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Notes on the reproduction of the Swinhoe's tree lizard, *Japalura swinhonis* Günther, 1864, (Squamata: Agamidae) from southwestern Taiwan

Gerrut Norval[1]*, Jean-Jay Mao[2] and Kerry Slater[1]

Abstract. Thirteen clutches of eggs were obtained from *Japalura swinhonis* females collected from late March 2004 to early October 2010. The specimens had an average snout-vent length, tail length, and maternal post-oviposition body mass of 66.9 mm, 150.9 mm, and 7.67 g, respectively. The clutch sizes ranged from three to five eggs (mean = 4). A total of 52 eggs were obtained, and had an average length, width, mass, and volume of 12.6 mm, 7.2 mm, 0.4 g, and 344.9 mm³, respectively. The average relative clutch mass was 20.51%. Only two eggs successfully hatched after an incubation period of 45 days. The hatchlings had an average snout-vent length, tail length, and body mass of 22 mm, 30 mm, and 0.2 g, respectively.

Keywords. Taiwan, Agamidae, *Japalura swinhonis,* arboreal, oviposition, clutch size, relative clutch mass.

Introduction

The Swinhoe's tree lizard (*Japalura swinhonis* Günther, 1864) is an endemic species in Taiwan, and occurs throughout the island, as well as on the offshore islet Lanyu Island, also known as Orchid Island, at elevations below 1500 m (Ota, 1991a). It is an arboreal species, and is sexually dimorphic in body coloration and size (Fig.1) (Kuo, Lin and Lin, 2009). *Japalura swinhonis* has a confusing taxonomical history, and currently, the former recognized subspecies, *Japalura swinhonis formosensis* Liang and Wang, 1976 and *Japalura swinhonis mitsukurii* Stejneger, 1898, are regarded as synonyms (Ota, 1991b; Ota, 1991c; Ota, 2000), while specimens of the nominate form have been allocated to either the short-legged tree lizard (*Japalura brevipes* Gressitt, 1936) by Ota (1989) or the yellow-mouthed tree lizard (*Japalura polygonata xanthostoma* Ota, 1991) by Ota (1991c). Based on the location, habitat, and sizes of the lizards used in studies by Chou (1996), Lin (1978), Lin and Cheng (1986), Lin and Lu (1982), and Wei and Lin (1981) the lizards were most likely of the species that is currently regarded as *J. swinhonis*. Previous studies concerning the reproductive biology (Lin, 1978; Lin and Cheng, 1986; Huang, 2007) were conducted on dissected specimens, which made it difficult to describe aspects such as the average clutch mass and relative clutch mass. In this study, clutch, egg and hatchling sizes of this species, are described.

Materials and Methods

From late March 2004 to early October 2010, *J. swinhonis* were collected on an ad hoc basis in Chiayi and Yunlin Counties, Taiwan (Fig.2), and while in captivity, some females laid eggs. For all the lizards, the snout-vent length (SVL) and tail length (TL) were measured with a transparent plastic ruler to the nearest mm, and the length and width of each egg was measured with a dial caliper to the nearest 0.01 mm. The lizards and eggs were weighed to the nearest 0.1 g with a digital scale, and the number of eggs of each clutch was recorded (CS). Females that had laid eggs were weighed again to the nearest 0.1 g to obtain the maternal post-oviposition body mass (POBM). The relative clutch mass (RCM), which indicates the degree the gravid female is physically burdened by her clutch, was calculated using the formula (Shine, 1980):

RCM = (the total clutch weight / POBM) × 100

The volume of each egg was determined, using the formula for a prolate spheroid:

volume =4/3π(length/2)*(width/2)²

After the dimensions and weights of the eggs were measured, the eggs were buried in a mixture of 50% river sand and 50% soil, in a plastic container, at a depth of ca. 10 mm. The container was placed on the floor in a room, where it was exposed to sunlight during the morning, and to avoid desiccation the interior of the container was misted with water every 2 to 3 days.

A one-way analysis of variance (ANOVA) was used to compare the mean SVL of the lizards from the different collection sites with each other, and to compare the females that laid eggs with those that did not. It was also used to compare the mean dimensions of the eggs from the various clutches. Spearman's rank correlation coefficient (r_s) was used to examine the relationships between SVL, POBM, CS, mean ova mass, and RCM.

1 Applied Behavioural Ecology & Ecosystem Research Unit, Department of Environmental Sciences, UNISA, Private Bag X6, Florida, 1710, Republic of South Africa; e-mail: a_sagrei@hotmail.com

2 Department of Natural Resources, National Ilan University. No. 1, Sec. 1, Shen-Lung Rd., Ilan, 260, Taiwan, R.O.C.

* Corresponding author.

Figure 1. The Swinhoe's tree lizard (*Japalura swinhonis*) is a common endemic lizard species in Taiwan. The males (top) are larger than the females (bottom), and have a different coloration pattern and a much larger dewlap. The female illustrated here has a brick-red brown dorsal area, which is not present in all females of this species (photographed by Gerrut Norval).

Results

During the study period, 161 specimens (58 females; 103 males) of *J. swinhonis* were collected. There was no statistically significant difference in the mean SVL of females (ANOVA, $F_{1, 56} = 3.38$; $P = 0.07$) from the different sites, so the data from the different sites were

Table 1. The results of the one-way analysis of variance (ANOVA) comparisons between the females that deposited eggs with those that did not (* statistically significant).

Females that deposited eggs	Females that did not deposit eggs	*F*	*P*
SVL	SVL (all)	$F_{1,56} = 6.98$	$P = 0.01$ *
Pre-oviposition body mass	Body mass (all)	$F_{1,56} = 18.41$	$P = 0.00007$ *
POBM	Body mass (all)	$F_{1,56} = 7.91$	$P = 0.007$ *
SVL	SVL (> 63 mm)	$F_{1,32} = 0.47$	$P = 0.5$
Pre-oviposition body mass	Body mass (> 63 mm)	$F_{1,32} = 6.33$	$P = 0.02$ *
POBM	Body mass (> 63 mm)	$F_{1,32} = 0.004$	$P = 0.95$

pooled. They ranged in SVL, from 27.0 to 74.0 mm (mean ± SD = 62.1 ± 12.4), TL, from 47.0 to 191.0 mm (mean ± SD = 45.8 ± 35.0), and body mass, from 0.6 to 13.9 g (mean ± SD = 7.1 ± 3.1), and the females that laid eggs (n = 13) ranged in SVL, from 64.0 to 70.0 mm (mean ± SD = 66.9 ± 2.3), TL, from 127.0 to 164.0 mm (mean ± SD = 150.9 ± 10.7), pre-oviposition body mass (measured on the day the lizard was collected), from 7.5 to 10.1 g (mean ± SD = 8.9 ± 0.8), and POBM, from 5.7 to 9.8 g (mean ± SD = 7.7 ± 1.3). The mean SVL, TL, and pre-oviposition body mass of the females that laid eggs were larger than that of the females that did not lay eggs (Fig. 3). Between these two groups of females there were statistical significances in the difference in the mean SVL; the mean body mass of the females that did not lay eggs and the mean pre-oviposition body mass of the females that did lay eggs; the mean body mass of females that did not lay eggs and the mean POBM of the females that laid eggs; and the mean body mass of the females (SVL > 63 mm) that did not lay eggs and the mean pre-oviposition body mass of the females that did lay eggs (Table 1).

Oviposition was recorded in the months April to September. Thirteen clutches were recorded, and the clutch sizes ranged from three to five eggs (mean ± SD = 4 ± 0.91). The relative clutch mass ranged from 12.64 to 35.29% (mean ± SD = 20.51 ± 6.78).

A total of 52 eggs were obtained, all of which were white and oval shaped (Fig.4). The eggs ranged in length, from 9.46 to 14.93 mm (mean ± SD = 12.60 ± 0.90); width, from 4.96 to 9.28 mm (mean ± SD = 7.18 ± 0.77); mass, from 0.2 to 0.5 g (mean ± SD = 0.4 ± 0.1); and volume, from 121.91 to 565.68 mm³ (mean ± SD = 344.78 ± 79.94). There was a statistically significant difference in the mean lengths (ANOVA, $F_{12,39} = 2.99$; $P = 0.005$), widths (ANOVA, $F_{12,39} = 6.25$; $P = 0.000006$), weights (ANOVA, $F_{12,39} = 4.16$; $P = 0.0003$), and volumes (ANOVA, $F_{12,39} = 4.71$; $P = 0.0001$) of the eggs from the various clutches.

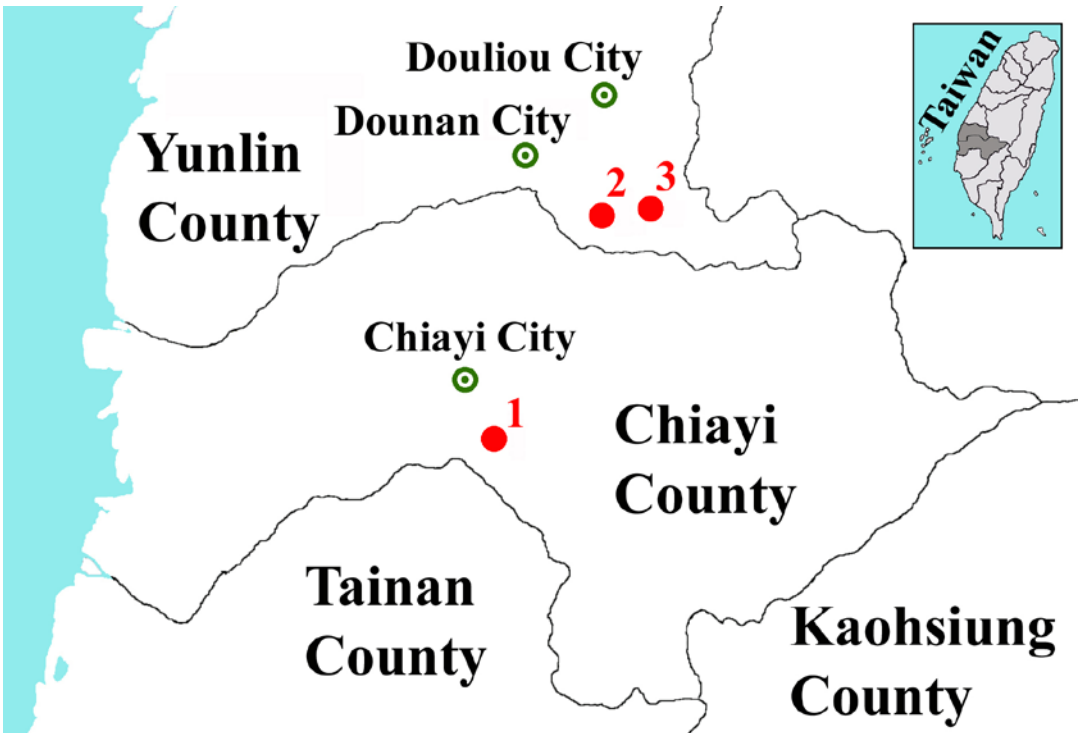

Figure 2. The localities in Taiwan, from where the *Japalura swinhonis* used in this study were collected (datum: WGS84). 1 – 23°25‘42“N, 120°29‘06“E; 2 – 23°36‘34“N, 120°34‘13“E; and 3 – 23°35‘44“N, 120°35‘47“E.

There was no significant correlation between SVL and POBM (r_s = 0.02; n = 13; p = 0.96), SVL and CS (r_s = 0.02; n = 13; p = 0.94), SVL and RCM (r_s = -0.19; n = 13; p = 0.55), or POBM and CS (r_s = -0.07; n = 13; p = 0.82). But, there was a significant negative correlation between SVL and the mean egg mass (r_s = -0.69; n = 13; p = 0.009), and between POBM and RCM (r_s = -0.58; n = 13; p = 0.04). A significant correlation between the mean egg width and mean egg weight (r_s = 0.67; n = 13; p = 0.01) was also found, and there was also a strong positive correlation between the CS and RCM (r_s = 0.77; n = 13; p = 0.002).

Only two of the 52 eggs successfully hatched on October 1st, 2006, after an incubation of 45 days. The hatchlings were very similar in appearance and had an average SVL, TL and body mass of 22 mm, 30 mm, and 0.2 g.

Discussion

Lin and Cheng (1986) made a comparison between *J. swinhonis* from central western (formerly *J. s. formosensis*) and southern (formerly *J. s. mitsukurii*) Taiwan, and found that there are differences between these lizards with regards to their sizes at a given age, mean adult weight, reproductive effort, and the reproductive period, indicating that there is some variation between *J. swinhonis* populations from different localities. From the observations described herein, the reproductive period of *J. swinhonis* from southwestern Taiwan is similar to that reported by Lin and Cheng (1986), and Huang (2007).

As for the SVL of the lizards, the females collected in our study were smaller than the maximum SVL reported by Lin and Lu (1982; max. SVL = 76.1 mm), Lin and Cheng (1986; max. SVL = 80.0 mm), and Huang (2007; max. SVL = 76.3 mm), but exceed that reported by Lin (1978; max. SVL = 67.0 mm). According to Lin (1978) and Lin and Cheng (1986), *J. swinhonis* females become reproductively mature at a SVL of 53.3 and 56 mm, respectively. However, the smallest *J. swinhonis* females that laid eggs, in this study, had a SVL of 64 mm (n = 3), which is very similar to the minimum SVL of 63.3 mm, reported by Huang (2007), for *J. swinhonis* females from Orchid Island. A possible explanation for the variations among the different studies is that it takes *J. swinhonis* females about two to three months to produce one clutch of eggs (Lin, 1978; Huang, 2007). Since *J. swinhonis* females grow fairly fast (Lin and Lu, 1982), and their appetite does not decrease before oviposition (G. Norval, own data) they experience some growth during the two to three months that they are gravid. The differences in the reported SVL at which *J. swinhonis* females become sexually mature are thus probably due to an increase in body size between the time when yolked follicles are detectable (dissection studies; Lin, 1978; Lin and Cheng, 1986; Huang, 2007), and when oviposition takes place (this study).

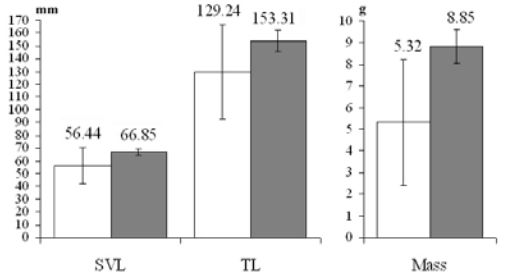

Figure 3. The mean snout-vent length, tail length, and mass of the *Japalura swinhonis* females that did not lay eggs (white bars), and those females that did lay eggs (grey bars), on the day they were collected (i.e. measured before oviposition).

The eggs examined by Lin (1978) and Lin and Cheng (1986) were taken from dissected lizards (pre-oviposition), and the eggs described in this study were examined after being laid (post-oviposition), and therefore a detailed comparison cannot be made. However, similarly to Lin (1978), we found that the lengths, widths, and masses of eggs from within a clutch were very similar, but varied considerably between clutches from various females. A strong correlation between CS and RCM was however observed. The mean clutch sizes of 4.27, and 4.6 reported by Lin (1978) and Lin and Cheng (1986) respectively, are slightly larger than that recorded in our study (4), which is larger than the mean clutch size of 3.27 reported by Huang (2007). No clutches larger than five eggs were observed during this study, which is similar to the findings of Huang (2007) for *J. swinhonis* from Orchid Island. Our findings did however indicate that in this species, clutch sizes do not necessarily increase with an increase in the maternal body size, which was also found in the studies done by Lin and Cheng (1986), and Huang (2007). We did nevertheless find that in our study, larger females tended to produce smaller eggs. *Japalura swinhonis* females emerge from hibernation with their fat reserves almost depleted, and they remain fairly low until reproduction ends, after which they increase rapidly before the lizards enter hibernation again (Lin, 1978; Lin and Cheng, 1986). The fact that the fat reserves remain fairly low until reproduction ends indicates

Figure 4. One of the larger clutches of *Japalura swinhonis* eggs described herein; illustrating the shape, size and coloration of the eggs (photographed by Gerrut Norval).

that the female lizards have to expend parts of their acquired energy for reproduction soon after that energy is obtained (Lin, 1978), i.e. they are "income breeders" (Jönsson, 1997). In studies on another agamid, the Jacky dragon (*Amphibolurus muricatus*) from Australia, it was found that females that fed on a poor-quality diet produced larger eggs (Warner, Lovern and Shine, 2007; Warner et al., 2008). Although speculative, this is also a very likely explanation for our observations. *Japalura swinhonis* feeds on arthropods, especially hymenopterans (primarily Formicidae) and, to a lesser extent, lepidopterans and orthopterans (Kuo, Lin and Lin, 2007; Huang, 2007; G. Norval, own data). Due to gape size limitations, it can be expected that smaller *J. swinhonis* females would feed more frequently on small prey such as ants, which, weight for weight, are generally accepted to have low caloric values (Redford and Dorea, 1984; Withers and Dickman, 1995; Meyers and Herrel, 2005), i.e. poor quality food items, so as a result the smaller lizards produce larger eggs. As the lizards grow, they are able to feed on larger prey, such as caterpillars and crickets, which are better quality food items (Marconi et al., 2002; Vantomme, Göhler and N'Deckere-Ziangba, 2004; Ghaly and Alkoaik, 2010), and subsequently the lizards produce smaller eggs.

It is common in oviparous reptiles that the incubation period increases as temperatures decrease within an acceptable range wherein successful development can take place (Birchard, 2004). However, Lin (1978) reported an incubation period of 23 days, at an incubation temperature of 22 ºC, which is much shorter than the 45 days reported in this study. Similarly to Lin and Cheng (1986), the eggs used in our study were incubated at room temperature (25 – 28 ºC), and the incubation period is very similar to the mean incubation period of 46.9 days reported by those authors. The incubation period reported by Lin (1978) therefore deserves further study.

Evidently, since there seems to be some variation in the reproductive biology of *J. swinhonis* from different localities, the reproductive biology of this species in the northern and eastern parts of Taiwan requires further empirical study.

In conclusion, it is worth mentioning that while previous reports indicated that females of *J. swinhonis* bury their eggs and may guard them (Wei and Lin, 1981; Lin and Lu, 1982; Chou, 1996), only one of the females from our study did this, which was most likely resulted from the small space of captivity and the shallow substrate. Also, irrespective of how the eggs were treated, we had a very low hatching success rate, which could be because the eggs were not buried by the females and were often disturbed as she moved around within her cage. This should be taken into consideration when these lizards are kept in captivity, and they should therefore have relatively spacious cages with a deep substrate, and disturbance to the eggs should be minimized.

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References

Birchard, G.F. (2004): Effects of incubation temperature. In: Reptilian Incubation: Environment, Evolution, and Behaviour. pp. 103–123. Deeming, D.C. ed., Nottingham, Nottingham University Press.

Chou, W.H. (1996): Observations on the postovipositional behavior of the Taiwanese agamid lizard, *Japalura swinhonis* (Squamata: Reptilia). Bull. Nat. Mus. Nat. Sci. **07**: 107–112.

Ghaly, A.E., Alkoaik, F.N. (2010): Nutritional value of the maize stalk borer and American bollworm as unconventional protein sources. Am. J. Appl. Sci. **07**: 1–12.

Huang, W.S. (2007): Ecology and reproductive patterns of the agamid lizard *Japalura swinhonis* on an East Asian island, with comments on the small clutch sizes of island lizards. Zool. Sci. **24**: 181–188.

Jönsson, K.I. (1997): Capital and income breeding as alternative tactics of resource use in reproduction. Oikos **78**: 57–66.

Kuo, C.Y., Lin, Y.S., Lin, Y.K. (2007): Resource use and morphology of two sympatric *Japalura* lizards (Iguania: Agamidae). J. Herpetol. **41**: 713–723.

Kuo, C.Y., Lin, Y.T., Lin, Y.S. (2009): Sexual size and shape dimorphism in an agamid lizard, *Japalura swinhonis* (Squamata: Lacertilia: Agamidae). Zool. Stud. **48**: 351–361.

Lin, J.I. (1978): Reproductive biology, and seasonal fat body and liver cycles in the Taiwan tree dragon: *Japalura swinhonis formosensis*. Biol. Bull. Dept. Biol. Coll. Sci., Tunghai University. **49**: 349–360.

Lin, J.Y., Cheng, H.Y. (1986): Annual reproductive and lipid storage patterns of the agamid lizard, *Japalura swinhonis mitsukurii* in southern Taiwan. Bull. Inst. Zool., Academia Sinica. **25**: 13–23.

Lin, J.Y., Lu, K.H. (1982): Population ecology of the lizard *Japalura swinhonis formosensis* (Sauria: Agamidae) in Taiwan. Copeia. **1982**: 425–434.

Marconi, S., Manzi, P., Pizzoferrato, L., Buscardo, E., Cerda, H., Lopez Hernandez, D., Paoletti, M.G. (2002): Nutritional evaluation of terrestrial invertebrates as traditional food in Amazonia. Biotropica. **34**: 273–280.

Meyers, J.J., Herrel, A. (2005): Prey capture kinematics of ant-eating lizards. J. Exp. Biol. **208**: 113–127

Ota, H. (1989): *Japalura brevipes* Gressitt (Agamidae: Reptilia), a valid species from a high altitude area of Taiwan. Herpetologica. **45**: 55–60.

Ota, H. (1991a): Taxonomic status of *Mabuya multicarinata* (Gray, 1845) (Scincidae: Squamata: Reptilia) from Taiwan, with comments on the herpetofauna of Lanyu Island. Bull. Coll. Sci. Univ. Ryukyus. **51**: 11–18.

Ota, H. (1991b): Classification of agamid lizards of the genus *Japalura* from the insular East Asia: a history of confusion. Biol. Mag. Okinawa. **29**: 21–28.

Ota, H. (1991c): Taxonomic redefinition of *Japalura swinhonis* Günther (Agamidae: Squamata), with a description of a new subspecies of *J. polygonata* from Taiwan. Herpetologica. **47**: 280–294.

Ota, H. (2000): On the validity of *Japalura yunnanensis popei* Wettstein, 1938 (Squamata: Agamidae). Amphibia-Reptilia. **21**: 397–403.

Redford, K.H., Dorea, J.G. (1984): The nutritional value of invertebrates with emphasis on ants and termites as food for mammals. J. Zool., Lond. **203**: 385–395.

Shine, R. (1980): "Costs" of reproduction in reptiles. Oecologia (Berl.). **46**: 92–100.

Vantomme, P., Göhler, D., N'Deckere-Ziangba, F. (2004): Contribution of forest insects to food security and forest conservation: The example of caterpillars in Central Africa. ODI Wildlife Policy Brief. **03**: 01–04.

Warner, D.A., Lovern, M.B., Shine, R. (2007): Maternal nutrition affects reproductive output and sex allocation in a lizard with environmental sex determination. Proc. R. Soc. B. **274**: 883–890.

Warner, D.A., Bonnet, X., Hobson, K.A., Shine, R. (2008): Lizards combine stored energy and recently acquired nutrients flexibly to fuel reproduction. J. Anim. Ecol. **77**: 1242–1249.

Wei, S.Y., Lin, J.Y. (1981): Behavioral study of *Japalura swinhonis formosensis* (Sauria: Agamidae). Tunghai J. Biol. **22**: 33–48. (In Chinese)

Withers, P.C., Dickman, C.R. (1995): The role of diet in determining water, energy and salt intake in the thorny devil *Moloch horridus* (Lacertilia: Agamidae). J. Roy. Soc. W. Aust. **78**: 3–11.

Appendix 1. The morphological data of the gravid *Japalura swinhonis* females, and their eggs, used in this study. (SVL – snout-vent length (mm); TL – tail length (mm); POBM – post-oviposition body mass (g); CS – clutch size; MEL – mean egg length (mm); MEW – mean egg width (mm); MEM – mean egg mass (g); MEV – mean egg volume; RCM – relative clutch mass)

Date	SVL	TL	POBM	CS	MEL	MEW	MEM	MEV	RCM
2006-08-17	65	157	8.7	5	11.8	6.97	0.36	300.65	20.69
2007-04-27	65	141	7.5	3	12.83	8.19	0.4	455.71	16
2007-05-22	64	140	8.3	3	12.34	7.72	0.47	386.24	16.87
2007-06-07	70	155	6.3	4	11.92	6.39	0.28	254.95	17.46
2007-08-02	68	164	8.7	3	12.74	6.99	0.37	361.88	12.64
2007-08-26	68	164	9	4	12.84	6.77	0.33	307.94	14.44
2008-05-28	70	150	7.5	5	12.14	6.77	0.34	345.49	22.67
2008-06-01	66	127	8.3	3	13.15	7.08	0.4	291.33	14.46
2008-06-10	64	153	6.8	5	12.2	8.53	0.48	464.85	35.29
2008-06-16	70	152	7	3	14.13	6.66	0.4	328.14	17.14
2008-06-17	68	163	6.1	5	12.23	7.25	0.36	337.87	29.51
2008-06-18	64	152	5.7	4	13.1	6.57	0.4	295.82	28.07
2010-09-26	67	145	9.8	5	13.28	7.36	0.42	377.56	21.43

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