# THE

# NATIONAL BIODIVERSITY MONITORING PROGRAM



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University of Belize
UB
Education Empowers a Nation

ERI
Environmental Research Institute

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Forest Department
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Friends for Conservation and Development
Friends of Swallow Caye
GIZ – Selva Maya
Healthy Reefs Initiative
Lamanai Field Research Center
National Protected Areas Secretariat
Oceanic Society
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Protected Areas Conservation Trust
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Southern Environmental Association
Steadfast Tourism and Conservation Association
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# ACRONYMS

| | |
|---|---|
| AD | Agriculture Department |
| APAMO | Association of Protected Areas Management Organizations |
| BAS | Belize Audubon Society |
| BCC | Belize Chamber of Commerce |
| BELPO | Belize Institute of Environmental Law and Policy |
| BFF | Belize Federation of Fishers |
| BFREE | Belize Foundation for Research and Environmental Education |
| BGFA | Belize Game Fishing Association |
| BRUV | Baited Remote Underwater Video |
| BTB | Belize Tourism Board |
| BTFS | Belize Tropical Forest Studies |
| BV | Blue Ventures |
| BWS | Belize Water Services Limited |
| CATHALAC | Centro del Agua del Tropico Humedo para America Latina y El Caribe |
| CBO | Community Based Organization |
| CBS | Community Baboon Sanctuary |
| CCCCC | Caribbean Community Climate Change Centre |
| CSCP | Communities of Southern Coastal Plain |
| CSFI | Corozal Sustainable Future Initiative |
| CZMAI | Coastal Zone Management Authority and Institute |
| DoE | Department of Environment |
| EIA | Environmental Impact Assessment |
| FCD | Friends for Conservation and Development |
| FD | Forest Department |
| FFG | Fly Fishing Guides |
| Fisheries | Fisheries Department |
| GIS | Geographic Information System |
| GIZ | Deutsche Gesellschaftfür Internationale Zusammenarbeit |
| HRI | Healthy Reefs Initiative |
| LAMP | Long-term Atoll Monitoring Program |
| LD | Lands Department |
| LFRC | Lamanai Field Research Center |
| LIC | Land Information Center |
| MBRS | Mesoamerican Barrier Reef System |
| MWG | Manatee Working Group |
| NCRMN | National Coral Reef Monitoring Network |
| NEMO | National Emergency Management Organization |
| NHCMN | National Hicatee Conservation and Monitoring Network |
| NIWRA | National Integrated Water Resources Authority |
| NPAS | National Protected Areas Secretariat |
| OS | Oceanic Society |
| PAM | Protected Area Managers |
| PfB | Programme for Belize |

| | |
|---|---|
| PS | Private Sector |
| RCNP | Runaway Creek Nature Preserve |
| RDEG | Rancho Dolores Environmental Group |
| SACD | Sarteneja Alliance for Conservation and Development |
| SATIIM | Sarstoon-Temash Institute for Indigenous Management |
| SEA | Southern Environmental Association |
| SIB | Statistical Institute of Belize |
| SSA | Sea to Shore Alliance |
| STACA | Steadfast Tourism and Conservation Association |
| STMN | Sea Turtle Monitoring Network |
| TASA | Turneffe Atoll Sustainability Association |
| TBD | To Be Determined |
| TIDE | Toledo Institute for Development and Environment |
| UB ERI | University of Belize Environmental Research Institute |
| VT | Virginia Tech |
| WCS | Wildlife Conservation Society |
| Ya`axché | Ya`axché Conservation Trust |

# BACKGROUND

Biological diversity or biodiversity may have little meaning to many people and thus be considered of little importance (Gaines *et al*., 1999). However, biological diversity (referred to as biodiversity herein after) offers many goods and services that benefit people in many ways. Biodiversity is comprised of much more than just the number and variety of species or organisms found within a specified ecosystem or landscape (Feinsinger, 2001 and McField& Kramer, 2007). It encompasses all attributes of ecosystem, species and genetic diversity (Stadt *et al.*, 2006). Despite its importance, biodiversity is facing increasing threats globally that its conservation has become an issue of both national and international concern (Gaines *et al.*, 1999). The Convention on Biological Diversity (CBD) is a comprehensive, binding agreement that covers the use and conservation of biodiversity with three main goals: to conserve biological diversity, ensure sustainable use of its components and that benefits from the use of genetic resources is shared in a fair manner. The Strategic Plan for Biodiversity 2011-2020 of the CBD is a ten year framework for action by all countries and stakeholders to save biodiversity and enhance its benefits for people (CBD, 2012).

However, the only way of ‘saving’ biodiversity is to detect changes in its status and health which can only be achieved through monitoring. Monitoring is a continuous process that enables managers to identify changes and trends over time and is the only way of improving our ability to conserve biodiversity (Gardner *et al*., 1999). Biodiversity monitoring is an essential part of conservation and management because it can help natural resources/protected area managers adjust their interventions. Biodiversity monitoring needs to be based on standardized indicators and protocols and undertaken in a systematic manner to allow for meaningful comparisons through time and across different areas. This is because biodiversity is influenced by both temporal and spatial scales (Gaines *et al*., 1999). Since it is not effective to monitor all species in an ecosystem, indicators are used because they serve as a signal for wider patterns to the status of biodiversity and threats to it, which should then assist with management. Belize’s National Protected Areas Systems Plan (2005) states that it is necessary to monitor biodiversity indicators. In order to do so, standardized protocols/methods will need to be developed for the indicators. Castri *et al*. (1992) states that it is necessary to utilize similar sampling methods in order to obtain a comprehensive view of the status of biodiversity on the global level.

Standardized and systematic monitoring can also allow for systematic data-basing and analysis. This systematic monitoring using standardized protocols as well as accompanying systematic data-basing and analysis of monitoring data has been recognized as a long-standing need not only for Belize but for the entire Latin American and Caribbean region. The Convention on Biological Diversity’s 2010 target highlighted the need for standardized and comparable methods for measuring and monitoring biodiversity status and loss (Reyers & McGeoch, 2007).

Systematic and non-systematic monitoring efforts have occurred in the past and continue to take place in Belize. However, these have not been properly catalogued nor are they coordinated to produce national level results or impact. Without conducting a methodical assessment of cross-disciplinary monitoring activities it remains uncertain whether monitoring efforts are being optimized. Monitoring may be occurring haphazardly or redundantly, involving numerous or incompatible methodologies, or may not be providing the necessary outputs to ensure adaptive management or timely remedial action.  With increasing rates of biodiversity decline across the globe, the implementation of a standardized, systematic monitoring system/program for Belize's terrestrial and marine ecosystems has become imperative.

Belize's National Protected Areas System Plan (NPASP) 2005 with its accompanying operational framework for implementation highlights the need for a National Biodiversity Monitoring Program (NBMP), which will enable effective monitoring of biodiversity and protected areas. Moreover, the NBMP can serve as a tool to monitor the effectiveness of the implementation of the updated National Biodiversity Strategy and Action Plan (NBSAP) which is currently being finalized. As the national research and monitoring coordinating entity this has led the University of Belize Environmental Research Institute (UB ERI), in collaboration with key national agencies such as the National Protected Areas Secretariat, and the Fisheries and Forest Departments, to embark on the development of a National Biodiversity Monitoring Program.

# THE PROCESS

The National Biodiversity Monitoring Program has three phases, similar to that of the Alberta Biodiversity Monitoring Program. Phase 1 focuses on the technical design (development) of the program; we are currently at this phase. Phase 2 is the testing phase where the indicators and protocols will be tested and the data management and reporting systems will be developed. Phase 3 will focus on implementation of the full program (Stadt*et al*., 2006).

At the commencement of phase 1 and throughout the development of the NBMP, it was important to identify and consult the relevant stakeholders. These stakeholders included governmental and non-governmental organizations from both the marine and terrestrial realms that have been and are currently undertaking monitoring activities in Belize. Once these stakeholders were identified, it was vital to take stock of what monitoring has been taking place and continue to take place in Belize. Hence, baseline data were collected on monitoring activities from the identified stakeholders (organizations and individuals). The data provided by the stakeholders were analyzed in the most efficient manner taking into account inconsistencies in answers, missing or unnecessary data. The data was then used to prepare a summary report which served as a diagnostic of the type of monitoring activities that have been and are being carried out by organizations working in both marine and terrestrial natural resource and/or protected areas management.

Following this, a first national workshop was held to present theresults of the diagnostic on monitoring activities in Belize and to establish an overall goal and the general objectives of the program. Representatives from theNational Protected Areas Secretariat and the Forest Department addressed the National Biodiversity Monitoring Program within the context of the NPASP and the Convention on Biological Diversity, respectively. Stakeholders from both marine and terrestrial realms and governmental and non-governmental organizations were present in the discussions which led towards the development of the goal and objectives.

A similar process as the biodiversity indicator development framework (BIDF) (see Annex 1)was used to develop indicators for the program. The BIDF is based on three thematic areas: stakeholder involvement to define the purpose; producing indicators to meet objectives; and making indicators work in a sustainable manner. A survey was conducted to receive suggestions from stakeholders for possible indicators that would address the specific monitoring objectives identified for the program. The suggestions were compiled and a second national workshop was held to refine the suggested indicators so as to have a list of tentative indicators for the program. The modified goal, and monitoring objectives were also presented at the second workshop to have stakeholders review and approve of them. Before closure of the workshop, experts (scientists in Belize and abroad who have expertise/scientific background to assist in determining the most appropriate indicators as per the objectives) were suggested by participants to form a marine and terrestrial expert working group. Expert working groups were then formed based on the acceptance and confirmation of the experts that were suggested. They reviewed the tentative indicators and provided feedback which was then used to modify the list of tentative indicators.

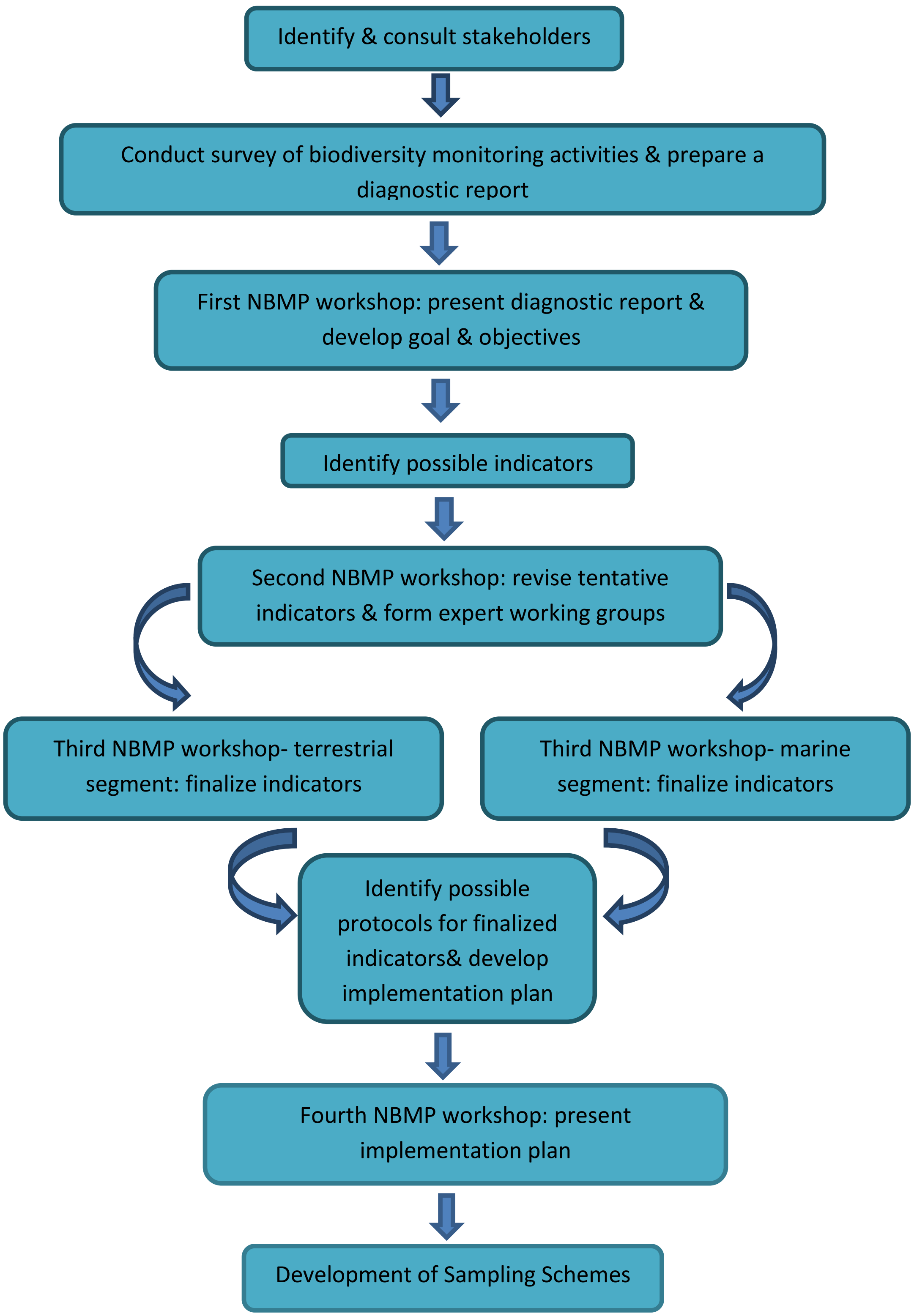
With this list of tentative indicators, a third national workshop (divided into two segments: marine and terrestrial) was conducted to present the tentative indicators and to provide justifications (done by various experts)for inclusion of the indicators in the NBMP. The workshop was split into segments to allow for better and more focused discussions. The justifications provided for some of the indicators assisted in further understanding those indicators, which made it easy to prioritize and rank the indicators using the developed criteria (see Annex 2) and ranking system (see Annex 3). These (criteria and ranking system) were developed by the UB ERI using the Healthy Reefs for Healthy People Initiative (2006) and the Designing Studies for Biodiversity Conservation (2001) books as a guide. At the end of the workshop, a final list of indicators was derived (those that scored 2 and above in the ranking exercise). However, final indicator list was subsequently sent to stakeholders and experts via email for further input to ensure that all stakeholders had an opportunity to input.

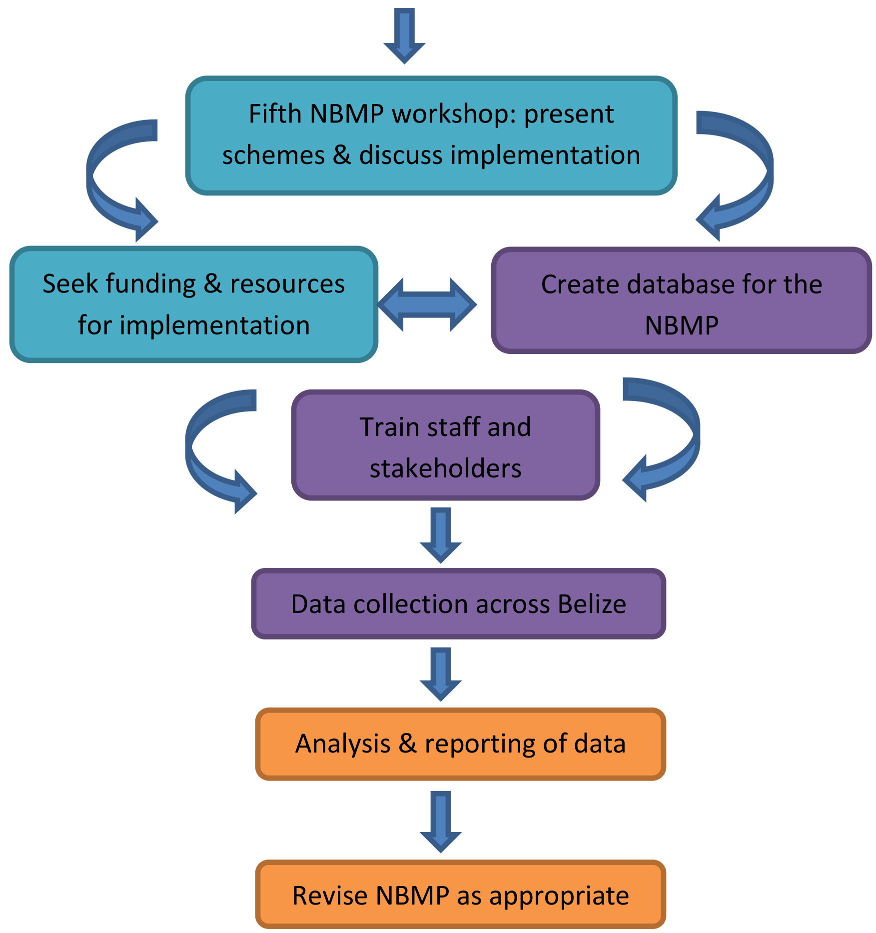
After a working session, it was decided by the UB ERI that the indicators were too specific and 'separated' (in terms of realms) for a national program, therefore the list was revisited in relation to the CBD's Strategic Plan for Biodiversity 2011-2020. Several of the headline indicators with their operational indicators have been adapted for the NBMP and the previously finalized indicators developed by stakeholders now serve as specific targets for those operational indicators. A five year implementation plan was then developed to present the aforementioned, highlighting the indicators, source of obtaining/collecting data, implementing partners and frequency. This draft implementation plan was then presented at a fourth national workshop where participants (stakeholders) were given the opportunity to provide their feedback and also to suggest variables for consideration in site selection. The modified implementation plan was then included in the NBMP document and sampling schemes for indicators in Section 1 were developed since these are the more 'ready to go' ones.

The sampling schemes include a brief background, methodology and potential monitoring sites; where methodology is being adopted from an already established method/protocol (for instance with most marine indicators), details of the method/protocol have not been provided within this document. A fifth and final national workshop was organized to present the sampling schemes and to discuss implementation with stakeholders. Based on feedback, modifications were made and sampling schemes were included in the document. However, this is not a final version but more of a working document since there still needs to be further discussion with partners in regards to details outlined in the schemes, specifically with appropriateness of sites. Nonetheless, this document presents the final draft to date.

The follow up process along with that of securing funding and resources for the second phase (implementation) of the NBMP will serve as a finalization of the first phase (development). This will be done in conjunction with the creation of the database that will house the data collected for the indicators and also mark the commencement of the second phase. The database will provide long-term data security while facilitating easy access by stakeholders, and providing training in its use. The second phase also involves the implementation of training in the use of the NBMP protocols (source); and initiating data collection across the National Protected Area System and Belize. The third phase will repeat data collection efforts; analysis of the data and periodic reports; and revision of the NBMP as appropriate. The actions under phase three will be ongoing. Hence, the first run will serve as a pilot from which the program will be revised when necessary.

The following flowchart (Fig. 1) provides a figurative summary of the main steps described above.




Fifth NBMP workshop: present schemes & discuss implementation
Seek funding & resources for implementation
Create database for the NBMP
Train staff and stakeholders
Data collection across Belize
Analysis & reporting of data
Revise NBMP as appropriate

# THE PROGRAM

The following are the goal and objectives of the NBMP as decided upon by all stakeholders.

**Goal:** Implement coordinated, standardized monitoring that indicates the status of biodiversity and natural resources and informs sustainable management, policy formulation and implementation.

**General Objectives:**

1. To enable coordinated monitoring at the national level
2. To enable comparable monitoring at the national and international level
3. To provide standardized monitoring of selected indicators
4. To detect changes in, threats to, and benefits of biodiversity
5. To provide biodiversity data to measure the success of management (management effectiveness)
6. To provide information to report progress on international convention commitments
7. To provide results for information sharing and dissemination to decision-makers

**Specific monitoring objectives:**

1. Determine species abundance, distribution and connectivity in order to monitor population dynamics of species and predict probability of local extinction.
2. Monitor the extent and rate of change, fragmentation and degradation of key ecosystems.
3. Monitor impacts of and potential species adaptation and ecosystem responses to climate change.
4. Monitor human impacts & threats and their ecological and socioeconomic effects.
5. Monitor effects of natural disasters on biodiversity and its recovery.
6. Determine and monitor characteristics and impacts of invasive species.
7. Monitor the use of species of socioeconomic importance.
8. Monitor key ecosystem processes and functions that support the sustainable provision of goods and services.
9. Monitor change in public perception towards ecological and economic value of biodiversity and the goods and services it provides.

## Indicators

The list of indicators for the National Biodiversity Monitoring Program adapted from the Convention of Biological Diversity Strategic Plan for Biodiversity 2011-2020 along with the suggested indicators (specific indicators) by stakeholders is presented below in a five year implementation plan. These specific indicators are presented in relation to Aichi Biodiversity Targets along with their corresponding headline indicators and/or operational indicators. The implementation plan is separated into two main sections: year 1-3 and year 4-5.

**Section I: Year 1-3**

The first three years of the program will mainly involve training partners and data collection. The first year in particular will be geared towards training partners in use of the protocols of the NBMP. Once the training has been successfully completed, data collection will be initiated on the first set of indicators which are presented below. These indicators have been selected as the first set since they scored high (2 and above) in the ranking and prioritization exercise which was conducted at the Third National Workshop and because they are already being monitored by partners.

**Aichi Target 4:** By 2020, at the latest, Governments, business and stakeholders at all levels have taken steps to achieve or have implemented plans for sustainable production and consumption and have kept the impact of use of natural resources well within safe ecological limits.

**Headline Indicator:** Trends in pressures from unsustainable agriculture, forestry, fisheries and aquaculture

- **Operational Indicator:** Trends in population and extinction risk of utilized species, including species in trade

| Specific Indicator | Source | Implementing Partner (s) | Frequency |
|---|---|---|---|
| Hunting frequency & amount of harvest | Social Surveys (hunters) | UB ERI, FD, CSFI, PfB, FCD, BAS, Ya’axche, TIDE | Triennially |
| Trends in contribution of wild meat in diet | Social Surveys (households) | UB ERI, FD, CSFI, PfB, FCD, BAS, Ya’axche, TIDE | Triennially |

**Aichi Target 5 –** By 2020, the rate of loss of all natural habitats, including forests, is at least halved and where feasible brought close to zero, and degradation and fragmentation is significantly reduced.

**Headline Indicator:** Trends in extent, condition and vulnerability of ecosystems, biomes and habitats

- **Operational Indicator:** Trends in extent of selected biomes, ecosystems and habitats

| Specific Indicator | Source | Implementing Partner (s) | Frequency |
|---|---|---|---|
| Forest Cover<br>➢ Broadleaf<br>➢ Mangrove<br>➢ Littoral<br>➢ Savannah | Remote Sensing (Landsat) | UB ERI, FD | Annually |
| Seagrass Cover | Seagrass Net, Remote Sensing | UB ERI, BAS, SEA, HRI, Fisheries, SACD | Biannually |
| Coral Cover | MBRS | UB ERI, HRI, NCRMN | Annually |
| Macroalgae Cover | MBRS | UB ERI, HRI, NCRMN | Annually |

- **Operational Indicator:** Trends in fragmentation of natural habitats

| Specific Indicator | Source | Implementing Partner (s) | Frequency |
|---|---|---|---|
| Extent of broadleaf forest | Remote Sensing (Landsat) | UB ERI, FD | Annually |
| Extent of mangroves | Remote Sensing (Landsat) | UB ERI, FD | Annually |

**Aichi Target 8 –** By 2020, pollution, including from excess nutrients, has been brought to levels that are not detrimental to ecosystem function and biodiversity.

**Headline Indicator:** Trends in pressures from habitat conversion, pollution, invasive species, climate change, overexploitation & underlying causes

- **Operational Indicator:** Trends in water quality in aquatic ecosystem

| Specific Indicator | Source | Implementing Partner (s) | Frequency |
|---|---|---|---|
| Stream macroinvertebrate community composition and assemblage | AQEM, Microhabitat approach | Ya'axche, FCD, TIDE, Communities, PfB, CSFI, SACD, CBS | TBD |

**Aichi Target 9 –** By 2020, invasive alien species and pathways are identified and prioritized, priority species are controlled or eradicated, and measures are in place to manage pathways to prevent their introduction and establishment.

**Headline Indicator:** Trends in pressures from habitat conversion, pollution, invasive species, climate change, overexploitation & underlying causes

- **Operational Indicator:** Trends in number and distribution of invasive alien species

| Specific Indicator | Source | Implementing Partner (s) | Frequency |
|---|---|---|---|
| Lionfish | Lionfish Focused Search Method 2016 | NCRMN, UB ERI | Annually: October to November (Level 1 & 2) and 5 years (Level 3) |

**Aichi Target 10:** By 2015, the multiple anthropogenic pressures on coral reefs, and other vulnerable ecosystems impacted by climate change or ocean acidification are minimized, so as to maintain their integrity and functioning.

**Headline Indicator:** Trends in pressures from habitat conversion, pollution, invasive species, climate change, overexploitation and underlying drivers

- **Operational Indicator:** Trends in coral reef condition

| Specific Indicator | Source | Implementing Partner (s) | Frequency |
|---|---|---|---|
| Coral Bleaching | Revised Coral Bleaching Monitoring Protocol | NCRMN | Monthly during bleaching season (Sep- |

| | | | |
|---|---|---|---|
| | | | Feb) at minimum during peak bleaching month and February |
| Coral Health Index | HRI and MBRS modified protocol | NCRMN | Annually |

**Aichi Target 12:** By 2020, the extinction of known threatened species has been prevented and their conservation status, particularly of those most in decline, has been improved and sustained.

**Headline Indicator:** Trends in abundance, distribution and extinction risk of selected species

- **Operational Indicator:** Trends in abundance of selected species

| Specific Indicator | Source | Implementing Partner (s) | Frequency |
|---|---|---|---|
| JaguarAbundance Index | Camera traps, Radio tracking/Telemetry | UB ERI, FD, CSFI, PfB, FCD, BAS, Ya'axche, TIDE, VT | Annually |
| Puma | Camera traps | UB ERI, FD, CSFI, PfB, FCD, BAS, Ya'axche, TIDE | Annually |
| Pacas | Camera traps with burrow surveys, | UB ERI, FD, CSFI, PfB, FCD, BAS, Ya'axche, TIDE | Annually |
| White-lipped peccary | Radio tracking/Telemetry | UB ERI, FD, CSFI, PfB, FCD, BAS, Ya'axche, TIDE | Annually |
| Yellow headed parrot | Line transects, Roost counts, Nest search | PfB, TIDE, FD, BAS, CBS, Monkey Bay, RDEG, CSCP, RCNP, | Biannually, Biannually, Annually (respectively) |

| | | | |
|---|---|---|---|
| | | Ya'axche, | |
| Birds | Point transects | BAS, Ya'axche, TIDE, FCD, CSFI, CBOs, UB ERI | Biannually (dry and wet season) |
| Timber species | Plot and Transect | FD, UB ERI, PS | 5 years |
| Sea turtle | In-water surveys, Nest monitoring | STMN, UB ERI, MAR Alliance | Early June to mid-August for nesting & Mid-August to mid-Oct for hatching |
| Acropora | MBRS, GIS | NCRMN | Annually |

- **Operational Indicator:** Trends in extinction risk of species

| Specific Indicator | Source | Implementing Partner (s) | Frequency |
|---|---|---|---|
| Trends in jaguar conflict & lethal control | Social Surveys (animal owners) | UB ERI, FD, CSFI, PfB, FCD, BAS, Ya'axche, TIDE | Triennially |

- **Operational Indicator:** Trends in distribution of selected species

| Specific Indicator | Source | Implementing Partner (s) | Frequency |
|---|---|---|---|
| Jaguar Abundance Index | Camera traps, Radio tracking/Telemetry | UB ERI, FD, CSFI, PfB, FCD, BAS, Ya'axche, TIDE, VT | Annually |
| Puma | Camera traps | UB ERI, FD, CSFI, PfB, FCD, BAS, Ya'axche, TIDE | Annually |

| | | | |
|---|---|---|---|
| Pacas | Camera traps with burrow surveys, | UB ERI, FD, CSFI, PfB, FCD, BAS, Ya'axche, TIDE | Annually |
| White-lipped peccary | Radio tracking/Telemetry | UB ERI, FD, CSFI, PfB, FCD, BAS, Ya'axche, TIDE | Annually |
| Yellow headed parrot | Line transects, Roost counts, Nest search | PfB, TIDE, FD, BAS, CBS, Monkey Bay, RDEG, CSCP, RCNP, Ya'axche, | Biannually, Biannually, Annually (respectively) |
| Birds | Point transects | BAS, Ya'axche, TIDE, FCD, CSFI, CBOs, UB ERI | Biannually (dry and wet season) |
| Timber species | Plot and Transect | FD, UB ERI, PS | 5 years |
| Sea turtle | In-water surveys, Nest monitoring | STMN, ERI, MAR Alliance | Early June to mid-August for nesting & Mid-August to mid-Oct for hatching |
| Acropora | MBRS, GIS | NCRMN | Annually |

**Aichi Target 14 –** By 2020, ecosystems that provide essential services, including services related to water, and contribute to health, livelihoods and well-being, are restored and safeguarded, taking into account the needs of women, indigenous and local communities, and the poor and vulnerable.

**Headline Indicator:** Trends in distribution, condition and sustainability of ecosystem services for equitable human well-being.

- **Operational Indicator:** Population trends and extinction risk trends of species that provide ecosystem services

| Specific Indicator | Source | Implementing Partner (s) | Frequency |
|---|---|---|---|
| Bats | Acoustic reading stations, Mist nets, Harp traps | TIDE, Ya'axche | Biannually |
| Acropora | MBRS, GIS | NCRMN | Annually |
| Parrotfish | MBRS | NCRMN | Annually |

**Aichi Target 15:** By 2020, ecosystem resilience and the contribution of biodiversity to carbon stocks has been enhanced, through conservation and restoration, including restoration of at least 15 per cent of degraded ecosystems, thereby contributing to climate change mitigation and adaptation and to combating desertification.

**Headline Indicator:** Trends in distribution, condition and sustainability of ecosystem services for equitable human well-being

- **Operational Indicator:** Status and trends in extent and condition of habitats that provide carbon storage

| Specific Indicator | Source | Implementing Partner (s) | Frequency |
|---|---|---|---|
| Land Use Cover | Remote Sensing (Landsat) | UB ERI, FD, Ya'axche, FCD, DOE, Lands, AD | Annually |
| Deforestation rate | Remote Sensing (Landsat) | UB ERI, FD | Biennially |

**<u>Section 2: Year 4-5</u>**

After the first three years, the NBMP will be reviewed and modified as necessary. Depending on the results of the revision and success of indicators, some will remain and some may need to be eliminated. Additional specific indicators and/or operational indicators may also be incorporated into the program and piloted. The specific indicators listed in this section are those indicators that were suggested by partners but that did not score high in the ranking and prioritization exercise and have not been monitored by partners as yet. The operational indicators were adapted from the CBD Strategic Plan for Biodiversity 2011-2020.

The addition of indicators will require more training, specifically in any new protocols associated with the additional indicators. This may take another six months to a year depending on the amount and extent of the protocols. Once this has been completed, data collection will continue along with analysis and periodic reporting of the data.

**Aichi Target 1:** By 2020, at the latest, people are aware of the values of biodiversity and the steps they can take to conserve and use it sustainably.

**Headline Indicator:** Trends in awareness, attitudes and public engagement in support of biological diversity and ecosystem services

| Operational Indicator | Source | Implementing Partner (s) | Frequency |
|---|---|---|---|
| Trends in awareness and attitudes to biodiversity | Social Surveys | BAS, TIDE, FCD, NPAS, Fisheries, WCS, PAM | 3-4 years |
| Trends in public engagement with biodiversity | Social Surveys | BAS, TIDE, FCD, NPAS, Fisheries, WCS, PAM | 3-4 years |
| Trends in number of community based conservation initiatives | Social Surveys | BAS, TIDE, FCD, NPAS, Fisheries, WCS, PAM | 3-4 years |
| Trends in number and level of tourism activities | Socioeconomic monitoring assessment | BTB, BAS, SEA, PAM | 3-4 years |

**Aichi Target 2:** By 2020, at the latest, biodiversity values have been integrated into national and local development and poverty reduction strategies and planning processes and are being incorporated into national accounting, as appropriate, and reporting systems.

**Headline Indicator:** Trends in integration of biodiversity, ecosystem services and benefits sharing into planning, policy formulation and implementation and incentives

| Operational Indicator | Source | Implementing Partner (s) | Frequency |
|---|---|---|---|
| Trends in integration of biodiversity and ecosystem service values into sectoral and development | Review relevant policies | APAMO, BELPO, BCC | 3-4 years |

| | | | |
|---|---|---|---|
| policies | | | |
| Trends in policies considering biodiversity and ecosystem service in environmental impact assessment and strategic environmental assessment | Review EIAs, policies | DOE, APAMO, BELPO | 3-4 years |

**Aichi Target 3:** By 2020, at the latest, incentives, including subsidies, harmful to biodiversity are eliminated, phased out or reformed in order to minimize or avoid negative impacts, and positive incentives for the conservation and sustainable use of biodiversity are developed and applied, consistent and in harmony with the Convention and other relevant international obligations, taking into account national socio economic conditions.

**Headline Indicator:** Trends in integration of biodiversity, ecosystem services and benefits sharing into planning, policy formulation and implementation and incentives

| Operational Indicator | Source | Implementing Partner (s) | Frequency |
|---|---|---|---|
| Trends in the number and value of incentives, including subsidies, harmful to biodiversity, removed, reformed or phased out | Review laws | DOE, HRI, APAMO | As needed |

**Aichi Target 4:** By 2020, at the latest, Governments, business and stakeholders at all levels have taken steps to achieve or have implemented plans for sustainable production and consumption and have kept the impact of use of natural resources well within safe ecological limits.

**Headline Indicator:** Trends in pressures from unsustainable agriculture, forestry, fisheries and aquaculture

- **Operational Indicator:** Trends in population and extinction risk of utilized species, including species in trade

| Specific Indicator | Source | Implementing Partner (s) | Frequency |
|---|---|---|---|
| Timber species extraction rate | Trade felling reports | FD, UB ERI,PS | Annually |
| Commercial species extraction rate (marine) | Catch data, Managed Access data, Fishing Cooperative landings data | Fisheries, SEA, TASA, BAS, TIDE, WCS | Monthly; Annually |

**Aichi Target 5 –** By 2020, the rate of loss of all natural habitats, including forests, is at least halved and where feasible brought close to zero, and degradation and fragmentation is significantly reduced.

**Headline Indicator:** Trends in extent, condition and vulnerability of ecosystems, biomes and habitats

- **Operational Indicator:** Trends in proportion of degraded/threatened habitats

| Specific Indicator | Source | Implementing Partner (s) | Frequency |
|---|---|---|---|
| Agricultural expansion rate | Remote Sensing (Landsat) | AD, LIC, UB ERI | Annually |
| Extent & distribution of developments | Remote Sensing (Landsat) | DOE, UB ERI, LIC | Annually |
| Rate & extent of natural habitat conversion | Remote Sensing (Landsat) | FD | Annually |

- **Operational Indicator:** Trends in condition and vulnerability of ecosystems

| Specific Indicator | Source | Implementing Partner (s) | Frequency |
|---|---|---|---|
| Frequency, distribution& extent of fires by land use | Remote Sensing (MODIS) | FD, AD | Annually |

**Aichi Target 6 –** By 2020, all fish and invertebrate stocks and aquatic plants are managed and harvested sustainably, legally and applying ecosystem based approaches, so that overfishing is avoided, recovery plans and measures are in place for all depleted species, fisheries have no significant adverse impacts on threatened species and vulnerable ecosystems and the impacts of fisheries on stocks, species and ecosystems are within safe ecological limits.

**Headline Indicator:** Trends in pressures from unsustainable agriculture, forestry, fisheries and aquaculture

| Operational Indicator | Source | Implementing Partner (s) | Frequency |
|---|---|---|---|
| Trends in population of target and bycatch aquatic species | LAMP, MBRS, transects | Fisheries, TASA, BAS, SEA, TIDE, WCS, Coops | Biannually |
| Trends in catch per unit effort | Managed Access Program, Fishing Cooperative landings data, Belize Game Fishing Association statistics | Fisheries, TASA, BAS, SEA, TIDE, WCS, Coops, BGFA | Monthly; Annually |

- **Operational Indicator:** Trends in fishing effort capacity

| Specific Indicator | Source | Implementing Partner (s) | Frequency |
|---|---|---|---|
| Fishing Pressure | Fisheries Catch statistics, Managed Access data, Fishing Coops landings data, BGFA statistics | Fisheries, TASA, BAS, SEA, TIDE, WCS, Coops, BGFA | Annually |

**Aichi Target 8 –** By 2020, pollution, including from excess nutrients, has been brought to levels that are not detrimental to ecosystem function and biodiversity.

**Headline Indicator:** Trends in pressures from habitat conversion, pollution, invasive species, climate change, overexploitation & underlying drivers

| Operational Indicator | Source | Implementing Partner (s) | Frequency |
|---|---|---|---|
| Trends in sediment transfer rates | Sediment stations (sample collection) | DOE | TBD |
| Trend in level of contaminant in wildlife | Manatee blood tissue work | DOE, SSA | Annually |

**Aichi Target 9 –** By 2020, invasive alien species and pathways are identified and prioritized, priority species are controlled or eradicated, and measures are in place to manage pathways to prevent their introduction and establishment.

**Headline Indicator:** Trends in pressures from habitat conversion, pollution, invasive species, climate change, overexploitation & underlying causes

- **Operational Indicator:** Trends in number and distribution of invasive alien species

| Specific Indicator | Source | Implementing Partner (s) | Frequency |
|---|---|---|---|
| Tilapia and Armored catfish | Electro-fishing | Fisheries | TBD |

**Aichi Target 11 –** By 2020, at least 17 per cent of terrestrial and inland water, and 10 per cent of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystems services, are conserved through effectively and equitably managed, ecologically representative and well-connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscapes and seascapes

**Headline Indicator:** Trends in coverage condition, representativeness and effectiveness of PA and other area-based approaches

| Operational Indicator | Source | Implementing Partner (s) | Frequency |
|---|---|---|---|
| Trends in coverage of PA | GIS, Remote Sensing | NPAS, Fisheries, FD | Biennially |
| Trends in extent of marine PA, coverage of key biodiversity areas and management | GIS, National MEE Tool | NPAS, Fisheries, FD, Co-managers | Triennially |

| | | | |
|---|---|---|---|
| effectiveness | | | |
| Trends in PA condition/management effectiveness including more equitable management | National MEE Tool | NPAS, Fisheries, FD, Co-managers | 5 years |
| Trends in representative coverage of PAs and other area based approaches, including sites of particular importance for biodiversity, and of terrestrial, marine and inland water systems | GIS, Remote Sensing | NPAS, Fisheries, FD, CZMAI, LIC, BTFS | 5 years |
| Trends in connectivity of Pas and other area based approaches integrated into landscape and seascapes | GIS, Remote Sensing | NPAS, Fisheries, FD, CZMAI | Triennially |

**Aichi Target 12**- By 2020, the extinction of known threatened species has been prevented and their conservation status, particularly of those most in decline, has been improved and sustained.

**Headline Indicator:** Trends in abundance, distribution and extinction risk of selected species

- **Operational Indicator:** Trends in abundance of selected species

| Specific Indicator | Source | Implementing Partner (s) | Frequency |
|---|---|---|---|
| Hicatee | Social Surveys, Spotlight survey, Nets | TIDE, BAS, Ya'axche, Fisheries, LFRC (NHCMN) | Annually |
| Shark and Rays | BRUVs, In-water transects, Long Line Catch & Release | WCS/MAR Alliance | Annually |

| | | | |
|---|---|---|---|
| Manatee | Extended area search type (national aerial surveys), Boat-based surveys | OS, Wildtracks, CZMAI, MWG | Biennially; Seasonally |
| Freshwater fish (Tilapia, Armored catfish) | Electro-fishing | Fisheries | TBD |
| Sport fishing species (bonefish, permit, tarpon, snook) | Mark-recapture methods | Fisheries, FFG | Opportunistically |

**Aichi Target 14** – By 2020, ecosystems that provide essential services, including services related to water, and contribute to health, livelihoods and well-being, are restored and safeguarded, taking into account the needs of women, indigenous and local communities, and the poor and vulnerable.

**Headline Indicator:** Trends in distribution, condition and sustainability of ecosystem services for equitable human well-being.

| Operational Indicator | Source | Implementing Partner (s) | Frequency |
|---|---|---|---|
| Trends in proportion of the population using improved water services | BWS, NIWRA, Bowen water volume statistics | BWS, NIWRA | 4-5 years |
| Trends in benefits that humans derive from selected ecosystem services | Social Surveys, environmental statistics, national census | SIB, Co-managers, Fisheries, FD | 4-5 years |
| Trends in delivery of multiple ecosystem services | Social Surveys, environmental statistics, national census | SIB, Co-managers, Fisheries, FD | 4-5 years |
| Trends in economic and non-economic values of selected ecosystem services | Marine Invest Tool | CZMAI | 4-5 years |
| Trends in well-being of communities who depend directly on | Social Surveys, national census | SIB, Ministry of Human Development, | 4-5 years |

| | | | |
|---|---|---|---|
| local ecosystems goods and services | | Social Transformation & Poverty Alleviation | |
| Trends in human and economic losses due to water or natural resources related disasters | NEMO Data, Community Vulnerability Assessment, Damage Assessment | NEMO, Red Cross, CCCCC | As needed |

- **Operational Indicator:**Population trends and extinction risk trends of species that provide ecosystem services

| Specific Indicator | Source | Implementing Partner (s) | Frequency |
|---|---|---|---|
| Bees | Plot, Pan Traps, Netting | AD | Annually |

**Aichi Target 18 –** By 2020, the traditional knowledge, innovations and practices of indigenous and local communities relevant for the conservation and sustainable use of biodiversity, and their customary use of biological resources, are respected, subject to national legislation and relevant international obligations, and fully integrated and reflected in the implementation of the Convention with the full and effective participation of indigenous and local communities, at all relevant levels.

**Headline Indicator:** Trends in integration of biodiversity, ecosystem services and benefits sharing into planning, policy formulation and implementation incentives.

| Operational Indicator | Source | Implementing Partner (s) | Frequency |
|---|---|---|---|
| Trends in land use change and land tenure in the traditional territories of indigenous and local communities | Remote Sensing (LUC) & Lands Data (tenure) | FD, LD | Annually |
| Trends in the practice of traditional | SIB Data, Fisheries licensing, Managed Access Data | SIB, Fisheries | 4-5 years |

| | | | |
|---|---|---|---|
| occupations | | | |

## Sampling Schemes

**1. HUNTING FREQUENCY AND AMOUNT OF HARVEST (See Annex 4)**

**2. TRENDS IN CONTRIBUTION OF WILD MEAT IN DIET (See Annex 4)**

**3. FOREST COVER (broadleaf, mangrove, littoral & savannah); SEAGRASS COVER; EXTENT OF BROADLEAF FOREST; EXTENT OF MANGROVES; LAND USE COVER; and DEFORESTATION RATE (See Annex 5)**

**4. SEAGRASS COVER**

**Background**

Seagrass beds are an important nursery for juvenile fish and primary food source for manatees and sea turtles. Other marine organisms also inhabit and forage in seagrass beds such as commercially important fish and shellfish (Morrison and Greening, N.D.). Seagrass beds act as a transitional zone between mangrove and coral reef ecosystems (McField and Kramer, 2007), so they are key for healthy coral reefs.

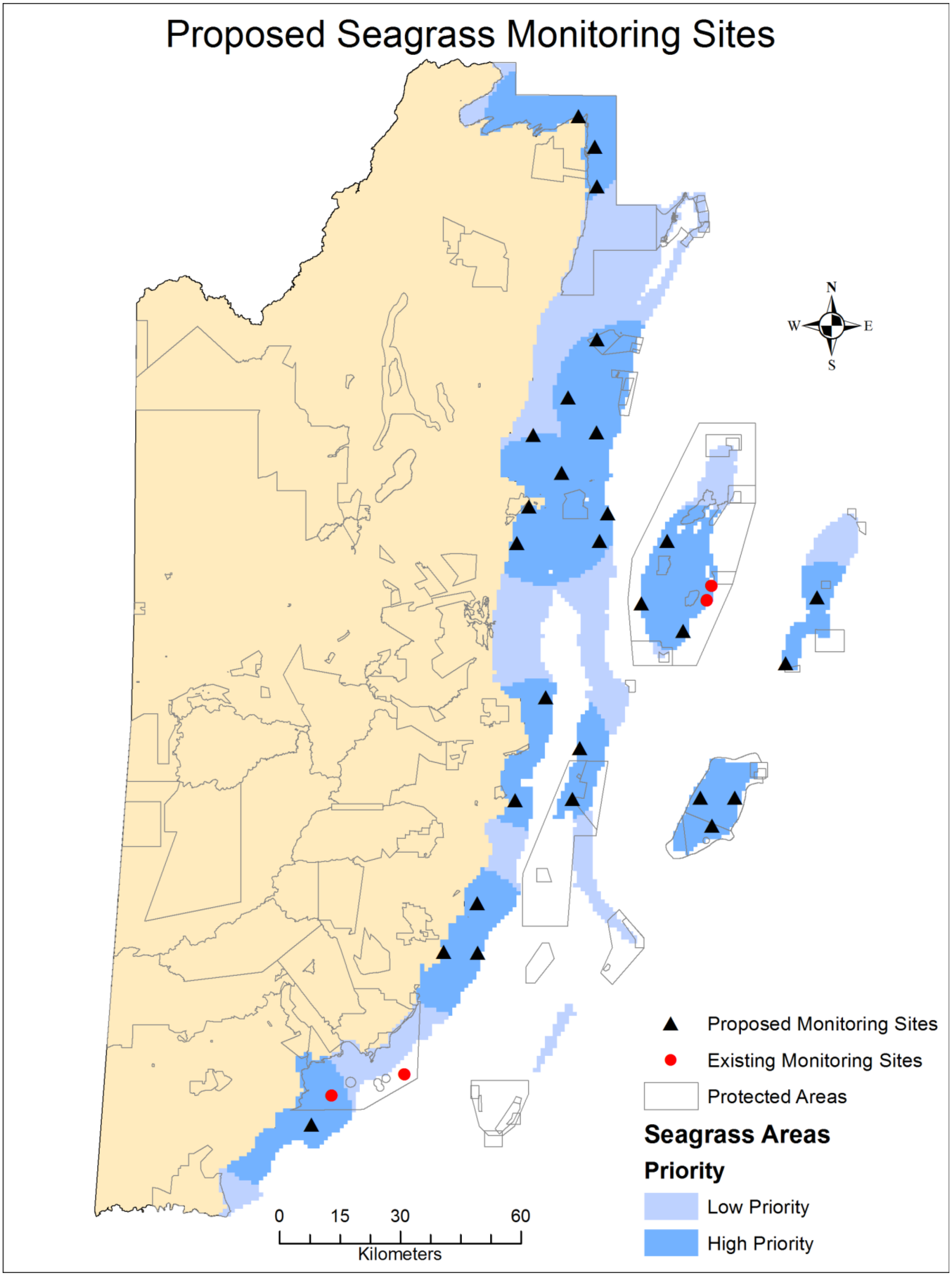
Seagrass also play a vital role in nutrient cycling and sediment stabilization which promotes water clarity (McField and Kramer, 2007). A decrease in seagrass cover will impact the services they provide and also the marine organisms that depend on it.

**Methodology**

SeagrassNET

**Sites**

**Figure 2**. Map illustrating a small portion of the overall existing SeagrassNET monitoring sites (red dots). Existing sites that are currently not on the map will be included and proposed sites will be generated based on gaps once all existing sites have been taken into account. At the moment, proposed monitoring sites (black triangles) are based on available data and as such, were randomly distributed in seagrass areas where no monitoring has occurred and that partners have easy access to (areas of high priority indicated by the darker shade of blue on the map).


Proposed Seagrass Monitoring Sites
N
W
E
S
Proposed Monitoring Sites
Existing Monitoring Sites
Protected Areas
Seagrass Areas
Priority
Low Priority
High Priority
0 15 30 60
Kilometers

## 5. CORAL COVER; MACROALGAE COVER; and ACROPORA

### Background

Corals play a vital role in the livelihoods of people and marine organisms. They provide defence mechanism against storms, provide opportunities for tourism based/recreational activities, and provide critical habitats and food for marine organisms, some of which are commercially important fisheries (Mumby, 2014). Coral reefs have undergone several bleaching and disease events in the past which have led to mass mortality of branching corals, such as *Acropora palmata* and *Acropora cervicornis*, that negatively impacted coral cover (Mumby, 2014).

Moreover, a loss of Diadema and herbivorous fish has also contributed to the decline of coral cover. Jackson *et al*. (2014) states that coral cover has declined by more than 80% since the 1970s mainly because of human overfishing, pollution and climate change. Hence, reefs are no longer able to fully provide the ecosystem services that they did in the past and that many rely on.

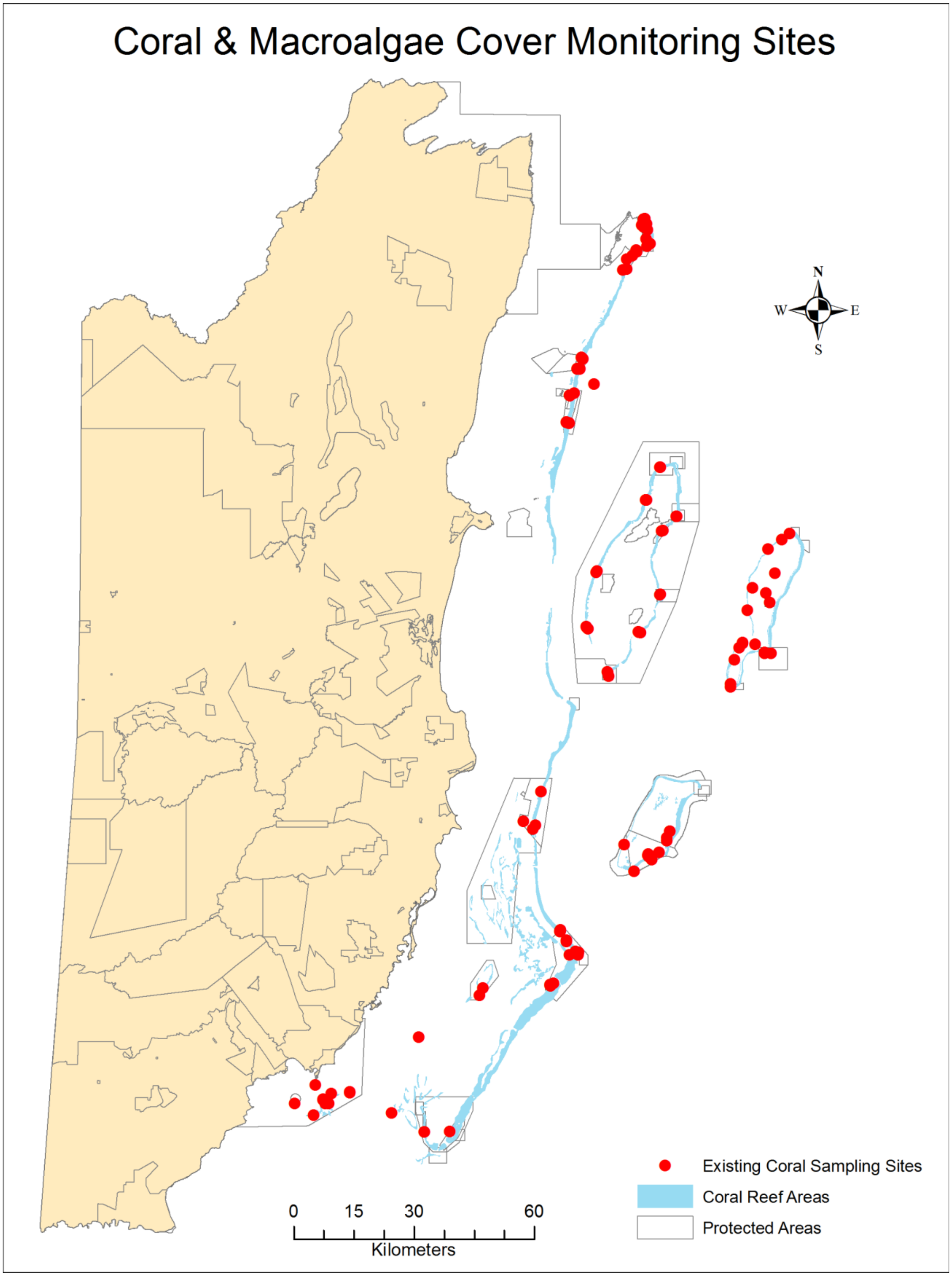
Monitoring both coral and macroalgae cover (including *Acropora*) is important to track the health and status of the reef. A higher coral to macroalgae ratio is a good indicator of a healthy reef (McField and Kramer, 2007).

### Methodology

MBRS Protocol - Point Intercept Method

### Sites

**Figure 3**. Map illustrating existing monitoring sites for coral and macro algae cover; *Acropora* included in these monitoring sites. Since these sites are extensive, no additional/new monitoring sites have been proposed. These existing sites will be used for continued coral bleaching monitoring unless the NCRMN identifies the need to expand sites.


Coral & Macroalgae Cover Monitoring Sites
N
W
E
S
0
15
30
60
Kilometers
Existing Coral Sampling Sites
Coral Reef Areas
Protected Areas

## 6. STREAM MACRO-INVERTEBRATE COMMUNITY COMPOSITION AND ASSEMBLAGE (See Annex 6)

## 7. LIONFISH

### Background

Since the first observation and capture reported in 2008, lionfish have been reported throughout Belize from north to south: Bacalar Chico Marine Reserve to Port Honduras Marine Reserve (Searle *et al*., 2012). Lionfish have been found to inhabit coastal mangroves, seagrass beds, coral reefs, and even man-made structures. They prey on small fish, shrimps and crabs; they also consume groupers and snappers which are important commercial fishery products (Searle *et al*., 2012).

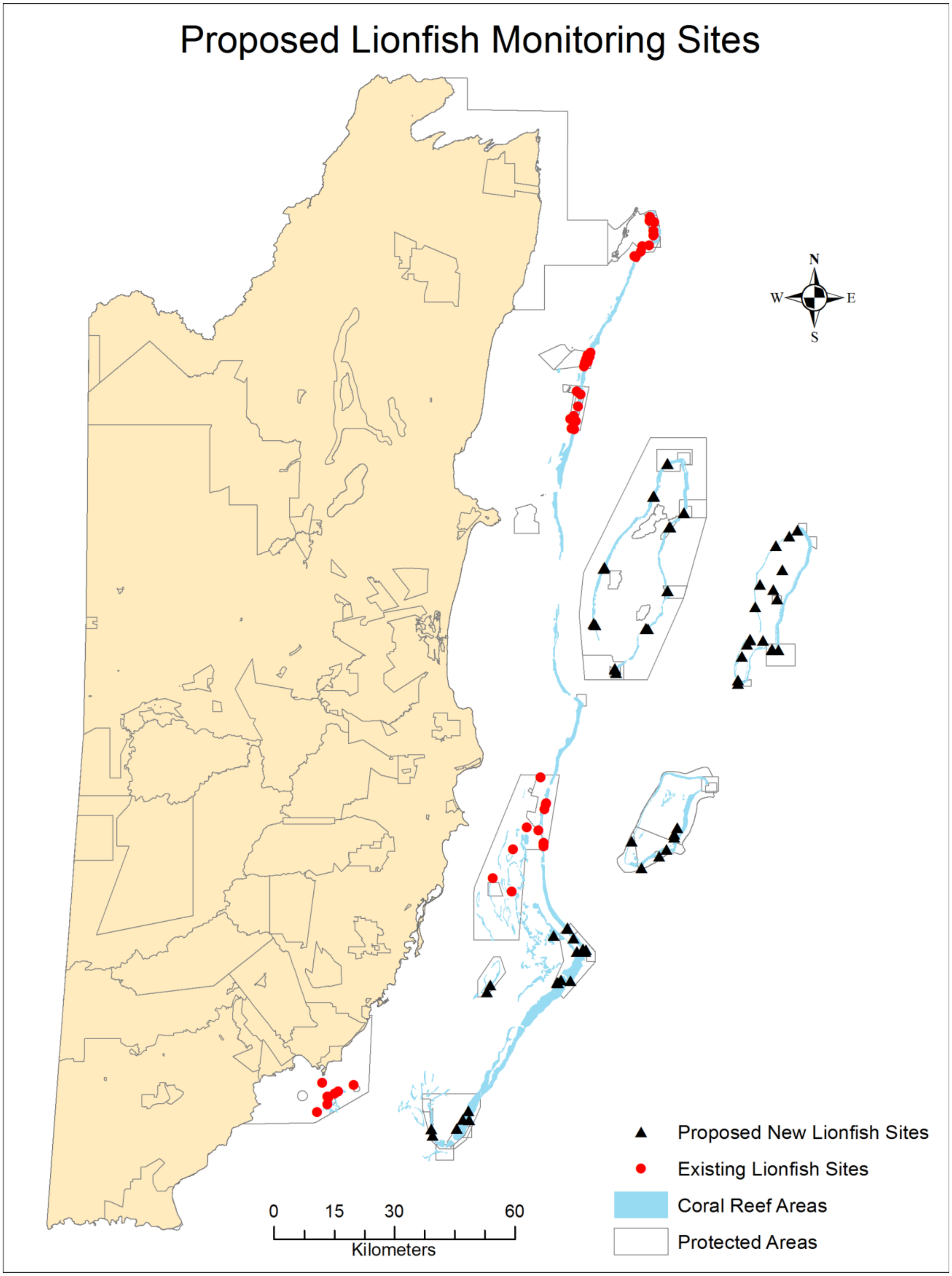
Although the impacts are uncertain, studies such as one conducted by Albins and Hixon (2008) have shown a reduction in native fish where lionfish are present. Hence, a major concern in Belize is the survival of native fish due to predation and competition. Efforts are focused on determining their numbers and distribution in order to control and minimize their presence in the Belize Barrier Reef.

### Methodology

Lionfish Focused Search Method (2016)

### Sites

**Figure 4**. Map illustrating existing lionfish monitoring sites (red dots) which are spread across five of the marine reserves (Bacalar Chico, Hol Chan, Caye Caulker, South Water Caye and Port Honduras). New sites (black triangles) are being proposed in order to fill gaps in the other marine reserves. The sites being proposed are those that are used to conduct coral monitoring (Figure 3).



Proposed Lionfish Monitoring Sites
N
W
E
S
Proposed New Lionfish Sites
Existing Lionfish Sites
Coral Reef Areas
Protected Areas
0
15
30
60
Kilometers

## 8. CORAL BLEACHING

### Background

Bleaching is one of the key components used to determine the condition of corals (McField and Kramer, 2007). Coral bleaching has occurred throughout the tropics since the 1980s but the first mass bleaching event in Belize occurred in 1995 (Searle *et al*., 2014). Since then, Belize's corals have undergone several bleaching events, some more severe than others.

Severe bleaching can lead to reduction in species diversity, coral cover and eventually loss of reef framework (McField and Kramer, 2007). This has great implications for marine organisms since they highly depend on the reef for food and shelter. Fortunately, bleached corals may only die partly and are even able to recover.

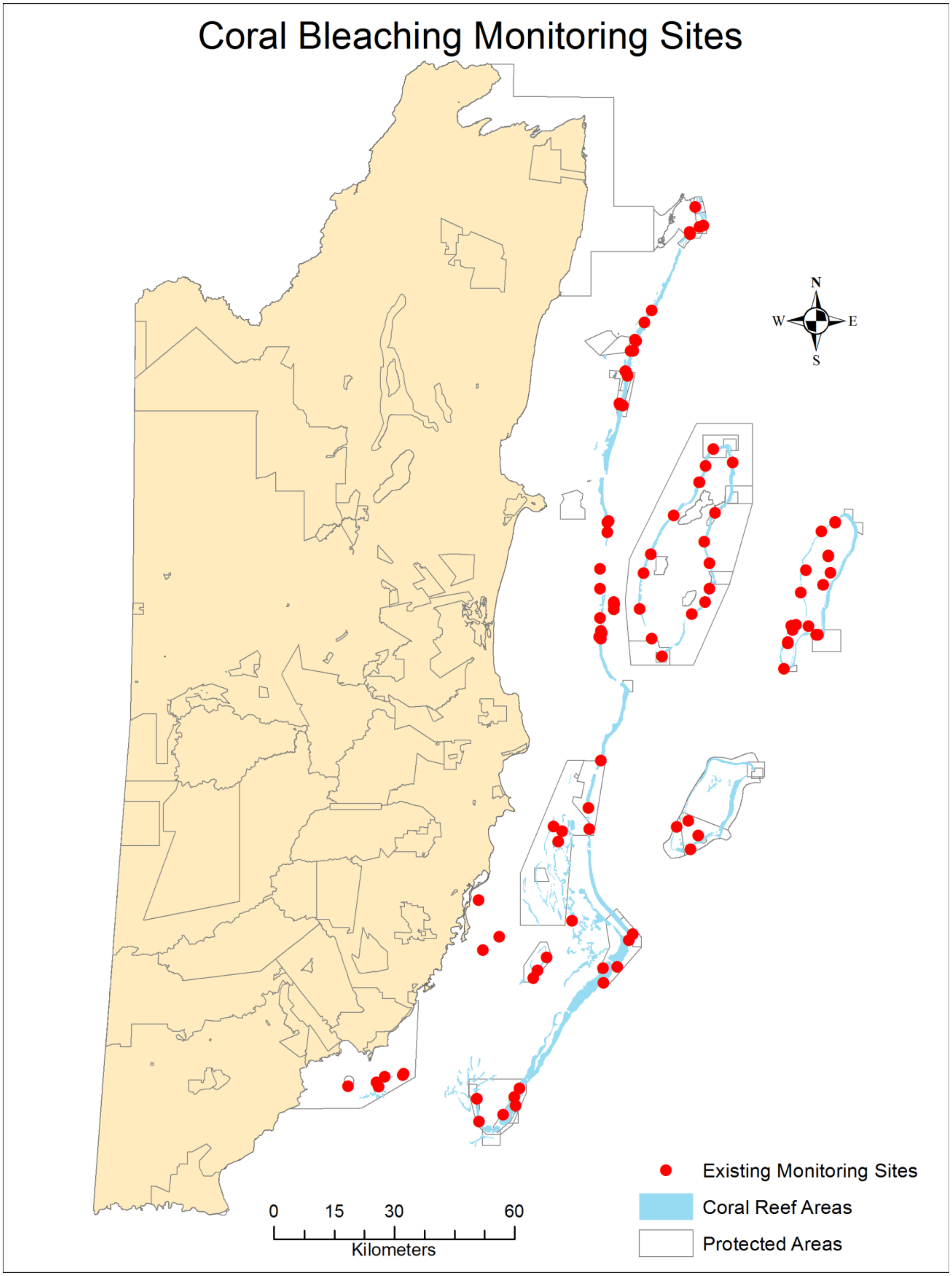
Nonetheless, it is imperative to keep track of bleaching, especially since it appears that mass bleaching is increasing in both frequency and severity (McField and Kramer, 2007) and is bound to cause severe impacts.

### Methodology

Weighted-Bar Swimming Transect Method (modified by Kramer and Kramer 2000)

### Sites

**Figure 5.** Map showing the existing monitoring sites for coral bleaching. Since these sites are extensive and cover most of the reef areas, no additional/new monitoring sites have been proposed. These existing sites will be used for continued coral bleaching monitoring.


Coral Bleaching Monitoring Sites
N
W
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0
15
30
60
Kilometers
Existing Monitoring Sites
Coral Reef Areas
Protected Areas

**9. JAGUAR; PUMA; PACAS; WHITE-LIPPED PECCARY (See Annex 7)**

**10. YELLOW HEAD PARROT (See Annex 8)**

**11. BIRDS (See Annex 9)**

**12. TIMBER SPECIES (See Annex 10)**

## 13. SEA TURTLE

### Background

Six of the seven sea turtle species inhabit Belize's waters and/or beaches (Green, Hawksbill, Kemp's Ridley, Leatherback, Loggerhead and Olive Ridley) at different times of the year. Sea turtles are charismatic species, which make them important for tourism. However, they are more important for the vital roles they occupy in marine ecosystems. Sea turtles maintain healthy seagrass beds and coral reefs which are invaluable for other marine life (Wilson, *et al*., N.D.). They also assist in balancing marine food webs and facilitating nutrient cycling.

Green sea turtles graze on seagrass, increasing productivity and nutrient content of seagrass blades; Hawksbill turtles forage on marine sponges, thereby allowing space for reef-building corals to colonize and grow; and Leatherback turtles are top jellyfish predators, controlling jellyfish populations which prey on fish eggs and larvae (Wilson *et al*., N.D.) These are only a few examples of the key contributions that sea turtles make to marine life.

Though important, all sea turtles are endangered and/or threatened. They are directly and indirectly affected by anthropogenic activities and even climatic conditions which may lead to a decrease in their population. Changes in sea turtle population will certainly have an effect on the marine ecosystem they inhabit; it is, therefore, necessary to monitor the population trends of these indicator species.

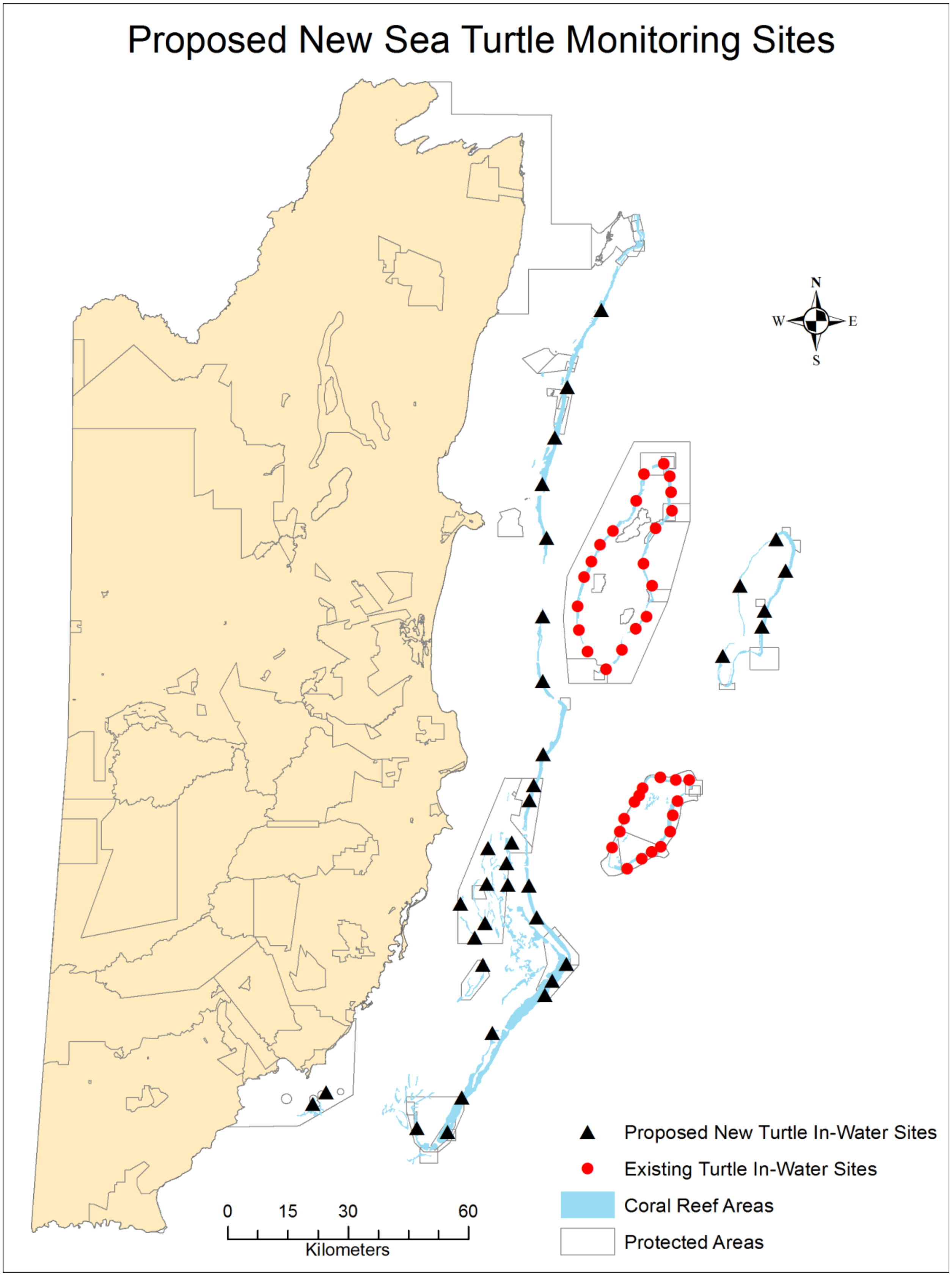
### Methodology

A. In-water Surveys – In Water Sea Turtle Monitoring Protocol (2011)

B. Nest Monitoring – Research and Management Techniques for the Conservation of Sea Turtle (1999) (*Sites for nest monitoring to be determined*)

### Sites

**Figure 6.** Map illustrating the existing sea turtle in water survey monitoring sites (red dots) and proposed new in water monitoring sites (black triangles). The proposed sites were randomly generated based on gaps in the reef area. On the ground inspections and discussion with partners will need to take place before sites are established/finalized for monitoring.


Proposed New Sea Turtle Monitoring Sites
N
W
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Proposed New Turtle In-Water Sites
Existing Turtle In-Water Sites
Coral Reef Areas
Protected Areas
0
15
30
60
Kilometers

**14. TRENDS IN JAGUAR CONFLICT AND LETHAL CONTROL (See Annex 4)**

**15. BATS (See Annex 11)**

# FOLLOW UP

Details within this document, specifically in the proposed sampling schemes (including sites) are subject to change depending on discussions with partners and on the ground appropriateness. Moreover, as pilot studies are carried out, the program will be modified to take into account any changes deemed necessary. The items below are already being addressed but not completed as yet:

- Formalization of a Biodiversity Committee to review the NBMP periodically and identify gaps and priorities moving beyond Section I
- Formalization of working groups (social science, camera trapping, bird etc.) to provide assistance regarding indicators and sampling schemes
- Liaise with organizations to receive shapefiles/GPS coordinates to include existing monitoring sites that are still lacking
- Meet with stakeholders on a one on one basis to further discuss implementation, especially in regards to appropriateness of monitoring sites since they are more familiar with the on the ground
- Develop TORs for the committee and working groups

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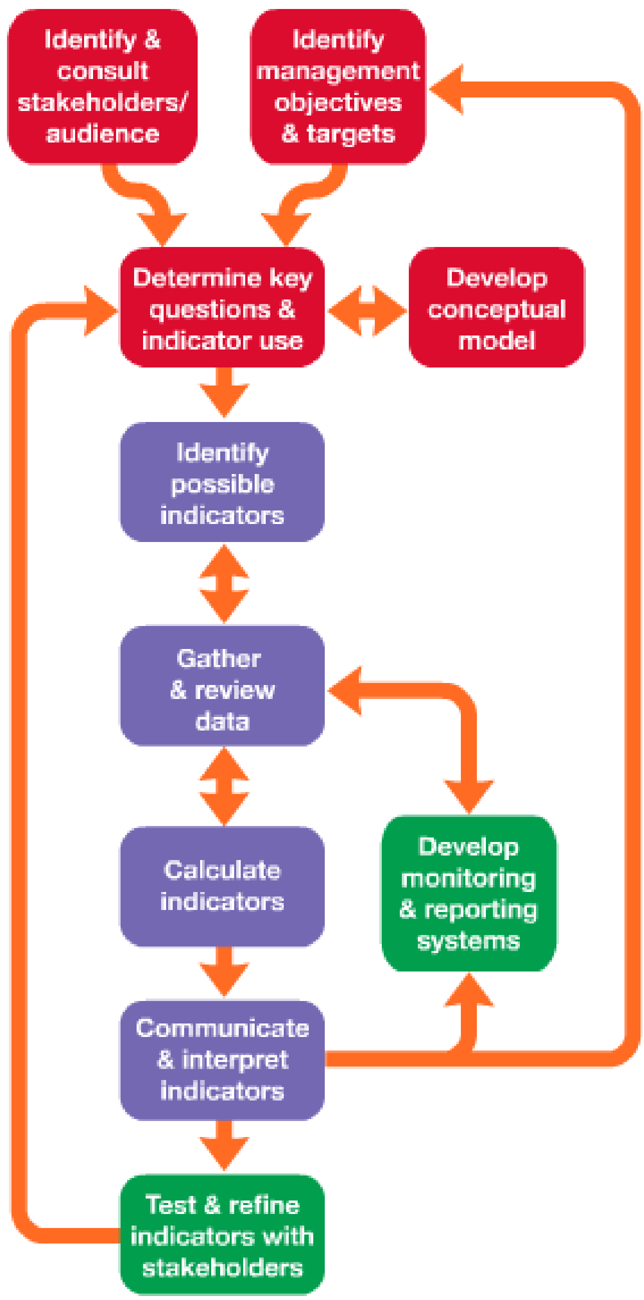
# ANNEX1:

The Biodiversity Indicator Development Framework



# ANNEX 2:

## CRITERIA

1. **Measurable –** should be able to be sampled effectively through observations, measurements or counts with a minimum of sampling bias

2. **Scale –** should correspond to the scale most appropriate to the conservation concern

3. **Consistency** –should be equally active or accessible at all times when sampling might occur

4. **Ecological relevance** –should provide a true indication of the parameter you are trying to measure (e.g. ecosystem health, population status etc.), i.e. it responds consistently to environmental change over time and space either in similar manner or in directly opposite manner to what you are trying to measure (e.g. much of the remaining biota when you are measuring ecosystem health). The natural history, taxonomy, ecology etc. of the species or group should be well known and trustworthy studies should already have demonstrated that the indicator is sensitive to factors of conservation concern.

5. **Feasibility** –should be capable of providing sufficient data per unit time, effort or money invested requiring a minimum of expensive equipment and sophisticated procedures. Basically, overall capacity and limitations in collecting and interpreting the data should be considered.

6. **Scope –** should address one or more specific monitoring objectives of the program

7. **Social relevance** –should have significance to social needs and concerns of the society i.e. measure something of interest or be something of direct interest to society (e.g. ecosystem services, status of commercial species, species, ecosystems, practices of traditional or cultural significance etc.)

# ANNEX 3:

## CRITERIA RANKING

**Ecological Relevance (Factor= 0.4)***

Group or Species

1- Little is known of the natural history, taxonomy and ecology and there is limited literature/studies that exists to suggest it might be a good indicator

2- Little is known of the natural history, taxonomy and ecology but there are several literature/studies that exists to suggest it might be a good indicator

3- Natural history, taxonomy and ecology are well known and literature/studies support it as a good indicator

Social Related Indicator

1- Indicator is not well known and what it measures is not well documented through literature/studies

2- Indicator is well known and what it measures is documented through limited literature/studies

3- Well known and what it measures is well documented through literature/studies

**Feasibility (Factor= 0.25)***

Human (physical-on the ground and capacity to conduct data collection) and financial resources required; ease of obtaining funding for data collection; capacity in managing, analysing and interpreting data; ease of collecting data on this indicator at the same time with other indicators.

1- Low

2- Medium

3- High

**Scope (Factor= 0.2)***

1- Collecting data on indicator satisfies ≤3 specific monitoring objectives

2- Collecting data on indicator satisfies >3 but <6 specific monitoring objectives

3- Collecting data on indicator satisfies 6 or more specific monitoring objectives

**Social Relevance (Factor=0.15)***

1- Indicator nor what it measures is of interest to society

2- Indicator measures factors that concern society but is itself not of direct interest to society

3- Indicator measures factors that concern society and is of direct interest to society

***In order for the indicators to be weighted, the score allocated to the indicator (chosen from the ranking system provided) will be multiplied by the factor corresponding to the specific criterion.

| |
|---|
| Example: |
| Beetle Diversity, Abundance & Diversity - scores 1 for Ecological Relevance |
| 1 (score) X 0.4 (factor) = 0.4 |

**ANNEX 4:**

# Social Indicators

## Hunting, Game Meat Consumption and Livestock Depredation

Hunting and Game Meat: Yahaira Urbina, BSc. and Rebecca Foster, Ph.D.
Livestock Depredation: Rebecca Foster, Ph.D. and Yahaira Urbina, BSc.

Yahaira Urbina - University of Belize Environmental Research Institute
Rebecca Foster - Panthera

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### *Hunting and game meat consumption*

Wild prey populations are important for ecosystem functioning and are often a vital source of protein for many rural people (Robinson & Bennett 2000). Over-exploitation of game species may have long-term consequences for rural livelihoods, ecosystem functioning and, indirectly, may increase rates of depredation as predators are forced to hunt livestock and domestic animals. To assess whether game hunting is sustainable or linked to livestock depredation, we must identify the species which are most commonly hunted and evaluate patterns and intensity of hunting across the landscape (this protocol), monitor and map incidents of livestock depredation (see Depredation Protocol), and estimate abundance of target prey species (see Species Monitoring Protocols).

Game meat is eaten across all cultures in Belize, and wild mammals comprises at least 7% of the meat and fish consumed nationally (Foster et al. 2014, Urbina & Foster unpublished data). Although hunting is officially regulated by the issuance of hunting licenses, few hunters apply and the government has little capacity to enforce the restrictions (Foster et al. 2014, Urbina & Foster unpublished data). As such, there is limited information on harvest rates or hunting hotspots across the country.

A standardized semi-structured interview (Appendices 1-3) will be used to collect data on hunting activities and game meat consumption across the country. To ensure quality control, partners must receive training prior to data collection from in-country experts on interviewing techniques, the structure of the interviews, the significance of each question and how to complete the data collection sheets. Partners will identify the extent of their study area, who will conduct the survey and the number of villages in which surveys will be conducted. Interviewers must familiarize themselves with the study area and questionnaire prior to conducting any interviews. Partners will conduct surveys triennially in order to avoid respondent fatigue (Kuper & Kuper 1996).

The sampling scheme is adaptive according to the target population, size of settlement and site-specific objectives. There are two surveying schemes: one is specific to harvesting by hunters, and the other assesses game consumption by households.

**Scheme 1: Hunting**

Partners will conduct informal discussions with the community leaders as a preliminary attempt to quantify the number of hunters in each village. During this scoping period, the partners will obtain approval from community leaders to conduct the study and identify an initial sample of hunters to interview (Appendix 1). As such, purposive sampling (i.e. non-probabilistic sampling) will be used. Purposive sampling does not involve random selection of respondents; rather the interviewers will sample a pre-defined group within the population, in this case, known hunters

(Marshall 1996; Trochim 2006). Due to the difficulty of identifying individuals involved in hunting, a 'snowball' sampling approach is recommended; in this method the hunters identified during the scoping period will be interviewed and asked to identify other hunters within the village, who in turn will be asked to identify other hunters and so forth. The sample size per village will depend on (1) the number of hunters estimated to live in each village; (2) the available time and resources to conduct interviews; and (3) accessibility to the hunters. In general, approximately 20% of Belizeans hunt (Urbina & Foster unpublished data) therefore it can be roughly assumed that 20% of the adults in a village are hunters. For example, in a large village of 1,000 adults we may anticipate that there are at least 200 hunters. The aim would be to interview as many of the hunters as possible, ideally at least 20% (in this example, at least40 hunters). In small villages (< 200 adults) it is often possible to interview all the known hunters (Urbina pers obs). It is important to have a precise estimate of the number of hunters in the village, regardless of whether they are interviewed, in order to accurately extrapolate results from the sampled hunters to the entire population of hunters within the village. Partners will obtain estimates of the number of hunters in the village during the scoping period and during the survey by asking respondents how many hunters they know of in the village, and compiling a list of known hunters.

Hunters will be asked about the species that they target and the associated harvest rates, where they hunt (hunting sites), their motivation and strategies, their socio-economic background and their attitudes towards wildlife (Appendix 2). Identifying and documenting the hunting sites requires the use of maps. The electoral divisions will be used as a reference guide to broadly describe where people hunt (Figure 1). The respondent will be asked to indicate in which districts and divisions they hunt.

Belize has been divided into 4 x 4 (16km$^2$) grid cells (e.g. Figure 2) to aid collection of fine-scale spatial data on hunting activity. In order to collect fine-scale spatial data, the interviewer must have good knowledge of the geography of the study area and must take with them an OS Ordnance Survey map (50,000: 1) of the study area, overlaid with the hunter grid, (Figure 3). GIS maps and the grid shape files can be provided to partners as required. Each hunter will be asked to identify the grid cells in which they hunt; and then asked how often they visit each of the identified cells, to rank the cell as a hunting site, and to estimate the time spent at the hunting site per hunting trip. The maps shown to respondents must be neutral (i.e. must not demarcate property boundaries, e.g. protected areas, private properties) so that respondents do not bias their answers to avoid indicating that they trespass.

At the end of each interview, interviewers need to document all additional relevant information which was not directly recorded during the session. The data obtained will allow partners to identify the most common game species hunted; off-take rates of the games species; hunting hotspots in and around their study site; the extent to which the villagers depend on hunting; and the attitudes of the hunters towards wildlife in the areas where they hunt.

Hunters will also be invited to start keeping their own records of harvest rates and to retain body parts of hunted animals for collection by researchers. This will allow verification of species hunted and investigation of the age structure and reproductive potential of hunted populations. If any hunters agree to keep records or body parts; partners should inform the University of Belize's Environmental Research Institute researchers for further details on how to proceed. In this scenario, partners would visit the hunters monthly to collect records and body parts for sharing with the UB-ERI researchers; visiting hunters so regularly will provide an ideal opportunity for partners to develop long-term working relationships with the hunters.

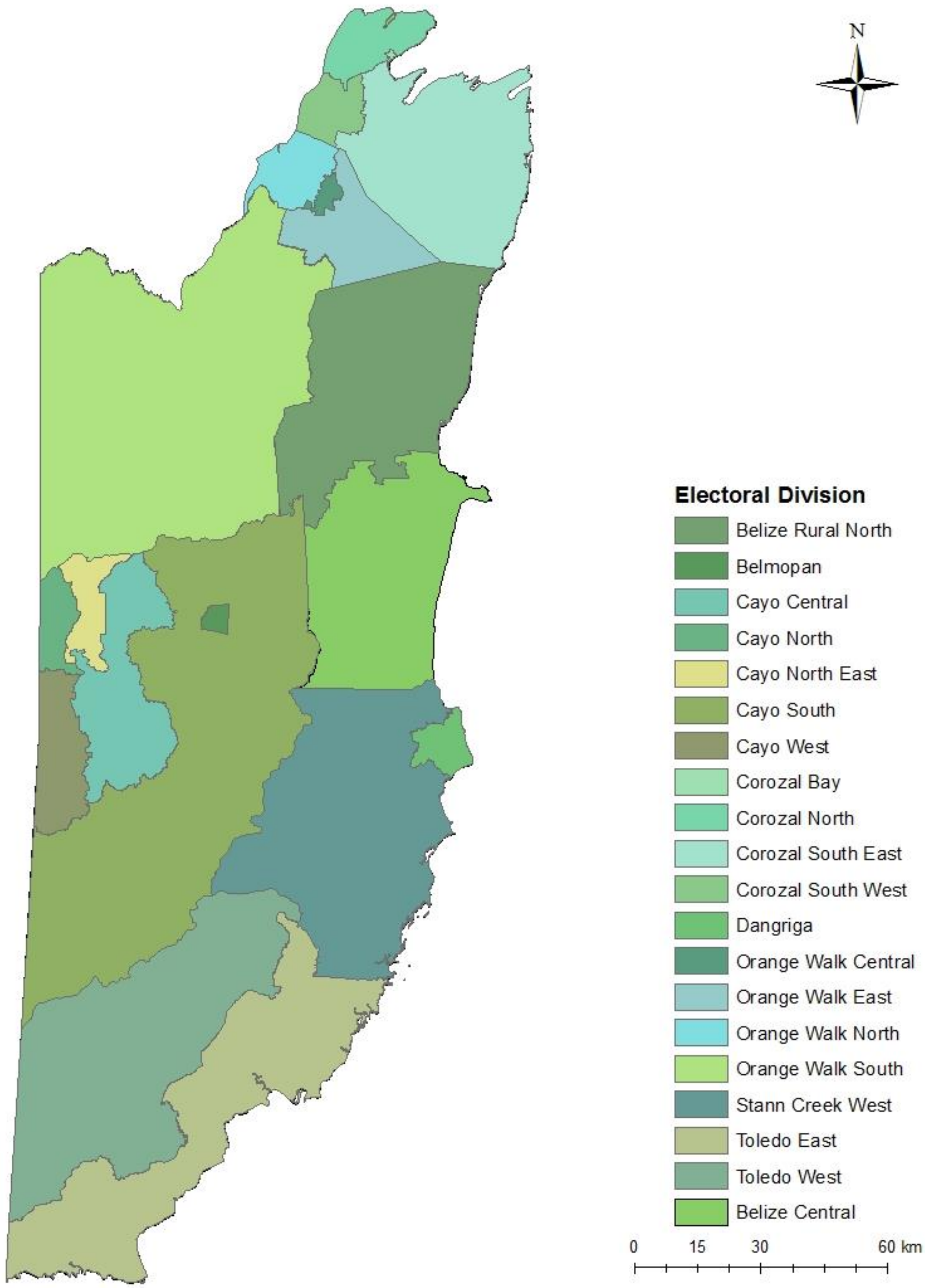


**Figure 1** Electoral division assigned by the Election and Boundaries Department

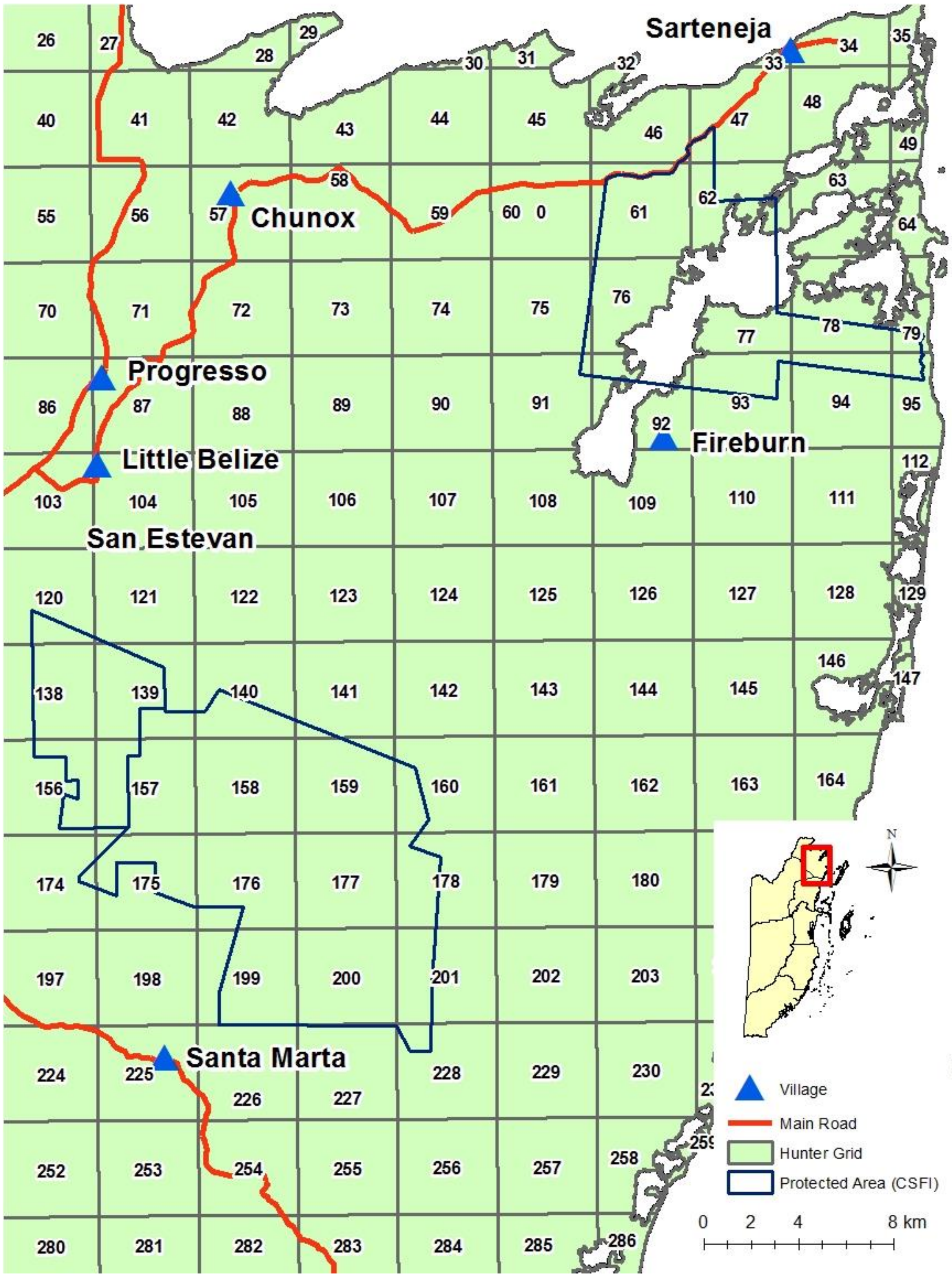


**Figure 2** Grid cells spanning the three protected areas managed by the Corozal Sustainable Future Initiative (CSFI) and the communities they engage.; the cell ID numbers are from the national hunter grid, allow interviewers to identify and record the grid cells in which respondents hunt

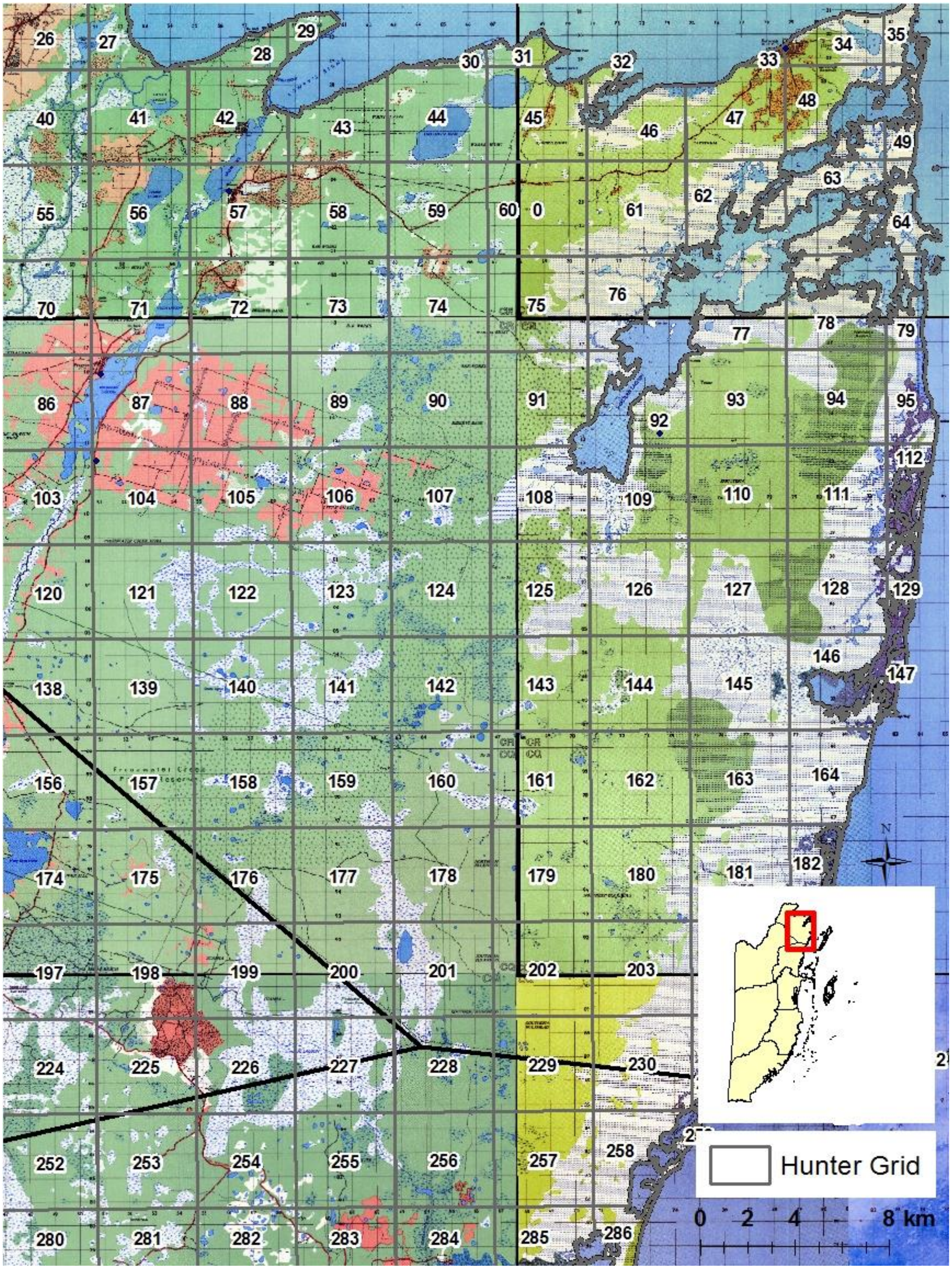


**Figure 3** Example map, with hunting grid overlaid, shown to respondents during the interview; note the neutral background

**Scheme 2: Households**

Partner will obtain a rough estimate of the number of households in the village from the 2010 Population Census. Partners will then ask community leaders to verify the current number of households in the village and obtain approval to carry out the study. During this scoping period, partners will systematically number every household and record the GPS location of each, by moving either clockwise or anticlockwise through the village.

Households will be selected using systematic sampling (i.e. probabilistic sampling). Systematic sampling is a modified form of simple random sampling; instead of referring to random number, it refers to units directly from the sample frame. The first sampling unit is selected at random and rest of the sample frame is assigned by a fixed interval, **K** (Särndal et al*.* 1991). The interval (**K**) is calculated by dividing the target population (**N**) by the sample size (**n**) (Trochim2006; Statcan 2016). For example, where the number of households in the village is 1000 (**N**), and the goal is to interview 100 households (**n**), then **K** = 10 (**K** = **N**/**n** = 1000/100 = 10). Thus, in this example, every $10^{th}$ household would be interviewed. A random number between one and **K**(in this example, between 1 and 10) is chosen and this becomes the random start for the survey. Subsequently, the remainder of sample will be selected as every $\mathbf{K^{th}}$ house after the first interview (Figure 4). In Belize, villages have on average 200 households (2010 Population Census); ideally 20% of the households will be sampled, i.e. 40 households in a village of 200 households (if more than 20% can be sampled, so much the better). In this scenario, **K** = 200/40 = 5, i.e. every $5^{th}$ house is sampled until at least 40 households have been sampled. For villages with ≤30 households, all should be interviewed.

An adult present at the household, preferably the person who regularly prepares meals, will be asked about the household's level of game meat consumption, the source of game meat, attitudes towards wildlife, demographic and socio-economic information about the household, and number of active hunters in the village (Appendix 3*).* In cases where the respondent reports that the game meat is hunted by a member of the household, the interviewer will ask them to identify the person. If the hunter is present and willing, a Hunter Survey (Scheme 1, above) will be conducted; if absent, contacts will be obtained in order to schedule an appropriate time to conduct a Hunter Survey.

At the end of each interview, interviewers need to document all additional relevant information which was not directly recorded during the session. The data obtained will allow partners to identify the source of game meat consumed in the village; most common game species consumed; consumption rates of the game species; the extent to which the villagers depend on game meat as a protein source; and the attitudes of the villagers towards hunting and wildlife around their village.  Additionally, households will be invited to start keeping their own records of game meat consumption and to retain body parts of consumed game animals for collection by researchers. This will allow verification of species hunted and investigation of the age structure and reproductive potential of hunted populations. If any households agree to keep records or body parts; partners should inform the University of Belize's Environmental Research Institute researchers for further details on how to proceed. In this scenario, partners would visit the households monthly to collect records and body parts for sharing with the UB-ERI researchers; visiting households so regularly will provide an ideal opportunity for partners to develop long-term working relationships with the households.

By combining data from Hunter Surveys and Household Surveys, partners and the University of Belize's Environmental Research Institute researchers will be able to make inferences such as whether the off-take rate of game species exceeds the rate of game consumption in/around the village (i.e. excess game meat is sold outside the village); or the rate of game consumption exceeds the off-take rate of game species in/around the village (i.e. villagers buy game meat from elsewhere).

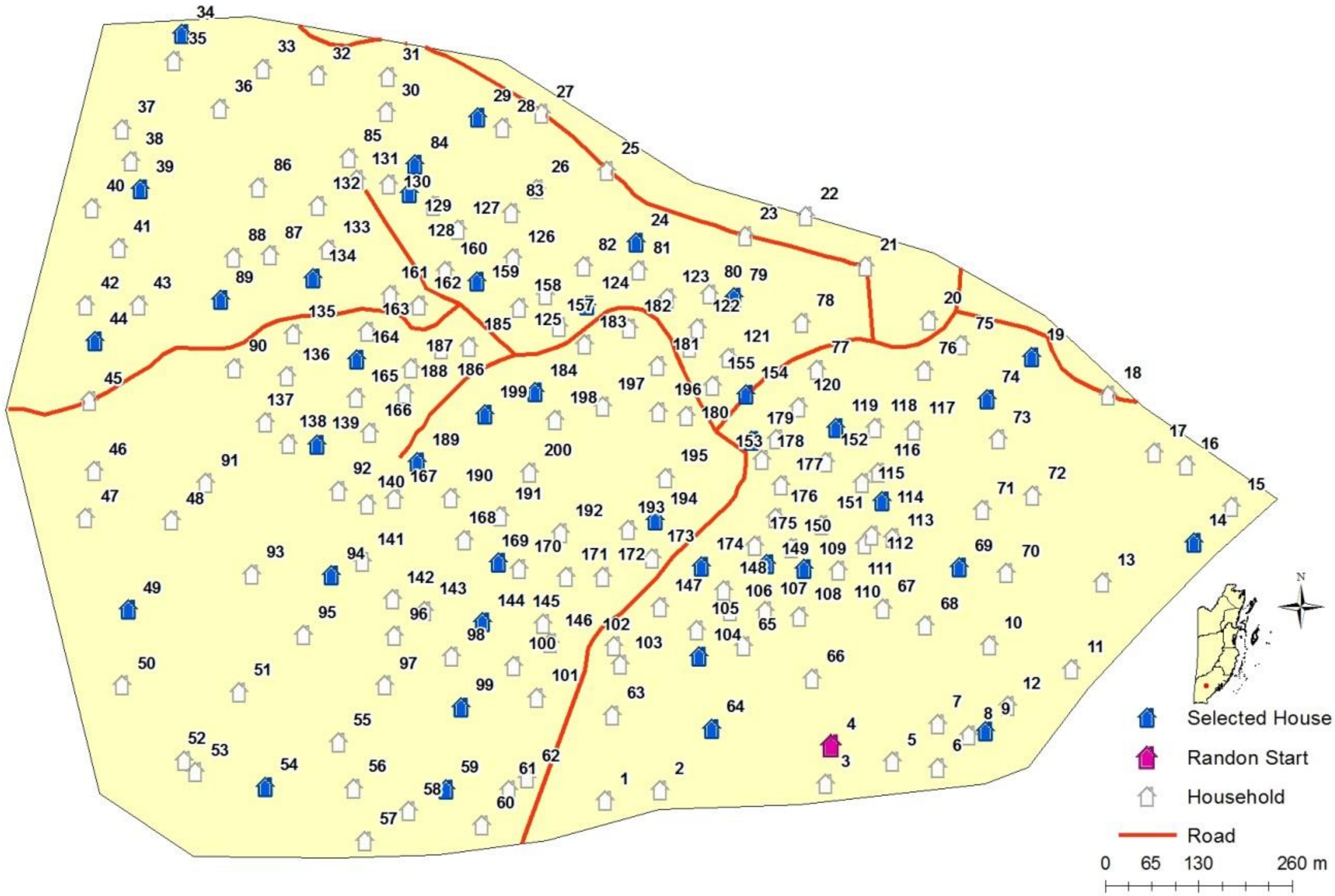


**Figure 4** Example of selecting households within a village boundary where K = 5: household #4 (pink) is selected as the random start (4 is a random number between 1 and 5), and every 5th household (blue) is selected thereafter until 40 of the 200 households have been sampled

**Pilot Sites**

Six sites have been identified throughout Belize to pilot the National Biodiversity Monitoring Program. Partners working in each study site will choose one or both of the two survey schemes to implement (Hunting and/or Household). Communication among partners will be essential where there is overlap in communities between hunting grids (Figure 5). This will prevent multiple partners duplicating surveys in villages, which may otherwise lead to hostility from the communities if they are asked to participate in a survey more than once. For example, Toledo Institute for Development and Environment (TIDE) and Ya`axché Conservation Trust manage protected areas within the same geographic area, therefore will use the same hunting grid, and hunting pressure on either protected area will likely come from the same subset of villages (Figure 6). In this case, TIDE and Ya`axché will need to coordinate their respective surveys so as not to duplicate surveys within the same communities.

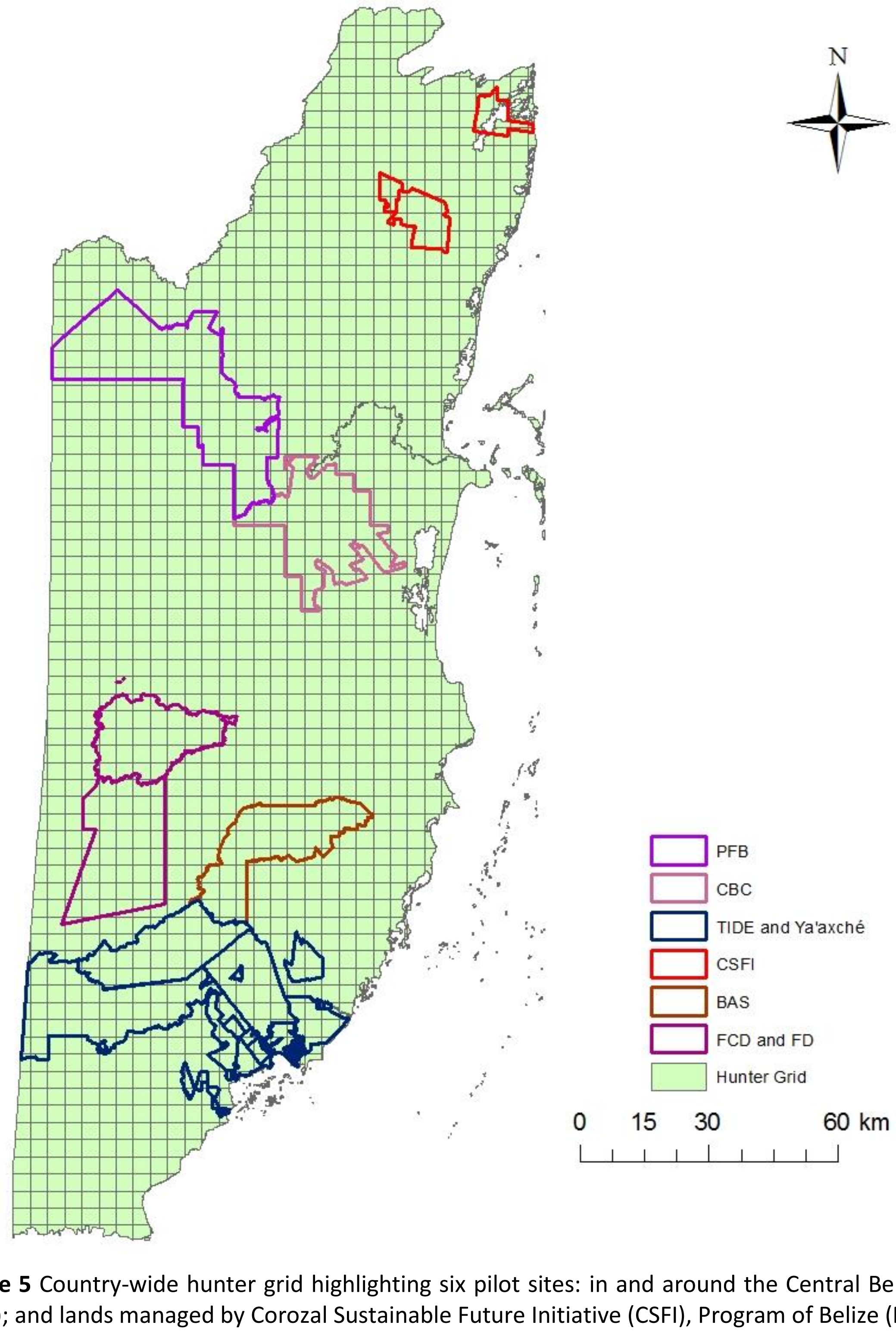


**Figure 5** Country-wide hunter grid highlighting six pilot sites: in and around the Central Belize Corridor (CBC); and lands managed by Corozal Sustainable Future Initiative (CSFI), Program of Belize (PFB), Toledo Institute for Development and Environment (TIDE), Ya`axché Conservation Trust, Belize Audubon Society (BAS), and Friends of Conservation and Development (FCD) and the Forest Department (FD). Note that grid cell numbers are not shown here due to the scale of the map

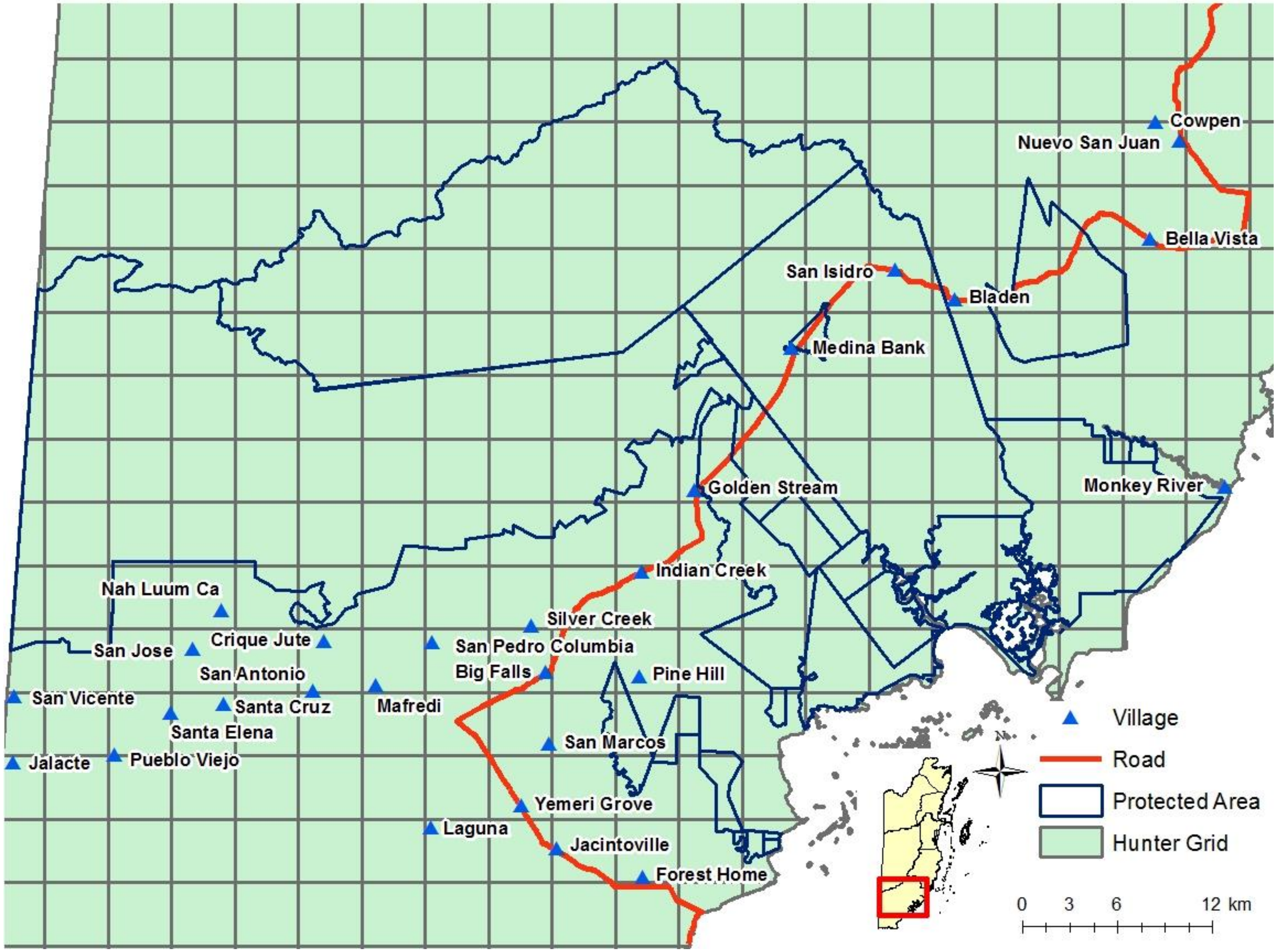


**Figure 6** Hunter grid across the landscape managed by Toledo Institute for Development and Environment and Ya`axché Conservation Trust, showing the protected areas managed and the communities engaged by both NGOs

## *Livestock Depredation*

Conflict between people and wildlife for space and resources threatens many terrestrial mammals. Due to their large home ranges and dietary requirements, large carnivores often come into conflict with humans (Linnell et al. 2001; Macdonald & Sillero Zubiri, 2002). Large cats are declining globally, in part due to persecution by humans in response to livestock depredation (Mazzolli et al. 2002). In the neotropics, forest clearance for pastoral agriculture is increasing the contact zone between livestock and large cats (jaguars and pumas) as well as other carnivores, such as coyotes.

In this protocol we describe how to assess and monitor human-carnivore conflict associated with depredation of farm and domestic animals and the pro-active or retaliatory killings of carnivores. This protocol does not cover other human-induced causes of carnivore mortality or removal from the wild (i.e. opportunistic/accidental killings by game hunters; planned killings for trade in body parts; removal from the wild for the pet trade; road traffic accidents). Therefore any estimates of human-induced mortality of carnivores derived from the implementation of this protocol should be considered conservative.

There are approximately 100,000 head of cattle in Belize, and the industry is growing following the formalization of cattle trade agreement with Mexico and increased trade with Guatemala. Belize retains 60% forest cover, therefore many villages and farms lie in close proximity to the forest edge and potential contact with predators. Reports of livestock depredation, whether real or perceived, are common throughout the country, and associated with a high level of retaliatory lethal control of predators (Brechin & Buff, 2005; Foster, 2008; Foster et al. unpublished data; Urbina & Foster., unpublished data). Monitoring changes in livestock management, reports of depredation and lethal control of predators is essential for understanding drivers and patterns of human-carnivore conflict across the country and finding solutions.

Partners will use a standardized semi-structured interview (Appendix 4) to collect current and historic data on human-carnivore conflict, specifically on the management of farm and domestic animals, depredation, and lethal control of predators. The survey will be conducted every three years. Prior to data collection, partners must receive training from in-country experts on interviewing techniques, the structure of the questionnaire, the significance of each question and how to complete the data collection sheets.

Partners will identify the target villages and/or agricultural landscapes within their sphere of influence where they will conduct the survey. They will meet with community leaders to discuss the objectives of the survey and to request permission to do the study. During this scoping period, the partners will gather information from the leaders and other community members on the approximate number of people owning farm or domestic animals (farmers or households), and what proportion of those are known to be experiencing depredation (Appendix 1).

Depending on the number of animal owners identified, and prevalence of depredation, partners may choose either to sample all animal owners in the study area (or a random sample thereof), or use purposive sampling (i.e. non-probabilistic sampling) to sample only those known to be suffering depredation now or in the previous three years. Purposive sampling does not involve random selection of respondents; rather the interviewers will sample a pre-defined group within the population, in this case, animal owners suffering depredation (Marshall 1996; Trochim 2006). For the purposive sampling scheme, 'snowball' sampling is recommended: the animal owners suffering depredation identified during the scoping period will be interviewed and asked to identify other animal owners who they think have suffered depredation, who in turn will be asked to identify others and so forth.

For either sampling scheme, the sample size will depend on (1) the number of animal owners in the study area; (2) the available time and resources to conduct interviews; and (3) accessibility to the households/farms of the animal owners. The data will be more informative, the larger the sample relative to the population of animal-owners. It is important to note that the inferences that can be drawn from the two sampling approaches will differ subtly, and are described below.

**Scheme 1: All animal owners**

All animal owners will be interviewed regardless of whether they are suffering depredation or not. Partners will be able to fully evaluate the level of depredation and lethal control in their study area; and to make links between management strategies that are associated with no depredation, as well as those that are associated with depredation. It is essential to understand both scenarios in order to identify management strategies that are effective against depredation. Because every animal owner will be interviewed, partners are well-placed to identify and advise animal owners who have not suffered depredation but who may be at high-risk based on an assessment of their existing animal management strategies.

Repeating the survey every three years will allow the detection of temporal change in the management of animals, and in the rates of depredation and lethal control. For example, in Survey 1, Farmer X may report no depredation but when interviewed three years later, in Survey 2, he may report depredation incidents, which may be linked to changes in farm management, and associated with a change in the rate of lethal control on the farm.

In cases when it is not logistically possible for the partners to sample all the animal owners, a random sample of at least 60 animal owners is recommended in order to allow extrapolation to the population level.  It will be possible to estimate the level of depredation and lethal control in study area, by assuming that the proportion of people suffering depredation (or killing predators) in the sample reflects the proportion suffering depredation (or killing predators) in the population of animal owners in the sampled landscape. The larger the sample, the more precise the estimate will be. Note, for detecting temporal change, the same sample of animal owners should be surveyed in subsequent survey years.

**Scheme 2: Only animal owners suffering depredation**

Interviews will be conducted only with animal owners who are experiencing depredation now or have experienced it during the previous three years. If all animal owners in this subset are identified and interviewed, then it will be possible to fully evaluate the level of depredation and lethal control in the study area. However, it will not be possible to make links between management strategies that are associated with no depredation; or to identify at high-risk animal owners who have not suffered depredation now or in the past three years.

Under this scheme, it will be possible to detect temporal change in animal management, depredation and lethal control, conditional on the sampling strategy used in subsequent survey years:

(a) If the same individuals are interviewed in subsequent surveys, regardless of their depredation status, then it will be possible detect temporal change in their circumstances, however it will not be possible to detect new cases of depredation experienced other individuals in the study area

(b) If purposive sampling is used in subsequent surveys, then it will not be possible to detect temporal changes. This is because individuals who are no longer suffering from depredation will be excluded from the corresponding survey.

(c) If the same individuals are interviewed in subsequent survey years, regardless of their depredation status, and all animal owners who are newly experiencing depredation are also interviewed in subsequent survey years, then it will be possible to detect temporal change. Note however that the sample size will increase with consecutive surveys as new individuals are added.

If the number of animal owners experiencing depredation is extremely high, then partners may only be able to interview a subset. In this case, a sample size of at least 60 is recommended. In order to extrapolate to the population level it is essential to have obtained reliable estimates of the total number of animal owners, and, of those, the total number suffering depredation, across the target landscape. Estimates of the number of animal owners, and the proportion suffering depredation in the study area, are obtained during the scoping period and during the survey by asking every respondent how many animal owners they know are/are not suffering depredation, and then compiling a list of names.

From previous work in the Central and Southern Belize Corridors (Foster et al unpublished data), we suggest that in a landscape of many rural villages where nearly every household owns animals, purposive sampling of animal owners suffering depredation may be more logistically feasible, while in agricultural landscapes of farms (e.g. 20-50 farms) sampling of all farm owners is realistic, regardless of their current or historic record of depredation.

Following the first survey, the University of Belize's Environmental Research Institute's researchers will ask partners for constructive feedback regarding the success and difficulties of its implementation in their respective study areas. The protocol (sampling schemes and survey sheets) may then be adapted and if necessary, and site-specific protocols may be developed depending on the subtle differences between the study areas.

**National (Depredation) Response Network**

Real-time response to reports of depredation should be conducted in accordance with the National Depredation Protocol developed by the Belize Forest Department, the government agency responsible for the enforcement of wildlife laws in Belize. The protocol details the series of steps that should be followed when receiving a report of possible predator attack, how to prioritize reports, data that should be collected in order to make informed decisions, and the decision tree for implementing actions to resolve the issue. Through a long-term partnership with Panthera, a global non-profit NGO dedicated to cat research and conservation, the Forest Dept. has developed a standardized data collection sheet for investigating and advising on reports of depredation, and maintains these data in a national database. In order to increase the capacity of the Belmopan-based Jaguar Officer to monitor and respond to reports of depredation nationally, the Forest Dept. is developing a National Response Network comprising Forest Dept. officials across the district ranges and NGOs/Protected Area managers who are willing to respond to reports of depredation within their sphere of influence. Members of the network will receive training in in basic predator ecology, issues of livestock depredation, the protocol and data collection sheet, how to report back to the Forest Dept., and the advice that they can give to people suffering from depredation. Partners are encouraged to join the network.

### *Data Management*

It is important that partners review the interview sheets and input the data within a week of conducting an interview so as not to forget key notes that may have been written on the data sheet during the interview process. Interviewers should enter the data themselves as they will best understand what was written during the interview and thus minimize errors during transcription. Data need to be transcribed weekly into the standardized database by the partners, and the completed database should be shared with the University of Belize Environmental Research Institute for integration into the national database.

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## *Appendix*

Appendix 1: Scoping Survey Sheet

| SCOPING | VILLAGE | | DISTRICT | CO OW CY BZ SC TO | INITIALS | DATE (dd/mm/yy) |
|---|---|---|---|---|---|---|
| | | | | | | __ __/__ __/__ __ |

| POPULATION | NO. HH | NO. FARMS | ASIA | CAUC | KRIOL | E-IND | GARIF | M-QUECHI | M-MOP | MEN | MEST | OTHER | PERMIT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ ___________ | Yes No |

| ATTACKS ARE PROB | ATTACKS SINCE 2013 | NO. WITH ANIMALS | NO. AFFECTED | SINCE | ATTACK LOCS | HUNT | NO. HTR | HOUSES | ROOFS | UTILITIES (% houses) ELECTRICTY | WATER | PHONE RECEPTION SMART | DIGI | GUAT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Yes<br>No<br>Resp-dk | Yes<br>No<br>Resp-dk | HH ____<br>FARMS____<br>Resp-dk | HH ____<br>FARMS____<br>Resp-dk | 2016<br>2015<br>2014<br>2013 | In village<br>On farms<br>Resp-dk | Yes ____<br>No<br>Resp-dk | | Wood<br>Cement | Thatch<br>Zinc | 100<br>50-99<br>1-49<br>0 | 100<br>50-99<br>1-49<br>0 | Good<br>Poor<br>None | Good<br>Poor<br>None | Good<br>Poor<br>None |

| CONTACTS | FIRST NAME | LAST NAME | PHONE | COMMENTS |
|---|---|---|---|---|
| CHAIR/LEADER | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

| USEFUL LOCATIONS | X (UTM NAD27) | Y (UTM NAD27) | COMMENTS |
|---|---|---|---|
| ENTRANCE | | | |
| | | | |
| | | | |

| COMMENTS |
|---|
| |

Appendix 2: Hunters Survey Sheet

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Int** | | **ID** | _____ | **Date** | DD___ MM___ YY___ | **District** | CO OW CY BZ SC TO | **Resp. village** | ________ |

| | | | | | | |
|---|---|---|---|---|---|---|
| **HH UTM NAD27** | X _ _ _ _ _ _ _ _ | Y _ _ _ _ _ _ _ _ | **Resp. name** | ____________ | **Resp. ph** | _ _ _ _ - _ _ _ _ |

---

| | | | | | |
|---|---|---|---|---|---|
| **Gen** | *M F* | **Occup** | _________ | **Eth** | *Asia Cauc. Creole E.Ind Garif May Men Mest Other* ______________ |
| **HH** (incl. self) | ___ Adults __ Children | **Ed** | *None Prim High Coll Uni* | **Main earner Ed** | *None Prim High Coll Uni* |

| | | | |
|---|---|---|---|
| **HH income BZD/week** | *0 1-150 151-300 301-450 451-600 601-750 751-900 901-1050 1051-1200 1201-1350 1351-1500 1501-1650 1651-1800 1801-1950 1951-2100 2101+* | **Nat** | ______________ |
| | | **Hunters in village** | ______________ |

---

| | | | |
|---|---|---|---|
| **Hunt?** | Day Night Both | **Use?** | Machete Gun Dog Light Traps Bow&Arrow Fire Other ____________________ |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **# of Dogs?** | _______ | **# of ppl?** | _______ | **Travel?** | Foot Bike Boat Car Other _____________ | **H. Time?** | ___________ |

| | |
|---|---|
| **When do you hunt?** | *All year Specific months: Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec* |
| **What?** | *Paca NB-Arm Col-Pec WL-Pec WT-Deer rb-deer CA-Riv-Turt G-Igu Other* __________________________ |

---

| **You hunt ...** | |
|---|---|
| ... to get game meat as a special treat for your/your HH, e.g. Easter, Christmas or other celebrations | *Yes No* |
| ... to get meat to share with your family & friends | *Yes No* |
| ... to get meat to sell to your family & friends | *Yes No* |
| ... to get meat to sell to other people (not family & friends) | *Yes No* |
| ... to spend time with family &/or friends | *Yes No* |
| ... to spend time outdoors | *Yes No* |
| ... to remove animals that are damaging your crops | *Yes No* |
| Hunting is your main job | *Yes No* |
| If you did not hunt, your household would not have meat to eat | *Yes No* |
| If you did not hunt, your household would not have income | *Yes No* |

**Which district you hunt?**

| CO | OW | BZ | CY | SC | TO |
|---|---|---|---|---|---|
| *Bay N SE SW* | *C N E S* | *Rural N C* | *C N NE S W* | *Dang W* | *E W* |

| Grid # | Score (1-3) | Years H'd? | Comments |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

| | | | | | |
|---|---|---|---|---|---|
| Int. | _______________ | ID | ___________ | Date | DD_____ MM_____ YY_____ |

| | | | |
|---|---|---|---|
| Species | | When? | *All year Specific months: Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec* |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Trips per mth? | | Successful trips? | | Avg. # of Ind.? | | Equ. to hunt? | |

| | |
|---|---|
| Avg. yearly off-take? | 1-2 3-5 6-10 11-15 16-20 21-25 26-30 31-40 41-50 >50 [How much_______] |

| | | | |
|---|---|---|---|
| Entire Body ? | Yes No | No, which parts are discarded in field ? | |

---

| | | | |
|---|---|---|---|
| Species | | When? | *All year Specific months: Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec* |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Trips per mth? | | Successful trips? | | Avg. # of Ind.? | | Equ. to hunt? | |

| | |
|---|---|
| Avg. yearly off-take? | 1-2 3-5 6-10 11-15 16-20 21-25 26-30 31-40 41-50 >50 [How much_______] |

| | | | |
|---|---|---|---|
| Entire Body ? | Yes No | No, which parts are discarded in field ? | |

---

| | | | |
|---|---|---|---|
| Species | | When? | *All year Specific months: Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec* |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Trips per mth? | | Successful trips? | | Avg. # of Ind.? | | Equ. to hunt? | |

| | |
|---|---|
| Avg. yearly off-take? | 1-2 3-5 6-10 11-15 16-20 21-25 26-30 31-40 41-50 >50 [How much_______] |

| | | | |
|---|---|---|---|
| Entire Body ? | Yes No | No, which parts are discarded in field ? | |

---

| | | | |
|---|---|---|---|
| Species | | When? | *All year Specific months: Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec* |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Trips per mth? | | Successful trips? | | Avg. # of Ind.? | | Equ. to hunt? | |

| | |
|---|---|
| Avg. yearly off-take? | 1-2 3-5 6-10 11-15 16-20 21-25 26-30 31-40 41-50 >50 [How much_______] |

| | | | |
|---|---|---|---|
| Entire Body ? | Yes No | No, which parts are discarded in field ? | |

| Int. | _______________ | ID | __________ | Date | DD_____ MM_____ YY_____ |
|---|---|---|---|---|---|

| The area I hunt, … has ENOUGH … | Agree | Disagree | Resp-dk | Care | Don't care | Comments |
|---|---|---|---|---|---|---|
| Armadillo | ☐ | ☐ | ☐ | ☐ | ☐ | |
| Paca | ☐ | ☐ | ☐ | ☐ | ☐ | |
| Collared peccary | ☐ | ☐ | ☐ | ☐ | ☐ | |
| White-lipped peccary | ☐ | ☐ | ☐ | ☐ | ☐ | |
| White-tailed deer | ☐ | ☐ | ☐ | ☐ | ☐ | |
| Red brocket deer | ☐ | ☐ | ☐ | ☐ | ☐ | |
| **… has FEWER than 10y ago** | | | | | | **Why?** |
| Armadillo | ☐ | ☐ | ☐ | ☐ | ☐ | |
| Paca | ☐ | ☐ | ☐ | ☐ | ☐ | |
| Collared peccary | ☐ | ☐ | ☐ | ☐ | ☐ | |
| White-lipped peccary | ☐ | ☐ | ☐ | ☐ | ☐ | |
| White-tailed deer | ☐ | ☐ | ☐ | ☐ | ☐ | |
| Red brocket deer | ☐ | ☐ | ☐ | ☐ | ☐ | |

| | Agree | Don't care | Disagree | Resp-dk | Comments |
|---|---|---|---|---|---|
| Only people who live in your area should be allowed to hunt there | ☐ | ☐ | ☐ | ☐ | |
| It is responsibility of hunters not to over-hunt an area | ☐ | ☐ | ☐ | ☐ | |
| It is responsibility of Gov to make sure that Hs do not over-hunt an area | ☐ | ☐ | ☐ | ☐ | |

| | | |
|---|---|---|
| Hs are allowed to use fire | *YES NO RESP-DK* | |
| H'ing is allowed in national protected areas | *YES NO RESP-DK* | |
| Hs are allowed to hunt imm. animals or females w/ young | *YES NO RESP-DK* | |
| Hs should have a hunters license, by law | *YES NO RESP-DK* | |
| Dealers should have a dealers license, by law | *YES NO RESP-DK* | |
| Hs are only allowed to hunt in certain seasons | *YES NO RESP-DK* | |
| Hs are allowed to use light | *YES NO RESP-DK* | |

| | | |
|---|---|---|
| Who should monitor & control how much is hunted so we do not run out of game animals? | | |
| Keep a record of what and how much you hunt? | *YES NO* | |
| Keep parts? | *YES - Head Hind Foot Rep org NO* | |

| Int. | ________________ |
|---|---|

| ID | ___________ |
|---|---|

| Date | DD_____ MM_____ YY_____ |
|---|---|

**Who are the other hunters in the villages (Name and residence location)?**

**Comments**

Appendix 3: Game Consumption Survey Sheet

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Int.** | ____ | **ID** | _____ | **Date** | DD___ MM___ YY___ | **District** | CO OW CY BZ SC TO | **Resp. village** | ________ |

| | | | | | | |
|---|---|---|---|---|---|---|
| **HH UTM NAD27** | X __ __ __ __ __ __ __ | Y __ __ __ __ __ __ __ | **Resp. name** | ______________ | **Resp. ph** | __ __ __ - __ __ __ __ |

| | | | |
|---|---|---|---|
| **HH** eat game meat? | *Yes No* | **What?** | *Paca NB-Arm Col-Pec WL-Pec WT-Deer rb-deer CA-Riv-Turt G-Igu Other* ________________________________ |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Gen** | *M F* | **Status** | ________ | **Eth** | *Asia Cauc. Creole E.Ind Garif May Men Mest Other* ______________ | **Nat** | _______ |

| | | | | | |
|---|---|---|---|---|---|
| **HH** (incl. self) | ___ Adults ___ Children | **Ed** | *None Prim High Coll Uni* | **Main earner Ed** | *None Prim High Coll Uni* |

| | | | |
|---|---|---|---|
| **HH income BZD/week** | *0 1-150 151-300 301-450 451-600 601-750 751-900 901-1050 1051-1200 1201-1350 1351-1500 1501-1650 1651-1800 1801-1950 1951-2100 2101+* | **Hunters in village** | ________________ |

| **Members of HH eat game meat because ...** | |
|---|---|
| We have it as a treat/special occasions | *Yes No* |
| It makes a change from domestic meat like chicken, pork, beef | *Yes No* |
| It is the only animal protein available to the HH | *Yes No* |
| We believe it is more healthy than domestic meat | *Yes No* |
| It is easier to get than domestic meat | *Yes No* |
| It is cheaper to get than domestic meat | *Yes No* |
| It is free | *Yes No* |
| We have always eaten game meat | *Yes No* |

| **Members of HH do not eat game meat because ...** | |
|---|---|
| We do not like the taste or smell | *Yes No* |
| It is unhealthy & we may get a disease | *Yes No* |
| It is difficult to get | *Yes No* |
| It is difficult to prepare & cook | *Yes No* |
| It is easier to get than domestic meat | *Yes No* |
| We have never eaten game meat | *Yes No* |
| We do not eat any meat | *Yes No* |
| It is bad for the environment | *Yes No* |

| **HH game meat consump changed in 10y, if so why?** | | |
|---|---|---|
| **Paca** | *More Same Less Resp-dk NA* | ______________________________ |
| **NB-Arm** | *More Same Less Resp-dk NA* | ______________________________ |
| **Col-pec** | *More Same Less Resp-dk NA* | ______________________________ |
| **WL-Pec** | *More Same Less Resp-dk NA* | ______________________________ |
| **WT-Deer** | *More Same Less Resp-dk NA* | ______________________________ |
| **RB-Deer** | *More Same Less Resp-dk NA* | ______________________________ |

| **Final questions** | |
|---|---|
| Are you worried that supply might run out? | Yes No Resp-dk |
| Do you think hunting for game meat should be monitored & controlled? | Yes No Resp-dk |
| If yes, who do you think should control it? | |
| Would you be willing to keep discarded body parts for us to collect & analyse? | Yes No |
| If yes, which -- | Head /Skull Foot Reprod organs |

**Int.** ____ **ID** _____ **Date** DD___MM___YY___

**HH eats** ______________________ **When?** *All year Specific months: Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec*

**HH deps on it for food?** *Yes No* **How much HH gets each time?** ___ *lb* **How often HH gets this amount?** ____________

**Where from?** *HH hunts* (who?_____________________) *Gift Buy it* (where? ____________________________; cost? ______*BZD/lb*)

**What?** *Carcass Carcass minus* ______________________ Parts: *meat only (no bone) Leg Ribs Head Feet Other* _________________

**Store or use fresh?** *Fresh Dry Smoke Salt Freeze Other*_________

**Parts cooked fresh for HH meals?** _______________________ **Amount?** ___ *lb* **Feed HH?** ________ *people for* ____ *days*

**Parts not HH meals?** ____________________ **are** *Given raw/cooked Sold raw/cooked Feed dogs Discard Other* ______________

HH gets ____ lb per ____, & cooks ____ lbs of it fresh for HH meals for ___ ppl in the HH to eat for ___ days; and the rest is ________________

**COMMENTS**

---

**HH eats** ______________________ **When?** *All year Specific months: Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec*

**HH deps on it for food?** *Yes No* **How much HH gets each time?** ___ *lb* **How often HH gets this amount?** ____________

**Where from?** *HH hunts* (who?_____________________) *Gift Buy it* (where? ____________________________; cost? ______*BZD/lb*)

**What?** *Carcass Carcass minus* ______________________ Parts: *meat only (no bone) Leg Ribs Head Feet Other* _________________

**Store or use fresh?** *Fresh Dry Smoke Salt Freeze Other*_________

**Parts cooked fresh for HH meals?** _______________________ **Amount?** ___ *lb* **Feed HH?** ________ *people for* ____ *days*

**Parts not HH meals?** ____________________ **are** *Given raw/cooked Sold raw/cooked Feed dogs Discard Other* ______________

HH gets ____ lb per ____, & cooks ____ lbs of it fresh for HH meals for ___ ppl in the HH to eat for ___ days; and the rest is ________________

**COMMENTS**

| Int. | ____ | ID | _____ | Date | DD___ MM___ YY___ |
|---|---|---|---|---|---|

ADDITIONAL SHEET FOR COMMENTS

Appendix 4: Depredation Survey Sheet

# 1-BACKGROUND

| DISTRICT | VILLAGE NAME | ID | INITIALS | DATE (dd/mm/yy) |
|---|---|---|---|---|
| CO OW BZ CY SC TO | | ___ ___ ___ | | __ __/__ __/__ __ |

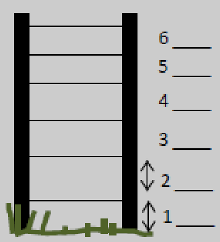
| FIRST NAME | LAST NAME | STATUS IN HH | YRS LIVED IN VILLAGE |
|---|---|---|---|
| | | | |

| HH HAS/HAD | ANIMALS | HOUSE | ROOF | HH SUPPORTS | HH HAS | HH INCOME BZD/week |
|---|---|---|---|---|---|---|
| Animals<br>Local farm | Home/yard<br>In village<br>Local farm | Wood<br>Cement | Thatch<br>Zinc | ____ Adults<br>____Children | Electric<br>Water<br>Phone | 0-150 151-300 301-450 451-600<br>601-750 751-800 801-85 0 851-900<br>901-950 951-1000 1001-1150 |

## DETAILS ABOUT HOME (if have or had animals at home in past 3 years)

| LAND AREA | ______ x ______m | DIST. TO NEAREST NEIGHBOUR | ______ m |
|---|---|---|---|

| LAND | % COVER | PERIMETER | % |
|---|---|---|---|
| BUILDINGS | | FENCED | |
| PENS | | UNFENCED | |
| GRASS | | | |
| SHRUBS | | BUSH | |
| TREES | | NO BUSH | |
| BARE | | | |

| FENCE MATERIAL | CONDITION | HGHT (cm) | GARBAGE DISPOSAL |
|---|---|---|---|
| None<br>Plain wire<br>Barbed<br>Chain-link<br>Wooden<br>Natural poles<br>Electric (___V)<br>Other:<br>__________ | Tight<br>Slack<br><br>AND<br><br>Many broken<br>Few broken<br>None broken |  | Bin with lid<br>Bin without lid<br>Garbage pile<br>Garbage scattered<br>Other:<br>__________ |



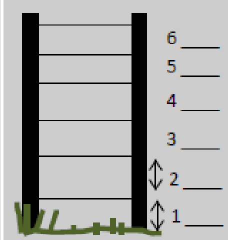
| X (UTM NAD27) | Y (UTM NAD27) |
|---|---|
| | |

## DETAILS ABOUT FARM (if they have or had animals at farm in past 3 years)

| FARM AREA | _____ acres | DIST. TO NEAREST HOUSE | _____ m |
|---|---|---|---|

| USED BY ANIMALS | AREA (acres) |
|---|---|
| **TOTAL** | |
| NATURAL GRASS | |
| IMPROVED GRASS | |
| FOREST | |
| OTHER __________ | |

| FENCED ANIMAL SECTIONS | |
|---|---|
| TOTAL AREA (acres) | |
| NO. OF SECTIONS | |
| OUT.PERIM ADJ. FOREST (%) | Resp Int<br>100 50-99<br>1-49 0 |
| BUFFER WIDTH (m) | Resp Int<br>N Y________ |

| FENCE MATERIAL | CONDITION | HGHT (cm) | WATER SUPPLY |
|---|---|---|---|
| None<br>Plain wire<br>Barbed<br>Chain-link<br>Wooden<br>Natural poles<br>Electric (___V)<br>Other:<br>__________ | Tight<br>Slack<br><br>AND<br><br>Many broken<br>Few broken<br>None broken |  | None<br>Creek (canopy cover)<br>Creek (exposed)<br>Water hole (c. cover)<br>Water hole (expd)<br>Water trough<br>Other:<br>__________ |



| X (UTM NAD27) | Y (UTM NAD27) |
|---|---|
| | |

## DETAILS ABOUT VILLAGE (if have or had animals elsewhere in village in past 3 years)

| ANIMAL LOCATION | FREE-RANGING ☐ | OTHER HH ☐ | COMMUNAL PEN SITE ☐ | OTHER ☐ ______________ |
|---|---|---|---|---|

| X (UTM NAD27) | Y (UTM NAD27) |
|---|---|
| | |

# 2-ANIMAL MANAGEMENT

| ANIMAL | AMOUNT | YEAR 1st ACQUIRED |
|---|---|---|
| | | |

| ID |
|---|
| ___ ___ ___ |

**DAY**

| WHERE → MGMT ↓ | YARD | VILLAGE | FARM | OTHER | COMMENTS |
|---|---|---|---|---|---|
| FREE RANGE | ☐ | ☐ | ☐ | ☐ | If 'Other', specify<br>If 'Guarded', specify by what |
| TIED | ☐ | ☐ | ☐ | ☐ | |
| FENCED | ☐ | ☐ | ☐ | ☐ | |
| PEN | ☐ | ☐ | ☐ | ☐ | |
| GUARDED | ☐ | ☐ | ☐ | ☐ | |
| OTHER | ☐ | ☐ | ☐ | ☐ | |

**NIGHT**

| WHERE → MGMT ↓ | YARD | VILLAGE | FARM | OTHER | COMMENTS |
|---|---|---|---|---|---|
| FREE RANGE | ☐ | ☐ | ☐ | ☐ | If 'Other', specify<br>If 'Guarded', specify by what |
| TIED | ☐ | ☐ | ☐ | ☐ | |
| FENCED | ☐ | ☐ | ☐ | ☐ | |
| PEN | ☐ | ☐ | ☐ | ☐ | |
| GUARDED | ☐ | ☐ | ☐ | ☐ | |
| OTHER | ☐ | ☐ | ☐ | ☐ | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **HEAD COUNT** | NEVER | DAILY | WEEKLY | MONTHLY | 4X/YEAR | 2X/YEAR | YEARLY |
| **BIRTHS** | NEVER | ANY | DRY | WET | J F M A M J J A S O N D | | |
| **EAT ANIMAL OR PRODUCTS** | NEVER | DAILY | WEEKLY | MONTHLY | 4X/YEAR | 2X/YEAR | YEARLY |
| **SELL ANIMAL OR PRODUCTS** | NEVER | DAILY | WEEKLY | MONTHLY | 4X/YEAR | 2X/YEAR | YEARLY |
| **AMNT OF HH INCOME THESE ANIMALS PROVIDE** | NONE | > 0 TO ¼<br>(1 - 25%) | > ¼ TO ½<br>(26 - 50%) | > ½ TO ¾<br>(51 - 75%) | ALL<br>(76 – 100%) | | |

| MGMT CHANGED SINCE 2013? |
|---|
| NO<br>YES - describe |

| COMMENTS |
|---|
| |

| PEN | L x W (m) | WALL HGHT (m) | ROOF HGHT (m) | ENCLSD? | CONDITION | LOCATION | CONSTRUCTION MATERIALS |
|---|---|---|---|---|---|---|---|
| 1 | | | | YES<br>NO | GOOD<br>AVERAGE<br>POOR | YARD<br>VILLAGE<br>FARM | WIRE: PLAIN BARBED MESH CHAIN-LINK ELECTRIC (___V)<br>WOODEN PLANKS NATURAL POLES ZINC PLASTIC<br>OTHER:_______________ |
| 2 | | | | YES<br>NO | GOOD<br>AVERAGE<br>POOR | YARD<br>VILLAGE<br>FARM | WIRE: PLAIN BARBED MESH CHAIN-LINK ELECTRIC (___V)<br>WOODEN PLANKS NATURAL POLES ZINC PLASTIC<br>OTHER:_______________ |

# 3-ATTACKS

## MOST RECENT ATTACK

| ID | MM | SEASON | YYYY | TIME(1) | TIME(2) |
|---|---|---|---|---|---|
| ___ ___ ___ | __ __ | Dry Wet | __ __ __ __ | __ __ : __ __ | __ __ : __ __ |

| TYPE OF ANIMAL | AGE | SIZE (LB) | CONDITION | GENDER | OUTCOME |
|---|---|---|---|---|---|
| | --------- *not for fowl* --------- | | *not for fowl* --------- | | |
| | Newborn<br>Juvenile<br>Adult<br>Resp-dk | ______<br>Resp-dk | Good<br>Poor<br>Resp-dk | Male<br>Female<br>Resp-dk | Missing<br>Injured & survived<br>Injured & died<br>Killed<br>Other: ______________________ |

| WHERE → MGMT ↓ | HOME /YARD | VILLAGE | FARM | OTHER | COMMENTS |
|---|---|---|---|---|---|
| FREE RANGE | ☐ | ☐ | ☐ | ☐ | If select 'Other', specify<br>If select 'Guarded', specify by what |
| TIED | ☐ | ☐ | ☐ | ☐ | |
| FENCED | ☐ | ☐ | ☐ | ☐ | |
| PEN | ☐ | ☐ | ☐ | ☐ | |
| GUARDED | ☐ | ☐ | ☐ | ☐ | |
| OTHER | ☐ | ☐ | ☐ | ☐ | |

| LOCATIONS *(e.g. attack site; carcass)* | X (UTM NAD27) | Y (UTM NAD27) |
|---|---|---|
| | | |
| | | |

| INJURIES & EVIDENCE OF PREDATOR | | RESPONDENT BLAMES |
|---|---|---|
| ☐ Respondent (if described by Resp) | ☐ Interviewer (If Int encounters evidence) | ______________________<br>Resp-DK |

## HOW MANY ATTACKS?

| | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|
| CATTLE | | | | |
| BUFFALO | | | | |
| SHEEP | | | | |
| GOAT | | | | |
| PIG | | | | |
| HORSE | | | | |
| DONKEY | | | | |
| DOG | | | | |
| FOWL | | | | |
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |

| IF > 3 ATTACKS, WERE THEY MAINLY -- |
|---|
| Dry season Wet season Not seasonal |

## CAN RESPONDENT IDENTIFY PREDATORS?

| | PHOTO | TRACK |
|---|---|---|
| JAGUAR | Y N | Y N |
| PUMA | Y N | Y N |
| OCELOT | Y N | Y N |
| JAGUARUNDI | Y N | Y N |
| MARGAY | Y N | Y N |
| COYOTE | Y N | Y N |
| DOG | - | Y N |

## 4-PREDATOR CONTROL

| ID | MOST RECENT CONTROL (lethal or live removal) | MM | SEASON | YYYY |
|---|---|---|---|---|
| __ __ __ | | __ __ | Dry Wet | __ __ __ __ |

| TYPE OF ANIMAL | METHOD | REASON FOR REMOVAL |
|---|---|---|
| Jaguar<br>Puma<br>Ocelot<br>Jaguarundi<br>Margay<br>Spotted cat<br>Coyote<br>Resp-dk<br>Other:____________ | Poison carcass<br>Track with dogs & shoot<br>Wait at kill site & shoot<br>Wait at bait & shoot<br>Trap & shoot<br>Trap & remove to captivity<br>Resp-DK<br>Other:____________ | |

| PRED. SIZE (LB) | CONDITION | GENDER | COMMENTS |
|---|---|---|---|
| Estimate ____<br>Weighed ____<br>Resp-dk | Good<br>Poor<br>Resp-dk | Male<br>Female<br>Resp-dk | |

| DID ATTACKS RESUME AFTER CONTROL? | YES NO NA | IF YES, HOW MANY DAYS? | ________ |
|---|---|---|---|

| LOCATIONS *(e.g. poison, trap)* | X (UTM NAD27) | Y (UTM NAD27) |
|---|---|---|
| | | |
| | | |

### CONTROL 2013-2016 (lethal or live removal)

Amount removed or killed by the HH

| SUCCESSFUL | '13 | '14 | '15 | '16 |
|---|---|---|---|---|
| JAGUAR | | | | |
| PUMA | | | | |
| OCELOT | | | | |
| JAGUARUNDI | | | | |
| MARGAY | | | | |
| COYOTE | | | | |

Amount removed by other people in the village

| SUCCESSFUL | '13 | '14 | '15 | '16 |
|---|---|---|---|---|
| JAGUAR | | | | |
| PUMA | | | | |
| OCELOT | | | | |
| JAGUARUNDI | | | | |
| MARGAY | | | | |
| COYOTE | | | | |

### COMMENTS

| ID |
| --- |
| ___ ___ ___ |

## 5-LOCAL WILDLIFE

| | Encounter within mile of farm or village | Amount compared with 10 years ago More | Same | Less | Resp-dk | Why? | COMMENTS |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Paca | Yes No | ☐ | ☐ | ☐ | ☐ | | |
| Armadillo | Yes No | ☐ | ☐ | ☐ | ☐ | | |
| White-lipped peccary | Yes No | ☐ | ☐ | ☐ | ☐ | | |
| Collared peccary | Yes No | ☐ | ☐ | ☐ | ☐ | | |
| White-tailed deer | Yes No | ☐ | ☐ | ☐ | ☐ | | |
| Red brocket deer | Yes No | ☐ | ☐ | ☐ | ☐ | | |
| Jaguars | Yes No | ☐ | ☐ | ☐ | ☐ | | |
| Attacks in the area | ------------------ | ☐ | ☐ | ☐ | ☐ | | |

## 6-ATTITUDES

| | Agree | Don't care | Disagree | Resp-dk | COMMENTS |
| --- | --- | --- | --- | --- | --- |
| Jaguars are a threat to your livelihood | ☐ | ☐ | ☐ | ☐ | |
| Jaguar attacks on your animals should be dealt with by you | ☐ | ☐ | ☐ | ☐ | |
| Jaguar attacks on your animals should be dealt with by the Forest Dept. | ☐ | ☐ | ☐ | ☐ | |
| Jaguars are a threat to humans (may physically harm them) | ☐ | ☐ | ☐ | ☐ | |

## 7-END OF SURVEY

| CHECK LIST |
| --- |
| Encourage reporting |
| Give contact numbers |
| Review brochure |
| Give brochure |
| Would like to work Y N |

| NAMES/CONTACTS OF OTHER ANIMAL OWNERS | |
| --- | --- |
| DEPREDATION | NO DEPREDATION |
| | |

# ANNEX 5:

**FOREST COVER (broadleaf, mangrove, littoral & savannah); SEAGRASS COVER; EXTENT OF BROADLEAF FOREST; EXTENT OF MANGROVES; LAND USE COVER; AND DEFORESTATION RATE**

### Background

Marine ecosystems (mangrove and littoral forests, and seagrass) and terrestrial ecosystems (broadleaf forest, savannah) are primary habitat for an array of marine and terrestrial organisms. Many juvenile fish inhabit mangroves and seagrass as nursery grounds, and different species of birds inhabit mangrove and littoral forests. A wide range of wildlife, including small and large mammals and birds (both residents and migrants) inhabit broadleaf forests and savannahs and utilize these ecosystems to forage as well.

These ecosystems also provide ecosystem services and goods which many people rely on such as food (fish, shellfish), protection from storms, timber and non-timber products etc. A change in these ecosystems such as decrease in cover and/or extent will certainly have an effect on the organisms and people that depend on them. Thus, tracking cover, extent and even use of these ecosystems is critical in determining their health and status. This will then aid in development and implementation of management practices.

### Methodology (Remote Sensing)

One of the most effective ways of monitoring extent and cover of ecosystems is through remote sensing which involves the use of images. Basically, acquiring information without physical contact. The steps below outline the method to be used:

1. Search for best cloud free Landsat-7 / Landsat-8 images (path 19, rows 47-49) on the USGS Glovis website (http://glovis.usgs.gov/) and download those for use.

2. Perform stack/composite of images in ArcGIS/ArcCatalog by using the 'Composite Bands' tool.
    - ArcToolbox
    - Data Management Tools
    - Raster
    - Raster Processing
    - Composite Bands

3. Mosaic 3 scenes (19-47, 19-48, 19-49) in ArcGIS/ArcCatalog using the 'Mosaic to New Raster' tool.
    - ArcToolbox
    - Data Management Tools

- Raster
- Raster Dataset
- Mosaic to New Raster

4. Subset images to smaller area of interest (AOI)
    - ArcToolbox
    - Spatial Analyst Tools
    - Extraction
    - Extract by mask

5. Gap fill Landsat-7 imagery in ERDAS
    - Interpreter
    - Spatial Enhancement
    - Focal Analysis

6. Convert original digital number (DN) imagery to TOA reflectance in ENVI, using parameters specified in the imagery metadata, followed by conversion to BOA reflectance using Dark Object Subtraction (DOS) correction in ENVI

7. [Alternative] Convert original digital number (DN) imagery to BOA reflectance using LEDAPS (http://ledapsweb.nascom.nasa.gov/index.html)

8. [Alternative] Convert original digital number (DN) imagery to BOA reflectance using CLASlite

9. Supervised classification in ENVI or ERDAS Imagine, using Maximum Likelihood supervised classification algorithm, and using AOI or ROI polygons for land cover types

10. Post-processing, including extraction of change polygons, and comparison with previous land cover maps

**Sites**

No specific sites. The images to be used cover Belize entirely.

# ANNEX 6:

## FRESHWATER MACROINVERTEBRATE IDENTITY, STATUS AND DISTRIBUTION AND THE DEVELOPMENT OF AN INDEX OF BIOTIC INTEGRITY FOR BELIZE'S WADEABLE STREAMS

Prepared by Rachael Carrie, Ph.D.
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### Background

Benthic macroinvertebrates are an important component of stream systems: enhancing biodiversity value and providing numerous ecosystems services. They are the animals without backbones, large enough to be seen by eye, and that live in sediments and on and around the plants, stones, leaves and other material on the channel bed. As a group, macroinvertebrates are taxonomically and structurally diverse and they exhibit wide and often predictable variation in habitat requirements, feeding strategies, tolerance to pollution and sensitivity to fluctuations in local environmental conditions. As such, they integrate conditions in a watershed over time, and because they are relatively sedentary and often respond rapidly to a wide range of environmental stressors, aspects of their assemblage structure can provide a useful measure of the overall environmental quality or health of stream systems (Rosenburg and Resh, 1993). As such, macroinvertebrates are often incorporated within bio-assessment systems like the Index of Biotic Integrity (IBI) (e.g. Weigel et al., 2002, Kerans and Karr, 1994). Furthermore, because of the relative ease and low cost with which macroinvertebrates can be sampled, they offer a potentially cost-effective method for monitoring stream condition in developing countries like Belize (Resh, 2007).

Bio-assessment based on benthic macroinvertebrate assemblages has become a key method for monitoring change in temperate streams (Rosenburg and Resh, 1993, Bonada et al., 2006) and despite the relatively recent interest in macroinvertebrates as indicators in the Caribbean and Central and South America's, there is a growing body of evidence supporting their use. Change associated with urbanisation, deforestation, intensive row crop farming, rice cultivation and other agricultural practices that characterise tropical landscapes has been documented, with characteristic shifts in biotic metrics and taxa considered intolerant to pollution in temperate regions (e.g.(Castillo et al., 2006, Couceiro et al., 2007, de Jesus-Crespo and Ramirez, 2011, Lorion and Kennedy, 2009, Echeverría-Sáenz et al., 2012, Corbi et al., 2013, Knee and Encalada, 2013, Rizo-Patrón et al., 2013). Furthermore, methodologies that enable catchment and national-scale assessments are increasingly emerging (Baptista et al., 2007, Moya et al., 2011) and regional tools and national assessments produced (Pérez et al., 2010, Springer et al., 2010, Villamarín et al., 2013).

The potential for using macroinvertebrates for bio-assessment of streams in Belize has been considered since at least 1980 (Gonzalez, 1980, Boles, 1998, Carrie, 2013), yet knowledge about the identity, distribution and response of macroinvertebrates to environmental change is far from complete (Carrie and Kay, 2014). This knowledge needs to be developed so that sources of natural variation in macroinvertebrate assemblages that may confound bio-assessment efforts can be controlled, and existing and new indicators and threshold criteria that reflect stressors and scales of degradation occurring across Belize can be developed. Below is an outline plan to develop this knowledge for wadeable streams. It includes the following components:

1. Design of a sampling network
2. Training of and support for local survey teams
3. Collection and compilation of macroinvertebrate and environmental information
4. Data analysis and production of a preliminary IBI

**Proposed Approach**

This plan should be implemented as a coordinated project overseen by a dedicated member of staff with experience in freshwater monitoring and family-level taxonomy, employed ideally within the ERI and advised by a Technical Committee comprising international and national expertise. Critical to the success of the plan, and to the sustainability of resulting monitoring tools and subsequent program, is the inclusion of those who will ultimately use the IBI. By participating in the proposed plan, survey teams (potentially including individuals from government departments, NGO's, CBO's and the University of Belize) will receive training in the collection of environmental and macroinvertebrate data, and in family-level macroinvertebrate taxonomy. This process will not only build capacity, but also encourage ownership of the final IBI.

It is important to note that this plan and associated protocols relate to the development of the IBI only, and include techniques (such as laboratory/field station sorting of full samples and taxon-specific preservation methods) that will support efforts to expand knowledge about the identity, status and distribution of macroinvertebrate taxa in streams in Belize. **Protocols for using the IBI once it has been validated may vary**. A follow-on project should focus on the development and dissemination of the resources required for IBI use (methods manuals, taxonomic resources, decision support systems etc.) and an implementation program.

1. **Generating a Sampling Network**

To achieve sufficient spatial coverage and statistical power, a network of replicated sites that reflect the diversity of environmental conditions in streams that are minimally influenced and in those that reflect the full range of human activities and land-use present in Belize is required. At a minimum this should involve the random selection of sites in a sampling network stratified by the aquatic ecosystems (AES) (see Esselman et al., 2005)potentially containing wadeable freshwater sections and 'impact categories' (e.g. low, moderate, high) derived from the relative upstream risk intensity GIS layer devised by Esselman (2009). At least six replicate sites should be identified within each AES-risk combination. It would be beneficial to give consideration to the influence of watershed boundaries, local knowledge and stream size during this process. It is recommended that a dedicated workshop is convened at the beginning of this process to bring together the required local and scientific expertise to develop the sampling network and finalise survey protocols.

## 2 Training of Local Survey Teams

A series of workshops is proposed at appropriate points in the schedule (Table 1) to provide training for pairs from interested organisations and institutions in: 1) the collection of standardised local environmental information and macroinvertebrate samples; 2) sample processing and taxonomic identification of macroinvertebrates to family-level; and 3) specialist taxonomy and ecology of specific taxon groups. The latter is not critical to the success of the project, but would add value if dedicated funding could be secured.

Full instruction, protocols, field recording sheets and spreadsheets for data compilation should be provided during the training workshops. The dedicate staff member should act as a point of contact for any queries during the course of the project and be available to provide targeted and/or refresher training where needed, and quality control.

## 3 Collection of macroinvertebrate and local environmental data

*Timing of fieldwork*

Survey work should be undertaken during a defined timeframe (or index period) to minimize seasonal variability that may confound bio-assessment outputs. The index period recommended for this sampling campaign is between March 1$^{st}$ and May 31$^{st}$. At this time, more streams are likely to be accessible and many taxa more mature, and so easier to identify. Sampling should not be undertaken during or immediately after high rainfall events occurring within the index period.

*Establishing the macroinvertebrate sampling stretch and support reach*

At each sampling location a macroinvertebrate sampling stretch and a support reach representative of habitat conditions, where local environmental information will be collected, should be established. The macroinvertebrate sampling stretch should be selected as close to the randomly generated site location as possible. It should measure approximately 2xthe average channel width, and including a riffle-pool section where possible. The support reach has a length of 40x the average wetted width of the channel at the location where macroinvertebrates will be sampled, and is established upstream of (but including) the macroinvertebrate stretch.

The protocol for establishing the support reach broadly follows the methods developed for the USEPA Regional Environmental Monitoring and Assessment Program (EMAP) by Peck et al., (2006). It enables the quantitative collection of data for statistical control of local habitat influences so the influences of anthropogenic responses on macroinvertebrates can be isolated, meaningful habitat indicators of anthropogenic disturbance can be developed, and potentially to allow additional ecological questions to be considered.

> Measure the wetted width of the channel at 5 places around the sampling location. Multiply the average of these widths by 40 to obtain the length of the support reach. If the average width is less than 3.5m, use 150m as the minimum length for the support reach.
>
> Identify the support reach boundaries by marking the downstream location as Transect A, and measuring 4 channel widths (or 15m if the total support length is 150m) upstream to mark Transect B. Continue marking transects upstream for 9 additional transects (C through K). Check the condition of the reach for confluences, impoundments, physical barriers or access restrictions. If obstacles are found, move the other end of the support reach the equivalent distance away so that the original length of the support reach is maintained. Where possible avoid entering the channel to reduce disturbance before sampling commences.
>
> Take a photo at the downstream boundary looking upstream and at the upstream boundary looking downstream.

*Local environmental information*

The exact local environmental information to be collected should be confirmed following discussions at the site planning workshop. At a minimum it will probably include the measurement of water chemistry (water temperature, dissolved oxygen, pH and electrical conductance) using hand held probes, and information about channel substrates, embeddedness, current velocity, water turbidity, depth and width, riparian canopy, and observable in-stream and catchment anthropogenic disturbance. Protocols for measuring local environmental and habitat information should be drawn from the quantitative methods developed for the USEPA Regional Environmental Monitoring and Assessment

Program (EMAP) by Peck et al., (2006) and the Stream Visual Assessment Protocol (SVAP)Human Impact Mapping methods developed and/or adapted by Esselman(2001) for Belize.

*Macroinvertebrate sampling – field protocol*

The macroinvertebrate field sampling protocol is based on methods used across the US and Europe for sampling wadeable streams where the major habitats which might host different macroinvertebrate groups are sampled proportionally according to their presence within the sampling stretch(Barbour et al., 1999, AQEM Consortium, 2002, Barbour et al., 2006). This semi-quantitative multi-habitat approach to sampling is used as standard within rapid assessments of this type to deal with intra-site variability, meaning that data collected from different sites can be compared. It should be conducted after training in the techniques described below.

Following AQEM Consortium (2002) procedures, a rough sketch should be made along the macroinvertebrate sampling reach and extending across the entire width of the channel, to identify the key microhabitats from which macroinvertebrate samples (or 'units') should be taken.

Starting at the downstream end of the sampling site, 20 units should be sampled, each covering an approximate area of 30 x 30 cm using a kick net (D frame net) (30 x 25 cm frame, 300 µm mesh) and manual sampling as appropriate for the microhabitat type (see below). Microhabitats with a coverage of at least 5% are selected for sampling according to their occurrence. For example, if the habitat in the sampling reach is 50% sand and 50% cobbles then 10 units should be taken in sand and 10 units taken from cobbles. If different flow types are clearly distinguishable, microhabitats should be taken from both in accordance with their relative importance. This procedure results in sampling of approximately 1.5 $m^2$ stream bottom area.

- To sample **cobbles and gravels**, hold the net vertically with the frame at a right angle to the current, downstream from your feet, and disturb the substrate upstream of the net by kicking to a depth of at least 15-20 cm. Hold the net close enough for the macroinvertebrates to flow into the net with the current, but far enough away for most of the substrate to drop out before entering the net. The surface of large cobbles (and also **boulders**), should be brushed by hand to dislodge macroinvertebrates, taking care to ensure animals wedged into cracks are not missed.

- To sample **sands, silt and fine organic microhabitats** disturb the top 2-5 cm, using the net or by kicking and then sweep the net through the resulting 'cloud' of substrate.

- To sample **woody debris and coarse organic matter**, jab the net into the area, which may also be gently kicked to disturb. The surface of large pieces of woody debris should be brushed by hand to dislodge macroinvertebrates (ensure the net is in place downstream of the habitat prior to jabbing, kicking or brushing)

- To sample **vegetation, tree roots and vegetated bank margins** sweep the net either from bottom to top (marginal habitats) or from downstream to upstream (submerged habitats in flowing water) through the vegetation. It may be necessary to jab the net into areas and/or gently kick the area to disturb.

The net should be emptied into a labelled plastic pot before the net becomes clogged. Because the mesh size on the nets is very small, it will clog easily and should be emptied into the pot regularly to prevent loss of material. Microhabitats can be mixed together in the same pot to form a composite sample. It is important to avoid collecting unnecessarily large quantities of microhabitat material. Large stones or woody material can be removed from the sample after being rinsed and inspected for macroinvertebrates. After all 20 units have been collected, the sample should be gently rinsed into a second pot, through a 1mm (1000 μm) sieve, and the pot sealed with a lid.

The survey team should spend 30 minutes examining ('sorting') the coarser size fraction remaining in the sieve for Trichoptera, Ephemeroptera, Plecoptera and Diptera. This should be done by placing separate portions of the sample into a white tray so specimens can be seen more easily. Care should be taken to stop macroinvertebrates escaping. Trichoptera, Ephemeroptera, Plecoptera and Diptera observed in the coarse size fraction should be preserved in a labelled vial of 95% ethanol, following the procedures outlined below.

- Fat, fleshy specimens of the true fly larvae(**Diptera**) should be picked with forceps and placed in a petri dish or similar container. Hot (near boiling) water should be poured on to the larvae (which will make them relax and stretch out, making identifying features accessible). As soon as stretching is observed, the specimens should be removed from the water. This is very important! If left more than **a few seconds** they willcook potentially hindering taxonomic analysis. After removal from the waterthe larvae should be placed into a vial of 95% ethanol.

- Mayfly (**Ephemeroptera)**, stonefly (**Plecoptera**) and caddisfly (**Trichoptera)** larvae should be carefully removed from the sample using forceps and placed into the vial containing 95% ethanol. This should ensure the features necessary for identification are retained and/or that specimen identity can be further analysed using DNA sequencing.

After 30 minutes of searching, Jute snails (Pachychilidae) should be removed from the sample, separated into groups with different shell forms and counted. Three representative specimens of each different shell form should be retained in a separate vial of 95% ethanol and the rest of the snails returned to the stream.

The remainder of the coarser size fraction should be returned to the original labelled pot and covered with 95% ethanol at a 2:1 volumetric ratio (ethanol:sample) before it is sealed with a lid.

A further 30 minutes should be spent examining the finer size fraction (in the 2$^{nd}$ pot) for water mites (Hydrachnidia):

- Water Mites (**Hydrachnidia**), should be sorted by placing portions of the sample into a white tray (leaving space around the edge of the tray can facilitate this process: after a few minutes mites should leave the sample and stray onto the white edge). Mites should be removed using a pipette or forceps into a labelled vial of Koenike's fluid (10 parts glycerine, 6 parts water, 3 parts acetic acid). If using a pipette, the mite can be dropped onto the hand before it is put into the vial using forceps. Water mite specimens should be retained separately from the rest of the specimens so they can be sent for expert taxonomic analysis.

The finer size fraction (in the 2$^{nd}$ pot) should be carefully added to the sample in the original labelled pot containing the coarse size fraction and ethanol. Care should be taken to check the thepot has been labelled inside (using a pencil and waterproof paper) and outside (using a permanent marker) and the vials have been labeled (using a pencil and waterproof paper). The vials should be placed inside the pot. Non-fibrous packing material (e.g. bubble wrap) should be placed in the pot if there is sufficient room to help prevent specimens being damaged by gravel and sand during transport. The pot should be returned to the field station/laboratory for further processing. Care should be taken not to shake or jerk the sample more than is necessary during transport to prevent damage to fragile specimens.

*Macroinvertebrate - lab sorting*

In a departure from AQEM and EPA methods, it is recommended that the whole sample is sorted rather than a sub-sample (a portion of the sample). This is because few macroinvertebrate records exist for Belize and retained specimens can provide valuable taxonomic information in the future (provided they are not damaged and have been carefully preserved).

Samples should be sorted as soon as possible. If not sorted immediately, the sample should be drained through a sieve (300μm), returned to the original sampling pot and replenished with fresh ethanol (95%) after 24 hours and again after 48 hours. Maintaining a high concentration of ethanol in the pot will facilitate DNA analysis. To reduce the amount of ethanol used, it is recommended that samples are sorted within 48 hours.

To sort, the contents of the pot should be **gently** rinsed over a combination of sieves of increasing mesh size (300, 500, 1000 and 2000) that have been placed in a container large enough to collect the ethanol. Washing the sample through the sieves separates size fractions prior to sorting. The smallest size fraction (in the 300 μm sieve) should be re-preserved for future analysis. The 500, 1000 and 2000 μm size fractions should be sorted separately by distributing a small amount of the sample across a white tray marked with black lines or squares drawn across the base. The sample in the tray should be covered with water and the sorter should systematically remove specimens by sorting from one side of the tray to the other. Placing too much material in the tray can result in specimens being missed. Sorting should be done by illuminating the tray with a lamp. All invertebrates should be picked out using forceps and put in a vial of fresh ethanol (95%) for identification.

When each tray is finished, the residue should be poured over a fine mesh sieve (300 μm) and returned to the original pot (with the original ethanol) for quality control. All vials should be labelled (using pencil on waterproof paper) with the same information on the labels created in the field.

*Macroinvertebrate - identification*

Microscopes will be necessary for the identification of certain taxa, since identifying features cannot always be readily seen with the naked eye. When sorting and identifying taxa care should be taken to stop them drying out, as this often makes identification difficult.

All specimens with the exception of Brachyura, Ostracoda, Oligochaeta, Polychaeta and Collembola should be identified to Family-level using appropriate taxonomic keys (Springer et al., 2010, Merritt et al., 2008, Thorp and Covich, 2009). Brachyura, Ostracoda, Oligochaeta, Polychaeta and Collembola should be recorded at the level of Order. Care must be taken when using keys for North and South American taxa because even at Family-level it is easy for inexperienced taxonomists to be misguided by descriptions of taxa that are not present in Central America, or that are present in Central America but not included in the keys. A family level key in preparation for Belize should be available in time for the beginning of this program.

Terrestrial or aerial stages of aquatic animals, empty mollusc shells, exuviae (the skin of emerged insects), empty puparia, empty caddis cases and eggs should not be recorded. If necessary, caddis cases and mollusc shells should be carefully poked with a mounting needles or forceps to check for occupants. Where fragments of damaged specimens are found, a record should only be made if the head AND thorax is present, OR the thorax AND abdomen. Records should not be made for single heads, single abdomens, legs or other smaller parts. In some cases it may be impossible to identify the specimen because it is too small, or because critical features such as gills have been lost. In this case, do not guess. If it is not clear what the specimen is, it should be recorded as undetermined at the finest taxonomic resolution possible (e.g. Zygoptera undetermined).

The identity and abundance of each taxa should be recorded in the spreadsheets provided during the training workshops. If there are any uncertainties with identification, the specimen should be retained separately with notes for validation. Following identification all vials (fully labelled) should be retained for quality control and further taxonomic analysis.

All equipment (lab and field) must be thoroughly rinsed and examined carefully before and after use to ensure it is clean and where applicable, free of organisms. Sample residues and sorted vials of invertebrates for each site should be retained. 10% of samples will be randomly selected for re-analysed by the coordinator to check for taxa missed during initial sorting, and to check the accuracy of identifications.

Specimens should ultimately be consolidated to build reference collections reflecting the national checklist, and that can be used for teaching purposes and to facilitate identifications in the future. This responsibility should fall to the coordinator since reference material must include validated representatives.

## Data Analysis

*Development of a Family-level IBI*

The response of habitat and macroinvertebrate data to anthropogenic stress will be analysed to generate habitat, community-based and taxon specific sensitivity and threshold information (Baker and King, 2010), whilst controlling for natural variation. This process will enable the identification of habitat and macroinvertebrate indictors responsive to stressors prevailing across the studied streams. A preliminary IBI comprising statistically robust indictors will be generated for local review. The above-described analysis should be undertaken by the Technical Committee.

*Genus and species level taxonomic analysis*

Where possible, specimens should undergo DNA amplification and sequencing and/or be distributed to appropriate regional taxonomic experts to obtain validated genus- and species- identifications. For the purposes of this survey effort, the coordinator should be responsible for consolidate specimens and distributing them in bulk to appropriate experts (Table 2). As and when more finely resolved taxonomic information becomes available, it should be used to expand knowledge about the presence and distribution of freshwater macroinvertebrates of Belize, update and develop taxonomic reference material (keys and reference collections), and investigate genus- and species-level threshold responses to environmental change. This information will allow future refinement of the IBI where necessary and facilitate the development of additional assessment approaches. It will also inform and enable a variety of separate ecological studies.

Table 1. Proposed schedule.

| Activity | N | D | J | F | M | A | M | J | J | A | S | O | N | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Planning and sample network design | x | x | x | | | | | | | | | | | |
| Training (field measurements, lab processing, data management) | | | x | x | | | | | | | | | | |
| Fieldwork | | | | | x | x | x | | | | | | | |
| Sample processing | | | | | x | x | x | x | x | | | | | |
| Training (family-level macroinvertebrate taxonomy, storage, data management) | | | | | | | | x | | x | | | | |
| Invertebrate identification | | | | | | | | x | x | x | | | | |
| Data compilation | | | | | x | x | x | x | x | x | x | | | |
| Quality Control | | | | | | | x | x | x | x | x | | | |
| Distribution of specimens for DNA/finer | | | | | | | | | | | x | x | | |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| taxonomic analysis | | | | | | | | | | | | | | |
| Data Analysis (Preliminary IBI) | | | | | | | | | | | x | x | x | |
| Reporting (Preliminary IBI) | | | | | | | | | | | | x | x | x |
| Dissemination (Preliminary IBI) | | | | | | | | | | | | | | x |

Table 2

Contacts for further analysis and validation of specimens.

| Taxon Group | Contact | Comments |
|---|---|---|
| Coleoptera (Beetles) | Professor William Shepard<br><br>1170 Valley Life Sciences Building #4780, University of California, Berkeley, CA 94720-3112<br><br>william.shepard@csus.edu | Prof. Shepard has described a number of Coleoptera found in Belize and has published details of the aquatic Dryopidae, Elmidae, Lutrochidae, Psephenidae, Ptilodactylidae. Prof. Shepard has agreed to receive Coleopteraspecimens for validation. He is particularly interested to receive adult Psephenidae and adult Elmoparnus (Dryopidae). |
| Ephemeroptera (Mayflies) | Dr David Baumgardner<br><br>Department of Biology, Faculty of Ecology and Evolutionary Biology, Texas A&M University, 3258 TAMU, College Station, TX 77843-3258<br><br>dbaumgardner@tamu.edu | DrBaumgardner&Dr Carrie are currently preparing a manuscript detailing the status and distribution of Ephemeroptera in Belize.<br><br>DrBaumgardner has agreed to receive specimens for taxonomic analysis. |
| Hydrachnida (Water mites) | Dr Tom Goldschmidt.<br><br>Bavarian State Collection | Dr Goldschmidt has agreed to receive Hydrachnida specimens for taxonomic analysis collected as part of this program. Specimens |

| | | |
|---|---|---|
| | of Zoology, Section Arthropoda varia, Muenchhausenstrasse 21, 81247 Munich, Germany.<br><br>tomgoldschmidt@web.de | should be sent in bulk by the coordinator at the end of the survey campaign.<br><br>Dr Goldschmidt has expressed interest in collaborating to investigate the performance of Hydrachnid bio-indicators, and has also to provide assistance in their collection and an 'Introductory Hydrachnidia' workshop if funds are secured. |

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## ANNEX 7:

# Monitoring large wildlife in Belize

## Emphasis on large carnivores and their prey

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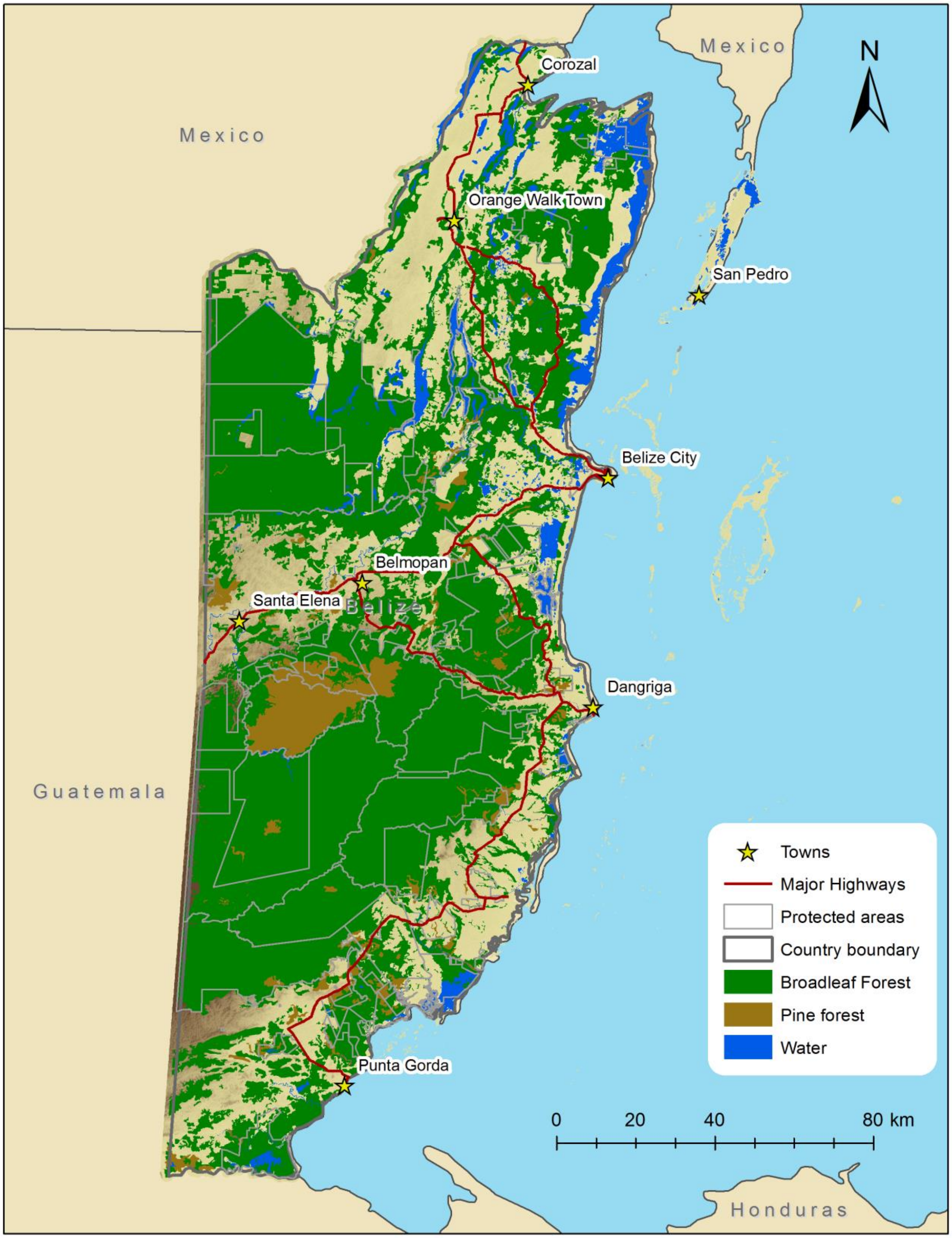
## *INTRODUCTION*

Managing wildlife biodiversity in productive areas of wilderness encompasses five main components:

1. Initial inventory and subsequent monitoring of wildlife biodiversity, abundance, distribution and extinction risk within an area of interest (protected area, forest reserve etc). Monitoring is necessary to investigate numbers and geographic variation and distribution of biodiversity. This is a prerequisite for potential sustainable extraction, if part of a management plan. Alternatively, if the goal is solely protection, which is frequently the case within protected areas, an inventory and monitoring program to understand the effectiveness and efficacy of any area is equally a necessity.
2. Monitoring outside of the area of interest. Where protected or managed areas have distinct boundary lines, wildlife will "spill over" into the surrounding human dominated landscape. This can cause negative consequences in terms of human wildlife conflict (crop raiding, livestock depredation) as well as positive consequences in terms of the potential for game meat harvesting by local buffer communities.
3. Monitoring connectivity on a landscape and larger scale. Examining to what extent the target population is embedded within the wider meta-population of Belize and beyond.
4. Monitoring conflict levels. This can be in terms of economic loss from wildlife conflict (e.g. quantifying crop losses or livestock losses) as well as monitoring wildlife losses from retaliatory killing or game hunting (quantifying hunting levels and retaliatory killing levels).
5. Potential sustainable extraction of wildlife from areas of management if politically and economically viable. This requires monitoring of abundance in relation to extraction rates.

Information on these variables will allow regular evaluations on the viability of wildlife populations in relation to their economic benefit to communities and negative effects arising from conflict. Adaptive management can take place, whereby informed decisions can be made about the potential for commercial wildlife extraction, protective measures to safeguard economic resources and minimizing the risk of extinction. Although greatly discouraged, in rare circumstances the need for culling of wildlife populations might be necessary (e.g. to prevent the spread of diseases whilst local containment is still viable).




***Habitats and protected areas of Belize.***

## *OVERVIEW OF METHODS*

ABUNDANCE, DISTRIBUTION AND EXTINCTION RISK

Several methods are available to monitor wildlife presence, abundance and extinction risk. Monitoring extinction is effectively the repetition of abundance monitoring events to establish trends in change of abundance and turnover rates of individuals. The repetition of monitoring has to take place across a biologically reasonable period of time in relation to the species (i.e. per year for a species with an average lifespan of 10 years, 3 months for a species with a maximum lifespan of 2 years). There are broadly two types of information that can be gathered from the environment concerning the presence of wildlife:

1. Information which indicates the presence of a species but is unable to distinguish individuals (e.g. finding footprints, camera trap photos of species without individually recognizable features). This kind of information can give distribution and frequency data for species in an area of interest, but is unable to indicate abundance of the population at a particular point in time.
2. Information which indicates the presence and distribution of individuals of a particular species (e.g. camera trap photos of individually recognizable species, DNA samples of species). Individual recognition is a prerequisite for estimating abundance accurately. Only data with individual recognition will provide enough statistical power to indicate change between monitoring events and therefore give an early warning mechanism for extinction risk.

It is for this reason that the focus will be on methods which involve individual recognition in populations, as it provides more accurate abundance measures allowing quantification of extinction risk. Several types of methods that can be used to gather information on abundance, distribution and ultimately extinction are outlined below.

### Sign Surveys

Random or stratified sampling grids (area search) or lines (linear search) are established in the area of interest. In both cases active searches are used to establish number of signs per sampling unit (grid or line). This method mainly produces signs that can be identified up to the species level, but not up to individual level (e.g. footprints, burrows, feeding remains). Exceptions to these are fecal samples, which can provide individually recognizable DNA.

#### *Advantages*

*It does not require expensive equipment (pen, paper and GPS units). Frequently personnel with limited technical training but good natural history skills are able to carry out these tasks with minimal instruction.*

#### *Disadvantages*

*It requires large amounts of man hours to gather enough data across large enough areas. When gathering DNA samples, the added the cost of lab analysis must be considered. This may become financially more viable if collaborations are in place in which a partner organization takes on the cost and expertise of carrying out any DNA profiling.*

### Passive Point Detectors

Passive point detectors indicate the time and date of when a particular species or individual passed a sampling location. Examples include:

1) Camera traps. Individuals pass the detector, and the subsequent date and time stamped photos provide information on presence at that location. If the species has individually recognizable features, the photos can be used for counting individuals.
2) Pit tag detectors. Implanted pit tags log detections of individuals who pass by.
3) Bat detectors. These detect the use of echo location pulses, identifiable to species level.

Information from passive detectors is only gained from particular point locations. It is therefore extremely important how detectors are distributed across a landscape in terms of number, habitat and distance between them. Sampling regimes depend on behavior and distribution of the species. Species with large home ranges necessitate widespread distribution but low density of point detectors. A denser distribution strategy, over a smaller area, would be used for species with small home ranges (potentially repeated with several clusters to detect variation in the landscape).

#### *Advantages*

*If detectors are robust and do not require high maintenance, they can be left for extended periods in the field gathering constant streams of data from fixed points. Therefore the manpower needed for maintaining the detectors is limited to deployment and maintenance cycles. Robust point detectors allow monitoring further afield as one time deployment and retrieval expeditions are easier to carry out compared to frequent sampling schemes far afield.*

#### *Disadvantages*

*Equipment units and maintenance are expensive and require a certain amount of technical expertise. This can be a challenge for warden and ranger personnel whose skills are more focused on natural history knowledge and "bush skills". When skilled personnel are in place and a core set of passive detectors is available, the cost benefit analysis of passive detectors versus sign surveys goes in favor of passive detectors*

### Active Point Detectors without Capture of Individuals

These point detectors require active checking to register the presence of species or individuals. Two main detectors fall into this category:

1) Footprint traps. These consist of carefully prepared sand or mud patches and analysis of subsequent tracks indicates the presence of species in the area.
2) Hair traps. These include any device that snatches hair and skin samples after direct contact. Hair traps usually consist of barbed surfaces or lines. The animal is induced to rub against the surface of the trap for marking purposes, via the use of a lure. Alternatively the animal must crawl underneath a line of barbed wire to reach a bait site, removing hairs from its back in the process.

Date and location of capture is the information unit of interest and only active checking of the detectors can discern this (footprints or hairs occurring between checks correspond to the time period between those checks).Usually the frequency of checking needs to take into account the degradation of signs (rain will wash away tracks and hairs from the detector sites). Detectors must be cleaned after registering and collecting data each time.

### *Advantages*

*Active point detectors without capture of individuals are cheap and easily operated, which allows relatively non-technical personnel to carry out surveys.*

### *Disadvantages*

*They require frequent checking and thus many man hours to acquire an appropriate number of samples. The capture probability of samples must be high enough to warrant the use of these techniques. When dealing with hair samples, the cost of genetic or other chemical analysis must be considered.*

## Active Point Detectors with Capture of Individuals

These point detectors consist of any trapping device, such as cage traps, snare traps, pitfall traps or nets. In similar fashion as active point detectors without capture, the checking regime dictates the recording of the time frame of when individuals were captured. In the extreme case of pitfall traps where frequent checks are not necessary for welfare reasons, the collection times of samples indicate the time frame of when the sample was collected (i.e.. this specimen was collected in pitfall trap 3 at check 5, meaning it fell into the trap between check 4 and 5). Infrequent checking will therefore result in inaccurate estimates of time of capture. Live trapping creates the situation whereby frequent checking of traps is necessary for welfare reasons, apart from the accurate estimation of time of capture.

### *Advantages*

*Having specimens of the species in hand means that samples for DNA, chemical and pathogenic analyses can be collected. Captured individuals without recognizable features can be given unique markers for recognition (e.g. ear tags, rings around legs, ID collars). Deploying GPS or VHF collars on captured specimens will acquire detailed data on distribution patterns of specific individuals.*

### *Disadvantages*

*It is extremely labor intensive and requires highly skilled personnel to run such capture operations. It can therefore be extremely expensive. There are however data types that cannot be gathered without having the specimens in hand.*

Human-wildlife conflict and wildlife harvesting are the main direct human induced causes of mortality for wildlife populations. Both conflict and harvesting require similar methods to quantify these variables. It is therefore that the two issues will be clumped within the sections below.

A monitoring program on human-wildlife conflict requires baseline data on farming within the area of influence. Information needs to be gathered on number of farms, contact details on farm owners, type of farms what kind of livestock and types of crops) and a quantification of economic activity (number of livestock or quantity of crop production). This information can be gathered from agricultural extension officers with the potential need for follow up surveys, mapping farms. After acquiring a list of stakeholders, the level of wildlife conflict they experience must be established. For livestock farms, level of predation (e.g. jaguars killing cattle, sheep, and pigs) and in the case of crop farmers, level of crop destruction (e.g. tapirs and peccaries eating and trampling crops). Stakeholders need to be equally queried on the level of retaliatory killing they use as a management strategy. Only in this manner can a balanced view of economic loss in relation to biodiversity loss be acquired.

Acquiring baseline data on wildlife harvest requires a different approach. Hunters are not readily visible and one needs to go into communities to find them. The potential illegality associated with the wildlife harvest economy makes this kind of information difficult to acquire. Rigorous quantification of harvest levels and understanding of the economic gain associated with this is vital for management purposes. Unsustainable practices are in nobody's interest in the long run, while legal sustainable harvest should be the management strategy to strive for. There are several means of gathering information on conflict and harvest.

## Structured or Semi-Structured Interviews

Interviews are a relevant tool to extract information from stakeholders at fixed time intervals. Structured and semi-structured interviews are excellent for acquiring baseline data to establish the level of conflict, level of retaliatory killing and harvest of target species. Livestock farmers and hunters are frequently unaware of their rights and killing of jaguars or hunting of game species is perceived as illegal and unwanted by portions of Belizean society. This means that stakeholders might not be willing to tell the truth or will provide misinformation. To prevent this from happening, the main emphasis in interviews needs to be placed on building trust. The interviewer needs to assure the stakeholder that the "questioning" concerns the gathering of mutually beneficial scientific data and any information provided is kept confidential. A standardized interview is frequently not suitable for gaining such information. A strategic approach to interviewing is required to build trust. Once baseline data and trustworthy relations are established, continued communication with stakeholders is important so that when conflict or hunting events have taken place they will willingly provide the information themselves.

Training needs to be provided to interviewers so they learn how to approach interviewees in gathering sensitive information (e.g. retaliatory killing and hunting).The process of training entails being faced by stakeholder response scenarios. Once comfortable with responding in these training scenarios, the trainee will go into the field accompanied by an experienced interviewer. Trainee interviewers will start carrying out interviews in the presence of an experienced interviewer until the trainee is comfortable and confident in carrying out interviews on their own.

#### *Advantages*

*Detailed information can be gathered on domestic animals present in the area, levels of conflict, timing of conflict, management practices and wildlife harvest or retaliatory killing.*

#### *Disadvantages*

*Information gathered is as good as the memory or the willingness to tell the truth of the interviewee. This is especially the case with retaliatory killing and wildlife harvest when these might have an element of illegality. The interviewee might therefore not be willing to share or provide misinformation. Interviews require a high amount of skill on the part of the researcher in gather reliable information and being able to detect deception. Gathering interview data are extremely time consuming and often requires an extremely good relation of trust between the interviewer and interviewee.*

### Continuous gathering of conflict or hunting information

Interviews can provide information on wildlife issues at particular points in time. They are however snapshots that would not provide managers with continuous data flows necessary for adaptive management to deal with problems where and when they occur. For this to happen, stakeholders (e.g. livestock farmers or hunters) need to be motivated to report problems immediately to the area managers. This requires a high level of participation and reporting from community members. Each management area needs to have a contact officer, which stakeholders can call concerning wildlife problems; e.g. livestock farmers can call concerning predator-livestock conflict or cases of retaliatory killing of jaguars. The officer needs to follow up on these calls according to developed protocols and discuss option concerning mitigation or management. At the same time, the officer needs to regularly gather data on hunting exploits by going out into the communities following up with known hunters. The contact officer needs to be a person that is trusted and respected in the community but at the same time well-motivated to gather accurate data and passionate about the need for this monitoring program. The ultimate goal of the program is therefore to get people to call the monitoring program and actively participate.

#### *Advantages*

*A continuous feedback loop of information concerning conflict and extraction is acquired. Management can be tailored according to the real needs and requirements.*

#### *Disadvantages*

*Good and useful information is only gathered if people are willing to report. The system breaks down if people are unwilling to do this and there is a low level of trust in the contact officer. Everybody needs to participate, if there is a section of the community that does not report, an unknown portion of conflict and harvest remains unknown to management.*

### Collection and documentation of evidence pertaining to depredation and crop-raiding

Conflict sites are visited and evidence of conflict logged. When it concerns depredation, examination and photographic documentation of carcasses with subsequent surveying of the surrounding site for signs (e.g. tracks) are important to discern the likely perpetrator. If possible, samples should be collected, e.g. skull and damaged vertebrate parts. In case of crop-raiding, the damaged crops need to be photographed, extend of damage documented (percentage of crop or number of plants damaged).

#### *Advantages*

*This type of collection aids in building up a detailed picture of conflict levels within an area, if the network of informants is good and reliable. Conflict samples can be used as educational tools for farmers on what signs to look for in carcasses (skull with canine punctures and broken vertebrae).*

#### *Disadvantages*

*Reliance is completely on reporting by stakeholders to gather this type of information. Accuracy of data therefore relies entirely on the willingness of reporting. Conflict evidence degrades rapidly over time allowing only a small window of opportunity to investigate. Little can be accomplished in this respect if stakeholders do not understand the need for immediate reporting and if relations are not strong.*

### Collection and documentation of evidence pertaining harvest and retaliatory killing

This type of collection revolves around any type of physical evidence of people killing animals. In case of harvest, collection of specific body parts that have no commercial value can inform scientists about the individual of a particular species (e.g. collection of specific feet (left, right, hind or front feet), ears, tails etc.). If a reliable relationship exists between the size of the collected body parts and the actual size of the animal, one can investigate size variation within the population and potential changes. These samples can provide further information on the sex of the individual when there is high level of sexual dimorphism within species. Small payments can be made for these parts, requiring careful pricing not to induce harvest, while being high enough to be an incentive for retaining the part for collection. Skulls, lower mandibles or other none edible body parts can all be considered. Teeth can provide an estimation of age, providing data on age structure of harvested species. We would advise all monitoring agents to strive for this level of data collection. A good way of starting such a program is to initiate such collections with a few hunters and let the rest of the community find out that this can be a mutually beneficial relation, potentially leading to hunters providing valuable data on extraction levels and them receiving advice/recommendations for suitable hunting sites based on monitoring outside of the management area. This could be a first step in starting a sustainable hunting program in which hunting is guided and controlled by the hunters and researchers through a good working relation. It is a bonus if the human harvester can provide extra information on sex or body condition of the individual harvested animals. Photographic evidence can be very useful in case of individually recognizable species, e.g. photographs of pelts.

### *Advantages*

*This type of collection allows collection of solid and detailed evidence on the minimum number of individuals killed in combination with biometric data. Samples like hair can be used for further scientific research on chemical accumulation e.g. mercury, while skulls and other bone parts can be used for population analysis (e.g. size variation) and educational purposes in the university.*

### *Disadvantages*

*It requires high levels of cooperation. Relations with stakeholders have to be extremely strong and reliable. There is always the potential of people using compensation for body parts as economic gain. Equally such programs can be negatively targeted by more extreme animal rights groups.*

## Measuring detrimental effects of domestic animals on wildlife

Free ranging domestic animals can have considerable impacts on wildlife areas. Domestic animals are a high source of pathogens which can spread to wildlife and humans alike. Once pathogens are established in wildlife populations, they become a difficult source to control and can easily be transferred back to domestic animals even after eradication in the domestic population. Closely related domestic and wild species have a high chance of infecting each other (pigs and peccaries, deer and cattle, dogs and other carnivores).Rural free living dogs often explore wildlife areas in groups and use them as hunting grounds. Such hunting incursions create further possibilities for disease transmission to wildlife. Several cases of mange have been detected in protected areas with dogs being the only possible source. The transmission of pathogens may also occur the other way, from wild populations to domestic animals and potentially onto humans. The frequent incursions of domestic animals into protected areas increase the chances of disease transmission both ways. Livestock foraging in wilderness areas can have a similar detrimental effect, when both wildlife and domestic species are exposed to larger amounts of fecal material.

Carnivorous companion animals (cats and dogs) can also have a considerable impact on wildlife in terms of hunting. Their well-nourished body conditions, getting supplementary food from humans, create healthy and effective hunters. The detrimental effects of disease and hunting of domestic animals must be taken into account and potentially made part of any wildlife monitoring program near communities.

Domestic animals can be treated as another wildlife species when dealing with presence/incursions into areas of management, using surveys with passive and active point detectors. Presence and abundance of these species in human dominated landscapes can be discerned from interviews by simply asking stakeholders what they own in terms of specific species and if they are free ranging.

## Collection of samples and following domestic animals

Monitoring levels of pathogens and vectors (ticks, mites and other parasites) requires samples and capture of individuals. As these are domestic species, this is less problematic compared to wildlife. It is extremely useful to acquire detailed spatial data on levels and distance of incursions from free ranging domestic animals. The use of relatively inexpensive store on board GPS collars can be considered as domestic animals always return home eventually. Collars can be used again on other individuals and single collars can provide samples from multiple individuals.

### *Advantages*

*Treating domestic animals as wild ones in point detectors will give a general idea on the level of incursions in protected area and where these are likely to happen; providing managers with data to incorporate in their management strategies. Pathogens can easily be sampled from a domestic population because of their ease of accessibility.*

### *Disadvantages*

*The sheer volume of domestic animals creates the situation that a monitoring program, especially concerning pathogens, can become costly. The larger the program the more costly it will become.*

## *SPECIES SPECIFIC METHODS*

### *JAGUARS (PANTHERA ONCA)*

The jaguar (*Panthera onca*) is the largest and arguably most well-known predator of the Neotropics. Once found from southwestern USA to Argentina, today it has been extirpated to just 46% of its historic range. Conflict and competition with humans, as well as deforestation and degradation of its' natural habitat mean numbers are in decline with populations left becoming increasingly isolated. Although worrying for any species, this is especially troubling for the jaguar, which is the only true big cat with no discrete subspecies. It is crucial that jaguars are able to disperse throughout the landscape, on a local and global scale, maintaining genetic flow between populations.

Within Belize the two largest populations of jaguars are found within the two largest contiguous forest blocks, the Maya Mountains and the Rio Bravo, Selva Mayan forest in the North (CAP 2015). These forest blocks are considered large enough to house source populations of jaguars. Monitoring of these populations and the surrounding areas will help elucidate how and where jaguars are moving between the source forests and surrounding target areas and reserves (e.g. between the Maya Mountains and Toledo coastal plains or Central Belize Corridor, or between the Central Belize Corridor and North / East Belize). Monitoring within these surrounding areas is also essential to establish information such as survival of individuals throughout time, or the carrying capacity of certain environments.

The elusive behavior of jaguars, combined with the fact they often occur at low densities due to their wide ranging nature, mean much is still unknown about the ecology of jaguars. A long term study in the Cockscomb Basin Wildlife Sanctuary (CBWS) has been working to improve knowledge not only of the species, but also of the best ways to study them. They have shown that the most reliable way to study jaguar presence is via use of existing trail systems such as old logging roads. Off trail sampling resulted in much lower capture rates compared to trails, with a higher amount of effort needed to acquire similar samples of jaguar presence (Harmsen *et al.,* 2010). Utilizing trails will create highly male biased camera trap records, as females have been shown to avoid trail use (Harmsen *et al.,* 2010). However, this trail sampling is still the most cost effective method available. Due to jaguars unique rosette patterns, individuals can be followed through time, allowing assessment of abundance, survival and extinction risk.

Jaguars show large amounts of clinal variation in phenotypic and behavioral characteristics. Within Belize, diet consists mainly of armadillos (46%) followed by coati (11%), while lipped peccary (10%) and collared peccary (5%) (Foster *et al.,* 2010). Territoriality by jaguars is not yet properly understood but high amounts of overlap have been reported in male jaguars within CBWS (Harmsen *et al.,* 2009). Yearly home range sizes of male jaguars range from 257km$^2$ (SD: 119km$^2$) in Central Belize to 127.5 km2 (SD: 19km$^2$) in CBWS. A female followed for a year in Central Belize indicated a range size of 111 km$^2$ (Figueroa 2013). Females are difficult to capture on camera traps and therefore have been poorly understood in terms of the spatial and temporal movement patterns. A national monitoring program for jaguars in Belize has the huge potential to elucidate critical information about this cryptic species.


***Historic and current range of Jaguar (Pantheraonca)***

Main Methods of Monitoring

1. Initial sign surveys
2. Camera trap surveys
3. Scat surveys
4. Interviews with stakeholders concerning conflict, retaliatory killing of jaguars and harvest of prey species
5. Investigation of jaguar-livestock conflict reports

Camera traps have been the main method to monitor jaguar populations across their range. Jaguars are a wide ranging, solitary species which means that camera trap arrays need to cover large areas to assure an adequate sample size of detected individuals. Cameras need to be placed at the most optimal locations to allow sampling of the maximum number of individuals.

## Initial Sign Surveys

If the managed area has an existing trail system we will concentrate our efforts here. We will first require accurate maps of trail systems and these needs to be surveyed for signs. Sign surveys will be used to initially investigate the distribution of jaguar signs (footprints, scats and scrape marks) to allow optimal camera locations. Capture probability away from trail systems is extremely low and when no obvious alternative travel paths are present (small streams, rivers); we might have to resort to the creation of a monitoring grid with an extensive trail system that jaguars will use. Ideally trails need to be >5 km to be useful for jaguars.

## Camera Trap Surveys

### *Area size of study site*

Within an extremely high density population, like the Cockscomb Basin Wildlife Sanctuary, a camera trap array of 19 stations, covering ~200 km$^2$, results in 20-30 individuals photographed within a 3 month period. Similar arrays placed in extremely low density areas (Honduras) result in the detection of <5 individuals (unpublished data, Castañeda). Accurate and precise measures of abundance estimation require high enough sample sizes of ≥ 10 individuals but preferably > 20 individuals. These individuals equally need to have high enough recaptures within the camera grid to allow abundance estimation (half of these need to be captured > 5 times) to assure compliance with statistical model estimator assumptions. This means that low density areas will require an even higher sampling effort across even larger areas to assure the required +10-20 individuals. Logistically it will not be possible to increase study areas to this extent, prompting compromise in designs between logistical feasibility and statistical rigor.

We suggest areas for jaguars in which the outer boundary of cameras covers an area of at least 200 km$^2$ to assure precise enough measures for high density populations. If the population lives at lower abundance the decision can be taken to increase the area to 300 km$^2$ to investigate if statistical rigor can still be achieved. We foresee that any further increase in study area size will be logistically difficult. In these cases we will report of minimum number alive (report the number of individuals captured without any statistical inference). If the area of management is < 200 km$^2$, automatically means that the study site needs to be expanded beyond the boundaries of the protected area to achieve the desired size for monitoring. Initial area size will start at 200 km$^2$ and adjusted according to numbers of jaguars recorded.

### *Distance between cameras*

The distance between camera stations for jaguar surveys range from 2-3 km between stations. The rationale behind this revolves around the smallest range for jaguars reported (10 km$^2$). This range is likely not realistic and an underestimate but camera surveys indicated that this distance still serves well as a rule of thumb in terms of capture and recapture frequency. Wider ranging males trigger multiple cameras (> 3) in such a grid system while females usually only trigger one or two camera locations. As such using distances between cameras of 2-3 km is a good starting point.

### *Number of cameras needed for surveys*

Within a ~200 km$^2$ camera grid with cameras being 2-3 km apart, we suggest the use of 20-25 camera stations. One station requires two cameras on either side of the trail. Only in this manner do we acquire the two flanks of each individual. This means that a core survey requires 40-50 cameras. Most statistical analyses require that stations work continuously and two cameras provide a level of redundancy assuring that at least one of the cameras remains operational. Cameras do break down and these need to be replaced this means that a number of spare cameras need to be present to allow replacement of cameras. We suggest that for a survey with 50 cameras an extra 10 cameras are available for replacement (60 cameras in total).

### *Length of survey*

One of the main statistical assumptions for estimating abundance and density concerns the closed population assumption (population remains stable for the period of measurement). To satisfy this assumption, a rule of thumb was developed in which surveys would not exceed 3 months in time. Most jaguar surveys would run for periods of 2-3 months. In Cockscomb we found that keeping cameras operational for year round periods resulted in a dramatic increase of the number of individuals detected, especially females. When running year round surveys, we can distinguish between resident individuals, transients and examine the amount of change in occupation of the study area. This will give us extremely valuable information on survival and population dynamics. It will also allow us to run several sets of abundance estimates per year by subsampling the yearly capture records into sections of 2-3 months surveys. We will therefore acquire 4-6 estimates per year.

If money, weather conditions or manpower would not allow year round surveys, we suggest several options for reduced surveys.

- The minimum is running a single 3 months survey in the most optimal period of the year. In Belize this usually means the dry season. This will provide us with yearly snapshots of jaguar populations and we can ascertain fluctuations between years. Survival, residency and flux in presence can all be estimated but the snapshot nature of the survey will make these estimates less precise compared to the year round option.

- The next best option would be running two surveys per year, one 3 month dry season survey and one 3 month wet season survey. In this manner we can compare fluctuations between seasons in terms of occupancy of the managed area and we will have a more robust measure of survival, residency and flux between years with high coverage of the entire year.
- The next best option would be running surveys for any extended length of time beyond the 3 month period, preferably up to 6 months so we can split the capture record into 2 or 3 estimation periods for comparison. This will mean that an entire season will be missing in terms of monitoring but all variables can be estimated.
- Another entirely different option would be to run the main survey for 3 months and maintain a portion of the cameras year round. This continuous monitoring would take place in the most accessible part of study area. This portion of the study area would provide us with continuous information of survival, residency and flux in presence. It would mean that we have a smaller more precise measurement of these variables from a smaller subarea.

### Scat collection

Jaguar scats are difficult to find as they decompose relatively quickly (in the rainy season sometimes within 2 days). The sporadic nature of finding scats would not warrant special surveys. It is possible to increase the number of scats found with the use of scat detector dogs (specially trained dogs) but this would incur a large investment. Potentially the scat detector dog could be rotated between monitoring areas, using rigorous survey protocols with the detector dogs. Without such dogs, we propose that warden and ranger personnel collect scats opportunistically.

Scats can also be used for the monitoring of intestinal parasites. Part of the scat needs to be kept in fridge before analysis. For optimal results in parasite analysis, scats need to be fresh to medium fresh (2-3 days). The moisture in the scat is necessary for the survival of eggs that can be identified in the lab. There are several veterinary labs within Belize that are willing to help with the analysis of monitoring intestinal parasites. GPS location and date are the main variables that need to be collected with each scat. Scats need to be stored in dry paper bags with desiccate before shipment.

There are several institutes who will collaborate with larger scale scat collection programs to genotype scats at no cost (e.g. American Natural History Museum in New York). Genetic typing of ~100 scats per area would allow us to see how many individuals are present on the basis of genetic analysis, the level of heterozygosity within the population and the level of genetic isolation of the target population (level of inbreeding). This is vital information on countrywide population dynamics. Jaguars and pumas use scats for marking purposes. Continuous rigorous removal of whole scats from study areas will therefore influence the social dynamics of the cats. To circumvent this, we will only remove part of the scat and portions remain to assure their signal function.

### Monitoring jaguar abundance outside the area of management

Methods of monitoring are similar inside and outside of the area of management, using of camera traps and scat collection. In an ideal situation, the protocols would be completely similar in terms of area covered, distance between cameras etc. However it is more difficult to write precise protocols for monitoring outside areas of management because of the high level of variation in human activity and distances at which people live away from the area of management. People differ considerably within these areas in terms of: economic activity, distribution, density, level of potential conflict and extraction. Monitoring should take into account that camera traps inside human dominated areas are more prone to theft and vandalism. Relationships between the managing organizations and the buffer communities are important to keep this to a minimum.

Monitoring within the human dominated landscape, bordering a management area is important to understand the interface with wildlife "spilling out" of the management area. The more the monitoring protocols can reflect the proposed protocol above, the more we can compare population dynamics inside and outside of the managed area and we can quantify the effect of human influence. The more the inside and outside areas are directly connected and adjacent, the more accurately we can study movement of individuals in and out of the managed area. Monitoring protocols for the outside areas have to be developed on a case by case basis.

### Monitoring jaguar-livestock conflict and retaliatory killing

Information will be obtained from agricultural extension officers concerning number of farms, livestock numbers and identification of stakeholders. All farmers in buffer communities need to be approached and baseline interviews will establish the historic level of conflict in the area. Careful unstructured interviews will further tell us about levels of retaliatory killing of jaguars. After this, continuous monitoring of conflict and retaliatory killing is required to allow adaptive management of jaguar-livestock conflict. This requires good relations with the farmers and we therefore advise the instatement of a wildlife conflict officer within each area of management. This person can collect continuous data on conflict levels and retaliatory killing according to fixed protocols and maintain good relations with the livestock farmers. This officer will be in charge of implementing a mitigation program, entailing assistance to farmers concerning non-lethal methods of conflict mitigation. This will be done in close collaboration with the Forest Department as the overseeing body for managing jaguars as a species.

### Additional methods

Capture and collaring of jaguars provides extremely useful information on detailed movement of individuals. It can provide information on jaguar movement both inside and outside of the managed area. It will indicate to what extend breeding females make use of the area, how males optimize their area for finding females, how young can disperse from the area and to what extend individuals come into conflict with livestock or other domestic animals. Collars can be used to monitor potential cattle killing culprits and allow managers to follow individuals that cause too many problems. The high variation in range size between Central Belize and Cockscomb indicates the potential for even higher variation throughout the country. This variation needs to be documented and understood so we can develop models concerning distribution and abundance of jaguars throughout the country. Captured individuals provide us with extremely useful samples in terms of parasite loads (internal and external) and general measures of health and variations in size and weight.

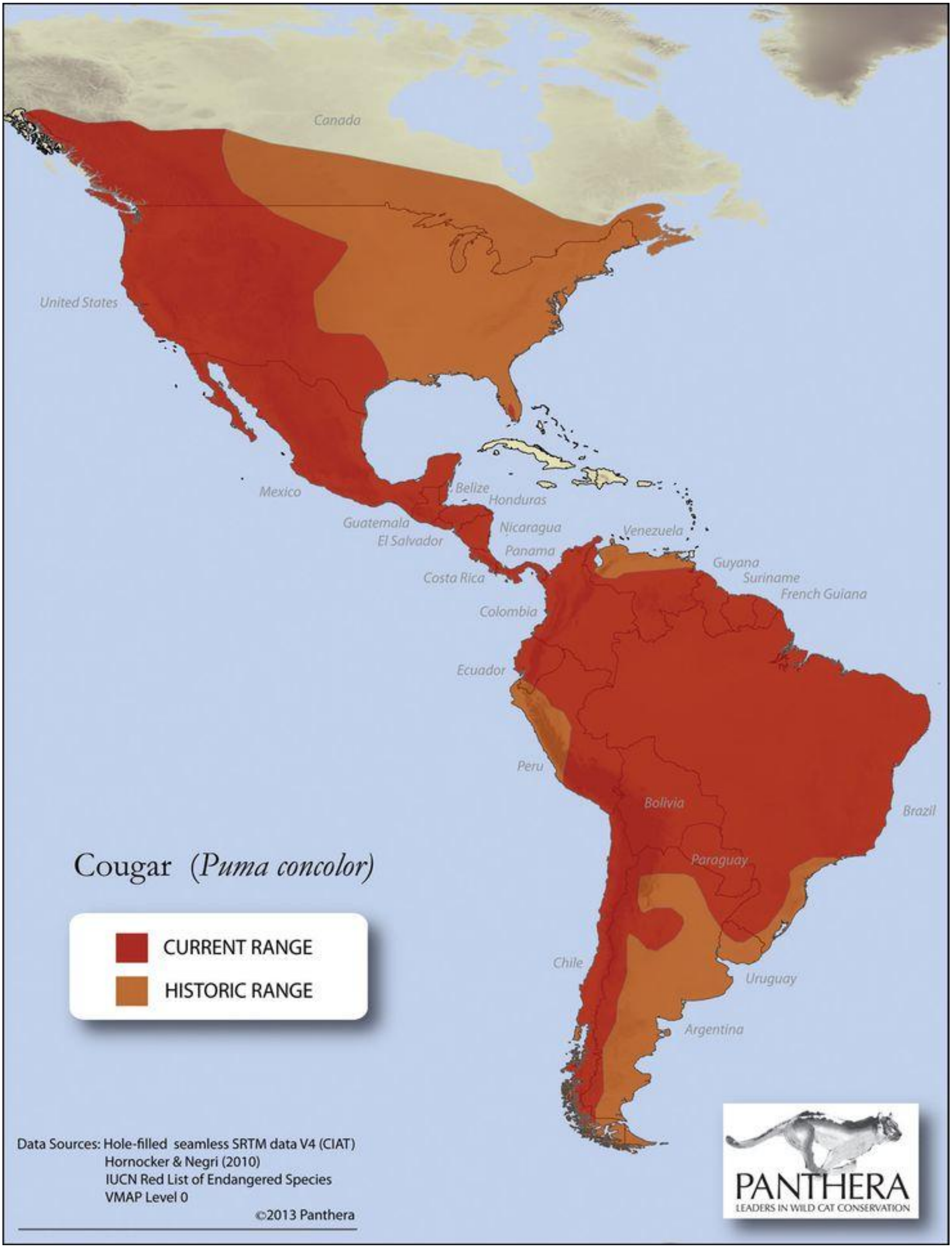
The process of capturing needs to be planned carefully to assure the welfare of the animal. This process consists of selecting the time of the year best suited to carry out the trapping session along with selecting the sites where traps will have a higher chance of capturing target individuals. Selection of the sites consists of camera trapping and choosing trap locations on the basis of photo evidence of presence of particular target individuals. Once the sites are selected, experienced personnel will set up the traps (snare or cage traps). When the traps are in place and set, the team will monitor at hourly intervals over 24 hours, using trap site transmitters. These VHF transmitters will indicate a change in signal in case of trigger so the team can respond promptly to assure the welfare of the trapped animal. A strict protocol will be followed for taking samples and health monitoring and the animal will be fitted with the appropriate collar. An experienced trapping team should be present at all times for all times to assure smooth implementation of all procedures (drug dosage, drug delivery, induction of anesthesia, health monitoring, taking of samples, collar deployment, and recovery).

## PUMAS (PUMA CONCOLOR)

Pumas have the largest geographic range of any carnivore in the world, currently spanning from Canada to the Southern tip of Chile. Their versatility and adaptability is shown through their habitation of every major habitat type in the Americas (IUCN 2015). However, numbers are declining in areas due to habitat fragmentation, forest degradation and prey depletion.

Large scale studies in puma ecology have shown a level of plasticity in the behavior of pumas. Whilst in some areas they have been shown to excel in human dominated landscapes, this trend has not been found in Belize, whereby higher densities are found inside protected areas (Foster *et al.,* 2010). The average home range size for male pumas in Central Belize is 205 $km^2$ (SD: 7 $km^2$, $n$ = 2). In CBWS a single male puma currently has a home range of 112 $km^2$ (unpublished data Harmsen, Sanchez, Foster). No information is available on range size of female pumas in Belize. Pumas in Belize are reported to have an average weight of 36.9 kg (SD: 3.9 kg) for males and 19.63 kg (SD: 2.9 kg) for females (Figueroa 2013), whilst their diet has been found to consist of mainly pacas (58%), red brocket deer (9%), white lipped peccaries (8%) and armadillos (7%) (Foster *et al.,* 2010).

Whilst pumas can be found throughout Belize, their wide ranging nature and general low density mean many management areas are not suitable to hold viable puma populations. The Maya Mountains and Rio Bravo/Selva Mayan Forest are considered source populations (CAP 2015). Similarly to jaguars, monitoring is required to examine population dynamics of pumas throughout Belize, and to establish how they are using the human dominated landscape to move between contiguous forest blocks. Due to pumas having a lack of reliable identifying features, studies must focus on presence/absence and distribution rather than abundance and individual distribution. Marking of a subsection of the population is therefore highly recommended to assure more in-depth population assessment.




Historic and current range of Puma (Puma concolor)

Main Methods of Monitoring

1. Initial sign surveys
2. Camera trap surveys
3. Scat surveys
4. Interviews with stakeholders concerning conflict, retaliatory killing and harvest of prey species
5. Investigation of puma-livestock conflict reports

Jaguars and pumas behave very similar in terms of space use. Both cats make extensive use of existing trails within natural areas (Harmsen *et al.,* 2010). Home range size and overlap are very similar between the two species. This means that monitoring effort and spatial distribution of camera traps would be similar for both species. A monitoring protocol for jaguars is also perfectly suited to pumas in terms of initial sign surveys, camera trap surveys and subsequent scat surveys.

The main disadvantage of monitoring pumas concerns their lack of uniquely identifiable external features, making surveys for abundance estimates with camera traps difficult. Long-term camera trap monitoring in CBWS has shown that short term individual recognition is possible in areas with high ecto-parasite loads due to the patterns established from botflies (unpublished data, Harmsen, Sanchez Foster). However, frequent images are needed to follow this throughout time (a gap of 3-4 weeks between captures of the same potential individual does not allow identification with certainty). Consequently, it is likely that only a small portion of mainly dominant male pumas can be followed within an area. Shyer and infrequently photographed females cannot be identified unless they have permanent scars or marks (e.g. kink in tails). The lack of reliable external identifiable features means that scat collection is vital for pumas, as DNA typing of scats will provide an individually identifiable feature.

Puma-livestock conflict appears rare in Belize and any instances will be noted within the jaguar-livestock conflict monitoring. It is therefore that this monitoring should simply be called “big cat-conflict monitoring” and thus will include conflict events for pumas. Frequently, the livestock owners do not know what kind of cat they are dealing with and the assume jaguars. Experts visiting recent livestock kill sites will be able to differentiate puma from jaguar signs (footprints, kill remains). Camera traps on conflict farms will further reveal visitation rates by both species. Current knowledge indicates that pumas are rare in the Belizean human dominated landscape and they rarely seem to prey on livestock (Foster, Harmsen &Doncaster 2010). A “big cat monitoring program” will confirm to what extend this is true and to what extend pumas kill livestock.

Any protocol for monitoring of pumas is therefore similar to protocols for jaguars with a higher need for scat samples to assure some level of individual identification.

### Additional methods complementing jaguar protocols

The main problem with following the jaguar protocols for pumas concerns the lack of data on individuals. This prevents rigorous statistical analysis on abundance, survival, turnover rates and residency. Accurate individual puma recognition from camera traps would greatly enhance the ability to monitor the species. In large scale US capture programs, a portion of the puma population is provided with ear-tags or identifiable neck collars. This has been shown to be an effective way of making individuals recognizable, with no ill effects on puma survival (Hornocker & Negri 2010). This method would equally be suitable for a large scale census in Belize. The capture program would provide additional information on size measurements, parasite samples and blood samples which would be used to establish general health and examine genetic variability of captured individuals. Individual identification would mean statistical methods could be applied to acquire estimates on abundance, survival, turnover rates and residency, using the marked portion of the population. Marking efforts should be concentrated within the two source populations with an emphasis on edges where marked individuals could potentially disperse. Trapping protocol would follow that outlined for jaguars earlier. We suggest the use of snares, already successfully used within Belize.

Additionally, if money allows, a portion of the puma population could be fitted with GPS collars to understand movement, but this is not the main impetus of the proposed capture program. In similar fashion to jaguars, high variation has been noted in Belizean puma ranges. This variation needs to be documented and understood to allow development of models concerning distribution and abundance of jaguars throughout the country.

## OCELOTS (LEOPARDUS PARDALIS)

Ocelots are the third largest cat in the western hemisphere, distributed from southwestern USA to Northern Argentina. Known to occupy a variety of habitat types, they show clear preference for dense habitats with well-structured vegetation cover (IUCN 2015). Ocelots are in general less well studied compared to their larger counterparts.

In Belize, ocelots have been extensively camera trapped for 12 years in CBWS, where they are known to exist in high densities even with the presence of the two larger cats. A telemetry study in the Chiquibul Forest Reserve in Belize reported home ranges of 19.8 ± 6.9 $km^2$ for males and 18.4 ± 4.2 $km^2$ for females (Dillon & Kelly 2008). The similar home range sizes between males and females indicate a potential deviation from normal feline spatial distribution systems, in which large male home ranges encompass several smaller females. Monitoring throughout management areas could provide more evidence of this unique behavior. Further, monitoring in CBWS has shown lower levels of overlap of ranges (although same sex overlap is still common) of ocelots compared to jaguars (unpublished data, Harmsen, Sanchez, Foster). This indicates higher levels of exclusivity territorial behavior.

Currently no diet studies have been conducted on Ocelots within Belize, however they are known to feed on a variety of prey species including howler monkeys, coatis, tamanduas, juvenile peccaries and deer, agoutis, pacas, opossums, armadillos, to smaller animals like birds, reptiles, amphibians, fish and insects (Hunter 2011). Interspecific competition is a large factor in ocelot distribution across Belize, facing competition from the big cats, coyotes and domestic dogs, which have all been known to opportunistically prey on ocelots (pers. observation, Harmsen, Sanchez, Foster).

The smaller home ranges of ocelots and their much securer food resources of rodents and birds creates a situation in which they likely have viable populations in areas where the more vulnerable larger cats cannot. Monitoring of ocelots at sites throughout Belize will show to what extend this hypothesis of higher resilience is justified.

Main Methods of Monitoring

1. Initial sign surveys
2. Camera trap surveys
3. Scat surveys

Ocelots have the similar advantage to jaguars in terms of their individually recognizable coat patterns. Camera traps have been the main method of surveying ocelot populations. Ocelots regularly walk trails and thus cameras placed for jaguars and pumas will capture ocelots. However, home range sizes of ocelots are considerably smaller and thus spacing of cameras needs to be much closer together if one is targeting this smaller cat.

## Camera Trap Surveys

### *Area size of study site*

Due to their smaller home ranges, 100km$^2$ is suggested as a suitable area over which to run a survey. This should provide enough individually recognizable individuals to satisfy statistical assumptions and allow estimation of abundance.

### *Distance between cameras*

The large spacing between camera traps within a jaguar/puma camera grid (2-3 km) could allow individual ocelots to live in between camera traps and remain undetected. However, data from Cockscomb indicates adequate recapture rates at multiple camera stations using 2-3 km spacing (unpublished data Harmsen, Sanchez, Foster). This indicates that the 2-3 km spacing could be used for abundance estimation of ocelots. Dillon & Kelly (2007) found however that the distance for ocelot sampling should be reduced to ≤ 1.5 km at a minimum. Potentially this could be area specific and based on local variation in home range size. It is therefore proposed that per area several "in between" camera stations will be inserted within the jaguar and puma camera grids. This will assure adequate sampling of ocelots for these locations with shorter distances and it can test the adequacy of 2-3 km spacing on an area by area basis.

### *Number of cameras needed for surveys*

Ten extra stations should be inserted between camera stations within proposed jaguar and puma survey grids. In this manner the distance will be reduced to ≤ 1.5 km for a cluster of a minimum of 3 cameras within these grids (the two outer and the middle). It can be studied if the shorter spacing results in significantly higher recaptures on multiple cameras. If these cameras are clustered within a single section of the grid, we can create a single smaller area for ocelot sampling.

### Ocelot information gained from jaguar/puma monitoring

A widespread camera grid designed for jaguars and pumas also detect ocelots at point locations without being able to know what lives in between the camera locations. This makes estimation of abundance difficult, but will allow the estimation of survival, residency and turnover rates. Scat surveys provide ocelot scats, but at a very low frequency.

There is very limited livestock-ocelot conflict and this is mainly confined to free ranging chickens. These incidences of limited conflict with domestic animals will surface within the big cat- livestock conflict surveys and monitoring program.

### Additional methods, complementing jaguar protocols

Area managers can decide to carry out more compact surveys (camera spacing ≤ 1 km) within the larger cat study areas so they can monitor ocelot abundance at specific intervals (yearly, bi-yearly, every 5 years). Survey length for such compact surveys should be 2-3 months to satisfy the closed population assumption discussed earlier.

## *WHITE LIPPED PECCARY (TAYASSU PECARI)*

Considered vulnerable under the IUCN red list (2013), white lipped peccaries' geographic range is confined solely to the neotropics. Primarily frugivorous, their wide ranging habits mean they can be found in several habitats, although this would primarily be tropical forested areas. A combination of hunting pressure and deforestation is causing peccary population numbers to decline on a global scale. Within Belize this is also the case, with peccary herds being forced into geographic areas they have never been found before due to habitat degradation.

The extremely large ranges of white lipped (WL) peccary herds, frequently exceeding ranges of jaguars, make them difficult to study using conventional survey methods. Although no data is currently available on home range sizes in Belize, telemetry based studies in other locations have found home ranges of up to 200km$^2$ (Fragoso 2004).

Their group living nature and gregarious foraging habitats by ploughing up the ground make them easy to detect when present in an area. However, due to their nomadic lifestyle they only remain within an area for a short period of time before moving to other foraging grounds. When study areas are (considerably) smaller compared to the peccaries total group range, surveys will result in sporadic but intense seasonal detection patterns. Such patterns have been noted within ~200 km$^2$ survey grids for jaguars. Anecdotal evidence from protected area managers shows similar seasonal detection patterns by ranger personnel.

Individual recognition of WL peccaries is not possible, making it difficult to assign individuals photographed to particular herds. This means there is currently no information on the number of herds or herd sizes within Belize. The information gathered from any survey is therefore limited to detection of presence. Any monitoring program for WL peccaries will require artificial permanent marking of a portion of the herd to obtain national estimates on number of herds, herd sizes, movement between herds (dispersal), movement within a study area and individual survival.

Main Methods of Monitoring

1. Initial surveys
2. Capture of a portion of the herd
3. Camera trap surveys
4. Interviews with stakeholders concerning conflict and harvest
5. Investigation of crop raiding and hunting
6. Monitoring of diseases

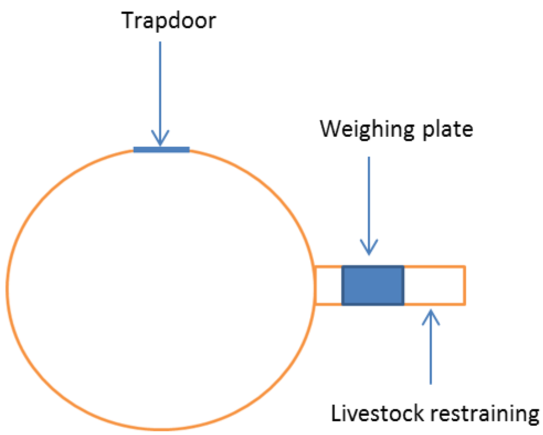
### Initial surveys

The first step is to interview the staff working in the management area and acquire location and seasonal timing of WL peccary sightings. After this initial assessment, cameras can be placed at these locations, with subsequent monitoring of up to a year. On the basis of these surveys, 3-5 locations will be chosen as potential reliable trapping sites. The sites will be chosen on the basis of accessibility and potential to attract WL peccaries. The sites will be baited with attractive food (e.g. cassava, corn, apples) and cameras will continually monitor the location. When it is established that some of these locations attract WL peccaries regularly at predictable times of the year, construction of trap sites can begin.

### Capture of individuals

As capture is essential for monitoring WL peccaries, the trapping procedure is described in more detail. WL peccaries can be captured in larger numbers using small sturdy fenced corral areas set up in their natural environment.

1) One or two of best baited sites will be converted into trapping sites. The choice of trapping sites will be based on high visitation rates and predictability.
2) A sturdy fenced corral area is built, containing a trapdoor and a livestock restraining funnel on one side. The funnel consists of a slues system of two doors allowing one individual to push in after the trapping team opens this first door. The funnel is so narrow that a peccary can only move forward and has no means of manoeuvring sideways. It should contain a weighing plate so individuals can be automatically weighed upon entering the funnel. The corral area should be built to hold a maximum of 20 individuals at one time.
3) The corral will be rebaited regularly with the same food items used successfully when bait sites were not fenced. The trapdoor is initially inactive to allow the peccaries to get used to freely moving in and out of the corral.
4) Rebaiting will coincide with the maintenance (battery / SD card change) of an infrared camera used to monitor the activity pattern of corral use by the peccaries.
5) Once the peccaries are comfortable using the corral, the trapdoor is activated and a trapsite transmitter is installed. At this point the trapping team needs to be available near the corral site monitoring 24 hours of the day, 7 days a week while the corral trap is active.The trapping team should monitor the trap site transmitters at hourly intervals and be close enough to the corral so they can be present within two hours maximum.
6) Triggering of the trap door will set off the remote VHF trapsite transmitter, indicating to the trapping team that they should respond to the trap with all equipment to process animals.
7) The first door of the livestock restraining funnel is opened and a peccary enters the funnel. The first door is closed, confining and restraining the individual inside the funnel.
8) Processing of the individual takes place; samples are taken (blood and parasites), the individual is weighed, and fitted with ear tags, to make the individuals recognisable.
9) The individual is freed through the second door. The first door is opened again after the second door is closed and the next animal enters the funnel. The process is repeated until all individuals in the corral are tagged and processed.




Top view of corral design with restraining funnel

## Camera trap surveys

After a section of the herd has become visually distinctive (i.e. through ear tags), cameras can be placed to ascertain presence of herds, recaptures rates and distribution of the marked individuals. In the jaguar section we argued that it is logistically not feasible to cover areas larger than 200-300 $km^2$. Previous studies have shown that jaguar camera grids pick up WL peccary presence reliably when they are present within the study area (Harmsen *et al.,* 2010). We therefore suggest maintaining a jaguar camera grid, to provide further data on WL peccaries after the addition of ear tags. The ideal survey length for monitoring WL peccaries would initially be year round, as this would provide the most complete dataset on their distribution and use of the study area. When presence and absence within the study area is better understood, camera surveys can coincide with periods of high use and be concentrated during these periods. Large herd sizes ensure a high capture probability of WL peccaries when present within an area. If logistically feasible, camera grids should be expanded to include as much of the herds ranges as possible.

## Estimating herd size

The described method above will provide knowledge regarding herd numbers and individual survival. It does not however provide clarification of herd sizes or variation in herd sizes. Knowledge of these variables is necessary to ensure estimation of population size. The field of view in front of cameras is too limited to allow such estimation. Peccaries walk in and out of the frame but it is unknown if it is the same individuals over and over again or new individuals. There are three methods that can be used for estimating herd size and both should be tested in different sites:

1) Deploy GPS and/or VHF collars on several herd members. This allows field staff to locate the herd through the tagged members. The field staff will, at several intervals throughout the year, carry out herd counts by visual inspection. These should preferably be done in more open locations and several observers should strategically be placed to avoid double counts and

missing of parts of the herds. This requires experienced staff and potentially a level of trial and error and confidence. The location of counting is crucial and open areas with bait would be ideal.

2) Inundate an area with video camera traps. Several cameras will be placed to cover all fields of views within a particular area known to be frequented by WL peccaries (again a more open bait site would be advisable). The field of views from the cameras should overlap to assure complete coverage of an area. In this manner a “map” can be build that allows counting of all the individuals present within the area. When individuals walk out of the frame of one camera they should be seen walking into the frame of the next. The use of this “video net” is not time specific (e.g we run the survey for 3 months). The cameras can be taken down as soon as a good “herd event” has taken place and the researchers are confident they got the edges and interior of the herd well covered. Survey time is therefore not restricted and could be short or small depending on the “herd event” taking place.
3) Use a conservation drone. These drones are mounted with cameras, giving an aerial view of the landscape. This would allow video footage of the whole herd from above, eliminating issues produced by cameras used at ground level. If one member of a herd was tagged with a GPS or VHF collar, the drone could be flown over the herd producing a reliable estimate of herd size. The collar will produce points which can be used as coordinates for the drone to locate the herd. Ideally the herd can be lured in open areas using baited sites.

### Interviews with stakeholders

WL peccaries are extremely visible when present in an area and thus vulnerable to hunting. Large herds can trample and eat crops and cause economic loss. Interviews would be the main instrument to understand levels of economic loss by crop farmers. The interviews can also provide information on the distribution and timing of presence of WL peccaries within the human dominated landscape. Retaliatory killing and hunting of WL peccaries should also be ascertained from interview data but requires a more sensitive approach. The conflict officer, (see section jaguars as this should be the same person) should monitor conflict and hunting of WL peccaries. Contact should be made with all the stakeholders and hunters should be regularly approached to acquire information and samples of hunting events.

### Investigation of crop raiding and hunting

Instances of crop raiding should be followed up with site visits. Damaged crops should be photographed and mapped carefully using handheld GPS. The damage should be related to the total amount of crop that is produced so an accurate estimate can be made of the percentage of the crop lost. It is important to understand the economic loss in relation to the remainder of crop. Such site visits should result in a yearly analysis of economic loss for the whole area. Hunter investigations should focus on asking about sightings of herds in time and space, as well as gaining estimates of herd sizes encountered. Offtake levels should be monitored carefully and hunters should be queried frequently concerning hunting of WL peccaries. Samples should be collected of hunted individuals. Hoofs would be a good candidate for samples as they are small and can indicate the size of the individual. Skulls are potentially too large for collection, but if possible should be collected. It should be emphasised that tags from marked individuals should be returned without any repercussions. Payment for tag returns should potentially be considered.

## Monitoring of diseases

There are indications that WL peccary are prone to domestic diseases, exacerbated by their herding behaviour which causes the rapid spread of any introduced pathogen. Therefore, pathogenic analysis of any tick and blood samples would be beneficial. If hunters are able to provide foot or skull tissue samples these could be analysed as well. Monitoring of pig and livestock pathogens within local buffer communities would be recommended. Partnering with the agricultural department is advisable.

PACA (CUNICULUS PACA)

The nocturnal Paca (*Cuniculuspaca*) is difficult to study due to its cryptic nature (Beck-King *et al.,* 1999). They live in self-constructed burrows or modified Armadillo (*Dasypusnovemcinctus*) burrows, where they remain during daytime (Eisenberg, 1989). They feed upon fruits, nuts and seeds and fulfil an important ecological role by dispersing seeds (Marcus 1984, Beck-King *et al*., 1999). Their importance is also reflected by the significant position they hold in the ecosystem; in some areas pacas represent as much as 16% of the total non-volant mammal biomass (Eisenberg *et al*., 1979). Pacas can also pose an important food source for predators like jaguars, pumas and ocelots, which often include the paca as main prey in their diet (Harmsen *et al.,*2010a,Foster *et al.,* 2010, Weckel*et al*., 2006).

The paca is endangered in some regions within Belize or even locally extinct (Perez 1992, Estrada *et al*., 1994). This is mainly because pacas are the most appreciated neotropical animals for bush meat. Additionally, their low reproductive rate, habitat loss and pest behavior in agricultural landscapes negatively affect populations throughout their range (Perez 1992). Pacas are an extremely good indicator species for human disturbance, being the most popular game species and widespread throughout the country. Therefore low population numbers can indicate high levels of human disturbance, especially considering pacas do not move large distances and thus recolonization of any area is slow. Temporary local extinction or reduction to extremely low densities will occur when hunting pressure is high.

Pacas are able to live in a variety of habitats as long as there is water nearby. An extremely useful feature of pacas, in terms of monitoring, is the spotted coat pattern, allowing individual recognition. This allows assessment of similar ecological parameters as jaguars and ocelots, due to the fact they can be counted.

Main Methods of Monitoring

1. Choice of plots
2. Initial surveys
3. Camera and burrow surveys
4. Camera and burrow surveys outside protected area
5. Interviews with stakeholders concerning conflict and harvest
6. Investigation of crop raiding and hunting

## Plot selection

Ranges of pacas are small, meaning that sampling should be done in a concentrated manner within small areas (e.g. camera stations need to be close together). However, abundance and range size might vary with varying resource availability (food, water, shelter) in space and time. To assure this variation in abundance is captured across the landscape, the environment must be sampled using independent sampling plots to estimate the variability in density/abundance within an area. We propose plot sizes of ≥ 6 $km^2$. This assures the inclusion of a minimum of 3 individuals considering maximum exclusive home ranges (unpublished data, Harmsen, Foster). Pacas have on average much smaller ranges and they are generally not exclusive (unpublished data Harmsen, Foster). We therefore expect that a 6 $km^2$ plot will generate detections of > 10 individuals under average Belizean habitat conditions. The plot sizes might have to be increased if this turns out to be too optimistic. If the habitat of the management area is uniform we propose the use of 3 independent sample plots within a study area of ~200 $km^2$.

If the managed area is highly variable in terms of habitat, this variation needs to be taken into consideration to understand abundance/density variation per habitat type. This requires stratified sampling with adequate number of plots per habitat type: 3 plots per habitat ≥ 200 $km^2$, 1-2 plot for habitat types spanning between 100-199 $km^2$, and 1 plot for habitat types < 99 $km^2$. Habitat types with < 20 $km^2$ should be discarded as insignificant unless important for special conservation reasons.

A random distribution of plots within the landscape would be ideal for statistical reasons, but to assure logistically reasonable monitoring plot choice location will be done on the basis of accessibility, independence between plots and access to water (small streams, rivers, lakes, lagoons).

### Initial surveys

The 6 $km^2$ plots will be rectangular shaped and located away from existing trail systems. A permanent access route will be created to each plot from the nearest existing trail. Each plot will be subdivided into 6 squares of 1 $km^2$, which will be demarcated by cutting thin boundary lines and marked with flagging tape. This marking should be relatively minimal so not to disturb or change the site. These lines will be used as the main arteries for moving to and within the plot. In the case of extremely dense vegetation, further subdivision might be necessary to assure accessibility. Each square will be thoroughly surveyed and mapped for topographical features (E.g Rivers, streams, slope and height). From here on the 6 $km^2$ plots will simply be called “plots” and the subdivided 1 $km^2$ squares called “squares”.

### Camera and burrow surveys

Two methods will be used to establish (relative) abundance of pacas:

1) Camera trap surveys, making use of individual recognition via flank spot patterns
2) Surveys for paca burrows, there is evidence that burrow counts are correlated to paca abundance (Euwe, 2015). Some studies suggest that these relationships only hold locally and cannot be extrapolated far beyond the habitats of study (Euwe, 2015). When solid relationships have been established between burrow count estimates and abundance at each site, camera trap studies will likely be phased out, as burrow counts offer a cheaper and quicker method of estimating paca abundance.

### *Camera trap surveys*

Two camera stations should be placed per square, requiring 12 camera stations for the total plot (6x2). Spacing between cameras should be ≥ 150m. The camera stations must be doubled to assure recording of both flank patterns of pacas, meaning 24 cameras per plot. Pacas are infrequently photographed on trails and are known to actively avoid wider open (trail) areas (Harmsen *et al.,* 2010). Therefore camera placement should be along smaller game trails, paths along streams and water bodies. Camera surveys should run for 2 months per plot. Depending on camera trap availability, plots will either be run simultaneously or sequentially. It has to be noted that simultaneous running of three plots would require (3x24)72 cameras.

### *Burrow surveys*

The logistical feasibility of burrow surveys depends on the amount of undergrowth within the sample plots. If undergrowth is sparse, squares can be searched almost completely. A group of 3-10 people walk in a straight line from one end of the square to the other, covering a strip as wide as the number of people within the formation. Usually people can see 5 meter on either side of their line of walking. This means that if people walk 10 meters apart and they can cover 30 – 100 meters per line sweep. Everybody in the line must stop when somebody spots a burrow to assure that the line formation is kept. When reaching the other end of the square, the line sweeps back covering the next strip of 30 -100 meters adjacent to the one that was just surveyed. To ensure people remain on a straight line, especially in dense habitats, it is crucial everyone carries a compass. If surveying in the directional north across the square, surveyors can follow the compass due north. The sweeping back and forth, the group can cover the whole area.

Having encountered a burrow, several measurements and types of data must be taken: digital photograph of burrow, measurement of height and width of hole. Further encountered burrows must be assigned to one of four categories based on their activity status; active, recently active, old, very old (Price and Rachlow, 2011). Active burrows contain fresh pellets, a trail towards the burrow, clearing of leaves at the burrow entrance, tracks and/or hairs (Beck-King *et al*., 1999). Recently active burrows contain weathered pellets, older clearings at the burrow entrance, a trail towards the burrow and/or old tracks. Old burrows contain no pellets, clearings, trails or tracks, and very old burrows also show partial collapse of the burrow. GPS locations of burrows should be taken, and locations marked with flagging tape to ensure burrows are not recounted.

If the undergrowth is very dense, the above method is virtually impossible and too time consuming. If this is the case transect lines that sample the squares instead of the total carpet search can be conducted. These transect lines need to be thin but can be made permanent. Creation of the lines within the squares is labor intensive but once created, used and maintained, surveys can be executed in a timely manner. Six transect lines of 1 km through the middle of each square would suffice (6 lines per plot).

Other methods that have been used in dense undergrowth are random line searches through each square, covering specific distances. Random paths are chosen in advance and roughly walked through each square. In this manner survey lines do not have to be maintained. One person with a machete clears obstacles and two surveyors walk behind. 6 random paths of 1km, per square, would suffice.

Due to uncertainty about seasonal variation in burrow numbers and use, it is proposed to initially carry out surveys twice per year. If variation is low in seasonal burrow detection, or at a minimum seasonally consistent, annual surveys will suffice.

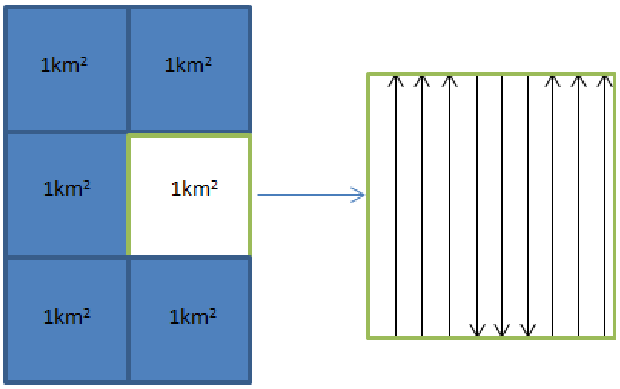



Diagram of the paca plot design and illustration of burrow search

### Camera and burrow surveys outside protected area

To investigate the response of paca abundance to decreased protection, survey activity should be extended outside of the managed area. Camera trapping within the surrounding areas can be considered, but the risk of theft should be taken into account. In this regard burrow surveys are ideal as they do not require the use of equipment. For comparability, the plots and their distribution should be similar to what is described above; 3 plots, spread out along the boundary lines of the protected area (≥ 1 km from boundary line). These plots can be sampled on an annual basis.

### Interviews with stakeholders concerning conflict and harvest

Pacas are the most important game species for Belize, especially commercially. Initial assessments indicate that offtake might not be sustainable (Foster *et al.,* 2016). It is therefore important to acquire data on harvest amounts in relation to population dynamics at a regular basis. The proposed format for monitoring hunting of WL peccary should be extended to paca hunting. A local conflict/wildlife officer investigates incidences of paca hunting among local hunters.

The solitary nature and small size of pacas means that they have minimal impact on crops and are thus not considered a major crop raiding pest species. However, they will still have a very minor role in economic damage to agricultural output and the officer should include pacas within their general enquires of crop raiding and keep systematic records regarding the subject.

### Investigation of crop raiding and hunting

The continued monitoring of paca hunting requires good relations between stakeholders and the conflict officer (described in the jaguar and WL peccary section). Hunting of pacas will be more frequent and less seasonal compared to WL peccary hunting. This means information gathering and record keeping for pacas should be more frequent and rigorous. When relations between officer and hunters are good enough, a system of self-record keeping by hunters is preferred. Hunters should receive some sort of incentive for keeping these records, which could potentially be monetary. Collection of body parts would again be the preferred means of keeping tabs on population offtake (skulls/feet), and could function to ensure the validity of any records hunters produce. The body parts can again provide morphometric data that can be used to draw conclusions on population structure. Skulls are highly sexually dimorphic and therefore can provide large amounts of information. The officer should collect this information at regular intervals (minimum monthly). If possible hunters should provide photo record of flank patterns of pacas so we know something about individuals being hunted.

Regular contact with stakeholders regarding crop raiding should always include pacas as a potential culprit species. It is unlikely that they will be a major factor but farmers should be aware that they are a possibility. The main concern with pacas as a species concerns their popular game species status.

Other species as detected on cameras and surveys

Jaguars, pumas, ocelot, white lipped peccary and paca are the main target species, but the proposed camera trap, sign and burrow surveys will pick up information on other species that should not be discarded. In this section we will name several important wildlife species (presented in alphabetical order) and indicate how proposed surveys will provide information on these species and how systematic record keeping can maintain a level of national monitoring.

### Armadillo (*Dasypusnovemcinctus*)

This medium size insectivorous species can be considered a game species and an important prey item for jaguars. They are likely very abundant and distributed widely throughout Belize. However systematic information on abundance and distribution is not available. Burrows of armadillos will be noted when carrying out paca burrow surveys. We should therefore extend these surveys to include armadillo burrows within the general framework of paca burrow. We should encourage more detailed study on the relation between burrow density and true armadillo density, potentially through a MSc or PhD study. In this manner the burrow survey counts could provide detailed abundance information on two species simultaneously.

Camera traps do note armadillo but capture rates of armadillo are a poor representation of armadillo abundance. The small size of armadillos and low profile means they walk underneath censor beams of camera traps placed for larger species. Capture rates are therefore more related to camera placement rather than abundance (width of trail, soil composition around camera etc). Potentially cameras placed within paca grids will be more suitable for photographing armadillos as these will be placed in denser vegetation habitats equally preferred by pacas.

### Brocket deer (*Mazamatemama*)

This relatively common tropical forest deer is data deficient but still frequently photographed on camera traps set for jaguar surveys. It is a relatively popular game species and as such a candidate for monitoring. Brocket deer are not individually recognizable and it is difficult to discern abundance information from camera data. More research is needed concerning if sheer camera trap captures rates represent abundance. The establishment of such a relation will require a mark-recapture study format of tagging deer, which will be relatively labor intensive. Although relatively crude, initially simple systematic record keeping of camera trap photos will reveal differences between monitoring sites and potential trends in population fluctuations.

### Collared peccary (*Pecaritajacu*)

Unlike the white lipped peccary, collared peccaries are considered common with a wide distribution in Belize. In relation to their apparent abundance, collared peccaries are photographed relatively infrequently (due to their avoidance of trails and thus trail cameras). As such camera traps are not a good means of monitoring this species. When combined with the fact that they are not individually recognizable, this creates a situation in which they are very difficult to monitor.

Photo capture records should be noted but will be of limited value in terms of trends. Any further study on the species should include marking of a portion of individuals within a study area. Marking of collared peccary can be included within the study of white lipped peccary; they will be attracted to the same bait as white lipped peccary and potentially frequent baiting corrals. Any chance of capture of this species within the monitoring of white lipped peccary should be opportunistically taken. Even limited photo capture records which include marked individuals will be valuable. Collared peccary will show up more frequently within paca camera grids, as such the presence of marked individuals will be more valuable within a cluster of paca grids.

### Tapir (*Tapirusbairdii*)

This large herbivore with relatively small home range size (~1 km$^2$; Foerster& Vaughan 2002) is frequently detected on camera traps. Some researchers have used wounds, scars and imperfections as individually identifiable features (i.e. Gonzalez-Maya *et al.,* 2009, Jordan & Urquhart 2013, Carbajal-Borges *et al.,* 2014, Naranjo *et al.,* 2015) and as such records from tapirs can be included within any monitoring program. When abundant in an area, camera studies for large cats accrue large numbers of tapir photos. It is likely that camera grids set out for jaguars and pumas will equally be useful for monitoring tapirs. Sheer capture rates will likely indicate relative abundance. Their ease of capture on camera with the potential ability for individual identification should be considered within a national monitoring program, especially considering its endangered status on the IUCN red list. Development of a national monitoring program should be explored within a PhD study format.

### Tayra (*Eirabarbara*)

The data deficient nature of this medium size mustelid warrants inclusion in any monitoring project. We propose to simply maintain a national database of records and monitor distribution and local trends.

### White tail deer (Odocoileusvirginianus)

Known to inhabit forest edges and savannahs, the white tailed deer has a limited range within Belize. The species is extremely popular as a game species and due to its restricted range is extremely vulnerable to overhunting. Although of limited conservation concern and actually considered a pest species in temperate climate countries, the white tail deer is in considerable trouble within Belize. It is therefore important to start monitoring programs within specific open habitat management areas. They are not individually identifiable and thus are difficult to study. At a minimum, maintenance of camera trap records at the national level should be considered. Similar to brocket deer, examination of whether sheer camera trap captures rates represent abundance could take place. Further specific studies, using specific camera grids in open areas using mark-recapture methods are recommended (although it must be noted this would involve capture and tagging of some of the population)

## *ANALYSIS OF SURVEY DATA*

The monitoring methods described above are proposed to allow wildlife managers to make informed decisions on policy and wildlife management, using methods that are both practical and cost effective. Data analyses need to result in accurate and precise population estimates which can reveal trends in population status of species over time, allowing timely intervention. In this section we will describe briefly and in broad terms how population status of the monitored species can be estimated.

### Camera trap data of individually recognizable species

Camera traps provide capture frequency of the different individuals of jaguars, ocelots and pacas per station, per survey period. The uniquely recognizable coat pattern allows use of mark-recapture (MR) models to estimate abundance. There are a multitude of mark-recapture models available. Through their individual marks we can follow individuals through time allowing us to estimate survival rates, movement in and out of areas and describe their general social structure.

#### *Estimation of abundance*

The main assumption for the use of MR models concerns the assumption of closure; no individuals will leave or enter the population during the assessment period (birth, death, immigration and emigration). It is for this reason survey periods are kept between 2 – 3 months. The downside of using these models concerns the need for an absolute minimum of 10 (+20 is more ideal) individuals to be captured, while at least half of these individuals require ≥ 5 recaptures. The more heterogeneous the recapture records, the less precise the estimates. Sometimes estimates become completely meaningless (e.g. we estimate that there are between 2-200 jaguars in this area). Study areas therefore need to be large to assure the

+10 detected individuals, while having a high enough density of cameras to assure sufficient recapture rates.

Recently spatially explicit models have been developed that make it easier to convert abundance into density. Density is the comparable unit of analysis between sites. However, there are issues with these types of models and they require equal or higher effort in terms of camera detections. The camera trap world of abundance and density estimation for wide ranging, low density species is currently in flux with a shift in paradigm. We work closely with the top analytical experts in the world to develop the most robust RM models to analyze our datasets. The proposed survey designs are however robust and will provide good enough data for estimating density and abundance.

### *Survival and movement estimates*

As jaguars and ocelots can live +10 years, estimation of survival rates is a long term affair. Paca longevity is shorter but poorly understood. Survival rates are calculated as the average chance for an individual to make it from one survey event to the next (annual survival in our case). Survival will likely fluctuate between sites and years, dependent on density (intraspecific competition), availability of resources and the chance of human induced mortality. Estimates of survival need to be precise enough to indicate trends over time. Robust Design open population MR models are the most likely candidates to estimate these variables. The top analytical experts are equally working on the production of improved spatially explicit open MR models.

Open population MR models will equally provide estimates of yearly movement in and out of study areas. These movement parameters can only estimate temporary movements, as there is no statistical difference between permanent movement out of the study area and a mortality event. Both indicate that an individual is not detected in the study area anymore. Permanent movement or dispersal events can only be studied by monitoring multiple populations and noting the level of exchange of individuals.

### *Dispersal and movement*

There are no statistical models currently available which can quantify permeability and movement between sites with confidence intervals based on rare detection events. Therefore these will be quantified through the maintenance of long term records. Each site should have a log book of detection histories for individuals. A database of the unique coat patterns of individuals from all sites will be shared nationwide among managers. Recognition software will be used to match new records of individuals with this national database and assess if these were detected at multiple sites (the animal pattern recognition software 'HotSpotter' is one we have found works well on the flank patterns of jaguars and ocelots). For pacas this will likely only happen between grids but for jaguars such exchange has already been noted between different protected areas (a young male moved from Cockscomb to Toledo).

## Camera trap data of species requiring tags for individual identification

Tagging of individuals (pumas and WL peccary) assures that similar analytical models can be used as described above. However, MR modeling can only make statistical inferences on the proportion of captures with marks. Extrapolation is necessary to the proportion of captures without markings. These models (commonly known as mark-resight models) are less powerful compared to full closed population MR models. The assumption is that the marked population is completely representative to the remainder of the detected individuals and this portion of the population would provide equal ratios of captures and recaptures. Survival and movement parameters can only be estimated for the tagged portion of the populations. The accuracy of mark-resight estimates increases with increasing numbers of tagged individuals. The mark-resight analysis format can be extended to species in which only a portion of the population is naturally recognizable, like tapirs. Here equally, only a portion of the population can be followed through time.

### Camera data for species using only capture rates

For species without any individual identification, the number of captures per unit effort can be used as a relative abundance surrogate. Effort for a survey is defined as number of cameras in a grid and the length of time they are operational. The number of captures from the cameras might not be reflective of abundance differences between sites. They could be an odd mixture of true abundance differences and differences in detection probability between sites (e.g. cameras were placed on better trails in one site compared to the other). It is for this reason caution should be taken if comparing between sites based on capture frequency alone. A better use of capture frequency is to analyze differences within sites over time, assuming stable detection probability. Capture frequency can be compared at two levels: 1) presence/absence at the different permanent camera stations (the more cameras detect a species the wider its distribution within the study area). 2) Average detection frequency per camera with standard deviation (higher averages mean higher use of the area, low standard deviations mean consistent use of the area). Finally, assessing the level of flux in capture frequency can inform about population trends.

### Genetic data from scats

Scats will be sent to foreign laboratories to extract the unique individual DNA sequences of the depositing individual. Genetic data therefore provides information on detection of individuals. MR models can be used on scat data if the search for scats is standardized and systematic (for example, searches need to be conducted on a weekly basis, along x number of trails, walking 5km transects etc). Only in this manner can detections of scats be considered capture and recapture events. We cannot use MR models if scat search is opportunistic. The number of individuals detected from scat searches is usually lower compared to camera trapping within a similar area. The MR model format for systematic scat searches will therefore be most useful for species lacking individual markers like pumas.

The main strength of genetic data lies in the assessment of population structure. Genetic data can reveal patterns of paternity and maternity and levels of inbreeding (similarity of genetic patterns between and within populations). Comparison between sites can reveal the level of genetic exchange or isolation and the subsequent changes in these variables over time. This means that it is imperative to maintain continuous genetic records over time to monitor long-term health of national populations.

### Data from burrow surveys

Regression analyses will indicate if there is a relation between burrow counts and paca abundance, as derived from camera trap and visual surveys. The strength and slope of the relationship will indicate if burrow counts can be used as a surrogate abundance estimate. We can only use burrow counts as an index if the relationship is strong (high $R^2$ value ≥ 0.5; meaning a proportion of the variance of burrow numbers is explained by variance in abundance of pacas). If $R^2$ is high enough, a function of the type below can be used as a correction factor, changing burrow count numbers into abundance:

paca abundance = intercept + (slope x burrow counts)

Standardization of burrow count protocols across sites is essential to establish a universal or site specific correction factor. Plot, grid sizes and search effort (line or area search) need to be similar across all sites. Only precise and accurate estimates of abundance can provide data for such a correction factor. Abundance estimates from burrow count correction factors will only tell something about the number of pacas and their trends over time. It will not indicate anything about individual survival, movement or dispersal. Only continued camera trapping can reveal these variables.

### Extrapolation (regional and national estimates)

So far, it has been described how to set up site specific monitoring programs and estimate important variables like abundance, survival and movement. Low detection rates and high effort means that such surveys can only be carried out at a few strategically chosen sites. To say something about national populations and its viability requires extrapolation from these sites to the regional and national landscape. It is therefore important that the chosen sites represent the landscape adequately in terms of habitat, food resources, human impact and topography. Using the site specific information we will use spatial models to estimate the abundance of the remaining landscape. New sites will need to be considered in cases of high uncertainty of value assignment. This means that in the future potential new monitoring sites need to be set up to fill gaps or deal with changes in land use. Using this method we will create GIS layers for the different monitoring variables across the country.

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## *APPENDICES*

## Data input

| A | B | C | D | E | F | G | H | I | J | K | L |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Survey site | Species | Sex | ID | Regional-suffix | Year 1st detection | Animal Side | Station | Camera Side | Camera ID | Dup | Recorder |
| TOL 2016 | Jaguar | M | M16-4 | TOL | 2016 | R | 16 | R | | 1 | RW |
| CBC 2016 | Puma | F | F12-8 | CBC | 2012 | L | 2 | R | | 1 | ES |
| CBWS 2016 | Ocelot | M | TRO2-15 | CBWS | 2015 | R | 5 | R | | 1 | RW |
| RBCMA 2016 | WL peccary | U | | | | NPD | 8 | L | | 1 | ES |
| SNR 2016 | Paca | U | | | | L | 3 | L | | 1 | RW |

A: Survey site & year: TOL = Toledo
CBC = Central Belize
CBWS = Cockscomb Basin Wildlife Sanctuary
RBMCA = Rio Bravo Conservation Management Area
SNR = Shipstern Nature Reserve

B: Species in photograph. Below see species names used for input. Use of inconsistent species names will result in faulty searches due to several names of the same species in the list.

- ☑ Agouti
- ☑ Bat
- ☑ Coati
- ☑ Copossum
- ☑ Cpeccary
- ☑ Crested guan
- ☑ Curassow
- ☑ Dog
- ☑ FEOpossum
- ☑ Gfox
- ☑ HNSkunk
- ☑ Hunter
- ☑ Iguana
- ☑ Jaguar
- ☑ Margay
- ☑ Mouse
- ☑ NBArmadillo
- ☑ NTArmadillo
- ☑ Ocelot
- ☑ Paca
- ☑ Person in unexpected place/time
- ☑ Person with dog, gun, kill
- ☑ Person with gun
- ☑ Person with kill
- ☑ Pjaguarundi
- ☑ Puma
- ☑ Raccoon
- ☑ RBDeer
- ☑ Snake
- ☑ Squirrel
- ☑ Tamandua
- ☑ Tapir
- ☑ Tayra
- ☑ Tinamou
- ☑ Unk
- ☑ Vehicle in unexpected place/time
- ☑ WLPeccary
- ☑ WTDeer

C: Sex (Male, Female, Unknown)
D: ID (jaguar, ocelot, tagged individuals)
E: Regional-suffix: Location where the individual was first detected.
F: Year 1$^{st}$ detection: The year the individual was first detected
G: Animal Side: Right, Left, NPD (direction the head in facing in the image)
H: Name of camera station (code provided for camera station)
I: Camera Side: Right / Left (side of camera on trail or path, orientation should always be going to the station not going back)
J: Camera ID: Number on camera
K: Duplicate: 1 or 2 (1 for first image, 2 for remaining images, i.e. with double sided stations), this is so one can easily filter in the document for unique events only choosing "1".
L: Recorder: Initials of person entering data

| M | N | O | P | Q | R | S | T | U |
|---|---|---|---|---|---|---|---|---|
| Date | Time | Time final photo | # of photos | Max Adults in 1 photo | Max Juvs in 1 photo | Adults in Event (est) | Juvs in Event (est) | # of animals |
| 3-Oct-16 | 11:36 | | 1 | 1 | 0 | 1 | 0 | 1 |
| 3-Oct-16 | 4:21 | 4:30 | 2 | 1 | 0 | 1 | 0 | 1 |
| 3-Oct-16 | 16:10 | | 1 | 1 | 1 | 1 | 1 | 2 |
| 3-Oct-16 | 21:30 | 21:50 | 22 | 7 | 3 | 22 | 4 | 26 |
| 3-Oct-16 | 18:41 | 18:45 | 3 | 1 | 0 | 1 | 0 | 1 |

M: Date: day/month name/year
N: Time: hr:min
O: Time final photo: If repeat images of same individual within 30minute event
P: Number of photos within 30 minute event
Q: Maximum number of adults in one photo
R: Maximum number of juveniles in one photo
S: Adults in event: Total number of adults that you estimate passed the camera within an event
T: Juveniles in event: Total number of juveniles that you estimate passed the camera within an event
U: Direction: Up / Down / NPD. Direction the individuals or herd is walking in.

| V | W | X | Y | Z |
|---|---|---|---|---|
| Still/Video | Direction | x-coord | y-coord | Comments |
| Still | U | | | |
| Still | D | | | changes direction |
| Still | U | | | mother with cub |
| Still | D | | | |
| Still | U | | | foraging in the area |

V: Still/Video: Photograph or video data
W: Number of animals in total in event (adult & juvenile)
X: X Coordinate of station
Y: Y Coordinate of station
Z: Comments

In the case of multiple recognizable or tagged species, separate lines should be created, recording the event of detection for each individual. E.g if jaguar M16-4 is detected together with female F12-8 both require a separate line. In this manner we can search for all animals detected. In the comments and number of animals in the line it should be made apparent that the individuals were photographed within the same picture.

## *Organizing data*

Folders of tagged and untagged images need to be created, organized by date of camera check, i.e.

**Untagged**

- Check 1 (13Jan16 – 13Feb16)
    - CAM46372
    - CAM46633
- Check 2(13Feb16 – 15March16)
    - CAM46372
    - CAM46633

Untagged folders are kept in case there are particular pictures that are suitable for publication. In this case a copy needs to be retained without the date and time tag on it.

Tagged folders must be labelled with station ID and side (R / L):

**Tagged**

- Check1 (13Jan16 – 13Feb16)
  - 16R_CAM46372
  - 8L_CAM46633

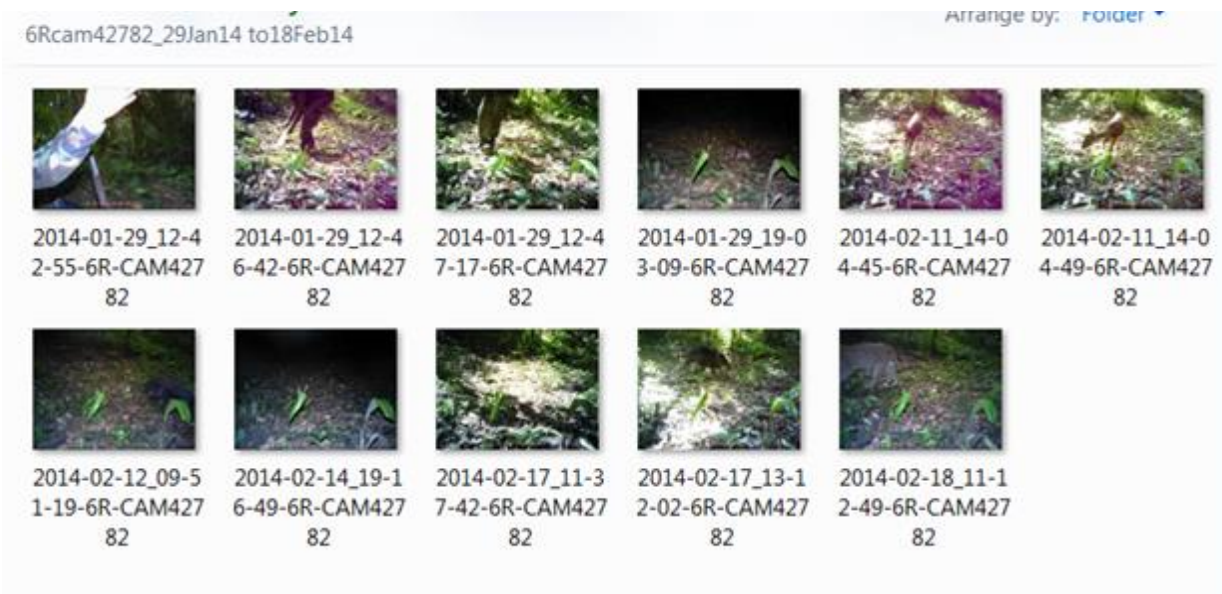
All tagged images of species (with date and time) should be put into species folders. This includes a folder for birds, which are NOT entered into the database, unless of special interest to your project. The reason for excluding birds concerns the high volume of common species like pigeons and the large amounts of work it would entail to include all of them. – see species names for the list and formatting of entering species.

For individually recognizable animals, subfolders must be created within the species folder with individual ID's:

- Jaguar
  - M16-4
  - F12-8

## Inputting trapping record

| | A | B | C | D | E | F | G | H | I | J | K | L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Station ID | Camera ID | Side | 13-Mar-15 | 14-Mar-15 | 15-Mar-15 | 16-Mar-15 | 17-Mar-15 | 18-Mar-15 | 19-Mar-15 | 20-Mar-15 | 21-Mar-15 |
| 2 | 1 | 40965 | L | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 |
| 3 | 1 | 42755 | R | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 4 | 2 | 42515 | L | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 5 | 2 | 42687 | R | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 6 | 3 | 42739 | L | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 7 | 3 | 42782 | R | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |




**TRAPPING EFFORT SHEET**

- Record camera functioning properly as a **Capture = 1**
- Record camera failure or no camera on that side as **No Capture = 0**
- **No pictures taken between two capture dates does not imply camera failure. It simply means that no animals passed in front of the camera. For example:** Acapture was taken on 29-Jan-14, no animals passed in front of the camera from 30-Jan to 10-Feb, but then a capture on 11th. Record 1 from 29-Jan to 18-Feb.
- **Camera Failure is determined by Field Check Photos.** Field check photo is 29-Jan-14 , No Field check after the last photo, therefore, camera failure and recorded capture as 0 after 18-Feb-14 until matched up with a field check photo date.

## Naming individually recognizable species

Check all images against national database. If a new individual it must be given an ID:

**Example: M16-4CBWS**

First letter stands for sex: **M**(ale), **F**(emale). If sex is unknown, first letter of species name is used; **J**(aguar), **O**(celot) etc.

Second is year of first detection, i.e. (20)**16**, (20)**17**

Third, the **4** indicates this is the fourth new individual captured this year.

Last is the regional suffix, which indicates the location the individual was **FIRST** imaged. For example, monitoring within Toledo may capture images of cats first imaged in CBWS, the survey site would indicate "TOL" but the ID and regional suffix of the cat would indicate CBWS.

Females and males are run separately, i.e. there can be an M16-4 and a F16-4.

**Example: FC16-5TOL**

'C' stands for cub, so this is the fifth female imaged in 2016, and it is a cub.

All individuals should have images of both flanks due to double stations, however, if only one side of the individual is captured the ID is different:

**Example: TLM1-16CBC**

First letter stands for **T**emporary (as only one side). Second letter stands for side of animal imaged; **L**(eft) or **R**(ight). Third letter is sex; **M**(ale), **F**(emale), **J**(aguar), **O**(celot) etc

For one-sided individuals the year is given last, with the number that individual was within the year first. Only when both sides of an individual have been imaged can the year and prefix be switched around, indicating a double sided individual.

*A high level of meticulousness and care must be given to this process to ensure accurate records, and avoid situations in which the same individual has two or more IDs.*

## Data sheets

LOCATION: **PACA BURROW SURVEY**

DATE: NAME OF SURVEYOR:

| | | Burrow Status | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Burrow Number | Photo ID | Active | Relatively Active | Old | Very Old | Height | Width | Depth | GPS Coordinates | Comments |
| | | | | | | | | | | |
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Notes (e.g. topographical features of the survey plot)

LOCATION:

## CAMERA CHECK SHEET

DATE: NAME OF SURVEYOR:

| Camera Station | Side (L/R) | Camera ID | Time of Arrival | Downloaded | Battery (%) | Time of Departure | Field Check Photo | New Camera ID (If switched) | Comments |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |
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Notes:

LOCATION:

**SIGN SURVEY SHEET**

DATE: NAME SURVEYOR:

| | Sign | | | Coordinates | | |
|---|---|---|---|---|---|---|
| Location(e.g. trail name) | Footprint | Scat | Scrape | X | Y | Comments |
| | | | | | | |
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Notes:

## Track ID


F
H
55
40
Jaguarundi:
toes splayed in front track
after a jump
F
H
85
80
Puma:
top of foot pad indented,
toe pads tapered,
almost pointed.
F
H
120
95
Jaguar:
foot pads broad, not
indented at top,
toe pads rounded.
F
H
35
35
Margay:
front and hind track
about the same size
F
H
58
50
Ocelot:
front track wider
than hind track
F
H
20
20
Long-tailed Weasel
F
H
60
Neotropical River Otter: 75
toes webbed
F
H
50
45
Greater Grison
F
H
55
55
Tayra
F
H
30
35
Nine-banded Armadillo
F
H
25
30
Central
American
Agouti
F
H
40
45
Paca
F or H
55
White-lipped Peccary
F
H
35
35
Collared Peccary
26
Red Brocket
F
H
20
20
Spotted Skunk
F
H
180
180
Baird's Tapir
F
H
35
35
Striped Hog-nosed Skunk
F
H
30
25
Gray Fox: claw marks
not always visible
F
H
40
50
Water Opossum
F
H
50
60
Common Opossum
F
H
45
45
White-nosed Coati:
long claws on
front foot; toe pads
separate from foot pads.
F
H
50
55
Raccoons:
long fingers continuous
with foot pad;
claws small,
may not show.

## SCAT COLLECTION INSTRUCTIONS

1. The scat collection kit contains: collection bags (ziplock), gloves, sharpie, masking tape, GPS unit and hand sanitizer.

3. When samples are collected record the following on masking tape over bag:

    a. Date: Format DD/MM/YYYY (letter)

    b. State whether it was “in scrape” or “no scrape”.

    c. Coordinates: Record both on GPS and on collection bag. On GPS name point same as on bag.

4. The naming of sample will be done in relation to date collected. Add letters at the end to differentiate samples collected on the same date. Letters will not run consecutively between dates.

    Eg. 18092015A, 18092015B, 18092015C, 19092015A, 19092015B

    *As samples will be used for DNA profiling, it is very important that gloves are worn whilst handling scats and collection bags. Extreme caution should be taken to ensure samples and the inside of the collection bags are not contaminated with human, or other, DNA.*

# TOLEDO COASTAL LANDSCAPE

The forest of coastal Toledo contains the last intact river systems of Belize, flowing through a natural environment from the interior of the Maya Mountains all the way to the coast. Wildlife currently still roams freely along these systems, moving from the Maya Mountains to the coastal forests. Currently there is still connectivity across the Southern Highway, as there are enough stretches of road quiet at night with connecting forests on both sides to allow animal crossings. However, development along this economic life-artery of the Toledo district will increase, making the Eastern Coastal plain forests more isolated from the large contiguous inland Forest patches of the Maya Mountains. Connectivity with the source population of the Maya Mountains is vital for maintenance of these coastal populations, especially for wide ranging species living at low densities like jaguars, pumas, white lipped peccaries and tapirs. Figure 1 shows the general area of the coastal plains of Northern Toledo.

The proposed monitoring program for the Toledo coastal landscape has therefore been designed to emphasize this connectivity aspect. Yearly or biannual surveys are required to show that individuals are still occasionally moving across the road, ensuring genetic exchange between populations. The larger river arteries are already a conservation priority for the local NGO's of TIDE and Ya'axche. This means that monitoring should focus on connectivity along the river and connectivity across the road in general, together with general population assessments of the coastal plain areas. Smaller more abundant species, like pacas and armadillos, will likely have self-sustaining populations within this coastal landscape. Monitoring here will therefore only reveal estimations of abundance, survival and movement within the coastal population. We will describe the camera trap deployment and burrow surveys and recommend the use of GPS collars to study movement within this landscape.

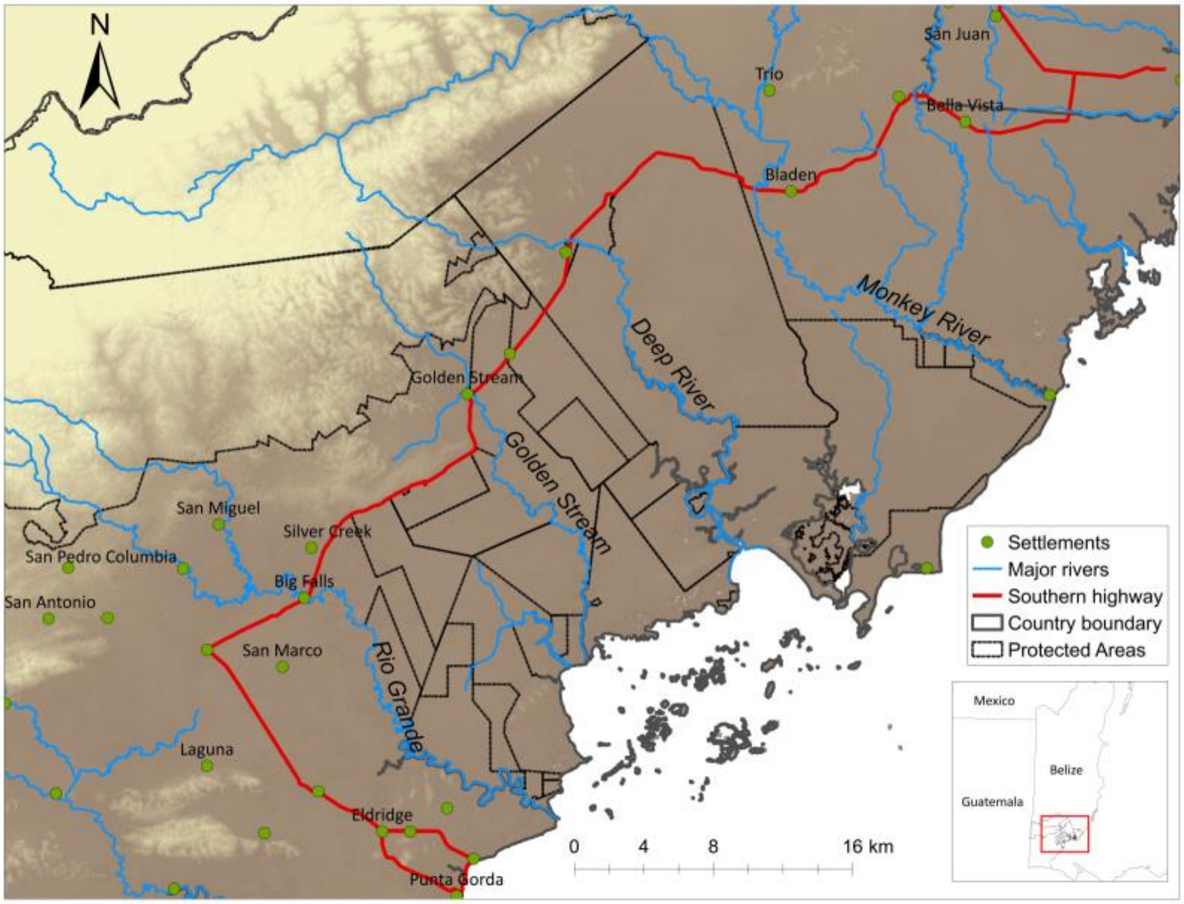


Figure 1. Monitoring area of Northern coastal Toledo

## Landscape level camera grid

A single large scale camera grid is proposed for monitoring jaguars, pumas, ocelot, white lipped peccary and tapirs. Monitoring of population dynamics of these species needs to be surveyed at the landscape level, allowing the use of a single grid to monitor all these species simultaneously. The difference between these species concerns their ability to use the rivers as corridors. Jaguars and tapirs are comfortable around rivers and will use them as travel routes and to forage along. Pumas, ocelots and white lipped peccaries are less comfortable around water but may use them when required. The landscape composition requires sampling along and between the major rivers. Sampling rivers and habitats on both sides of the highway will indicate whether individuals are crossing and to what extent they use the land in between the river systems.

The boundaries of the study area landscape are demarcated by the Monkey River and the Rio Grande with Deep River and Golden Stream both flowing through the middle of the area. The area of protected areas east of the highway encompasses 552 $km^2$ and can be broken up into 3 distinct areas through the roughly parallel flow of all 4 rivers. The Southern Highway dissects two reserves: Deep River Forest Reserve and Golden Stream Private Reserve. We developed a camera grid on the basis of landscape characteristics and the general methodology described above, using a rough camera spacing of ~3 km (maximum usable for jaguars, pumas and white lipped peccary). The rivers were used as transects running perpendicular to the east side of the road. Three imaginary transect lines are placed running east and parallel to the road creating a gridded box. Cameras were placed where road systems where known to be present. Where this information was lacking camera locations were randomly placed along the imaginary line. Twenty-eight camera stations spread across the landscape covering ~20 protected area blocks.

On the west side of the road a smaller grid system containing less camera stations (17) was developed. Instead of using three imaginary lines, this grid used only two running parallel to the road. This creates a camera grid of 45 camera locations, covering an area from Bladen Nature Reserve and Columbia Forest Reserve in the Maya Mountains to the Coast (Figure 2).

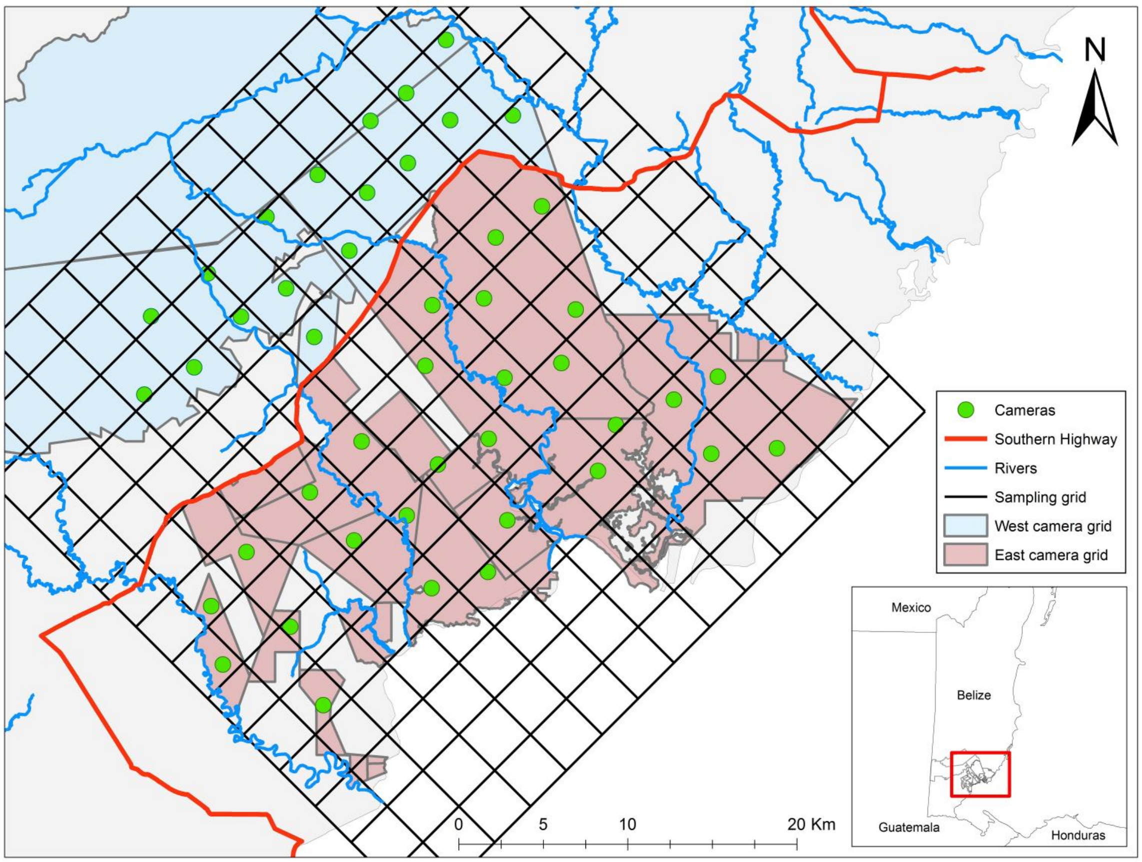


Figure 2. Proposed camera distribution for landscape monitoring of coastal zone of Toledo.

### Additions to camera grid

The distance between camera stations is mainly configured for jaguars, pumas and white lipped peccary, while being too large for tapirs and ocelot. Ten extra stations will be placed within this grid to assure sampling at higher density (see methodology section of Ocelots). We will assess if the additional cameras obtain a higher number of individuals of ocelots and tapirs and if the recapture rate between stations increases significantly. The decision can be made at later survey rounds to add or subtract these additional cameras based on their contribution to recapture and movement data. Figure 3 shows an example of the possible distribution of ten additional cameras.

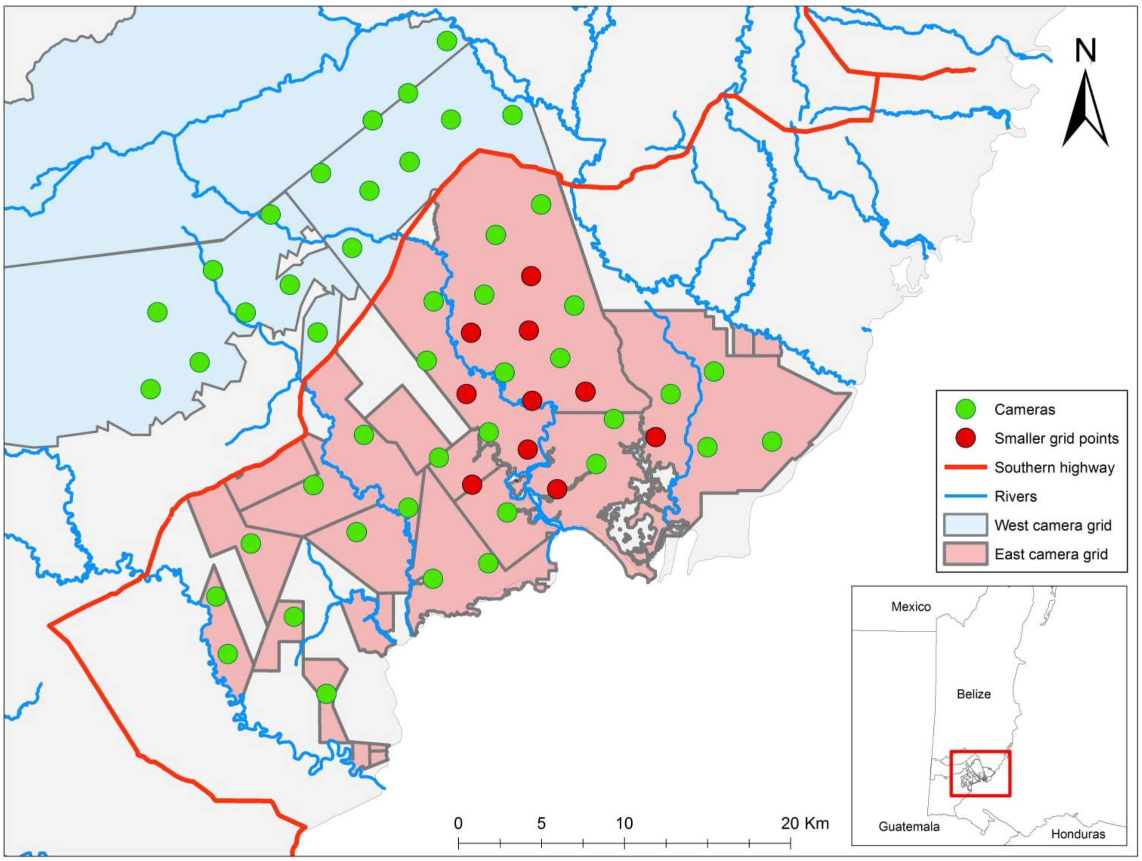


Figure 3. Example of adding 10 extra cameras to for species with smaller home ranges like tapirs and ocelots.

### Capture of pumas and jaguars

Camera trap data from the Toledo district has indicated that pumas suffer less exposure to ecto-parasites compared their conspecifics in the Cockscomb Basin Wildlife Sanctuary allowing limited individual recognizability (unpublished data, ERI/Panthera/TIDE/Ya'axche collaboration team). Although good for the general health of pumas, it means that they have even less distinguishing marks (see Methodology section pumas). The need for individual recognition therefore necessitates tagging of individuals. A regular but limited trapping operation will target the plain colored cats. We therefore need to establish good locations to trap pumas, using snares. Camera data can indicate which locations are most suitable for trapping. Trapping and tagging will therefore not happen until the second or third year of survey. In the meantime, a thorough assessment can be made of the individual recognizability of pumas in the coastal Toledo area and estimates can be made of the trapping effort necessary for reliable population assessment.

The use of GPS collars would greatly enhance our understanding of movement of jaguars and pumas across the highway, between the Maya Mountains and the coastal plain. Monitoring of movement will therefore be greatly aided by the presence of collared individuals in the landscape. It would provide valuable data on dispersal and general movement patterns across the landscape. While pumas are targeted for tagging for individual recognition, jaguars will be equally captured. Capture operations are expensive, labor intensive and require high expertise. It is therefore extremely useful to acquire the maximum pay-off of such operations. Deployment of GPS collars on jaguars and pumas would provide information on dispersal, movement patterns and could equally inform us whether the cats remain in wilderness areas, or if they turn into conflict cats, causing trouble on livestock farms. Young adult males will produce the highest amount of movement and are good candidates for collaring. Females will be prime targets for ecological study on population viability and cub survival. The deployment of 3-5 collars simultaneously should be strived for if funding allows.

### Capture of white lipped peccary

The coastal plain still has a healthy presence of white lipped peccary (WL peccary) and crossing of the highway still occurs (personal comment, Elmar Requeña). There is however no information available on number of herds, herd size and movement patterns across the coastal areas and crossing of the highway. Although the method of capture for WL peccary is different compared to jaguars and pumas, it is equally labor intensive, expensive and requires experienced personnel. Preparation of bait sites should happen after the initial survey has shown patterns of distribution and timing of presence. After the initial survey, 5 to 10 bait sites should be maintained, and over time reduced to 2-3 reliable sites maintained and monitored with infrared camera traps (see methods white lipped peccary). Preferably the first cohort of tagged WL peccary should be ready for the second survey to assure improved monitoring of particular individuals and herds over time. This means capture should happen in between the first and the second large grid camera surveys. The use of GPS collars should equally be considered to improve data on movement and landscape use, especially near the highway and vulnerable locations near villages and croplands.

Tagging of collared peccaries should be considered if they equally start entering the corral reliably. Collared peccaries are smaller and herds are therefore easier to handle. They will provide good local rehearsal for the larger numbers of target WL peccary.

### Monitoring of paca

Figure 4 shows a potential distribution of paca plots in accordance with the proposed paca methodology. The shown plots would require 60 camera stations, needing 120 cameras. The stratification according to habitat means that the different plots will be very different in terms of ability to move through and thus different in terms of ability to carry out burrow surveys. The choice of area search, straight line transect search or random line search needs to be considered after a thorough assessment on the ground in consultation with managers. Consistency and comparability are required across all sites within the area. This means the method will be chosen on the basis of the most difficult plots. Setting up of cameras, creation of infrastructure for plots and subsequent surveys should ideally happen in the first year of monitoring.

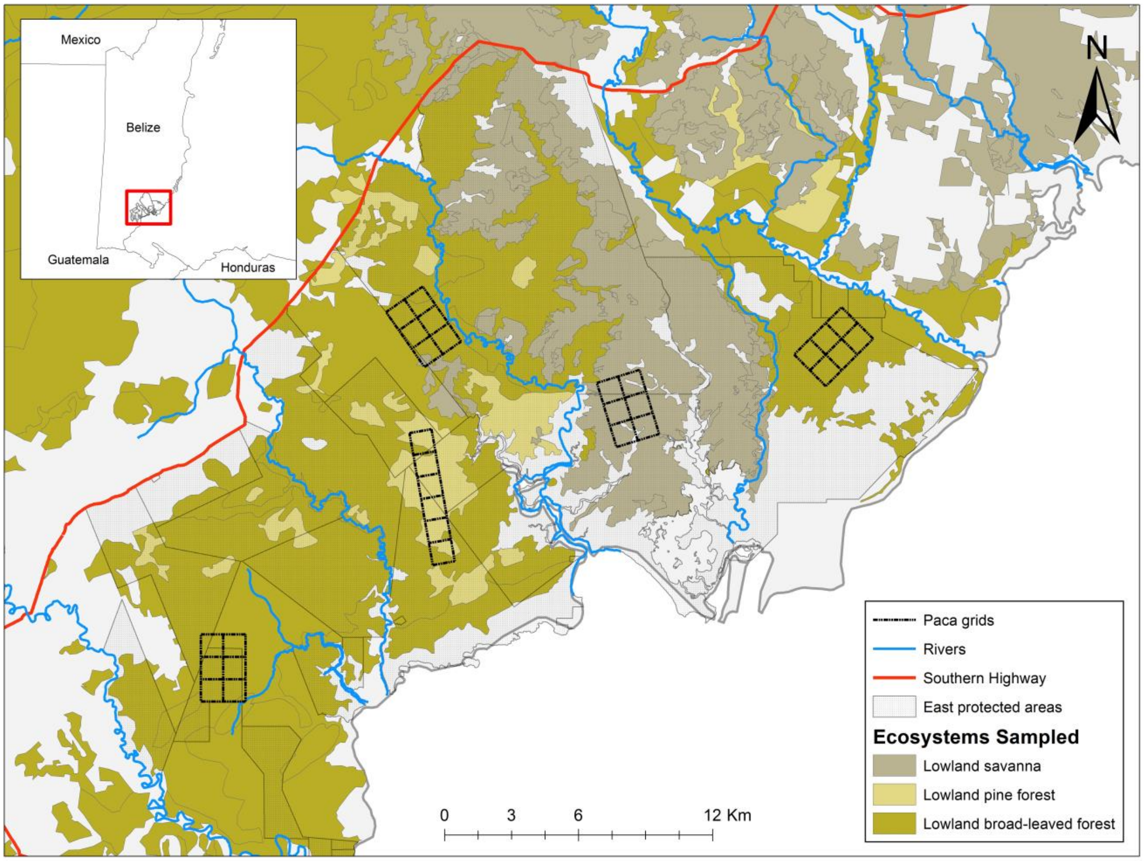


Figure 4. Proposed plots for monitoring pacas within the landscape of the coastal zone of Toledo.

## Human-wildlife conflict monitoring

The two main protected area managing organizations TIDE and Ya'axche need to assure that there is specific personnel assigned to monitoring of conflict situations. Ya'axche has experience with monitoring of jaguar-livestock conflict, but capacity to monitor this continuously and actively remain in contact with stakeholders is limited by other job requirements, fuel and vehicle limitations. For conflict monitoring to be effective, it must happen continually, with active visits to stakeholders and rapid responses to problems. It is essential that this conflict team has permanent access to a vehicle and fuel.

Livestock and crop farms need to visited and farmers interviewed. Contact must be continuously maintained and camera traps made available. We propose the availability of at least 25-35 cameras for this sole purpose with 15-20 cameras continuously running on and around farms with the highest chances of conflict. 10-15 cameras should be retained for immediate response to calls of conflict. The officer (or officers) should remain in close contact with the responsible wildlife officer at the Machaca Forest Station and regularly meet to assure close communication with the Belmopan head office wildlife officer. Regular meetings with conflict officers around the country should be maintained to assure a national network.

### Monitoring outside of protected areas

The strip of unprotected human dominated landscape is very narrow within the Toledo coastal landscape. It is confined to the middle area around the highway and one single block of the agricultural Mennonite community of Pine Hills. Systematic monitoring is not possible within the Pine Hill community; efforts will therefore focus on the communities along the highway. This area splits the study site completely in half, and if intensified and expanded threatens major disruption to wildlife ecosystem functionality. The current strip is not wide enough to warrant equal intensity of monitoring inside and outside of the protected area. It is therefore proposed that monitoring within this landscape will be entirely managed by the conflict officers who will distribute cameras within this landscape. The conflict officers will therefore have a higher number of cameras at their disposal compared to other landscapes within Belize. If relations are good the officers and communities can decide to start a paca monitoring program with the potential for a sustainable harvest program. This will however require good relations and long-term trust and contact.

### Monitoring of domestic animals

The human dominated landscape cuts the wildlife management zone completely in two halves. Domestic animals living in communities along the Toledo highway therefore have a more extensive contact zone with the protected areas on either side of the road. Monitoring of diseases within dogs and livestock is therefore important. Ticks will be collected and sampled from dogs and livestock from all villages on a yearly basis (see methods section). Pigs are the main livestock species within the area and blood samples should be collected for pathogens, which could potentially be transferred to WL peccary. Dogs should be equally tested for mange and blood samples taken to test for other carnivore diseases.

Camera traps will detect domestic animals, allowing the calculation of frequency and distribution of incursions. The further study of dogs as potentially competitors carnivores preying on wildlife should be considered if incursions are frequent and widespread (e.g. use of cheap store on board GPS collars for known culprits based on camera trap data, see method section).

## COCKSCOMB BASIN WILDLIFE SANCTUARY

The Cockscomb Basin Wildlife Sanctuary covers ~425km$^2$ of protected secondary tropical moist broad-leaf forest. It lies on the Eastern side of the Maya Mountains, the largest contiguous forest block in Belize (Figure 5). CBWS has a high density of waterways, especially compared to the bordering western forest blocks of Chiquibul and Mountain Pine Ridge. Before CBWS was declared protected in 1984, areas had experienced intensive logging which created the trails currently used to deploy cameras. CBWS has been managed by Belize Audubon Society (BAS) since its conception in 1984.

CBWS has been shown to have one of the highest densities of jaguars globally, at ~10 individuals per 100km$^2$ (Harmsen et al 2010a). A stable puma population also exists, although at lower densities than jaguars (Harmsen et al 2010b). CBWS is one of several protected areas within a contiguous forest block called the Maya Mountains. This largest forest block in Belize contains the most important source populations of jaguars and pumas. Individuals move within this forest block, as well as dispersing out towards other forest blocks like the RBCMA in the North, the coastal plains of Toledo or the North Eastern forests of Orange Walk and Corozal. These movements are vital for the genetic exchange between the populations allowing the maintenance of a healthy Belizean meta-population.

As CBWS is already home to one of the longest monitoring programs for jaguars and pumas, the proposed monitoring program has been designed to assist the established program. In building up a long-term data set, questions can to be answered about survival, fecundity and other essential ecological and population dynamics. Long-term sites with stable populations like CBWS and RBCMA will be used as methodological testing grounds.

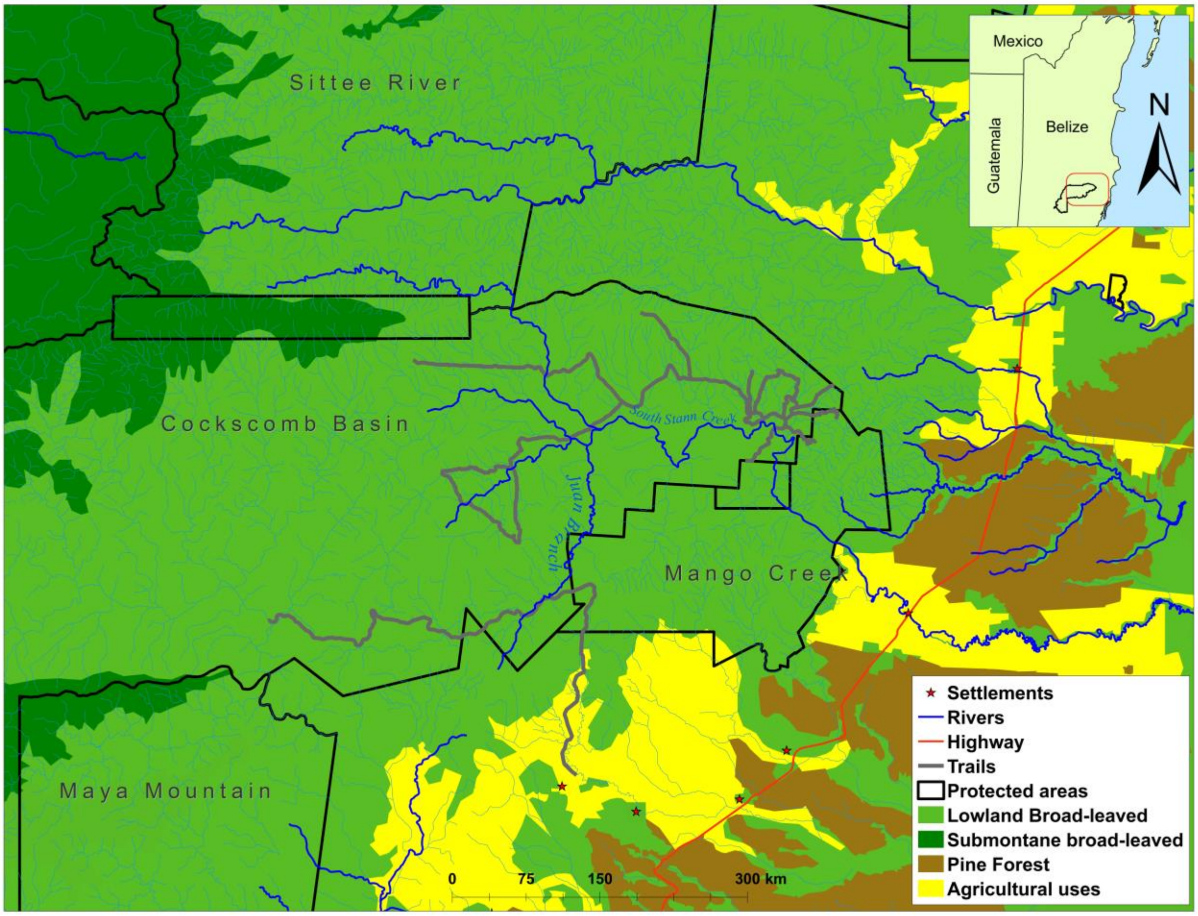


Figure 5.Map of Cockscomb Basin Wildlife Sanctuary

Landscape level camera grid

There are two types of camera grid proposed for simultaneous monitoring of jaguar, puma, ocelot, white lipped peccary and tapir. These could either be run simultaneously (if not constrained by equipment levels, e.g. cameras) or be alternated between years.

The first camera grid proposed utilizes the extensive trail system of old logging roads present at CBWS (Figure 6). Twenty-two camera stations have been chosen which encompass an area of ~200km$^2$ (the area needed to capture enough jaguar individuals to satisfy statistical rigor in mark-recapture models). The cameras are spaced ~3km apart (the maximum useable for jaguars, pumas and white lipped peccary). Using the trail systems should ensure high enough capture rates of the target species, but may lead to male biased records (Harmsen, Foster &Doncaster 2010). This leads to the second proposed camera grid.

The second camera grid has been designed to utilize the extensive river system present within CBWS. Cameras will be deployed along the South Stann Creek, Juan Branch, Mexican Branch and Sittee Branch, as well as along the smaller creeks that diverge of from these main branches. Twenty-one camera stations have been chosen, spaced ~3km apart, encompassing an area of ~200km$^2$ (Figure 6). Jaguars often move through the landscape via the river systems, and as such it is hoped that this camera grid will provide less biased records of individuals (i.e. identify more resident females).Tapirs are also comfortable around water and often forage along rivers. Puma, ocelot and white lipped peccary are less comfortable around water, but will use rivers when necessary. By alternating camera grids each year (i.e. the first year use the trail system survey, second year river system survey, third year trail system survey etc) a more complete view of the population dynamics of each of the target species can be inferred from the data.

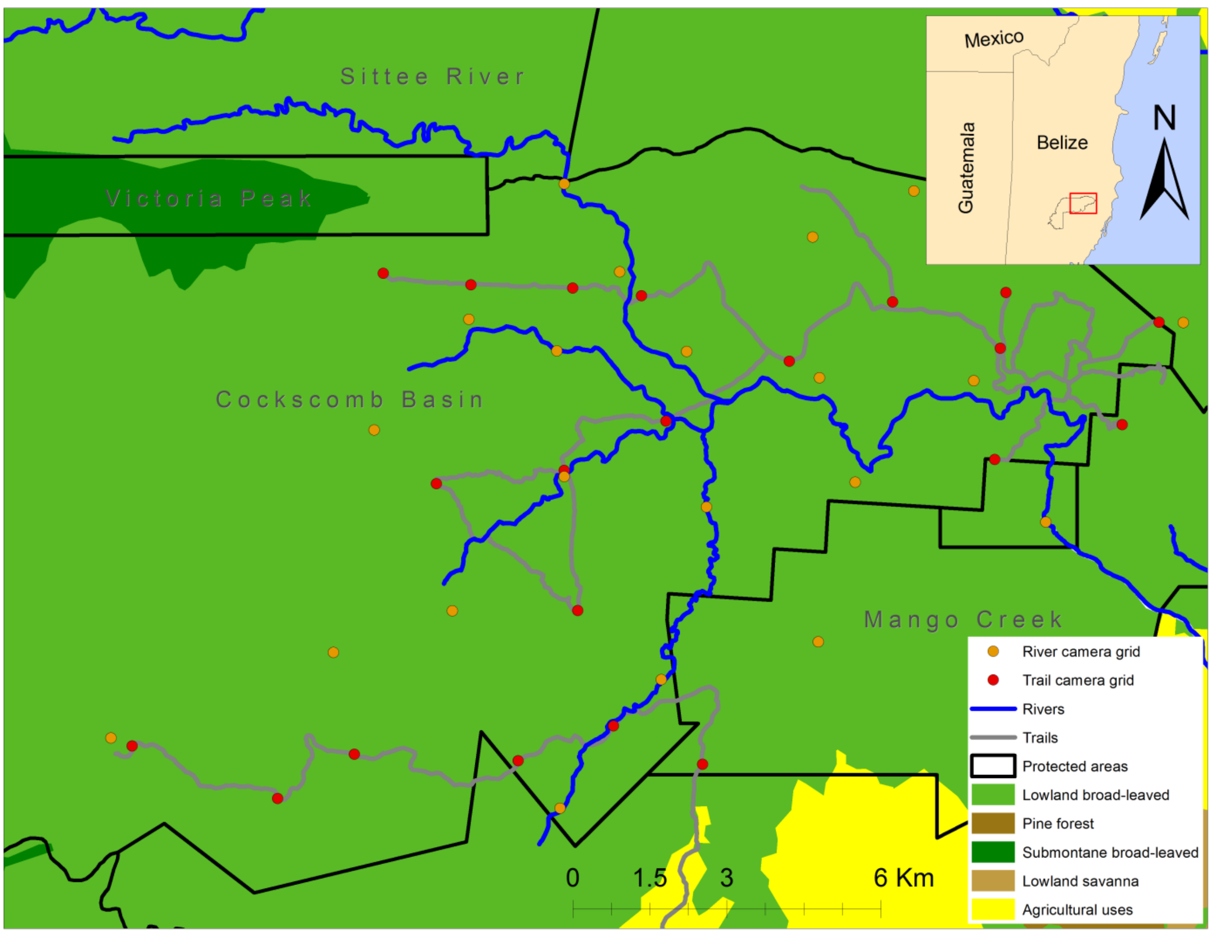


Figure 6. Proposed camera grids for monitoring within Cockscomb Basin Wildlife Sanctuary

## Additions to camera grid

The distance between camera stations is mainly configured for jaguars, pumas and white lipped peccary, while being too large for tapirs and ocelot. Ten extra stations will be placed within this grid to assure sampling at higher density (see methodology section of Ocelots). We will assess if the additional cameras obtain a higher number of individuals of ocelots and tapirs and if the recapture rate between stations increases significantly. The decision can be made at later survey rounds to add or subtract these additional cameras based on their contribution to recapture and movement data. Figure 7 shows an example of the possible distribution of ten additional cameras. Additional cameras will only be placed on the trail system grid, as this is likely to have a higher capture rate of ocelots than the river systems grid.

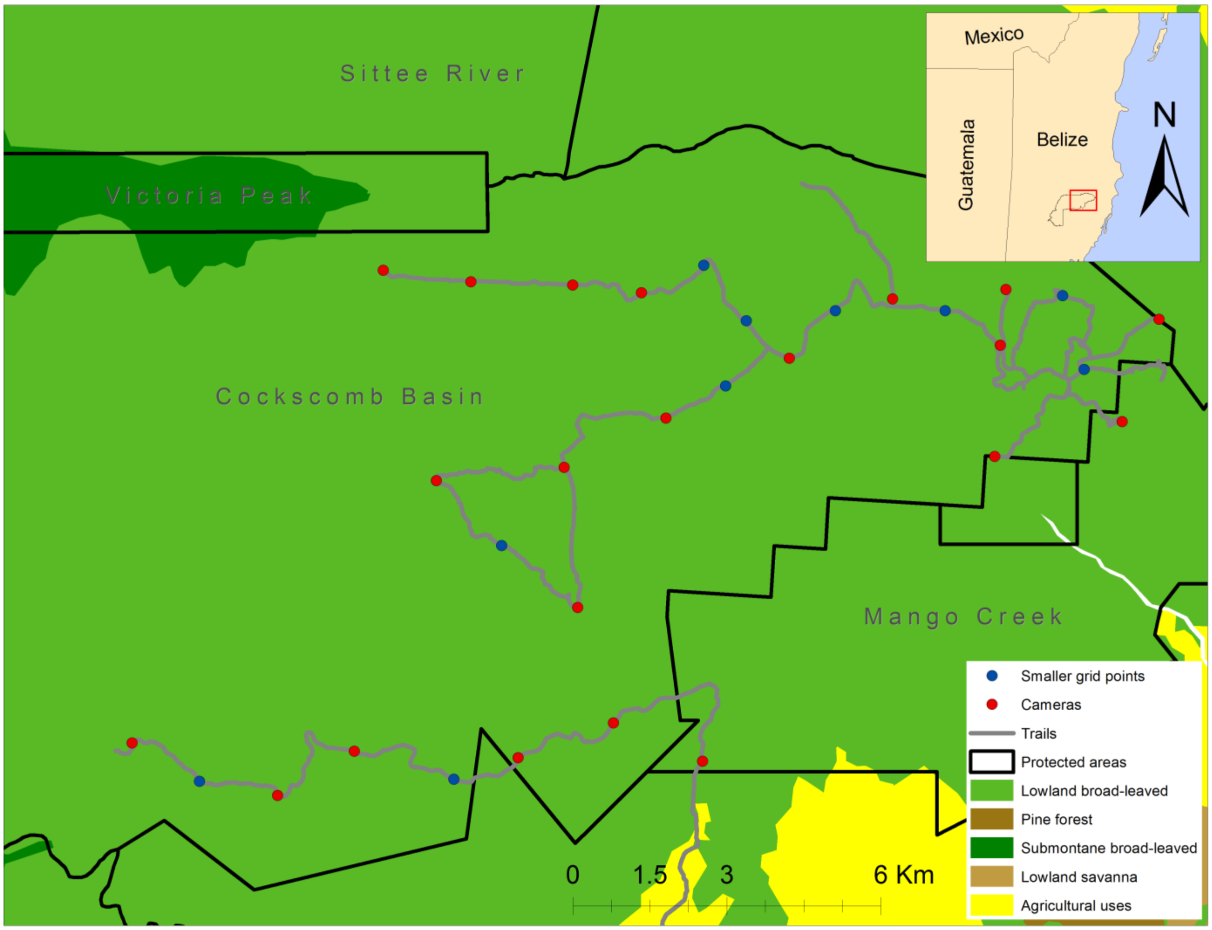


Figure 7. Example of adding 10 extra cameras for species with smaller home ranges like tapirs and ocelots.

## Capture of pumas and jaguars

Long-term camera trap monitoring in CBWS has shown that short term individual recognition of pumas is possible in areas with high ecto-parasite loads due to the patterns established from botflies (unpublished data, Harmsen, Sanchez Foster). However, frequent images are needed to follow this throughout time (a gap of 3-4 weeks between captures of the same potential individual does not allow identification with certainty). Consequently, it is likely that only a small portion of mainly dominant male pumas can be followed within an area. Shyer and infrequently photographed females cannot be identified unless they have permanent scars or marks (e.g. kink in tails). To understand population dynamics both male and female need to be followed over a reasonable length of time, which is not possible using ecto-parasite patterns. The need for individual recognition therefore necessitates tagging of individuals. A regular but limited trapping operation will target the plain colored cats. As there has already been monitoring within CBWS for a number of years which has established good locations for trapping pumas (with success in trapping pumas) trapping and tagging of individuals could start within the first year of the survey.

The use of GPS collars would greatly enhance our understanding of movement of jaguars and pumas within the Maya Mountains, and dispersal from these forest blocks across the human dominated landscape to other populations (e.g. Toledo coastal plains). Monitoring of movement will therefore be greatly aided by the presence of collared individuals in the landscape. It would provide valuable data on dispersal and general movement patterns across the landscape. While pumas are targeted for tagging for individual recognition, jaguars will be equally captured. Capture operations are expensive, labor intensive and require high expertise. It is therefore extremely useful to acquire the maximum pay-off of such operations. Deployment of GPS collars on jaguars and pumas would provide information on dispersal, movement patterns and could equally inform us whether the cats remain in wilderness areas, or if they turn into conflict cats, causing trouble on livestock farms. Young adult males will produce the highest amount of movement and are good candidates for collaring. Females will be prime targets for ecological study on population viability and cub survival. The deployment of 3-5 collars simultaneously should be strived for if funding allows.

### Capture of white lipped peccary

Whilst CBWS appears to have a healthy population of white lipped peccary (WL peccary), there is no information available on number of herds, herd size and movement patterns within CBWS. There is also no information on whether herds move between forest blocks within the Maya Mountains (e.g. from Chiquibul to CBWS or CBWS to Bladen) or from CBWS to the coastal plains of Toledo.

Although the method of capture for WL peccary is different compared to jaguars and pumas, it is equally labor intensive, expensive and requires experienced personnel. As the pattern of distribution and timing of presence at locations is largely known within CBWS, 2-3 bait sites should be chosen before the initial survey and baited throughout and monitored with infrared cameras (see methods white lipped peccary). The first cohort of WL peccary should be tagged before the end of the initial survey. Otherwise this can take place before the second survey to assure improved monitoring of particular individuals and herds over time. The use of GPS collars should equally be considered to improve data on movement and landscape use, especially between the forest blocks which make up the Maya Mountains.

Tagging of collared peccaries should be considered if they equally start entering the corral reliably. Collared peccaries are smaller and herds are therefore easier to handle. They will provide good local rehearsal for the larger numbers of target WL peccary.

### Monitoring of paca

Figure 8 shows a potential distribution of paca plots in accordance with the proposed paca methodology. The shown plots would require 18 camera stations, needing 36 cameras. Within the eastern lowland block of CBWS, the habitat consists mostly of only lowland broad-leaf forest, therefore only requiring 3 paca grids. However, the terrain may prove difficult to move through and thus carry out burrow surveys. The choice of area search, straight line transect search or random line search needs to be considered after a thorough assessment on the ground in consultation with managers. Consistency and comparability are required across all sites within the area. Setting up of cameras, creation of infrastructure for plots and subsequent surveys should ideally happen in the first year of monitoring.

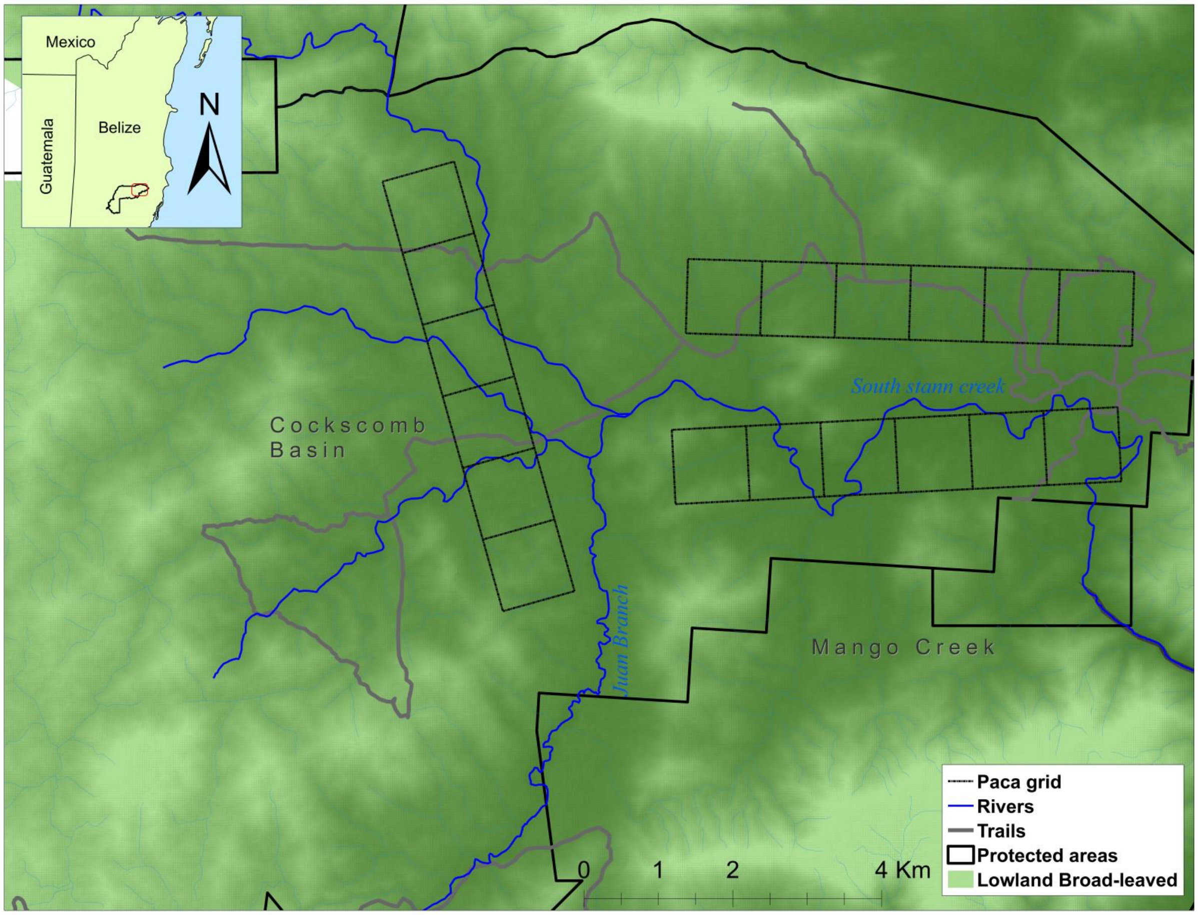


Figure 8. Proposed plots for monitoring pacas within Cockscomb Basin Wildlife Sanctuary

## Human-wildlife conflict monitoring

CBWS is partially buffered from human development to the East by a band of unprotected forest. Beyond this lies a mosaic of cattle pastures, milpa farms and villages with the highway running North-South. Historically the surrounding area suffered high levels of human-wildlife conflict, which is likely still true; however there has been a lack of monitoring of cat-livestock conflict in the area surrounding CBWS. Specific personnel must be assigned to monitor conflict situations around CBWS. A conflict officer should be employed through BAS to monitor conflict and wildlife distribution outside of CBWS. For conflict monitoring to be effective, it must happen continually, with active visits to stakeholders and rapid responses to problems. It is essential that this conflict team has permanent access to a vehicle and fuel. A BAS conflict and monitoring officer or team would be able to maintain the ongoing field research activities.

Livestock and crop-growing farms need to be visited and farmers interviewed. Contact must be continuously maintained and camera traps made available. We propose the availability of at least 15-25 cameras for this sole purpose with 5-10 cameras continuously running on and around farms with the highest chances of conflict. 5-10 cameras should be retained for immediate response to calls of conflict. Regular meetings with conflict officers around the country should take place to assure communication within an active national conflict network.

### Monitoring outside of protected areas

The relatively large band of unprotected forest to human dominated landscape provides an interesting area to study edge effects and comparisons between protected and unprotected areas. Understanding the impact of human extraction and harvest on the system would be ideal in this area.If possible, one or two paca grids could be established in the area surrounding CBWS.

### Monitoring of domestic animals

The Maya Center village is the closest to CBWS and there is evidence of incursions by dogs from the village into CBWS. Monitoring of diseases within the dogs located within the Maya Center should take place, with testing done on a yearly basis for ticks, mange and blood samples taken to test for other domestic carnivore diseases.

Camera traps will detect domestic animals, allowing the calculation of frequency and distribution of incursions. Further study of dogs as potential competitor carnivores, preying on wildlife should be considered if incursions are frequent and widespread (e.g. use of cheap store on board GPS collars for known culprits based on camera trap data, see method section).

## CHIQUIBUL AND MOUNTAIN PINE RIDGE

The Chiquibul is the heart of the Maya Mountains and the only monitored area on the Western side of the Maya divide. The area is more sparsely inundated with rivers and streams compared to areas on the Eastern side of the divide. The level of incursions and illegal activity means that wildlife numbers are likely lower compared to the more protected areas on the Eastern side of the divide. Monitoring is therefore a vital component. The area was monitored by Virginia Tec University (VTC), Dr. Marcella Kelly between 2002 and 2008. Monitoring had to be abandoned due to high amounts of camera theft and safety issues. However, whilst monitored there was evidence of decreasing wildlife population densities, which were consistently lower than population levels on the Eastern side of the divide, in areas such as CBWS. Currently the area is managed by Friends for Conservation and Development (FCD) and security has been increased within the area. It is important to start gathering data from this area again.

The Mountain Pine Ridge (MPR) area is adjacent to the Chiquibul. This area consists of higher altitude Caribbean Pine with a small section of broadleaf forest mostly found on the western boundary. It has a few streams flowing through valleys and a logging road system making relatively accessible. Monitoring has been consistent since 2006 by Virginia Tec University, Dr. Marcella Kelly. Densities of wildlife are lower within this area compared to other areas within the Maya Mountains such as Chiquibul and CBWS. It is however vital to understand the importance of more marginal wildlife habitat and to what extent individual jaguars, pumas and white lipped peccary herds occupy the area continuously. Comparison of abundance, distribution and survival of populations between habitat types can help inform management decisions for conservation plans and help inform us of the ecological needs of a species for long term survival of healthy populations.

The partnership with Virginia Tec remains necessary to maintain cameras within these two areas.

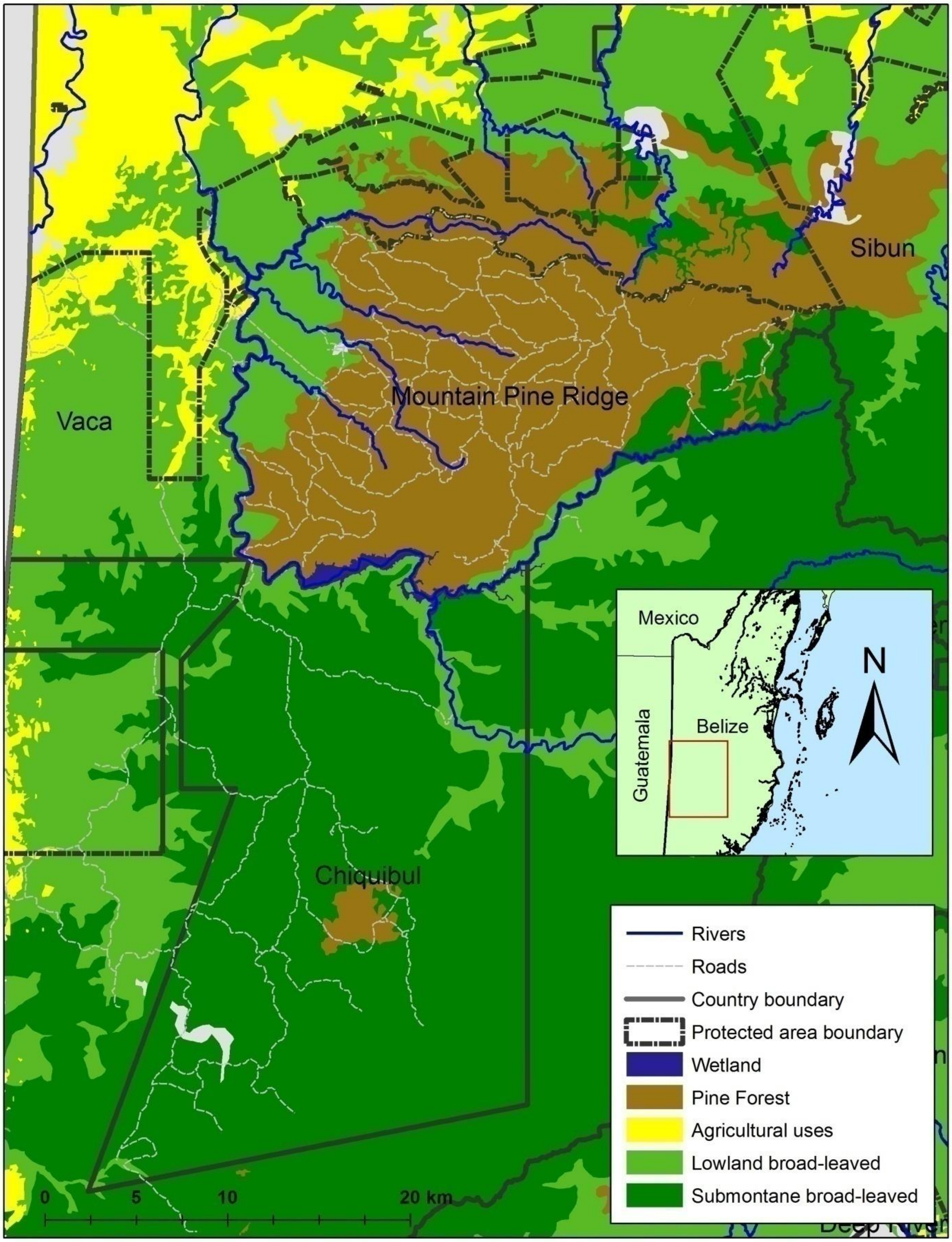


Figure 9. Monitoring area of the Chiquibul and Mountain Pine Ridge

### Landscape level camera grid

The proposed camera grids are based on historic camera locations from Virginia Tec, Dr. Marcella Kelly. Figure 10 shows the camera locations for Chiquibul (36 stations, 72 cameras). The biological field station of Las Cuevas is the center of this survey and can be used as a base. The MPR survey consists of 39 stations, 78 cameras (Figure 11). These stations are currently being used by VTC, Dr. Marcella Kelly for her annual surveys. The MPR survey makes use of the network of logging roads throughout the area and the Forestry station can be used as the base.

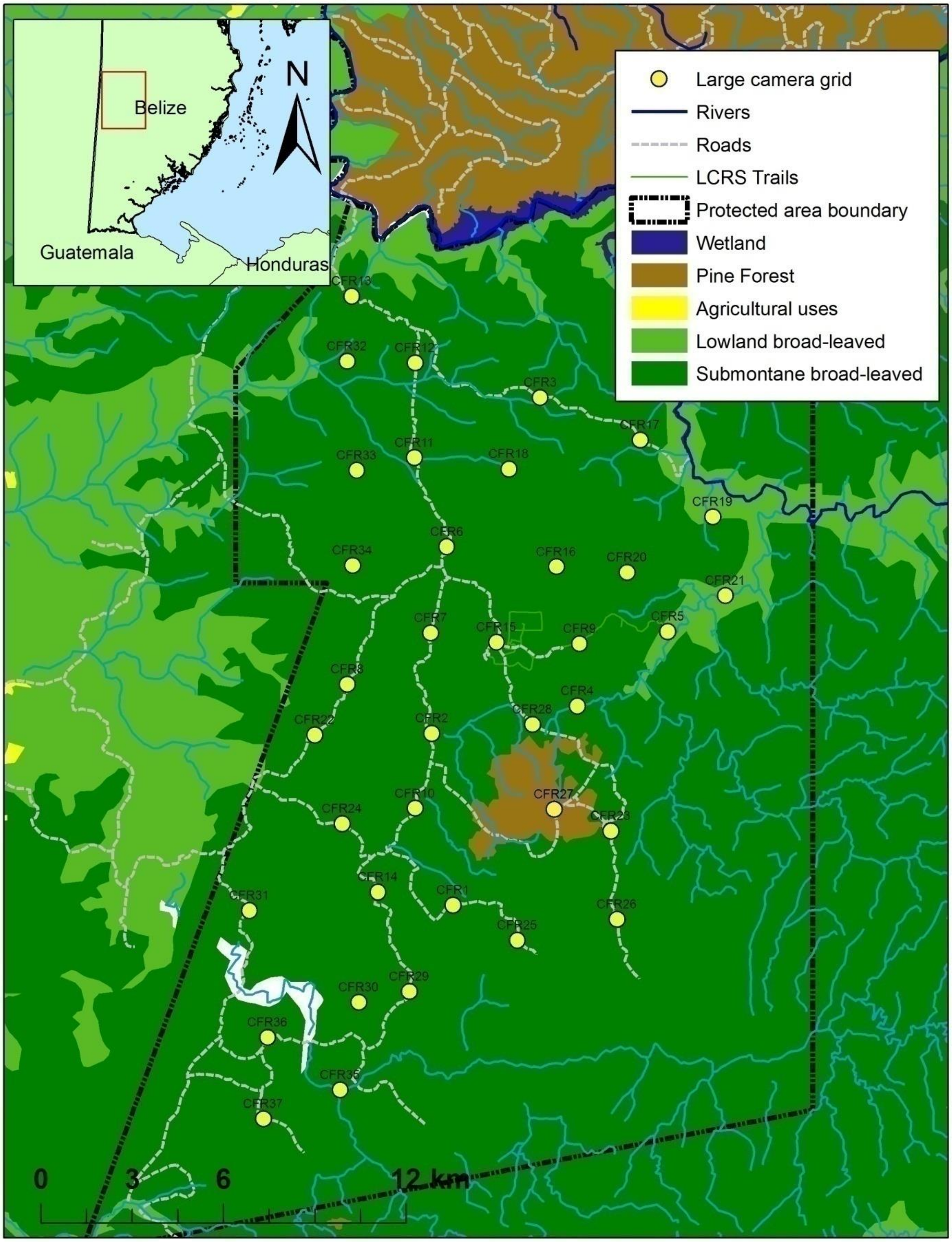


Figure 10. Proposed camera distribution for landscape monitoring of the Chiquibul.

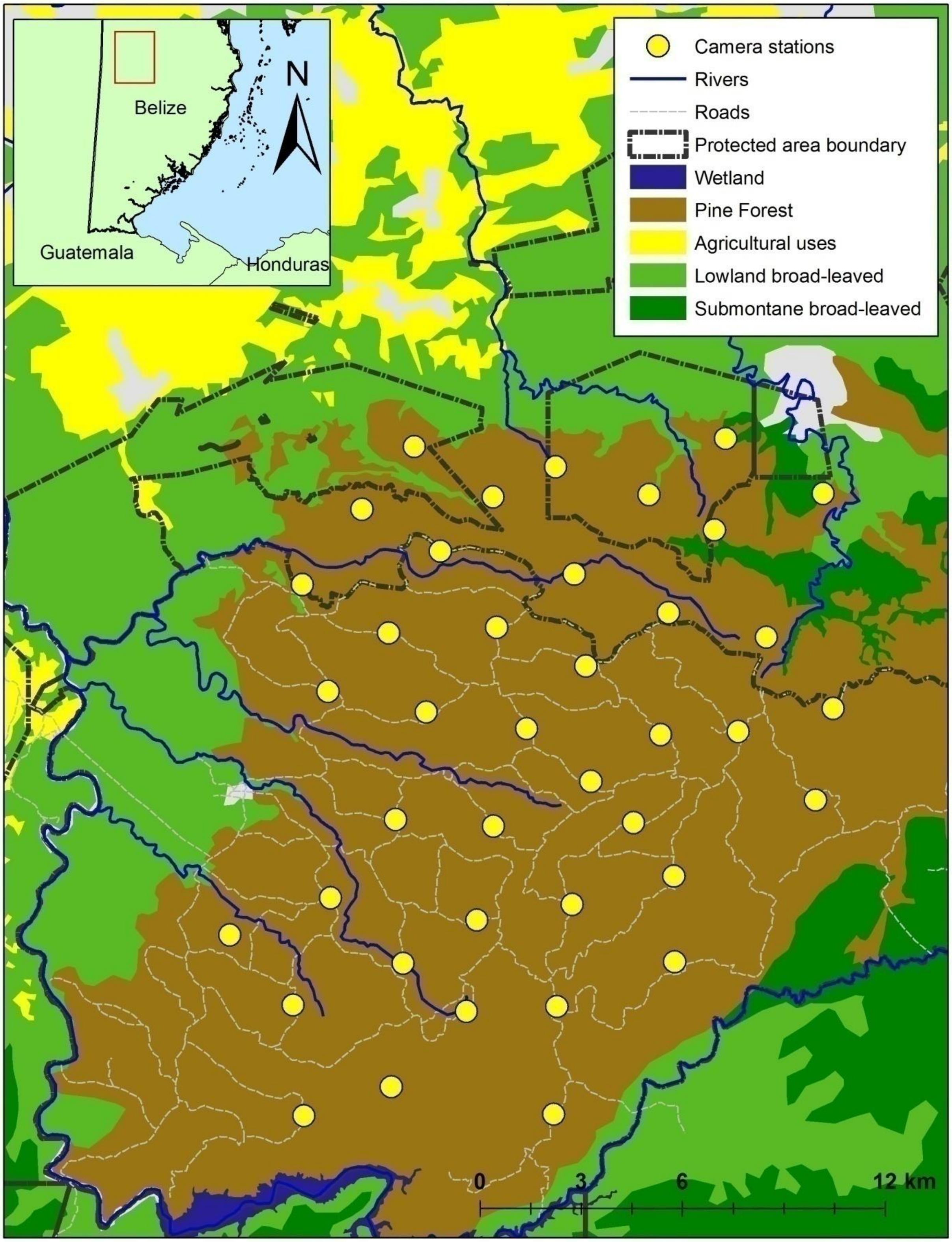


Figure 11. Proposed camera distribution for landscape monitoring of the Mountain Pine Ridge.

## Additions to camera grid

Ocelots have been well studied in the Chiquibul, which was the location of the first telemetry study of ocelots in the region. We therefore propose to put 10 additional camera stations in the Chiquibul grid (Figure 12 green dots represent the 10 additional camera stations). This grid will also be used to develop a better understanding of other species with smaller ranges, such as tapirs.

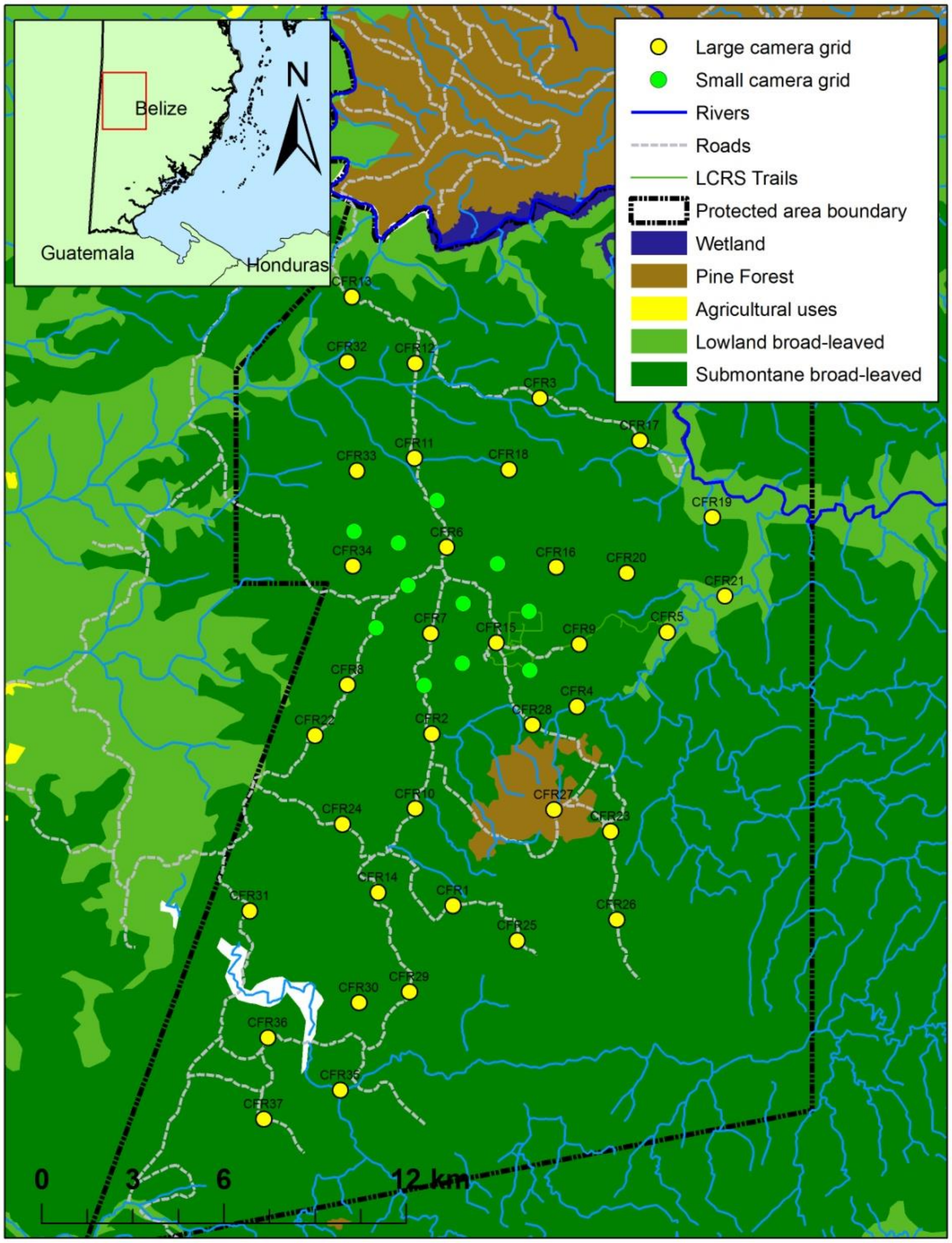


Figure 12. Example of adding 10 extra cameras for species with smaller home ranges like tapirs and ocelots.

### Capture of pumas and jaguars

The importance of the Maya Mountains as a source population for larger wildlife means that the Chiquibul should equally have a marked portion of pumas within its population. Puma numbers are considered lower compared to jaguars, similar as CBWS. As personal safety is an important issue in this region trapping has to be carefully planned, and can only be confined to specific areas with adequate enforcement (around Las Cuevas field station). The logistical requirements still need to be discussed and will therefore need to wait until we have at least two years of camera data and security of camera sites can be properly evaluated.

The use of GPS collars would greatly enhance our understanding of movement of jaguars and pumas within the Chiquibul and MPR area. Monitoring of movement will therefore be greatly aided by the presence of collared individuals in the landscape. The two areas are in the heart of the Maya Mountains and it is therefore interesting to note how individuals will disperse from this area. While pumas are targeted for tagging for individual recognition, jaguars will be equally captured. Capture operations are expensive, labor intensive and require high expertise. It is therefore extremely useful to acquire the maximum pay-off of such operations. Deployment of GPS collars on jaguars and pumas would provide information on dispersal, movement patterns and could equally inform us whether the cats remain in wilderness areas, or if they move far out of the Maya Mountains becoming conflict cats, causing trouble on livestock farms. Young adult males will produce the highest amount of movement and are good candidates for collaring. Females will be prime targets for ecological study on population viability and cub survival. The deployment of 3-5 collars simultaneously should be strived for if funding allows.

### Capture of white lipped peccary

White lipped peccary (WL peccary) are still present within the Chiquibul range but at much reduced numbers. Capture operations should be carried out with extreme caution as any corral left behind might be monitored by people wanting to illegally hunt WL peccary. We will wait with deployment of corrals and bait sites until we have a better understanding of current movement and presence from the camera trap surveys. Bait sites can likely only be deployed in known safe zones around Las Cuevas.

When corral sites are built and baited, tagging of collared peccaries should be considered if they equally start entering the corral reliably. Collared peccaries are smaller and herds are therefore easier to handle. They will provide good local rehearsal for the larger numbers of target WL peccary.

### Monitoring of paca

Three paca plots are placed within broadleaf forest within the Chiquibul area (Figure 5) and three within the pine forest of the MPR (Figure 13). This requires 72 camera stations and 144 cameras in total. It is likely that a rotation system needs to be employed when carrying out these camera surveys. The choice of area search, straight line transect search or random line search needs to be considered after a thorough assessment on the ground in consultation with managers. Consistency and comparability are required across all sites within the area. This means the method will be chosen on the basis of the most difficult plots. Setting up of cameras, creation of infrastructure for plots and subsequent surveys should ideally happen in the first year of monitoring. However safety constraints and logistical issues are less well understood for this area.

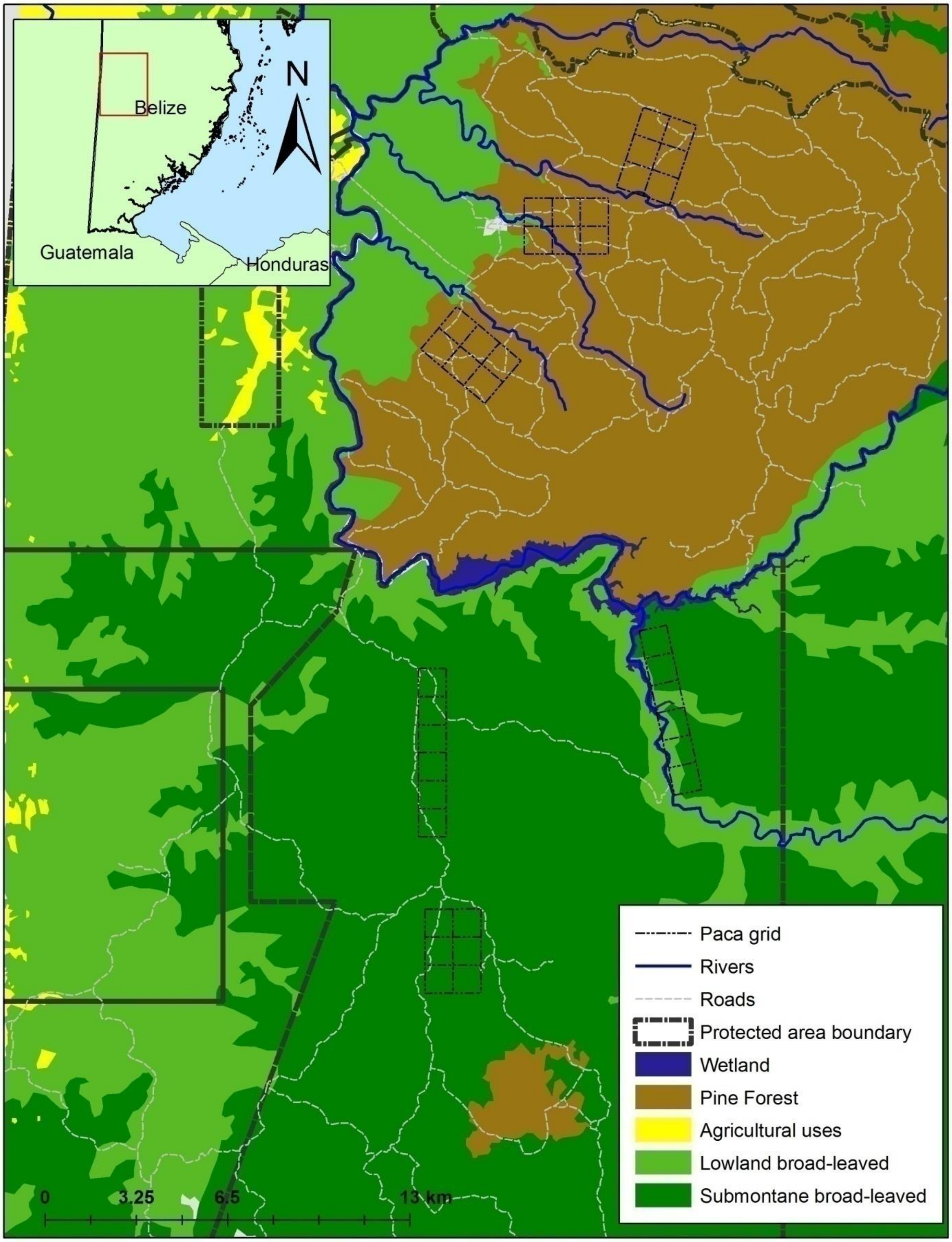


Figure 13. Proposed plots for monitoring pacas in Chiquibul and Pine Ridge.

### Human-wildlife conflict monitoring

The central location of Chiquibul and MPR means that there are no communities surrounding this area that might be directly affected by wildlife from the areas. There are lodges and some logging camps. Potentially the person monitoring cameras and other parts of the program should be appointed as a conflict officer for any human-wildlife conflict that might occur in the area. It is however not necessary to monitor this particularly.

Hunting happens in the area but this is mainly an enforcement issue. All hunting happening here will be considered illegal and not open to normal monitoring and discussion.

### Monitoring outside of protected areas

Both areas are surrounded by other protected areas and therefore monitoring of adjacent unprotected forest is not applicable.

### Monitoring of domestic animals

There should be no presence of domestic animals within the area. They should however be noted on camera traps and changes in monitoring should take place if domestic animals become an issue in the area.

## CENTRAL BELIZE CORRIDOR LANDSCAPE

The Central Belize Corridor (CBC) is the last remaining forest connection between Rio Bravo and the Maya Mountains. It is a vital wildlife link, assuring genetic exchange between the otherwise isolated Maya Mountains and the Northern Selva Maya forest of Rio Bravo, extending into Péten. Almost entirely privately owned, this last stretch of forest requires extra attention due to its connectivity function for the Maya Mountains and surroundings. Monitoring has happened here from 2009 onwards. Capture probability is lower compared to protected areas; however the number of individuals captured is actually relatively high, with high turnover rates and levels of transience for jaguars. The importance of the area and lower densities of species creates a situation whereby monitoring needs to be extensive across the area. We therefore propose total coverage of the area with camera traps.

The CBC is likely the most varied monitoring area in terms of habitat, ranging from the karst hills in Runaway Creek and Peccary Hills, to savannah-and broken ridge in between the gallery forests of the Sibun and the Belize River (Figure 14). There are a number of larger lagoons in the area. The area dries up considerably between February and June and the larger two rivers and the lagoons are extremely important sources of water for wildlife during these times. During the wet season the area is inundated with water and large parts of the CBC are underwater and unsuitable for permanent living by terrestrial species.

The function of the CBC as the main bottleneck corridor for Belize means that management should be entirely tailored towards movement, while overall survival and abundance are of less concern. The area does not have to contain viable populations or high amounts of breeding. The most important judgement of successful management concerns the continuous movement across the Belize River, highway and the Sibun River

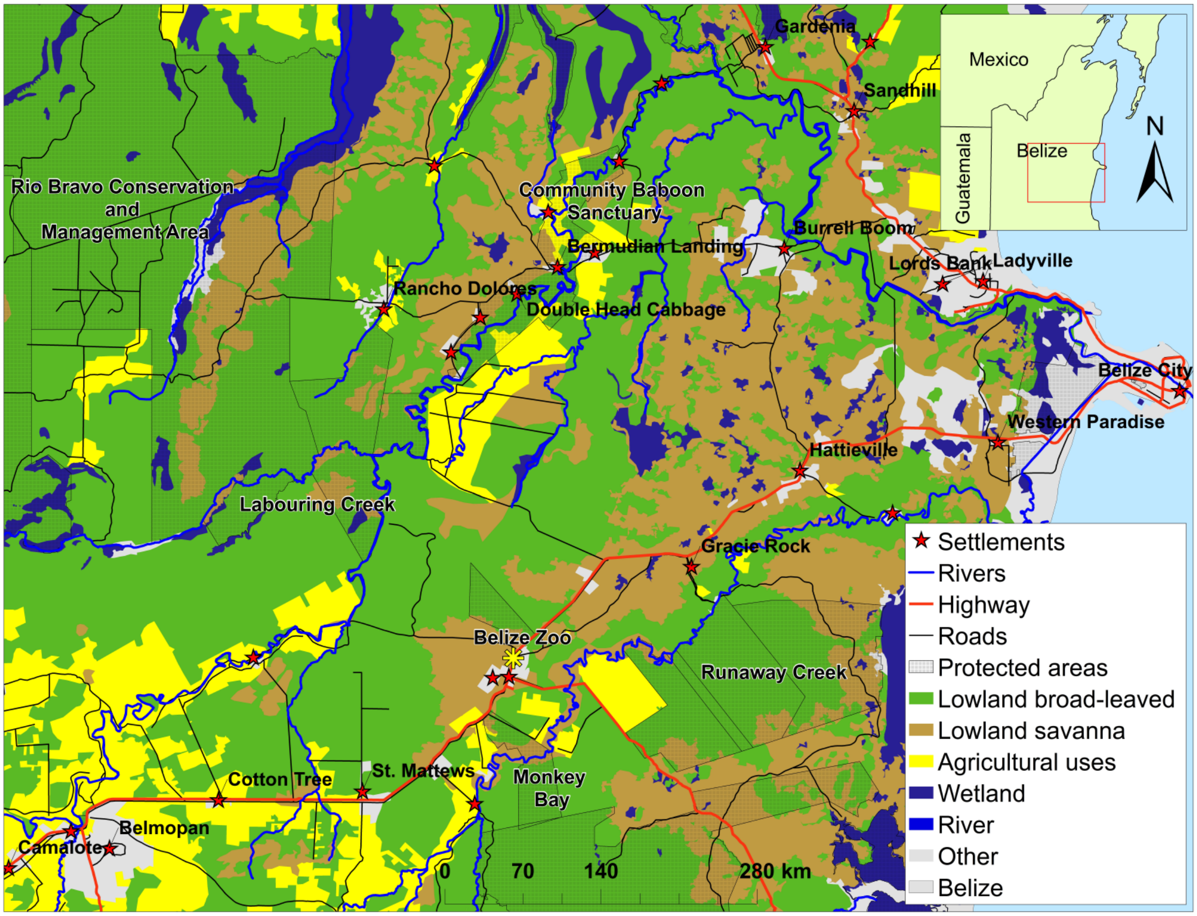


Figure 14. Monitoring area of the Central Belize Corridor

### Landscape level camera grid

The proposed camera grid is the amalgamation of 5 different surveys that have been carried out within Central Belize and the Belize River valley area over the years. We propose the continuation of these surveys sequentially. Fifteen camera stations will be placed within the Runaway Creek – Peccary Hill area (East of Sibun River, coral colored circles in Figure 15). Sixteen camera stations will be placed on either side of the Western Highway (light green color circles in Figure 15). Twenty cameras will be placed within the large farm called Big Falls between the Belize River and the Western Highway (light blue circles in Figure 15). Fifteen camera stations will be deployed along the River banks on the Western side of the Belize River with an emphasis on the canal (pink color circles in Figure 15). Twenty five stations will be distributed across the rural Belize landscape (purple circles in Figure 15). This makes a total of 91 camera stations, requiring 182 cameras. As it would not be logistically and financially feasible to carry out these surveys in one time period, they will be carried out in sequence. Runaway Creek – Peccary Hill and Rural Belize become inundated with water in the wet season and thus require surveying during the dry season. Surveys around the Western Highway, Big Falls and canal can be conducted at the fringes of the wet season, although surveying during the dry season would be preferable. In this manner the entire area will be covered in detail. Exchange between every potential barrier can be estimated (Belize River, Sibun River and Western Highway). The variability in landscape with savannah and secondary forest growth will be completely covered. Enough cameras are present to detect the presence and distribution across the landscape in detail.

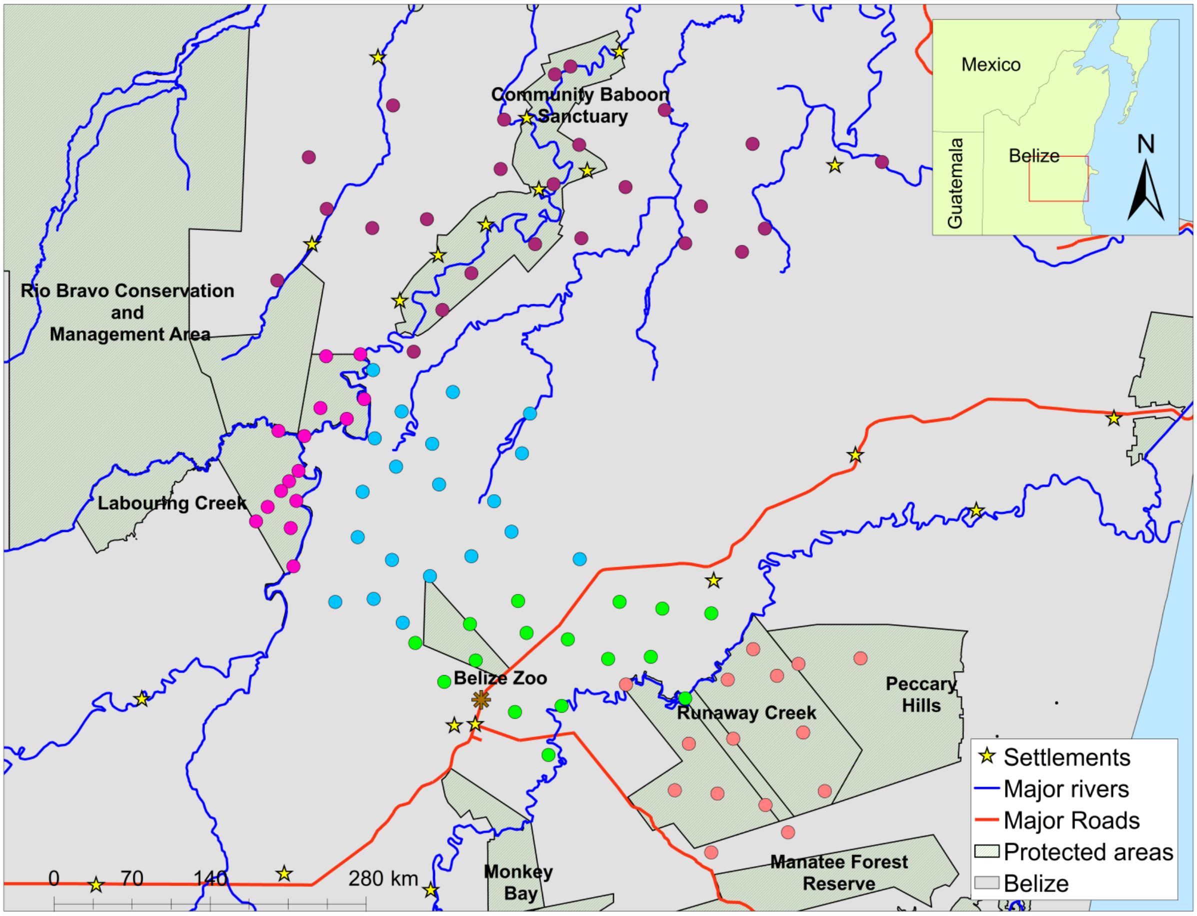


Figure 15. Proposed camera distribution for landscape monitoring of Central Belize Corridor.

### Additions to camera grid

The considerable number of cameras necessary to monitor the use of species and individuals within this important human dominated landscape means there will not be an additional grid placed within the proposed camera grid. The use of additional cameras placed at closer distance will be encouraged but beyond the limits of a national monitoring program. These grids are more important within protected area landscapes.

### Capture of pumas and jaguars

There is a need for individual recognition of pumas within the CBC. A regular but limited trapping operation will target the plain colored cats. We therefore need to establish good locations to trap pumas, using snares. As monitoring has been taking place in CBC for +5 years, good records are available for pumas. These have indicated puma presence is much scarcer than jaguars within the CBC. As historic data for presence of jaguars and pumas is available, trapping and tagging can therefore start whenever logistically possible.

The use of GPS collars would greatly enhance our understanding of movement of jaguars and pumas within the CBC and surrounding areas. Monitoring of movement will therefore be greatly aided by the presence of collared individuals in the landscape. The king pin location of the CBC puts extra weight on collaring individuals within this landscape. While pumas are targeted for tagging for individual recognition, jaguars will be equally captured. Capture operations are expensive, labor intensive and require high expertise. It is therefore extremely useful to acquire the maximum pay-off of such operations. Deployment of GPS collars on jaguars and pumas would provide information on dispersal, movement patterns and could equally inform us whether the cats remain in wilderness areas, or if they turn into conflict cats, causing trouble on livestock farms. Young adult males will produce the highest amount of movement and are good candidates for collaring. Females will be prime targets for ecological study on population viability and cub survival. The deployment of 3-5 collars simultaneously should be strived for if funding allows.

### Capture of white lipped peccary

White lipped peccary (WL peccary) are still present in the Northern part of the CBC. A single small herd of ~30 individuals has been noted here (Foster & Harmsen unpublished data). Frequency of WL peccary detections have been going down over the years. Preparation of bait sites can start immediately as WL peccary distribution in the area is relatively well known. They are a hunted population and will be skittish to any bait or feeding sites. Five to 10 bait sites should be maintained, and over time reduced to 2-3 reliable sites maintained and monitored with infrared camera traps (see methods white lipped peccary). Preferably the first cohort of tagged WL peccary should be ready for the second camera survey to assure improved monitoring of particular individuals and herds over time. The use of GPS collars should equally be considered to improve data on movement and landscape use, especially near the highway and vulnerable locations near villages and croplands.

Tagging of collared peccaries should be considered if they equally start entering the corral reliably. Collared peccaries are smaller and herds are therefore easier to handle. They will provide good local rehearsal for the larger numbers of target WL peccary.

## Monitoring of paca

Three paca plots are placed within lowland broadleaf forest, one (1) in Runaway Creek and two (2) within Big Falls landscape North of the Highway. A single grid is placed within savannah area. This area is grass savannah with small patches of denser shrub growth, mainly palmetto. Figure 16 shows the 4paca plots proposed within the CBC. The plots would require 48 camera stations, needing 96 cameras. The choice of area search, straight line transect search or random line search needs to be considered after a thorough assessment on the ground in consultation with managers. Consistency and comparability are required across all sites within the area. This means the method will be chosen on the basis of the most difficult plots. Setting up of cameras, creation of infrastructure for plots and subsequent surveys should ideally happen in the first year of monitoring.

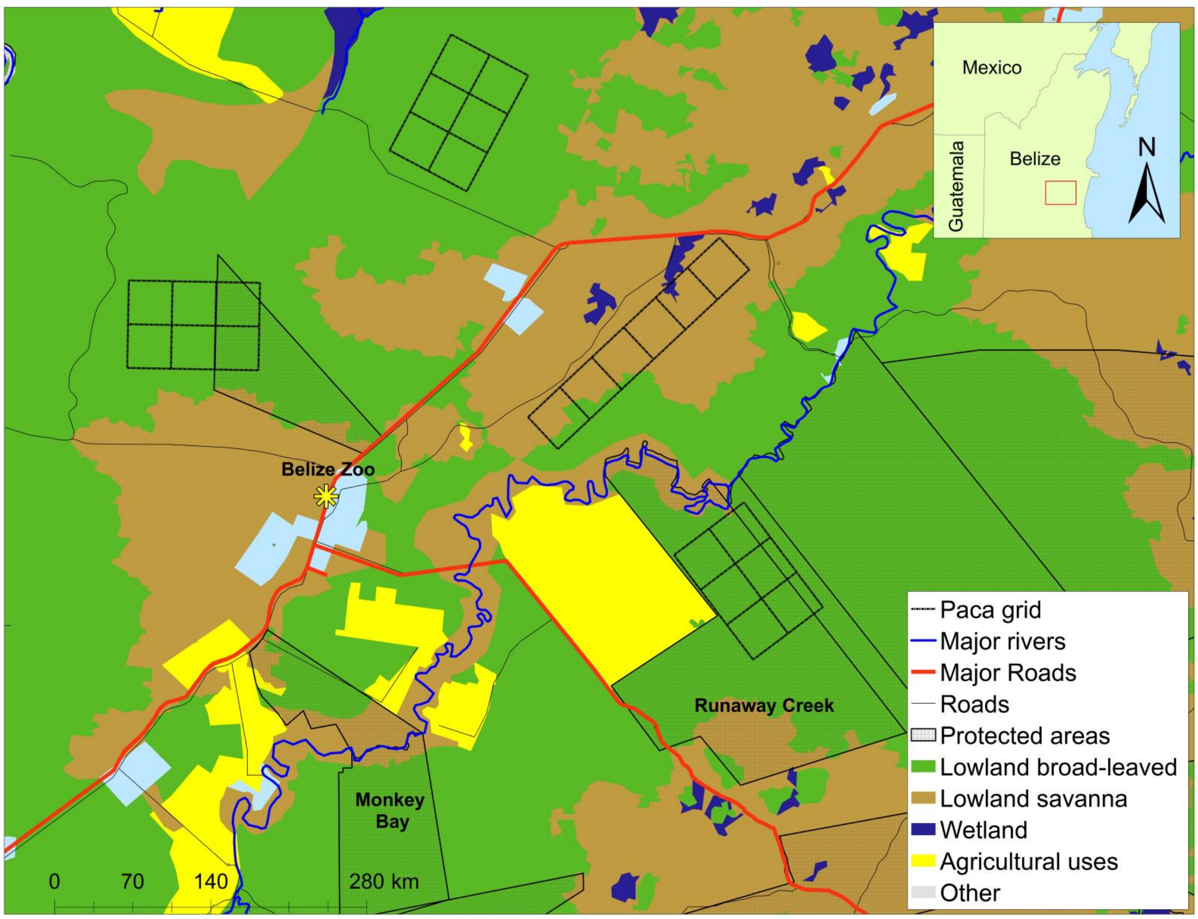


Figure 16. Proposed plots for monitoring pacas within the landscape of the Central Belize Corridor.

### Human-wildlife conflict monitoring

CBC has received considerable attention in terms of human wildlife conflict. The UB/ERI/Panthera research team has considerable experience in terms of conflict and farm management within this area. The work needs to be continued using the same model as proposed here. There needs to be a CBC conflict officer who actively investigates cases of conflict and maintains a database. The transition from UB/ERI/Panthera to a permanent conflict officer position requires adequate handover and introduction from current staff to new staff. Stakeholders need to feel that relations are maintained rather than newly forged. They should fall under an NGO management group. A potential managing candidate could be the Community Baboon Sanctuary (CBS). Conflict incidences are relatively common in the CBC area, especially jaguar-livestock conflict but crop raiding incidences are noted as well.

The mosaic nature of the landscape with farms, villages interspersed with forest patches creates a landscape with a high probability of conflict. Monitoring of wildlife and the negative effects of humans on wildlife and vice versa should be more carefully quantified. Careful analyses are necessary to assure movement of wildlife remains as the most important variable within this landscape. Conflict resolution should therefore never impede movement across the landscape, even if it goes at the cost of higher mortality of wildlife.

### Monitoring outside of protected areas

Most of the CBC is unprotected forest and therefore this section is not applicable to the CBC.

### Monitoring of domestic animals

The highly fragmented nature of the landscape means an increased chance of wildlife to be infected with domestic diseases. Monitoring of diseases within dogs and livestock is therefore important. Ticks, blood and skin samples will be collected and sampled from dogs and livestock from surrounding communities (to be decided, see methods section).

Camera traps will detect domestic animals, allowing the calculation of frequency and distribution of incursions within the two protected areas. The further study of dogs as potentially competitors carnivores preying on wildlife should be considered if incursions are frequent and widespread (e.g. use of cheap store on board GPS collars for known culprits based on camera trap data, see method section).

## SELVA MAYA LANDSCAPE

The Selva Maya forest is the second largest contiguous forest block in Belize extending into Péten, Guatemala and Calakmul, Mexico. The largest portion of the Selva Maya forest, the Rio Bravo Conservation and Management Area (RBCMA), is managed in its entirety by Program For Belize (PFB). The two most southern sections are logging concession areas; Gallon Jug and Yalbac. Both have an uncertain long-term future in terms of conservation ownership. They are currently owned by commercial logging companies who will sell their property when economic profits drop below a certain level. The diverse area is mainly lowland broadleaf forest, savannah and wetland areas forms an extremely important block for wildlife. This important source population is relatively accessible, especially compared to many areas in the Maya Mountains where there are no roads or trails and the terrain is extremely mountainous. For this reason a high amount of attention will be placed on monitoring the area in its entirety. In this manner we will get a good sense of distribution and range of individuals within this large and important landscape. Continuous monitoring will allow us to acquire adequate baseline information on populations of target species, survival, recruitment, genetic variation and dispersal. Sites like RBCMA with long term stable populations can be used as methodological testing grounds. Further, data gained on population dynamics such as ranges of individuals, population densities and flux can be compared between sites monitored in RBCMA and the Maya Mountains (including CBWS) to look for differences, and what may be driving these differences.

The two logging areas will be monitored for as long as there remains commitment to wildlife conservation and sustainable logging.

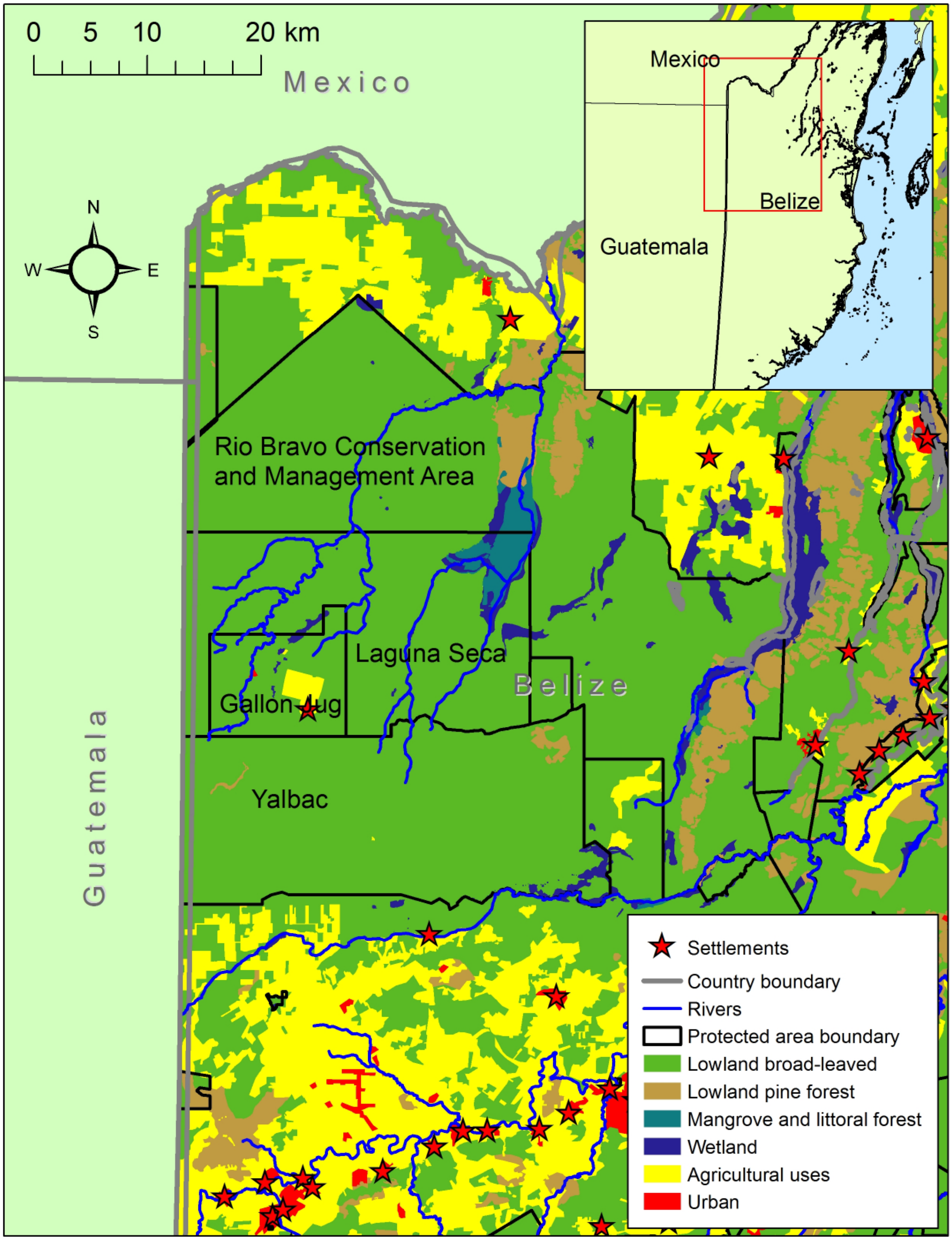


Figure 17. Monitoring area for the Selva Maya on the Belizean side

## Landscape level camera grid

The proposed camera grids are an amalgamation of historic camera survey locations, with extra locations added to try and connect these areas as much as possible. A hundred (100) camera stations are proposed, which would cover the entire survey area (200 cameras in total). The area is separated into 4 different survey areas with 25 camera stations each (50 cameras in total). These areas should be surveyed sequentially, dependent on man power and availability of camera traps. The two Rio Bravo areas have priority: La Milpa area (blue dots Figure 18) and Hill Bank area (red dots Figure 18). The two logged areas of Gallon Jug (purple dots Figure 18) and Yalbac (orange dots Figure 18) should only have continuous monitoring if resources allow and there is commitment from the logging organizations to logistically support surveys.

Historically surveys have been carried out by the US based university, Virginia Tec by Dr. Marcella Kelly. Involvement of such partners remains vital to assure continuation of monitoring. This is especially true with the current proposed high number of cameras spread across such a large area.

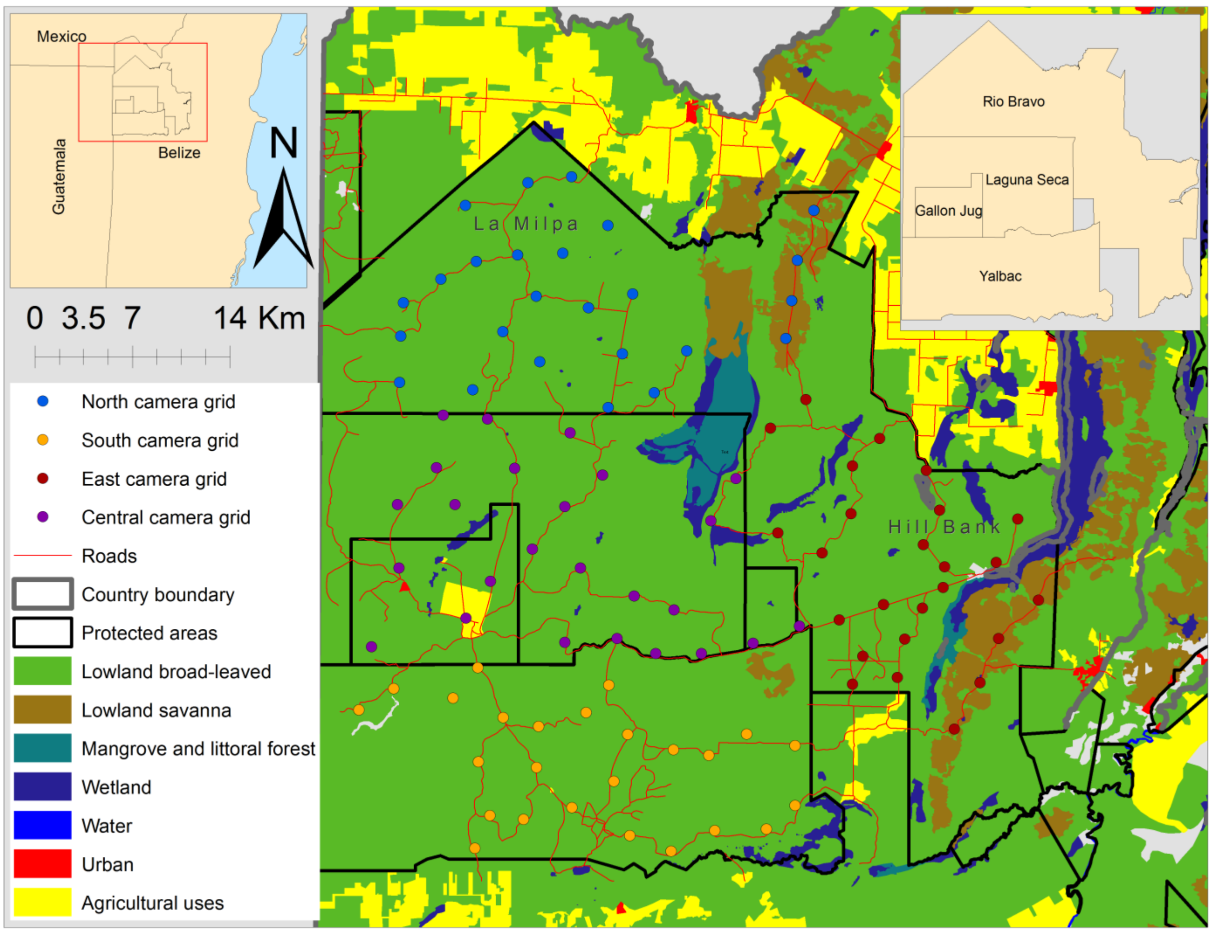


Figure 18. Proposed camera distribution for landscape monitoring of the Selva Maya within Belize boundaries or RBCMA to Yalbac.

### Additions to camera grid

The high number of camera traps within the entire monitoring area means that additional camera traps would be logistically even more difficult. If the survey reveals low recapture rates of species such as ocelots and tapir we propose initially adding an extra 10 camera stations to the La Milpa camera grid (Figure 19 yellow dots represent the 10 additional camera stations). If the data produced is deemed valuable enough to warrant running a smaller grid every year, the 10 extra locations could be alternated between La Milpa and Hill Bank sites each year.

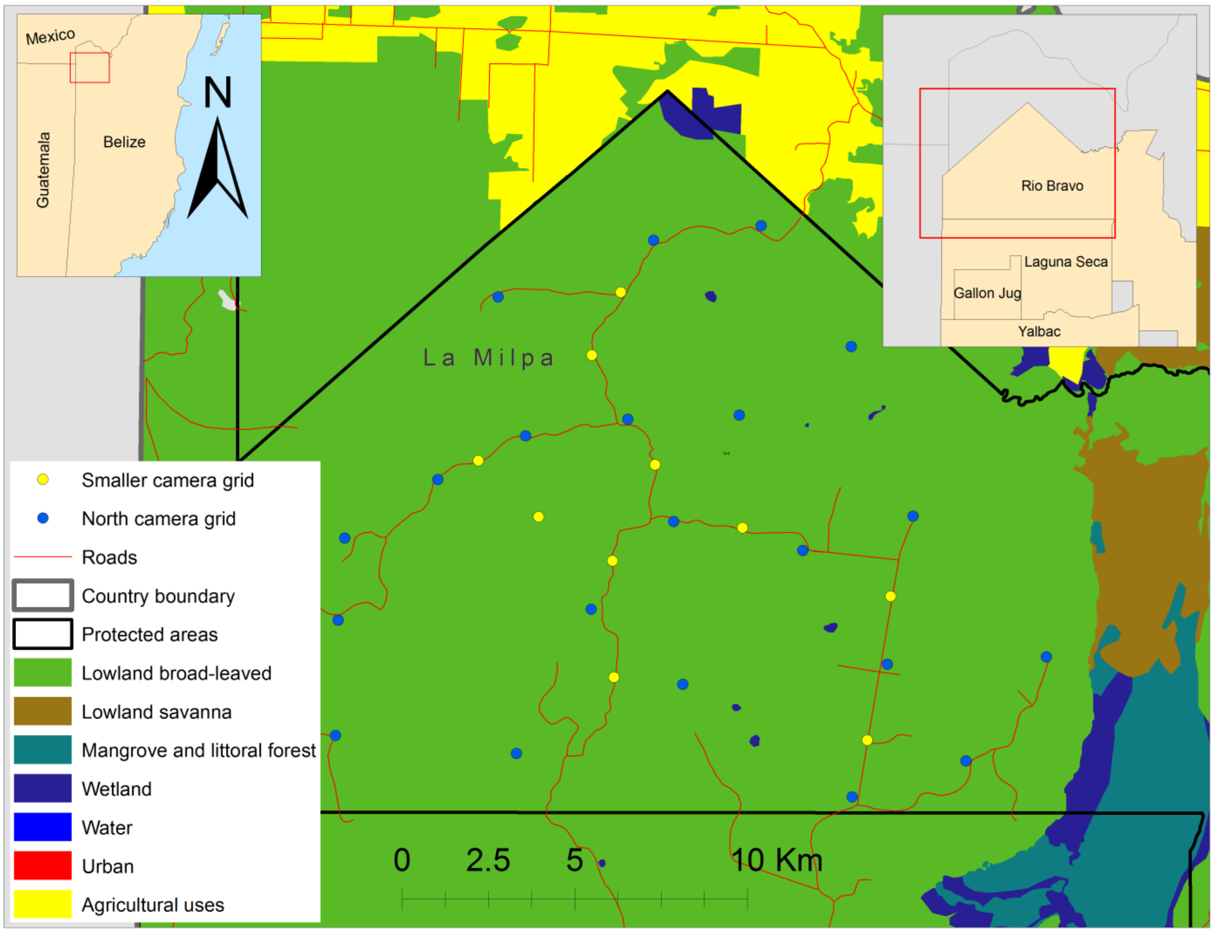


Figure 19. Example of adding 10 extra cameras for species with smaller home ranges like tapirs and ocelots.

### Capture of pumas and jaguars

The RBCMA area, being drier and more open compared to the Maya Mountains will be more conducive to pumas. The higher number of white tail deer present within this area equally means prey that is more suitable to pumas compared to jaguars. Historic camera trapping has shown high numbers of pumas in the area. The larger numbers of pumas therefore require a larger trapping and tagging effort to assure a portion of the population is identifiable which is required for analysis of population dynamics. Trapping and tagging of pumas will be confined to specific areas in La Milpa and Hill Bank. Through Historic records from Dr. Marcella Kelly, we already have a good record of pumas within Rio Bravo, allowing us to choose logistically feasible locations for trapping. Trappingand tagging can therefore start when it is logistically possible.

The use of GPS collars would greatly enhance our understanding of movement of jaguars and pumas within the CBC and surrounding areas. Monitoring of movement will therefore be greatly aided by the presence of collared individuals in the landscape. The importance of the RBCMA as a source population and its proximity to the CBC means that collaring individuals within this landscape is extremely important to identify movement. While pumas are targeted for tagging for individual recognition, jaguars will be equally captured. Capture operations are expensive, labor intensive and require high expertise. It is therefore extremely useful to acquire the maximum pay-off of such operations. Deployment of GPS collars on jaguars and pumas would provide information on dispersal, movement patterns and could equally inform us whether the cats remain in wilderness areas, or if they turn into conflict cats, causing trouble on livestock farms. Young adult males will produce the highest amount of movement and are good candidates for collaring. Females will be prime targets for ecological study on population viability and cub survival. The deployment of 3-5 collars simultaneously should be strived for if funding allows.

### Capture of white lipped peccary

White lipped peccary (WL peccary) are present within RBCMA. The large area of Rio Bravo means that sampling should take place in the two distinct areas of La Milpa and Hill Bank. We will therefore set up baiting stations within both areas. Preparation of bait sites can begin immediately as there is historic data from the sites of WL peccary presence. In each area, 5 to 10 bait sites should be maintained, and over time reduced to 2-3 reliable sites maintained and monitored with infrared camera traps (see methods white lipped peccary). Preferably the first cohort of tagged WL peccary should be ready for the second survey to assure improved monitoring of particular individuals and herds over time. This means capture should happen in between the first and the second large grid camera surveys. The use of GPS collars should equally be considered to improve data on movement and landscape use.

Tagging of collared peccaries should be considered if they equally start entering the corral reliably. Collared peccaries are smaller and herds are therefore easier to handle. They will provide good local rehearsal for the larger numbers of target WL peccary.

### Monitoring of paca

Three paca plots were placed within the broadleaf forest of RBCMA;, 2 in La Milpa area and 1 in Hill Bank. Figure 20 shows the three paca plots for Rio Bravo, requiring 36 camera stations, needing 72 cameras. The choice of area search, straight line transect search or random line search needs to be considered after a thorough assessment on the ground in consultation with managers. Consistency and comparability are required across all sites within the area. This means the method will be chosen on the basis of the most difficult plots. Setting up of cameras, creation of infrastructure for plots and subsequent surveys should ideally happen in the first year of monitoring.

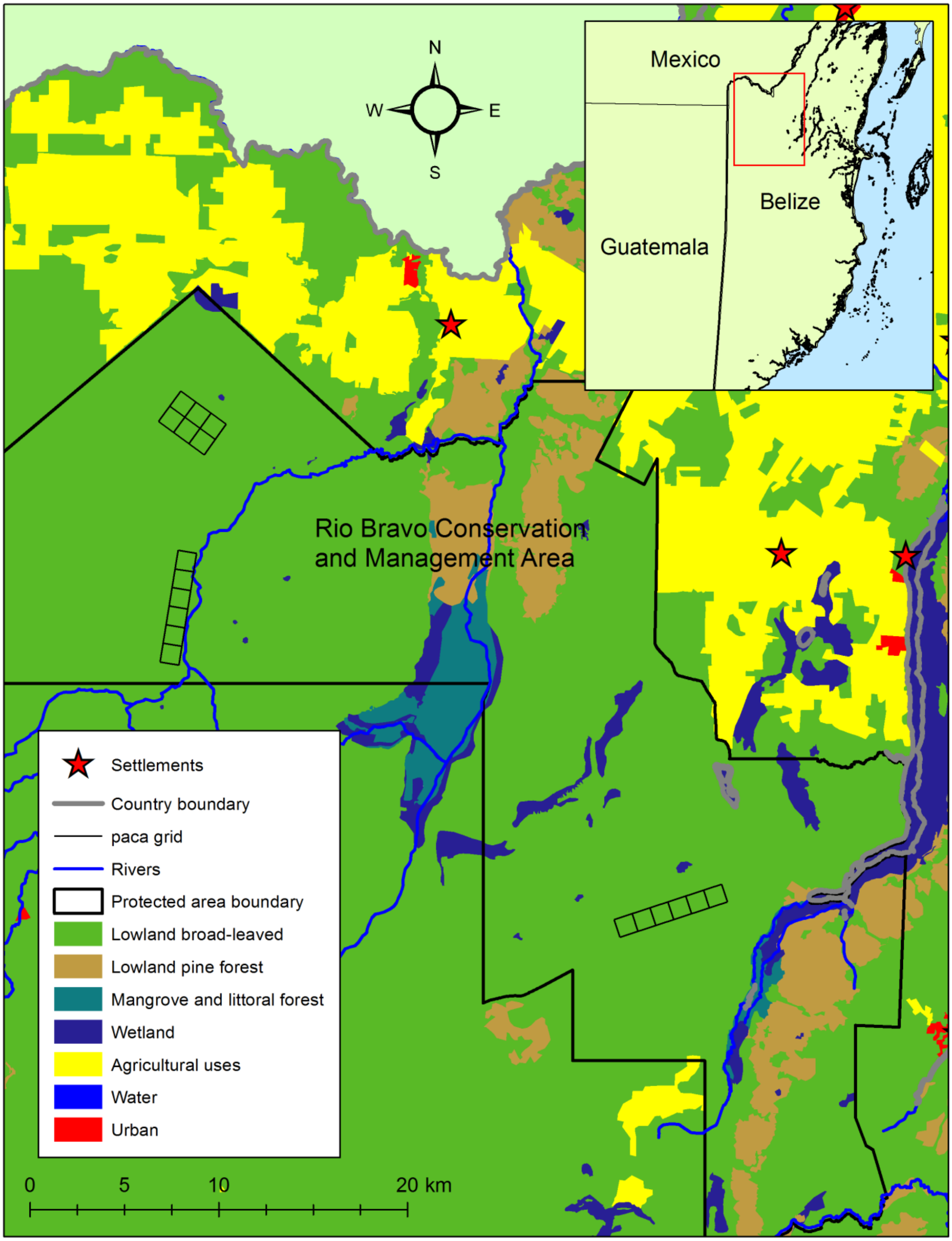


Figure 20. Proposed plots for monitoring pacas within the Rio Bravo Conservation and Management Area.

### Human-wildlife conflict monitoring

The sheer size of the boundary of the RB landscape makes it an extremely hard task to monitor human-wildlife conflict across its boundaries. A single conflict officer would not be able to cover this area adequately and travel time in a vehicle would be too much to respond timely if operating from a single base. The area requires at a minimum a team of 3 people covering; La Milpa, Hill Bank and Yalbac. For conflict monitoring to be effective, it must happen continually, with active visits to stakeholders and rapid responses to problems. It is essential that this conflict team has permanent access to vehicles and fuel.

Livestock and crop-growing farms need to visited and farmers interviewed. Contact must be continuously maintained and camera traps made available. We propose the availability of at least 35-45 cameras for this sole purpose with 15-20 cameras continuously running on and around farms with the highest chances of conflict. Fifteen to twenty cameras should be retained for immediate response to calls of conflict. The officers should remain in close contact with the Belmopan head office wildlife officer. Regular meetings with conflict officers around the country should take place to assure communication within an active national conflict network.

### Monitoring outside of protected areas

As mentioned in the previous section, the boundary area of the Rio Bravo and Yalbac is extremely large. Monitoring the buffer areas in their entirety would be logistically impossible. It is therefore proposed that monitoring outside of the areas mentioned will not be part of a current monitoring plan. Initiatives should be encouraged wherever there is capacity or interest within communities to start some sort of monitoring program. However it is not logistically feasible to develop an implementable program. Candidate areas for such a program might come out of Blue Creek or other more affluent agricultural communities.

### Monitoring of domestic animals

The highly fragmented nature of the landscape means an increased chance of wildlife to be infected with domestic diseases. Monitoring of diseases within dogs and livestock is therefore important. Ticks, blood and skin samples will be collected and sampled from dogs and livestock from surrounding communities (to be decided, see methods section).

Camera traps will detect domestic animals, allowing the calculation of frequency and distribution of incursions within the two protected areas. The further study of dogs as potentially competitors carnivores preying on wildlife should be considered if incursions are frequent and widespread (e.g. use of cheap store on board GPS collars for known culprits based on camera trap data, see method section).

## COROZAL FOREST LANDSCAPE

The forests of Corozal are fragmented and under high amounts of pressure for agricultural conversion. In a similar vein to the coastal forests of Toledo, the main issue here is maintenance of connectivity with the larger forest blocks of the Maya Mountains and the Selva Maya. Connection with these source populations is vital as the Corozal forests are too small to sustain isolated populations by themselves. The two main protected areas here, Shipstern Nature reserve and Freshwater Creek, will both be used as monitoring sites. Both are at the end of a thin patchy forested chain connecting the Northern Forests with remaining forests in Belize. Monitoring in both areas will allow quantification of wildlife exchange between the two protected areas and equally measure the level of wildlife exchange with adjacent monitored populations (CBC and Rio Bravo). In this manner we can quantify the permeability of the landscape within Corozal (between Shipstern and Freshwater Creek) and between Corozal and the outside (between Corozal, CBC and Rio Bravo). Shipstern and Freshwater Creek are managed by Corozal Sustainable Future Initiative (CSFI).

As the focus is on connectivity, the priority species will consist of the similar landscape species, jaguars, pumas, white lipped peccary, ocelot and tapir. We will start with grids in both protected areas and expand from this into the human dominated landscape if no exchange of individuals is found between protected areas. Expansion outside of the protected areas needs to be accompanied by permission and good communication with the private landowners in the area to avoid theft and vandalism of cameras. We propose two smaller grids for monitoring paca populations. We will describe the camera trap deployment and burrow surveys and recommend the use of GPS collars to study movement within this landscape.

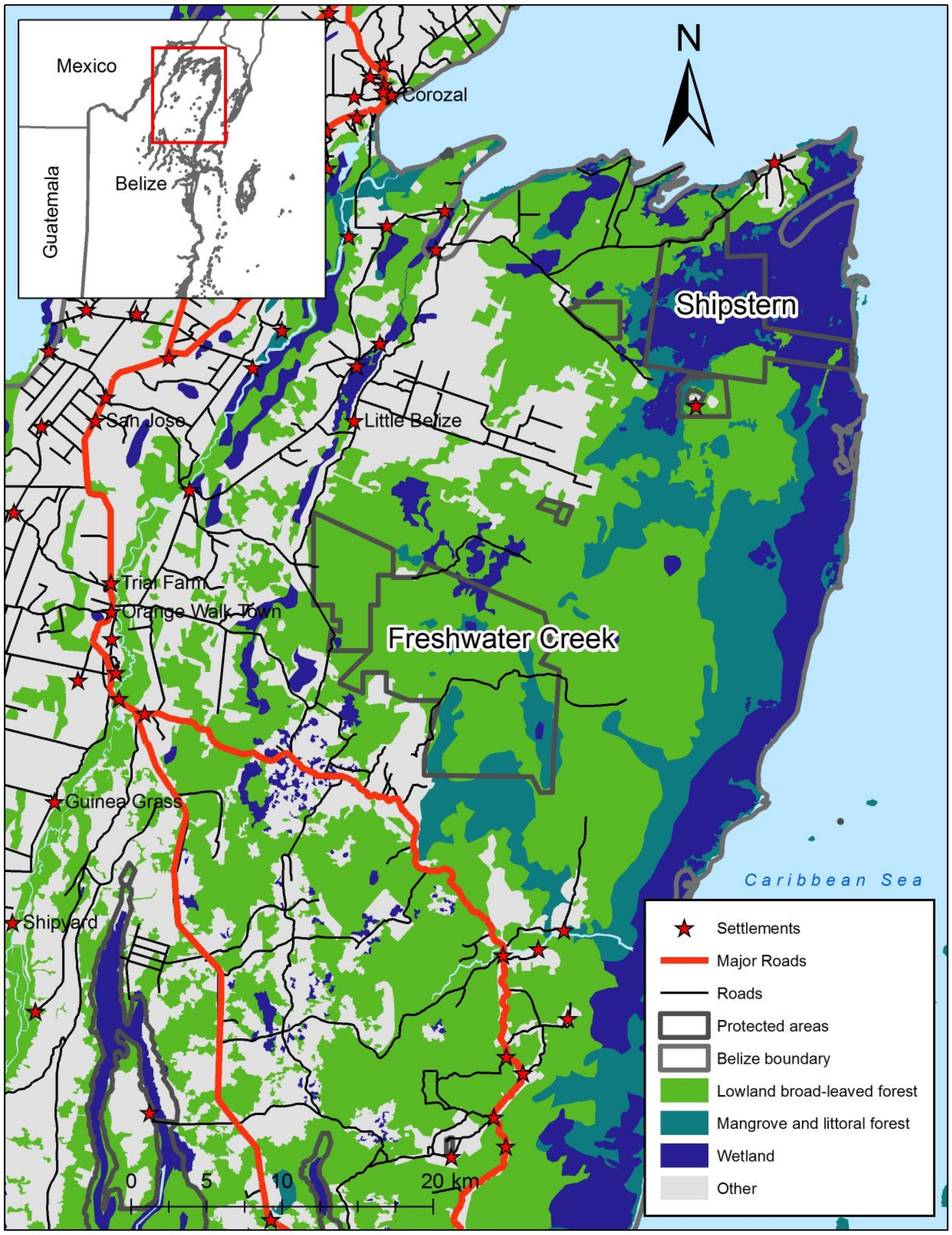


Figure 21. Monitoring area of Corozal

### Landscape level camera grid

Two separate landscape grids are proposed for monitoring jaguars, pumas, ocelots, white lipped peccaries and tapirs. One will be in Freshwater Creek and the other in Shipstern (see Figure 22). In this manner we will be able to monitor the mean level of survival in the area, the retention of residents, exchange of individuals between areas and if capture probabilities are high enough, estimate abundance and density. Using a grid of 3 $km^2$overlaid on the Shipstern Nature Reserve, Freshwater Creek and Honey Camp National Park twenty-three cameras were spread within the boundaries of these protected area. Six of these cameras stations were distributed within SNR and Fireburn, avoiding the wetlands. Each grid was scrutinized to locate best possible locations. Using Google Map ©2016, camera locations were placed where information of roads or watering holes was present. The use of watering holes was used to increase capture probabilities of wildlife, especially jaguars. Most cameras were placed at a distance from the boundary line to decrease chances of vandalism. Seventeen camera stations were chosen within the Freshwater Creek block. This means 23 stations, using 46 cameras for the total larger grid (see Figure 22).

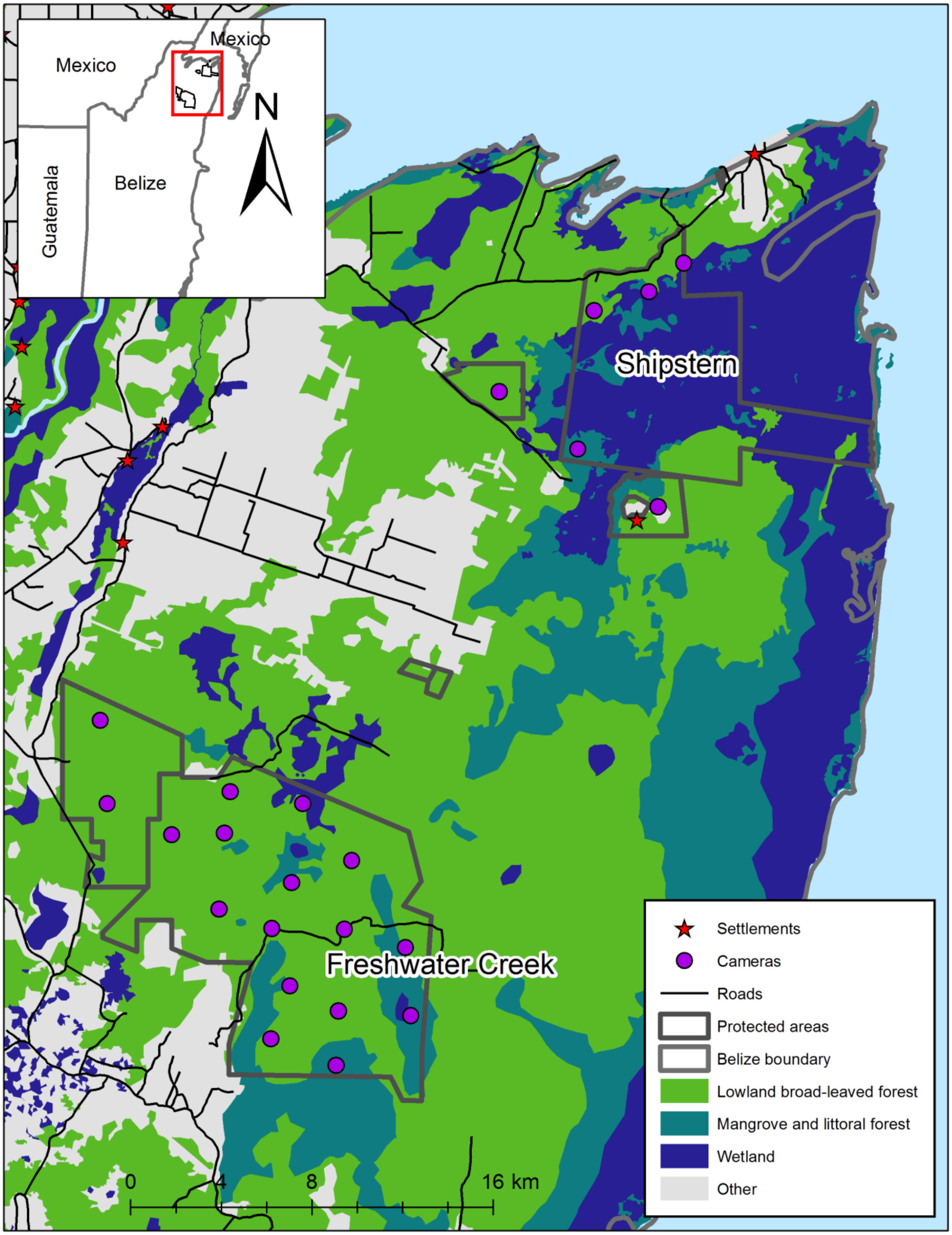


Figure 22. Proposed camera distribution for landscape monitoring of coastal zone of Corozal.

## Additions to camera grid

The distance between camera stations is mainly configured for jaguars, pumas and white lipped peccary, while being too large for tapirs and ocelot. Ten extra stations will be placed within this grid to assure sampling at higher density (see methodology section of Ocelots). We will assess if the additional cameras obtain a higher number of individuals of ocelots and tapirs and if the recapture rate between stations increases significantly. The decision can be made at later survey rounds to add or subtract these additional cameras based on their contribution to recapture and movement data. Figure 23 shows an example of the possible distribution of ten additional cameras.

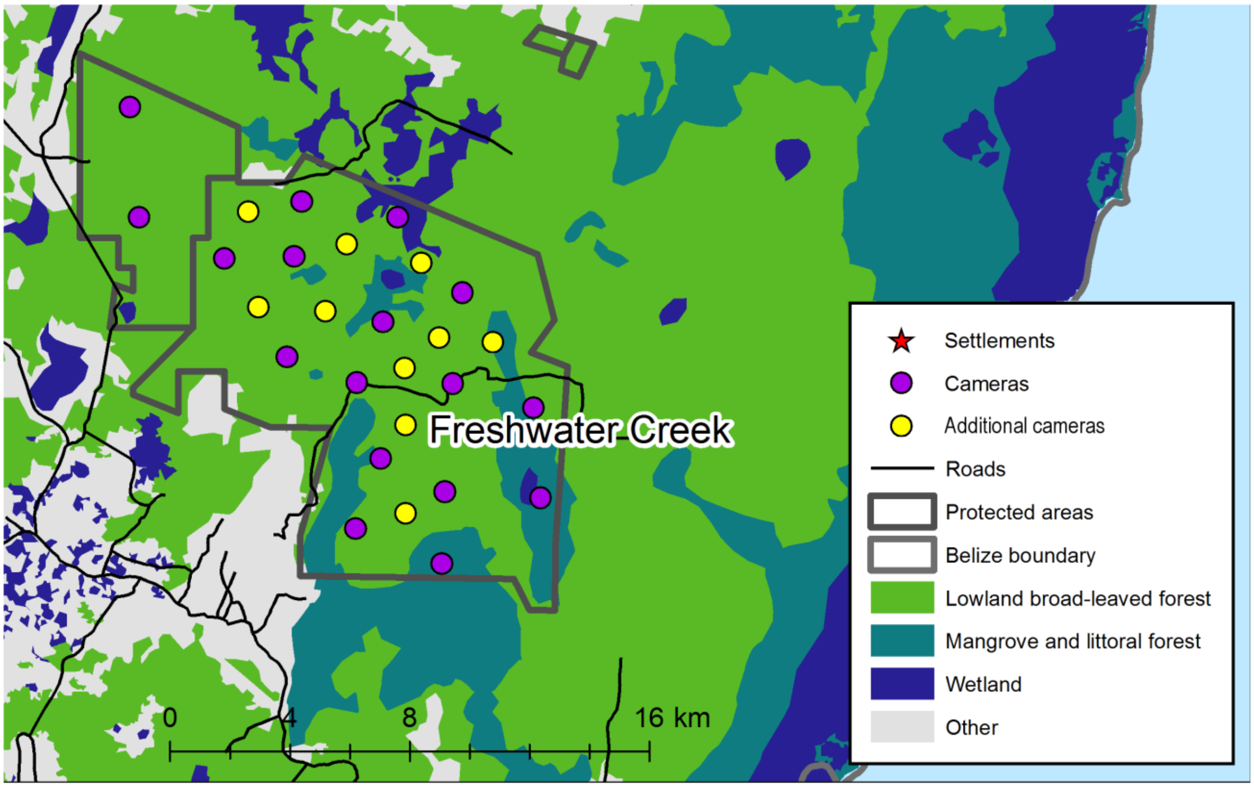


Figure 23. Example of adding 10 extra cameras for species with smaller home ranges like tapirs and ocelots.

## Capture of pumas and jaguars

There is a need for individual recognition of pumas within the Corozal area. The need for tagging of individuals is therefore urgent here. A regular but limited trapping operation will target the plain colored cats. We therefore need to establish good locations to trap pumas, using snares. Camera data can indicate which locations are most suitable for trapping. Trapping and tagging will therefore not happen until the second or third year of the survey. In the meantime, a thorough assessment can be made of the individual recognizability of pumas in Corozal and estimates can be made of the trapping effort necessary for reliable population assessment.

The use of GPS collars would greatly enhance our understanding of movement of jaguars and pumas within and between the Corozal landscape. Monitoring of movement will therefore be greatly aided by the presence of collared individuals in the landscape. While pumas are targeted for tagging for individual recognition, jaguars will be equally captured. Capture operations are expensive, labor intensive and require high expertise. It is therefore extremely useful to acquire the maximum pay-off of such operations. Deployment of GPS collars on jaguars and pumas would provide information on dispersal, movement patterns and could equally inform us whether the cats remain in wilderness areas, or if they turn into conflict cats, causing trouble on livestock farms. Young adult males will produce the highest amount of movement and are good candidates for collaring. Females will be prime targets for ecological study on population viability and cub survival. The deployment of 3-5 collars simultaneously should be strived for if funding allows.

### Capture of white lipped peccary

White lipped peccary are still present in the Corozal landscape with some of them being detected in areas where they have not been seen for a long time (personal communication, Heron Moreno). These movements were attributed to displacement due to habitat clearing. There is however no information available on number of herds, herd size and movement patterns and how many are left within the North Eastern landscape. Although the method of capture for WL peccary is different compared to jaguars and pumas, it is equally labor intensive, expensive and requires experienced personnel. Preparation of bait sites should happen after the initial survey has shown patterns of distribution and timing of presence. After the initial survey, 5 to 10 bait sites should be maintained, and over time reduced to 2-3 reliable sites maintained and monitored with infrared camera traps (see methods white lipped peccary). Preferably the first cohort of tagged WL peccary should be ready for the second survey to assure improved monitoring of particular individuals and herds over time. This means capture should happen in between the first and the second large grid camera surveys. The use of GPS collars should equally be considered to improve data on movement and landscape use, especially near the highway and vulnerable locations near villages and croplands.

Tagging of collared peccaries should be considered if they equally start reliably entering the corral. Collared peccaries are smaller and herds are therefore easier to handle. They will provide good local rehearsal for the larger numbers of target WL peccary.

### Monitoring of paca

Freshwater Creek was jointly evaluated with Shipstern Nature Reserve to select where to place the grids. Shipstern's main ecosystem is wetland and mangrove forest making it unlikely for paca to be established in these ecosystems. The remaining area of lowland broadleaved forest is too small to fit the required 6km$^2$grid. As a result, only Freshwater Creek will be used to evaluate paca densities. Lowland broad-leaved forest is the dominant ecosystem at Freshwater Creek, the size of the area requires two 6km$^2$ grids. The northern-most grid incorporates both Freshwater Creek and Honey Camp National Park. Figure 24 shows two paca plots within Fresh Water Creek. The shown plots would require 12 camera stations, needing 24 cameras. The choice of area search, straight line transect search or random line search needs to be considered after a thorough assessment on the ground in consultation with managers. Consistency and comparability are required across all sites within the area. This means the method will be chosen on the basis of the most difficult plots. Setting up of cameras, creation of infrastructure for plots and subsequent surveys should ideally happen in the first year of monitoring.

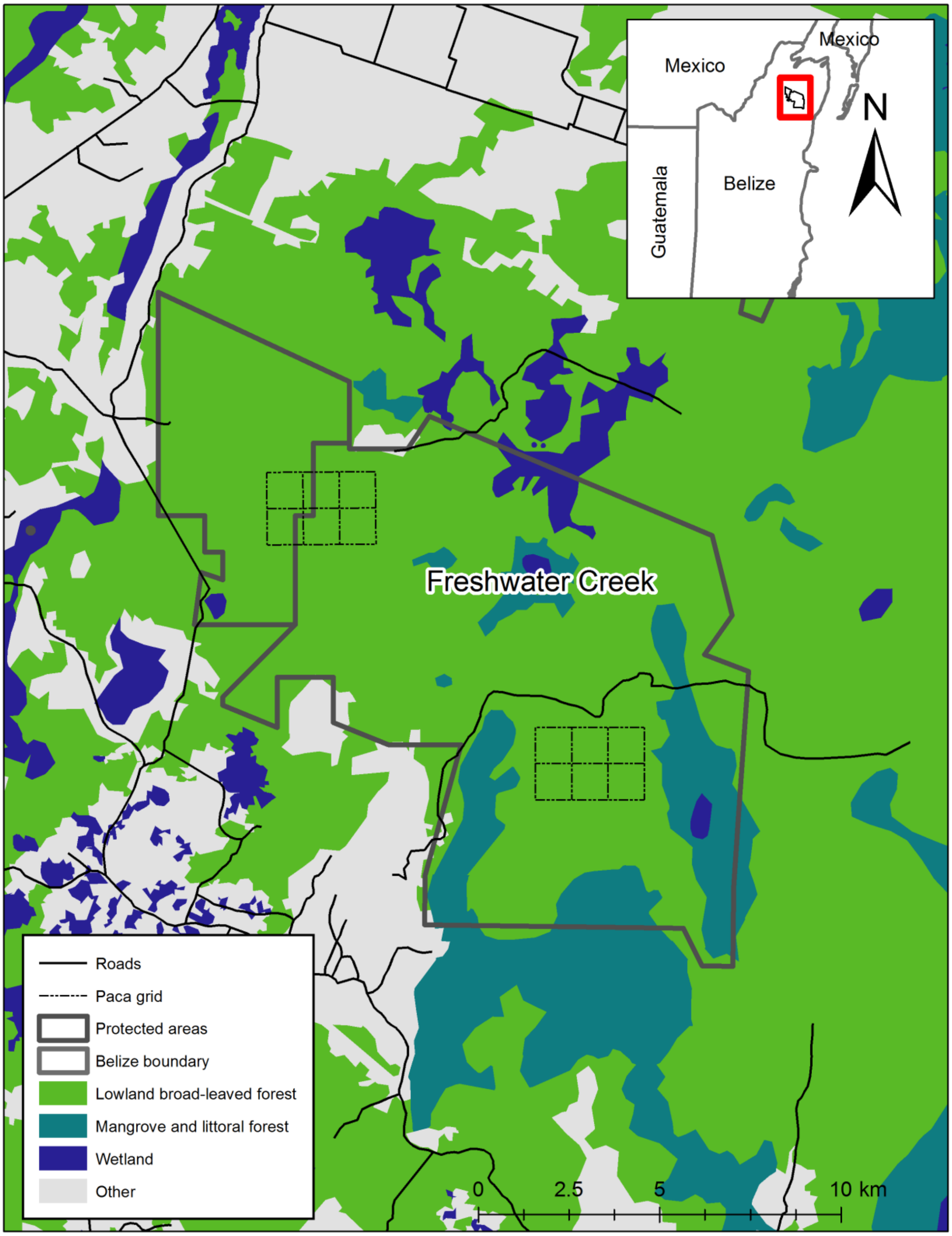


Figure 24. Proposed plots for monitoring pacas within the landscape of Corozal.

### Human-wildlife conflict monitoring

Although CSFI already carries out considerable work in the field of community relations, they need to assure that there are specific personnel assigned to monitoring of conflict situations.A trained and dedicated officer needs to actively remain in contact with stakeholders and monitor conflict and wildlife related issues within the human dominated landscape outside of the two protected areas. For conflict monitoring to be effective, it must happen continually, with active visits to stakeholders and rapid responses to problems. It is essential that this conflict team has permanent access to a vehicle and fuel.

Livestock and crop-growing farms need to be visited and farmers interviewed. Contact must be continuously maintained and camera traps made available. We propose the availability of at least 15-25 cameras for this sole purpose with 10-15 cameras continuously running on and around farms with the highest chances of conflict. 5-10 cameras should be retained for immediate response to calls of conflict. The officer (or officers) should remain in close contact with the responsible Forest Department wildlife officer in Orange Walk or Corozal and regularly meet to assure close communication with the Belmopan head office wildlife officer. Regular meetings with conflict officers around the country should take place to maintain the national network active.

### Monitoring outside of protected areas

The remaining forests between SNR and FC are very narrow and broken, but these is the only possible route for individuals moving through the remaining wilderness landscape. Monitoring for wildlife presence here is essential for the maintenance of the larger fauna ecosystem in the North. We therefore propose that the community liaison officer in conjunction with conflict officer (potentially the same person) should first discuss with local stakeholders and residents the risk of placing cameras, and mechanisms to reduce this risk. Cameras will be made available according to the ability to expand. Eventually the area between Shipstern and Freshwater Creek should be covered by camera stations, using the~3 km distance between stations criteria. Connection between Freshwater Creek and CBC and Rio Bravo is more difficult but the more camera grids can be expanded South of Freshwater Creek the better. This is however something that will be discussed with personnel on the ground in relation to community and stakeholder wishes.

### Monitoring of domestic animals

The highly fragmented nature of the landscape means an increased chance of wildlife to be infected with domestic diseases. Monitoring of diseases within dogs and livestock is therefore important. Ticks, blood and skin samples will be collected and sampled from dogs and livestock from surrounding communities (to be decided, see methods section).

Camera traps will detect domestic animals, allowing the calculation of frequency and distribution of incursions within the two protected areas. The further study of dogs as potentially competitors carnivores preying on wildlife should be considered if incursions are frequent and widespread (e.g. use of cheap store on board GPS collars for known culprits based on camera trap data, see method section).

# ANNEX 8:

## YELLOW HEAD PARROT (*Amazonaoratrix belizensis*)

Prepared by Charles Britt, MSc.
Scarlet Six Biomonitoring Team

**Background**

The Yellow-headed Parrot (*Amazonaoratrix*) is an IUCN Red-listed species and is considered in endanger of extinction across its range. In 1994, there was an estimated 7,000 individuals remaining in the wild; 4,700 were considered mature (Bird Life International 2015). A range-wide decline was judged to be approximately 90% from the 1970's. In addition to habitat loss, the yellow-headed parrot is the most highly valued Amazon parrot in trade because of its attractive plumage and ability to imitate human speech (Cantu et al 2007).

The distribution of the species includes Mexico, Belize, Guatemala, and Honduras. The distribution in Mexico is disjunct along the coastal areas of the Pacific, Gulf of Mexico, and Caribbean. Monterrubio et al (2010) estimates a 79% reduction in distribution along the Mexican Pacific coast. The largest remaining habitat were found in the states of Oaxaca and Michoacán. They are likely extirpated from the state of Colima and were only observed in less than ten percent of historic localities in Jalisco and Guerrero.  The race *A. oratrixtresmariae* occurs in Islas Tres Marias off the Pacific coast. The race of *A. oratrix magna* occurs disjunctly in the Gulf of Mexico coastal and inland areas in the states of Tamaulipas, San Luis Potosi, and Veracruz. The largest number of Yellow-headed Parrots observed in Mexico was 183 in San Luis Potosi. However, the largest flock was only 25 individuals. There is a contiguous area of occurrence shared by the states of Chiapas, Tabasco, and Campeche.

The distribution of the race *Amazonaoratrix belizensis* is primarily restricted to the coastal pine savannas found throughout eastern Belize. Densities of this species in Belize may be the highest found throughout its distribution. There are areas in northern Belize have extensive occurrences natural nest cavities in pines resulting from hurricane-related disturbance (Nash 2004). The coastal pine savannas in southern Belize have experienced annual illegal fires that likely reduce the presence of natural cavities in dead pines (TIDE 2015). Introduction of artificial nests have been quickly occupied (M. Muschamp, pers. com.), suggesting a lack of suitable natural cavities. Large roosts in southern Belize of upwards of 400 individuals (C. Bech, pers. com.) suggests a large number of individuals remaining in Belize. Breeding season roosts (presumed to have the lowest number of individuals) have been observed to have over 200 individuals in Payne's Creek National Park and up to 50 individuals in the Rio Bravo Conservation Area (C. Britt, pers. obs.).

Yellow-headed Parrots in Guatemala of the race *A. oratrixguatemalensis* are found in Punta de Manabique and northwestern Honduras. They experienced a decline of 30% to 70 individuals from 1994 to 2001 primarily because of nest poaching (Eisermann 2003, Eisermann in litt. 2007). An attempt to relocate this population in 2014 resulted in 4 individuals being observed (C. Britt, pers. obs.). However, safe access to these areas was an issue and surveys in 2016 have been canceled (L. Joyner, pers. comm.). In Honduras, Flores and Martinez (2015) reported 115 sightings of this race in the Cuyamel-Omoa National Park in the Valle Cuyamel.

*Historic Distribution in Belize*

Russell (1964) reports specimens from Hill Bank, Gallon Jug, Crooked Tree Lagoon, All Pines, Ycacos Lagoon, the lower sections of the Sibun and Sittee rivers.

*Current Distribution in Belize*

From the examination of eBird data, there are reports of Yellow-headed Parrots from every district except Corozal District. For Cayo District, there are only two reports. These occurred at Blancaneaux Lodge located on the Mountain Pine Ridge Forest Reserve. Most occurrences are within or adjacent to dense or open pine savanna ecosystems and ecotonal areas.

*Habitat Use in Belize*

Russell (1964) reported that the species roosts and nests in the pine ridges but flies daily into nearby tall, humid forests in order to feed. Nash (2004) reported that important nesting areas tended to occur in open pine savanna ecotonal areas.

Table 1. Common food plants utilized by Yellow-headed Parrots (*Amazonaoratrix*) in Belize.

| Common Name | Scientific Name |
|---|---|
| Coco Plum | *Chrysobalanusicaco* |
| Pine | *Pinuscaribaea* |
| Sandpaper Tree (Ya ha) | *Curatellaamericana* |
| Oak | *Quercus spp.* |
| Black Poisonwood | *Metopiumbrownei* |
| Sapodilla | *Manilkarazapota* |
| Mammee Apple | *Calocarpummammosum* |
| Hogplum | *Spondias sp.* |
| Mango | *Mangiferaindica* |
| Oranges | *Citrus × sinensis* |
| Flamboyant Tree | *Delonixregia* |
| Cashew | *Anacardiumoccidentale* |

*Reproduction*

Breeding pairs initiate the nesting season in January and February, laying 2-4 eggs by March. Incubation lasts approximately 25 days. Chicks fledge in May and June. It is believed to have an affinity for *Pinuscaribaea*trees, where it nests in tree hollows, cavities, and even termitaria. However, there have been instances of them using oak and palm tree cavities (Nash 2004). In southern Belize, a successful artificial nest box program has been implemented at Payne's Creek National Park.

*Threats*

Miller and Miller (1998) noted Parrots in the local pet trade are a matter of concern. Yellow-headed Parrots have been observed as pets across Belize (C. Britt, pers. obs.). Nash (2004) noted that 31% of the nests she monitored (n = 66) were poached. Apparently there was some evidence that the regional endemic Yellow-headed Parrot (*Amazonaoratrix*) is being exploited for foreign markets (Somerville 1997).

**Methods**

*Line Transects*

Distance sampling has been used in studies of parrots for estimating population size (Walker and Cahill 2000; Rivera-Mila ´n et al. 2005), assessing abundance in different habitats (Marsden et al. 2001; Marsden and Symes 2006), and evaluating conservation actions (Jepson et al. 2001; Barre et al. 2010). This protocol will use distance sampling (Buckland et al. 1993, 2001) to carry out line transect surveys in pine savanna habitat throughout Belize.

The relatively open habitat type and conspicuous nature of Yellow-headed Parrots make walking line transects a good sampling technique to utilize. 200 – 1km line transects will be surveyed from February to May (Figs 1 and 2) to establish a baseline survey from which to plan additional surveys. Transects are stratified by savanna types (Open/Dense) and protected area status (Protected/Unprotected) and divided as follows: open savanna protected, dense savanna protected, open savanna unprotected, dense savanna unprotected. 50 transects are randomly assigned to each. In the event that partners in this effort are able to put forth additional time to conduct surveys then additional random transects will be assigned to their respective protected area.

Open savanna has a dominant graminoid layer with scattered trees and/or shrubs that have a maximum canopy closure of 10%. The tree component is dominated by Carribean pine and palmetto, with patches of other shrubs found throughout. Dense tree savanna encompasses savanna that is usually conspicuously dominated by pine or oak (*Quercusoleoides*) the former occasionally with an understory of oak that can be quite dense in places. Canopy closure tends to be between 10-50%, and a grass-dominated herbaceous layer is found throughout.

In order to maximize the probability of detecting birds near the transect line, surveyors will carry out surveys in fair weather (i.e. no rain or strong wind). Surveying will begin at sunrise and continue for 3 hours. Similar to Lee and Marsden (2012), surveyors will move at approximately 1km/hr; one team will complete 1-2 transects per day, depending on location of each transect and logistical conditions.

Surveyors will begin transects at the easternmost end of the each transect and walk to the westernmost end in order to limit the interference of the sun on the detection and identification of species. Surveyors will walk quietly during surveys so that birds can be easily detected; listening for the sounds of wings flapping or parrots chattering. Whenever parrots are seen or heard, surveyors will make their way to their location as quickly as possible. All parrot species encountered and abundance will be recorded. Unknown parrot species will be recorded as an unknown parrot. Distance (m) and direction ($^{o}$) of each encounter, relative to the survey transect, will be noted. If surveyors suspect movement cannot not locate parrots during searches, then they will estimate their original location based on their calls. In addition, the GPS coordinates (NAD27, UTM) of each parrot or flock detected will be recorded. Surveyors should note flying birds at each location where first encountered, and pay attention to their flight path in order to minimize the possibility of counting them twice along the same transect. All observations occurring under 200m distance from the observers will be utilized to estimate the abundance of Yellow-headed Parrots using the program Distance.

The distance sampling data will be analyzed with the latest version of the software, Distance (Thomas et al. 2010), using methods described by Legault et al. (2013). Analysis will use the program's default CDS (Conventional Distance Sampling) engine, which analyses transect data using an approach described by Buckland et al. (1993, 2001). Exact distance measurements and cluster sizes will be used to estimate densities. The variance of each density estimate will be empirically calculated, based on the variance in observations between samples. Abundances will then be extrapolated for each savanna type and protected area status combination.

*Roost counts*

Roost counts comprise the identification of communal roost sites and the attempted undertaking of absolute parrot counts by a varying number of surveyors (dependent upon roost size and accessibility) as birds fly to or from the roost (Cougill and Marsden 2004). The accurate identification of roost site locations is critical to the method, and is often based upon extensive fieldwork, in addition to interviews with local people (Cockle et al. 2007). The real benefit of undertaking roost count surveys is that they allow demographic, in addition to population, data to be collected. This allows the estimation of both recruitment and fledging rates, and an assessment of the size of the effective breeding population at the roost (Matuzak and Brightsmith 2007). Overall, roost count surveys can potentially provide useful information on changes in the roosting populations of threatened *Amazona* taxa (Pitter and Christiansen 1995).

Surveyors will interview local people and workers in the survey areas to gather information on the location of known roost sites. It is advised to contact the Alcalde or Chairperson before conducting surveys in villages. In addition, surveyors will place themselves at high points throughout the project area in the evenings (1.5 hours prior to sunset), wherever they are conducting line transect surveys and/or nest monitoring in order to observe any large congregating movements of Yellow-headed Parrots. Any observations of congregating movements will be followed up by searches in the following evenings until roost sites are located.

Any roost sites that are located will be monitored a minimum of three times throughout the year; during the breeding season (Feb-Jun), post-breeding (July - Aug), maximum flocking (December). Ninety minutes before sunset, observers will spread out such that all approach directions to a roost site can be observed. All parrots entering the roost will be recorded in 5 minute increments until dark. The number of individuals in each group and the direction they are flying from will be recorded. Large flocks often contain many singles, pairs, triplets, quadruplets, and quintuplets, but each family group should be able to be accurately identified due to the proximity of individuals in pairs and family groups and the time interval between successive flocks. Following the count, observers will compare notes to ensure that groups were not double counted. The totals of each observer will then be compiled. Similar to the method used by Matuzak and Brightsmith(2007), to estimate the proportion of breeders in the population and potential recruitment of young, it is assumed that all groups of 3–5 parrots consisted of pairs with one, two, and three young, respectively. Because family groups in other parrots in the genus

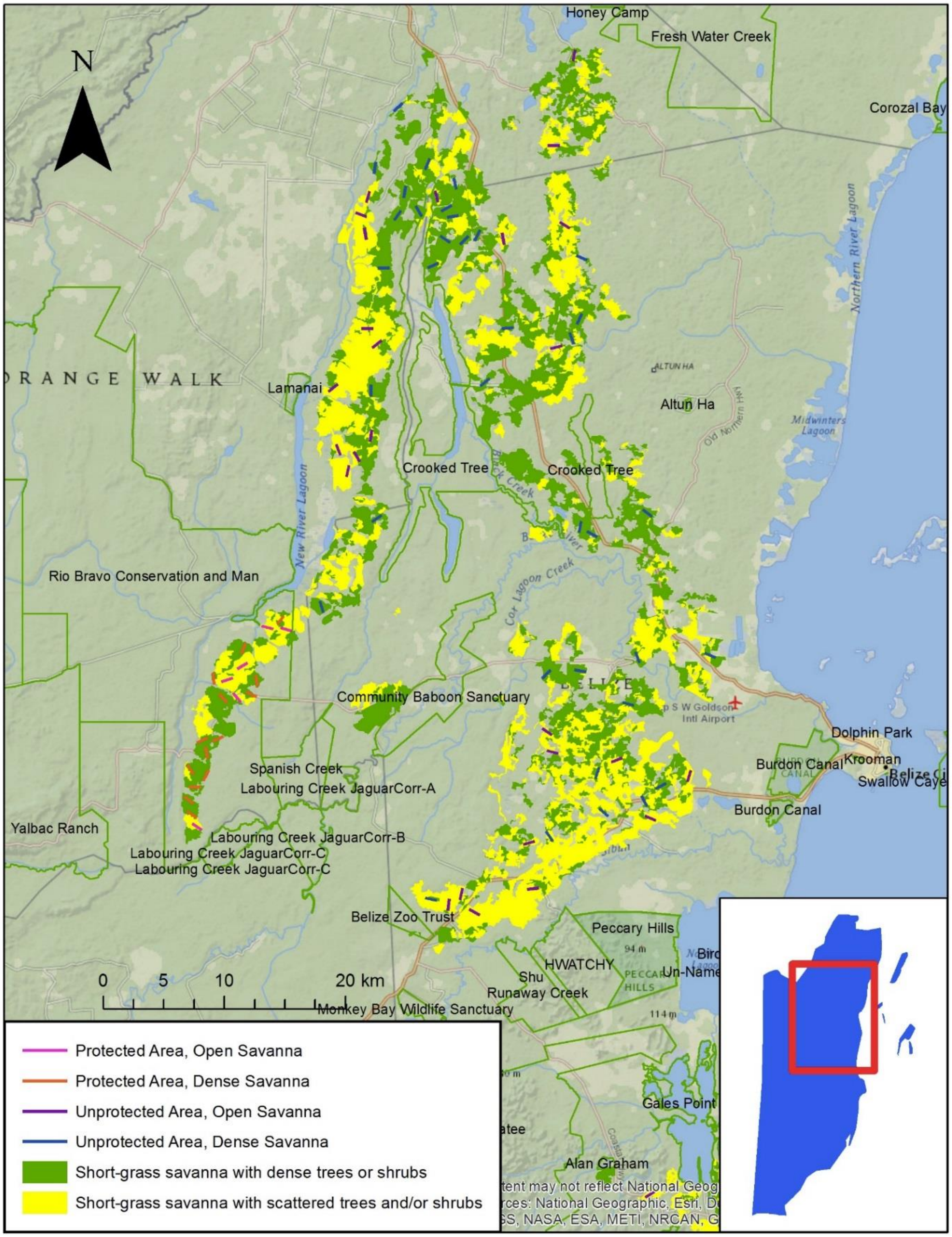


Figure 1. Sampling transects in northern Belize. Transects are stratified and randomly placed in four types of habitat/protected status: open savanna protected, dense savanna protected, open savanna unprotected, dense savanna unprotected.

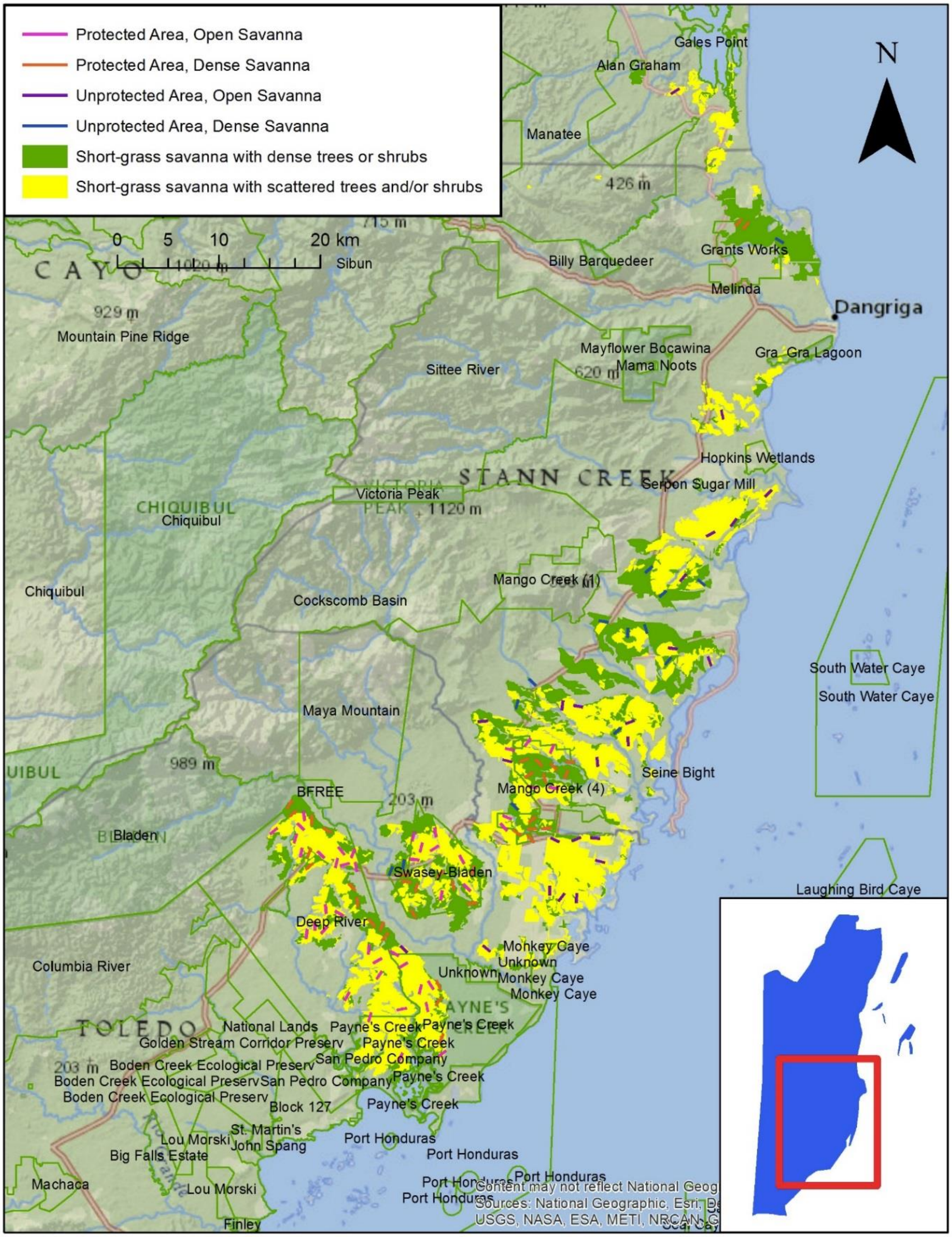


Figure 2. Sampling transects in southern Belize. Transects are stratified and randomly placed in four types of habitat/protected status: open savanna protected, dense savanna protected, open savanna

*Amazona* break up about 5 months after fledging, the period from 2 – 5 months after nesting appears to be the best time to determine the size of family groups and the recruitment of recently-fledged young. The percentage of young in the population will be estimated by dividing the number of young by the daily total. The number of young per family group will be calculated using data from the counts when the estimated percent of young in the population is highest.

*Nest Searches and Monitoring*

Nests will be searched for in an ad hoc fashion through opportunistic discovery during line transect surveys, movement between transects, and post-transect searches in survey areas. Located nests will be monitored on a weekly basis by either NGO staff, Scarlet Six Biomonitoring team staff, or volunteers. The location of each nest will be recorded. At each monitoring event, the number of parents present, eggs, chicks, and fledglings will be recorded. Any nest failures will be noted and cause of failure, if determined, will be noted. Nest site information will be collected: tree species, tree status, tree height, tree DBH, cavity height, cavity depth, and amount of openness each site (distance and direction to nearest tree in 4 equal quadrants surrounding the nest tree. If nests seem to be at high risk of being poached or if chicks appear unhealthy, the Belize Forest Department, Belize Bird Rescue, and collaborating NGO (if in a protected area) will be consulted to determine if chick(s) should be removed and transferred to Belize Bird Rescue for captive rearing and eventual soft release. In the event that veterinary support is available, then more intensive health checks will be permitted.

*Timing of Activities*

During the initial survey year, all surveying and monitoring activities will be conducted to create a data baseline (Table 2). Following the initial year, a follow up line transect survey may need to be conducted if the sample size is deemed too few. After baseline data is established, different activities will be conducted annually or bi-annually (Table 3).

Table 2. Timeline of activities during the initial year (2016) of survey effort

| Activity | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sept | Oct | Nov | Dec | Jan |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Planning Meetings | x | | | | | | | | | | | | |
| Training | | x | | | | | | | | | | | |
| Roost Surveys | | x | x | x | | | x | | | | | x | |
| Line Transects | | x | x | x | | | | | | | | | |
| Nest Searches and Monitoring | | x | x | x | x | x | | | | | | | |
| Data Compilation | | | | | | | x | | | | | | |
| Data Analysis | | | | | | | | x | | | | x | |
| Reporting | | | | | | | | | | | | | x |
| National Strategic | | | | | | | | | | | | | x |

| | |
|---|---|
| Meeting | |

Table 3. Proposed occurrence of survey and monitoring activities

| Activity | Every year | 2 yrs |
|---|---|---|
| Line Transects | | x |
| Nest Searches and Monitoring | x | |
| Roost Searches | | x |
| Roost Surveys | x | |
| Evaluate reproduction | x | |
| Evaluate population | | x |

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**Appendix A. Estimated budget for the initial year of survey activities (in Belize dollars)**

| Item | Amount |
|---|---|
| **Personnel** | |
| Coordinator ($2000/mo. for 3 months) | 6000 |
| Technicians (3@$45/day for 90 days) | 12150 |
| **Travel Costs** | |
| Fuel | 2000 |
| Vehicle Maintenance | 500 |
| Vehicle Insurance | 200 |
| **Field Expenses** | |
| Rations (4 people @$12/day for 90 days) | 4320 |
| Project shirts (8@$30) | 240 |
| Pens | 20 |
| Paper | 50 |
| Phone Credit | 200 |
| **Equipment** | |
| Tents (4@$300) | 1200 |
| Backpacks (4@$200) | 800 |
| Binoculars (4@$500) | 2000 |
| Cameras (2@$700) | 1400 |
| GPS (2@$300) | 600 |
| Climbing rope, static (2@$400) | 800 |
| Climbing harness (2@$90) | 180 |
| Jumars (ascenders) (4@$160) | 640 |
| Figure 8 descender (2@$20) | 40 |
| Ascending foot straps (webbing) | 100 |
| Locking carabiners (10@$20) | 200 |
| Ladders (2@$150) | 300 |
| Rangefinder (2@$240) | 480 |
| Compass (2@$120) | 240 |
| **Project Total** | **$34,660.00** |

**Appendix B. Line Transect Survey Datasheet**

**Yellow-headed Parrot Line Transect Form**

Transect: ________ Page: ___ of ___

Date: ________ Obs: ________ Start: ________ End: ________

Temp (°C): ________ CC(%): ________ Precip: ________ Wind(m/s): ________ Area: ________

| Time | Species | Abundance | Dist (m) | Dir (°) | Behavior | Comments |
|---|---|---|---|---|---|---|
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Behavior: P (Perched), F (Flying; direction?), N (Nesting), B (Pair bonding), FG (Foraging)

Notes:

## Appendix C. Yellow-headed Parrot interview form

**Yellow-headed Parrot Interview Form**

Date: ____________ Location: ____________________ X-Coord: __________ Y-Coord: __________

Time: ____________ Data Collector: ____________________ Interviewee: ____________

Do you see parrots where you work/live? ____________ YHPA? ____________

Do you see them all year or part of the year? ________ When are they most abundant? ________

What are they doing? Feeding Roosting Nesting Flying Other ________

What plants do they use? ________________________________

Are there more/less now than in the past? Why? ____________________

When was the last time you saw them? ____________ How many? ____________

How many are pets where you live? ____________________

Do you know they are endangered with extinction? ____________________

Directions to place(s) they have been observed:

Additional Notes:

## Appendix D. Single Observer Roost Monitoring Datasheet

**Yellow-headed Parrot Roost Monitoring Datasheet** Page _____ of _____

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Roost ID: | | Start Time: | | X Coord: | | Elev (m): | |
| Date: | | End Time: | | Y Coord: | | Tree sp: | |
| Location: | | | | Obs: | | Obs Position: | |
| Temp(°C): | | CC (%): | | Precip: | | Wind (m/s): | |

| Time | Species | Group Size | Direction | Comments |
|---|---|---|---|---|
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| Species | Total |
|---|---|
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Notes:

## Appendix E. Daily Total Roost Monitoring Datasheet

**Yellow-headed Roost Monitoring Daily Totals Datasheet**

Roost ID: ________ Start Time: ________ X Coord: ________ Elev (m): ________
Date: ________ End Time: ________ Y Coord: ________ Tree sp: ________
Location: ________ Obs: ________
Temp(°C): ________ CC (%): ________ Precip: ________ Wind (m/s): ________

| Species | Total | Group Size | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 |
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| Notes |
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**Yellow-headed Roost Monitoring Daily Totals Datasheet**

Roost ID: ________ Start Time: ________ X Coord: ________ Elev (m): ________
Date: ________ End Time: ________ Y Coord: ________ Tree sp: ________
Location: ________ Obs: ________
Temp(°C): ________ CC (%): ________ Precip: ________ Wind (m/s): ________

| Species | Total | Group Size | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 |
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| Notes |
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## Appendix F. Nest Monitoring Datasheet

**Yellow-headed Parrot Nest Monitoring Datasheet**

| | | | | | |
|---|---|---|---|---|---|
| Nest ID: | ______________ | X Coordinate: | ______________ | Elevation (m): | ______________ |
| Location: | ______________ | Y Coordinate: | ______________ | Tree Species: | ______________ |
| Tree Status: | ______________ | Nest Ht (m): | ______________ | Previous poaching: | ______________ |
| # Eggs laid: | | # Hatched: | | # Chicks fledged: | |

Cause of Nest Fate: Fledged ( ) Poached ( ) Predation ( ) Structural Failure ( ) Other____________

| Date: | Surveyors | Observations |
|---|---|---|
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Notes

## Appendix G. Incidental Observations Datasheet

**Yellow-headed Parrot Incidental Sightings Location**

| Date | Time | Observers | X-Coord | Y-Coord | Abun-dance | Group Sizes | Comments |
|---|---|---|---|---|---|---|---|
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**Appendix H. Chicks Health Exam Datasheets**

| | | | |
|---|---|---|---|
| Date: | | GPS: | |
| Nest #: | | Weather: | |
| Scribe: | | Examiner: | |

| | |
|---|---|
| Nest Condition: | |
| # Chicks Present: | |
| # Eggs Present: | |
| Parents Present? | |
| Parents Vocalizaing? | |
| Chick vocalizing? | |

| | | | |
|---|---|---|---|
| **Chick #1** | | | |
| Time Out of Nest: | | Time Back In Nest: | |

| | | | |
|---|---|---|---|
| Age: | | Is this estimated? | |
| Band #: | | | |

| | | | |
|---|---|---|---|
| Attitude: | | Posture: | |
| Heart Rate: | | Respiratory Rate: | |
| Feeding Response: | | Crop Size: | |
| Crop Contents/Food Type: | | Crop Motility: | |

| | | | | | |
|---|---|---|---|---|---|
| Weight: | | Body Score: | | | |
| Tarsus: | | Radius: | | Wing Cord: | |
| Bill Width: | | Bill Depth: | | Bill Length: | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Primary: | | Secondary: | | C. Ret: | | |
| Feather Condition: | | | | | | |
| **Stress Lines:** | | # Feathers: | # Lines | # Severe | # Moderate | # Slight |
| | Body: | | | | | |
| | Primary: | | | | | |
| | Secondary/Tertiary: | | | | | |
| | Coverts: | | | | | |
| | Ret: | | | | | |
| **Skin Condition:** | | | | Dehydration: | | |
| Estimated # of Mites: | | | | Mite Location: | | |
| Estimated # of Larvae: | | | | Larvae Location: | | |
| Lesions: | | | | Lesion Location: | | |
| **Head/Beak/Nares:** | | | | | | |
| **Eyes:** | Open? | | Other: | | | |
| **Ears:** | Open? | | Other: | | | |
| **Oral Cavity:** | | | **Wings:** | | | |
| **Abdomen:** | | | **Umbilicus:** | | **Cloaca:** | |
| **Back/Preen Gland:** | | | **Legs:** | | | |
| Feces: | | Urine: | | Urates: | | |
| Treatments: | | | | | | |
| Samples: | | | | | | |

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|---|---|---|---|---|---|---|
| **Chick #2** | | | | | | |
| Time Out of Nest: | | | | Time Back In Nest: | | |
| Age: | | | Is this estimated? | | | |
| Band #: | | | | | | |
| Attitude: | | | | Posture: | | |
| Heart Rate: | | | | Respiratory Rate: | | |
| Feeding Response: | | | | Crop Size: | | |
| Crop Contents/Food Type: | | | | Crop Motility: | | |
| Weight: | | | Body Score: | | | |
| Tarsus: | | | Radius: | | Wing Cord: | |
| Bill Width: | | | Bill Depth: | | Bill Length: | |
| Primary: | | Secondary: | | C. Ret: | | |
| Feather Condition: | | | | | | |
| **Stress Lines:** | | # Feathers: | # Lines | # Severe | # Moderate | # Slight |
| | Body: | | | | | |
| | Primary: | | | | | |
| | Secondary/Tertiary: | | | | | |
| | Coverts: | | | | | |
| | Ret: | | | | | |
| **Skin Condition:** | | | | Dehydration: | | |
| Estimated # of Mites: | | | | Mite Location: | | |
| Estimated # of Larvae: | | | | Larvae Location: | | |
| Lesions: | | | | Lesion Location: | | |
| **Head/Beak/Nares:** | | | | | | |
| **Eyes:** | Open? | | Other: | | | |
| **Ears:** | Open? | | Other: | | | |
| **Oral Cavity:** | | | **Wings:** | | | |
| **Abdomen:** | | | **Umbilicus:** | | **Cloaca:** | |
| **Back/Preen Gland:** | | | **Legs:** | | | |
| Feces: | | Urine: | | Urates: | | |
| Treatments: | | | | | | |
| Samples: | | | | | | |

# ANNEX 9:

## BIRDS

Prepared by Ivanna Waight-Cho, MSc. and Elma Kay, Ph.D.
University of Belize Environmental Research Institute

### Background

Belize's diverse ecosystem types provide a home to many resident birds and its ideal location in the Mesoamerican continent makes it instrumental in flyaway for migratory birds (Burke *et al*., 2009). Russell (1964) recognized a total of 465 species of birds in Belize (then British Honduras); 128 of those 465 species were winter visitants and transients. According to eBird (2016), 572 species of birds have been recorded in Belize to date.

Birds are sensitive species; they are easily affected by disturbances and as such can be used as indicators of overall ecosystem health, especially habitat quality (Canaday, 1997). The trends in their population can be indicative of changes to the ecosystem. However, there is limited bird monitoring in Belize to be able to determine this. Hence, there is a need to conduct monitoring (systematic and standardized) to determine trends in abundance and distribution in bird population in order to be able to detect any changes in ecosystem/habitat quality.

### Methodology

*Point Transects*

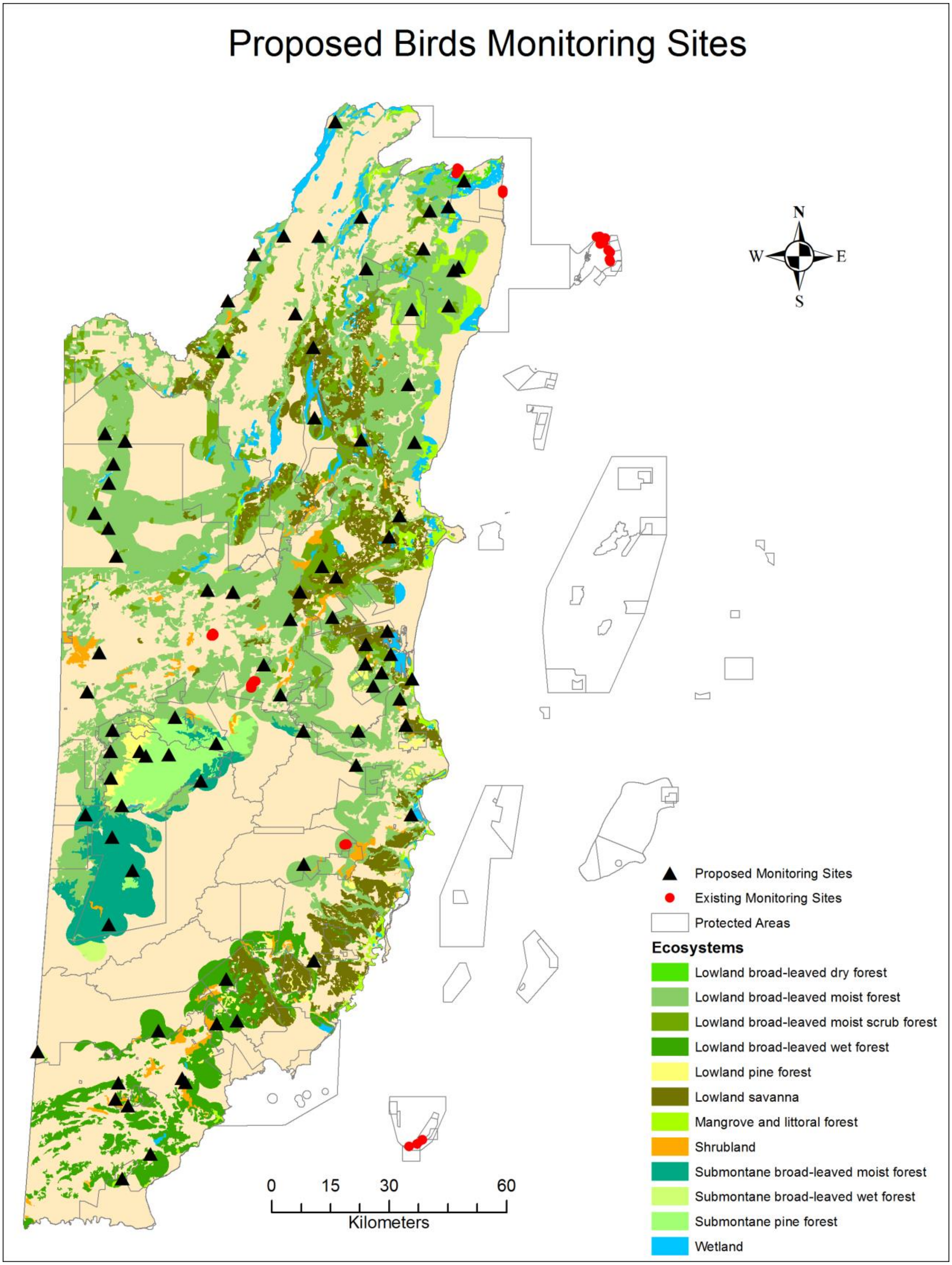
Point transect sampling is one of the two most common and widely used methods to survey birds. It is suitable for monitoring the trends in abundance of songbirds and is suited to conduct surveys in dense habitats such as forests and scrubs (Gregory *et al*., 2004). Point transects are also an efficient and inexpensive method to estimate presence and richness of birds (Vergara, 2010; Thoisy, Brosse and Dubois, 2008); it allows the surveyor to record more data per time expended.

1km transects will be surveyed across Belize in both protected and unprotected areas (Figure 1). The location of transects were based on a simple random sample, where transects were placed randomly across ecosystems that were within 3 km of access to a road. Count points should be separated by 250m along the 1km transect as recommended by Ralph *et al*., 1993 and 1995. Controllable and uncontrollable factors such as weather, time of day, season, distance from observer, habitat structure, etc. can influence sampling efficiency and affect the data (Vergara, 2010). Thus, surveys will start at sunrise and continue for 3 hours; if the weather is hot then the survey should start and end an hour earlier than usual (Zoological Museum). Also, in order to maximize the probability of detecting birds, surveyors should not conduct surveys if it's raining, if there is heavy fog, or if wind interferes with counting since these weather conditions have shown to almost always decrease number of birds detected (Zoological Museum, Ralph *et al*., 1995 and Huff *et al*., 2000).

The surveyor should allow an initial settling time of one minute before beginning the five minutes count at each point as recommended by Bibby *et al*. (1998), Huff *et al.* (2000) and Gregory *et al*. (2004). The surveyor will identify and record birds that are seen and/or heard using three belts of fixed distance: 0-25 m, 25-50 m and >50 m (Ralph et al., 1995). Employing distances within two or three belts have been recommended by Bibby *et al.* (1992) since estimating exact distances of bird contact, especially for calling birds in dense habitats, can be quite difficult. However, a digital rangefinder can be used to assist in measuring and estimating the distance (Schulze *et al*., 2004). Surveyor will record time, species, estimated distance, method of detection (visual or sound), behaviour, and sex if possible (see Appendix A). Unknown species will be recorded as unknown. Flying birds will be recorded separately; an estimate of their numbers should be recorded at each point.

**Sites**

**Figure 1** Map illustrating existing bird monitoring sites (red dots) and proposed new monitoring sites (black triangles). The proposed sites were randomly generated based on a 3km road buffer taking into account ecosystem types and protected areas. However, sites need to be expanded to cover more cayes.



Proposed Birds Monitoring Sites
N
W
E
S
Proposed Monitoring Sites
Existing Monitoring Sites
Protected Areas
Ecosystems
Lowland broad-leaved dry forest
Lowland broad-leaved moist forest
Lowland broad-leaved moist scrub forest
Lowland broad-leaved wet forest
Lowland pine forest
Lowland savanna
Mangrove and littoral forest
Shrubland
Submontane broad-leaved moist forest
Submontane broad-leaved wet forest
Submontane pine forest
Wetland
0 15 30 60
Kilometers

**Literature Cited**

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**Appendix A: Point Transect Survey Datasheet**

**BIRDS TRANSECT DATASHEET**

| | | | | | | |
|---|---|---|---|---|---|---|
| **Date:** | ________ | **Transect:** | ________ | **Station:** | ________ | **Behaviour:** |
| | | | | | | Perched (P) |
| **Surveyor:** | ________ | **Start:** | ________ | **End:** | ________ | Flying (F) |
| | | | | | | Foraging (FG) |
| **Wind:** | ________ | **Precipitation:** | ________ | | | |

| Time | Species | Abundance | Detection | Distance | Behaviour | Comments |
|---|---|---|---|---|---|---|
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# ANNEX 10:

# Proposed Approach to Monitor Timber Species Populations in Belize Under a Continuous Forest Inventory Framework

Prepared by Percival Cho, Ph.D.
Oxford University and Belize Forest Department

## *Table of Contents*

### *Background*

Under the National Biodiversity Monitoring Program, an essential element of the Conventional on Biological Diversity, Belize is required to design a system to monitor major biodiversity indicators across the country. One of these indicators is the status of commercially important tree species - the intensity of extraction of which is proportionally related to the severity of forest degradation, and by extension biodiversity losses. Natural mortality also has an impact on the status of timber species, as does pest and disease outbreaks. No continuous data collection is currently taking place that can answer questions about the status of populations of timber species on a national level over time. There is therefore a need to establish a national monitoring system that uses standardized, cost-effective methods to inform the status of timber species.

### *Introduction*

An efficient biodiversity monitoring programme will take into account prior data, especially if it can help to reduce the cost of monitoring. Some 'one-off' baseline data has been collected from forest inventories of several independently managed forest blocks across the country which can potentially be used to inform a 'prior' state of species population size and structure. Some of this data, however, has been collected by private sector firms for commercial purposes and there may be limitations with data sharing. Another potentially useful existing set of data is the Trade Inspection Felling Reports continuously collected by the Forest Department that can inform the rate of extraction of timber species over time from individual forest blocks. However, timeliness and completeness are some of the limitations with this data.

There are other limitations of these existing data that are more critical and which may affect the reliability of the assessment of the status of timber species. Firstly, the existing forest inventory data collected for the commercial assessment of timber species stocks and the data on timber extraction collected for the commercial assessment of taxes are not independent from the main process affecting the status of timber species, which is logging. For statistical reasons, the data used to assess the status of timber species needs to be independent from data about the processes affecting it. For accountability and transparency reasons, the assessment of the status of timber species need also to be independently performed. These reasons alone would be enough to discount the use of existing data, but another important reason to not use the existing datasets on species population size and structure coupled with data on extraction rates, is that neither are spatially extensive enough nor do they account for all factors affecting the status of timber species, such as diseases, pests, and illegal logging.

What is needed is an independent, continuous assessment of the status of the populations of timber species that is both spatially extensive and temporally intensive, and able to capture the effect of all factors affecting timber species populations. This document proposes a way forward with respect to the monitoring of the status of timber species that can inform the status of this important indicator of biodiversity health. The objective is to monitor the state and distribution of the population of Belize's timber species.

## *Partnerships and collaboration*

For this approach to be successful, it will be necessary to garner the support and participation of several key partners including forest land owners, the Forest Department, academic institutions, private consultants, and independent experts.

Forest land owners are key because data collectors will have to enter upon their land to collect data. The Forest Department is a key player because they are the agency responsible for the management of all forest resources and as such can facilitate the access arrangements between forest land owners and data collectors. Academic institutions will add an element of independence and credibility to the monitoring efforts and may also be involved in data collection and analysis, especially if research can 'piggy-back' upon the monitoring programme. Private consultants have collected a wealth of 'prior' data that may be able to add value to the baseline dataset. Experts in the field can provide the kind of scientific and logistical advice that will help to ensure cost-effectiveness and efficiency.

## *Methodological framework*

As with any long-term monitoring programme, cost-effectiveness is of utmost importance. Several methodological considerations are made to reduce cost with minimal loss of statistical power. These considerations create a methodological framework that aims to achieve monitoring objectives at least cost. These are as follows:

(i) Only hardwood timber species are to be surveyed (reduces cost related to surveying pine areas and difficult to identify species that are not used for timber);

(ii) Long belt transects are to be used as replicates as opposed to small plots (reduces effort/cost related to traversing long distances along which no data is collected only to collect data from a small plot located at the end of the journey);

(iii) Each replicate will intersect an all weather access road (reduces cost related to travelling time);

(iv) Only forests undergoing the main process which affect timber species populations (i.e. logging) will be monitored (reduces cost related to surveying areas which add no relevant information to answering the question at hand);

(v) Populations will be assessed for the status of established trees (≥10 cm DBH) only, i.e. no saplings or seedlings will be assessed (reduces the cost related to surveying smaller stems whose numbers are very temporary in nature as they undergo high mortality between inventories - in any case, focussing on established trees ≥10 cm DBH between points in time informs population changed due to successful recruitment which is more permanent in nature and therefore of more value).

(vi) The replicates will form a permanent and continuous sample frame to be revisited for data collection to detect change (reduces cost associated with re-establishing new transects);

(vii) Replicates will be re-measured every five years to maximise change detection (reduces cost associated with frequent sampling of no change scenarios).

### *Sampling objectives*

This is a monitoring exercise and as such the sample objectives are to detect changes in the populations of different timber species and to try to attribute causes. It is not the objective of this activity to determine exploitable volumes of timber species and other non-timber forest products or the status of regeneration of timber species. The specific objectives of this monitoring activity are as follows:

(i) To determine the status of established populations of presently commercialized hardwood timber species with Gaussian population curves from 10 cm DBH and above as listed below:

| | |
|---|---|
| Mahogany | Swieteniamacrophylla |
| Cedar | Cedrelamexicana |
| Rosewood | Dalbergiastevensonii |
| Bastard Rosewood | Swartziacubensis |
| Billywebb | Sweetiapanamensis |
| Black Cabbage Bark | Lonchocarpuscastilloii |
| Granadillo | Platymisciumyucatanum |
| Hesmo | Lysilomaacapulcense |
| Barbajolote | Cojobaarborea |
| Salmwood | Cordia alliodora |
| Prickly Yellow | Xanthoxylum spp. |

(ii) To determine the status of established populations of presently commercialized hardwood timber species with inverse-J population curves from 25 cm DBH and above as listed below:

| | |
|---|---|
| Hobillo | Astroniumgraveolens |
| Redwood | Erythroxylumareolatum |
| Red Mylady | Aspidospermamegalocarpum |
| Santa Maria | Calophyllumbrasiliense |
| Sapodilla | Manilkarasapote |
| Nargusta | Terminalia amazonia |
| Black Poisonwood | Metopiumbrowneii |
| Red Sillion | Pouteriaizabalensis |
| Chicle Macho | Manilkara chicle |
| Bullet Tree | Terminalia buceras |
| Yemeri | Vochysiahondurensis |

(iii) To construct stand tables showing the numbers of stems by 5 cm DBH classes

(iv) To achieve a sampling error (confidence interval) of no greater than 20% of the mean number of stems at 95% probability.

## *Sample frame*

The broadleaf forest was divided into two parts: areas presently subject to extraction (Forest Reserves, private extractive estates, national lands, and indigenous communal lands) and areas that are not (protected areas and privately protected lands). Only the former is of interest for monitoring the status of populations of timber species. The forest areas subject to logging was then divided into 5 x 5 km blocks, each of which must be at least 30% forested and contain a road. This resulted in 244 sample blocks and a representative sample frame equal to 447,000 hectares of forest or about 34% of the total forest area of the country.

In every resulting 5 x 5 km block 1 sample transect was randomly located subject to the restriction that each transect should intersect an access road, and that transects in adjacent blocks should not lie closer together than 800 metres of each other. In some cases it was necessary to vary the latter requirement due to the more important access constraint. Transects were 5,000 metres long and 20 metres wide spanning the full extent of a block and oriented in an east-west direction. For booking purposes the transects were subdivided into 100 subplots of 50 x 20 m. The subplots were numbered consecutively from 1 to 100 starting from the east. Figure 1 shows the sample locations.

## *Sample intensity (spatial and temporal)*

Spatial intensity

The total area of a transect was 10 hectares, and over all 244 sample blocks represent a sample of 2,440 hectares resulting in a sample intensity of around 0.54% of the sample frame.

All 244 blocks were represented at 0.54% sample intensity for the widest spatial spread possible, but it is foreseeable that an alternative scenario might result in half of the blocks being selected at random for inclusion in a sample of lesser intensity and therefore cost, say 0.27%. Although not very spatially representative, this intensity is still expected to result in a reliable estimate approaching or meeting the requirement of confidence interval as 20% of the mean. Other alternative sampling intensities along with the corresponding number of blocks/transects sampled are provided below for ease of reference. A word of caution: any lessening of the sample intensity should be accompanied by a random which ensures even spread.

| Sample intensity | Number of blocks/transects surveyed | Representative sample size (ha) |
|---|---|---|
| 0.54 % | 244 | 2,440 |
| 0.27 % | 122 | 1,220 |
| 0.135 % | 61 | 610 |
| 0.067 % | 30 | 300 |

Temporal intensity

A trade-off between frequency of measurement and cost has to be made in any monitoring exercise. In the case of this sampling framework for monitoring the status of timber species, a return period of five years is envisioned. This should allow ample time for in-growth into the sample DBH classes after extraction, allow ample time for extractive activities to take place in most areas, while reducing the cost of monitoring considerably.

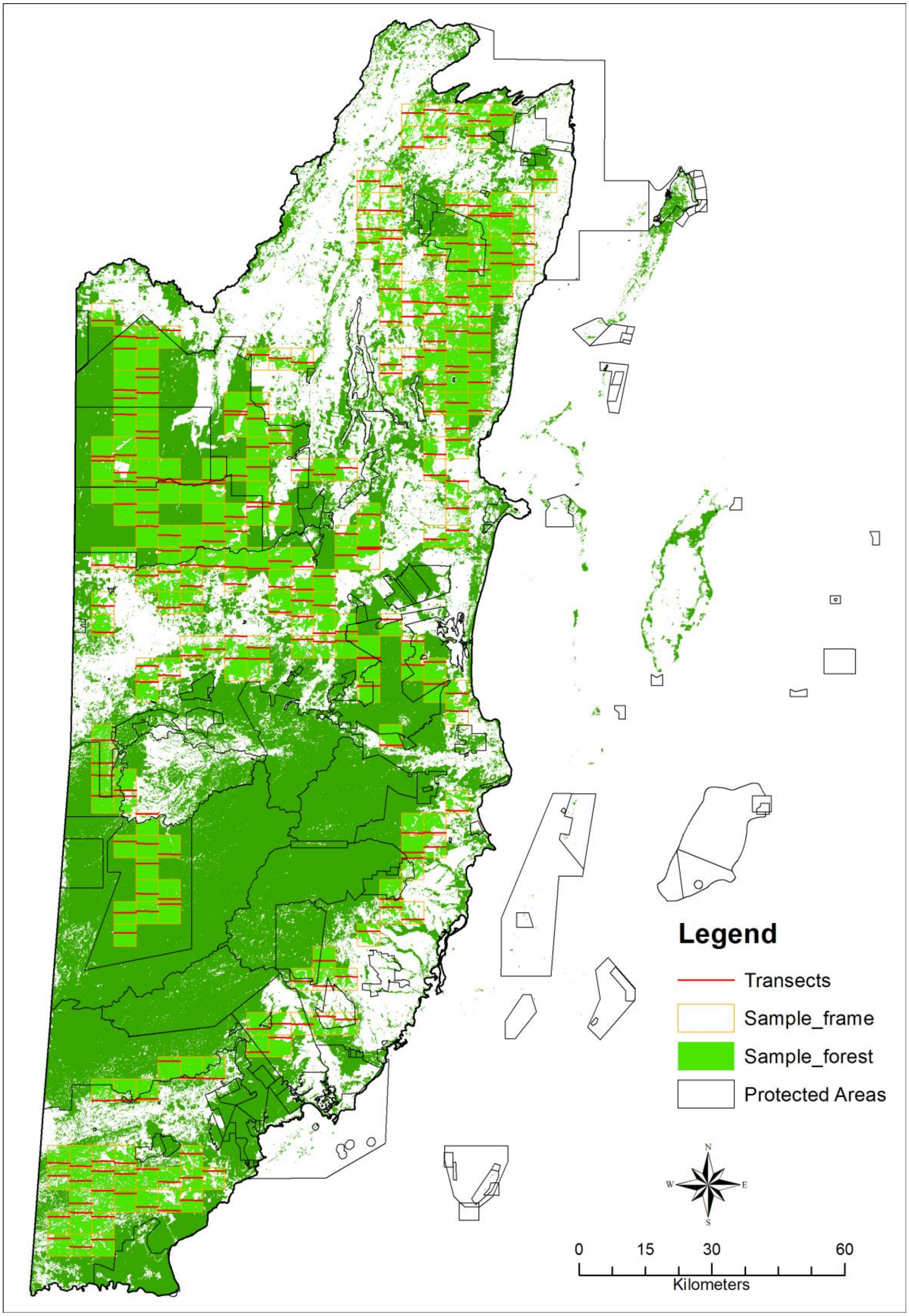


**Figure 1. Sample frame and sample transect locations.**

## *Data collection methodology*

The field work will be guided by a Job Control Document which all field workers should become familiar with. The Job Control Document describes all aspects of field work and data collection and is included here.

**JOB CONTROL DOCUMENT**

**Monitoring the Status of Timber Species Populations**

INVENTORY PERIOD: 2017 onward - every five years

LOCATION: Nationwide

PURPOSE: The purpose of this inventory is to collect sample data necessary to evaluate the status of populations of listed timber species as per the objectives of monitoring.

CRUISE: Transects 10 hectares in area will be sampled throughout the sample frame. The dimensions of each transect will be 5,000metres by 20 metres oriented in an East to West direction. Transects will be located based on where they intersect roads, using as a guide the location of the transects entered as lines in a GPS unit. This will generally be the starting point of the survey. It is expected that each transect should take half a day to measure. A team can therefore do two transects per day under normal conditions.

TEAMS: There will be 4 persons to a team and 1 team leader. The team leader is responsible for accurate data recording and for making sure the protocol is followed at every stage. The other team members will each be assigned a role: tree measurer, assistant tree measurer, linesman, assistant linesman. Their duties will be to accurately measure each tree, assist with the measurement of each tree, cut and flag the central transect line, and assist with cutting the central transect line, respectively.

I. TRANSECT LAYOUT AND SAMPLING DESIGN

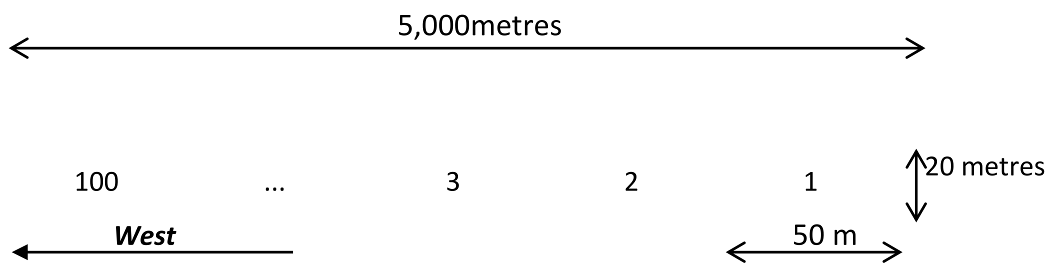

***Figure 2.*** *The transect layout to be used. All* *<u>Gaussian species</u>* *≥10 cm DBH and all inverse-J species ≥25 cm DBH are sampled in the entire transect.* *<u>All logged stumps</u>* *of any species and* *<u>all old truck-o-passes</u>* *are recorded throughout the transect.*

a. **Transect monumentation**: The starting point where sampling begins should be marked on each transect with a sturdy post of about 3 inches diameter and flagged with two rings of flagging tape. In addition, the eastern and western ends of each transect should also be marked in the same way. The location of these posts represent an imaginary central line dividing the transect into two halves each 10 m in width. The transect number should be written on the flagging tape. A 10 metre rope should be stretched due north and south of the starting point so that the team may become oriented with the transect northern and southern dimensions.

b. **Central transect**: From this starting point, a line heading due west or east (whichever the case may be) should be minimally cleared and posts erected and flagged at 50metre intervals along the line, and labelled with the distance from the starting point. Between these main posts there may be additional posts erected and flagged minimally but not labelled with distances.

c. **Subplots:** Each 50 metre by 20 metre section of the transect constitutes a subplot labelled as per Fig. 2. There will be 100 such subplots each being 1/20$^{th}$ of a hectare. Trees will be tallied on the field sheets by subplot in which the trees are located.

d. **Trees to look for in the subplots**: All trees ≥10 cm DBH of Gaussian species are recorded in the entire transect. For all inverse-J species, trees ≥25 cm DBH are recorded. <u>All logged stumps</u> of any species and <u>all old truck-o-passes</u> are recorded in the entire plot according to subplot.

e. **Data to record**: The species of all target trees should be recorded. The DBH at 1.3 m of all target trees should be recorded to the nearest 0.1 cm. Stumps which are the result of recent logging <50 years should simply be recorded as "Stump" with no diameter measurement. The presence of old truck-o-passes should be recorded per subplot.

f. **Edge trees:** Trees whose middle point falls exactly on the perimeter of the transect as measured from the centre line are included in the tally.

g. **Dead trees**: No clearly dead trees (snags, standing dead, broken dead) will be recorded.

h. **Species names:** A detailed species list is to be provided and includes the English, Spanish, Maya, and scientific names for the different species to be tallied. Prior to any data collections, a single name should be selected for each species to be used throughout the data collection process.

II. EQUIPMENT

Field sheets

One metric transect tape

One 25 m yellow rope

Two DBH tapes

One clipboard

One10 m yellow rope

Ample flagging tape

One GPS

### *Data sheets and storage*

Data are to be entered into a simple spreadsheet laid out in the same format as the field sheets (see Fig. 3 below). This can then be imported later into a database for processing.

NBMP Timber Species Status Survey Transect number: ___________ Sheet: _______ of ________

Name of Recorder: _______________________________________________ Date: ______________________

| Sub Plot | Tree # | Species of Tree | DBH | Comments | Sub Plot additional data | | |
|---|---|---|---|---|---|---|---|
| | | | | | 1 | 34 | 67 |
| | | | | | 2 | 35 | 68 |
| | | | | | 3 | 36 | 69 |
| | | | | | 4 | 37 | 70 |
| | | | | | 5 | 38 | 71 |
| | | | | | 6 | 39 | 72 |
| | | | | | 7 | 40 | 73 |
| | | | | | 8 | 41 | 74 |
| | | | | | 9 | 42 | 75 |
| | | | | | 10 | 43 | 76 |
| | | | | | 11 | 44 | 77 |
| | | | | | 12 | 45 | 78 |
| | | | | | 13 | 46 | 79 |
| | | | | | 14 | 47 | 80 |
| | | | | | 15 | 48 | 81 |
| | | | | | 16 | 49 | 82 |
| | | | | | 17 | 50 | 83 |
| | | | | | 18 | 51 | 84 |
| | | | | | 19 | 52 | 85 |
| | | | | | 20 | 53 | 86 |
| | | | | | 21 | 54 | 87 |
| | | | | | 22 | 55 | 88 |
| | | | | | 23 | 56 | 89 |
| | | | | | 24 | 57 | 90 |
| | | | | | 25 | 58 | 91 |
| | | | | | 26 | 59 | 92 |
| | | | | | 27 | 60 | 93 |
| | | | | | 28 | 61 | 94 |
| | | | | | 29 | 62 | 95 |
| | | | | | 30 | 63 | 96 |
| | | | | | 31 | 64 | 97 |
| | | | | | 32 | 65 | 98 |
| | | | | | 33 | 66 | 99 |
| | | | | | | | 100 |
| | | | | | ^---Place an 'S' if stumps or 'T' if truckopass are present | | |
| | | | | | | | |

**Figure 3. Data recording sheet**

### *Analysis*

Analysis is to be performed by a suitably qualified forester. It is envisioned that a data analysis toolpak will be created which will automate data analysis in the future.

### *Recommendations*

It is recommended that a working group be created to spearhead the planning an execution of the timber species status survey. Certainly, this type of work will have to fall on the shoulders of contractors, which will require the sourcing of sufficient funds every 5 years. As a rule of thumb, given 5 people surveying two transects per day at a survey cost of $210 per day, it will cost approximately $25,620 to survey all 244 transects. Analysis, if also contracted out will cost a further $7,500, for a grand monitoring cost every 5 years of $33,120. This estimate does not include transportation, subsistence, and any unforeseen delays.

# ANNEX 11:

## BATS

Prepared by Ivanna Waight-Cho, MSc.
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### Background

Bats are the second largest order of mammals and also the most diverse group of mammals in many tropical ecosystems. More than fifty percent of terrestrial mammal fauna in the neotropics are bats (Miller, 2010). Eight families of bats have been identified in Belize (Emballonuridae, Phyllostomidae, Mormoopidae, Noctiliobidae, Natalidae, Thyropteridae, Vespertilionidae and Molossidae) and approximately 80+ species (Medellin, 2016). Bats provide key ecosystem services and play important roles in pollination and seed dispersion. They are also key insect predators and excellent bioindicators since they respond to a number of changes in habitat quality (Meyer *et al*., 2011). Bat diversity and community structure should reflect changes in structure and diversity of rainforest (Medellin, 2016). Changes in their population will also reflect changes in their prey species, for instance arthropods (Miller, 2010).

However, an inventory/baseline along with monitoring is still lacking in Belize. Without an initial abundance, it is difficult to determine and keep track of their population status. Now faced with increasing urbanization, agriculture intensification, habitat loss and fragmentation (Meyer *et al*., 2011), it is imperative that such a task is conducted.

### Methodology

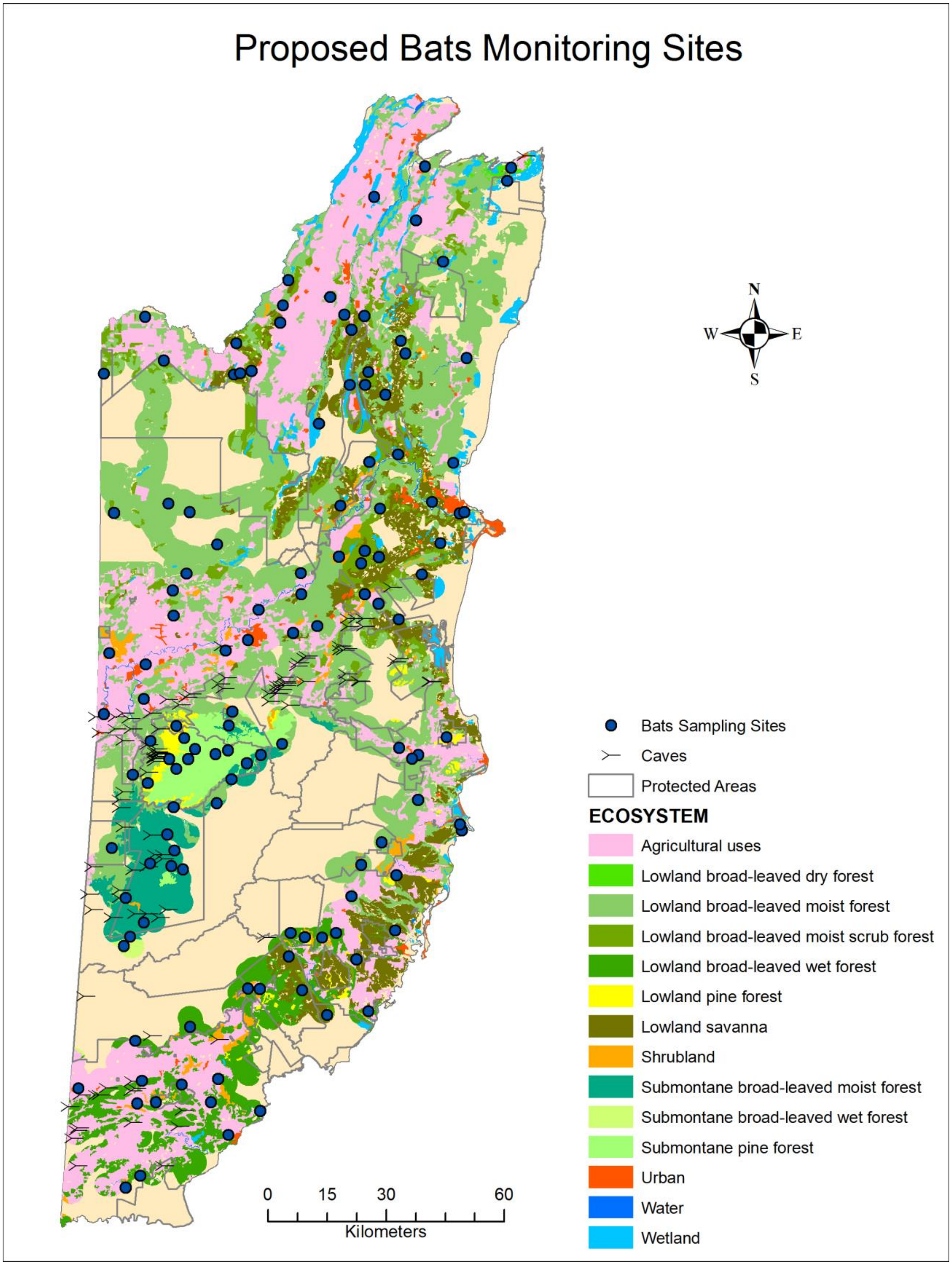
Since some species of bats fly too high to be caught in a net, some use low intensity echolocation calls that are too quiet to be picked up by detectors and some don't echolocate, the best method of monitoring bats is a combination of methods (Foxley and Gartzia, 2016). When monitoring bats in forested areas, mist nets and full spectrum bat detectors are a better combination. Surveyors should set up four mist nets per site based on proximity to habitat features such as openings, rivers etc. The nets should be opened at sunset until four hours after. Surveyors should check the nets every 15 minutes within the survey period. Once bats are caught in the nets, they should be extracted and placed in cloth bags until processed. When processing bats, surveyors need to identify species, determine sex, measure weight and forearm size. Trapping should not be conducted on bright nights or consecutive nights in order to prevent mist net avoidance.

Full spectrum detectors (model to be determined) should be used to record species of bats that are able to echolocate. As recommended by Foxley and Gartzia (2016), the detectors should start recording at sunset until five hours after for three consecutive nights since aerial insectivores' activity decreases after this time.

When monitoring bats in more open areas such as entrance of caves, harp traps and full spectrum bat detectors are a better combination. Similarly to the first combination of methods (mist nets and detectors), traps will be opened at sunset and continue for four hours. However, only two harp traps will be used. The detectors will start recording at sunset until five hours. Minimum of two to four within year site visits is suggested. Capture rate is determined by the number of mist net hours (bats/mnh) or harp trap hours (bats/hth) (MacSwiney *et al*., 2008).

**Sites**

**Figure 1** Map illustrating proposed sites for bat monitoring based on a 3 km road buffer and also taking into consideration habitat (ecosystem types and caves). The map should be used as a guide to facilitate discussion and on the ground inspection before finalization of long term monitoring sites.


Proposed Bats Monitoring Sites
N
W
E
S
Bats Sampling Sites
Caves
Protected Areas
ECOSYSTEM
Agricultural uses
Lowland broad-leaved dry forest
Lowland broad-leaved moist forest
Lowland broad-leaved moist scrub forest
Lowland broad-leaved wet forest
Lowland pine forest
Lowland savanna
Shrubland
Submontane broad-leaved moist forest
Submontane broad-leaved wet forest
Submontane pine forest
Urban
Water
Wetland
0
15
30
60
Kilometers

**Literature Cited**

Foxley, T and Gartzia, O. 2016. The Bats of the Maya Golden Landscape. Unpublished.

MacSwiney, M., Clarke, F., and Racey, P.. 2008. What you see is not what you get: the role of ultrasonic detectors in increasing inventory completeness in Neotropical bat assemblages. Journal of Applied Ecology, 45,pp. 1364-1371.

Medellin, R. 2016. Bat Lecture. Bat Biology Training Course.

Meyer, C.F.J., et al. 2010. Long-term monitoring of tropical bats for anthropogenic impact assessment: Gauging the statistical power to detect population change. Biological Conservation.

Meyer, C.F.J., et al. 2011. Accounting for detectability improves estimates of species richness in tropical bat surveys. Journal of Applied Ecology, 48,pp. 777-787.

Miller, B. and Miller, C. 2010. Results of the Pilot Monitoring Project for Bats (Chiroptera).

## Appendix A. Mist Net Survey Datasheet

**BAT MIST NET DATASHEET**

**Date:** ____________________ **Site:** ______________ **Mist Net #:** ______

**Surveyor:** ____________________ **Start Time:** ______________ **End Time:** ______

**Wind:** ____________________ **Precipitation:** ______________ **Temperature:** ______

| Time | Species | Bag Number | Weight with bag | Weight of bag | Sex | Forearm |
|---|---|---|---|---|---|---|
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**Comments:**

## Appendix B. Harp Trap Survey Datasheet

**BAT HARP TRAP DATASHEET**

**Date:** ____________________ **Site:** ______________ **Harp Trap #:** ______

**Surveyor:** ____________________ **Start Time:** ______________ **End Time:** ______

**Wind:** ____________________ **Precipitation:** ______________ **Temperature:** ______

| Time | Species | Bag Number | Weight with bag | Weight of bag | Sex | Forearm |
|---|---|---|---|---|---|---|
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