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A Method to Count Pirarucu *Arapaima gigas*: Fishers, Assessment, and Management

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Abstract.—The giant and obligate air-breathing fish pirarucu *Arapaima gigas* (also known as arapaima) is a species endemic to the Amazon Basin that is increasingly managed by artisanal fishers because of government failure to control the fishery. In this study the ability of experienced artisanal fishers to count the number of pirarucu at the moment of aerial breathing was assessed. Counts were strongly correlated ($r = 0.98$) with mark–recapture abundance estimates calculated for the same populations. The potential for trained fishers to train other fishers to count pirarucu without slow and expensive mark–recapture work was also assessed and confirmed. Not only are the counts a cost-effective method for assessing pirarucu populations, they also allow fisher participation in decision making and contribute to effective management. The increasing number of community-based management schemes can now be matched with the training of fishers to count pirarucu.

The pirarucu *Arapaima gigas* (also known as arapaima) is a giant, obligate air-breathing fish that can grow up to 3 m in length and 200 kg in weight endemic to the Amazon Basin (Bard and Imbiriba 1986). Higher concentrations of pirarucu are found in floodplain lakes during the dry season where they are harpooned by artisanal fishers at the moment they surface to breathe (every 5–15 min; Bard and Imbiriba 1986; Goulding et al. 1996; Queiroz and Sardinha 1999).

In Brazil, pirarucu landings and the average size of capture have decreased drastically in the last decades, and pirarucu is now considered overexploited (Isaac et al. 1993, 1998; Goulding et al. 1996). However, only one study in a small region of the Solimões River provides quantitative evidence of overexploitation (Queiroz and Sardinha 1999). For the entire Amazon Basin, the status of the stock is unknown (IUCN 2002). The two major problems in assessing pirarucu populations in Brazil are that (1) conventional mark–recapture methods are prohibitively expensive due to the enormous geographic areas involved, and (2) monitoring landings is nearly impossible due to the decentralized and illegal nature of the trade (Bayley and Petrere 1989).

Management attempts to date have consisted of size and season limitations, and even a moratorium in the Amazonas State. But these regulations have not achieved success because the Brazilian government lacks the human and financial resources to enforce the law (Neves 1995; Crampton et al., in press), and because little effort was made to integrate fishers into the management process (see Isaac et al. 1993). As a consequence, an increasing number of artisanal fishers are implementing measures to improve lake productivity and to aid in the recovery of overexploited populations of pirarucu (Crampton et al., in press; McGrath et al. 1994). Despite their intentions, however, in many cases artisanal fishers are hampered by a lack of information on the current status of pirarucu populations.

This study assesses a simple and cost-effective method to estimate the abundance of pirarucu based on the skills of experienced artisanal fishers in counting individuals at the moment the fish emerge to breathe, as well as the potential for experienced fishers to train other fishers to count pirarucu.

Methodology

Assessment of the Count Method

In order to evaluate a pirarucu stock assessment method based on the knowledge and skills of fishers, I conducted two sets of experiments. First, I assessed the accuracy of the counts of pirarucu made by fishers by comparing their counts with mark–recapture abundance estimates calculated for the same populations; these pirarucu populations were found in closed lakes. Second, I assessed the potential for fishers to learn how to

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count pirarucu from the fishers involved in previous set of experiments by comparing their counts with mark–recapture abundance estimates calculated for the same populations; this assessment was done in order to determine if the knowledge and skills necessary to count pirarucu could be passed on to another fisher without the need for slow, expensive, and labor intensive mark–recapture work.

Study Area

This study was conducted at the Mamirauá Sustainable Development Reserve (MSDR), which is located at the confluence of the Solimões and Japurá rivers in the Brazilian Amazon (approximately 3°S and 65°W). The MSDR is entirely formed by várzea, a nutrient-rich, white-water influenced floodplain (SCM 1996). There, during the low-water period, 12 hydrologically isolated lakes were chosen; these included lakes of various depths, sizes, and marginal vegetation types to reflect the diversity of lake types in the area.

Count Estimates

The count method was standardized as follows. Fishers divided each lake into differently sized sampling units based on the perceived degree of difficulty of observing and listening pirarucu breathing in each unit. Areas of each sampling unit ranged in size from 0.01 to 2 ha, with smaller units representing areas where detection is more difficult. Factors contributing to increased difficulty in sighting and hearing pirarucu breathing included the size of the area, the amount of floating vegetation (macrophytes), and the thickness of shoreline vegetation. Each fisher then quietly entered their unit area and counted the pirarucu simultaneously over a 20-min interval. Only fish longer than 1 m were counted. Estimation of fish size was done through the sighting of a fish's dorsal region and by listening to the fish's breath. Counted fish were classified as either juveniles (1–1.5 m) or adults (>1.5 m, corresponding to the Brazilian regulation regarding minimum catch size). When the area of the lake was larger than the area that could be covered by the available fishers, fishers proceeded on to the next section of the lake as a team, and repeated the count procedure until the entire lake was surveyed. When necessary, to avoid the double-counting of fish (which sometimes moved between counted areas), fishers informed one another of such instances. Counts were not made during windy or rainy conditions because of reduced visibility and hearing (a schematic protocol of the different approaches to surveying lakes is presented in Figure 1).

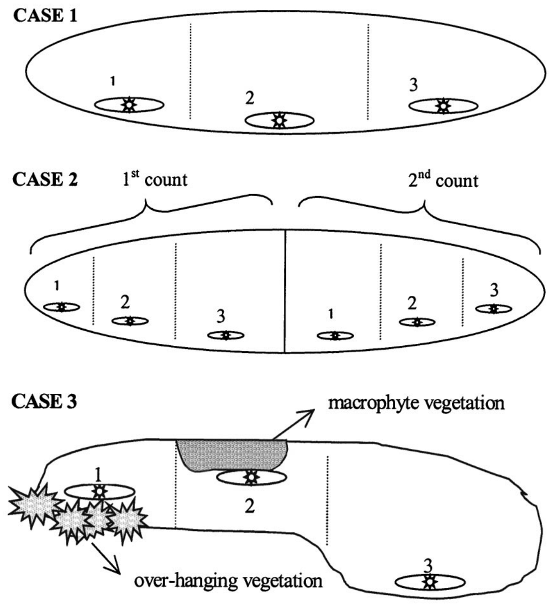

FIGURE 1.—Schematic model of sampling approach used by fishers to count pirarucu in várzea lakes. This scheme is based on a team of three fishers counting from canoes, but counts can also be made from shore depending on the vegetation type and size of lake. Case 1 illustrates a situation where the area of the lake is equal to or smaller than the area that can be surveyed by all fishers together. In this scenario, each fisher determines an area so that all the lake will be surveyed simultaneously. Start and end of the count is signaled by producing a ''hum'' noise. Case 2 illustrates a situation where the area of the lake is larger than the area that can be simultaneously surveyed by all fishers at one time. In this case, successive counts are made until the entire area of the lake is surveyed. Case 3 illustrates a lake with poor visibility due to macrophyte or overhanging vegetation from shore. Areas of the lakes with macrophyte (fisher 2) or overhanging vegetation (fisher 1) are surveyed mainly by listening for pirarucu surfacing and exhaling. Note that the area surveyed by fisher 3 is greater than that of fishers 1 and 2 because the area is less vegetated, allowing better observation.

Mark–Recapture Estimates

Immediately after counting at each lake, multiple mark–recapture estimates of abundance were calculated for pirarucu longer than 1 m. Mark–recapture work began with a systematic inspection of the whole lake before each seine. Seining was done where it was possible to successfully deploy the net and catch fish, and each seine haul was considered one sample. Fish were captured using a seine net (140 × 10 m, 19 cm stretched mesh size). Fish were kept in the water of the lake and held within the capture net while they were measured (±5 cm from the extremity of the inferior lip to the tip of the caudal fin) and tagged with dart tags (Floy Tag & Manufacuring, Inc.). Upon capture we tagged new fish and recorded tagged fish as recaptures; all tagged fish were released at their capture location. (We followed this procedure in order to minimize stress on the captured fish.) As the total number of tagged fish in the lake increased, so did the proportion of recaptures for each sample. To improve the accuracy of the estimate, sampling was continued until we had tagged at least 70% of the number of fish estimated by the model. Mortality was checked in situ by constantly searching for pirarucu corpses during daylight hours.

Abundance estimates and confidence intervals were calculated using the Schumacher and Eschmeyer linear regression model for closed populations (Schumacher and Eschmeyer 1943; described in detail in Abuabara and Petrere 1997). This method considers that the ratio between the number of tagged individuals in the lake (M_i) and the total number of individuals in the lake (N) is directly proportional to the ratio between the number of tagged individuals caught in the sample (t_i) and the total number of individuals caught in the sample (n_i). The estimate of the total number of individuals in the lake ($\tilde{N}$) is given by multiple samples, which form a line passing in the origin with inclination $1/N$. The equation to calculate $\tilde{N}$ is:

$$\tilde{N} = \left(\sum_{i=1}^{s} n_i M_i^2\right) \Bigg/ \left(\sum_{i=1}^{s} n_i M_i\right).$$

where i = denotes the recapture samples. An estimate of the mean square weighted residual for the adjusted line (σ^2) is given by:

$$\sigma^2 = \left(\frac{1}{s-2}\right)\left\{\sum_{i=1}^{s}\left(\frac{t_i^2}{n_i}\right) - \left[\frac{\left(\sum_{i=1}^{s} t_i M_i\right)^2}{\sum_{i=1}^{s} t_i M_i^2}\right]\right\}.$$

Confidence intervals (CI) can then be constructed with the following equation:

$$\mathrm{CI} = \frac{\sum_{i=1}^{s} t_i M_i^2}{\sum_{i=1}^{s} t_i M_i \pm t_{s-2}\left(\frac{\alpha}{2}\right)\left(\sigma^2 \sum_{i=1}^{s} t_i M_i^2\right)^{1/2}}.$$

where t_{s-2} [$\alpha/2$] is the value of t-student table with ($s - 2$) degrees of freedom for the confidence level of 100 (1 − α) %.

This method assumes that catchability between tagged and untagged individuals is equal, tags are not lost, and that migration, recruitment, and mortality do not occur. An advantage of this method is that the relationship between $Y_i = t_i/n_i$ versus $X_i = M_i$ can be used to verify if the assumptions have been met, because departure from any of the assumptions would be indicated by the presence of a curvilinear relationship (Abuabara and Petrere 1997). Thus, the quadratic regression model is:

$$Y_i = a + bx + cx^2.$$

The test for the presence of a curvilinear relationship evaluates (H_0: $c = 0$) versus (H_a: $c \neq 0$) for every mark–recapture abundance estimate calculated.

Accuracy of the Counts

The accuracy of the counts made by eight local fishers from the MSDR was assessed in 8 of the 12 chosen lakes between September 13, 1999, and January 7, 2000. Each lake was surveyed a minimum of four times during two consecutive days, and these replicate count censuses were analyzed according to their distribution. Counts were also conducted at different times of the day to characterize count variability during the course of the day. In two very small lakes (Poço Lake, 0.21 ha; and Redondo Lake, 1 ha), all fishers conducted individual counts in order to characterize count variation among fishers.

Training Fishers to Count

The potential to train fishers to count was assessed in 5 of the 12 chosen lakes between October 10 and 28, 2000. From here, fishers involved in the previous set of experiments are known as trainers, and fishers who received training in counting from the trainers are known as trainees. Three groups of trainees were involved: four fishers from Santa Maria do Tapará, four from São Miguel (both communities near Santarém, Pará-Brazil), and four from the Amanã Sustainable Development Reserve communities (near MSDR, Amazonas-Brazil).

Training occurred for the first 4 d. The trainees observed how the trainers made the counts during the first 2 d, and on the third and fourth days, trainees practiced the counts with the trainers. On the fifth day onward, the counts made by the train-

TABLE 1.—Replicate count censuses of pirarucu longer than 1 m made by the trainers for each lake (n_i). For most lakes the counts presented are the sum of the counts made by all fishers simultaneously. In the small lakes Poço and Redondo, each count presented (n_i) was made individually by each fisher. Mean and coefficients of variation (CV = 100 × SD/mean) are presented for the counts.

Lake	n_1	n_2	n_3	n_4	n_5	n_6	n_7	n_8	n_9	n_{10}	n_{11}	n_{12}	n_{13}	n_{14}	Mean	CV (%)
Comprido	61	60	65	55	57	58									59.3	5.9
Samaumeirinha	117	125	105	131	109	99	99	114							112.4	10.4
Samaumeira I	8	10	8	9											8.8	10.9
Samaumeira II	14	12	14	17	19	19	14	15	16	15	13	15	15	16	15.3	13.2
Goleiro	100	93	76	75	87	100	100	89							90.0	11.4
Serapião	61	59	62	65	57	61									60.8	4.5
Poço	22	23	21	20	22	18	18	19							20.4	9.4
Redondo	10	10	9	8	10	14	10	9							10.0	17.7

ees were assessed. Count and mark–recapture procedures were conducted similarly as in the first set of experiments. Each group counted each lake three times.

Results

Trainers' Counts

The counts made by all trainers together at each lake varied little (around 10.4%; Table 1) and was not influenced by population density (see coefficients of variation [CV = 100 × SD/mean] in Figure 2) or the time of the day. Count variation between fishers remained low when fishers individually counted the same populations in the small lakes Poço and Redondo (Table 1). The tests of Lilliefors, Shapiro–Wilk, and extreme values indicated these count censuses followed a normal distribution.

Mark–Recapture Estimates

Mark–recapture abundance estimates of pirarucu longer than 1 m were calculated for most lakes (Tables 2, 3). In Poço and Redondo lakes, due to their small sizes, it was possible to know the true abundance of pirarucu without the need for mark–recapture work (see Table 2 for details).

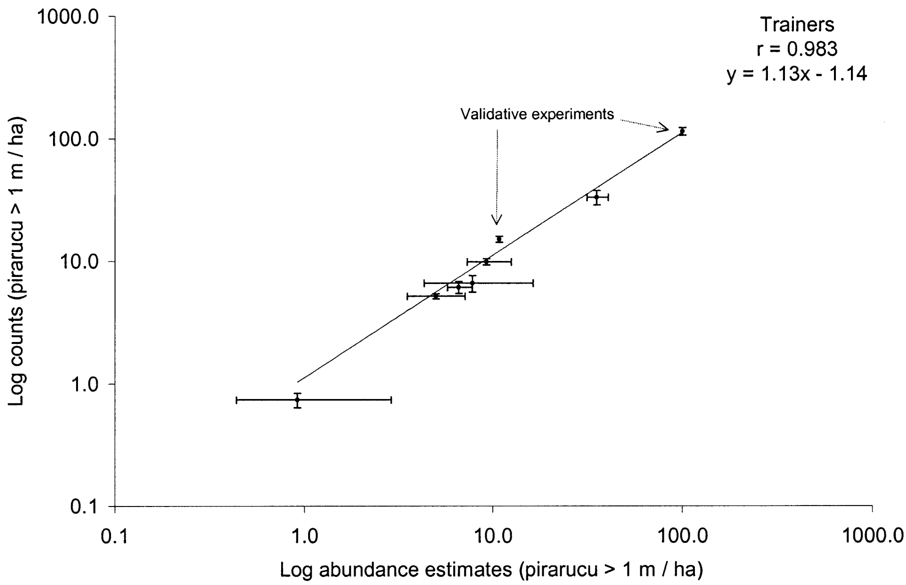

FIGURE 2.—Regression between population density estimates (except where indicated) and counts of individuals longer than 1 m long made by the trainers. Values of measured abundance were used in the validative experiments indicated; see Table 2 for details on these measures. Confidence intervals (95%) of the mark–recapture estimates and coefficients of variation (CV = 100 × SD/mean) of the counts are presented. The regression is based on unweighted means of the counts of different sample sizes in each lake. Data are presented in log scale for better display.

TABLE 2.—Seine captures for the mark–recapture work conducted at each lake to assess the counts made by the trainers. The total number of individuals captured in the seine (n_i) and the number of tagged individuals captured in the same seine (t_i) are indicated. In the small Poço and Redondo lakes, only one seine haul was conducted; the number of individuals caught was considered equal to the number of individuals present in the lake because the net was large enough to capture all the individuals with a single haul. After seining and before returning the tagged fish to the lake, the fishers resurveyed the lake and found no more fish.

Seine samples	Comprido		Poço		Samaumeirinha		Samaumeira I		Samaumeira II		Redondo		Serapião		Goleiro	
	n_i	t_i	n_i	t_i	n_i	t_i	n_i	t_i	n_i	t_i	n_i	t_i	n_i	t_i	n_i	t_i
1	5	0	24		7	0	2	0	3	0	15		8	0	8	0
2	4	0			3	0	3	0	1	1			6	2	9	1
3	5	1			13	0	1	0	5	1			6	2	15	3
4	13	0			5	0	1	1	2	0			7	1	12	4
5	25	15			3	2	1	1	1	0			9	2	12	7
6	17	8			13	3	2	2	2	1			4	1	7	3
7	5	5			6	1			1	1			2	1	13	8
8	4	3			3	1			1	1			4	2	4	2
9	4	2			2	0			3	3			3	2	9	8
10	4	2			10	5							10	6	3	2
11	9	7			11	5							4	3	4	3
12					5	5							4	3	2	2
13					6	4							5	3	6	3
14					4	2							2	0		
15					2	1							4	4		
16					3	2							3	2		
17					3	1							4	3		
18					1	1										
19					10	8										
20					2	2										
21					7	4										
22					5	2										
23					2	0										
24					6	5										
25					3	3										
26					6	5										

TABLE 3.—Abundance estimates of pirarucu longer than 1 m calculated to assess the counts of the trainers. Confidence intervals (lower and upper limits), number of individuals estimated ($\tilde{N}$), and P-values of the quadratic regression analyses are presented for the mark–recapture estimates. The total number of individuals longer than 1 m found in lakes Poço and Redondo is presented; see Table 2 for details on these values.

Estimate type and lake	Lower limit	$\tilde{N}$	Upper limit	P-value
Mark–recapture				
Comprido	50.6	63.0	83.9	0.631
Samaumeirinha	89.4	103.8	123.7	0.948
Samaumeira I	24.0	7.0	25.8	0.258
Samaumeira II	6.1	12.9	29.7	0.281
Goleiro	65.4	74.5	86.4	0.798
Serapião	44.3	61.9	87.5	0.893
Known abundance				
Poço		24.0		
Redondo		15.0		

The quadratic regression analyses conducted with the mark–recapture data indicated an absence of curvilinear relationships; nonsignificant P-values are shown in Table 3.

Since mortality rates were very low (less than 1%), their effect in the estimation of population size was minimal. Two fish died soon after tagging in Samaumeirinha Lake, where the population size was estimated to be 103 fish. One fish died while being tagged in Goleiro Lake, where the population size was estimated to be 61 fish.

Assessment of the Trainers' Counts

Counts made by the trainers (Table 1) and respective mark–recapture estimates of individuals longer than 1 m (Table 3) were strongly correlated (r = 0.983) by a linear relationship (y = 1.13–1.14; Figure 2).

Mark–recapture estimates of abundance were calculated for each size-class (juveniles and adults) in order to assess the reliability of the counts for these categories. However, dividing the data into categories provided unreliable results as

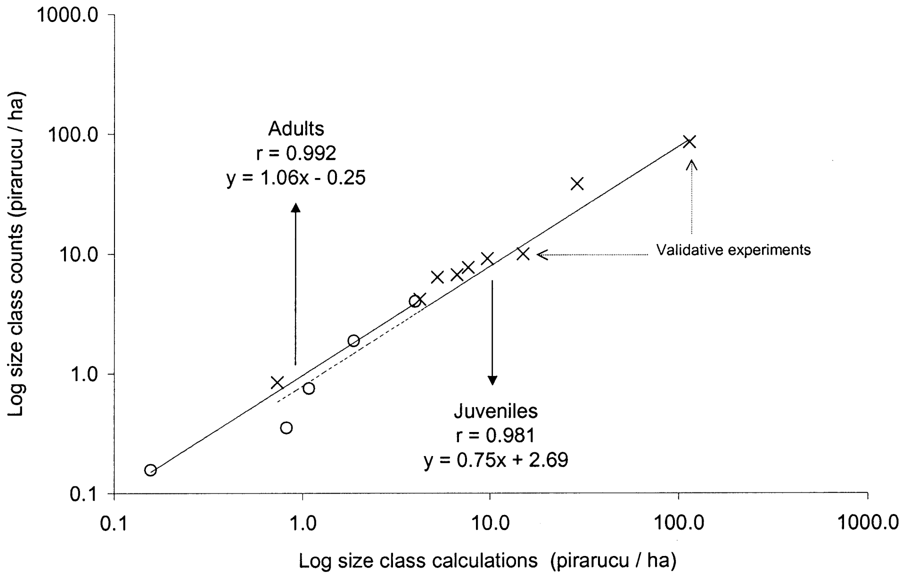

FIGURE 3.—Regressions between size-class counts and calculated estimates of population density. This regression is also based on samples of counts of different sample sizes that were not weighted. Data are presented in log scale for better display.

indicated by extremely high values; the low number of observations involved in the adult class (usually less than 10) may explain this problem. Field observations, however, suggest another possible explanation. We observed that at the end of most mark–recapture experiments, most (and in some lakes, all) adults had already been tagged, while juveniles formed the untagged part of the population.

In attempting to assess the size-class counts by considering the higher catchability of adults to be true, it was assumed that the number of tagged adults was equal to the number of adults present at each lake. Thus, the number of tagged adults was compared with the number of counted adults. Such a relationship, however, showed a weak correlation because Poço Lake was an outlier. In Poço Lake, the fishers indicated the presence of two adults when only juveniles existed. The fishers stated that this error occurred because the ''fish of this lake were very fat,'' giving them the impression to be longer than they actually were. Their explanation is supported by the observation that the majority of these fish measured 1.4 m. The linear equation between their counts of adult pirarucu and respective abundance estimates ($y = 1.06x - 0.25$) showed a strong correlation ($r = 0.992$) when the results from Poço Lake were discarded (Figure 3).

In order to assess the counts of juveniles it was also assumed that at the end of each mark–recapture experiment all adults were tagged and juveniles formed the untagged portion of the population. The number of untagged juveniles was calculated with the assumption that the mark–recapture estimates of individuals longer than 1 m were accurate (as indicated by the quadratic regression analyses), and by subtracting the total number of individuals tagged from the total number of individuals estimated by the mark–recapture model. The number of juveniles counted was then compared with the number of juveniles tagged added to the calculated number of untagged juveniles. A regression of these estimates (Figure 3) resulted in a linear relationship ($y = 0.75x + 2.69$) with a strong correlation ($r = 0.981$).

Assessment of the Trainees' Counts

Counts made by the trainees showed larger CVs in comparison with counts previously made by the trainers in other lakes (compare Table 1 with Table 4 and Figure 2 with Figure 4).

In four of the lakes abundance estimates were calculated through mark–recapture work, and in the small Redondo Lake it was possible to measure the true abundance (Tables 5 and 6). The quadratic regression analyses indicated an absence of curvilinear relationships for the mark–recapture data (see nonsignificant *P*-values in Table 6).

Counts made by trainees from Santa Maria do

TABLE 4.—Counts of pirarucu longer than 1 m made by the trainees from Amanã, São Miguel, and Santa Maria do Tapará for each lake. In Redondo Lake the counts presented were made individually by three fishers.

Lake	Amanã				São Miguel				Santa Maria do Tapará			
	n_1	n_2	n_3	Mean	n_1	n_2	n_3	Mean	n_1	n_2	n_3	Mean
Urucuraninha I	7	7	5	8.7	7	7	5	6.3	7	7	5	6.3
Urucuraninha II	5	5	4	4.7	8	7	8	7.7	3	5	3	3.7
Cedrinho	7	8	10	8.3	6	10	9	8.3	8	9	10	9.0
Jurupari	21	22	20	21.0	25	25	25	25.0	29	26	20	25.0
Redondo	3	2	3	2.7	2	3	2	2.3	2	3	2	2.3

Tapará, São Miguel and Amanã were strongly correlated with mark–recapture estimates ($r = 0.971$, $r = 0.998$, and $r = 0.977$, respectively; see Figure 4). I did not divide this data set into size-class categories because of the low number of adults present in these lakes. The trainers stated that all of the trainees are capable of differentiating juveniles from adults.

Discussion

Mark–Recapture Estimates

All the mark–recapture estimates of abundance of pirarucu longer than 1 m were considered to be accurate. In Poço and Redondo lakes it was possible to measure the abundance of pirarucu (see Tables 2, 3, and 6). These estimates and measures of abundance allow for considerable precision for means of assessing the counts made by the fishers.

Trainers' Counts

The counts of pirarucu longer than 1 m made by the trainers seem to be accurate given the strong correlation with mark–recapture estimates and measured abundances (Figure 2). But the assessment of the size-class counts was hampered by the lack of reliable abundance estimates (Figure 3); the size-class equations, which indicate that fishers accurately count the number of adults and that they underestimate the number of juveniles, are not accurate because all adults were assumed to be tagged, when, in fact, field observations only suggest that in most lakes adults tended to be more tagged relative to juveniles. Nevertheless, these size-class equations, with the information of the validative experiments, provide some evidence of the accuracy of the size-class counts.

Trainees' Counts

The training sessions were successful as trainees from Santa Maria do Tapará, São Miguel, and Amanã all counted well (Figure 4). An explanation for the higher variation of the counts made by the trainees in comparison with those made by the trainers (compare Figure 2 with Figure 4) was given by the fishers, who said that the noise made by the large number of people forming trainer-trainees groups (~25) caused the pirarucu to change behavior, and that this change in behavior made it

TABLE 5.—Seine captures from the mark–recapture work conducted at each lake to assess the learning of the trainees. The total number of individuals captured in the seine (n_i) and the number of tagged individuals captured in the same seine (t_i) are indicated. In small Redondo Lake, which was studied previously, only one seine haul was conducted; see Table 2 for details on capture work at this lake.

Seine samples	Urucuraninha I		Urucuraninha II		Cedrinho		Jurupari		Redondo	
	n_i	t_i	n_i	t_i	n_i	t_i	n_i	t_i	n_i	t_i
1	2	0	4	0	3	0	2	0	3	
2	4	1	1	1	1	1	4	0		
3	4	3	1	1	2	1	3	1		
4	2	1	2	1	2	1	4	0		
5			1	1	2	1	2	0		
6			4	2	1	1	2	1		
7							3	1		
8							2	2		
9							2	1		
10							1	1		
11							2	2		
12							3	3		
13							3	2		

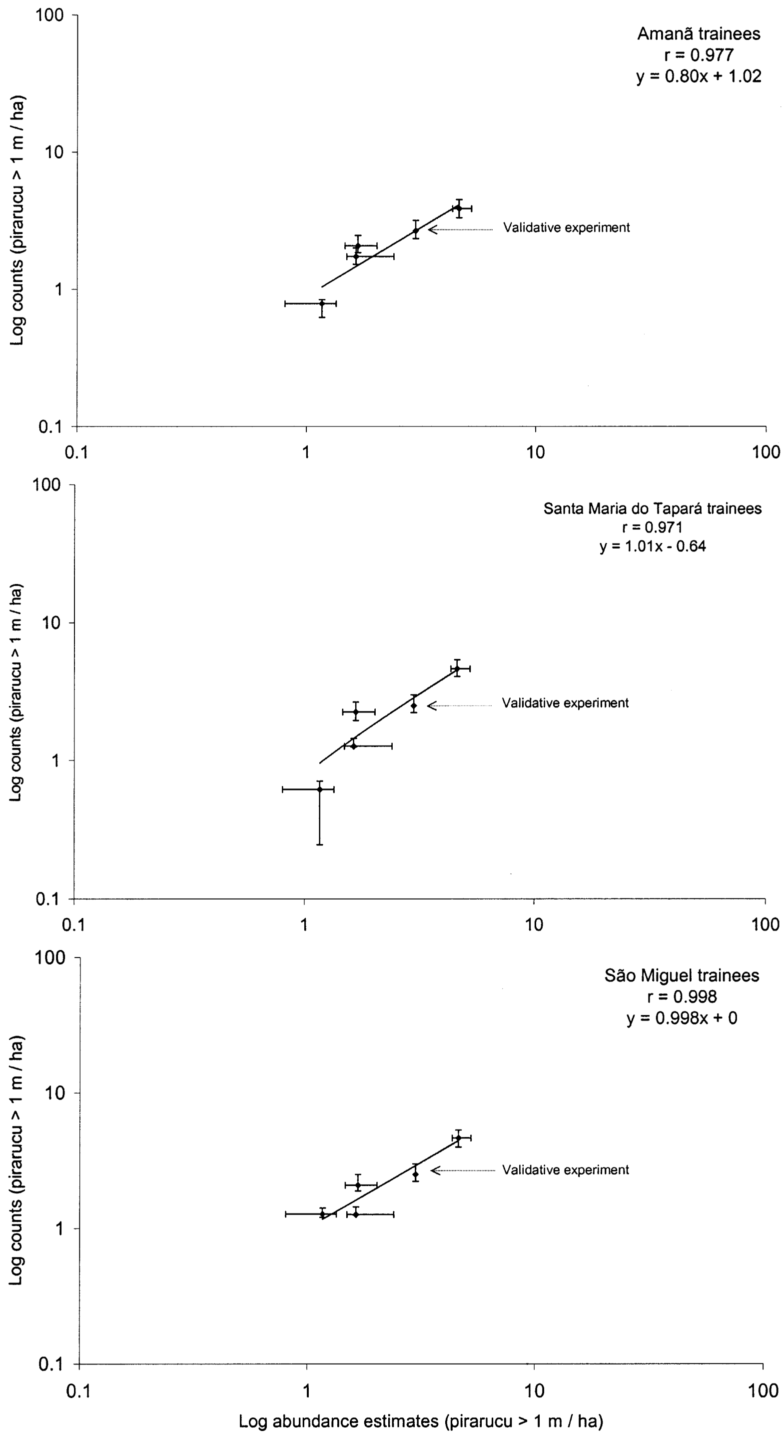

FIGURE 4.—Regressions between counts made by trainees from Amanã, São Miguel, and Santa Maria do Tapará, and estimates of abundance of fish longer than 1 m long. Abundance estimates were obtained through mark–recapture work, except where indicated. A value of measured abundance was used in these validative experiments; see Table 2 for details. Confidence intervals (95%) of the mark–recapture estimates and CVs of the counts are presented. Data are presented in log scale for better display.

TABLE 6.—Abundance estimates of pirarucu longer than 1 m calculated to assess the counts of the trainees from Amanã, São Miguel, and Santa Maria do Tapará for each lake. Confidence intervals (lower and upper limits), number of individuals estimated ($\tilde{N}$), and *P*-values of the quadratic regression analyses are presented for the mark–recapture estimates. The total number of individuals longer than 1 m found in Lake Redondo is presented; see Table 2 for details on this value.

Estimate type and lake	Lower limit	$\tilde{N}$	Upper limit	*P*-value
Mark–recapture				
Urucuraninha I	4.6	8.2	37.6	0.607
Urucuraninha II	4.4	7.0	16.1	0.435
Cedrinho	4.2	6.7	15.8	0.462
Jurupari	22.2	25.0	48.2	0.294
Known abundance				
Redondo		3.0		

difficult to observe and hear the pirarucu, which reacted to the disturbance by hiding under logs and floating vegetation, and by surfacing at longer intervals. Another explanation is that small errors in the counts (±1 pirarucu) were magnified due to the lower number of fish involved.

Fishers' Skills and Knowledge

Fishers explained that they use two methods to count pirarucu. The first is through individual identification on the basis of subtle visual and acoustical cues at the moment of aerial breathing, such as the size, condition factor, color, amount of water displaced, noise of breathing (indicating amount of air exhaled), and behavior. The second is through the detection of ''waves'' of individuals surfacing more or less simultaneously at different locations. I would add to their explanation that the skills and knowledge base that allow them to do this is acquired through the extensive practice of observing and listening to surfacing pirarucu and catching it immediately after, and that such a skills and knowledge base is improved further when fishers use artisanal fishing methods such as harpoons. However, different fishers adopt different approaches to count pirarucu; for instance, two fishers explained to me that they count pirarucu mostly based on listening, which is a more effective way because they can listen to all pirarucu independently of whether it is observed or not.

Although all fishers involved in this work succeeded in counting, an important note is that fishers report that not all fishers can accurately count pirarucu. They say that fishers that are less experienced and/or that use modern fishing methods (such as gill netting) do not have as much knowledge on the species nor the skills needed for accurate counting.

Counts Versus Mark–Recapture and Monitoring of Landings

Fisher counts are much less variable than mark–recapture estimates (compare confidence intervals with CVs in Figures 2 and 4), and much more cost-effective at assessing pirarucu stocks. Counts can estimate the population size of most lakes in the Solimões River in as short as 20 min, while the mark–recapture method used here would require an average of 2 weeks to achieve the same result. The Amazon Basin is enormous, and the use of mark–recapture methods would greatly reduce the area that could be assessed. Pirarucu populations could also be monitored at fish markets; however, this method is unlikely to produce reliable results because it involves monitoring the black market.

Management Implications

By assessing pirarucu stocks themselves, fishers can self-manage the species (see Pinedo-Vasquez et al. 2001) and become independent from unsound government management schemes. An outstanding example of the success of this approach is provided by the MSDR communities where fishers have increased the pirarucu population by 300% in only 3 years by formulating fishing quotas based on count data (Viana et al., in press). In the MSDR, fishers have engaged in the decision-making process partly as a result of being directly involved in stock assessment (Viana et al., in press).

The count method has great potential to promote management, but success depends on fishers' engagement with the process. Fishers that are concerned with pirarucu stocks are unlikely to cheat as would, for instance, many fishers that live in the MSDR and in other regions of the Amazon. Identifying who such fishers are is crucial for determining success. However, I do not believe that a management system could require, by law, the use of the counts because not all fishers are concerned with the status of pirarucu stock, and because not all fishers possess the skills and knowledge necessary for accurate counting.

Conclusions

Experienced pirarucu fishers have an extraordinary ability to detect very subtle visual and acoustic information from surfacing pirarucu. Their knowledge and skills were combined with a simple standardized procedure and resulted in a fairly accurate and cost-effective method to assess pirarucu populations that has potential for research and management initiatives.

The increasing number of community-based fishery management programs in the Amazon can now be linked with the training of fishers to count pirarucu, and with the education of government officials about the knowledge and skills of fishers. Fishers have much to offer for pirarucu management and conservation. Fishers' knowledge and skills allow for stock assessment, which adds to decision making and to the long-term sustainability of the fishery, which, in turn, are important for the well-being of fishers and the survival of their knowledge and skills.

However, only fishers that are specialized in pirarucu have the expertise to make reliable counts, and such specialization is threatened by the increasing use of modern fishing methods and declining pirarucu populations.

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