Darwin Initiative Main and Post Project Annual Report

To be completed with reference to the "Writing a Darwin Report" guidance: (http://www.darwininitiative.org.uk/resources-for-projects/reporting-forms). It is expected that this report will be a **maximum** of 20 pages in length, excluding annexes)

Submission Deadline: 30th April 2021

Darwin Project Information

Project reference	25-032
Project title	Biodiversity and agriculture: addressing scale insect threats in Kenya
Host country/ies	Kenya
Lead organisation	Natural History Museum
Partner institution(s)	National Museums of Kenya (NMK); University of Nairobi (UoN); Kenya Agricultural and Livestock Research Organisation (KALRO); Kenya Forestry Research Institute (KEFRI); Kenya Plant Health Inspectorate Service (KEPHIS); CABI
Darwin grant value	£236,658
Start/end dates of project	1 July 2018 – 31 March 2021
Reporting period (e.g., Apr 2018 – Mar 2019) and number (e.g., Annual Report 1, 2, 3)	April 2019 – March 2021 (Annual Report 3)
Project Leader name	Andrew Polaszek
Project website/blog/Twitter	https://www.cabi.org/projects/project/67610
Report author(s) and date	Andrew Polaszek – 30 April 2021

1. Project rationale

A Kenyan working group on invasive species and vulnerable ecosystems (KEPHIS, KALRO, KEFRI) identified a need for increased in-country capacity to identify and monitor threats to biodiversity and livelihoods (Conference of the parties to the Convention on Biological Diversity; Fifth meeting; Nairobi, 15-26 May 2000; Agenda item 18.3).

The (incomplete) list of scale insects of Kenya shows 71 potential pests (most non-native) out of 299 species (23.8%); this level is much higher than in any other group of insects (<1% for all other insects combined). Recent outbreaks of alien scale pests have occurred in Kenya and neighbouring countries; within the country more scale species have become invasive, impacting a wider range of crops and causing yield losses of up to 91% (Macharia et al., 2017). This puts smallholder farmers and foresters at high risk of yield and income loss; however, their awareness of the growing risk is low.

It is the poorest people who are most dependant on growing subsistence crops. Heavy untargeted pesticide application to try to control scale pests can exacerbate pest problems by reducing biodiversity through the elimination of natural enemies. It raises production costs, resulting in smallholder debt; there are also negative impacts on human health, local biodiversity and the environment such as water quality.

Biological pest control (as part of Integrated Pest Management) facilitates long-term reduction in pesticide use, so improving farm income, natural enemy diversity, and reducing pest problems. Many scale insects have host-specific parasitoids suitable for use as biocontrol agents, but the development of biological control requires accurate identification of the pest species. Some past attempts at biological control failed due to misidentifications resulting in misdirected pest control efforts, e.g. 15 years elapsed time between the outbreak and control of the coffee mealybug (*Planococcus kenyae*), and 80% cassava production loss over <10 years caused by cassava mealybug (*Phenacoccus manihoti*, which can still cause problems). At the start of this project, taxonomic expertise on scale insects and tailor-made identification aids were not available in Kenya.

The accurate identification of scale pests will enable appropriate targeting of pest management, and help to stop the expensive, untargeted use of pesticides that currently impacts native beneficial entomofauna, soil organisms and ground water quality.

This project targets lowland agro-ecosystems, mainly in three coastal counties: Kilifi, Mombasa and Kwale, which have a recent (and ongoing) outbreak of the newly recorded papaya mealybug (Fig. 1). The main objectives there are:

- To enable early future detection, identification and accurately targeted responses against invasive scale pests threatening biodiversity on farms and in natural habitats, through effective scientific monitoring and updating of the national pest list (all impossible without the necessary knowledge and awareness); and to reduce response time to new introductions of invasive scale species from several years to 6 months or less.
- In smallholder-farmer/forester communities, target appropriate pest management to conserve natural enemies and pollinators so that ecosystem services reduce the need for pesticide use and give rise to improved yields.
- In multi-scale farms/forestry, target appropriate pest management to improve agro-ecosystem function and hence crop yields, reducing pesticide use and farmers' debt levels.

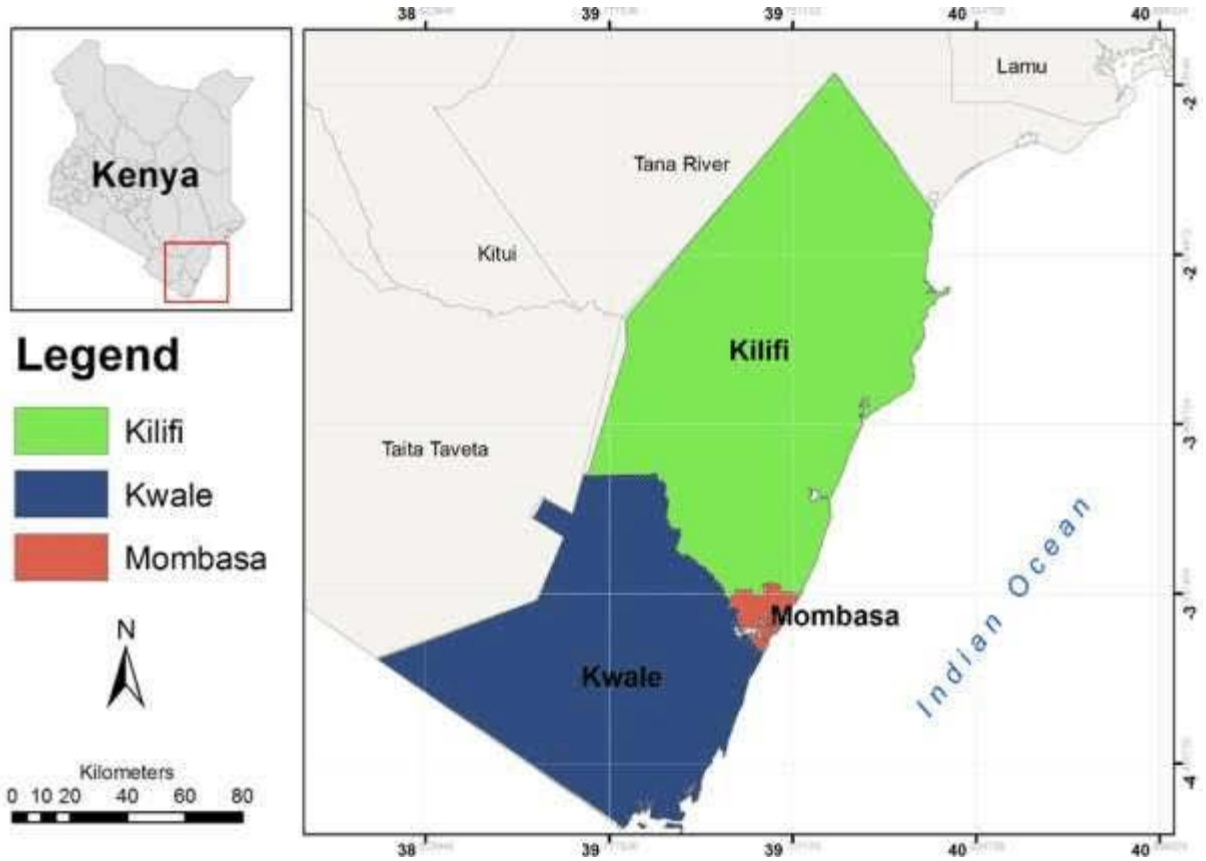

Fig 1: Map of the study area

Macharia I., Kimani E., Koome F., Kosiom T., Heya H., Otipa M. & Oronje M. 2017. First Report and Distribution of the Papaya Mealybug, *Paracoccus marginatus*, in Kenya. *Journal of Agricultural and Urban Entomology* 33: 142-150. https://doi.org/10.3954/JAUE17-02.1

2. Project partnerships

The partnership with one university, four government and one not-for-profit organisations was initiated through a former Darwin Initiative scoping award in June 2017, enabling an initial common engagement in developing the current Darwin Initiative main project. Only 11 days after the official start date, all six Kenyan partners engaged in an important training session in Nairobi led by NHM and NMK. However, subsequently sub-grant agreement contracts took much longer than expected to be signed by five partners, despite an early start of the negotiation process. The two major issues were:

1. The request for advance payment by four of the six Kenyan partners. These government institutions could not initiate their activities without start-up funds, which required NHM to adapt the standard museum practice of mirroring terms offered by the funder.

2. The draft Intellectual Property Rights clause was rejected by our partners who, in turn, took several weeks to propose a revised version that was acceptable to the parties.

Sub-grant agreement contracts were signed with all six Kenyan partners, and payments were made, at the following dates:

Institution	**Signature**	**Payment**
NMK	15 March 2019	23 May 2019
University of Nairobi	1 March 2019	2 April 2019
KALRO	28 March 2019	2 April 2019
KEFRI	8 March 2019	2 April 2019
KEPHIS	28 February 2019	23 May 2019
CABI	5 March 2019	2 April 2019

These late involvements of our partners led to postponement of several important activities, and delayed making a head start on several others.

3. Project progress

3.1 Progress in carrying out Project Activities

Output 1. Increased informed perception by smallholder farmers/foresters and extension providers of the scale insect threats to agricultural production, and on the means to manage the pests without disturbing agro-ecosystems, leading to increased crop yield for affected farms.

Activity 1.1 At least 250 smallholder farmers and foresters recognise scale insect attack and pest impact in all cases by end of project, with data disaggregated by gender. A Socio-Economic Survey questionnaire developed by KALRO and KEFRI with the technical support of CABI and inputs from NHM and NMK was administered on 242 small-scale farms in three coastal counties where both field crops and fruit trees are grown, to capture the knowledge and perceptions of farmers about scale insects and the role of natural enemies.

In Mombasa County a total of 48 farmers were interviewed from four sub-counties (Jomvu, Changamwe, Kisauni and Likoni). In Kilifi County, 92 farmers were interviewed from five subcounties (Kilifi North, Kilifi South, Malindi, Kaloleni and Ganze). In Kwale County, 102 farmers were interviewed from three sub-counties (Matuga, Msambweni and Lunglunga) using ODK Collect, an open source Android app used in survey-based data gathering. Unfortunately, answers from 4 farms got lost during the data upload, so only 238 farmers' data were captured.

The current agricultural practices by smallholder farmers were analysed, listing crops grown, land surfaces used, pesticides used if any, etc. Farming capacities and responsibilities based on gender were captured (to ensure that more women will have access to farming extension information by the end of the project). One member of NMK and one Masters student from the UoN joined the socio-economic survey team for preliminary field exploration, and to take photographs for use in developing various identification aids (Activities 3.4 and 4.4). Due to delays in sub-grant contract negotiations, this questionnaire was administered in June 2019 (Q2 Year 2) instead of near the end of year 1 as originally planned. The report, prepared by KEFRI and KALRO scientists and biometricians can be found as Annex 4 of the year 2 report.

During the survey a majority of the farmers claimed to have seen scale insects, especially the two species of invasive mealybugs, on some of their crops or in the neighbourhood. However, they claimed that, so far, they had not received any information on scale insects, and had no idea how to manage these pests and that they would be glad if someone offered them training on controlling them. The farmers said that they had lost some of their crops, especially papaya and cassava, due to scale pests.

On most farms, women carried out the actual farming activities in addition to taking care of the children, although decisions regarding farm management were made by the men (heads of the households). There were fewer female respondents than male in all three counties.

The survey analysis found that less than 50% of farmers could easily identify mealybugs and scale insects, particularly non-mealybug scale insects. However, they were aware of the damage caused to a wide diversity of crops by these pests, which pose a serious threat to the livelihood of most of these households. The control of scale insect and mealybug pests was the most challenging aspect of crop management, and the main control agents used against them were pesticides. The farmers obtained information about pests from a variety of sources.

During the natural enemy survey in February 2020, a few of the farms visited in Kwale County were successfully using high-pressure water jets to reduce infestations of papaya mealybug on papaya fruits, so at least some of the farmers have managed to access information on sustainable practices.

At the time of writing this report, KALRO and KEFRI have started preparations to train farmers, and to carry out assessments of knowledge levels and the effects of control practices. Assuming a fairly imminent reduction in the impact of coronavirus on such activities, they envisaged that this training could be complete by December 2021 (Year 3 Q3)

Activity 1.2 Increased income through higher yield and less pesticide expense in at least 250 smallholder farmers and foresters where scale insect outbreaks occurred by the end of the project. The baselines for both yield and pesticide use were captured in June 2019 in the Socio-Economic Survey (Activity 1.1).

Activity 1.3 By the end of the project, sustainable agro-ecosystems restored, with biodiversity benefits, in and around 250 smallholdings where massive untargeted pesticide application occurred. Sampling of natural enemies was carried out by NHM, NMK and UoN during the Socio-Economic Survey in June 2019 (Q2 Year 2). The Socio-Economic Survey allowed the selection of target farms for a smaller field survey in February 2020. Identification of these samples has been substantially delayed by the virus epidemic; however, a limited number of reared natural enemy specimens have been identified by AP. These include several known species of parasitoid wasps; also one species possibly new to science that was reared from a polyphagous scale insect feeding on a wild tree sapling.

Output 2. A publicly-available scale insect and natural enemies inventory for Kenya developed, with distributions maps for species recorded from the study area in three coastal counties of Kenya.

Activity 2.1 One student and 4 technicians from UoN and KEPHIS trained in field recognition, collection, preservation, slide-mounting, digital photography and identification [COMPLETED]

A scale insect identification course was given 11 - 27 July 2018 and the skills were refreshed in a workshop 1 - 5 July 2019 at NMK in Nairobi. These sessions were attended by members of all the Kenyan partner institutions. Fifteen people were trained to collect and preserve specimens from the field, prepare microscope slides for specimen identification, and were familiarised with useful taxonomic characters for identifying scale insects. Several of them are intended to become trainers of students in learning institutions, as well as extension officers and farmers during the project and beyond. On both sessions, planning and organisation was challenging because of the limited number of microscopes (especially compound microscopes), insufficient equipment and chemicals available. However, good coordination between NMK and KEPHIS allowed the training to be held in the best conditions possible. The original training manual drafted for the July 2018 training course (Annex 4A) was substantially expanded and customised for use on the July 2019 workshop. The manual covers most species known to occur in Kenya, but will require further expansion to include new identification records and more taxonomic illustrations. It is intended to expand and publish this work as a series of peer-reviewed journal articles (listed with abstracts in Annex 4B), most before the end of the project extension or shortly after; these publications will be important project outputs that will benefit the whole of continental Africa.

Coverage in the current training manual draft is: 23 families, 170 genera and 501 species, comprising 294 pages. Twenty five copies were printed, bound and taken to Kenya in July 2019. NHM taxonomist Dr Gillian Watson gave several talks on scale insect systematics and biology, as well as on integrated pest management case studies, all made available to the trainees on a Box shared folder.

The postgraduate student, Michael Mathenge Githae, enrolled for the Agricultural Entomology course at the University of Nairobi on September 5^{h}, 2018. He competed the first-year course work in April 2019, defended his research proposal, namely *Assessment of diversity and seasonal dynamics of scale insects and associated natural enemies in three coastal counties*, and progressed to second-year research project work. He collected data in the three coastal counties during August 2019 (the dry season), and in November 2019 (during the rainy season). A survey of the ants associated with citrus scales was published in January 2021 (see Annex 4B). At the time of writing (April 2021), Mr Mathenge has submitted a first-authored account of scale species found on citrus in Kenya to a peer-reviewed journal(see Annex 4B), and expects the MSc thesis defence (considerably delayed due to the pandemic) to take place in May 2021.

Activity 2.2 At least 30 scale insect species recorded in target areas, with associated natural enemies. The first samples from the three target counties on the coast were collected during the Socio-Economic Survey (June 2019) and the extension service training session (July 2019); together with samples from the Socio-Economic Survey, February 2020 insect survey and the MSc student, we have recorded 46 species of scale insects and mealybugs from farms in the three coastal counties so far. The February 2020 (Annex 4C, year 2 report) survey collected an additional 79 samples; 60 have not yet been slide mounted or identified due to the virus epidemic. Meanwhile, intensive taxonomic research on the Natural History Museum (UK) and KALRO collections and 39 recent samples from various regions of Kenya continues when virus restrictions permit. So far, we have found two new continental records for Africa, new Kenya records for one family and 68 species, not including eight scale insect species new to science. This illustrates the current poor knowledge of the Kenyan fauna, and of threats presented by alien introductions.

Around 860 archival-quality slides of Kenyan scale insects have been made from project-collected material so far, which will be shared between partner collections once identified to species. At the time of writing (April 2021), about 95% of the slides have been identified to species level already. These reference collections in Kenyan institutions will facilitate future identifications by Kenyan entomologists.

In the meantime, more work was done on the KALRO collection (over 3,500 slides stored at KALRO in Nairobi, untouched since the 1970s) in July 2019. The entire collection was removed

from its drawers; each name card was updated to the current name; and the slides were sorted into alphabetical order of genera and species within each family, accounting for synonymies as necessary. The number of slides of each taxon was checked and a collection database compiled and updated. As a result, the collection at the KALRO National Agricultural Laboratory is now up-to-date nomenclaturally and the slides are stored in the same order as the names in the collection database. The updated database has been made available to workers at NMK, University of Nairobi and the collection curator (Joseph Mulwa) at KALRO.

Project staff at KEPHIS are continuing identification of samples resulting from the scale insect survey in which they were involved.

Activity 2.3 At least 250 farms in the three coastal counties visited. All species discovered entered in the National reference collection. The Socio-Economic Survey visited 242 farms in the three coastal countries in June 2018, from some of which samples were collected. A smaller insect survey of farms in the same countries took place in February 2020 (Q4 Year 2), producing 79 samples, most of which have not been identified yet due to virus epidemic restrictions.

At the time of writing this report, KALRO staff continue to collect samples of scale insects and natural enemies, subject to virus epidemic constraints.

Specimens of collected species (see activity 2.2) have been mounted on 860 archival-quality slides so far, and more will be prepared from the February 2020 samples. These will be shared amongst the reference collections of each of the institution partners.

Activity 2.4 At least 600 data records entered into a relational database (species identity, locality, date collected, host, natural enemies, images). This activity is planned for the project extension (Q1-2 of Year 4); as sample identification progresses at NHM, regular updates are shared with the Kenyan partners. Although the identification data is incomplete (due to virus constraints), preparation of distribution maps has been initiated at NMK.

Activity 2.5 At least 30 distribution maps produced. See activity 2.4.

Activity 2.6 Kenyan pest list reviewed to include scale insect species not recorded previously. This activity was planned for Q3 of Year 3, but is now continuing into the extension period. However, 68 new country species records have already been found and are being published in collaboration with KEPHIS. As identification work progresses it is likely that more new records will be found. Before KEPHIS can update the official Kenyan pest list, and a checklist for Kenya can be produced, the two official publications on new country records, currently (April 2121) in press and submitted respectively (see Annex 4B), need to be published.

Output 3. Taxonomic researchers, [parataxonomists] and extension officers trained, and pest management decision chain implemented through identification capacity building among all stakeholders. [Note: about midway through the project it was realised that the term “parataxonomist” is not appropriate for this project, and we stopped using it.]

Activity 3.1 Fifteen taxonomists and 30 extension officers trained in scale insect collection and handling, preservation, slide mounting and identification (disaggregated by type of training and profession) by end of year 1. Initial training of 15 taxonomists occurred in July 2018 (see activity 2.1), and the knowledge gained from this initial training was reinforced by a workshop in July 2019. Forty-four extension officers (including senior staff) in the three coastal counties were trained on basic scale insect biology, field collection, sorting, preservation and basic identification; also on natural enemy recognition and sustainable agricultural practices, in June 2019 and February 2020. The training materials were shared electronically so that the trainees will be able to train more people in their counties. Six photo-illustrated handouts have been distributed to the counties on the following major topics: scale infestation symptoms; recognition of soft scales, armoured scales, and mealybugs; look-alikes of scale insects; and natural enemies. Two oral presentations and a printed document covered sustainable practices for control of scale insects and mealybugs. Appropriate additional training and information materials were discussed during the sessions, especially between CABI and the extension

services. An extensive identification manual of 294 pages has been drafted and covers now 23 families, 170 genera and 501 species. The extension service capacity building is now complete.

Activity 3.2 NMK national collection of scale insects enhanced, and 4 institutional reference collections established at UoN, KALRO, KEFRI and KEPHIS. See activity 2.3 above.

Activity 3.3 One identification key to scale families, 12 keys to genera and 90 keys to species developed and published for taxonomists by end of year 2. A key to 23 families occurring in continental Africa has been prepared, tested using the NHM collections, made available in the draft training manual (Annex 4A), and a manuscript has been submitted to *Zootaxa* for publication. The key to families and keys to most of the genera in most of the families have been prepared, tested using the NHM collections and made available in the draft training manual, and coverage of most families will be prepared for publication during 2021. Coverage of the armoured scale insects (Diaspididae, the largest family) is less advanced and will only be done to genus level because the family is large and diverse and the taxonomy is not well understood.

Activity 3.4 One photo guide for smallholder farmers, 1 photo guide for smallholder foresters, [1 photo guide for parataxonomists,] 1 photo guide and at least 30 fact sheets for extension officers developed by end of year 2. Three double-sided, laminated photosheets were developed to train extension officers in the coastal counties in July 2019 and February 2020; these are suitable for use with farmers also. At the same training sessions, CABI, in charge of developing field identification aids, discussed further the needs of extension services for internal training and for delivery of information to farmers and foresters.

A Photo Guide book was prepared by CABI, with support from the NHM and KEPHIS, providing pest identification support for all stakeholders – smallholder farmers and foresters, [parataxonomists] and extension workers. It provides colour photographs and bullet-point information on pest field appearance, host range and crops attacked, for each of 30 pest scale insects and mealybugs. This was completed at the end of July 2020 and was shared with extension workers and partner institutions, both as e-copies and hard copies.

The Factsheets for Farmers (covering 30 pest scale insects and mealybugs) have been prepared by CABI, with support from the NHM and KEPHIS. These provide accessible pest identification support and sustainable control advice to both county extension officers and farmers. Each factsheet is illustrated with colour photographs of live insects, and includes a list of sustainable control practices that can be used against the pest. The Factsheets were completed at the end of July 2020 and were shared with extension workers and partner institutions, both as e-copies and hard copies.

CABI has also developed a Pest Management Decision Guide (PMDG) for papaya mealybug.

Output 4. Best practices for improving management of scale insect pests developed and disseminated to raise key stakeholder awareness and capacity, and adopted by them.

Activity 4.1 Best practices intended to guide sustainable scale insect pest management practice developed by mid-year 2. This activity was originally planned for Q2&3 of Year 2. At the extension officer training sessions in July 2019 and February 2020, CABI made a presentation on sustainable practices and a laminated information sheet was provided to trainees. Results from the Socio-Economic Survey (early stage) have been used to refine the information (see activities 3.1 and 3.2). KEPHIS is currently producing a draft to be shared with other partners during Q1 of year 3. At the time of writing (April 2021), the draft best practices document is awaiting stakeholder review and adoption.

Activity 4.2 Policy brief produced by the end of the project. This activity is planned for Q1-2 of Year 4 (extension). The policy brief has been drafted with the assistance of CABI and other partners. It will be presented to stakeholders before the end of September 2021.

Activity 4.3 Five media articles and radio programs every year of the project, for general public information. This activity was delayed by the too-long negotiations with several of the partners involved in media campaigns. As a first step towards wide communication of project results,

tools and processes, a project web page has been developed: https://www.cabi.org/projects/addressing-scale-insect-threats-in-kenya/, as well as two blog pages on taxonomy training and extension-service capacity building respectively:

https://www.cabi.org/news-article/fighting-the-scourge-of-scale-insects-affecting-livelihoods-and-food-security-in-kenya/

https://blog.invasive-species.org/2019/07/17/collaborative-effort-in-kenya-to-manage-the-impact-of-scale-insect-in-coastal-region/

A 3-day stakeholder workshop was held to synthesize evidence on scale insects and develop information materials relevant for farmers, foresters and the general public. The workshop was attended by Scientists from the partner institutions in Kenya (KALRO, CABI, KEFRI, UoN and NMK), Extension workers and County Directors of Agriculture from Kwale, Kilifi and Mombasa counties, Policy makers from Ministry of Agriculture, Livestock, Fisheries and Cooperatives (MALFC) and Communication Experts from Precision Agriculture for Development. During the workshop, the team agreed to prioritise papaya mealybug, since it was already posing serious threats to papaya production at the coast.

A technical brief for papaya mealybug was therefore developed, as a pre-requisite for development of messages for the general public. The technical brief ensures delivery of consistent messages by users, and covers the biology of the pest, monitoring, management and direct control. The technical brief was presented to the Horticulture Crops Directorate (HCD) of the Ministry of Agriculture, and the production committee under HCD, who unanimously gave approval for the brief. The current virus epidemic has affected further efforts to engage stakeholders to develop messages for various media. The immediate planned activity was the development of a communication campaign on papaya mealybug using radio and other appropriate measures.

A draft policy brief for papaya mealybug has been developed, but has yet to be discussed and agreed by the partners. This will form a basis for engaging policy makers in the issue of scale insects in general and papaya mealybug in particular.

Update (April 2021):

A radio campaign on the management of scale insects was launched with particular focus on the papaya mealybug, given its already devastating effects on papaya production in the country and its significance on other crops of importance such as mango, coffee, citrus and cassava. The selection of the channel to use was informed by a rural communications appraisal that was conducted by telephone. The communications appraisal was funded by CABI's Plantwise program, which also co-funded the radio campaign.

The content was guided by the technical brief and was packaged for the radio campaign in three formats: -

- One-hour talk shows conducted every Thursday for six weeks. This was run on a segment which typically hosts an agricultural show.
- Sponsorship messages (4 weeks of sponsorship messages)
- Short features (<5min) with specific themes and targeted information (3 weeks)

The three formats complemented each other, with the talk shows being interactive formats in which the experts were able to respond to farmer queries; sponsorship messages were direct, concise messages drawing attention to the talk shows or reinforcing key messages in the talk shows. Features elaborated on specific themes such as identification of Papaya mealybug, preventing its spread, and its management using natural enemies. The content broadcast in these 3 formats can be listened to through CABI's YouTube page at https://www.youtube.com/watch?v=erlYIbEXSfI

The radio campaign was a collaborative process involving farmers, extension personnel, the content development team and Darwin Initiative project partners. The content aired responded directly to farmer questions and practices and DI stakeholders, and the county staff served as the experts guiding responses to farmer queries.

An after-action review was done at the end of the campaign involving stakeholders who participated in the campaign. Telephone calls were also made to some of the farmers in the radio coverage area to obtain their feedback about the campaign and messages delivered. Using data obtained from previous surveys conducted on rural households growing papaya in the target coastal regions, as well as radio coverage, it was estimated that 47,835 farmers listened to the radio programs in Kwale, Kilifi and Mombasa counties. Detailed feedback from the campaign is described in the after-action report (attached).

Activity 4.4 Three hundred stakeholders (smallholder farmers, smallholder foresters, extension officers and plant quarantine inspectors) engaged through various fora and use of information materials (disaggregated by category) by end of the project. Trainees belonging to UoN (one technician, one MSc student), NMK (one senior researcher, one research technician, two scientific associates), KALRO (two technicians), KEFRI (three technicians), KEPHIS (one entomologist, one chief inspector, two inspectors) and CABI (one project manager plus three additional staff) have now received the necessary basic knowledge on scale insects and their threats to agricultural production, and on the means to manage the pests without disturbing agro-ecosystems (see activities 2.1 and 3.1). They all now have the capacity to train more stakeholders from various categories, and to develop and disseminate appropriate informative material. The trainees will continue to collect scale specimens, prepare them on slides and identify them. Training materials (simplified, laminated photosheets) were prepared to train extension services on the coast in June 2019 and February 2020, and further material needed to engage with more stakeholders was discussed at the time.

In addition to the project web pages developed in the previous period, one news story (https://www.cabi.org/news-article/fighting-the-scourge-of-scale-insects-affecting-livelihoods-and-food-security-in-kenya/) and one blog post (https://blog.invasive-species.org/2019/07/17/collaborative-effort-in-kenya-to-manage-the-impact-of-scale-insect-in-coastal-region/) were developed and shared through various media outlets including social media. These stories and project web pages have been visited/viewed by 3,305 users (as at Jan 31 2020). The viewers were mostly from Kenya, UK and India.

The blog was also publicised by EnviroNews in Nigeria https://www.environewsnigeria.com/scientists-launch-research-on-biological-control-of-papaya-mealybug-in-kenya/

Update (April 2021):

All project products – fact sheets, photo guides and recordings from the radio campaign have been made available to the general public on the project webpage at https://www.cabi.org/projects/addressing-scale-insect-threats-in-kenya/

and on CABI's YouTube channel at https://www.youtube.com/watch?v=erlYIbEXSfI

During the year, three blogs/media articles were developed and shared via the project page. These stories were visited/viewed by 308 users (between October 2020 and March 2021).

- https://www.cabi.org/news-article/taking-to-the-airwaves-to-help-kenyas-smallholder-farmers-fight-back-against-devastating-papaya-mealybug/
- https://www.cabi.org/news-article/taking-to-the-airwaves-to-help-kenyas-smallholder-farmers-fight-back-against-devastating-papaya-mealybug/
- https://www.cabi.org/news-article/cabi-searches-for-biological-control-to-halt-surge-of-papaya-mealybug-menace-in-kenya/

Other relevant work/stories:

https://www.cabi.org/news-article/new-research-maps-potential-global-spread-of-devastating-papaya-mealybug-pest/

3.2 Progress towards Project Outputs

Output 1. Increased informed perception by smallholder farmers/foresters and extension providers of the scale insect threats to agricultural production, and on the means to manage the pests without disturbing agro-ecosystems, leading to increased crop yield for affected farms. At the start of this project, the knowledge in Kenya among extension workers and taxonomists to collect, prepare and identify scale insects was non-existent. The necessary training of trainers started in Q2 of Year 1 with the involvement of researchers, technicians and students of all partner institutions and was reinforced by a workshop in Q2 of Year 2. They can now rely on the dedicated manual, forthcoming published identification aids and reference collections to keep this capacity at a high standard, and use their skills to train extension officers.

Output 2. A publicly-available scale insect and natural enemy inventory for Kenya developed, with distributions maps for species recorded from the study area in three coastal counties of Kenya. The survey of scale insects and their natural enemies on the coast could not start until Q4 of Year 1 due to long negotiations with the partners involved in collecting activities. Initial sampling around Nairobi and studies of past collections have already led to the discovery of 68 species not recorded from Kenya before, some of them on important fruit and beverage trees (coffee, pawpaw, guava, citrus and baobab), field crops (cassava, pigeon pea), fodder shrubs (*Calliandra* sp.) and ornamentals (rose, *Hibiscus* and *Pachysandra*). Survey samples from Q4 of Year 1 have contributed to our knowledge, and samples from Q4 of Year 2 (mostly not processed yet due to the virus epidemic) should yield more information. Although largely prepared, publication of a Kenyan checklist will not be possible until near the end of the project when all the samples have been identified and the new country records have been published.

Output 3. Taxonomic researchers and extension officers trained, and pest management decision chain implemented through identification capacity building among all stakeholders. The project has already strengthened Kenyan national capacity for research and training in the field of scale insect and mealybug recognition. Kenyan researchers, biologists and technicians have been trained in all six partner institutions, where the expertise and the reference facilities were absent before. In addition to training staff in key national institutions in charge of agriculture and biodiversity, we have started to develop collections, databases and printed identification manuals, all durable tools which can be used from now onwards for further training of more stakeholders throughout the chain of decision.

Output 4. Best practices for improving management of scale insect pests developed, disseminated to raise key stakeholder awareness and capacity, and adopted by them. At the start of this project, none of the stakeholders was aware of most scale insect and mealybug threats, nor of the sustainable agricultural practices used to manage scale insect pests. A range of scientists have already been trained to be trainers throughout the project, to disseminate information on environment-friendly practices and methods to develop pest-resilient agroecosystems among farmer communities. At the extension officer training sessions in July 2019 and February 2020, CABI made a presentation on sustainable practices and a laminated information sheet was provided to trainees. Electronic copies of the sustainable management training presentation and hand-out have been made available to all the county extension services and other participating institutions, equipping them to carry out in-house training of more of their staff.

3.3 Progress towards the Project Outcome

Outcome: Kenyan livelihoods enhanced in >250 smallholdings; local agrobiodiversity improved by enhanced capacity to identify and manage scale insects at institutional, extension service and community levels, in smallholdings and native ecosystems. Despite long negotiations with most of the partners that ended only late in Year 1 with signed

sub-grant agreements, strong progress was made towards this outcome in Years 1 and 2, with the capacity to identify scale insects and mealybugs enhanced in all partner institutions and in the extension services of the three coastal counties. All indicators still appear to be adequate, with some of them probably being exceeded by the end of the project, especially regarding the improvement of local research infrastructures. Information on baseline yield and income of farmer and forester communities is available in the analysis of the Socio-Economic Survey results. The training given to coastal extension officers should lead to improvements in scale insect and mealybug pest management and reduction in pesticide use.

3.4 Monitoring of assumptions

All assumptions still remain valid; none of the listed risks have affected the outcome or any of the outputs yet. Especially, Kenya has shown political stability since the beginning of the project, which occurred after the end of the election period in early 2018. Another crucial assumption for the first year was the availability of sufficient equipment (especially microscopes) in good working order for training up to 20 to 25 trainees; good coordination between NMK and KEPHIS allowed these needs to barely be fulfilled. However, the virus epidemic affecting Years 2-3 was not foreseen in the assumptions and going forward, this may well reduce the amount of UK research, number of articles published, and field and final Socio-Economic Survey work in Kenya that can be done within the project timeline.

3.5 Impact: achievement of positive impact on biodiversity and poverty alleviation

By the end of the project, target groups will have a better understanding of biodiversity issues linked to unsustainable agricultural activities, and stakeholders will implement environmentally friendly practices and manage scale insect pests with sustainable methods. During the first and second years of the project, Kenyan researchers and biologists have developed appropriate taxonomic skills through training to identify and monitor agro-biodiversity. The initial assessment of agrobiodiversity using parasitic wasps as an indicator started in February 2020.

It is the poorest people who are most dependant on growing subsistence crops. Heavy untargeted pesticide application to try to control scale pests can exacerbate pest problems by reducing biodiversity through the elimination of natural enemies, and by developing insecticide resistance in the pests. It raises production costs and results in smallholder debt; there are also negative impacts on human health and the environment such as water quality. The baseline for both yield and pesticide use was captured by the Socio-Economic Survey questionnaire (Annex 4D, year 2 report) in June 2019 (six months later than originally planned, due to long negotiations between NHM and several Kenyan partners).

4. Contribution to the Global Goals for Sustainable Development (SDGs)

This project will contribute to the following SDGs:
Goal 2 (Zero hunger): in implementing resilient agricultural practices that increase smallholders' income.

- *Target: doubling the agricultural productivity and incomes of small-scale food producers, in particular women, indigenous peoples, family farmers*. The project will develop extension services and increase knowledge among smallholder farmers and foresters. Training of trainers was implemented in years 1 and 2, and was delivered to county extension services in year 2. The enhanced activities of extension officers will benefit family farmers, who are indigenous people and many of them are women.
- *Target*: *ensuring sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality.* The project will disseminate information on best practice for managing scale insect pests. Again, future trainers from all partner institutions have been trained during

years 1 and 2. The sustainable management methods recommended should enhance productivity and reduce pesticide impact on ecosystems and biodiversity.

Goal 15 (Life on land): in implementing resilient agricultural practices that preserve land and soil quality

- *Target: introducing measures to prevent the introduction and significantly reduce the impact of invasive alien species on land and water ecosystems and control or eradicate the priority species.* This project will facilitate assessment of the size of the threat to crops and indigenous plants, especially forest trees, by invasive scale insects, and establish up-to-date national lists of plant quarantine pests. Kenyan plant quarantine services and extension officers now have enhanced scale insect and mealybug identification skills, improving vigilance for new introductions of invasive species. Several newly introduced invasive scale insect and mealybug pests were discovered and identified in Kenya during years 1 and 2, two of which pose a significant threat to crops and one of which threatens the extinction of endangered endemic cycad species in the wild (their scientific names have been deliberately withheld here pending publication, as they are all new records for Kenya).

5. Project support to the Conventions, Treaties or Agreements

This study will contribute directly to articles 6 (*General Measures for Conservation and Sustainable Use*), 7 (*Identification and Monitoring*), 12 (*Research and Training*) and 13 (*Public Education and Awareness*) of the CBD. Kenya recognises several drivers of change to biodiversity in the country in the context of the CBD: inadequate involvement of local communities; invasive species; unsustainable agricultural development; chemical overload causing unacceptable loss of pollinators and other biodiversity; and land degradation and pollution occasioned by poor land-use practices. Our objectives are to reduce these pressures on Kenyan biodiversity, in line with the National Biodiversity Strategy and Action Plan objectives 5 (*Strengthen national capacity for monitoring and evaluation of biodiversity*), 16 (*Strengthen national capacity for research and training, technical and scientific cooperation, and biotechnology*), 17 (*Strengthen national programmes for public education, awareness and exchange of information*) and 20 (*Strengthen conservation and sustainable utilization of agricultural biodiversity for food and agriculture*).

Training researchers and extension officers in identifying and monitoring invasive scale insect species, as we did during years 1 and 2, helped in achieving the national goals which have been recently proposed by the Kenyan government to achieve Aichi targets: *make the population aware of biodiversity issues and the steps to be taken to conserve and use it sustainably*; *increase capacity to identify Invasive Alien Species (IAS) to 100 personnel to enhance surveillance and monitoring of IAS pathways.* During Years 1 and 2, 15 taxonomists, all permanent staff from institutions dealing with IAS, have been trained to collect, preserve and identify scale insects and have been provided with a training manual which will be a remarkable resource in the future, particularly the published outputs developed from it. Other durable facilities like reference collections have started to be established in several institutions. Forty-nine members of county extension services have also been trained in scale insect and mealybug recognition and sustainable control practices. All the institutions involved have been provided with the electronic resources to enable them to train more people in-house.

Mr Charles T. Sunkuli, Principal Secretary and CBD National Focal Point for Kenya, sent a letter of support. Dr Wanja Kinuthia (NMK) and Dr Eston Mutitu (KEFRI) will report regularly to the CBD National Focal Point at the Kenyan Ministry of Environment and Natural Resources on the project progress with regard to agro-biodiversity sustainability.

6. Project support to Poverty Alleviation

The project will lead to a reduction in pesticide use, mitigating the negative impacts of untargeted pesticide application on crop yields and smallholder debt, so alleviating poverty. The project has found that a serious, invasive mealybug pest introduced recently is now present country-wide, and is impacting not only papaya but also vegetables and cassava. Another serious invasive mealybug pest and an invasive armoured scale, not recorded in Kenya before, were collected in years 1 and 2 respectively (their scientific names have been deliberately

withheld here pending publication, as they are all new records for Kenya). This shows how our initial training has already increased awareness of scientists and extension services on scale insects and mealybugs. Complaints of farmers about scale insects, especially mealybugs, will be paid more attention from now onwards, and the project will continue to provide all stakeholders with the dedicated tools to manage scale insect threats in the country and beyond, with the ultimate goal to reduce poverty among smallholder farmers. Recognition of scale pests and damage symptoms will help to target the use of pesticides, so yield losses to pests related to inappropriate pesticide use will decrease. Dedicated cost-effective, reproducible and sustainable management programmes will improve crop quality and yield. A baseline for the level of scale insect damage on smallholders' yield and income was captured at the beginning of year 2 through the Socio-Economic Survey questionnaire.

7. Project support to Gender Equality issues

The initial Socio-Economic Survey established farming capacities and responsibilities based on gender amongst the household, so that contact contacted are selected on the basis of their involvement in crop and food production; this will give opportunities to more women to have access to agricultural extension information and to increase their influence in decision-making. The survey endeavoured to gather gender-disaggregated data, to better understand men and women's participation in farm activities, especially regarding perceptions, knowledge and changes in practice. The team will also aim to understand impediments to women's and men's full access to advice on good practices.

8. Monitoring and evaluation

The NHM project leader and NMK local coordinator lead the overall Monitoring and Evaluation process, ensuring that project activities are on track and outputs are delivered on time. The dedicated Steering Committee was unable meet in year 1, due to long negotiations between NHM and several Kenyan partners. Discussions on a weekly to monthly basis occurred on Skype between the project leaders and all partner institutions leaders to mitigate as much as possible the consequences of the long negotiations.

The composition of the Steering Committee has now been finalised, and the PI will initiate monthly video meetings with as many members as are available to discuss resolution of current issues, in particular the publication of new pest records in order to honour IPPC National Reporting Obligations, while respecting confidentiality pending availability of pest risk assessments (PRAs) and the development of mitigation strategies for any major pests that are as yet unrecorded.

9. Lessons learnt

The main impediments encountered were:

- the absence of start-up funds prevented several partner institutions from starting their activities on time
- belated decisions regarding the Intellectual Property Rights (IPR) section of the sub-grant agreement delayed the signature of sub-contract agreements

The change from an initial contract stipulating that payment was to be made quarterly in arrears based on actual expenditure to a contract agreeing to payment in advance took several months to be agreed on. The IPR issue was resolved more easily, but took a long time to be applied due to communication problems (one Kenyan partner experienced major defaults of their email system).

Signing 6 sub-grant agreements is certainly a long and challenging task which must be undertaken as early as possible, and major issues must be identified well in advance. Adaptation of institutional services to peculiar situations should be more reactive and inventive to make sure that activities are not seriously delayed.

However, all the partners have continuously shown strong interest in the project throughout, as shown by the success of capacity building activities among scientists. The engagement of the partners in development of the Socio-Economic questionnaire, and collaborative administration and analysis of the Socio-Economic Survey, are good examples of how some issues can be overcome successfully.

10. Actions taken in response to previous reviews (if applicable)

The visit to Kenya by the UK project staff in February 2020 was focused on the three coastal counties, delivering extension officer training and carrying out a natural enemy survey of representative farms.

A report on the training sessions provided on the project was submitted in March 2021.

11. Other comments on progress not covered elsewhere

Change of Principle Investigator

In December 2019 David Ouvrard, PI on this project, resigned from the NHM to take up a post in his native France. Andrew Polaszek, a close colleague of David's, his former line manager, and someone already with time dedicated to the project, was his obvious proposed replacement. This change of PI was approved by DEFRA, and Andy travelled with David to Nairobi in November 2019 for a series of meeting with other project partners, updates and some fieldwork (Annex 4B, year 2 report). Andy also travelled to the Kenya coast in February 2020 to participate in the extension workers training day, and for fieldwork (Annex 4C, year 2 report).

Second Socio-Economic Survey and 6-month project extension

The second Socio-Economic Survey was severely delayed due to Covid-19, and at the time of writing (April 2021) still has not taken place. Fortunately, an application for a budget-neutral extension to the project of 6 months was granted, and we anticipate that the survey will take place at a time between now and the middle of July 2021.

Natural enemy data

Identification of samples collected on the natural enemy survey in February 2020 has been severely delayed by the three pandemic lockdowns in the UK. Available data on predators and parasitoids of scale insects in Kenya are currently sparse. The 6-month extension provides time for identification of existing samples and an opportunity for further fieldwork (subject to constraints caused by Covid-19). New and existing data will be supplemented by a critical literature review, resulting in a published account of scale insect natural enemies in East Africa.

Monitoring and evaluation

Because of the necessity of the 6-month extension, monitoring and evaluation (led by Dr Ian Kitching, NHM) will take place towards the end of the extension period (September 2021).

12. Sustainability and legacy

The project has been given profile in the scientific community through its announcement on ResearchGate, and through an oral presentation made by Dr Watson at the XVth International Symposium of Scale Insect Studies in Zagreb in June 2018. CABI has also developed a web page on the project (https://www.cabi.org/projects/project/67610). In Kenya, the project is well-known in the scientific community due to the engagement of the key national institutions in charge of agriculture and biodiversity.

Fifteen Kenyan scientists were trained in scale insect identification during the first training session and reinforcement workshop. Most are permanent staff in government institutions,

which maximises the long-term impact of the project. The engagement of extension services and farmers through outreach activities, together with publication of various multi-media campaigns employing printed leaflets, posters, and/or social media, started in Year 2.

The proposed original exit strategy is thus still largely valid. We have successfully started to develop Kenyan expertise on scale insects and mealybugs. We think that the imminent publication of approved policy briefs will help to put sustainable management programs in place in three coastal counties (and will probably be extended country wide); this may lead to increased crop yields in targeted households by the end of the project, although the full impact of the project will probably take longer to become evident.

13. Darwin identity

The Darwin Initiative has been acknowledged in all meetings, training sessions and materials and blogs. The link to the DI website is displayed on the project-dedicated page hosted by CABI (https://www.cabi.org/projects/project/67610). The logo has been used on every document produced for either internal or external diffusion: the training manual, attendance certificates, and questionnaires.

14. Project expenditure

Table 1: Project expenditure during the reporting period (1 April 2020 – 31 March 2021)

Project spend (indicative) since last annual report	2020/21 Grant (£)	2020/21 Total Darwin Costs (£)	Variance %	Comments (please explain significant variances)
Staff costs (see below)	[redacted]			
Consultancy costs				
Overhead Costs				
Travel and subsistence				
Operating Costs				
Capital items (see below)				
Others (see below)				
TOTAL				

Annex 1: Report of progress and achievements against Logical Framework for Financial Year 2020-2021

Project summary	Measurable Indicators	Progress and Achievements April 2020 - March 2021	Actions required/planned for next period
Impact Improve awareness, response time and implementation of appropriate management strategies against threats to agro-biodiversity by invasive species		Awareness greatly improved for staff in six major agricultural institutions through training and participation in farmer surveys and field collection.	
Outcome Kenyan livelihoods enhanced in >250 smallholdings; local agrobiodiversity improved by enhanced capacity to identify and manage scale insects at institutional, extension service and community levels, in smallholdings and native ecosystems.	0.1 By the end of the project, at least 250 smallholder households have a better knowledge of scale insects and their impact, and they all show novel understanding and skills in recognition of scale insects as pests in their crops 0.2 By the end of the project, at least 50 extension workers have a better knowledge of scale insects and their impact, and they all show novel understanding and skills in identification of pests and diseases, and management of emerging scale insect pest using environmentally safe and sustainable management practices 0.3 By end of the project, relevant research and advisory infrastructure improved in the form of 1 national comprehensive reference collection, 4 smaller working institutional collections, and associated database, at least 15 taxonomic experts, [30 parataxonomists] and 50 extension workers delivering an accurate identification/advisory service with a	0.1 Baseline data about perception of scale insects collected during survey of 238 farms in Kwale, Mombasa and Kilifi in June 2019. Activity delayed but complete. 0.2 Staff from several key institutions including NHM trained a total 44 extension officers and 15 taxonomists in July 2018 (see last report), June 2019 and February 2020. 0.3 Reference collections currently being developed for 4 partner institutions, with primary focus on the KALRO collection. KALRO collection database complete. 15 taxonomists and 44 extension officers trained	Refine and publish the Socio-Economic survey with increased input from biometricians. Continue surveying scale insect natural enemies at relevant sites identified by the Socio-Economic Survey (during 6-month extension period). Publish identification keys. Complete the best practices document. Complete the policy brief Another oral presentation at the next International Symposium on Scale Insect Studies.

	response time of <6 months 0.4 By end of the project, at least 250 smallholder households display better scale insect management practices and record decreased yield losses to scale insects 0.5 By end of the project, local agrobiodiversity shows significant increase in at least 250 smallholder households 0.6 By end of the project, information disseminated to decision-makers through a policy brief and to a wider audience through mass media articles	0.4 Report on first Socio-Economic Survey completed, providing baseline data about current management methods 0.5 Quantified in Year 3. 0.6 Policy brief drafted	Final Socio-Economic Survey will document this Policy brief disseminated in Year 3.
Output 1. Increased informed perception by smallholder farmers/foresters and extension providers of the scale insect threats to agricultural production, and on the means to manage the pests without disturbing agro-ecosystems, leading to increased crop yield for affected farms.	1.1 At least 250 smallholder farmers and foresters recognise scale insect attack and pest impact in all cases by end of project, with data disaggregated by gender 1.2 Increased income through higher yield and less pesticide expense in at least 250 smallholder farmers and foresters where scale insects outbreaks occurred by the end of the project 1.3 By the end of the project, sustainable agro-ecosystems restored, with biodiversity benefits, in and around 250 smallholdings where massive untargeted pesticide application occurred	Scientific staff from all major government agricultural institutions continue training on scale insect biology, collection, slide-mounting and identification, and initiate training of extension services in the three coastal counties (June 2019, February 2020) Socio-Economic Survey on 238 smallholder farms in 3 coastal Counties and resulting report completed, to provide baseline data on perception and awareness. Report to be refined and published in Year 3 (delayed due to Covid; to be completed during extension period).	Second Socio-Economic Survey on 238 smallholder farms in 3 coastal Counties to be conducted in Year 3, to document any changes in farm productivity and income by the end of the project.
Activity 1.1 KALRO and KEFRI document perception and knowledge in smallholder farmers and foresters respectively, using Socio-Economic questionnaire (developed in		Completed (after delay). Socio-Economic Survey questionnaire	

collaboration with CABI) at local community meetings, during the early stage and towards the end of the project. Respective roles of men and women in rural households are captured through the surveys		administered in 238 farms in 3 coastal counties in June 2019. Report complete (see Annex 3 in Year 2 annual report)	
Activity 1.2 KALRO and KEFRI document yield increase and pesticide use in smallholder farmers and foresters respectively, at local community meetings, through assessments during the early stage and towards the end of the project		First survey completed (after delay). Socio-Economic Survey questionnaire administered in 238 farms in three coastal counties in June 2019. Report complete (see Annex 3 in Year 2 annual report)	Second Socio-Economic Survey on 238 smallholder farms in 3 coastal Counties to be conducted in Year 3, to document any changes in farm productivity, income and pesticide use by the end of the project.
Activity 1.3 NHM, UoN and NMK survey natural enemies at 250 smallholdings all along the project		Ongoing. Initiated in Year 2 on farms selected from the Socio-Economic Survey (Nov. 2019, Feb. 2020). To be continued and concluded in extension period.	Collecting continued until Q3 of Year 3; will continue into extension period.
Output 2. A publicly-available scale insect and natural enemies inventory for Kenya developed, with distributions maps for species recorded from the study area in three coastal counties of Kenya.	2.1 One student and 4 technicians from UoN and KEPHIS trained in field recognition, collection, preservation, slide-mounting, digital photography and identification	One MSc student hired, thesis completed and submitted, awaiting examination due May 2021. Scientists from all partner institutions have been trained (KEPHIS: 4; KALRO: 2; KEFRI: 3; UoN: 1 student and 1 technical staff; CABI: 1; NMK: 3).	
	2.2 At least 30 scale insect species recorded in target areas, with associated natural enemies	48 scale insect species recorded from farms in 3 Coastal counties so far; natural enemies are still being collected and identified	
	2.3 At least 250 farms in the three coastal counties visited. All species discovered entered in the national reference collection	242 farms visited, 238 survey responses recorded. 68 new country records of scale insects for Kenya are currently being prepared for publication in 2 papers (see Appendix 4A)	
	2.4 At least 600 data records entered into a relational database (species identity, locality, date collected, host, natural enemies, images)	Ongoing; 860 scale insect slide mounts prepared so far, for sharing with Kenyan institutions	

	2.5 At least 30 distribution maps produced 2.6 Kenyan plant quarantine pest list reviewed to include scale insect species not recorded previously	Ongoing; collection data for 166 samples compiled, 179 identifications so far In progress; revised plant quarantine pest list and Kenya checklist cannot be finalised until the new country records have been published	
Activity 2.1. NHM trains students and technicians from UoN and KEPHIS to field recognition, collection, preservation, slide-mounting, digital photography and identification		Completed in July 2018. Reinforcement training was completed in July 2019.	Lists of trainees and analysis of their feedback provided in Evidence of training delivery report, March 2021
Activity 2.2. UoN and KEPHIS coordinate the survey of scale insects and natural enemies (collecting, sorting, on-site preservation, slide-mounting, digitisation) on a variety of crops and indigenous trees in three counties of the coastal area		Ongoing	Continuing natural enemies of scale insects and mealybugs surveys in most relevant farms as demonstrated by the initial Socio-Economic Survey.
Activity 2.3. NMK and UoN identify specimens with the scientific support of NHM, and enter them in the National reference collection, with corresponding slide images and associated data. Duplicates are deposited in other institutions' smaller working collections and at the NHM		Ongoing. Fourteen different scale families recorded so far, including one not recorded in Kenya before. 68 new country records, including two new records for Africa.	Identification of specimens continues until the end of Q4 of Year 3, and is ongoing during extension period.
Activity 2.4. NHM and NMK set up the database for the scale insect fauna of Kenya and enter data on specimens, taxonomy, host-plants, natural enemies, associated diseases, environmental and socio-economic impact		Ongoing. Data associated with specimens collected in years 1-2 compiled in a spreadsheet for later incorporation in the specimen database.	Names will be entered in the spreadsheet as soon as specimens are identified.
Activity 2.5. NMK produces distribution maps of scale insects including vegetation and crop production, with historical and recent outbreaks highlighted		Ongoing. Data associated with specimens collected in years 1-2 gathered in a spreadsheet for later incorporation in the specimen database.	Distribution maps will be produced from data associated with collected specimens.
Activity 2.6. KEPHIS reviews Kenyan plant quarantine pest list to include scale insects not yet recorded		Ongoing. New records transmitted to KEPHIS.	Cannot be completed until 2 papers on 68 new country records have been published. KEPHIS and partners (esp.

			KALRO, NHM) will review the new records and communicate on pest species accordingly
Output 3. Taxonomic researchers, parataxonomists and extension officers trained, and pest management decision chain implemented through identification capacity building among all stakeholders	3.1 Fifteen taxonomists and 50 extension officers trained in scale insect collection and handling, preservation, slide mounting and identification (disaggregated by type of training and profession) by end of year 1 3.2 KALRO national collection of scale insects enhanced, and 4 institutional reference collections established at UoN, NMK, KEFRI and KEPHIS 3.3 One identification key to scale families, 12 keys to genera and 90 keys to species developed and published for taxonomists by end of the project 3.4 One photo guide for smallholder farmers and foresters; and 30 fact sheets for extension officers developed by end of year 2	Training of trainers, taxonomists (15) and extension officers (50) complete One set of handouts produced for training of extension service on the coast, made widely available (complete). 860 slides have been prepared so far (ongoing), which will be shared between partner institutions for constitution of reference collections. One identification key to 23 scale insect families for the whole African continent has been produced and submitted for publication. Twenty-three keys to genera and 60 keys to species in the training manual, now being expanded and prepared for publication. One photo guide and 30 fact sheets prepared by CABI and NHM, and made available online	
Activity 3.1 NHM trains taxonomic researchers (including technicians in participating institutions for continuity) on slide making and identification, digitisation, collection enhancement and curation		Completed. 15 taxonomic researchers have been trained on scale insect slide mounting and identification.	Trained taxonomists, using handouts, photo guide and factsheets provided, continue to train others and diffuse knowledge through the community.
Activity 3.2 KALRO national collection of scale insects enhanced, and 4 institutional reference collections established at UoN, NMK, KEFRI and KEPHIS"		Ongoing; KALRO collection databased and re-curated. 860 slides have been prepared which will be shared between partner institutions for constitution of reference collections.	57 samples from February 2020 survey still need to be prepared and identified
Activity 3.3 NHM, NMK and UoN develop and publish identification keys to families, genera and species for scale insect pests of Kenya, including putative		Under way. One extensive training manual produced (Annex 4A);	The 23rd family, the armoured scale insects, has 143 genera and over 500

future invasive species		manuscripts on identification of genera and species of 22 families are in preparation for publication (Annex 4B)	known species in Africa. Coverage of this family will be limited by the short time available.
Activity 3.4 CABI produces field identification aids, fact sheets and photo sheets which will be used by extension workers and NGOs to train farmers		Complete. 1 photo guide and 30 farmer fact-sheets including sustainable management advice, prepared by CABI/NHM and made available online	
Output 4. Best practices for improving management of scale insect pests developed, disseminated to raise key stakeholder awareness and capacity, and adopted by them	4.1 Best practices intended to guide sustainable scale insect pest management practice developed by project end 4.2 Policy brief produced by the end of the project 4.3 Five media articles and radio programs for general public information 4.4 Three hundred stakeholders (smallholder farmers, foresters, extension officers and plant quarantine inspectors) engaged through various fora and use of information materials (disaggregated by category) by end of the project	Initial list of best practices prepared by CABI and NHM, to be refined by KEPHIS and KALRO with input from the analysis of the Socio-Economic Survey. Ongoing. Policy brief in preparation by KEPHIS and KALRO Complete. CABI radio programmes transmitted in October – December 2020, and are now available through CABI's YouTube page at https://www.youtube.com/watch?v=erlYIbEXSfI&list=PLA6tUPK41nmj8pXseuKi-bwVlUftqF3z The Agricultural Officer of Mombasa County, Daniel Imunya, currently has an online engagement with a group of 1,000 farmers from Mombasa, Kilifi and Kwale Counties, where it is estimated that 47,835 farmers listened to the radio programmes. The radio campaign complemented ongoing efforts in the management of papaya mealybug	
Activity 4.1. KEPHIS produces a best practices document for sustainable scale insect pest management		A draft best practices document is complete	Awaiting stakeholder review and adoption
Activity 4.2. KEPHIS produces a policy brief based on social and insect surveys, results and analyses, regarding best practices in managing scale insect pests and benefit of natural enemies to biodiversity and agriculture. Meet policy brief stakeholders and agree on final texts to be published		A policy brief has been produced with the assistance of CABI and other partners	Yet to be presented to stakeholders
Activity 4.3. Mass media campaigns and programmes are prepared		Ongoing. Dedicated webpages on CABI website.	Further progress in several media completed in Year 3. Radio and newspaper articles were prioritised
Activity 4.4. All categories of stakeholders engaged through fit-for-purpose information materials and updated information websites, and working/quarantine lists		Ongoing. Team leaders awareness levels raised; capacity building at scientists, technicians, and plant health	Continue to engage coastal county extension services and farmers.

	officer levels.	

Annex 2: Project's full current logframe (updated and agreed March 2021)

Project summary	Measurable Indicators	Means of verification	Important Assumptions
Impact: Improve awareness, response time and implementation of appropriate management strategies against threats to agro-biodiversity by invasive species			
Outcome: (Max 30 words) Kenyan livelihoods enhanced in >250 smallholdings; local agrobiodiversity improved by enhanced capacity to identify and manage scale insects at institutional, extension service and community levels, in smallholdings and native ecosystems.	0.1 By the end of the project, at least 250 smallholder households have a better knowledge of scale insects and their impact, and they all show novel understanding and skills in recognition of scale insects as pests in their crops 0.2 By the end of the project, at least 50 extension workers have a better knowledge of scale insects and their impact, and they all show novel understanding and skills in identification of pests and diseases, and management of emerging scale insect pest using environmentally safe and sustainable management practices 0.3 By end of the project, relevant research and advisory infrastructure improved in the form of 1 national comprehensive reference collection, 4 smaller working institutional collections, and associated database, at least 15 taxonomic experts, 30 parataxonomists and 50 extension workers delivering an accurate identification/advisory service	0.1 Signed lists of surveyed individuals; capacity assessment technical report based on pre- and post-project surveys; scientific publication on the socio-economic impact of smallholders perception of scale insect threats and awareness of appropriate pest management strategies 0.2 Signed lists of surveyed individuals and training records; capacity assessment technical report based on pre- and post-project surveys 0.3 Technical reports on the reference insect collections and associated online data portal; relevant identification keys published by Kenyan new taxonomic researchers (M.I. 3.3); a novel, photo-illustrated field identification aid developed for and disseminated to each major stakeholder categories (smallholder farmers / foresters,	Kenya remains politically stable. Farmers and foresters want to make use of the knowledge provided by the extension services. Extension staff is motivated in transmitting new knowledge and pest management protocols to farmers and foresters. Crop yield is not negatively impacted by factors outside the scope of the project such as adverse weather conditions. Agrobiodiversity is not negatively impacted by factors outside the scope of the project such as adverse weather conditions or changed land use. Government ministries adopt the resulting policy brief

	with a response time of <6 months 0.4 By end of the project, at least 250 smallholder households display better scale insect management practices and record decreased yield losses to scale insects 0.5 By end of the project, local agrobiodiversity shows significant increase in at least 250 smallholder households 0.6 By end of the project, information disseminated to decision-makers through a policy brief and to a wider audience through mass media articles	extension officers, para-taxonomists); online information and research database; reports on time response to all new scale insect outbreaks 0.4 Reports from baseline and end of project participatory farmers and foresters communities assessment surveys for yield and income 0.5 Reports from baseline and end of project diversity and abundance surveys of natural control agents in participatory farmers and foresters households 0.6 Policy brief on sustainable management of scale insects submitted to governmental policy-makers and published online	
Outputs: **1**. Increased informed perception by smallholder farmers/foresters and extension providers of the scale insect threats to agricultural production, and on the means to manage the pests without disturbing agro-ecosystems, leading to increased crop yield for affected farms.	1.1 At least 250 smallholder farmers and foresters recognise scale insect attack and pest impact in all cases by end of project, with data disaggregated by gender 1.2 Increased income through higher yield and less pesticide expense in at least 250 smallholder farmers and foresters where scale insects outbreaks occurred by the end of the project 1.3 By the end of the project, sustainable agro-ecosystems restored, with biodiversity benefits, in and around 250 smallholdings where massive untargeted pesticide application occurred	1.1 Report on capacity assessment, including respective roles of men and women in rural households, and information/awareness constraints 1.2 Report on baseline yield and end of the project yield, in link with pesticide use 1.3 Reports on natural enemy diversity	Smallholder farmers, foresters and extension workers are willing to participate in the survey. Smallholder farmers, foresters and extension workers are willing to learn new information and change existing practices. Crop yield is not negatively impacted by factors outside the scope of the project such as adverse weather conditions. Agrobiodiversity is not negatively impacted by factors outside the scope of the project such as adverse weather conditions or changed land use.

			Extension workers remain active and motivated during the entire duration of the project to ensure both the before and after surveys are successful.
2. A publicly-available scale insect and natural enemies inventory for Kenya developed, with distributions maps for species recorded from the study area in three coastal counties of Kenya.	2.1 One student and 4 technicians from UoN and KEPHIS trained in field recognition, collection, preservation, slide-mounting, digital photography and identification 2.2 At least 30 scale insect species recorded in target areas, with associated natural enemies 2.3 At least 250 farms in the three coastal counties visited. All species discovered entered in the National reference collection 2.4 At least 600 data records entered into a relational database (species identity, locality, date collected, host, natural enemies) 2.5 Thirty distribution maps produced 2.6 Kenyan pest list reviewed to include scale insect species not recorded previously	2.1 Report providing lists of trainees and analysis of their feedback 2.2 Published checklist of scale insects of Kenya, and their natural enemies 2.3 Technical report on the survey results; technical report on the national scale insect reference collection 2.4 Technical report on the database, with specimens and associated data; database object statistics; publicly available database 2.5 Maps showing distribution of scale insect species including pests and associated plants 2.6 List of Kenyan scale insect pests for plant quarantine purposes updated by KEPHIS based on field surveys	Climatic conditions are conducive to sampling. Freedom from drought for the duration of the project. Smallholder farmers accept their field to be surveyed. Collecting, research and sample sharing permits are obtained in a timely manner from the government bodies in charge. Students interested in scale insects are available for recruitment.
3. Taxonomic researchers, parataxonomists and extension officers trained, and pest management decision chain implemented through identification capacity building among all stakeholders	3.1 Fifteen taxonomists and 30 extension officers trained in scale insect collection and handling, preservation, slide mounting and identification (disaggregated by type of training and profession) by end of year 1 3.2 KALRO national collection of scale	3.1 Participant certificates and assessment records	Equipment (especially microscopes) in good working order is sufficient for training up to 20 to 25 trainees.

	insects enhanced, and 4 institutional reference collections established at UoN, NMK, KEFRI and KEPHIS 3.3 One identification key to scale families, 12 keys to genera and 90 keys to species developed and published for taxonomists by end of project 3.4 One photo guide for smallholder farmers, foresters and extension officers, and at least 30 fact sheets for extension officers developed by end of year 2	3.2 Technical reports on number of specimens, coverage, curation methods, identification accuracy and completeness 3.3 Identification keys and publications 3.4 Identification aids, diagnostic tools and information sheets; dissemination records	
4. Best practices for improving management of scale insect pests developed, disseminated to raise key stakeholder awareness and capacity, and adopted by them	4.1 Best practices intended to guide sustainable scale insect pest management practice developed by project end 4.2 Policy brief produced by the end of the project 4.3 Five media articles and radio programs, for general public information 4.4 Three hundred stakeholders (smallholder farmers, foresters, extension officers and plant quarantine inspectors) engaged through various fora and use of information materials (disaggregated by category) by end of the project	4.1 Best practices document 4.2 Participant certificates and policy brief published 4.3 Report on communication (title, content, audience) 4.4 Publications, technical briefs, media articles, radio programmes, fact sheets, photo sheets; project progress and final reports; feedback from stakeholders in the final report	County and national stakeholders are willing to collaborate. Political climate remains suitable for holding county workshops.
Activities (each activity is numbered according to the Output that it will contribute towards, for example 1.1, 1.2 and 1.3 are contributing to Output 1) 1.1 KALRO and KEFRI document perception and knowledge in smallholder farmers and foresters respectively, using socio-economic questionnaires (developed in collaboration with CABI) at local community meetings, during the early stage and towards the end of the project. Respective roles of men and women in rural households are captured through the surveys 1.2 KALRO and KEFRI document yield increase and pesticide use in smallholder farmers and foresters respectively, at local community meetings, through assessments during the early stage and towards the end of the project			

1.3 NHM, UoN and NMK survey natural enemies at 250 smallholdings all along the project

2.1 NHM trains students and technicians from UoN and KEPHIS to field recognition, collection, preservation, slide-mounting, digital photography and identification

2.2 UoN and KEPHIS coordinate the survey of scale insects and natural enemies (collecting, sorting, on-site preservation, slide-mounting, digitisation) on a variety of crops and indigenous trees in three counties of the coastal area

2.3 NMK and UoN identify specimens with the scientific support of NHM, and enter them in the National reference collection, with corresponding slide images and associated data. Duplicates are deposited in other institutions' smaller working collections and at the NHM

2.4 NHM and NMK set up the database for the scale insect fauna of Kenya and enter data on specimens, taxonomy, host-plants, natural enemies, associated diseases, environmental and socio-economic impact

2.5 NMK produces distribution maps of scale insects including vegetation and crop production, with historical and recent outbreaks highlighted

2.6 KEPHIS reviews Kenyan pest list to include scale insects not yet recorded

3.1 NHM trains taxonomic researchers (including technicians in participating institutions for continuity) on slide making and identification, digitisation, collection enhancement and curation

3.2 NHM and UoN train parataxonomists and extension officers on basic scale biology, field collection, sorting, preservation and basic identification, on natural enemies recognition and on sustainable agricultural practices

3.3 NHM, NMK and UoN develop and publish identification keys to families, genera and species for scale insect pests of Kenya, including putative future invasive species

3.4 CABI produces field identification aids, fact sheets and photo sheets which will be used by extension workers and NGOs to train farmers

4.1 KEPHIS produces a best practices document for sustainable scale insect pest management

4.2 KEPHIS produces a policy brief based on social and insect surveys, results and analyses, regarding best practices in managing scale insect pests and benefit of natural enemies to biodiversity and agriculture. Meet policy brief stakeholders and agree on final texts to be published

4.3 Mass media campaigns and programmes are prepared

4.4 All categories of stakeholders engaged through fit-for-purpose information materials and updated information websites, and working/quarantine lists

Annex 3: Standard Measures

Table 1 Project Standard Output Measures

Code No.	Description	Gender of people (if relevant)	Nationality of people (if relevant)	Year 1 Total	Year 2 Total	Year 3 Total	Total to date	Total planned during the project
2	Number of people to attain Masters qualification (MSc, MPhil etc.) *	Male	Kenyan	0	0	1	1	1
6A	Number of people to receive other forms of education/training (which does not fall into categories 1-5 above) *	9 male, 6 female (year 1)	Kenyan	15	22	12	49	43
6B	Number of training weeks to be provided			2	2	1	5	5
7	Number of (i.e., different types - not volume - of material produced) training materials to be produced for use by host country			1	2	0	3	3
9	Number of species/habitat management plans (or action plans) to be produced for Governments, public authorities, or other implementing agencies in the host country			0	0	1	1	1
10	Number of individual field guides/manuals to be produced to assist work related to species identification, classification and recording			0	1	0	1	1
11A	Number of papers to be published in peer reviewed journals			0	1	5	6	3
11B	Number of papers to be submitted to peer reviewed journals			0	1	7	8	3

12A	Number of computer based databases to be **established** and handed over to the host country			0	1	1	2	1
12B	Number of computer based databases to be **enhanced** and handed over to the host country			0	0	2	2	1
13A	Number of species reference collections to be **established** and handed over to the host country(ies)			0	0	4	4	4
13B	Number of species reference collections to be **enhanced** and handed over to the host country(ies)			0	1	1	2	2
14B	Number of conferences/seminars/ workshops **attended** at which findings from Darwin project work will be presented/ disseminated.			0	1		1	1
21	Number of permanent educational/training/research facilities, structures, or organisations to be established and then continued after Darwin funding has ceased			0			0	0
23	Value of resources raised from other sources (i.e., in addition to Darwin funding) for project work			[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Table 2 Publications (see also Annex 4B)

Title	Type (e.g. journals, manual, CDs)	Detail (authors, year)	Gender of Lead Author	Nationality of Lead Author	Publishers (name, city)	Available from (e.g. weblink or publisher if not available online)
Ants (Hymenoptera: Formicidae) associated with scale insects (Hemiptera: Coccomorpha) on citrus trees in Coastal and Lower Eastern Counties, Kenya	*Journal of Agricultural Science and Practice*, 5(6), 245-249.	Mathenge, M., Ong'amo, G.O., Nderitu, J, Watson, G.W. & Kinuthia, W. (2021)	Male	Kenyan	Integrity Mega Research Publishers, Benin City, Nigeria	https://integrityresjournals.org/journal/JASP/article-abstract/C9BF0D654 Open Access, PDF available