Large macaw satellite telemetry in Tambopata, Peru

Progress as of October 2009

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Figure 1: A pair of wild Scarlet Macaws at Tambopata Research Center, Peru. The bird on the right is wearing a satellite telemetry collar affixed in early 2009. Photo by Matt Cameron.

Since 2003 a group of parrot researchers, conservation organizations, and manufacturers have been working together to design and test satellite collars for tracking large macaws (Appendix 1). To date, this consortium has developed two prototypes, tested these prototypes on captive macaws, tested one functioning prototype for accuracy in Guatemala (Garcia et al. 2007) and three prototypes in Peru (Brightsmith and Boyd 2006), attached two collars to birds in Guatemala (Bjork and McNab 2007), one collar to a bird in Costa Rica and seven collars to birds in Peru. In this report we will describe the collars and the accuracy testing in Peru, the relative performance of the two brands of collars currently on the market, and discuss the results of the collars attached to the birds in Peru.

Figure 2: Satellite collars attached to Blue and yellow Macaws in southeastern Peru. The Telonics unit is above and the North Star unit is below.

Development and testing of prototypes

To date, two different types of prototype satellite telemetry transmitters have been designed and tested. The first was developed in 2005 by North Star Science and Technology Inc., with the financial support of Amigos de las Aves USA and the Loro Parque Foundation. The second was developed in 2007 by Telonics Inc. with the financial support of Amigos de las Aves USA.

The North Star unit is a 32 g adjustable collar (Fig.2). A dummy prototype was tested for durability on captive Scarlet Macaws at Loro Parque, Spain. The collar was not damaged by the birds, and despite the size and rigid antenna, the birds were not hampered during the test period while moving in and out of nest boxes and living in the cage environment (Matthias Reinschmidt pers. com.). During September of 2006, a working prototype was tested at Tambopata Research Center to determine its accuracy. The collar was programmed to transmit for 5 hours per day and hung in emergent trees to simulate the favored perches of large macaws. Over the 15 day test, the collar provided 0.87 good locations per day (with average errors of about 1.5 ± 1.5 km) (Brightsmith and Boyd 2006). An additional 42 potentially useful locations with higher error rates were also logged.

The Telonics unit is also an adjustable collar with a total weight of 37.5 g (Fig 1). Two dummy prototypes constructed by Telonics were tested for durability on captive macaws at Texas A&M's Schubot Aviary in July 2007. Over the course of a month, one collar was completely destroyed by a Scarlet Macaw (*A. macao*) and its mate a Red-and-green Macaw (*A. chloropterus*). On the other collar, the antenna attachment was loosened by a pair of Blue-and-yellow Macaws. The collars were returned to Telonics to be hardened; however, the final unit sent to Tambopata in 2007 did not appear very different from the first prototypes. This collar was placed on a Blue-and-yellow Macaw on 25 January 2008, registered one unusable location on 26 January and then ceased transmitting. In September 2008 a redesigned dummy prototype was tested on captive macaws at Texas A&M University and was not damaged by the birds. Two collars of this model were attached to macaws in Peru in Jan – Feb 2009 and performed without problem.

Drop off mechanisms for telemetry collars

Macaws and parrots are long lived, social, and intelligent animals (Brouwer et al. 2000, Pepperberg 2006). For this reason, telemetry collars deployed by scientists should not remain on the birds indefinitely. However, recapturing individual parrots to remove their collars is often impractical or impossible. Currently, the drop off mechanism used by manufacturers of traditional and satellite telemetry collars is a small rustable bolt as the attachment mechanism. In theory this bolt rusts over the years following its attachment to the bird and eventually the collar falls off. This method is the state of the art for all parrot telemetry collars and is approved as humane by university animal use committees. However, we have no reliable information on how long it takes for these collars to fall off, and neither researchers nor manufacturers have information to show how much the rusting progresses in the first few years. As a result, we are spearheading the development of a new drop off mechanism that will allow telemetry collars to fall off within 2 – 4 years after they are attached to the birds. To date, a number of different weak links have been developed and tested on captive birds and development continues.

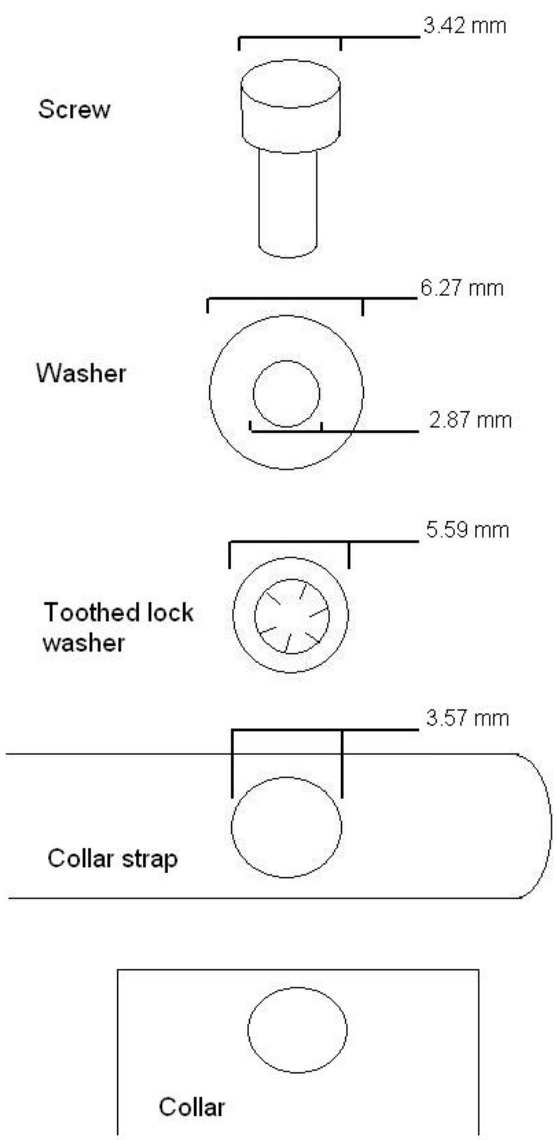

Figure 1: Collar attachment and drop off mechanism. One drop of Loctite low strength threadlocker is placed in the screw hole in the collar, then the screw is passed through the washer, lock washer and collar strap (in that order) and screwed in to the collar. The washer is pre-rusted in vinegar before deployment to remove the zinc and facilitate rusting. Since the head of the screw is smaller than the hole in the collar strap, the collar falls from the bird when the thin, pre-rusted washer and the toothed lock washer rust through.

In Dec 08 – Feb 09 four collars at TRC were deployed with a new collar detachment mechanism (Fig 1). It consisted of a socket cap screw (McMaster-Carr part # 92200A077), which is passed through a #3 zinc-plated washer (McMaster-Carr part number 90126A503), a #3 internal tooth lock washer (McMaster-Carr part #98449A505) screwed in to the collar and secured with loctite low strength “threadlocker 222”. The zinc-plated washers were pre soaked in mild HCl for until they stopped bubbling (about six hours). They were then rinsed, dried and stored until they were deployed on the birds. This process removed the corrosion-resistant zinc plating and caused them to start rusting. Since the head of the screw is smaller than the hole in the collar strap, the collar falls from the bird when the thin, pre-rusted washer and the toothed lock washer rust and break. There is good reason to believe that the very thin (0.58 mm) washers which hold the collar on will break much sooner than the ± 2 mm diameter unrusted screw which held on the collars in the previous system.

Of the collars deployed in 2009, three of them have remained on the bird from deployment through at least September 2009 (> 8 months). However, one collar may have fallen off the bird. This collar was attached to a Blue-and-yellow Macaw on 28 Dec 08. It provided good locations until 7 Jan 09. On 28 Jan, 8 Feb, 14 Feb, 30 Mar and 21 Sep we received messages from this collar but they were too weak and infrequent to provide a location. In our experience, when the batteries of these collars fail, they give weak broadcasts like this for only a period of a few days (< 1 week). In addition, it seems unlikely that the macaw would have damaged the collar and it circuitry in such a way that it would broadcast intermittently for > 8 months. I suspect that the collar is broadcasting from the ground and that it has either fallen off the bird, or that the bird was depredated. The annual survival rate for adult macaws like this is normally very high, and that the collar gave strong broadcasts for about 11 days which is long enough for the bird to become well accustomed to the presence of the collar. As a result I suspect that the bird may have been able to remove the collar. If these suppositions are correct, there may be a risk with this system of the collar being removed by the bird prematurely.

Collar deployment and performance

In January 2008, my team at Tambopata Research Center captured three Blue-and-yellow Macaws and attached a satellite collar to each. In Dec 08 – Feb 09 an additional three Scarlet Macaws and two Blue-and-yellow Macaws were trapped and fitted with satellite collars. The birds were trapped using tall perches covered with nylon nooses. For more information on the trapping system used see Brightsmith (2008). As mentioned above, the one collar manufactured by Telonics Inc. was placed on a Blue-and-yellow Macaw on 25 January 2008, registered one unusable location on 26 January and then ceased transmitting. Two collars manufactured by North Star were deployed on 22 and 28 January and functioned until November 2008. In 2009 one of the Scarlet Macaws flew in to the river upon release and was killed by a caiman. In the process the collar was destroyed and ceased transmitting. One collar stopped providing reliable locations about 11 days after it was deployed (see "Drop off mechanism" above for details). The remaining three collars, two constructed by Telonics and one by North Star have continued to function through the end of September 2009.

Since 2006 we have recorded a total of 359 locations from 3 different test transmitters. Two of these test transmitters, deployed in Feb and Mar 2009 are still transmitting, so these error analyses are not final. The average errors calculated for each error class are greater than those estimated and reported by ARGOS (Table 1).

Table 1: Location errors in kilometers of a satellite telemetry collar hung from emergent rainforest trees and towers at Tambopata Research Center, Peru. The errors were calculated using the minimum error of location 1 and location 2 provided by Argos.

LC code	Argos estimated error	Average	Stdev	N	Min	Max
3	< 0.15	0.59	0.31	48	0.03	1.58
2	< 0.35	0.88	0.61	45	0.08	3.20
1	< 1.0	1.70	1.45	41	0.03	6.22
0	> 1.0	4.99	2.71	20	1.45	9.38
A	No estimate	1.96	2.56	84	0.03	14.62
B	No estimate	12.1	22.6	113	0.12	201.4
Z	Invalid location	233	203	8	13.4	579
Total		10.1	46.1	359	0.03	579

A total of 560 good locations have been generated in a total of 2840 broadcast hours by the six transmitters combined over the two years of the study (Table 2). Good locations for the purpose of this report are defined as those with location quality 3, 2, and 1. So far, we have received 41 highly precise locations (class 3, < 1 km error) during the course of the study. The number of good locations per hour and the number of precise locations (class 3) have been greater in 2009 than in 2008. We suspect that this is due to the change in duty cycle between the two years (see "Broadcast cycles" below). Due to our analyses of home range, we now feel that class zero locations may not be accurate enough for use in this particular system (see Macaw home ranges, below). This is a change since our last report (Brightsmith 2008). However, in species with larger total displacement, class zero locations may be considered usable.

Table 2: Locations received from 6 satellite telemetry collars deployed on macaws in southeastern Peru. BYMA = Blue-and-yellow Macaw (*Ara ararauna*) and SCMA = Scarlet Macaw (*Ara macao*). The number of transmit hours is the number of hours the collar was transmitting while on the bird. The total days are the number of days from the day the collar was deployed until the day of the last transmission received. The "good per hour" is the sum of locations in classes 1, 2 and 3 received per transmit hour.

Transmitter	3	2	1	0	A	B	Z	Total	Transmit hours	Total days	Good per hour
2008 BYMA	5	20	35	26	49	69	73	277	609	298	0.10
2008 BYMA	1	20	45	51	38	61	77	293	571	288	0.12
2009 BYMA		1	6	1			8	16	154	93	0.05
2009 BYMA	7	15	102	145	53	54	69	445	468	245	0.26
2009 SCMA	10	40	93	83	52	44	102	424	480	233	0.30
2009 SCMA	18	56	86	68	58	66	61	413	444	233	0.36
Total	41	152	367	374	250	294	390	1868	2726	1390	0.21

Alternative locations

The ARGOS system calculates two possible locations for transmitters and supplies the more probable of the two as "Location 1". The second location, deemed less probable by the ARGOS algorithms and often called the "mirror image" location is reported as "Location 2" (CLS 2008). On 22 occasions in 2008 and 11 occasions in 2009 the secondary location was closer to the release site than the primary location (Table 3). In all but three of these instances, it was obvious that the secondary location was the correct one. It was usually obvious because location 1 was hundreds of kilometers away from the release sites and the other recent locations of the bird. In the remaining three cases it was impossible to determine which off the two locations was correct as both location 1 and location 2 were biologically feasible. These mirror location errors were much more common in 2008 than in 2009. In 2008 mirror errors were recorded in 5% of all locations and 6% of all good locations (location class 1, 2, 3). In 2009 mirror errors were recorded in only 1% of all locations and 1% of all good locations. It is unclear why the error rate dropped in 2009, but it may have been related to the longer broadcast periods (see "Broadcast cycles" below). Of note is that these mirror locations were recorded for all location classes except for location class 3. Fortunately, in only three occasions was it uncertain which of the two locations was correct and these occurred in location class 0, 0, and B. All researchers using ARGOS satellite technology must be on the alert for instances where the alternative location (location 2) is correct.

Broadcast cycles

The choice of the amount of time and the time of day the transmitter broadcasts and how long it remains off between transmissions is a vitally important aspect of working with satellite transmitters. These factors determine how long the transmitter will last, how many data points are received per day, and the quality of those locations. ARGOS and the manufacturers of satellite telemetry collars refer to the broadcast cycles discussed here as "Duty cycles." However, we will use the term broadcast cycle as it is somewhat more intuitive.

In our 2008 study we programmed the transmitters so that they would broadcast 6 to 11 hours per day once every 3 to 4 days (Table 3). For all broadcast days, the collar was programmed to start broadcasting at about 5:00 AM local time. This was chosen because there was good satellite coverage predicted during the mornings over the study area during the study period.

Table 3: Number of times the ARGOS system correctly chose which of the two reported locations was correct for satellite transmitters placed on wild macaws in southeastern Peru during two years of study. Location class indicates the quality of the location as assigned by ARGOS (see Table 1 for more information on these error classes). "Correct" indicates that location one was closest to the point of release and presumed to be correct. "Location 2 correct" indicates the number of locations for which the "mirror image location," location two as reported by ARGOS, was closer to the site of release and was clearly the correct location. "Unsure" indicates the number of times which it was impossible to determine which off the two locations was correct as both location 1 and location 2 were biologically feasible. "Error %" indicates the percentage of locations in each class for which location two was correct or it was uncertain which location was correct.

	2008				2009			
Location class	Correct	Location 2 correct	Unsure	Error %	Correct	Location 2 correct	Unsure	Error %
3	6	0	0	0.0%	35	0	0	0.0%
2	39	1	0	2.5%	110	2	0	1.8%
1	73	7	0	8.8%	286	1	0	0.3%
0	73	3	1	5.2%	291	5	1	2.0%
A	80	7	0	8.0%	163	0	0	0.0%
B	128	1	1	1.5%	164	0	0	0.0%
Z	3	1	0	25.0%	7	2	0	22.2%
Total	402	20	2	5.2%	1056	10	1	1.0%

At the beginning of the study in 2008 we programmed the collars to broadcast 6 hours per day once every 4 days (6 hours on and 90 hours off, Table 4). This phase lasted for 136 days, at which time the collars broadcast for 11 hours for one day then 6 hours per day once every 3 days for a month before repeating the process. For the final cycle, during which the battery was predicted to die, the collar was programmed to broadcast for 8 hours per day once every 3 days. More details on the justification for choosing this configuration can be found in Brightsmith (2008).

Our analysis of the 2008 data suggested that the 8 hour broadcast duration per broadcast day provided more locations per broadcast hour than broadcasts of either 6 or 11 hours (Brightsmith 2008). Broadcasts of 8 hours also appeared to maintain higher battery voltage than broadcasts of 6 hours (Brightsmith 2008). As a result, in 2009 we changed our broadcast schedule to have all broadcasts be 8 hours in duration (Table 5). The duty cycles used oscillated between one 8 hour broadcast every 4 days and one 8 hour broadcast every 3 days.

The number of locations per broadcast hour for the two collars during 2008 was 0.11 good locations (LC 1, 2, or 3) per broadcast hour. In 2009 this value jumped to 0.3 good locations per broadcast hour (combining the three collars that broadcast reliably throughout the period). This supports our hypothesis that the 8 hour broadcast cycle was more efficient than the 6 hour broadcast cycle. The exact reason for why the 8 hour broadcast cycle was more efficient is not known at this time. However, more detailed analyses of the number locations obtained per satellite pass are underway and may illuminate this point further. For now, we suggest that users of these collars program them for 8 hour broadcast cycles.

Table 4: Broadcast cycles used on two satellite telemetry collars deployed on Blue-and-yellow Macaws in southeastern Peru in January 2008.

	On (hrs)	Off (hrs)	Repetitions (#)	Duration (days)
Cycle 1	6	90	34	136
Cycle 2	11	13	1	1
Cycle 3	6	66	10	30
Cycle 4	11	13	1	1
Cycle 5	6	66	10	30
Cycle 6	11	13	1	1
Cycle 7	6	66	15	45
Cycle 8	8	64	40	120

Table 5: Broadcast cycles used on two Telenoics satellite telemetry collars placed on macaws in southeastern Peru in January 2008. The two North Star collars had slightly different broadcast cycles which are available from the authors upon request.

	On (hrs)	Off (hrs)	Repetitions (#)	Duration (days)
Cycle 1	8	88	6	48
Cycle 2	8	64	10	30
Cycle 3	8	88	10	40
Cycle 4	8	64	10	30
Cycle 5	8	88	40	160
Cycle 6	8	88	∞	

To further test the effect of broadcast cycles on the number of usable locations received, the two test collars deployed in 2009 were programmed with a complex broadcast cycle combining sets of 4, 6, and 8 hour broadcasts every 3, 4, and 5 days. The analysis of these data will be completed in spring of 2010, after the collars stop broadcasting.

Comparison of manufacturers

To date a total of 8 collars manufactured by North Star Technologies and 5 manufactured by Telonics have been deployed either on birds or as test transmitters (including data from Costa Rica, Peru, and Guatemala). Of these 6 North Star and 4 Telonics collars can be used to compare performance results. The North Star collars weigh 32.45 ± 0.2 g (N = 6) and the Telonics collars weigh 37.3 ± 0.2 g (N = 3).

If researchers wish to use collars that weigh less than 3% of the total weight of the birds as suggested in the literature (Kenward 2001), they should use Northstar collars on birds of ≥ 1080 g and Telonics collars on birds ≥ 1240 g.

Location accuracy

At this point there is no evidence that there are differences between the two manufacturers in the number of high quality locations they produced. For both brands of collars, 40% of the positions were of high quality with location codes 1, 2, or 3, implying that the electronics technology used by the two manufacturers is comparable and choice of which brand to employ will depend upon other factors such as reliability, ease of use, price, and customer support. Some of these factors are becoming apparent in these studies.

Battery duration

To date, a total of four North Star collars broadcast until their batteries died. They have broadcast 174, ~480, 583 and 639 hours (including data from both Peru and Guatemala). An additional 2 North Star collars are still broadcasting and to date have broadcast for approximately 300 and 480 hours. This gives a minimum average battery life of 423 ± 175 hours, N = 6. This number will increase as the last two collars finish transmitting. A total of only one Telonics collar has stopped transmitting to date: one on a Great-green Macaw in Costa Rica stopped transmitting after about 72 broadcast hours. The other three collars have broadcast for 444, 464, and 231 hours to date, giving a minimum average battery life of 302 ± 186 hours N = 4. This number will increase as the last three collars finish transmitting.

Both manufacturers have had one collar stop transmitting after < 200 broadcast hours which are much less than the anticipated 400+ hours. At this point sample sizes are too small and insufficient collars have finished their battery duration to compare the battery lives of the two manufacturers.

Programming errors

The two North Star collars deployed in Guatemala were programmed incorrectly by the manufacturer. As far as we can tell, on 21 October one collar began broadcasting and remained "on" broadcasting continuously, 24 hours per day until the battery died 19 days later. The battery on the other collar failed prematurely (before 21 October), so the programming error did not affect its performance. No other collars have been misprogrammed.

Time drift

A total of four North Star collars deployed in 2007 and 2008 showed a readily detectable drift in their internal clock (Guatemala 2007 and Peru 2008). In Peru, about 10 months after deployment the clocks were about 4 hours later than when they started (N = 2 collars). While the evidence is not as clear, the data suggest that in Guatemala in about 4 months the internal clocks may have been about 3 – 4 hours (N = 2 collars) later than when they started. This problem was brought to the attention of the manufacturer who responded by changing the clock circuitry. In the one North Star collar successfully deployed on a bird in 2009, the clock in the collar is apparently running slightly fast: 11 – 60 min fast seven months after deployment. This suggests that the problem had been improved, but perhaps not eliminated.

The three Telonics collars successfully deployed for more than 6 months have not shown any evidence for drift in their onboard clocks.

When the onboard clocks of satellite transmitters drift it causes changes in the time that the transmitter begins and ends its transmission cycles. If the transmitter is programmed to broadcast during times of peak satellite overpass, clock drift may cause the transmitter to broadcast outside these peak satellite times. In addition, if the animal is thought to be in a better position for broadcast during parts of the diurnal cycle (for example a species that has nocturnal roosts in dense vegetation or tree cavities) clock drift could cause the transmitter to eventually broadcast during inappropriate times.

Start time and deploying
The internal clocks of the two manufacturers differed in that the North Star collars have an onboard “timer” while the Telonics collars have a true onboard clock. The “timer” in the North Star transmitters is technically a timer as it begins to run the moment it is turned on, but does not record the actual time of day or the date. As a result, the broadcast cycle is programmed in such a way so that from the time the transmitter is activated (by removing the magnet) it will broadcast for 8 hours then turn off for 88 hours then on for 8 hours, off for 88, etc. As a result, this transmitter must be turned on at exactly the time you want your broadcast cycle to start. For example, in 2009 I wanted my transmitters to start broadcasting at 8 AM so I had to turn the collar on at exactly 8 AM one or more days before I captured the bird I wished to attach it to. I also wanted my transmitters to follow a predefined seasonal pattern so that there were less broadcast hours during December and January and more from February on. As a result, I had to turn on the collars as soon as I began trapping in mid December. If you turn off the collar and turn it back on again, the entire broadcast cycle resets and starts again from the beginning. Given the difficulty of trapping macaws at our site, it is impossible to predict when we will be able to capture the birds over the 2 month trapping period. As a result, I had to turn on the collars on average 28.5 ± 23.0 days before they were attached to the birds (N = 6 collars). This resulted in using up 39 ± 25.7 broadcast hours (N = 6 collars) before the collar was attached to the bird. These nearly 40 hours lost from the North Star collars represent 5 – 10% of the total broadcast time for the collars we have deployed to date.

There was another unexpected consequence of these onboard timers (not clocks) in the North Star collars. At some point during the trapping process, someone put a magnet near one of the North Star collars and reset it without my knowledge. As a result, a collar that I attached to a Scarlet Macaw which I had planned to have broadcast from 8 AM to 4 PM is broadcasting from about 1 – 2 PM until about 9 – 10 PM. As a result, about half of our locations are coming during the time that the bird is roosting and we may be missing the predicted peak times of satellite passes.

The Telonics collars have a true internal clock. As a result, they are programmed to turn on at 8 AM on 30 Jan for 8 hours then off, on at 8 AM on 3 Feb for 8 hours then off, etc. Because of this, the collars can be turned on after the parrot has been trapped and immediately before deployment. As a result, we have not wasted any of the broadcast hours of these collars before attaching them to the birds. In addition there is no risk of resetting them with a magnet and having them broadcast at the incorrect times.

Macaw range size
To date three Blue-and-gold Macaws and two Scarlet Macaws have provided enough locations to estimate their home ranges. To determine the biological relevance of the class 0 locations, we estimated the home range sizes of all the macaws using a combination of all locations with location class of 0, 1, 2 and 3 and compared this to the home ranges using only locations with a class 1, 2, and 3. The home ranges including the class 0 locations averaged 4.0 ± 3.4 times greater than the home ranges without the class 0 locations. Visual inspection of the home ranges also showed that nearly all the furthest outliers were class 0 locations. As a result, we feel that the home ranges including the class 0 locations do not

accurately reflect the true ranges of the birds and ranges calculated using only class 1, 2, and 3 locations will be used in the remainder of this report.

The two Blue-and-yellow Macaws tracked in 2008 had much larger ranges than the one bird tracked in 2009. The bird from 2009 also did not show the long distance displacement off to the southeast that both macaws showed in 2008 (Brightsmith 2008). There are a number of different scenarios that might explain these differences: different individuals have different strategies for dealing with seasonal scarcity of food, annual variations in food supply may result in different needs to move among years, or both. Additional data from different years will be required to begin to tease apart these different hypotheses. Of note, during 2010 we will likely experience a fairly strong El Niño event which will likely change food abundance patterns and may lead to unprecedented changes in macaw movements.

The ranges of the Blue-and-yellow Macaws average about 5 times larger than those of the Scarlet Macaws. This follows parrot censuses by DB, local people's reports, and previous publications which all suggest that the Blue-and-yellow Macaws show larger seasonal movements than Scarlet Macaws (Renton 2002, Brightsmith 2006b, a). Scarlet Macaws are thought to be more generalists in both diet and habitat than Blue-and-yellow Macaws (Forshaw 1989, Renton and Brightsmith 2009). As a result, the Scarlets may not need to undergo such long distance movements. However, additional data will be needed to determine if these differences hold among years and with larger sample sizes.

In 2008 none of the three macaws left the protected area complex of Bajuaha Sonene National Park and the Tambopata National Reserve. This stands in stark contrast to 2008 when both Blue-and-yellow Macaws left the protected area complex (Brightsmith 2008). Further work is needed to determine what variables influence the propensity of macaws to move long distances in this area.

Table 6: Range sizes of Blue-and-yellow Macaws (BYMA) and Scarlet Macaws (SCMA) in southeastern Peru determined using satellite telemetry. The start date shows the date on which the macaw was captured and fitted with the satellite collar. The end date was the day on which the last location was received. LC = location class, a reflection of location accuracy (Table 1). The numbers under "Locations" indicate the number of locations used to calculate each home range. The ranges on the left were calculated using all locations with class 0, 1, 2, and 3 while the ranges on the right were calculated using only locations with location class of 1, 2, and 3. The range sizes using LC 1, 2, and 3 are the ones the authors consider to be biologically relevant (see text). All home ranges are estimated using a minimum convex polygon including 100% of the locations.

				LC 0,1,2,3		LC 1,2,3	
Species	Name	Start date	End date	Range size	Locations	Range size	Locations
BYMA	Tiny	22-Jan-08	14-Nov-08	1891	86	1544	60
BYMA	Libertad	28-Jan-08	10-Nov-08	8136	117	2034	66
BYMA	Fuga	21-Jan-09	23-Sep-09*	1245	269	399	124
Average				3757	157	1326	83
SCMA	Wheezy	2-Feb-09	23-Sep-09*	579	226	279	143
SCMA	Danny	2-Feb-09	23-Sep-09*	2097	228	215	160
Average				1337	227	247	152

* Collar was still broadcasting as of the writing of this report.

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