# Darwin Plus:
# Overseas Territories Environment and Climate Fund
# Annual Report

**Important note** *To be completed with reference to the Reporting Guidance Notes for Project Leaders:*

*it is expected that this report will be about 10 pages in length, excluding annexes*

**Submission Deadline: 30th April 2018**

## Darwin Plus Project Information

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|---|---|
| Project reference | DPLUS064 |
| Project title | Characterising Bermuda's baitfish populations to improve management and fishery sustainability |
| Territory(ies) | Bermuda |
| Contract holder institution | Bermuda Zoological Society |
| Partner institutions | Bermuda Government DENR, Bermuda Institute of Ocean Sciences, Murdoch Marine |
| Grant value | GBP189,729 |
| Start/end date of project | April 2017 – September 2019 |
| Reporting period (e.g., Apr 2017-Mar 2018) and number (e.g., AR 1,2) | April 2017-March 2018<br>AR1 |
| Project leader name | Joanna Pitt |
| Project website/blog/Twitter | |
| Report author(s) and date | J.M. Pitt, S.R. Smith, T.J. Murdoch, G. Goodbody-Gringley and J.L. Welch |

## 1. Project overview

Small bony fishes are of both ecological and economic importance, as they provide food for larger fishes and waterbirds, but are also exploited by commercial and recreational fishers for bait. In Bermuda, there are six species of so-called baitfishes, but their life history characteristics are poorly understood. Reported catches of all baitfish groups have declined over the past 25 years, but it is unclear whether this indicates declining populations or changes in fishing practices. Current management restricts the size and type of nets that may be used, and prohibits net fishing in four inshore bays. However, a greater understanding of the abundance, distribution, life history and population genetics of these species will create opportunities for a wider range of management measures to be applied to these fishes, and will inform discussions with stakeholders regarding the need for additional management and the forms that it might take.

This project is describing the annual cycles in abundance and distribution of baitfishes around Bermuda, together with their life history (i.e. age, growth and reproduction) and population genetics. In the coming year, we will engage commercial and recreational fishers to examine bait fishing and bait use practices, including attitudes towards alternative baits. This information will contribute to a revised management plan for baitfish species in Bermuda, improving the sustainability of the fishery while ensuring that these species continue to fulfil their key ecological role.

## 2. Project stakeholders/partners

The Marine Management team of the Bermuda Government Department of Environment and Natural Resources (DENR), of which project leader JP is a member, is a key stakeholder in this project, responsible for utilising information in the output reports to develop an improved management plan for baitfish in Bermuda – the primary outcome. DENR has supported this project from the proposal stage and provides the office and lab space for key personnel and activities, as well as salary for JP and SRS. The Marine Resources Board, Bermuda's marine stakeholder consultation group, was consulted at the proposal stage and will provide input again in the final stages of the project, when the reports are complete and the revised management plan is being developed.

Other key stakeholders are the commercial and recreational fishermen that utilise baitfishes to greater or lesser degrees to make their living and enjoy their hobby. Engaging with resource users is a key part of resource management, and vital to the successful introduction of alternative management measures. The upcoming fisher surveys and interviews will play a key role in engaging these stakeholder groups, and will be conducted with the input of the Fisheries Extension Officer.

The local science community and students were not explicitly defined as stakeholders in this project. However, the Bermuda Institute of Ocean Science (BIOS), where GGG is on the faculty, has a range of education programmes, and the intern working with GGG on the genetics study was supported by one of these programmes. Our local science contacts at both BIOS and the Bermuda Zoological Society (which hosts the funds) have resulted in three additional spin off projects with local and visiting university students.

## 3. Project Progress

### 3.1 Progress in carrying out project Activities

The main focus of activities in the first year of the project has been conducting surveys of baitfish abundance (contributing to Output 1) and acquiring and processing samples to describe the life history of the various baitfish species (Output 2).

As discussed in our half-yearly review and the associated change request, the time lapse camera method originally proposed for monitoring baitfish schools did not provide images suitable for analysis with any consistency. Instead, we are conducting in person visual surveys to assess baitfish school presence and characteristics (now called activity 1.345, as it replaces 1.3, 1.4 and 1.5). Surveys aim to assess two time points per week, and are weather dependent, but provide a greater amount of detail on species composition and the sizes / ages of the fishes. The change to visual surveys for observing baitfish schools resulted in a lag before we started getting useful data, such that we are three months behind in our year-long monitoring program, and this activity will need to carry on through the first quarter of the 2018-19 year. However, this change has also allowed an additional site to be monitored regularly and for opportunistic observations to be incorporated into the analysis (see Figures 1 and 2).

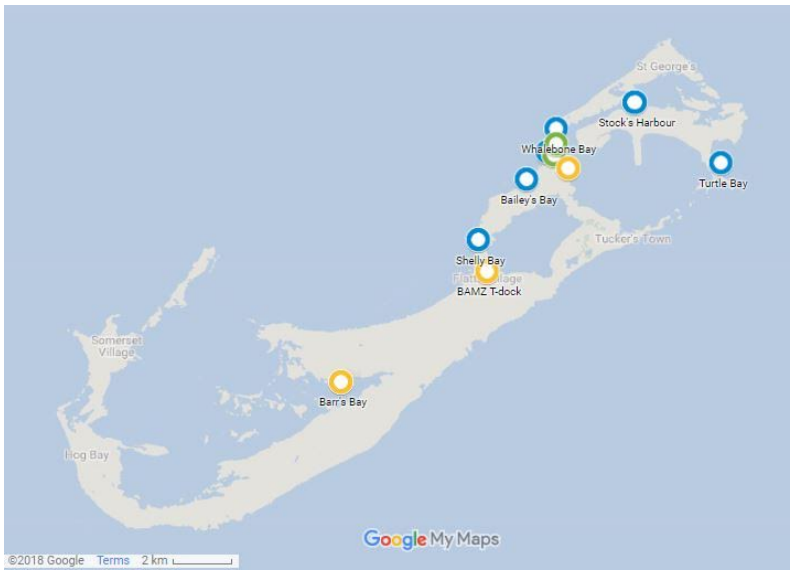


Figure 1. Map of Bermuda showing the locations of regular monitoring sites (blue), and other sites that have been surveyed more than 30 times (green) and more than 10 times (orange).

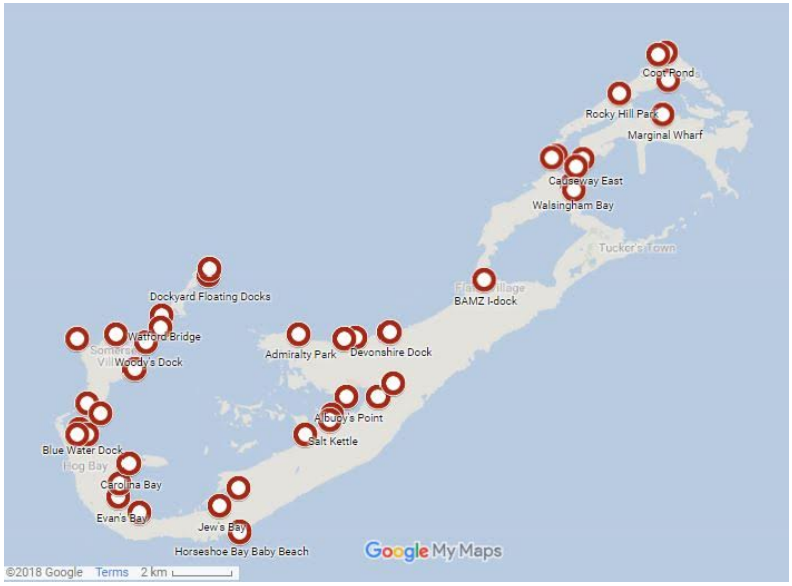


Figure 2. Map of Bermuda showing the locations of opportunistically surveyed sites in red.

Since July 2017, over 600 surveys have been conducted, and the primary monitoring sites (two bays closed to net fishing and two bays where fishing is permitted) have been surveyed at least weekly. Additional sites have been surveyed approximately monthly. The use of a google form and google sheets for data management and basic manipulation has reduced data entry and analysis time, and facilitated the instant sharing of data, which in turn makes monitoring progress easier and less time-consuming.

Based on observed fluctuations in baitfish presence and abundance during the surveys, plans have been made (Activity 1.6) to conduct the broad scale distribution survey (Output 4) during July and August of 2018. This timeframe been validated by discussions with expert Chris Flook, who has acted as an occasional consultant for the project even though he is no longer able to participate in collecting activities.

The time lapse camera monitoring (Activity 1.1) was maintained in order to monitor fishing activity. Since July, this approach has detected 79 separate instances of net fishing activity across the two study bays that are open to fishing, with activities concentrated in August and September. Monitoring of the closed bays did not detect any poaching during the period up to March 31st, 2018, but one poaching incident was detected in the first half of April 2018. This activity will now continue in its new form throughout the coming year.

Acquisition of loggers for in situ temperature monitoring (Activity 1.2) was delayed, and will now take place in year 2. However we have access to temperature data from another ongoing monitoring program for at least one of our regular monitoring sites. Temperature data will be used to help interpret reproductive data in Output 2.

Samples for the age, growth and reproduction study (Output 2) are accumulating, with over 4,000 fish from 40 locations having been measured, weighed and dissected (Activities 2.1-2.4). Approximately 1,000 individuals from each of the three main study species have been sampled for age and growth parameters. Across all species, more than 500 ovaries have been preserved for histological analysis. The new sampling arrangements have meant that we are often able to get samples from more than one day per week, which provides increased resolution when trying to determine spawning times. These activities will be ongoing through year 2 of the project, to corroborate cycles observed in year 1. Further activities working towards this output are scheduled in year 2.

Sampling and lab work (Activities 3.1 – 3.3) contributing to the population genetics study (Output 3) are complete, and the report and scientific publication (Activity 3.4) are in draft form. Uploading of genetic sequences (Activity 3.5) will take place once the manuscripts are submitted. A conference presentation in 2018 is anticipated.

In preparation for the survey of baitfishing and bait use practices (Output 5), catch records from the commercial fishery have been utilised to generate profiles for three different approaches to bait fishing amongst commercial fishers. This has allowed us to identify the specialised bait fishers who we will approach for interviews during the coming year, and to generate a mailing list for the mailout survey to other commercial fishers. The interview format and surveys (Activities 5.1-5.3) are in draft form. These activities have been delayed by approximately 5

months due to unforeseen circumstances that placed additional demands on staff time. These activities are not time-sensitive and are covered by matching funding, so they do not affect the year to year allocation of grant funds. As such, it was determined that this was the most reasonable output to deprioritise. However, the catch records compiled have been analysed to describe the seasonal fluctuations in baitfishing activity, which will be cross-referenced against the interview data. This additional activity was conducted in partnership with a student at the Bermuda Institute of Ocean Sciences. The more quantitative description of fishing seasonality will strengthen comparisons with the observed patterns in baitfish abundance (in Output 1).

## 3.2 Progress towards project Outputs

The completion of most year one outputs has been delayed by the time lag in the initiation of regular sampling and 'in situ' surveys. The year of visual surveys will be completed in June 2018, and completion of the first draft of the report on the annual cycle in baitfish abundance and distribution (Output 1) is anticipated by September of 2018. Additional material may be added after this point. The age, growth and reproduction study (Output 2) is the largest component of this project. Work is progressing well, with over 4,000 specimens dissected to date (see section 3.1), but the report on this work is not scheduled to be completed until the end of the funding in September of 2019. In terms of change from baseline, we now know a lot more about baitfish than we did a year ago! There is already evidence of seasonality in both abundance and reproduction emerging from the data, and it appears that the three focal species of small baitfish may reproduce at different times of year.

Results of the genetic study (Output 3) show no differentiation between fish sampled in different areas around Bermuda, indicating mixing across all of Bermuda for the various species. This implies a reduced need for an evenly distributed network of closed areas, and would allow any additional closures to be selected in a more flexible manner that may serve to reduce conflict. Further, levels of intraspecific diversity are suggestive of some levels of external input for the non-endemic species. This is interesting, given Bermuda's isolated location. These are the key pieces of genetic information required for managing fishery species. DENR has been provided with a summary of results, and the report and scientific publication that are the primary deliverables are in draft form, with submission anticipated in the next few months. (See Annex 3A.)

The remaining project outputs deliver on activities to be conducted during the coming year.

As this project primarily comprises a number of research strands that aim to fill recognised data gaps, most of the output indicators are based on the reports on this work being received by the DENR Marine Management team. The revised management plan that will be the primary outcome of this project will utilise information from the reports, which will be available far sooner than peer-reviewed journal articles.

Other outputs recognised in the standard measures but not specifically included in our logframe include increased local capacity related to the acquisition of, for example, scientific equipment. The DENR Marine Management Section has acquired a computer, a dissecting microscope and a microscope camera as a result of this project. These assets will enhance the ability of DENR marine scientists and managers to conduct further studies of a similar nature. Further, the addition of a quality microscope camera will facilitate the production of enhanced outreach and education materials, and make it easier to collaborate with overseas experts.

## 3.3 Progress towards the project Outcome

The main outcome of this project will be the development of a revised plan for managing baitfish in Bermuda, with the expectation that improved management will contribute to the stability of these populations, allowing them to continue to fulfil their important ecological and economic roles. As such, DENR's receipt of the output reports and the completion of the management plan are the obvious outcome indicators. The success of the revised management plan going forward will require buy-in from non-government stakeholders, particularly commercial fishers. Engagement with the public and fishers is currently occurring opportunistically during field work. However, the main work engaging with fishers, the surveys and interviews contributing to Output 4, will be taking place in the coming year.

As outlined in the proposal, the reports should all be complete and submitted by September 2019. Development of the revised management plan will be undertaken by DENR staff, so no further grant funds are required past that point. The target deadline for the completion of the

draft management plan is December 2019, allowing 3 months for the process once the reports are complete. Stakeholder consultation will happen during 2020. Thus, it is expected that the outcome will still fall within the 2019-2020 financial year.

### 3.4 Monitoring of assumptions

A key assumption in the original proposal was that the time lapse camera method would adequately capture the presence and size of baitfish schools in inshore bays, without being unduly affected by ambient conditions. As discussed in the September 2017 change request and in section 3.1, this was not the case and a different approach had to be implemented in order to acquire the information. The visual surveys are now supplying the information required, and the overall cost has not changed substantially.

Another key assumption is that of fisher co-operation with the upcoming surveys and interviews. In order to promote co-operation, a short article announcing the project was included in the quarterly newsletter that DENR sends out to commercial fishermen. The risk that fishers may be unco-operative is also being mitigated by engaging with them on an opportunistic basis and having informal conversations about the project, for example when we are out sampling. We will also work with the Fishermen's Association of Bermuda, our Fisheries Extension Officer and the former Extension Officer, who still has a lot of contacts amongst the commercial fishers, to build support for the survey process.

### 3.5 Project support to environmental and/or climate outcomes in the UKOTs

The development of a revised plan for managing baitfish in Bermuda, with the expectation that improved management will contribute to the future stability of these populations, will help ensure that these species continue to fulfil their important ecological role while also contributing to the local economy and local food security. It is hoped that building resilience at the base of the marine food web will enhance the ability of the broader marine ecosystem to withstand environmental perturbations, which are expected to increase under a changing climate.

The project has also added to local fisheries management capacity by providing an opportunity for a young Bermudian who has recently completed his undergraduate degree to work alongside DENR staff, developing his skills in fisheries biology techniques and exposing him to the practical aspects of marine environmental management that cannot really be taught in a university setting.

## 4. Monitoring and evaluation

At the start of the project, as we were testing the methods and then revising them, regular, planned meetings were critical. Meetings now have become more opportunistic, taking place over the physical exchange of samples or via email discussions. The use of a google form and google sheets for data management and basic manipulation has facilitated the instant sharing of data, which in turn makes monitoring progress easier and less time-consuming. Our original approach was based on making one person responsible for keeping track of progress in order to avoid confusion, but online access to the data means that everyone can keep track at the same time, reducing the burden of monitoring.

## 5. Lessons learnt

As discussed, we have had to replace the time-lapse camera monitoring of inshore baitfish schools with in person visual surveys, as the images were not of sufficient quality to allow discernment of baitfish schools under most weather conditions. The main limiting factor was finding a secure place for the cameras that was high enough, and yet close enough, to get a suitably angled view of the bays. This change also removed the need to use underwater cameras to occasionally validate the species composition of the schools. The surveys generate more detailed data that will still fulfil the primary goal of determining the annual cycles in the abundance and distribution of baitfish species. The time lapse cameras are still being used to monitor fishing activity, and the insertion of a piece of polarised film between the lens and the exposure housing has improved the quality of the images.

The survey results are uploaded using a specially designed google form, reducing analysis time to compensate for the additional field time. This has had the added benefit of facilitating instant sharing of data, making the monitoring of progress more efficient, and is an approach that we would recommend to others.

Although our initial plan was to use remote methods to save on personnel time and costs, this alternative approach has allowed the collection of more detailed data, from a greater range of locations, than we originally expected to gather. There is now the potential for a scientific publication based on these data. In addition, our presence in the field has provided the opportunity to connect with fishers and members of the public and talk to them about the project. It is hoped that this will encourage co-operation with the upcoming survey work, and promote acceptance of any regulatory changes that come about as a result of the revised management plan that will be developed at the end of this project.

From an administrative perspective, dealing with fluctuations in the GBP to USD exchange rate has been challenging, and is outside of anyone's control. When writing cross-currency proposals, it is therefore important to build in a small margin to account for this, and to be prepared to be flexible.

We have also learnt that it is important to avoid an over-reliance on particular personnel. We unexpectedly lost the services of a named contractor, and two key personnel had to take unplanned time away from work because of family emergencies. With salary costs as a major component of funding, grant funded work cannot allow margins for redundancy, but it is essential to have a back-up plan in the event that a particular person is either temporarily unable to work or no longer able to participate in a project. This is especially relevant for projects operating in small communities, which may not have a wide selection of replacement personnel from whom to choose.

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

## 7. Other comments on progress not covered elsewhere

## 8. Sustainability and legacy

This was project was initiated locally and supported by DENR to address key gaps in the data required for more comprehensive management of baitfish species in Bermuda. Project leader JP will work with the rest of the DENR Marine Management team to develop an improved management plan using the information presented in the output reports from this project. With the support of the Marine Resources Board, the political will is in place for such a plan to be implemented. By engaging with the various fisheries sectors and incorporating fishing practices and fishers' opinions into the discussion at an early stage, this management plan should be accepted by the commercial and recreational fishing communities. A more sustainable baitfish fishery will have lasting economic and ecological benefits.

## 9. Darwin identity

To date, there has not been a lot of opportunity to promote the project as we are still in the data gathering phase. Stakeholders, such as the Marine Resources Board, that were involved with the proposal were notified when we were approved for funding. Unfortunately, our planned public announcement was caught up in the snap election held last year and never made it to press because there was no sitting minister to approve it. More publicity for the project is anticipated in association with the upcoming surveys of the fishing community, so we intend to take this opportunity to promote the project more widely.

A short article was placed in the Fisheries Newsletter (see Appendix 3B) to make commercial fishers aware of the project. Defra and Darwin Plus were given appropriate credit during the Research Experience for Undergraduates mini-symposium at BIOS when intern ES presented the results of her work on the genetics study.

As this is Bermuda's second major DPLUS grant, most people engaged in environmental work locally are aware of the program. Awareness is high amongst DENR and BZS staff and associates, BIOS scientists, and anyone who was associated with the lionfish work undertaken previously.

## 10. Project Expenditure

**Table 1: Project expenditure during the reporting period (1 April 2017 – 31 March 2018)**

| Project spend (indicative) in this financial year | 2017/18 D+ Grant (£) | 2017/18 Total actual D+ Costs (£) | Variance % | Comments (please explain significant variances) |
|---|---|---|---|---|
| Staff costs | | | | |
| Consultancy costs | | | | |
| Overhead Costs | | | | |
| Travel and subsistence | | | | |
| Operating Costs | | | | |
| Capital items | | | | |
| Others (Please specify) | | | | |
| **TOTAL** | | | | |

The changes outlined in the table were all approved at the half-year review. The change in methodology aimed at gathering data for Output 1 resulted in a 3 month lag in the collection of useful data. This necessitated the rollover of some funds into year 2 in order for a full annual cycle to be studied. The withdrawal of the collecting consultant from the project necessitated the reassignment of this work. The project technician, JW, agreed to take on this task for half the cost, leaving funds available. Significant fluctuations in the GBP – USD exchange rate over the past year left some key items in shortfall, so funds were reallocated to these areas with approval. Additional funds were approved for reallocation to other areas to enhance the quality of equipment purchased and the number of genetics samples that could be analysed.

Bearing in mind the potential impact of exchange rate fluctuations, a number of consumable items were not ordered until March, when we had a clearer picture of our purchasing power based on how the grant funds would translate to US and Bermuda dollars. In addition, we have a lag in billing and some bills are only submitted at the end of the subsequent month. As such, we have only received some March bills during the past 24 hours. The late purchases and the local billing cycle have meant that it has not been possible to finalise the financial information. However, documentation for the final arrears-based claim for 2017-18 will be complete and submitted before the May 31 deadline. If needs be, a revised version of this table can be submitted as soon as the information has been processed.

## Annex 1: Report of progress and achievements against Logical Framework for Financial Year 2017-2018 – <u>if appropriate</u>

| Project summary | Measurable Indicators | Progress and Achievements April 2017 - March 2018 | Actions required/planned for next period |
|---|---|---|---|
| ***Impact***<br>This project will describe the life history, genetics, abundance and distribution of Bermuda's baitfishes, and the fishery for them, facilitating more sustainable management of these economically and ecologically important species. | | | [redacted] |
| ***Outcome***<br>Information on the genetics, life history, abundance and distribution of Bermuda's baitfish species, and the fishery for them, will be provided to DENR for incorporation into an improved management plan. | 0.1 Five reports / publications completed and provided to DENR's Marine Management Team.<br>0.2 Using information in the reports / publications, the project leader will work with senior DENR staff to develop a draft of a revised baitfish management plan by December 2019, to go to consultation by January 2020. | | In the coming year, Output 3 will be completed in Q 1, Output 1 will be completed in Q2, and Outputs 4 and 5 will be completed by Q4. |
| **Output 1.**<br>Report describing the annual cycle of baitfish populations | 1.1 Report completed and provided to DENR | The year of visual surveys will be completed in June 2018, and completion of the first draft of the report on the annual cycle in baitfish abundance and distribution is anticipated by September of 2018. | |
| Activity 1.1 - Use time-lapse cameras to monitor fishing activity in two bays that are open to fishing and poaching in two bays where net fishing is prohibited. | | The time lapse cameras have been redeployed to monitor fishing activity since July. This approach has detected 79 separate instances of net fishing activity across the two study bays that are open to fishing. Monitoring of the closed bays did not detect any poaching during the period up to March 31st, 2018. This activity will now continue in its new form throughout the coming year. | |
| Activity 1.2 - Install in-water temperature loggers at primary study bays. Retrieve data quarterly. Download, describe and compare annual temperature cycles across bays. | | Purchase of the temperature loggers was delayed, but we have access to suitable temperature data from at least one of our regularly monitored sites for the past year, and temperature data will be collected going forward for cross-referencing with reproductive seasonality. | |
| Activity 1.345 - Activities 1.3, 1.4 and 1.5 in the original logframe have been replaced by visual surveys of baitfish school presence, including information on size, species composition and size structure. (Agreed at half year review.) | | Since July 2017, over 600 visual surveys have been conducted, and the primary monitoring sites (two bays closed to net fishing and two bays where fishing is permitted) have been surveyed at least weekly. | |

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| Activity 1.6 – Identify the period of peak baitfish abundance to help plan a broadscale drone survey of abundance and distribution. | | Based on observations, the period of peak abundance has been identified as occurring primarily in July and August, extending in September. As such, the broadscale survey has been planned to take advantage of the best 10 weather days between July 15 – August 31. (Although conducted under Output 1, this activity contributes to Output 4.) |
| **Output 2.**<br>Report and scientific publication describing the age, growth and reproduction of Bermuda anchovy, reef silverside, and dwarf herring, with management suggestions | 2.1 Report completed and provided to DENR<br>2.2 Scientific publication | Samples have been collected at least weekly, more than 4,000 fish have been dissected, with otoliths extracted and gonads preserved for histology. This work will continue through year 2, with the output report expected in year 3. |
| Activity 2.1 - Sample baitfishes at a variety of locations on a weekly. Ensure that monitored bays are included in the sampling locations at least once per month | | Sampling has been taking place at least weekly since July, with sufficient coverage of the regular monitoring sites. The new sampling arrangements have meant that we are often able to get samples from more than one day per week, which provides increased resolution when trying to determine spawning times. |
| Activities 2.3 - 2.5 Measure (total length) and weigh at least 10 individuals from each 1cm size class present for each of Bermuda anchovy, reef silverside, and dwarf herring from each sample. Dissect specimens to remove gonads and otoliths. Stage gonads visually. Preserve at least 20 mature ovaries from each species each month for histology. | | More than 4,000 fish across all species have been measured, weighed and dissected, with otoliths extracted and more than 500 gonads have been preserved for histology and batch fecundity. |
| 2.5 Evaluate batch fecundity for up to 20 ripe ovaries per month, as available. | | Work on batch fecundity samples is underway. |
| **Output 3.**<br>Population genetics analysis of 3 small-bodied baitfish species published and sequences uploaded to publicly available databases. | 3.1 Advisory report completed<br>3.2 Scientific publication<br>3.3 Sequences uploaded | The genetic study showed no differentiation between fish sampled in different areas around Bermuda, indicating genetic mixing across all of Bermuda for the various species. Further, levels of intraspecific diversity are suggestive of some levels of external input for the non-endemic species. DENR has been provided with a summary of results, and a scientific publication is in preparation, with submission anticipated in the next few months. (Sequences will be uploaded to public databases following publication.) |
| Activities 3.1 – 3.3 Genetics lab work | | Genetics lab work is complete |
| Activity 3.4 - Write advisory report for DENR and scientific publication on genetic diversity and rates of connectivity of Bermuda anchovy, reef silverside, and dwarf herring. Present results at an international conference. | | Report and paper are in draft form, with submission expected during May 2018. |
| 3.5 - Upload sequences to publically available databases: the NCBI database, GenBank, and the barcoding of life data systems database, BOLD. | | Sequences will be uploaded to public databases following publication. |

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| **Output 4.**<br>Report describing broadscale survey of peak baitfish abundance / distribution | 4.1 Report provided to DENR | The broadscale survey has been planned for the window between July 15 and August 31 of 2018. |
| Activity 4.1. Test methods and calibrate against stationary cameras | | Stationary cameras are no longer being used. Visual snorkel surveys will be used to verify species composition of baitfish schools. |
| **Output 5.**<br>Report on baitfishing, bait use and fisher perceptions, with management suggestions | 5.1 Report provided to DENR | Although preparatory work has been done, work on activities contributing to this output has been delayed until year 2 due to unforeseen circumstances that placed additional demands on the time of key personnel. |
| **Output 6.**<br>All imagery curated and stored at BAMZ library for other researchers to access upon request | 6.1 Images provided to BAMZ library | Activities contributing to Output 6 will take place in 2019 |

## Annex 2: Project's full current logframe as presented in the application form (unless changes have been agreed) - if appropriate

*N.B. if your application's logframe is presented in a different format in your application, please transpose into the below template. Please feel free to contact Darwin-Projects@ltsi.co.uk if you have any questions regarding this.*

| Project summary | Measurable Indicators | Means of verification | Important Assumptions |
|---|---|---|---|
| **Impact:**<br>This project will describe the life history, genetics, abundance and distribution of Bermuda's baitfishes, and the fishery for them, facilitating more sustainable management of these economically and ecologically important species. | | | |
| **Outcome:**<br>Information on the genetics, life history, abundance and distribution of Bermuda's baitfish species, and the fishery for them, will be provided to DENR for incorporation into an improved management plan. | 0.1 Five reports / publications completed and provided to DENR's Marine Management Team.<br>0.2 Using information in the reports / publications, the project leader will work with senior DENR staff to develop a draft of a revised baitfish management plan by December 2019, to go to consultation by January 2020. | 0.1 Reports provided to DENR and made available at www.environment.bm<br>0.2 Draft baitfish management plan presented to the Marine Resources Board and Commercial Fisheries Council, and available at www.environment.bm | Publication schedules do not delay completion of reports or availability of scientific paper |
| **Outputs:**<br>**1**. Report describing the annual cycle of baitfish populations | 1.1 Report completed | 1.1 Report provided to DENR | Baitfish can be identified to species from underwater images. Mitigation: Samples will help to confirm species ID.<br>Weather does not interfere with cameras or compromise images for any extended period. |
| **2**. Report and scientific publication describing the age, growth and reproduction of Bermuda anchovy, reef silverside, and dwarf herring, with management suggestions | 2.1 Report completed<br>2.2 Scientific publication | 2.1 Report provided to DENR<br>2.2 Publication in press or available online | Adequate numbers of each species available for sampling throughout the year.<br>Publication schedules do not delay completion of reports or availability of scientific paper |

| | | | |
|---|---|---|---|
| **3**. Population genetics analysis of 3 small-bodied baitfish species published and sequences uploaded to publicly available databases. | 3.1 Advisory report completed<br>3.2 Scientific publication<br>3.3 Sequences uploaded | 3.1 Report provided to DENR<br>3.2 Publication in press or available online<br>3.3 Sequences available online | Publication schedules do not delay completion of reports or availability of scientific paper |
| **4.** Report describing broadscale survey of peak baitfish abundance / distribution | 4.1 Report provided to DENR | 4.1 Report provided to DENR | |
| **5.** Report on baitfishing, bait use and fisher perceptions, with management suggestions | 5.1 Report provided to DENR | 5.1 Report provided to DENR | Commercial and recreational fishers will co-operate and provide information and opinions during interviews and surveys. |
| **6.** All imagery curated and stored at BAMZ library for other researchers to access upon request | 6.1 Images provided to BAMZ library | 6.1 Images provided to BAMZ library on external storage media | |

**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 Test and install fixed time-lapse cameras for 'bird's eye' view of 4 bays – 2 bays that are closed to nets and two that are 'open'. Calibrate images for area. Service monthly over 1 year to change batteries and SD cards and download to external storage media.

1.2 Install in-water temperature loggers at the same 4 bays. Retrieve data quarterly. Download, describe and compare annual temperature cycles across bays.

1.3 Test and place fixed underwater cameras in the same bays for half a day on two occasions each month. Calibrate observed area to allow calculation of fish density.

1.4 Select and analyse up to 37,000 'bird's eye' images for presence and spatial extent of baitfish schools.

1.5 Select and analyse 1,040 underwater images for species composition and density of baitfish schools. Validate using species composition data from collected samples (Activity 2.1)

1.6 Identify the time of peak baitfish abundance to optimise the broadscale survey in year 2.

1.7 Complete report describing the annual cycle of baitfish abundance, comparing species, locations and temperature.

2.1 Sample baitfishes at a variety of locations on a weekly basis in year 1, and twice a month in year 2. Ensure that monitored bays are included in the sampling locations at least once per month.

2.2 / 3.1 During initial processing, take tissue samples for genetics analysis from 40 individuals of Bermuda anchovy, *Anchoa choerostoma*, reef silverside, *Hypoatherina harringtonensis*, and dwarf herring, *Jenkinsia lamprotaenia*, ensuring that each species is represented by samples from the widest possible range of locations.

2.3 Measure (total length) and weigh at least 10 individuals from each 1cm size class present for each of Bermuda anchovy, reef silverside, and dwarf herring from each sample.

2.4 Dissect specimens to remove gonads and otoliths. Stage gonads visually. Preserve at least 20 mature ovaries from each species each month for histology.

2.5 Evaluate batch fecundity for up to 20 ripe ovaries per month, as available.

2.6 Prepare and read daily growth rings from at least 10 individuals from each 1cm size class present for each of Bermuda anchovy, reef silverside, and dwarf herring for each month. Calculate growth rates and back-calculate spawning dates.

2.7 Have monthly ovary samples processed for histological analysis and read slides to evaluate spawning condition.

2.8 Write report on the age, growth and reproductive characteristics of Bermuda anchovy, reef silverside, and dwarf herring, including an assessment of the evidence for temperature-dependent sex-determination in the reef silverside. Include potential management measures based on these characteristics.

2.9 Present results at an international conference and prepare scientific publication(s).

3.1 (See sampling note above, in 2.2)

3.2 Extract DNA with Qiagen Extraction Kit, amplify via PCR, and sequence using single pass Sanger sequencing (Beckman Coulter Genomics).

3.3 Use Sequencher5.4 to align and edit sequence results, and analyse using standard population genetic approaches (Fst, Φst, AMOVA).

3.4 Write advisory report for DENR and scientific publication on genetic diversity and rates of connectivity of Bermuda anchovy, reef silverside, and dwarf herring. Present results at an international conference.

3.5 Upload sequences to publically available databases: the NCBI database, GenBank, and the barcoding of life data systems database, BOLD.

4.1 Test drone flyover technique for baitfish school detection, area calibration and calibration with underwater cameras as placed for Activity 1.3.

4.2 Survey 50-60 sites over 10 days during the period of peak baitfish abundance, as identified in Activity 1.6.

4.3 Select and analyse 300 aerial images for presence and spatial extent of baitfish schools.

4.4 Select and analyse 600 underwater images for species composition and density of baitfish schools.

4.5 Prepare report on the abundance and distribution of baitfish around Bermuda.

5.1 Develop survey instrument for commercial fishers to examine bait fishing and bait use practices, and attitudes towards alternative baits. Mail survey out to all commercial fishers.

5.2 Develop questions and conduct semi-structured interviews with specialised bait fishers.

5.3 Develop survey instrument and conduct roving, opportunistic in-person surveys of at least 25 recreational fishers engaging in bait fishing.

5.4 Analyse and summarise results and prepare report, including any potential management measures suggested by the results.

6.1 Assemble all images on external storage media

6.2 Catalogue media and metadata in BAMZ library

## Annex 3 Onwards – supplementary material (optional but encouraged as evidence of project achievement)

### Checklist for submission

| | Check |
|---|---|
| **Is the report less than 10MB?** If so, please email to Darwin-Projects@ltsi.co.uk putting the project number in the Subject line. | ✓ |
| **Is your report more than 10MB?** If so, please discuss with Darwin-Projects@ltsi.co.uk about the best way to deliver the report, putting the project number in the Subject line. | N/A |
| **Have you included means of verification?** You need not submit every project document, but the main outputs and a selection of the others would strengthen the report. | ✓ |
| **Do you have hard copies of material you want to submit with the report?** If so, please make this clear in the covering email and ensure all material is marked with the project number. | No |
| Have you involved your partners in preparation of the report and named the main contributors | ✓ |
| Have you completed the Project Expenditure table fully? | No – see explanation in this section |
| Do not include claim forms or other communications with this report. | |