AN ASSESSMENT AND MONITORING PROGRAM FOR BIRDS IN THE LOWER URUBAMBA REGION, PERU

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Abstract. We developed an assessment and monitoring plan for birds in connection with the exploration and potential development of a large natural gas field in the Lower Urubamba drainage of Peru, a project of Shell Prospecting and Development Peru (SPDP). Our objectives were to: (1) inventory the birds in the area, including information on habitat use and abundance, and (2) devise long-term monitoring protocols for birds. We sampled birds through a combination of visual and auditory surveys and mist-netting at 4 well sites and 3 sites along the Urubamba and Camisea rivers. We recorded 420 species during 135 days of field work. We consider the highest priorities for a future monitoring program to be: (1) establish whether edge effects are occurring at well sites, along roads and along the planned pipeline route and determine the significance and extent of these effects and (2) assess the impact of increased human access to the area on game and other exploited species. The remoteness of the area, its rugged terrain and dense vegetation and the lack of trained personnel limit the choice of survey and monitoring methods. We recommend use of mist-netting and transects for monitoring edge effects and use of transects for monitoring game and other exploited species.

Keywords: adaptive management, assessment, birds, development, monitoring, tropical forests

1. Introduction

Birds are the most diverse group of terrestrial vertebrates. As a taxa, they have been well studied, and relatively few species remain to be described.

Most birds are diurnal, and many are conspicuous both visually and aurally. Birds are important consumers at several trophic levels, including primary (as frugivores and granivores), secondary and tertiary (as insectivores and as consumers of vertebrates). Through insectivory, birds may control insect populations such as folivores that attack forest trees and other plants (Holmes, 1990; Holmes *et al*., 1979). Birds may also be important as prey for other vertebrate carnivores. Through frugivory, birds are among the most important plant dispersal agents (Snow, 1971, 1981; Howe and Smallwood, 1982; Moermond and Denslow, 1985), and they may be important pollinators, especially in tropical environments (Carpenter, 1978; Feinsinger and Colwell, 1978; Ford *et al*., 1979; Stiles, 1981; Proctor *et al*., 1996).

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As consumers, prey, dispersers and pollinators, some birds may be keystone species playing a disproportionate role in the structure and function of ecosystems.

Birds also serve as hosts to specialized parasites (Marshall, 1981) and interact as commensals with other organisms such as army ants (Willis, 1978). Many birds play an important role in human culture – as food, as a source of decorative materials, as pets and in religion and folklore (Stefferud, 1966).

However, despite the great diversity of birds and their ecological versatility, they are vulnerable to human-induced environmental threats, and as a result many bird species are declining (Collar *et al.*, 1994). For this reason, it is essential that we understand the potential impacts that habitat alterations may have on bird populations so that we are alerted to problems before they occur.

We had the opportunity to investigate these issues as they related to a natural gas development project in Amazonian Peru. Here we discuss our approach to developing an assessment and monitoring program for birds within an adaptive management framework.

1.1. BACKGROUND

In 1996, Shell Prospecting and Development Peru (SPDP) began exploration and evaluation of a large natural gas deposit in the Lower Urubamba Region (LUR), Cusco Province, Peru. The project included the construction of 4 test wells and a supply base. Because the well sites were supplied by helicopter, SPDP built no roads connecting the well sites to the region outside of the project area. SPDP planned the eventual construction of many additional production wells and an internal road system to connect them, but the company intended to continue to supply the project site by helicopter throughout the duration of the project.

Upon initiation of the production phase, plans called for the construction of an underground pipeline to transport the gas out of the project area and a reforestation effort to mitigate the impacts of burying the pipeline. The Smithsonian Institution's Monitoring and Assessment of Biodiversity Program (SI/MAB) worked closely with SPDP to formulate an adaptive management plan that would allow for development of the natural gas resource while conserving the region's rich storehouse of biological diversity.

We assessed the bird community at 7 sites within the LUR project area. These included the 4 well sites of San Martin-3 (Sanm-3), Cashiriari-2 (Cash-2), Cashiriari-3 (Cash-3), and Pagoreni (Pag) and 3 sites – Las Malvinas (Lasm), Peruanita (Perua) and Segakiato (Sega) – along the Urubamba and Camisea rivers. The terrain throughout the area was typically rugged, in part because it was dissected by many small stream drainages. Elevation ranged from 320 meters (m) at Perua to nearly 700 m at Cash-3. Cash-2 and Pag consisted primarily of lowland broadleaf forest with little if any bamboo, while Sanm-3 and Cash-3 consisted of a complex mosaic of forest and dense concentrations of the bamboo *Guadua sarcocarpa*. The moist stream and ravine bottoms at those 2 sites had a higher proportion of trees than the drier ridge tops, which were dominated by bamboo.

The 3 sites along the rivers included floodplain forest as well as some patches of bamboo. Because of fallen and interlaced stems, bamboo-dominated sites were difficult to traverse except on trails. Areas of human-disturbed habitat occurred along the Camisea and Urubamba rivers, including crops cultivated by the local inhabitants and young second-growth forest and areas of *Gynerium* cane. Abandoned roads, now covered by successional vegetation about 10 years in age, remain at Cash-2 and Pag.

The LUR study sites lacked major habitat types such as lakes, swamps and seasonally flooded forest, which have been found to contribute to bird diversity in other parts of southeastern Peru (Remsen and Parker, 1983; Robinson and Terborgh, 1990; Terborgh *et al.*, 1990; Servat, 1996). Although successional vegetation occurred along the rivers, it was primarily a result of human activity and may lack some species found in natural successional habitats at nearby Manu National Park and other areas.

Dallmeier and Alonso (1997) provide more detailed descriptions of the study area while Comiskey *et al.* (2001) provide a detailed description of the vegetation.

2. Adaptive Management

Tropical rainforests are complex ecosystems. Moreover, these forests are disappearing at alarming rates (FAO, 1997), often faster than our ability to study and understand them. Therefore, managers of rainforest ecosystems frequently adopt a 'learn as you go approach' that requires the ability to identify changes in those systems created by both natural and human influences (Dallmeier, 1997) and to adapt management strategies accordingly.

Assessment and monitoring programs can provide natural resource managers with the information necessary to recognize changes and make scientifically sound decisions regarding the management of natural resources while conserving the biodiversity contained within ecosystems (Spellerberg, 1992; Dallmeier and Comiskey, 1998). Adaptive management plans involve 4 steps: (1) definition of goals and objectives, (2) assessment and monitoring, (3) evaluation and (4) decision-making (Holling, 1978; Walters, 1986). Goals and objectives identify aspects of the ecosystem for monitoring. Assessments provide the baseline data on species presence and abundance. Monitoring follows trends in selected ecosystem parameters and measures progress toward or success in meeting management objectives (Holling, 1978; Dallmeier and Comiskey, 1998; Elzinga *et al.*, 1998). Managers then evaluate the trends and make decisions regarding management strategies.

SI/MAB initiated a multi-taxa assessment and monitoring program within an adaptive management framework to evaluate the impacts of development in the LUR. We were responsible for collecting information on the bird communities.

Our objectives were to: (1) inventory birds in the area, including information on habitat use and abundance, and (2) develop long-term monitoring protocols for those birds.

3. Potential Impacts of Gas Development on Bird Communities

The potential impacts of development in the LUR relate to the presence of the well sites, the internal road network and the pipeline. The total area that might be developed for gas production is approximately 170,000 hectares (ha), most of which is forest except for small areas of agricultural clearings along the rivers.

At the time of our work, four 3-ha test well sites had been cleared. SPDP planned to construct at least 50 kilometers (km) of roads to connect the existing test wells, although the total length of road needed to cover the known gas fields would probably be on the order of 100 km (straight line distance; actual road miles would be significantly longer). In general, the cleared right-of-way for roads in the area was to be between 60 and 120-m wide, although SPDP planned to minimize that distance wherever possible. Assuming that 100 km of roads would be constructed using a 120 m right-of-way in addition to 100 production wells of 3 ha each, about 1500 ha of forest would be directly cleared – less than 1% of the project area. But if edge effects have an impact on forest birds as much as 1500 m from the edge of the clearing (see below), the total area of forest affected would increase to 31,200 ha, or 18% of the project area.

SPDP also controlled hunting near the well sites by banning the importation of firearms into the project area by SPDP personnel. Hunting by local peoples continued, however. Construction of a road system may facilitate access to remote parts of the project area by local hunters.

Some potential impacts of human activity are obvious. Clearly, when a tropical forest is cut and replaced by open land or agriculture, many of the forest birds will disappear. Near human settlements, game species and those popular in the pet trade may be affected by over-hunting or capture. Other effects may be more subtle. For example, Canaday (1997) found a decrease in the number of insectivorous forest birds within forest that was close to large clearings. Forest fragmentation – that is, division of previously contiguous forest into smaller blocks – may result in drastic losses in species diversity (Willis, 1974; Karr, 1982; Bierregaard and Lovejoy, 1989; Bierregaard *et al.*, 1992). Cleared areas within forest, particularly if they are connected to other clearings by continuous strips of disturbed habitat such as those along roads, could facilitate colonization of an area by predators, parasites or competitors (Kroodsma, 1982, 1984; Andrews, 1990; Burkey, 1993; Rich *et al.*, 1994).

The indirect effects of these clearings must also be taken into account. It is possible that the presence of clearings within the forest could affect bird populations over a much wider area. Canaday (1997), investigating the impact of petroleum development in the Cuyabeno region of Ecuador, surveyed birds within 4 zones defined by their distances from clearings and roads. The classifications were: (1) coffee plantations within 100 m of uncut forest; (2) edge forest, uncut forest within 300 m of roads and within 100 m of the contiguous clearings bordering the roads; (3) intermediate forest, uncut forest 2 km from roads and about 200 m from small clearings; and (4) interior forest, uncut forest at least 3.5 km from roads and 1 km from any clearings. He found that the number of insectivorous bird species varied significantly among these 4 zones and that fewer species were found in forest within 100 m of clearings than in the interior forest. Although minor, some effects were detectable up to 1.5 km from these clearings. In contrast, the number of species of frugivores and omnivores did not differ among the four zones.

Canaday was not able to identify the specific causes for these differences, but he proposed that the following factors could be involved: (1) microclimatic changes affecting the arthropod prey base; (2) greater habitat sensitivity by insectivores, as a result of their high degree of ecological specialization; (3) changes in predation; and (4) competition from opportunistic, disturbance-adapted omnivores. Canaday did not indicate how long the roads and clearings had been in existence, but the Cuyabeno region has been under development for petroleum for more than 20 years. It is possible that the decline in the number of insectivorous species near clearings took place over a period of many years.

Given these results, the monitoring program in the LUR should investigate edge effects in the vicinity of the well-sites and the proposed road network and pipeline. If edge effects exist and extend for a considerable distance from clearings, they could have impacts on bird populations over a significant area of forest.

4. Developing an Assessment and Monitoring Program for Birds

4.1. Assessment and monitoring methods commonly used for birds

Bird species differ widely in their habitat needs, population densities, ease of detection, daily and seasonal activity patterns and a host of other factors. Because of this variability, no single methodology is capable of assessing all species with equal accuracy and efficiency. A variety of methodologies for assessing and monitoring bird populations exists (Ralph and Scott, 1981; Verner, 1985; Bibby *et al.*, 1992; Ralph *et al.*, 1993), but trade-offs must be considered among the proportion of the bird community sampled, costs, the degree of training needed and similar concerns. Therefore, a combination of techniques is generally the best approach to assess the bird community as a whole.

Historically, scientists documented avifaunas by collecting specimens, primarily through shooting and more recently through shooting and mist-netting. Today this approach is less feasible in many countries because of concern about the killing of animals, especially 'higher' vertebrates (birds and mammals). Thus, alternative methods of documentation of a species presence in an area are often necessary, including photography, detailed measurement and description of captured individuals and tape recordings of vocalizations.

Three widely used techniques for monitoring bird populations are mist-netting, point counts and transect counts. Other techniques such as spot-mapping (Kendeigh, 1944; Robbins, 1970) yield more detailed information, but they are labor and time intensive, and for multi-species surveys in diverse tropical habitats, they require extensive training. For a general discussion and comparison of bird survey methods, see Ralph and Scott (1981), Verner (1985), Bibby *et al.* (1992) and references therein.

4.1.1. *Mist-Netting*

Mist-netting surveys consist of the operation of an array of mist nets in an area over a period of time. Captured birds are identified to species and to sex (if distinguishable externally). They may be assessed for age (adult or juvenile), breeding condition (brood patch, etc.), molt, parasite load and general physical condition (weight, fat deposits). For long-term monitoring, birds may be permanently marked with a numbered metal leg band or color bands and released. Recaptures of marked birds during subsequent surveys provide information on year-to-year survival, production of young, movements and other demographic parameters. (See MacArthur and MacArthur (1974) and Karr (1981) for discussions of mist-netting as a survey technique).

4.1.2. *Point Counts*

Using the point-count technique, an observer counts all birds seen or heard from a fixed point within a standard period of time, usually 8 to 10 minutes. A survey consists of a series of such counts done at various points within the study area over a period of time. Independent sampling points are established and permanently marked in selected habitat types at locations preferably at least 200 to 250 m apart. Points must be sufficiently far apart to minimize the probability that the same individual will be detected from different sample points. Counts at each point provide presence/absence data and an index of abundance. If estimates of the population density of species are desired, the observer also needs to estimate the distance from the point to each bird detected. Observers may count birds within a circle of fixed radius, or they may count all birds out to the limit of detection for each species. A mixed technique may also be used, in which distances are estimated to all birds within a circle of fixed radius, while birds outside this circle are simply noted as being present. Because singing activity in many species drops off sharply a few hours after first light, point counts are often restricted to the first few hours of the morning. (See Järvinen (1978), Reynolds *et al.* (1980), DeSante (1981) and Ramsey and Scott (1981) for discussions of point counts).

4.1.3. *Transects*

In the transect technique, an observer walks a fixed route, usually several km in length. When a bird is encountered, its perpendicular distance from the transect line is estimated to obtain density estimates. As in the point count technique, the observer may attempt to estimate distances to all individuals encountered or only to individuals within a fixed distance of the transect line. (See Emlen (1971, 1977), Robinette *et al*. (1974), Järvinen and Väisänen (1975), Burnham *et al*. (1980) and Tilghman and Rusch (1981) for discussions of transects).

4.2. ADVANTAGES AND DISADVANTAGES OF AVAILABLE METHODOLOGIES

4.2.1. *Mist Nets*

Advantages of the mist-net approach include: (1) Relatively little training is necessary to extract birds from the nets, operate the nets and carry out measurement techniques. (2) Identification manuals can be consulted with the bird in hand. (3) The method does not require knowledge of vocalizations. (4) The repeatability and accuracy of the data collected is high. (5) Data can be collected on physical conditions. (6) The recapture frequency of marked birds over time provides data on demographic parameters. (7) Secretive and inconspicuous species that cannot be assessed through other methods may be detected.

Disadvantages of the mist-net approach include: (1) It is labor and time intensive. Substantial effort is required for site preparation, and a field crew of two to three people is preferred, depending on the number of nets. (2) It samples only part of the community, primarily understory species between 5 and 100 grams in body weight. (3) Because capture rates depend on movement patterns and behavior, mist-netting cannot provide information on population densities or be used to compare relative abundances of different species. However, within-species comparisons between years and sites can be valid, provided there are no systematic differences in vegetation structure or the birds' social structure.

Mist-netting samples birds from a relatively small area, typically less than 20 ha. This may be an advantage or disadvantage, depending on the question at hand. The small sample area may assist, for example, in distinguishing bird communities in adjacent or intermixed habitats. Furthermore, terrain can place limitations on the use of mist nets. If placed on slopes that are too steep, nets will not catch many birds because it is impossible to maintain the correct net tension, and such nets are also very difficult for researchers to operate.

The biases of forest mist-netting are well known (MacArthur and MacArthur, 1974; Karr, 1981; Remsen and Good, 1996) and are strongly influenced by the height and structure of the habitat and movement patterns of individual species. Most forest bird species utilize specific strata of vegetation. Ground level mist-netting generally samples species that inhabit the lowest forest strata (ground level to 3 m) and are highly mobile. Ground-level netting catches fewer territorial species (unless the nets happen to intercept their territory) and canopy-inhabiting species.

Although mist-netting is biased toward understory species, balanced against this is the fact that this group includes many of the species that are most vulnerable to local extinction because of changes in their habitat (Willis, 1974; Karr, 1982).

4.2.2. *Point Counts and Transects*

Advantages of these approaches include: (1) They are less labor-intensive than mist-netting. (2) They sample a larger proportion of the bird community than mist-netting. Data can be obtained on canopy and other species that are not susceptible to capture with mist nets. (3) Estimates of population density can be obtained.

Disadvantages of the point count approach include: (1) Substantial training is necessary. This problem is enhanced in highly diverse tropical forests where many similar species may occur in the same area, many vocalizations must be learned and reference recordings may not be available. In addition, training in distance estimation is necessary if information is desired on population densities. (2) Surveys by different observers may not be readily comparable. Observers may differ considerably in their aptitude for learning calls or estimating distances. (3) Points are spread over a much larger area than mist-net locations, thus requiring an extensive trail system. This is particularly true if points are chosen according to a random protocol. (4) No information is obtained on physical conditions or demography. (5) Results may differ between the breeding season, when species are most vocal, and the non-breeding season. (6) Secretive or non-vocal species may be missed. Point counts are well suited to obtain data on common species. However, for rare species it may be necessary to sample larger areas than can be conveniently surveyed by point counts. The main advantage of transects over point counts is that a larger area can be sampled per unit of time. Birds are not counted during transit time between stations on a point count, while on a transect they are counted continuously. Assuming that birds can be detected accurately within approximately 50 m of the observer, we estimate that a single observer can survey between 3 and 5 times more area in a single session with transects than with point counts. This may not be important for common species, for which the accuracy of the count within the circle may be more important than the total area surveyed. However, for rare species it may be necessary to obtain adequate sample sizes.

5. The LUR Assessment

5.1. Methods

In the LUR, collection of a large series of specimens was effectively ruled out because of limitations on permits. And in consideration of relations with indigenous communities, SPDP prohibited hunting and the use of firearms by project personnel in the area. Thus, we collected only a small number of specimens, principally difficult-to-identify species or those representing range extensions of species with limited distribution. As an alternative, we documented species occurrence in three ways: (1) photographs of mist-netted birds, as well as a few larger species such as raptors that were not captured and photographs of selected species were deposited with the Visual Resources of Ornithology (VIREO) database at the U.S. Academy of Natural Sciences, (2) detailed measurements and descriptions of captured birds and (3) recordings of vocalizations, with deposit of selected recordings in the Library of Natural Sounds at Cornell University's Laboratory of Ornithology. We recorded vocalizations with a Sony TCM-5000 portable cassette tape recorder with a Sennhauser short shotgun microphone.

During the first phase of the project, we focused on a detailed assessment of the avifauna. Rugged terrain, dense vegetation and limited time influenced the survey methods used. These factors precluded the establishment of random point-count arrays or transect lines of reasonable length. To use time efficiently while maximizing information gathered, we used a combination of mist-netting and thorough visual and auditory surveys of the area. An important consideration favoring mist-netting was the acquisition of easily reproducible data for any future monitoring program. Since there was no expectation that the personnel who participated in the initial surveys would also carry out future monitoring, any data generated by point counts would be difficult to replicate reliably. However at Cash-3, 2 of the authors field tested point counts as a survey method.

We attempted to maximize the diversity of species encountered by sampling in a range of habitats, including ridge tops, ravine bottoms, lowland forest, bamboo, primary forest and secondary vegetation. Whenever feasible, we also sampled adjacent to the 1-ha vegetation plots established by Comiskey *et al*. (2001). We typically set up arrays of up to 20 ATX-type mist nets (12×2.6 m with 36 millimeters (mm) mesh). We opened nets at first light (05:30 to 06:30) and closed them between 16:00 and 16:30 to permit processing of the last captures. We placed nets in locations that would maximize capture rates. Because of this consideration and the ruggedness of the terrain, we did not use any consistent spacing between nets. We operated nets in the same locations for up to five days (sometimes longer if rain forced early closing). Although capture rates typically fall off after the first few days of netting, we found that capture rates remained acceptably high even on the fifth day of operation. All birds were measured (culmen, wing, tail and tarsus) and assessed for molt, breeding condition and parasites. The first individual of each netted species (of each sex, if identifiable externally) was photographed and described in detail in field notes. We cut 1 or 2 tail feathers of each released bird so that recaptures could be recognized.

We used mist nets to examine edge effects at the Pag well site (at other sites, the terrain precluded setting up net lines in the areas immediately adjacent to the well sites). At Pag, we were able to conduct one round of netting in which all nets were placed within 100 m of the edge of the well site and several within 20 m. The site had been cleared 7 to 8 months before we conducted our surveys, so there was little obvious structural difference in the forest in the edge zone, and there was only a narrow band of young second growth between the forest edge and the bare soil of the well clearing. The area was near a landing pad for the large Chinook helicopter used at the site and was subject to strong propeller wash and noise during helicopter operations.

In the point-count surveys conducted at Cash-3, the terrain again constrained the placement of point stations so that it was impossible to place many points within 100 m of the well site to examine edge effects. We placed 15 stations along 1600 m of trail within 150 to 500 m from the well site. Ideally, stations should be placed randomly to avoid bias and be at least 200 m apart so that individual birds cannot be heard from two different points. Because of the limited distance of suitable trail, we placed stations 100 m apart. However, the steep terrain, intervening ravines and dense vegetation provided aural isolation between points, and we attempted to avoid double counts of birds heard from more than one station.

We conducted counts for 8 minutes at each of the 15 stations between 05:00 and 08:00 and repeated those counts on 3 mornings, for a total of 45 counts. All birds heard or seen from each station were tallied, but only those recorded within 25 m of the point were used in generating density estimates. Each point was categorized as 1 of 3 habitat types – bamboo-dominated, mixed bamboo-broadleaf or broadleaf-dominated. Results from each of the 3 counts at each point were pooled to generate species presence-absence lists and density estimates for each point.

There was insufficient time available at each site to set up the extensive trail network that would be necessary to assess low-density species such as game birds and large parrots. However, we did note the number of days at each site that such species were encountered.

5.2. Assessment results and discussion

We recorded 420 species of birds in the LUR over 135 days of field work (Angehr *et al.*, 2001). This compares favorably with the number of species recorded at other southeastern Peru localities. Servat (1996) recorded 415 species between 1987 and 1993 at Pakitza in Manu National Park, while Davis *et al.* (1991) recorded 342 species at Cuzco Amazónico in 87 days. Our total is well short of the 550-plus species recorded within a 15-km radius of Cocha Cashu in Manu National Park by Robinson and Terborgh (1990) between 1973 and 1989 and the 575-plus species recorded in the Explorer's Inn Reserve at Tambopata (Parker *et al.*, 1994) starting in the 1970s, but these lists were compiled over a much longer time period, and the LUR lacks habitats such as oxbow lakes and swamps that contribute to species diversity at Cocha Cashu and Explorer's Inn. Remsen (1994) stresses the importance of taking into account time and habitat availability when comparing bird lists. Angehr *et al.* (2001) present the complete species list along with details on habitat associations.

We documented 133 species with photographs and 187 with recordings, or 237 species (56% of the total) vouchered. An additional 22 species were captured but not photographed, mostly at the river sites where a camera was not available. Thirty-three species were both seen and heard, 124 seen only (mostly water birds, raptors and canopy species) and 4 heard only (2 tinamous, a rail and a nightjar). We made a total of 2401 captures, representing 2107 individuals of 145 species, in 8318 net-hours of mist-net surveys.

Mist-net samples provide a standardized means to compare understory bird communities at different sites. Capture rates can be compared on the basis of the number of captures (including recaptures) per 100 net-hours, with net-hours calculated by multiplying the number of nets in operation by the number of hours they were open. In mist-net studies, capture rates typically are highest for the first day of operation at a location and gradually decline as birds learn where the nets are. Because we operated nets at each location for different numbers of days and sometimes added nets over the course of the sample, first-day capture rates provided the best index of the relative capture rate at each location (Table I).

First-day capture rates were reasonably consistent at primary forest sites, whether bamboo or broadleaf (Table I). Broadleaf sites ranged from 35 to 43 captures/100 net-hours, with the exception of 67 at Sega location 1. Captures at bamboo sites tended to be slightly higher, between 33 and 53 captures/100 net-hours, with the exception of 59 and 60 at Lasm and Sega location 2, respectively. This was surprising, given the drastic differences in structure between bamboo and broadleaf-dominated forests. The highest capture rates were found in disturbed habitats – 83 captures/100 net-hours in secondary forest along an old road at Cash-2 location 2, and an extraordinary 122 captures/100 net-hours in regenerating agricultural clearings at Pag location 4.

Cash-3 was the only site at which both mist-net and point counts were used. At this site, we recorded 76 species in 366 captures (318 individuals) in 1154 net-hours (249 person-hours) of netting (Table I). During 45 point counts at 15 stations, we recorded 94 species over 18 person-hours. Clearly, in relation to species numbers, point counts are more time efficient for those species that they sample. However, although 53 species recorded during point counts were not recorded by mist nets, 35 species recorded by mist nets were not recorded during point counts. Greater effort during point counts would be expected to widen this disparity, by both increasing the number of species recorded only during point counts and decreasing the number recorded only by nets. But some species are still likely to be recorded only by nets. Some of the species we netted were not otherwise detected at the site.

While there was concordance between the encounter frequencies of some species in mist-net samples and during point counts, for many others there was not. Mist-netting tends to favor wide-ranging, non-territorial species such as understory nectarivores, frugivores and army ant followers, while point counts favor highly vocal territorial species and conspicuous non-territorial canopy frugivores. Of the 21 most frequently netted species, 6 were never recorded during point counts, while of the 20 most frequently recorded species during point counts, 8 were never netted. For example, Green Manakin (*Chloropipo holochlora*), a highly mobile

TABLE I

Mist-net capture rates and numbers of species captured at each location sampled in the Lower Urubamba Region, Peru. Net-hours are calculated by multiplying the number of nets by the number of hours they are in operation. First-day capture rates are those on the first day of operation at a location

Site	Location	Habitat	Net-hours	Captures	Captures per 100 net-hours	First-day capture rate	Total species
Cashiriari-2	1	Broadleaf primary	402	109	27	35	37
	2	Broadleaf secondary	263	139	53	83	45
Total			665	248			62
Pagoreni	1	Broadleaf primary-ravine	605	194	32	43	46
	2	Broadleaf primary-ridge	569	161	28	40	45
	3	Broadleaf primary-edge	567	144	25	39	42
	4	Agricultural second growth	107	105	98	122	37
	5	Treefall gap	10	13	–	–	11
Total			1858	617			80
San Martin-3	1	Bamboo-ravine	729	180	25	45	64
	2[a]	Bamboo-ridge	392	122	31	33[a]	42
	3[a]	Bamboo-ridge + ravine	675	138	20	36[a]	54
Total			1802	440			87
Cashiriari-3	1	Bamboo with broadleaf	586	191	33	53	56
	2	Broadleaf with bamboo	569	175	31	36	54
Total			1155	366			76
Las Malvinas	1	Bamboo-ravine	632	151	38	59	59
Segakiato	1	Broadleaf primary	691	231	43	67	74
	2	Bamboo	596	169	40	60	58
Total			1286	400			101
Peruanita	1	Bamboo	587	108	23	35	46
	2	Bamboo with broadleaf-ridge	333	71	27	38	38
Total			920	179			64
Grand total			8318	2401			145

[a] To calculate first day capture rates for San Martin Locations 2 and 3, we combined data from the first two days of net operation since the nets were open for less than half a day each of the first two days because of rain.

but inconspicuous and non-vocal frugivore, was the most common species in net samples, but was never recorded during point counts. Conversely Goeldi's Antbird (*Myrmeciza goeldii*), a highly vocal understory ant follower, was ranked second in point count samples, but was never captured in nets, probably because an ant swarm did not happen to cross our net lines during the course of the study.

Clearings and other disturbances within intact forest may cause changes in physical conditions such as light, temperature or humidity within the intact forest. These changes may result in alterations of forest structure and composition at the edge of the disturbance, making the zone unsuitable for some interior forest species. Also, bird species that colonize open areas or second growth may penetrate some distance into the forest itself. Therefore, the species composition of bird communities in areas adjacent to a clearing can be different from that in areas further away. In the pilot study of edge-effects at Pag, we caught 3 species (1 individual each) at the edge site that were not caught at interior forest sites and whose presence might be attributed to the proximity of the edge. All 3 species were present elsewhere in the study area in disturbed sites. The Ruddy Foliage-gleaner (*Automolus rubiginosus*) and Buff-throated Saltator (*Saltator maximus*) were present in tree fall gaps, while the Sulphur-bellied Tyrant-Manakin (*Neopelma sulphureiventer*) was fairly common in disturbed habitat along the Camisea River. Changes in capture rates can also be an indicator of disturbance. Capture rates are often much higher in young secondary habitat (Robinson and Terborgh, 1990, this study). In contrast, the edge site at Pag had virtually the same first-day capture rate as the other two interior forest sites (Table I). These results are preliminary and more comparative samples are needed. However, they do not suggest that there have been major changes in the bird community as yet because of forest edge effects. Few species of disturbed areas have colonized the well site to date. This could change as second growth develops along the edge and as the forest structure changes in the area close to the clearing. Eventually, it may be expected that many of the species found in disturbed areas will colonize the well site, especially if it is later connected to other sites by roads.

The frequency of encounter with game species, including tinamous, guans, curassows and trumpeters, was lowest at Pag, as might be expected (this site is closest to human settlements) and highest at Cash-3, the most remote site. These species were particularly unwary at the latter site. Encounter frequency was intermediate at Sanm-3, and we were not at Cash-2 long enough to evaluate encounter frequencies. Even though game species were uncommon at Pag, they were still present. This indicates that hunting pressure has not been severe enough to extirpate them.

6. Monitoring Birds in the LUR

SPDP's management strategy in the LUR was to preserve biodiversity while developing a series of well sites, an internal road network and an underground pipeline.

Monitoring within an adaptive management framework allows us to interpret and evaluate the effects of management strategies such as the SPDP approach. The monitoring objectives for birds are to determine if edge effects are occurring and assess what are the significance and extent of impacts from edge effects. The assessment provided the baseline data on species presence in relation to habitat type and provided insight into the effectiveness of sampling methods. The next steps are to identify which aspects to monitor and establish the monitoring protocols.

To monitor for edge effects, it will be necessary to determine whether these effects are occurring and over what distance from the well site. We also must ascertain which species are indicators of edge effects and which interior species are vulnerable to edge effects. Indicators of edge effects could be disturbance-related species, many of which have already been recorded in the LUR (Angehr *et al.*, 2001). Abundances of these species within intact forest will provide one component of the monitoring scheme. Studies have shown that insectivorous species in the understory are particularly vulnerable to edge effects and forest fragmentation (Canaday, 1997; Thiollay, 1997), and Canaday (1997) has shown that these effects can occur up to 1.5 km from forest edge. In addition to edge effects, gas development may lead to declines in game birds and species desired for the pet trade by allowing easier access within the area. We suggest that these groups also be monitored.

Mist-netting and point counts have great value as assessment and monitoring techniques, and we propose their continued use. Transects should be used to monitor trends in populations of game birds. We suggest conducting surveys in four zones: 0 to 100 m from an edge, 300 to 500 m in from the edge, 1 km in and 5 km in. Since both mist-netting and point counts require teams to be at the study site before dawn, surveys at 5 km will require the establishment of satellite camps. Budgetary and logistical constraints might preclude construction of such camps and surveys at the greater distances.

The four existing test well sites do not provide enough edge to allow the placement of many point counts within the 0 to 100 m range, and terrain limits the placement of net lines within these areas. However, future construction of more well sites and roads will make more study area available. We consider edges at well sites and along roads to be functionally equivalent, but edges along the pipeline will differ because of planned revegetation along the pipeline route.

Study sites should be selected through stratified random sampling, and sites that are too rugged for efficient survey should be rejected. We recommend that at least 6 bamboo-dominated and 6 broadleaf-dominated sites be selected along the road system and at well sites. Because the major habitat types to be crossed by the pipeline are unknown to us, we are unable to specify the number of study sites needed along the pipeline route. If additional major habitat types are identified during the course of the study, they should be added to the survey.

6.1. Mist-net surveys

We recommend that mist-net surveys be carried out in each zone at each of the sites. The surveys should be done twice a year, once just before the breeding season in the late dry season (July to September) and once after the breeding season in the mid- to late rainy season (February to April) so that the annual productivity of young birds can be assessed.

For each survey, an array of 20 nets should be used. Net lines and locations should be permanently marked and used in successive surveys. In the four survey zones, nets should be operated for a total of 6 days per site during each survey period. They should be operated 3 days each in 2 different microhabitats (streamsides and ridge tops) to fully sample the bird community at each site. Nets should be operated from just after dawn until just before dusk. Such 6-day samples will yield between 1000 to 1200 net-hours per site. Data collected on each bird should include age (adult or juvenile), sex, breeding condition, molt, weight and condition (fat, parasites). Each bird should receive a permanent numbered metal leg band so that survivorship and local movements can be assessed.

6.2. Point-count surveys

We recommend that point counts be carried out by zone at each of the sites. Surveys should be carried out once a year during the early breeding season when most species are calling; that is, during the transition between the late dry season and early wet season (October to January).

Trail systems should be established in the four study zones at each site. Ten permanent stations for point counts should be randomly located, at least 200 m apart, along these trails. Each point should be classified according to habitat type. Counts should be carried out between 05:00 and 10:00. At each station, the observer should count all birds seen or heard within a 10-minute period and estimate the distance and direction to all birds within 25 m of the count station. Birds beyond this point should be noted simply as present. Birds flying over the count point (for example, parrots and raptors) should be noted separately. Data recorded should include the sex of the bird, if identifiable, and whether the bird was first noted by call or by sight. Unfamiliar calls should be recorded for later identification by comparison to reference tapes.

6.3. Transects for game birds

Game birds should be monitored along transects. An annual survey with sites selected relative to their proximity to existing human settlements is suggested. The preferred timing is the late rainy season (March to April) when the least leaf litter is present in the forest and an observer can walk the trails with minimal noise. However, if further study reveals that mobile species such as macaws are more common at the sites at another time of year, then survey periods should be moved.

We estimate that approximately 50 km of transects per survey area per year will be needed to detect differences in game bird populations. This can be achieved by walking a shorter length of trail several times; for example, by walking a 5-km transect 10 times.

We recommend that at least 6 study sites be selected – 2 within 5-km of settlements, 2 in areas most remote from settlements and 2 at an intermediate distance. Two 5-km loop trails should be set up at each study area. The 5-km loops should be surveyed 5 times during a survey period to provide a sample size of 50 km. The observer should note all game birds seen or heard along the transect line and estimate their distance to the transect line when first encountered. Transect surveys should be started shortly before first light to record tinamous, wood-quail and other species that call mainly at dawn.

7. Evaluation and Decision Making

Throughout monitoring, scientists must continually evaluate the data. The interpretation and appraisal of the data assists scientists and managers in deciding whether the management strategies are meeting their stated goals. In our case, the goal was to ascertain and minimize the potential impact of gas development-caused edge effects on bird diversity. If the evaluation indicates that no effects from forest edge are occurring, then monitoring should continue without modification. If either increases in disturbance-related species or declines in vulnerable species are detected, then managers need to decide whether to alter the monitoring strategy, alter the objectives or adapt the management strategies (Dallmeier and Comiskey, 1998; Comiskey *et al.*, 2000).

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