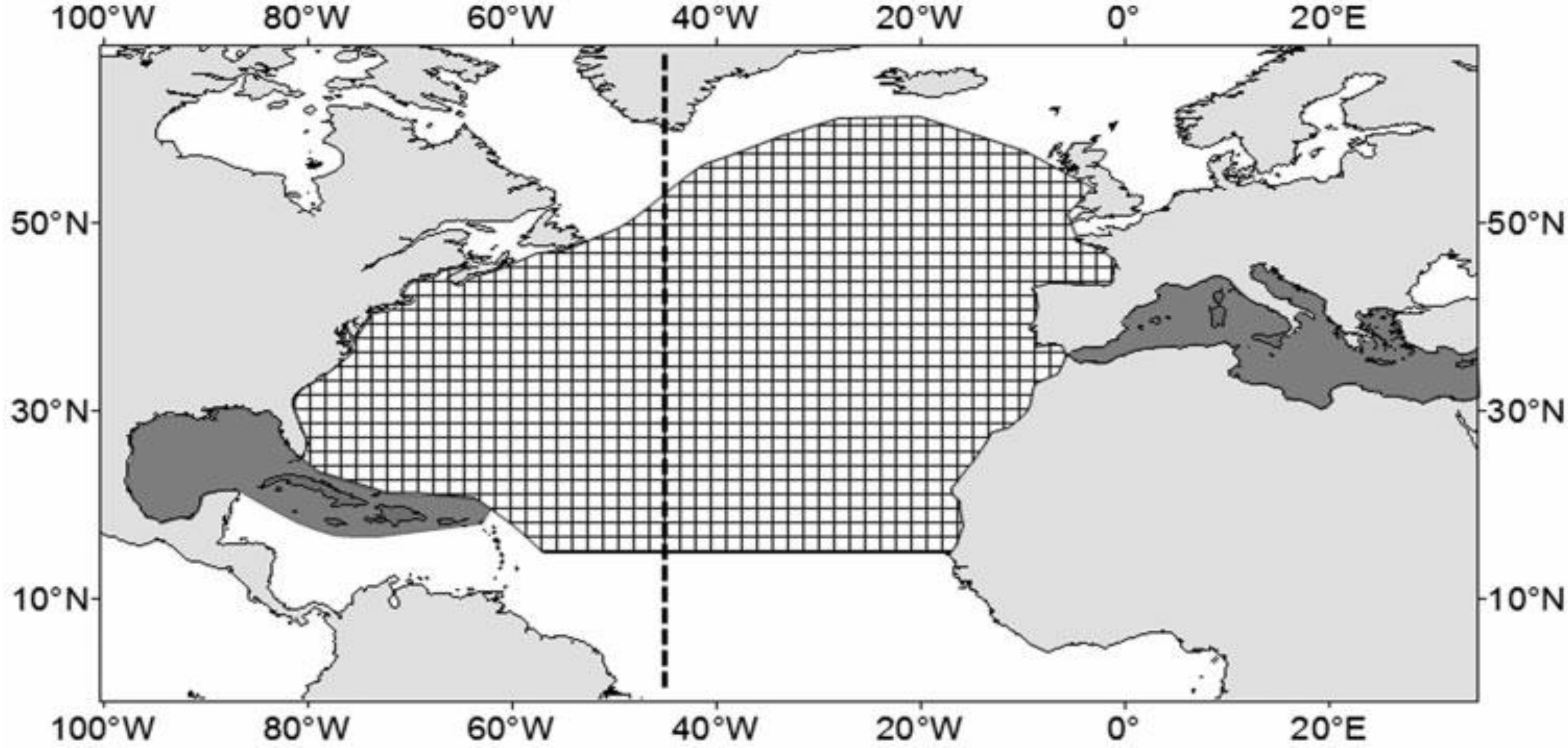


A MORPHOMETRIC APPROACH FOR THE ANALYSIS OF BODY SHAPE IN BLUEFIN TUNA: PRELIMINARY RESULTS

- Geometric morphometrics was used to explore body shape morphology in 120 bluefin tuna specimens captured in a traditional trap in the western Mediterranean during the years 2008 and 2009.

- Preliminary results highlight some shape differences between the two groups and we discuss their possible sources.

Illustration of spawning habitat (dark grey) of western and eastern origin Atlantic bluefin tuna (*Thunnus thynnus*) and range of overlap (hatched area) relative to the ICCAT management boundary (dashed line)



Western and Eastern Stocks of Atlantic bluefin tuna

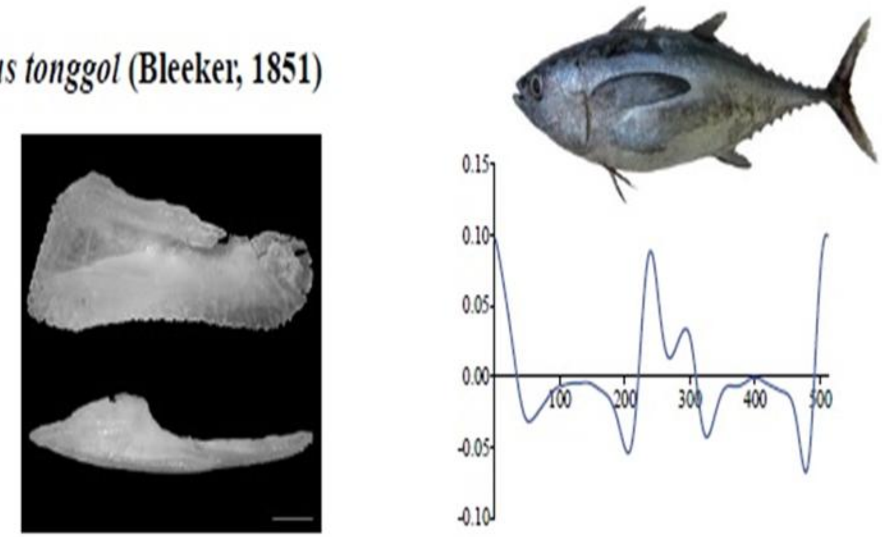
- Management of the commercially important Atlantic bluefin tuna (ABFT), *Thunnus thynnus*, considers two stocks separated at the 45°W meridian, relying on the assumption that individuals born at each of the two main spawning grounds (Gulf of Mexico and Mediterranean Sea) do not, or rarely, mix (Fromentin and Powers 2005). Yet, tagging (Arregui, et al. 2018, Galuardi, et al. 2010, Lutcavage, et al. 1999) and otolith chemistry analyses (Rooker, et al. 2014, Rooker, et al. 2008) have demonstrated regular and frequent trans-Atlantic migrations of ABFT adults while also suggesting that individuals return to their birthplace to spawn (Block, et al. 2005, Rooker, et al. 2014).

Western and Eastern Stocks of Atlantic bluefin tuna

- This process, termed “natal homing” would imply that ABFT should be managed as a mixed stock fishery (i.e., that composed by spatio - temporally defined aggregations of individuals from different biological populations), which would require individuals caught in the mixing areas be assigned to their birth location. Currently ICCAT has developed a Management Strategy Evaluation (MSE) framework, for which estimates of mixing are required for the development of Operating Models (Butterworth et al. 2016). The mixing proportions are determined by the stock of origin data (genetics and otolith chemistry).

Thank you for your consideration

Thunnus tonggol **(Bleeker, 1851)**



Shape: lanceolated. Margins: serrate. Sulcus acusticus: heterosulcoid, ostial, median with developed ridges. Ostium: funnel like. Cauda: tubular, straight wider posteriorly ending close to the posterior margin. Anterior region: peaked; rostrum long, medium, round; antirostrum medium narrow, pointed; excisura wide with a deep acute dentate notch. Posterior region: oblique.