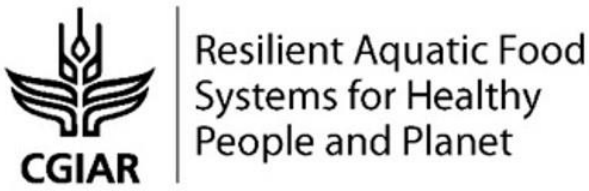

Study Protocol: Development of an economic trait prioritization for Tilapia in Nigeria

Prepared by

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Study Title

Development of an economic trait prioritization and breeding objectives for Tilapia in Nigeria

Study Investigator(s)

Principal Investigator (A):

Principal Investigator (B):

Principal Investigator (C):

Principal Investigator (D):

Background

A review and assessment of the Tilapia industry in Nigeria was carried out in preparation for the development of a breeding objective and selection index or indexes (AbacusBio and WorldFish report titled: Assessment of the Tilapia industry in Nigeria for economic trait prioritization; September 2023). The study involved stakeholder consultations and literature research. The objective of the study was to assess market and industry information to identify available data and data gaps in the context of economic breeding objective development needs. The outcome of the assessment was an outline of Tilapia traits, definitions, units, and level of importance for a potential breeding objective (Table 1). The importance level for these traits was determined through consultations with project partners and stakeholder engagements. The findings also included a list of available inputs and parameters that have the potential to vary and, to therefore, impact breeding objective and selection index outcomes. Further, information was collected for different groups (by region, gender, production system and farm size) to build an understanding of how trait priorities might differ across the industry.

Table 1: A shortlist of traits, definitions, units, and importance for a potential breeding objective.

Type	Trait	Definition	Units	Importance
Growth	Feed efficiency / FCR	Efficiency converting feed to body weight	kg growth / kg feed	Critical
	Harvest weight / Growth	Body weight at constant harvest age	Kg	Critical
Survival	TiLV Resistance	Probability of survival, given exposure	% survival	Low
	Black Spot resistance		% survival	Medium
	Streptococcus resistance		% survival	Medium
	Resilience to low oxygen		% survival	High
Reproduction	Reproductive rate	Fry produced per female	Fry/brood/ cycle	High
Market	Fillet weight		G	Low
	Body shape		% in spec.	Low
	Body colour		% in spec	Low

Following the review and assessment, a full-scale trait prioritization analysis was recommended, including more detailed economic modelling and a survey to establish trait preference coefficients (see below for definition of trait preference coefficients), to address gaps in existing data and produce a breeding objective and a selection index or indexes.

Aim(s) of Study

1. To investigate the variability between production systems, across geographies, and related to gender within and between systems in Nigeria in a) economic model input parameters, and b) Tilapia trait preferences.
2. To incorporate this variability into trait economic weights for a breeding objective and a selection index or selection indexes that meets the needs of the Nigerian Tilapia industry.

Both studies will be carried out in 2024 in Nigeria.

Objectives

Study 1

Study 1 will focus on quantifying trait economic weights (Hazel, L.N., 1943; James, 1980). across different production systems (cage, tank, and pond). This will provide the necessary information to understand and determine the value of different traits of interest to the different stakeholders, thereby directly linking selection decisions to real-world impact, incorporating revenue, costs, and resultant profit on a per trait basis (e.g., Byrne et al. 2016). Bio-economic modelling and willingness to pay approaches (e.g., Nielsen, H.M., Amer, P.R., 2007) will be used to quantify trait economic weights.

The process will also help to identify economic sustainability metrics, and the influence that different drivers (e.g., gender, production system etc.) have on these metrics.

Study 2

Study 2 will capture preferences for trait improvements, to understand market and as well as non-market drivers of trait improvement priorities. The systematic integration of farmers' preferences into selection and breeding decisions is expected to support faster and more balanced rates of genetic gain and deliver improved fish that best meet farmer and value chain needs (e.g., Martin-Collado et al, 2015; Byrne et al. 2016; Balogun et al, 2022; Okello et al, 2022).

Study 2 will capture both sociodemographic insights and data on the relative preferences for improvements in breeding program target traits. The preference data will be analyzed to identify clusters or groups of farmers/ supply chain actors with similar patterns of preference, and to calculate trait preference coefficients to inform selection indexes for specific market needs. Given the need to understand gender, and other sociodemographic dynamics in relation to Tilapia trait preferences (Murphy et al, 2020; Mehar et al.,2023), the survey sampling will be designed to account for the different sociodemographic groups that exist in the Tilapia industry in Nigeria. There is also an opportunity for a more in-depth investigation into the differences in production systems and trait preferences of women compared to men.

Study Design

Study 1 will use case studies involving an in-depth, detailed, analysis of a representative selection of farmers and wholesalers/ retailers from across the Tilapia industry in Nigeria.

Study 2 will be a cross-sectional study administered through structured questionnaires.

Study Setting/ Location

The study will take place in five geopolitical regions of Nigeria. The regions are south-east, south-south, south-west, north-central, and north-west regions. The states in these regions are Lagos, Ogun, Oyo, Delta, Rivers, Anambra, Kano, and Niger state. These were the locations utilized in the Nigeria fish futures study (Subasinghe et al., 2021).

Study Population

Study 1 population will comprise Tilapia farmers, hatchery operators and wholesalers/ retailers in Nigeria.

Study 2 population will comprise Tilapia farmers and hatchery operators.

Eligibility Criteria

Participants must engage in a Tilapia value chain activity. Table 2 presents inclusion/exclusion criteria for different value chain participants.

Table 2: Inclusion/exclusion criteria for different value chain participants.

Inclusion/exclusion criteria	Farmers/hatchery operators	Wholesalers/retailers
Production of Tilapia for more than one production cycle	✓	
Participation in production decision making	✓	
Aged 18 years and above	✓	✓
Willingness to continue producing Tilapia for at least one more production cycle	✓	

Recruitment of participants

Staff involved in the WP4 of the Aquatic Foods Initiative Nigeria will inform eligible participants prior to the interviews to seek their consent to carry out the research.

Study Procedures

The two studies (using questionnaires) will be administered via face-to-face meetings. AbacusBio staff will deploy study 1 with support from staff involved in the WP4 of the Aquatic Foods Initiative. Study 2 will be administered by trained enumerators. Each enumerator will have a tablet to administer the survey. Detailed study procedures for the two studies are outlined below.

Study 1

Milestone 1.1. Data gathering.

A data gathering exercise will be conducted across systems, geographies and with attention to gender. Separate approaches will be deployed for production and market traits.

For production traits, where parameters are available for the production system(s), data will be gathered to populate economic models. Table 3 shows the draft parameters collected during the initial assessment. These and other relevant parameters will be collected using a more in-depth methodology (i.e., case study) with a goal to uncover the level of variation across the production segments of the Tilapia industry in Nigeria.

Table 3: Draft input parameters.

	Production system			
Parameter	**Cage**	**Tank**	**Pond**	**Source**
Price of seed stock (NGN/Fry)	18.50	18.50	18.50	NFF: Page 25[1]
Price of feed (NGN/kg)	309.33	309.33	309.33	NFF: Table 5
Price of Tilapia (NGN/kg)	915.72	915.72	915.72	NFF: Table 9 & 14[2]
Feed conversion ratio	1.5	1.75	1.75	Industry assessment (IS)
Mortality (%)	20	20	20	NFF: Table 9[3]
Yield (t/ha)	10	2.49	5.67	NFF: Table 9 & IS
Harvest weight[4] (kg)	0.5	0.5	0.5	Industry assessment
Age at harvest (days)	182.5	182.5	182.5	Industry assessment
Annual Profit (m NGN/ha)	**25.81**	**6.19**	**14.11**	**Calculated**

For the market traits – fillet weight, body shape and body colour – that are more difficult to assign market value/ price premium to and include in the economic modelling, a willingness to pay approach will be deployed. Participants (wholesalers/ retailers) will be presented with options representing images of fish with the phenotypic range of the trait of interest from best to worse. This will be carried out in two steps.

In the first step, wholesalers/ retailers will indicate how much they are willing to pay to farmers for each option. In the second step, wholesalers/ retailers will indicate how much they would expect to sell each option for. Data on the buy/ sell price per fish will then be collated and averaged across respondents, within phenotypic option, to estimate the value of a one-unit improvement in the trait (i.e., the economic weight of each market trait). With this approach and the resultant dataset, it will be possible to define the market traits as valued in the market, at the farm gate, or via some weighted combination of the price at the two transaction points.

Milestone 1.2. Bio-economic model developed.

AbacusBio will develop models and calculate the economic weights for each of the identified traits ($b_{economic}$ in Figure 1). Economic weights allow for a breeding objective to be designed with the greatest emphasis placed on the most economically important traits. These economic weights are based on underlying economic parameters, which are used to define a "profit equation" for farmers (e.g., farmer profit model in AbacusBio and WorldFish report titled: Assessment of the Tilapia industry in Nigeria for economic trait prioritization; September

[1]Nigeria Fish Futures: Aquaculture in Nigeria. WorldFish (2021).

[2] Implied 2021 exchange rates: 1 USD = 362 NGN (date Nigeria Fish Futures report was published).

[3] Assuming that "other production" is representative of concrete tank producers.

[4] Harvest weight applied to both harvest weight and the growth parameter.

2023) – where farm profit is expressed as a function of underlying genetic trait. Economic weights are then calculated to reflect the change in farmer profit associated with a 1-unit increase in each trait, and where the economic weights vary between system and between region, according to underlying parameter variation between systems and region.

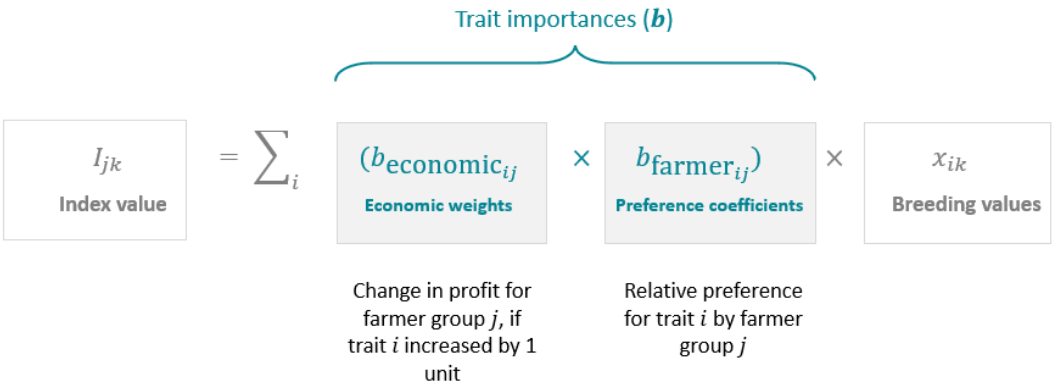

Figure 1: Calculation of a selection index value using economic weights and preference coefficients.

Staff involved in WP4 of the Aquatic Foods Initiative will also provide feedback on economic weights.

Milestone 1.3. Report.

The final report documentation for Study 1, covering rationale and methodology, and the codebase of economic models/algorithms and database containing the economic weights will be shared with the Aquatic Foods Initiative.

Study 2

Milestone 2.1. Engagement.

Staff involved in the Aquatic Foods Initiative will be engaged to support the development and deployment of the survey. Information about potential survey participants will be compiled and decisions around logistics in deploying the survey will be finalized.

Milestone 2.2. Survey designed and tested.

A questionnaire with sociodemographic and trait preference questions, including design elements to capture gender differences will be designed, with input from the Aquatic Foods Initiative, and tested.

The sociodemographic section of the survey will include important questions, the answers to which are expected to be different for respondents in different trait preference groups. These characteristics will be grouped into 5 sections, comprising:

i. Tilapia purchase, production, harvest, and sale – are purchase, production, harvest or sales etc. drivers of preferences for specific Tilapia traits?
ii. Farm characteristics – are total land/area devoted to aquaculture, total labor availability, proximity to markets, etc. drivers of preferences for specific Tilapia traits?
iii. Future important topics – are climate change, government policies, market forecasts, future traits of importance, and diseases concerns etc. drivers of preferences for specific Tilapia traits?
iv. Access to resources and inputs – are access to resources and inputs drivers of preferences for specific Tilapia traits?
v. Gender – is gender a driver of preferences for specific Tilapia traits?

The trait preference section of the survey will be designed to present trait changes that are of equivalent average economic effect (the equivalent "level"), using economic weights calculated in study 1. Trait preference coefficients are calculated from farmer trait preferences as deviations from the expected preference based on the bio-economic model average (b_{farmer} in Figure 2).

$$b\text{farmer}_{ij} = \frac{\text{observed preference (\%)}}{\text{expected preference (\%)}}$$

Figure 2: Calculation of preference coefficients from farmer preference data.

Harvest weight will be considered as the benchmark trait for level setting. Several factors will be considered to determine what a perceived meaningful increase in profit from harvest weight is (e.g., a 5, 10 or 15% increase in profit) by farmers. These factors could include the amount of profit worth marketing by a breeding program or the amount of profit seen as reasonable to a farmer, as it relates to the profitability of their current production system. This approach ensures that no individual trait will be inadvertently under- or over-valued through a trivial quantity being offered.

After setting a realistic level for harvest weight, the monetary equivalent of this increment in harvest weight will be calculated for the other traits, using the economic weights from study 1. This means farmers will be presented with alternative choices of trait improvements with the same average economic effect. Presenting the same economic equivalence for all traits ensures that no individual trait is under- or over-valued in the preference choice.

Figure 3 illustrates a hypothetical trait preference question. In this instance, the economic models (study 1) would have shown that a 0.1kg increase in harvest weight has the same average economic effect to a 4.3% increment in resilience to low oxygen, so that a farmer's choice reflects their perceived preference (either for market or non-market reasons) for an improvement in one trait over another.

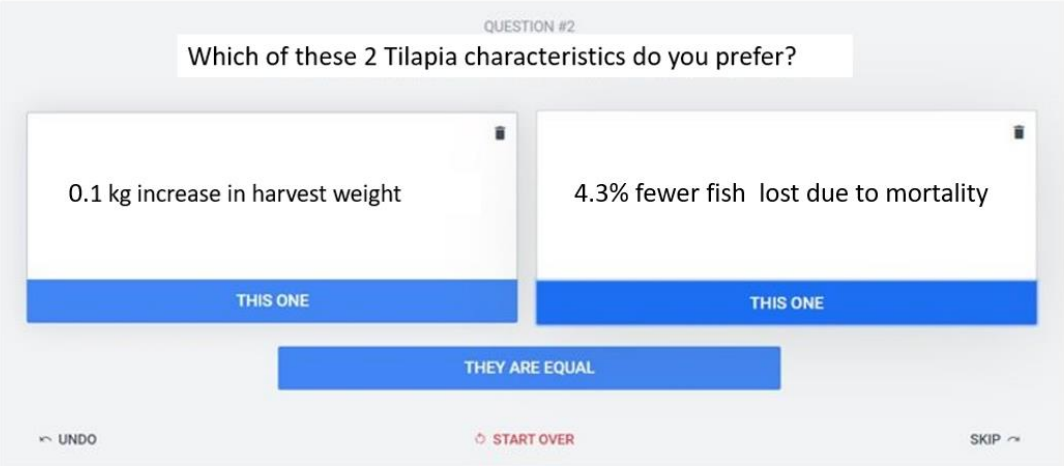

Figure 3: Hypothetical 1000Minds trade off question.

The trait preference survey design also ensures that traits in 1000Minds are defined in terms and units that farmers can understand and that can be transformed (if required) into the terms and units of traits in the bio-economic model (study 1).

The number of surveys to deploy (where a different survey means that traits are presented with different levels) is based on the variation in economic weights of different groups (region, production type, farm size and gender) and the final survey will be tested with project partners and a small group of farmers, with refinements made based on testing feedback.

Milestone 2.3. Enumerators trained.

Enumerators are trained on how to administer the structured questionnaires.

Milestone 2.4. Survey deployed.

Survey deployed via WorldFish's and IITA's channels and contacts, capturing data to be used in the survey data analysis.

Milestone 2.5. Survey data analyzed.

A set of trait preference typology groups is defined and characterized, and a set of trait preference coefficients calculated, to be used for economic weight development. The Aquatic Foods Initiative will also provide feedback on D2 trait preference coefficients. The analysis steps are:

i. Expected percent preferences are calculated for each trait, assuming the economic model is perfect and assuming the farmers make 'economically perfect' decisions. The expected preference is calculated as 100/ n, with n being the number of traits in the survey.

ii. 1000Minds software produces a percent preference for each trait, by respondent; this is the observed percent preference.
iii. The ratio between the observed percent preference and the expected percent preference is calculated (see Figure 2). This value becomes the trait preference coefficient.
iv. Trait preference typologies are created based on the trait preference coefficient data.

A trait preference coefficient of <1 implies that farmers/ hatchery operators value the trait less than expected based on the economic model, and so economic weights will be down weighted. A trait preference coefficient of 1 implies that the economic model is a reasonable predictor of farmers/ hatchery operators' preferences and so the economic weights are not changed. A trait preference coefficient of >1 implies that farmers value the trait more than expected based on the economic model, and so the economic weight will be upweighted. Trait preference coefficients will be calculated, and applied to economic weights, by typology. This effectively creates new sets of economic weights aligned with economic drivers (study 1) and with market needs (study 2).

The data will present an opportunity to conduct analysis within sociodemographic characteristics and the relationships between trait preference typologies (the trait preference coefficients within a typology) and farmer sociodemographic characteristics (e.g., Tilapia purchase, production, harvest, and sale; farmographics; future important topics, traits, and diseases; access to resources and inputs). The extent to which sociodemographic characteristic and relationships between trait preference typologies (the trait preference coefficients within a typology) and farmer sociodemographic characteristics, will be analysed will be agreed upon with staff involved in the WP4 of the Aquatic Foods Initiative during engagement prior to the commencement of the study, and dependent on the project budget available.

Milestone 2.6. Survey data archived.

The survey dataset will be transferred to the Aquatic Foods Initiative and archived.

Milestone 2.7. Report.

The final documentation covering methods, rationale, analysis, results, and outcomes of study 2 will be shared with the Aquatic Foods Initiative.

Measurement tools

For the calculation of trait preferences, the 1000Minds survey tool (www.1000minds.com) will be used. This tool employs adaptive conjoint analysis based on Potentially All Pairwise RanKings of all possible Alternatives (PAPRIKA) (Hansen & Ombler, 2008). The approach presents trait-by-trait trade-offs and adjusts which questions are asked based on responses

to previous questions. Hansen and Ombler (2008) provide a detailed description of the 1000Minds survey algorithm.

For the sociodemographic questions, Alchemer software (https://www.alchemer.com/) will be used.[5] The Alchemer software is an online survey platform that can be used to collect sociodemographic data. The Alchemer software can pass through survey respondents ID information to the 1000Minds platform. Internet access is required for the functioning of the survey.

R Software (R Core Team (2022)) will be used for the analysis of survey data.

Data monitoring

Data monitoring and data cleaning will be carried out daily during survey period. The following quality control checks will be put in place for the trait preference section of the survey:

i. Incorrectly answered the consistency check question that repeats, within the survey, some questions using two easy trait trade-offs.
ii. Only clicked the 'they are equal' button, as they are unlikely to have answered the survey questions genuinely.
iii. Only choose the 'left' or only choose the 'right' option, as they are unlikely to have answered the survey questions genuinely.
iv. Answered too fast (minimum), being farmers who answer any question in less than 1 second.
v. Answered too fast (median), being farmers with a median answer time of less than 2 seconds.

Responses from farmers who do not meet the quality control checks will be excluded.

Statistical Considerations and Data Analysis

Sample size and statistical power

The study will follow the sampling strategy of the Nigeria fish futures (Subasinghe et al., 2021). The two studies will employ multi-stage sampling. Five geopolitical regions: south-east, south-south, south-west, north-central and north-west region will be selected. Eight representative states will be selected within the five geopolitical regions.

Due to limited data available for farmed Tilapia in Nigeria, farm size is defined using values extrapolated from farmed Catfish earthen pond system (Subasinghe et al., 2021). Farm sizes categories are defined as:

[5] Alternative platforms can be used, at the discretion of WorldFish. However, these platforms must be able to pass through respondent ID information seamlessly to 1000Minds.

- Small – less than 0.13ha
- Medium – 0.13ha – 2.9ha
- Large – greater than 2.9ha

Study 1

Eight interviews will be conducted per state to account for different groups that exist among Tilapia farmers/ hatchery operators – production type (3), farm size (3), and gender (2). This will be a maximum of 64 interviews.

To conduct the willingness to pay exercise, 24 wholesales/ retailers (3 per state) will be surveyed to establish economic weights for market traits.

Study 2

To account for regional, production type, farm size, and gender differences, a sample size of 367 farmers will be required. The sample size was estimated following the fish futures sampling strategy (Subasinghe et al., 2021). Table 4 shows the breakdown of the sample sizes for the different categories of farmers.

Table 4: Sample Size (Study 2)

Criteria	Category	Sample size	Proportion
Region	South-east	17	5%
	South-south	117	32%
	South-west	187	51%
	North-central	24	7%
	North-west	22	6%
State	Lagos	111	30%
	Ogun	81	22%
	Oyo	46	13%
	Delta	36	10%
	Rivers	29	8%
	Anambra	24	7%
	Kano	22	6%
	Niger	17	5%
Production system	Cage	220	60%
	Tank	74	20%
	Pond	73	20%
Gender	Men	312	85%
	Women	55	15%
Farm size	Small (<0.13ha)	37	10%
	Medium (0.13-2.9ha)	294	80%
	Large (> 2.9ha)	36	10%

Statistical methods (study 2)

Statistical methods include:

- Descriptive summary statistics and appropriate presentation mechanisms.
- Potentially all pairwise ranking of possible alternatives (PAPRIKA) to rank respondent's Tilapia trait preferences.
- Cluster analysis (using k-means) and principal components analysis to identify groups that exist based on Tilapia trait preferences (preference coefficients).
- Examination of sociodemographic characteristics and relationships between trait preference coefficients within grouping and farmer sociodemographic characteristics (e.g., Tilapia purchase, production, harvest, and sale, farm characteristics, future important topics, traits, and diseases, access to resources and inputs) using the

appropriate methods, e.g., ANOVA to compare continuous variables between groups, where appropriate, with Tukey's test and Chi-square test of independence to examine categorical variables between groups, with Bonferroni Adjustment.

Study Outcomes

Study 1

The outputs from study 1 will be a codebase of economic models/algorithms and a database of bio-economic weights for target traits, for Nigeria, in the Tilapia breeding program. The specific outcomes of study 2 are to:

- Establish a connection between changes in genetic traits in Tilapia production and farmer profitability,
- Capture the level of variation in input data (and economic weights) across Tilapia production regions in Nigeria and the influence this has on bio-economic weights,
- Provide insight into economic sustainability metrics, and the influence that different drivers (e.g., gender, production system etc.) have on these metrics. Calculate bio-economic weights that will be used in study 2 to build preference survey questions.

These bio-economic weights form the basis of the selection index which allows breeders to select the best candidates for breeding/ dissemination in the Nigerian Tilapia production system/ market.

Study 2

The outputs from study 2 will be a set of trait preference coefficients that scale (up or down) economic weights from study 1, based coefficients per typology. This effectively creates new sets of economic weights targeted at market needs. Applying these trait preference coefficients to economic weights helps in understanding stakeholder's trait improvement preferences and ensures the systematic integration of stakeholders' preferences into selection and breeding decisions. The specific outcomes of study 2 are to:

- Integrate trait improvement preferences into the valuation of improvements in each trait of interest for different stakeholders and target markets,
- Understand the level of differentiation of trait improvement preferences driven by region, production system, gender etc., and
- Highlight key drivers of differences in trait improvement preferences.

Study Significance

This study represents the opportunity to employ economic weights, preference coefficients, selection indexes as a way of improving the effectiveness of breeding programs in developing countries. These approaches have been applied in dairy cattle (Martin-Collado et al, 2015 and Byrne et al. 2016), but to our knowledge, no such approaches have been delivered in this production system context for aquaculture species genetic improvement programs.

Furthermore, the ability to derive trait economic weightings that incorporate farmer preferences in the development of breeding objectives aligns market research more comprehensively with breeding program needs, compared to other approaches focused on understanding farmer preferences.

Timeline

Key milestones	month 1	month 2	month 3	month 4	month 5	month 6	month 7	month 8	month 9	month 10	month 11	month 12
Study 1												
Milestone 1.1. Data gathering												
Milestone 1.2 Bio-economic model developed												
Milestone 1.3. Report												
Study 2												
Milestone 2.1. Engagement												
Milestone 2.2. Survey designed and tested												
Milestone 2.3. Enumerators trained												
Milestone 2.4. Survey deployed												
Milestone 2.5. Survey data analyzed												
Milestone 2.6. Survey data archived												
Milestone 2.7. Report												

Estimated price

We provide a quote per study. Quoted prices exclude any VAT and disbursements (flights, transfers, accommodation, per diem for 10 consultation days in Nigeria for two AbacusBio consultants), and any costs associated with daily travel (study 1 and 2), hardware, enumerators and/ or support personnel required for survey deployment (study 2).

Study	Price (USD)
Study 1	55,000-65,000
Study 2	85,000-95,000
Total	**140,000-160,000**

Final pricing depends on agreed scope, and refinement of milestones, before project commencement.

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