Abstract: Stock identification methods have been developed with the progression of technology but this sometimes brings problems rather than the solution since the advancement in methods is not unidirectional but diffused. As of now, every method has pros and cons. The choice of the best method of population/stock discrimination is a critical issue depends on the frame of the study and the desired objectives to be fulfilled. The best method(s) would be the one which is rapid, reliable, low cost and easily applicable. In this article, the focus is given to morphological approaches. Since long, body morphology, as an efficient tool, has been used to delineate fish stocks, which contributes to the conservation management of important fauna. In stock or population delineation studies of fishes, landmark-based quantitative shape analysis of the organism body have a valuable role to play and complementing other existing approaches. Nevertheless, there is no single best method which can be applied to all or any species for their identification/delineation. The best method varies from species to species as does the requirement to one or more methods and even employing more than one discipline.

Keywords: Fish, Geometric morphometrics, Morphological techniques, Quantitative assessment.

INTRODUCTION
Stock or population words have been used interchangeably, although both are used in different contexts. Population structure is considered a prerequisite of conservation biology, on the other hand, stock identification is a basic element for any fishery-related study (Thorpe et al., 1995; Cadrin et al., 2005). In contrast to a fish population, a stock is described by management concerns defined boundaries or/and harvesting location. Interestingly, a fish stock may encompass more than one population. Stock identification is an integrative discipline, entails the identification of self-sustaining components within naturally occurring populations (Cadrin et al., 2005). With spatial or temporal coherence, stocks are the distinct assemblage of fishes, having similar life-history
traits and can self-reproduce with other members of a similar group (Ihssen et al., 1981; Hilborn and Walters, 1992). New analytical techniques are modernizing becoming more competent to study the fish population structure (Taylor et al., 2011). Fish exhibit more variations within and between populations as compared with other vertebrates, attributing to a predisposition to environmentally stimulated phenotypic divergences (Allendorf and Ryman, 1987; Wimberger, 1992). A large proportion of world fisheries occur on diverse stocks, it is essential to constantly develop new technologies to compute the various stock components that encompass these fisheries (Cadrin et al., 2005; Begg and Waldman, 1999). Stock identification is a multidisciplinary field and requires many techniques (Cadrin et al., 2005; Begg and Waldman, 1999; Waldman et al., 1997). It progresses along with fisheries management and conservation requirements (Begg et al., 1999). Assessments of morphological characters have been one of the traditional methods of characterizing biological stocks. Morphological methods have been extensively used in fisheries research for fish phenotypic stock assessment (Hubbs and Lagler, 1947). Moreover, in the new era of phenotypic characters based management, developments in statistical tools such as truss network and geometric morphometric technology could expand the understanding from the stock to the ecosystem and may help in developing better insight about ecosystem structure. Geometric morphometrics used for shape variation has many underpinned advantages as in the understanding of behavioural differences, phenotypic, ecological, and evolutionary line. Therefore, the fisheries’ evolutionary ecology and stock identification are having similar or complementary objectives (O’Reilly and Horn, 2004; Klingenberg et al., 2003). Although the existence of separate reproductive populations cannot be confirmed through phenotypic methods but they can be more suitable tools for defining phenotypic stocks than genetic methods. Considering the small sum of swap over between populations that are essential to upholding genetic homogeneity might be insignificant by fishery-management context (Edmonds et al., 1991). Different techniques have been employed to assess variation among fish populations (Table 1, Figure 1). This article summarises some of the important techniques used in phenotypic stock delineation, with emphasis on the most commonly used approaches. In this article, the focus has been given on the three most important methods of phenotypic stock identification.

Table 1. Different techniques used to assess variations among fish populations.

| Attributes         | Approach              | Techniques                                                                 |
|--------------------|-----------------------|----------------------------------------------------------------------------|
| Natural marks      | Phenotypic Marker     | morphological and meristic analyses                                         |
|                    |                       | anatomical structures                                                       |
|                    |                       | calcified structures                                                        |
|                    |                       | texture and spacing patterns of cerculi on otolith, scales, vertebrae        |
|                    |                       | otoliths shape analysis                                                     |
|                    |                       | otoliths thermal marking                                                    |
| Genetic analyses   |                       | genetic approaches mitochondrial DNA analysis (mtDNA)                       |
|                    |                       | allozyme electrophoresis                                                   |
|                    |                       | chromosome morphology                                                      |
|                    |                       | microsatellites or single nucleotide polymorphism                          |
## Fatty Acid Profiles

### Elemental Composition
- Otolith chemistry
- Scale chemistry

### Patterns of Commercial Fishing
- Fishing seasonality
- Regional catch compositions

### Tagging
- Biological tags
- Parasites
- Electronic tags

## Life History Traits

### Growth, Timing and Seasonality of Reproduction
- Size at maturity
- Timing of spawning
- Distribution of larvae and eggs
- Larval growth rates
- Adult and juvenile growth patterns
- Abundance
- Maturity
- Sex ratio
- Reproductive health
- Fecundity estimates
- Gonadal development
- Spawning seasons

### Application of Stock Identification:

1. In fisheries management or restoration of species.
2. For the desirable conservation measures of threatened and endangered species.
3. To know the current state of species and to achieve sustainable yield.
4. To avoid recruitment failures and rebuild overfished stocks.
5. In the formulation of fishery management advice desirable conservation measures.
6. To estimate the stock composition in mixed-stock fisheries.

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**Fig 1:** Tools and techniques used for delineation of fish populations/stocks.
Commonly used morphological methods for fish stock delineation:

Morphological traits have long been used to delineate stocks. These traits including shape or/and meristic counts reflect phenotypic dissimilarity (Swain and Foote, 1999; Cadrin, 2005). Therefore, meristic serve as another useful tool for stock identification (Swain and Foote, 1999; Cadrin, 2005). These morphological methodologies can be applied for different body structure and shapes. These methods of fish stocks delineation/identification are economical, fast, repeatable, reliable and consistent (Pérez-Quiñonez et al., 2018).

Table 2: Summary studies of stock delineation using phenotypic characteristics.

| S. No. | Fish species      | Area                                      | Populations undertaken for study | Technique                      | Approach                 | Reference               |
|--------|-------------------|-------------------------------------------|---------------------------------|-------------------------------|--------------------------|-------------------------|
| 1.     | Cirrhinus mrigala | Rivers Tons, Son, Chambal, Kalisindh, Ken, Betwa, Ganga, Sharda, Ghaghra, Gomti of India | ten                              | landmark based truss network morphometrics | single technique         | Dwivedi et al., 2019   |
| 2.     | Catla catla       | Betwa, Ken, Ganga of India                | three                           | landmark based truss network morphometrics | single technique         | Sarkar et al., 2014    |
| 3.     | Sardinella lemura | Zamboanga City Philippines                | two                             | landmark-based geometric morphometric | single approach          | Echem, 2016            |
| 4.     | Decapterus russelli | Sea, India                                | two                             | truss network analysis         | single approach          | Sen et al., 2011       |
| 5.     | Alburnus chalcoides | Caspian Sea                                | four                            | truss network                 | single approach          | Mohaddasi et al., 2013|
| 6.     | Puntius sarana    | Rivers, the Padma, Meghna, Jamuna and the Halda in Bangladesh | four                            | morphometric characters       | single approach          | Siddik et al., 2016    |
| 7.     | Caspiomyzon wagneri | two rivers southern Caspian Sea           | two                             | morphometric characters       | single approach          | Vatandoust et al., 2015|
| 8.     | Oreochromis spp.  | Philippine fisheries institutions         | four                            | truss measurements            | single approach          | Regala et al., 2018    |
| 9.     | Rutilus ru tiluscaspicus | Sin southern Caspian Sea Bandar-e-Turkmen shore, Anzali wetland and Aras River | three                            | geometric morphometric        | single approach          | Ghojoghi et al., 2014  |
|   | Species                                                                 | Location                                                                 | Approach | Morphometric Technique                  | Source                          |
|---|-------------------------------------------------------------------------|--------------------------------------------------------------------------|----------|-----------------------------------------|---------------------------------|
|10.| *Amblygaster clupeoides*                                               | Bay of Bengal coast, in Bangladesh                                        | four     | truss network technique                 | Hanif *et al.*, 2019            |
|11.| *Channa punctatus*                                                     | Gomti River, ponds situated at Kolkata, Malihabad                         | three    | truss analysis                          | Kashyap *et al.*, 2016          |
|12.| *Sperata aor*                                                          | Ganga River, viz. Narora, Kanpur, Varanasi and Bhagalpur                   | four     | truss network                           | Khan and Nazir, 2019            |
|13.| *Chalcalburnus chalcoides*                                             | Estuaries Haraz River, Shirud River                                       | two      | truss network                           | Bagherian and Rahmani, 2009     |
|14.| *Puntioplites bulu*                                                    | Peninsular Malaysia Kelantan River, Perak River and Pahang River          | three    | truss network analysis                  | Ghani *et al.*, 2018            |
|15.| *Xenentodon cancila*                                                   | Boluhorpurbao, Jhenaidah, Bhairab River, Jashore, Arial Khan River, Madaripur, and Bohnnibaor, Gopalganj in Bangladesh | four     | truss network system                    | Sarower-E-Mahfuj *et al.*, 2019 |
|16.| *Ponticola bathybius*                                                  | Iranian waters of the Caspian Sea                                         | three    | landmark-based geometric morphometric and meristic analysis | Tajbakhsh *et al.*, 2018         |
|17.| *Mullus surmuletus*                                                    | Eastern English Channel, Bay of Biscay                                     | two      | truss analysis and length measurements  | Mahe *et al.*, 2014             |
|18.| *Clarias batrachus*                                                    | Ganga (Narora and kanpur) and its tributaries: Yamuna and Gomti rivers    | four     | truss morphometric of fish body and variation in otolith chemistry | Miyian *et al.*, 2016           |
|19.| *Cirrhus reba*                                                         | Brahmaputra, the Padma, the Karatoya, and the Jamuna Rivers in Bangladesh | four     | meristic characters morphometric characters truss measurement | Ethin *et al.*, 2019            |
|20.| *Opisthonema libertate*                                                | Magdalena Bay, Guaymas, and Mazatlan, Mexico                             | three    | geometric morphometrics based on body and otolith shape | Pérez-Quifionez *et al.*, 2018 |
|21.| *Dentex dentex*                                                        | Corsica Island, four zones: Cap Corse, Galeria, Ajaccio, Bonifacio        | four     | microsatellite DNA markers, otolith shape analysis and parasites communities | Marengo *et al.*, 2017          |
MORPHOLOGICAL ANALYSIS TOOLS

1. Traditional morphological analysis
Morphology incorporates both morphometric and meristic study that is the most commonly used taxonomic tools for the separation of species and population. Several workers have used these techniques for taxonomic identification of fishes (Ihssen et al., 1981; Melvin et al., 1992; Quilang et al., 2007). Morphometric and meristic morphological characters are the simple, most direct and frequently employed methods to delineate stocks of fish (Mamuris et al., 1998; Bronte et al., 1999; Hockaday et al., 2000). Traditional methods of fish stock identification have served up immensely in fisheries management since ages and now also carrying out the same, nonetheless with the advancement in technology additional/substitute methods including other scientific disciplines with different traits coming into existence (Brander, 2003). These traditional methods having limitations too, like through these methods only linear distances around the body can be measured as this focuses on the measurements along the particular axis of the body (fish) thus in one direction hence, non-uniform coverage of the fish body. Some of the morphological measurements are standard length, body depth at the dorsal-fin origin, mandibular length, upper jaw length, body depth at the dorsal-fin origin, head length, pre-dorsal length, pelvic fin length, pre-anal length, pre-pelvic length, pre-maxillary teeth and head width, dorsal-fin base, anal fin base, peduncle length, peduncle depth, snout length. These techniques consist of principal component analysis, principal coordinate analysis, factor analysis, discriminant analysis, canonical variate analysis, and multivariate analysis of variance (Rohlf and Marcus, 1993; Adams et al., 2004).

2. Truss based morphological analysis
To overcome the limitation of traditional techniques, new technological advancement has been made that is facilitated by image processing methods, more inclusive and accurate data collection, more efficient quantification of shape, and new analytical tools (Cadrin, 2000). Truss network system (Strauss and Bookstein, 1982; Bookstein et al., 1985) is a landmark-based technique, measurements generated are a chain of distances estimated linking landmarks that construct a pattern of connected quadrilaterals across the body structure (Strauss and Bookstein, 1982). The truss morphology analysis is a good tool for observing information on the appearance of an organism (Cavalcanti et al., 1999). A digital picture is useful in the long term as it can obtain morphometric data and the potential for reprocessing each individual to confirm unusual measurements or accomplish substitute/additional sets of characteristics. Storage of picture also allows detailed examination of extreme variants or outliers, as well as more flexible characteristic selection (Cadrin and Friedland, 1999).

3. Geometric morphometric analysis
Geometric morphometrics has turned into the leading techniques to quantify differentiation in the shape of biological bodies (Klingenberg, 2010). The innovative introduction of geometric morphometrics in stock analysis has additionally been able to overcome multiple barriers imposed by subjectivity. This presents a powerful tool for the construction of fish stock delineation models, presenting a series of efficient tools for the processing of complex data. It involves the analysis of configurations of discrete anatomical loci (landmarks) among individuals and has been applied to several questions. In general, landmark positioning is first executed by hand on individual images. Procrustes superimposition and various multivariate statistics can be applied to distinguish variations in landmark pattern and consequently shape changes in populations (Vandaele et al., 2018; Lorenz et al., 2017).

PHENOTYPIC VARIATION AND STOCK IDENTIFICATION

Despite current progress in molecular techniques, morphological assessment is remaining the leading approach and the first important step for examining the stock structure of fishes (Costa et al., 2003; Solomon et al., 2015). Phenotypic markers may recognize morphological discrimination which is induced by environmental differences in the moderately
isolated stocks, practical level of portioning among self stock recruitments. Such self-recruiting stocks independently react to the exploitation of species even without showing any genetic differentiation (Carvalho and Hausar, 1994). The main advantage of using morphological characters in studies of stock/population structure is that these characters are often related to fitness and respond to selection, and thus may disclose genetic differentiation not obvious in neutral genetic character. Phenotypic traits are typically most useful when multiple traits are investigated to study short-term, environmentally induced variation (Begg et al., 1999). Phenotypic plasticity is one of the disadvantages of using morphological characters for population studies (Debat and David, 2001). Phenotypic variation is owing to both environmental and/or through inheritance. Distinguishing between them is the basic difficulty that should be addressed when using these characters to examine population/stock structure (Swain and Foote, 1999; Begg et al., 1999).

SINGLE TECHNICAL APPROACH VERSUS A HOLISTIC APPROACH

The argument in favour of single approach
In stock delineation, “more is not essentially better” a single technique that gives accurate and precise result may give better result than applying many techniques using different parameters and coming up with the discordant result. Multiple approaches exercised in stock delineation may show different patterns of the stock structure and combining the outcome can be complicated which lead to more confusion in declaring the unanimous result. Therefore, using multiple methods for one questionable stock identification problem may give conflicting outcome about the stock structure (Cadrin et al., 2013; Izzo et al., 2016).

The argument in favour of multiple approach
A wide study for stock identification should incorporate several techniques that accounts to diverse aspects of the stock concept appropriate to scientists, fish farmers and managers. No single stock definition can incorporate all dynamic such as environmental, biological, political and the useful definition has to adjust with the management endeavour (Coyle, 1998). Therefore, single technical approaches are inadequate to delineate complex fish stocks. There is a necessity to exploit the potentially of complementary approaches and tools because employing an approach may underused (Pita et al., 2016). Applying two or more methods of the same discipline is probably give a better and unanimous result. Combination of multiple approaches together could give complementary insights and a prospect to compare the utility of each of them and the potential to understand population interaction in a different context (Marengo et al., 2017).

CONCLUSION
Although multiple methods can provide conflict outcomes, such conflict cannot be dismissed by selecting single approach. It is not easy to select the best method, the best approach varies from species to species as does the need to use one or more methods or even more than one discipline.

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CONFLICT OF INTEREST
The authors declare that there is no conflict of interest.

REFERENCES
1. Adams D. C., Rohlf F. J. and Slice D. E. (2004). Geometric morphometrics: Ten years of progress following the revolution. Italian Journal of Zoology. 71(1):5-16.
2. Allendorf F. and Ryman N. (1987). Genetic management of hatchery stocks N. Ryman F. Utter (Eds) Population Genetics and Fishery Management University of Washington Press, Seattle WA 141–159.
3. Bagherian A. and Rahmani H. (2009). Morphological discrimination between two
populations of shemaya, *Chalcalburnus chalcoides* (Actinopterygii, Cyprinidae), using a truss network. *Animal Biodiversity and Conservation*. 32.1: 1-8.

4. Begg G. A. and Waldman J. R. (1999). An holistic approach to fish stock identification. *Fisheries Research*. 43: 35-44.

5. Begg G. A., Friedland K. D. and Pearce J. B. (1999). Stock identification and its role in stock assessment and fisheries management: An overview. *Fisheries Research*. 43 (1-3); 1-8. DOI: 10.1016/S0165-7836(99)00062-4

6. Chernoff B., Elder R. L., Humphries Jr J. M., Smith G. R. and Strauss R. E. (1985). *Morphometrics in evolutionary biology. Academy of Natural Sciences of Philadelphia, Special Publication 15, Ann Arbor.*

7. Brander K. M. (2003). What kinds of fish stock predictions do we need and what kinds of information will help us to make better predictions? *Scientia Marina*, 67(Suppl. 1): 21e33.

8. Bronte C. R., Fleischer G. W., Maistrenko S. G. and Pronin N. M. (1999). Stock structure of Lake Baikal omul as determined by whole body morphology. *Journal of fish biology*. 54, 787-798.

9. Cadrin S. X. (2000). Advances in morphometric identification of fishery stocks. *Reviews in Fish Biology and Fisheries*. 10: 91-112.

10. Cadrin S. (2005). Morphometric landmarks. In: Stock identification methods: applications in fishery science. S. X. Cadrin, K. D. Friedland and J. R. Waldman (Eds). Elsevier Academic Press, London, UK. 153-172p.

11. Cadrin S. X., Friedland K. D. and Waldman J. (2005). Stock identification methods: applications in fishery science. Elsevier Academic Press, San Diego, CA.

12. Cadrin S. X. and Friedland K. D. (1999). The utility of image processing techniques for morphometric analysis and stock identification. *Fisheries research*. 43. 129-139.

13. Cadrin S. X., Kerr L. A. and Mariani S. (2013). Interdisciplinary stock identification for fishery management and conservation biology. In: Cadrin, S.X., Kerr, L.A., Mariani, S. (Eds.), Stock Identification Methods. Elsevier Inc., San Diego.

14. Carvalho G. R. and Hauser L. (1994). Molecular genetics and the stock concept in fisheries. *Reviews in Fish Biology and Fisheries*. 4: 326-350.

15. Cavalcanti M. J., Monteiro L. R. and Lopez P. R. D. (1999). Landmark based morphometric analysis in selected species of Serranid fishes (Perciformes: Teleostei). *Zoological Studies*. 38(3): 287-294.

16. Costa L., Almeida P. R. and Costa M. J. (2003). A morphometric and meristic investigation of Lusitanian toadfish *Halobatrachus didactylus* (Bloch and Schneider, 1081): evidence of population fragmentation on Portuguese coast. *Scientia Marina*. 67: 219-231.

17. Coyle T. (1998). Stock identification and fisheries management: the importance of using several methods in a stock identification study. In: Hancock DA (ed) Taking stock: defining and managing shared resources. Australian Society for Fishery Biology, Sydney. 173-182.

18. Debat V. and David P. (2001). Mapping phenotypes: canalization, plasticity and developmental stability. *Trends in Ecology and Evolution*. 16: 555–561. DOI: https://doi.org/10.31032/IJBPAS/2018/7.6.44 68.

19. Dwivedi A., Uttam S., Javaid M., Tamot P. and Vyas V. (2019). The Ganges basin fish *Cirrhinus mrigala* (Cypriniformes: Cyprinidae): detection of wild populations stock structure with landmark morphometry. *Revista de biologia tropical*. 67.

20. Echem R.T. (2016). Geometric morphometric analysis of shape variation of Sardinella lemuru. *International Journal of Advanced Research in Biological Sciences*. 3(9): 91-97. DOI: http://dx.doi.org/10.22192 /ijarbs.2016.03.09.013
21. Edmonds J. S., Caputi N. and Morita M. (1991). Stock discrimination by trace-element analysis of otoliths of orange roughy (Hoplostethus atlanticus), a deep-water marine teleost. *Australian Journal of Marine and Freshwater Research.* 42: 383-389.

22. Ethin R., Hossain M. S., Roy A. and Marcellin R. (2019). Stock identification of minor carp, *Cirrhinus reba*, Hamilton 1822 through landmark-based morphometric and meristic variations. *Fisheries and Aquatic Sciences.* 22:12. https://doi.org/10.1186/s41240-019-0128-1.

23. Ghani I. A., Arshad A., Harmin S. A., Christianus A. and Ismail M. F. S. (2018). Intraspecific Morphological Variation of Crossbanded Barb, *Puntioplites bulu* (Bleeker, 1851) From Selected River in Peninsular Malaysia Based On Truss Network Analysis. *Pertanika Journal of Tropical Agricultural Science.* 41(3): 1059-1070.

24. Ghojoghi F., Kamali A., Eagderi S., Soltani M. and Segherloo I. (2014). Morphological variation among the Caspian roach (*Rutilus rutilus caspicus*) populations from the Southern Caspian Sea using Geometric Morphometrics technique. *Pharmacology and Life Sciences Bulletin of Environment, Pharmacology and Life Sciences.* 3(III): 105-111.

25. Hanif M. A., Siddik M. A. B., Islam M. A., Chaklader M. R. and Nahar A. (2019). Multivariate morphometric variability in sardine, *Amblygaster clupeoides* (Bleeker, 1849), from the Bay of Bengal coast, Bangladesh. *The Journal of Basic and Applied Zoology.* 80:53. https://doi.org/10.1186/s41936-019-0110-6

26. Hilborn R. and Walters C. J. (1992). Quantitative Fisheries Stock Assessment and Management. Choice, Dynamics and Uncertainty. New York, Chapman and Hall: xv + 570p.

27. Hockaday S., Beddow T. A., Stone M., Hancock P. and Ross L. G. (2000). Using truss networks to estimate the biomass of *Oreochromis niloticus* and to investigate shape characters. *Journal of Fish Biology.* 57: 981-1000.

28. Hubbs C. L. and Lagler K. F. (1947). Fishes of the Great Lakes region. *Bulletin of the Cranbrook Institute of Science.* 26: 1-186.

29. Ihssen P. E., Booke H. E., Casselman J. M., McGlade J. M., Payne N. R., and Utter F. M. (1981). Stock identification: materials and methods. *Canadian Journal of Fisheries and Aquatic Sciences.* 38:1838–1855.

30. Izzo C., Doubleday Zoe A., Grammer G. L., Gilmore K. L., Alleway H. K., Barnes T. C., Disspain M. C. F., Giraldo A. J., Nastaran M. and Gillandar B. M. (2016). Fish as proxies of ecological and environmental change. *Reviews in Fish Biology and Fisheries.* 26 (3): 265–286. DOI 10.1007/s11160-016-9424-3

31. Kashyap A., Awasthi M. and Serajuddin M. (2016). Phenotypic variation in freshwater murrel, *Channa punctatus* (Bloch, 1793) from Northern and Eastern Regions of India Using Truss Analysis. *International Journal of Zoology.* Article ID 2605404. pages 6. http://dx.doi.org/10.1155/2016/2605404.

32. Khan M. A. and Nazir A. (2019). Stock delineation of the long-whiskered catfish, *Sperataaor* (Hamilton, 1822), from River Ganga by using morphometrics. *Marine and Freshwater Research.* 70(1): 107-113.

33. Klingenberg C. P. (2010). Evolution and development of shape: integrating quantitative approaches. *Nature Reviews Genetics.* 11(9):623-635.

34. Klingenberg C.P., Mebus K. and Auffray J. C. (2003). Developmental integration in a complex morphological structure: how distinct are the modules in the mouse mandible? *Evolution & Development.* 5:522–531.

35. Lorenz S., Rasmussen J. J., Süß A., Kalettka T., Golla B., Horney P., Stähler M., Hommel B. and Schäfer R. B. (2017). Specifics and challenges of assessing exposure and effects of pesticides in small water bodies. *Hydrobiologia.* 793. 213e224. https://doi.org/10.1007/s10750-016-2973-6.
36. Mahe K., Villanueva M. C., Vaz S., Coppin F., Koubbi P. and Carpentier A. (2014). Morphological variability of the shape of striped red mullet Mullus surmuletus in relation to stock discrimination between the Bay of Biscay and the eastern English Channel. *Journal of Fish Biology*. 84: 1063-1073. doi:10.1111/jfb.12345.

37. Mamuris Z., Apostolidis A. P., Panagiotaki P., Theodorou A. J. and Triantaphyllidis C. (1998). Morphological variation between red mullet populations in Greece. *Journal of Fish Biology*. 52:107-117.

38. Marengo M., Baudouin M., Viret A., Laporte M., Berrebi P., Matthias V., Marchand B. and Durieux E. D. H. (2017). Combining microsatellite, otolith shape and parasites community analyses as a holistic approach to assess population structure of *Dentex dentex*. *Journal of Sea Research*. 128: 1-14. 10.1016/j.seares.2017.07.003.

39. Melvin G. D., Dadswell M. J. and McKenzie J. A. (1992). Usefulness of meristic and morphometric characters in discriminating populations of American shad (*Alosa sapidissima*) (Osteichthyes: Clupeidae) inhabiting a marine environment. *Canadian Journal of Fisheries and Aquatic Sciences*. 49:266-280.

40. Miyan K., Khan M. A., Patel D. K., Khan S. and Ansari N. G. (2016). Truss morphometry and otolith microchemistry reveal stock discrimination in *Clarias batrachus* (Linnaeus, 1758) inhabiting the Gangetic river system. *Fisheries Research*. 173: 294-302.

41. Mohaddasi M., Shabanipour N. and Abdolmaleki S. (2013). Morphometric variation among four populations of Shemaya (*Alburnus chalcoides*) in the south of Caspian Sea using truss network. *The Journal of Basic and Applied Zoology*. 66(2): 87-92. DOI: 10.1016/j.jobaz.2013.09.001.

42. O'Reilly K. M. and Horn M. H. (2004). Phenotypic variation among populations of *Atherinops affinis* (Atherinopsidae) with insights from a geometric morphometric analysis. *Journal of Fish Biology*. 64 (4): 1117-1135. https://doi.org/10.1111/j.1095-8649.2004.00379.x

43. Pérez-Quíñonez C. I., Quíñonez-Velázquez C. and GarcíaRodríguez F. J. (2018). Detecting *Opisthonema libertate* (Günther, 1867) phenotypic stocks in northwestern coast of Mexico using geometric morphometrics based on body and otolith shape. *Latin American Journal of Aquatic Research*. 46:779-790.

44. Pita A., Casey J., Hawkins S. J., Villarreal M. R., Gutiérrez M. and Cabral H. (2016). Conceptual and practical advances in fish stock delineation. *Fisheries Research*. 173 (3): 185-193. http://dx.doi.org/10.1016/j.fishres.2015.10.029.

45. Quilang J. P., Basiao Z. U., Pagulayan R. C., Roderos R. R. and Barrios E. B. (2007). Meristic and morphometric variation in the silver perch, *Leiopotherapon plumbeus* (Kner, 1864), from three lakes in the Philippines. *Journal of Applied Ichthyology*. 23:561-567.

46. Regala J. A., Fernando S. I. D. and Velasco R. R. (2018). Morphometric Differentiation Among Four Populations of Red Tilapia (*Oreochromis* spp.). *International Journal of Biology, Pharmacy and Allied Sciences*. 7(6): 1079-1094.

47. Vandaele R., Aceto J., Muller M., Péronnet F., Debat V., Wang C., Huang C., Jodogne S., Martinive P., Geurts P. and Marée R. (2018). Landmark detection in 2D bioimages for geometric morphometrics: a multi-resolution tree-based *Scientific Reports*. 8:538. DOI:10.1038/s41598-017-18993-5

48. Rohlf F. J. and Marcus L. F. (1993). A revolution in morphometrics. *Trends in Ecology and Evolution*. 8:129-132.

49. Sarkar U. K., Mir J. I., Dwivedi A. K., Pal A. and Jena J. K. (2014). Pattern of Phenotypic Variation Among Three Populations of Indian Major Carp, *Catla catla* (Hamilton, 1822) Using Truss Network System in the
50. Sarower-E-Mahfuj M., Rahman M. M., Islam M., Samad M. A., Paul A. K. and Adhikary R. K. (2019). Landmark-based morphometric and meristic variations of freshwater garfish, *Xenentodon cancila* from four natural stocks of South-Western Bangladesh. *Journal of Advanced Veterinary and Animal Research*. 6(1):117-124.

51. Sen S., Shriniwas J., Jaiswar A. K., Chakraborty S. K., Sajina A. M. and Dash G. R. (2011). Stock structure analysis of *Decapterus russelli* (Ruppell, 1830) from east and west coast of India using truss network analysis. *Fisheries Research*. 112: 38-43.

52. Siddik M., Chaklader M., Hanif M., Islam M., Sharker M. and Rahman M. (2016). Stock identification of critically endangered olive barb, *Puntius sarana* (Hamilton, 1822) with emphasis on management implications. *Journal of Aquaculture Research and Development*. 7 (2). 1000411 DOI: 10.4172/2155-9546.1000411.

53. Solomon S. G., Okomoda V. T. and Ogbenyikwu A. I. (2015). Intraspecific morphological variation between cultured and wild *Clarias gariepinus* (Burchell) (Clariidae, Siluriformes). *Archives of Polish Fisheries*. 23(1): 53-61.

54. Strauss R. E. and Bookstein F. L. (1982). The truss: body form reconstructions in morphometrics. *Systematic Zoology*. 31: 113-135.

55. Swain D. P. and Foote C. J. (1999). Stocks and chameleons: the use of phenotypic variation in stock identification. *Fisheries Research*. 43:113-128.

56. Tajbakhsh F., Stepien C. A., Abdoli A., Tabatabaei N. and Kiabi B. H. (2018). Geometric morphometric and meristic analysis of the deepwater goby, *Ponticola bathybius* (Kessler, 1877) (Teleostei: Gobiidae) in the Iranian waters of the Caspian Sea. *Iranian Journal of Ichthyology*. 5(1):64-73. doi: 10.22034/iji.v5i1.257

57. Taylor N., McAllister M., Lawson G., Carruthers T. and Block B. (2011). Atlantic bluefin tuna: a novel multistock spatial model for assessing population biomass. *PLoS One* 6 (12). e27693. http://dx.doi.org/10.1371/journal.pone.0027693

58. Thorpe J. E., Gall G. A. E., Lannan J. E. and Nash C. E. (1995). Conservation of Fish and Shellfish Resources: Managing Diversity. San Diego: Academic Press.

59. Vatandoust S., Mousavi-Sabet H., Razeghi-Mansour M., AnvariFar H. and Heidari A. (2015). Morphometric variation of the endangered Caspian lamprey, *Caspiozymon wagneri* (Pisces: Petromyzontidae), from migrating stocks of two rivers along the southern Caspian Sea. *Zoological Studies*. 56: 1-9.

60. Waldman J. R., Richards R. A., Schill W. B., Virgin I. and Fabrizio M. C. (1997). An empirical comparison of stock identification techniques applied to striped bass. *Transactions of the American Fisheries Society*. 126: 369-385.

61. Wimberger P. H. (1992). Plasticity of fish body shape, the effects of diet, development, family and age in two species of Geophagus (Pisces: Cichlidae). *Biological Journal of the Linnean Society*. 45: 197-218.