AgroLife Scientific Journal - Volume 9, Number 2, 2020
ISSN 2285-5718; ISSN CD-ROM 2285-5726; ISSN ONLINE 2286-0126; ISSN-L 2285-5718

VARIATIONS IN GROWTH AND REPRODUCTION MEASUREMENTS OF *Trachurus mediterraneus* FROM THE ROMANIAN BLACK SEA COAST

Cătălin PĂUN[1], Daniela BĂNARU[2], Liviu Daniel GALAȚCHI[3], Monica Paula MARIN[1], Livia VIDU[1], Carmen Georgeta NICOLAE[1]

[1]University of Agronomic Sciences and Veterinary Medicine of Bucharest, 59 Marasti Blvd, District 1, Bucharest, Romania
[2]Mediterranean Institute of Oceanography, UM110, Aix-Marseille University, Campus de Luminy, Marseille, France
[3]Ovidius University, University Alley no. 1, Constanta, Romania

Corresponding author email: cpaun@alpha.rmri.ro

Abstract

As the horse mackerel Trachurus mediterraneus (Steindachner, 1868) is one of the most exploited commercial species of the Black Sea fisheries, the knowledge of its different biological aspects related to growth and reproduction is highly important. This paper presents preliminary results of the analysis of morphological measurements (total length, total weight), Fulton relative body condition index, age, sex and degree of maturity of the horse mackerel population from the Romanian Black Sea coast. 563 individuals were collected between June and November in 2013, 2014, 2015 and 2018, from trawl and trap net catches. Their mean total length was 11.4 ± 2.4 cm, their mean total weight was14.4 ± 8.5 g and they had between 0 and 4+ years with a mean age of 1.7 ± 1.1 years. The data analyses of their measurements highlighted significant temporal differences between years and months, but no differences occurred between areas and sexes. These results should contribute to a better knowledge of the biology of the horse mackerel and may help to improve the management of the stock of this species for sustainable fisheries.

Key words*:age, biometry, Fulton index, sex-ratio.*

INTRODUCTION

The ecosystem approach to fisheries is an approach that supports the concept of sustainable development by promoting the maintenance of fishery resources in sufficient quantities for both current and future generations and it is envisaged that the development of conservation and management measures will be based on the best scientific evidence (ecological, social and economic) but also taking into account the traditional knowledge (Staples and Funge, 2009).

The horse mackerel (*Trachurus mediterraneus*) is a member of Carangid Family and represents a large part of the fisheries in Black Sea basin. The species of the genus *Trachurus* are pelagic fishes of economic importance (Bektas and Belduz, 2009). The small pelagic species horse mackerel is also important for Romanian fisheries for economic and social reasons in term of number of fishermen involved. Analysing the raw data from National Data Collection Programme, Păunet al. (2019) have noticed that this species represents about 30% of the Romanian summer pelagic catches, and a considerable percentage of the Black Sea total catches and provides income for the fisherman. Fisheries are a very diverse sector, which uses different fishing technologies and offers a wide variety of specific products (Nicolae et al., 2015). Fishermen from the Romanian Black sea area use diverse fishing methods such as setlines, long lines, and gillnets

Global state and dynamics of fish stocks of the main species with economic value represents a major concern since the size of fish stocks varies from year to year as a result of the most diverse natural and human causes (Nicolae et al., 2018). Multiple natural causes such as environmental variations and diet resources may influence growth, an important component of fish ecology, especially during early life history stages (Sogard, 1994; Claramunt and Wahl, 2000). These variations may be depicted by temporal survey of several biological population indicators such as size, weight, relative body condition factor, age and reproduction etc.

Biological characteristics of horse mackerel have been previously characterized in different areas of the Black Sea. Prodanov et al. (1997) studied growth and estimated the optimal level of exploitation of horse mackerel along the Bulgarian coast. Yankova and Raykov (2006), reported data for the growth parameters and natural mortality coefficient of this species in Turkey.

Ambroaz (1954) investigated the distribution, migratory patterns, and catch composition. The biology of this species along the Romanian coast has been reported in 1979 by Cautis and Jonescu. Despite the significant number of studies on horse mackerel, we notice a lack of recent data regarding morphometrics and reproduction of this species at the Romanian coast.

In the present paper growth and reproduction variables of the horse mackerel from the Romanian Black sea cost were reported. The studied variables were total length, total weight, condition factor, age, sex and gonadal maturity. The main hypothesis of our study is that they may change in time (year, month) and space and according to sex.

These variables are of high importance in fishery biology and stock management (Gulland, 1983).

MATERIALS AND METHODS

The study area was located in the north-western part of the Black Sea (Figure 1). The Romanian coastline (244 km) can be divided into two main geographical and geomorphological areas: North and South. These two areas present different hydrological, physical, chemical, sedimentary and biological characteristics (Panin, 2005). Seawaters of the Romanian coast are characterized by strong spatial and seasonal changes in temperature (0-27°C) and salinity (4-17) under Danube River and wind influences (Berlinsky et al., 2006).

For the purpose of this study, more than 563 individuals were collected from the trawl and traps net catches along the Black Sea coast area in the northern area (Corbu, Midia, Navodari, Mamaia) and the southern area (Eforie Sud, Costinesti, Olimp, Vama Veche) between June and November in 2013, 2014, 2015 and 2018 (Figure 1).

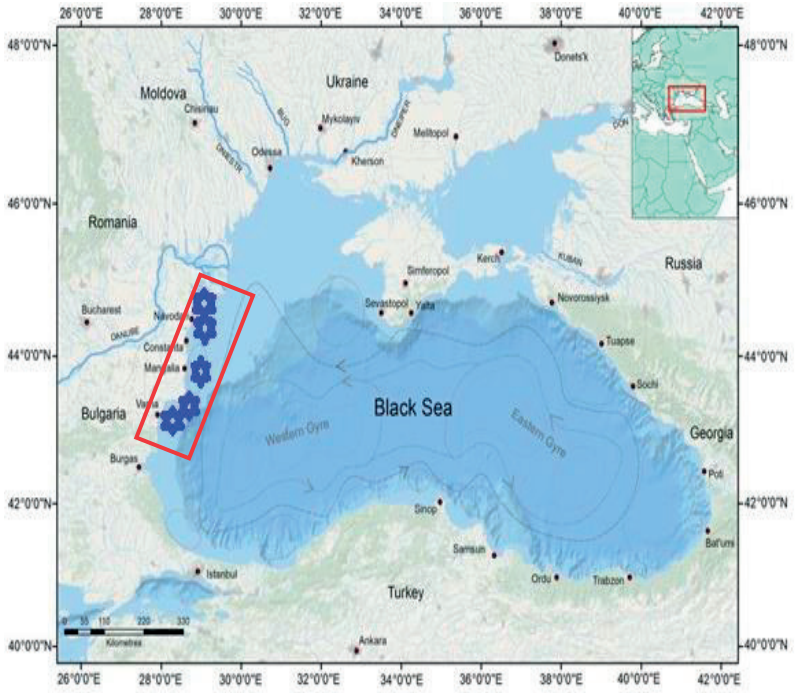

Figure 1. Sampling map (Photo original)

The captured fish were transported immediately on ice to the laboratory for analysis. Total length (TL) was measured to the nearest 0.1 cm and body weight to the nearest 0.1 g. The present study used otoliths to determine individuals'age for 383 individuals. Otoliths removed from the fish were stored dry in paper envelopes, and were then examined in

glycerine under a digital microscope. Age was determined from otolith rings, as previously described by Pravdin (1966).
Sexual maturity in fish has a great practical importance in the analysis of many population parameters. In general, fish are considered to be mature when they reach the middle of their maximum size (Holden and Raitt, 1974).
Sex, sex-ratio and reproduction stages were estimated for 325 individuals. Identification of sex and sexual maturity stages find their primary application in providing basic knowledge of the reproductive biology of a stock.
Regarding the determination of the degree of maturation, the visual examination is generally used. However, if difficulties are encountered in the determination, histological analysis of the gonads may be used.
The maturity stages used are those developed by Nikolski (1962) and taking into account the recommendations of DCRF, ver. 19.1 (GFCM, 2018) as follows: stage 0: undetermined; stage 1: immature; stage 2: beginning of ripening; stage 3: mature; reproductive; stage 4: in full reproduction activity; breeder; stage 5: end of reproduction; spent; stage 6: resting, recovering.
Fulton's relative body condition factor (Ricker, 1975) was calculated per individual for 563 individuals using the following formula: $K = (TW \times 100)/TL^3$, with TW = total mass (in grams) and TL = total length (in centimetres).
Non-parametric analyses of variance (Kruskal-Wallis) were performed using the STATISTICA 13.1 in order to analyze differences between years, months, areas and sex.
Normality and homogeneity of variances was tested using the Shapiro-Wilk and Levene tests prior to these analyses and means were compared using multiple comparison tests (Underwood, 1997).

RESULTS AND DISCUSSIONS

Determination of growth parameters and age is important in ichthyologic investigations, as fish growth is one of the main factors that determine stock variations (Mikhailov and Prodanov, 1983).
Growth parameters are based on morphometrics such as total length, total weight and age.
Environment and diet may influence their relative body condition.
Fulton relative body condition factor (Ricker, 1975) is used to compare the condition of individuals and is based on the initial assumption that for the same given length, a heavier individual will have better relative body condition.
Relative body condition is highly important since it influences growth, reproduction and survival of individuals (Shulman and Love, 1999).
In fact, larger and fatter individuals will have more reserves and more eggs with more yolk. These reserves will ensure better chances of survival and recruitment of larvae and juveniles in the population, as well as better chances of survival in a disturbed situation.

Total length

The mean total length of the 563 analyzed individuals was 11.4 ± 2.4 cm. High significant differences were shown between years, followed by differences between months and the lowest ones between sexes (see H tests values in Tables 1 to 3).
The highest mean total length was registered in 2015 (13.9 ± 1.2 cm), and the lowest one in 2014 (8.5 ± 1.5 cm) (Table 1).
The highest values were recorded in July and the lowest ones in October-November (Table 2).
Significant different values were found only between females and juveniles (Table 3). However the low number of juveniles sampled is not concluding and is related to the selectivity of the fishing gear and area.For all the analysed variables no significant differences were founded between northern and southern areas ($p < 0.05$).
The captured individuals were smaller than those identified on the Bulgarian Black Sea coast, up to 19 cm (Yankova, 2013).The horse mackerel samples from the Romanian Black Sea coast have a growth rate different from those in other areas of the sea, most likely due to different living conditions and availability of food (Bănaru et al., 2009). Inter annual variation may be related to differences in recruitment but also to migrations and larger scale studies should be make in the Black sea in order to cover the entire migration area of the horse mackerel.

Table 1. Mean values and standard error of the total length (TL), total weight (TW) and Fulton index (K) by year

Year	TL (cm)			TW (g)		K	
	N	Mean	SE	Mean	SE	Mean	SE
2013	155	11.1	2.3 [a]	12.7	6.4 [a]	0.84	0.18 [a]
2014	120	8.8	1.5 [b]	6.0	2.5 [b]	0.86	0.99 [a]
2015	108	13.9	1.2 [c]	22.8	5.7 [c]	0.84	0.06 [a]
2018	180	11.9	1.8 [a]	16.4	8.6 [d]	0.91	0.09 [b]
		H = 275.18		H = 291.33		H = 68.2	
		p < 0.001		p < 0.001		p < 0.0001	

N.B.: H represents the test statistics of Kruskal-Wallis testing the significance of the differences between years; P = associated p-value; Superscript letters represent post-hoc groups. For each variable values with similar post-hoc letters are not significantly different (P > 0.05); N= number of analysed individuals; SE = standard error.

Table 2. Mean values and standard error of the total length (TL), total weight (TW), Fulton index (K), age (A) and degree of maturity (DM) by month

Month	TL (cm)			TW (g)		K		Age (y)			DM		
	N	Mean	SE	Mean	SE	Mean	SE	N	Mean	SE	N	Mean	SE
June	70	11.9	0.6[bc]	13.4	2.0[bc]	0.80	0.06 [a]	70	2.7	0.5 [c]	70	2.7	0.9 [b]
July	192	12.4	2.0 [c]	18.4	8.8 [c]	0.89	0.09 [c]	63	2.0	1.0 [b]	72	3.3	0.9 [c]
August	130	11.2	3.0 [b]	14.4	8.9 [b]	0.89	0.19 [c]	130	1.6	0.9 [b]	63	2.1	0.8 [a]
September	61	12.0	2.6[bc]	16.4	9.4[bc]	0.84	0.07[ab]	50	1.8	1.2[b]	50	2.9	0.9[bc]
October	40	8.6	1.4[a]	5.7	2.1 [a]	0.87	0.11 [b]	40	0.7	0.6 [a]	40	2.0	0.6 [a]
November	70	9.5	1.2 [a]	7.4	2.4 [a]	0.85	0.09 [b]	30	0.8	0.7 [a]	30	2.0	0.6[a]
		H = 157.79		H = 167.06		H = 67.99			H = 132.92			H = 85.21	
		p < 0.001		p < 0.001		p < 0.0001			p < 0.001			p < 0.0001	

N.B.: H represents the test statistics of Kruskal-Wallis testing the significance of the differences between months; P = associated p-value; Superscript letters represent post-hoc groups. For each variable values with similar post-hoc letters are not significantly different (P > 0.05); N= number of analysed individuals; SE = standard error.

Table 3. Mean values and standard error of the total length (TL), total weight (TW) and Fulton index (K) by sex

Sex	TL (cm)			TW (g)		K	
	N	Mean	SE	Mean	SE	Mean	SE
Males	251	11.2	2.4[ab]	13.6	8.5[ab]	0.86	0.10 [a]
Females	310	11.6	2.3 [a]	15.1	8.5 [a]	0.86	0.09 [a]
Juveniles	2	3.1	0.1 [b]	0.6	0.1 [b]	2.11	0.53 [b]
		H = 9.2		H = 11.38		H = 6.15	
		p < 0.01		p < 0.001		p < 0.05	

N.B.: H represents the test statistics of Kruskal-Wallis testing the significance of the differences between sexes; P = associated p-value; Superscript letters represent post-hoc groups. For each variable values with similar post-hoc letters are not significantly different (P > 0.05); N= number of analysed individuals; SE = standard error.

Total weight

The mean total weight of the 563 analyzed individuals was 14.4 ± 8.5 g.

The highest total weight was registered in 2015 (22.75 ± 5.67 g), and the lowest ones in 2014 (6.03 ± 2.50 g) (Table 1). Similarly to the total length, the highest values were recorded in July and the lowest ones in October-November (Table 2) and significant different values were found only between females and juveniles (Table 3). Studies conducted for horse mackerel taken from the Turkish Black Sea region revealed a spectrum of weight between 3.32 g and 59.98 g (Aydin and Karadurmuş, 2012).

The total length was highly correlated with the total weight ($TW = 0.5058 * e^{0.2761TL}$; $R^2 = 0.9521$).

Fulton Index

The mean value of the Fulton index of the 563 analyzed individuals was 0.87 ± 0.12. Higher the Fulton coefficient is and better the relative body condition is. Higher relative body

conditions were shown in 2018 (0.91 ± 0.09) compared to the other years (Table 1). Seasonal variations of the relative body condition were highlighted with the lowest values in June and the highest ones in July and August (Table 2). These variations may be related to the life history traits and their environmental condition and diet during the previous months. Juveniles had better relative body condition than males and females (Table 3).

Age

Determining the age of fish is an important element for the study of the populations dynamics. Analyzedhorse mackerel individuals age varied between 0 and 4+ years. The mean age was 1.7 ± 1.1. Seasonal differences were highlighted with the oldest individuals were found in June (2.7 ± 0.5 years) and the youngest in October-November (0.7-0.8 years) (Table 2). No significant differences in ages were found between years, areas and sexes ($p < 0.05$).

Mean total length and total weight increased with age from 7.2 + 1.0 cm and respectively 3.7 + 1.0 cm for 0+ age individuals to 15.5 + 0.8 cm and, respectively 31.0 + 5.9 g for 4 years individuals (Table 4). Relative body condition factor decreases from 0+ (0.98) to 1-2 years (0.83-0.85) and to 3-4 years (0.80-0.83), while the degree of maturity increases with age from 1.5 ± 0.4 for 0+ year individuals to 4 ± 0.4 for 4 years individuals. This inverse relation may be related to higher energetic investment for reproduction in larger and older individuals.

Table 4. Mean values and standard error of the total length (TL), total weight (TW), Fulton index (K) and maturity degree by age (years)

Age (y)	TL (cm)			TW (g)		K		DM		
	N	Mean	SE	Mean	SE	Mean	SE	N	Mean	SE
0+	55	7.2	1.0	3.7	1.0	0.98	0.25	53	1.5	0.4
1	106	9.6	1.7	8.0	4.3	0.83	0.08	86	2.2	0.5
2	118	12.2	1.3	15.9	5.0	0.85	0.08	70	2.7	0.8
3	97	13.5	1.5	20.6	7.3	0.80	0.08	60	3.0	1.0
4	7	15.5	0.8	31.0	5.9	0.83	0.04	4	4.0	0.4

N.B.: N = number of analysed individuals; SE = standard error

Sex

Gonads differences between sexes appeared early at 0+ age individuals. Only two juvenile individuals were recorded. Mean sex-ratio (males/females) over the study period was 0.88. This ratio was variable between years (minimum = 0.46 in 2015 and maximum = 1.04 in 2013), months (minimum = 1.92 in June and maximum = 0.78 in July) and areas (0.74 in the north and 0.81 in the south). Males dominated the 0+ age class (sex-ratio = 1.1) while female dominated in 1 year age class (sex-ratio = 0.45). Natural variability of sex-ratio in recruitment but also fisheries pressure on young stages may be responsible of these differences.

Gonadal maturity

Sexual maturity has a practical importance in the analysis of population. Generally, fish are considered to be mature when they reach the middle of their maximum size (Păun et al., 2019).

Over the whole studied period, the mean value of the gonadal maturity index of the 325 analyzed individuals was 2.6 ± 1. Significant differences were shown between months with the highest values in July(3.3 ± 0.9) when they also had the better relative body condition, while the lowest values were observed in October and November (Table 2). No significant differences in ages were found between years and sexes for gonadal maturity ($p < 0.05$).

CONCLUSIONS

Mean total length and weight of the analyzed horse mackerels from the Romanian Black sea coast were rather low as the majority concerned 1 and 2 years aged individuals confirming the interest of this region as feeding and nursery

area. Temporal variations were highlighted. Total length and weight showed the highest values in 2015 and in July and the lowest ones in 2014 and in October-November. Inter-annual variations of the studied variables appeared to be the highest compared to monthly variations. Sex had low influence.

Relative body conditions values were higher in 2018 compared to the other years and higher in July and August compared to June. Relative body condition factor decreases from younger to older individual, while the degree of maturity increases with age. The gonadal maturity analyses showed that the reproduction occurs mainly during summer with a maximum in June. Between June and September larger, heavier and older individuals come in this area to reproduce.

This survey should be completed and extended to a longer period and to the others month of the year. Spatial coverage extension should also be considered at a larger scale in the Black sea area as the horse mackerel is a migratory species.

In recent years the Romanian catches of horse mackerel have not exceeded 2% of the total catch. However for the Black sea the percentage of species whose stocks are outside safety limits was close to 90%. Exceeding the safety limits is not only due to the over-exploitation of the Romanian marine sector, the majority of the fish species having a cross-border distribution, which requires a regional management, as well as an ecosystem approach. This management should also take into account these biological variables of the exploited populations and relate them to environmental and intra- and interspecific variations in order to put these data into a global ecosystem approach at the Black sea level.

REFERENCES

Ambroaz, A. (1954). Distribution and fishery of the Black Sea horse mackerel. Tr.VNIRO, 28, 113-125 (In Russian).

Aydin, M., Karadurmuș, U. (2012). Age, growth, length-weight relationship and reproduction of the Atlantic horse mackerel (*Trachurus trachurus* Linnaeus, 1758) in Ordu (Black Sea). *Ordu University Journal of Science and Tecnology*, II(II), 68-77.

Bănaru, D., Harmelin-Vivien, M. (2019). Feedingbehavior of Black Seabottomfishes: Did it change over time? *ActaOecologica*, 35, 769-777.

Bektas,Yu.,Belduz, A. (2009). Morphological variation among Atlantic horse mackerel, *Trachurus trachurus* Populations from Turkish Coastal Waters. *Journal of Animal and Veterinary Advances*, 8(3), 511-517.

Berlinsky, N., Bogatova, Y., Garkavaya, G. (2006). Estuary of the Danube. *Hdb Environ. Chem*., 5, 233-264.

Cautis, I.,Jonescu, N. (1979). Structura populatiilor de stavrid. In E. Poraed. - Le Chinchard de la Mer Noire (*Trachurus mediterraneus ponticus*) Etude monographique, Deuxieme Partie: 485-508 (in Romanian).

Claramunt, R.M., Wahl, D.H. (2000). The effects of abiotic and biotic factors in determining larval fish growth rates: a comparison across species and reservoirs. *Transaction of the American Fisheries Society*,129, 835-851.

Gulland, J.A. (1983*). Fish stock assessment: a manual of basic methods*. FAO/Wiley Series on Food and Agriculture, Rome, I, 184 pp.

Holden, M.J., Raitt, D.F.S. (1974). Manual of Fisheries Sciences, Part 2 - Methods of Resource Investigation and their Application, FAO, Rome, 255 pp. Retrieved November 12, 2019, from http://www.fao.org/3/F0752E/F0752E00.htm.

Mikhailov, K., Prodanov, K. (1983). Approximate assessment of the natural mortality rate of the anchovy in the Bulgarian Black Sea coast. *Pross. IRR*, Varna, 20, 173-182.

Nicolae, C.G., Moga, L.M., Nenciu, M.I., Bahaciu, G.V., Marin, M.P. (2015). Particularities and management of the distribution chain for fish and fishery products. *AgroLifeScientific Journal*, 4(1), 111-116.

Nicolae, C.G., Păun, C., Nuţă, A.M., Marin, M., Pogurschi, E., Bahaciu, G., Maftei, M. (2018). Study of the ichthyofauna diversity in the Romanian seaside area. *Current Trends in Natural Sciences*, 7(14), 168-175.

Nikolski, G.V. (1962). Fish Ecology, RPP Academy. The Institute of Romanian-Soviet Studies, p. 362 (in Romanian).

Panin, N. (2005). The Black sea coastal zone - an overview. *Geo-Eco-Marina (European seas: coastal zones and rivers – sea system)*, 11, 21-40.

Păun, C., Galaţchi, M., Popescu, A., Vidu, L., Pogurschi, E., Nicolae, C.G. (2019). Age at first sexual maturity of *Trachurus mediterraneus* (Steindachner, 1868) from Romanian Black Sea waters, indicator of good status of the population. *Scientific Papers. Series D. Animal Science*, LXII (2), 371-376.

Pravdin, U. (1966). Manual of fish research. Nutritional Industry, Moscow, 179-191 (in Russian).

Prodanov, K., Mikhailov, K., Daskalov, G., Maxim, K., Chashchin, A., Arkhipov, A., Shlyakhov, V., Ozdamar, E. (1997). General fisheries council for Mediterranean, FAO. Studies and reviews. Environmental management of fish resources in the Black Sea and their rational exploitation. *Studies and reviews*, 68, 73-81.

Ricker, W.E.(1975). Computation and interpretation of biological statistics of fish populations. *Bulletin of the Fisheries Research Board of Canada*, 191, 1-382.

Shulman, G.E., Love, R.M. (1999). The biochemical ecology of marine fishes. *Advances in Marine Biology*, 36, 1352.

Sogard, S.M. (1994). *Use of suboptimal foraging habitats by fishes: consequences to growth and survival*. In Theory and Application in Fish Feeding Ecology (Stouder, D.J., Fresh, K.L. & Feller, R.J., eds.), Columbia, SC: University of South Carolina Press, 103-131.

Staples, D., Funge-Smith, S. (2009).*Ecosystem approach to fisheries and aquaculture: Implementing the FAO Code of Conduct for Responsible Fisheries.* FAO Regional Office for Asia and the Pacific, Bangkok, Thailand. RAP Publication 2009/11, 48 pp.

Underwood, A.J. (1997). Experiments in Ecology – Their Logical Design and Interpretation Using Analysis of Variance. Cambridge University Press, 504 pp.

Yankova, M. (2013). A study on the growth of horse mackerel (*Trachurus mediteraneus* Aleev, 1956) from Bulgarian waters of the Black Sea using length frequency analysis. *Journal of the Black Sea/Mediterranean Environment*, 19(1), 111-120.

Yankova, M., Raykov, V. (2006). Approximate assessment of the horse mackerel natural mortality rate, *Trachurus mediterraneus ponticus,* Aleev in the Bulgarian Black Sea territorial waters. *Secretary marine I.N.C.D.M*., 36, 341-348.

***GFCM(2018). GFCM Data Collection Reference Framework (DCRF), Version: 19.1.