SPOTLIGHT SURVEYS OF NEW GUINEA FRESHWATER CROCODILE (*Crocodylus novaeguineae*) IN MID-ZONE MEMBERAMO RIVER (MEMBERAMO AND ROUFFAER RIVER SYSTEMS), PAPUA PROVINCE

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ABSTRAK

Data hasil survei Buaya Air Tawar Irian (Crocodylus novaeguineae) dengan metode penyinaran malam hari dari zona tengah Sungai Memberamo, Propinsi Papua, Indonesia telah dianalisa. Lokasi survei terdiri dari empat sungai (Memberamo Mati, Jaro, Baso dan Soi) dan sepuluh danau (Sobaki, Kamika, Waropen, Kweri Satu, Kweri Dua, Apuse, Bernekam Satu, Bernekam Dua, Cabang Tiga Satu dan Cabang Tiga Dua). Survei dilakukan pada waktu yang berbeda, yaitu antara tahun 1987 sampai 2002.

Hasil survei dari Sungai Jaro (1989-2002) menunjukan kenaikan yang nyata pada kepadatan bukan anakan dari waktu ke waktu. Sedangkan hasil survei dari 13 lokasi yang lain menunjukan kepadatan yang stabil pada bukan anakan selama periode survai. Survei yang dilakukan pada tahun 2001-2002 dipengaruhi oleh banjir yang menyebabkan menurunnya jumlah buaya yang dapat terhitung.

Tendensi dari pemanenan buaya hidup (anakan) dan kulit dipengaruhi oleh pasar dan waktu moratorium (awal tahun 1990) dari pada tersedianya buaya di alam. Secara umum, populasi buaya Crocodylus novaeguineae di daerah zona tengah Sungai Memberamo relatif stabil selama pemanenan terus berlangsung.

Kata kunci : *survei penyinaran, Buaya Air Tawar Irian, Crocodylus novaeguineae, Sungai Memberamo, Propinsi Papua.*

ABSTRACT

Data of spotlight survey for the New Guinea Freshwater Crocodile (Crocodylus novaeguineae) in Mid-zone Memberamo River, Papua Province, Indonesia, were analyzed. Survey areas consisted of four rivers (Memberamo Mati, Jaro, Baso and Soi) and 10 lakes (Sobaki, Kamika, Waropen, Kweri Satu, Kweri Dua, Apuse, Bernekam Satu, Bernekam Dua, Cabang Tiga Satu and Cabang Tiga Dua). Surveys were conducted at different times between 1987 and 2002.

Results from the Jaro River (1989-2002) indicated a significant increase in non-hatchling density over time. All other surveyed areas indicated stable non-hatchling densities over the periods of survey. The latest surveys (2001-2002) were affected by high water levels (flooding), which were likely to have reduced the sight ability of crocodiles.

Trends in live crocodile and skin harvests appear to be driven by market forces and a moratorium (early 1990s), rather than any limitations of the crocodile resource. In general, the population of C. novaeguineae in Mid-zone Memberamo River has been relatively stable, despite extensive harvesting.

Key words : *Spotlight survey, New Guinea Freshwater Crocodile, Crocodylus novaeguineae, Memberamo River, Papua Province*

INTRODUCTION

Indonesians have historically used crocodiles for a variety of non-commercial purposes. Since the last ten years, commercial collection from the wild has threatened the population status of Indonesian crocodiles. As pressure from the commercial hunting continuous, the successful conservation of Indonesian crocodiles will depend on the constant monitoring of their populations. Papua is one of several provinces in Indonesia which historically accommodates unknown numbers of commercial crocodiles (Webb and Jenkins, 1991).

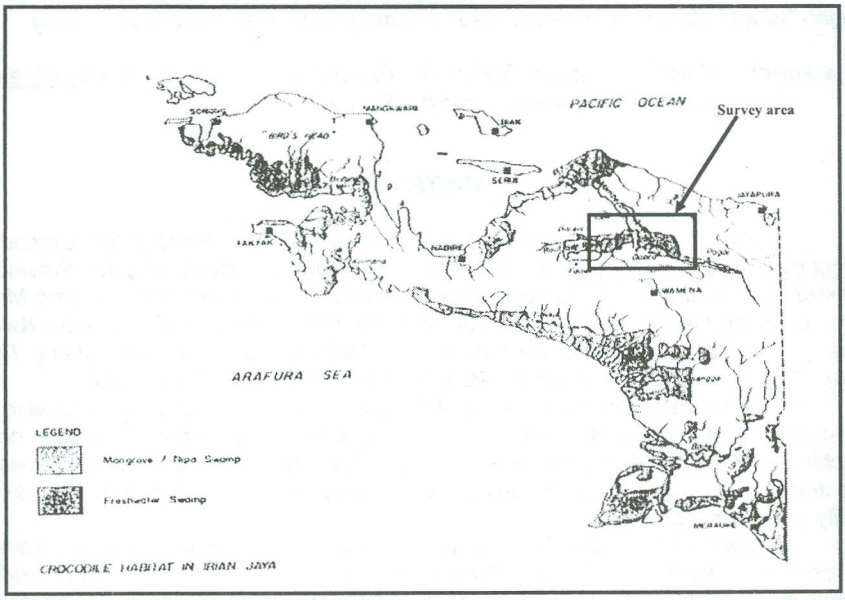
Thorough monitoring of the crocodile population in the Mid-zone Memberamo River (see Map 1 for the region) was conducted from 2000 to 2002, with spotlight surveys in Kamika Lake (Kaureh District), Waropen, Kweri Satu, Kweri Dua, Apuse, Bernekam Satu, Bernekam Dua, Cabang Tiga Satu and Cabang Tiga Dua Lakes (Memberamo Hulu District). Additional surveys were undertaken in 2001-2002, in the Memberamo Mati, Jaro, Baso and Soi Rivers, and Sobaki Lake (Memberamo Hulu District), all of which had been surveyed previously by the FAO-PHPA Project. All of these areas are within the Memberamo and Rouffaer River systems. Interviews with local people and harvest data indicated that the dominant species is *Crocodylus novaeguineae*.

This paper presents the most recent spotlight survey data (Table 1), and summarizes all spotlight data and population trends (total numbers and non hatchlings) for *C. novaeguineae* in Papua Province.

METHODOLOGY

1. Timing of Surveys

Surveys in 2000-2002 were undertaken between September - December period each year (Table 1).



Map 1. Survey area monitoring of the crocodile population in the Mid-zone Memberamo River.

2. Spotlight Survey Technique

Crocodile densities (number of individuals per kilometer of river or lake) were assessed by spotlight surveys using the method described by Messel *et al.* (1981). Spotlight surveys do not calculate absolute abundance, but provided an index or relative density which allows changes in population size and structure to be quantified over time (Baylis, 1987; Messel *et al.*, 1981). A halogen torch, powered by 6 DD batteries (7.2V, 0.85 amp) was used. When an eyeshine was detected, an attempt was made to approach the crocodile in order to estimate total length (TL; see 3. below).

Surveys typically started downstream and proceeded upstream in rivers or to the mouth of lakes, except in the Soi River. All distances were determined using 1:250,000 maps (between $2^0$00'00"S and $4^0$00'00"S to $138^0$00'00"E and $139^0$30'00"E) and a GPS. The speed of the boat and canoe were recorded by GPS. Prevailing weather conditions at the time of survey were also recorded.

3. Species

The species of crocodile surveyed, *C. novaeguineae,* is known locally as Buaya Air Tawar or Buaya Bob. Crocodiles were categorized as hatchling (H; <50 cm TL), juvenile (J; 50-150 cm TL), adult (A; >150 cm TL) and Eyes Only (EO).

Table 1. Dates of *C. novaeguineae* spotlight surveys in mid-zone Memberamo and Rouffaer River systems, 2000-2002.

Year	Duration	Number of sites	Total length of survey	Conducted by	Reference
2000	September 27-October 2	9 lakes	29.9 km	KSDA	KSDA (2000)
2001	November 26-December 5	10 lakes,4 rivers	162.5 km	LIPI-KSDA	Kurniati *et al.* (2001)
2002	December 13-23	10 lakes, 4 rivers	143 km	KSDA	KSDA (2002)

4. Locality

Surveyed Areas were within the Memberamo and Rouffaer River systems. Specifically, they comprised Memberamo Mati, Jaro, Baso and Soi Rivers, Sobaki, Waropen, Kweri Satu, Kweri Dua, Apuse, Bernekam Satu, Bernekam Dua, Cabang Tiga Satu, Cabang Tiga Dua Lakes (Memberamo Hulu District), and Kamika Lake (Kaureh District).

5. Vessels

Survey areas varied in length, so the type of used boat varied accordingly. In long distance areas (Memberamo Mati, Jaro, Baso and Soi Rivers, and Kamika, Bernekam Satu, Sobaki, Kweri Satu and Kweri Dua Lakes) a long boat powered by a 40 HP motor was used. In other areas (Cabang Tiga Satu, Cabang Tiga Dua, Apuse, Waropen and Bernekam Dua Lakes) a canoe was used.

6. Interviews with local people

Interviews with local people were conducted to confirm the species of crocodile being harvested in each river and lake surveyed.

7. Data analysis

Linear regression analysis was used to describe population trends (SPSS statistic analysis, version 9.0). Significant level of statistic analysis is $p<0.05$.

8. Harvest data

Harvest data for *C. novaeguineae* were provided by one company (CV Bintang Mas), for the period 1995 to 2002.

RESULTS

Generally higher water levels were encountered during surveys in 2001 and 2002, which affected the extent of riverbank that could be seen clearly (Table 2).

Spotlight survey results for all years are in Table 3. This includes previous survey results for Memberamo Mati River, Jaro River, Baso River, Soi River and Sobaki Lake, collected by the FAO-PHPA Project.

Population Trends :

Population trends of each area were determined using linear regression analysis. As hatchling numbers can vary greatly from year to year, and mortality rates for this size/age class can be high, analyses were carried using all data (ie H, A, J), and using only non hatchlings (Figs. 1-14).

Data for the Memberano Mati River span 14 years, from 1987 to 2001 (Table 3). Two spotlight surveys were carried out in 1990 (April, October) – the April (end of wet season) data were used in the analysis (Table 3). There was no significant relationship between density and time, for either total crocodile density (r^2= 0.159, p= 0.376, n= 7; Fig. 1a) or non-hatchling density (r^2= 0.124, p= 0.438, n= 7; Fig. 1b). Non-hatchling density decreased from a high of 10.0/km in 1987 to 2.0/km in 1988 (Table 3; Fig. 1b), and has stayed relatively stable since that time [mean= 2.08 NH/km (1988-2001)].

Memberamo Mati River

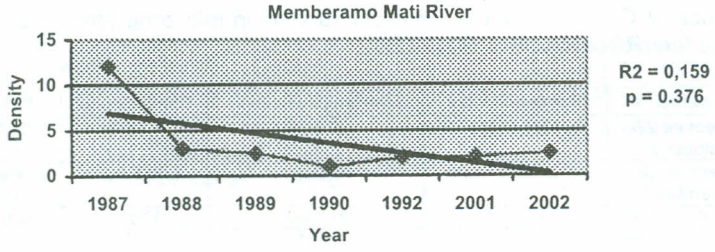


Figure 1a. Total density of *C. novaeguineae* sighted during spotlight surveys in the Memberamo Mati River, 1987-2002. Solid line indicates the non-significant trend (see text).

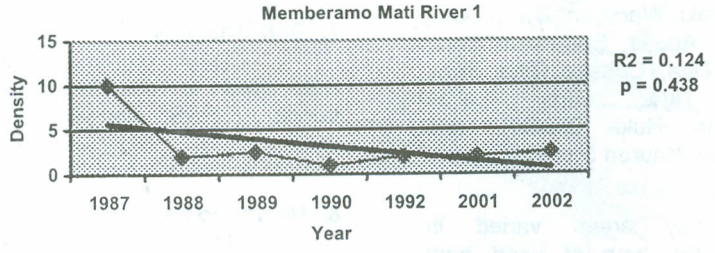


Figure 1b. Non-hatchling density of *C. novaeguineae* sighted during spotlight surveys in the Memberamo Mati River, 1987-2002. Solid line indicates the non-significant trend (see text).

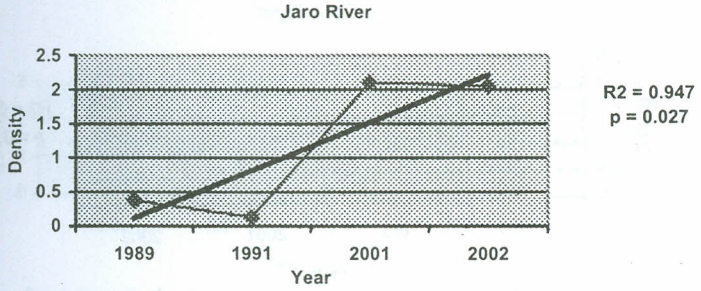


Figure 2a. Density of *C. novaeguineae* sighted during spotlight surveys in the Jaro River, 1989-2002. Solid line indicates the significant trend (see text).

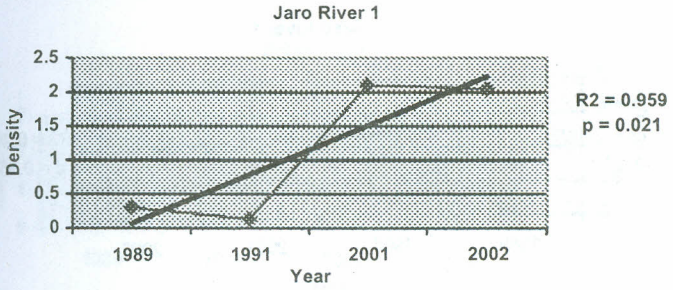


Figure 2b. Density of non-hatchling *C. novaeguineae* sighted during spotlight surveys in the Jaro River, 1989-2002. Solid line indicates the significant trend (see text).

Jaro River

Notwithstanding the limited number of surveys carried out in the Jaro River, there has been a significant increase in total crocodile density (r^2= 0.947, p= 0.027, n= 4; Fig. 2a) and non-hatchling density (r^2= 0.959, p= 0.021, n= 4; Fig. 2b) over time. The trend in the intervening period between surveys (10 years) is unknown. Certainly high densities have been recorded in both of the most recent surveys. Given the high water levels at the time of these surveys, the increase may actually be greater than recorded.

Baso River

The four surveys undertaken in the Baso River spanned a 12-year period (1989-2001), and indicated that the density of *C. novaeguineae* is relatively low and stable. Non-hatchling and total crocodile densities in the Baso River have not changed significantly over time [r^2= 0.330, p= 0.425, n= 4 (Fig. 3a) and r^2= 0.2, p= 0.553, n= 4 (Fig. 3b) respectively].

Soi River

Data for Soi River span 12 years, from 1989 to 2001 (Table 3). Regression analysis indicated a significant relationship between total crocodile density and time (r^2= 0.992, p= 0.004, n= 4; Fig. 4a), but not for non-hatchling density (r^2= 0.501, p= 0.292, n= 4; Fig. 4b). Analysis of results from the Soi River were complicated by the first two surveys involving a very short section of the river (0.5 km), and the later surveys a much longer section (20 km). The results for non-hatchling density (Fig. 4b) were more relevant here, and they indicate no change over time. Future monitoring will establish long-term population trends for the river.

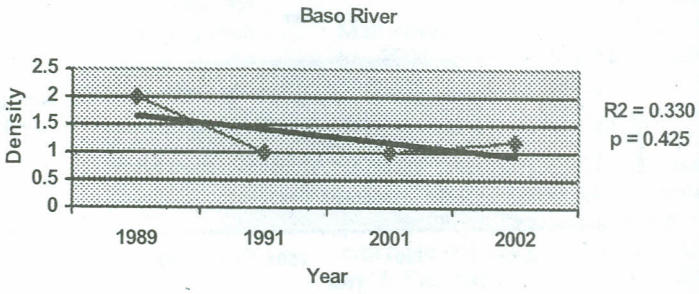


Figure 3a. Density of *C. novaeguineae* sighted during spotlight surveys in the Baso River, 1989-2002. Solid line indicates the non-significant trend (see text).

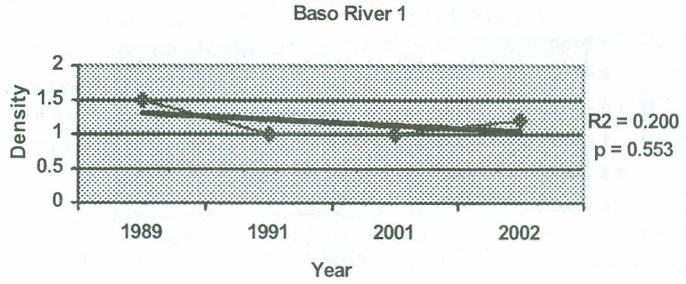


Figure 3b. Non-hatchling density of *C. novaeguineae* sighted during spotlight surveys in the Baso River, 1989-2002. Solid line indicates the non-significant trend (see text).

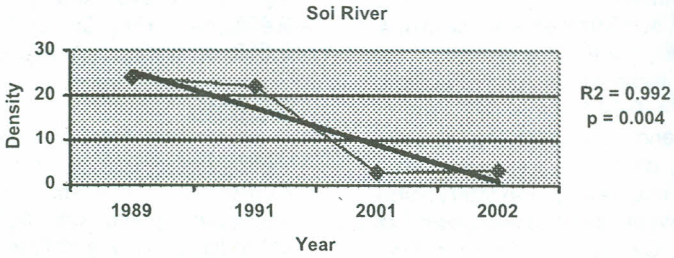


Figure 4a. Density of *C. novaeguineae* sighted during spotlight surveys in the Soi River, 1989-2002. Solid line indicates the significant trend (see text).

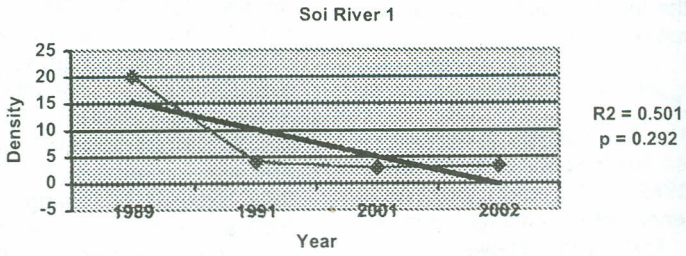


Figure 4b. Non-hatchling density of *C. novaeguineae* sighted during spotlight surveys in the Soi River, 1989-2002. Solid line indicates the non-significant trend (see text).

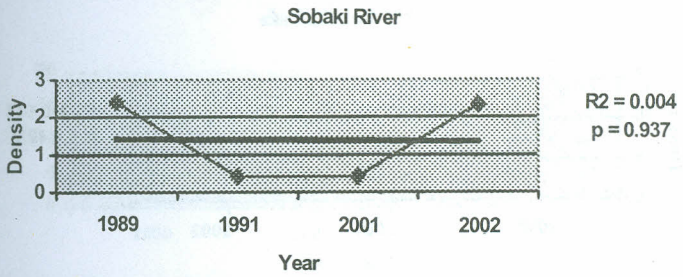


Figure 5a. Density of *C. novaeguineae* sighted during spotlight surveys in the Sobaki River, 1989-2002. Solid line indicates the non-significant trend (see text).

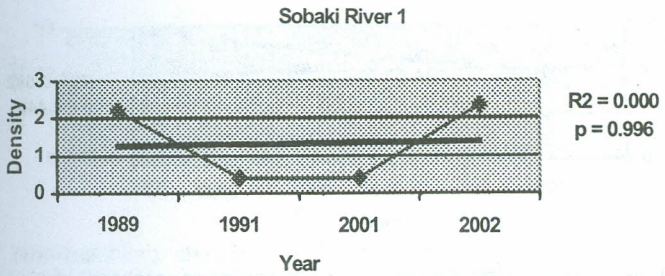


Figure 5b. Non-hatchling density of *C. novaeguineae* sighted during spotlight surveys in the Sobaki River, 1989-2002. Solid line indicates the non-significant trend (see text).

Sobaki River

There was no significant relationship between density and time for either total numbers (r^2= 0.004, p= 0.937, n= 4; Fig. 5a) or non-hatchlings (r^2= 0.000, p= 0.996, n= 4; Fig. 5b).

Kamika Lake

Survey data for Kamika Lake are available for three recent consecutive years (2000-2002). They indicate that total and non-hatchling densities have remained somewhat high (mean= 13.0 NH/km) and stable over the 3-year period (r^2= 0.614, p= 0.427, n= 3; Fig. 6a and r^2= 0.582, p= 0.448, n= 3; Fig. 6b, respectively).

Waropen Lake

There was no significant relationship between density and time for either total numbers (r^2= 0.530; p= 0.481; n= 3; Fig. 7a) or non-hatchlings (r^2= 0.988, p= 0.069, n= 3; Fig. 7b). The trend in non-hatchling density (Fig. 7b) is positive, increasing from 6.4 NH/km to 17.5 NH/km (Table 3). Additional surveys are required to confirm whether this increase is indeed significant. The first two kilometres of survey distance contained a high density of *C. novaeguineae* (see Table 3), and increasing survey distance for Waropen Lake may reduce the overall density.

Kweri Satu Lake

Densities in Kweri Satu Lake have remained stable over the period 2000-2002 [total numbers (r^2= 0.196, p= 0.347, n= 3; Fig. 8a), non-hatchling (r^2= 0.985, p= 0.078, n= 3; Fig. 8b)]. The trend is towards increasing densities, from 9.0 NH/km in 2000 to 12.3 NH/km in 2002 (Table 3).

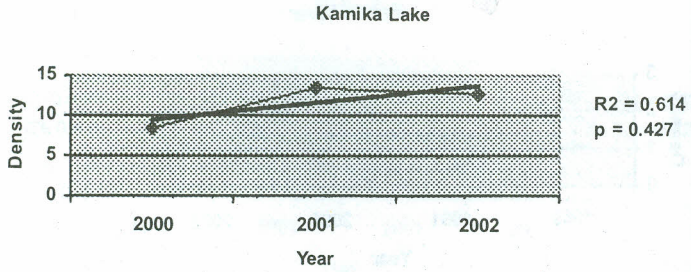


Figure 6a. Density of *C. novaeguineae* sighted during spotlight surveys in Kamika Lake, 2000-2002. Solid line indicates the non-significant trend (see text).

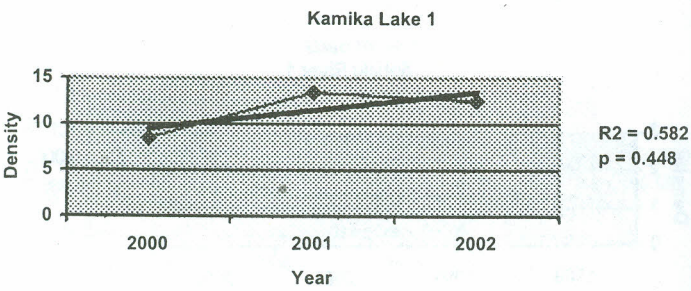


Figure 6b. Non-hatchling density of *C. novaeguineae* sighted during spotlight surveys in Kamika Lake, 2000-2002. Solid line indicates the non-significant trend (see text).

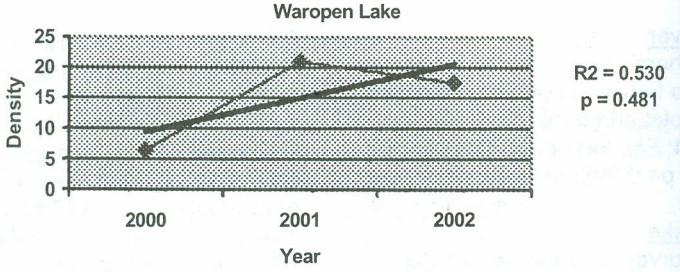


Figure 7a. Density of *C. novaeguineae* sighted during spotlight surveys in Waropen Lake, 2000-2002. Solid line indicates the non-significant trend (see text).

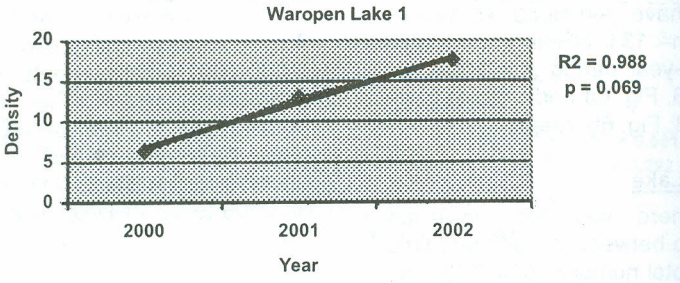


Figure 7b. Non-hatchling density of *C. novaeguineae* sighted during spotlight surveys in Waropen Lake, 2000-2002. Solid line indicates the non-significant trend (see text).

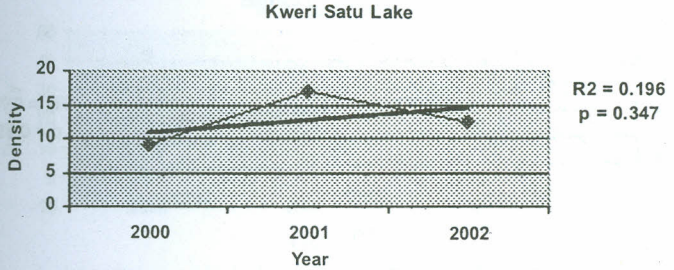


Figure 8a. Density of *C. novaeguineae* sighted during spotlight surveys in Kweri Satu Lake, 2000-2002. Solid line indicates the non-significant trend (see text).

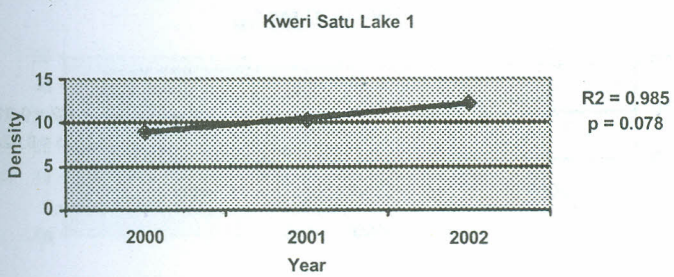


Figure 8b. Non-hatchling density of *C. novaeguineae* sighted during spotlight surveys in Kweri Satu Lake, 2000-2002. Solid line indicates the non-significant trend (see text).

Kweri Dua Lake

Densities in Kweri Dua Lake have remained stable over time [total numbers (r^2= 0.722, p= 0.353, n= 3; Fig. 9a), non-hatchling (r^2= 0.311, p= 0.624, n= 3; Fig. 9b)]. Although the trend indicates decreasing densities, it is not significant statistically.

Apuse Lake

Like Kweri Satu and Kwer Dua Lakes, data from Apuse Lake indicated no significant relationship between density and time for either total numbers (r^2= 0.227, p= 0.684, n= 3; Fig. 10a) or non-hatchlings (r^2= 0.138, p= 0.757, n= 3; Fig. 10b). Mean non-hatchling density is 8.1 NH/km.

Bernekam Satu Lake

A relatively high density (40.0 NH/km) was recorded in 2000, but subsequent surveys have indicated much lower levels (Table 3). Kweri Satu and Kweri Dua also showed similar trends, although the decrease was not as evident as it is for Bernekam Satu Lake. Water levels were higher in 2001 and 2002 (Table 2), and surveys were undertaken by boat rather than canoe (Table 3). These factors, particularly high water levels, could be expected to lead to lower sight ability of crocodiles. Nonetheless, the limited survey condition indicated no significant relationship between density and time for total numbers (r^2= 0.695, p= 0.372, n= 3; Fig. 11a) and non-hatchlings (r^2= 0.693, p= 0.374, n= 3; Fig. 11b).

Bernekam Dua Lake

Regression analysis for Bernekam Dua Lake indicated no significant relationship between density and time for total numbers (r^2= 0.123, p= 0.772, n= 3; Fig. 12a) and non-hatchlings (r^2= 0.052, p= 0.857, n= 3; Fig. 12b). Densities of *C. novaeguineae* are relatively stable and high (mean = 8.6 NH/km) in this area.

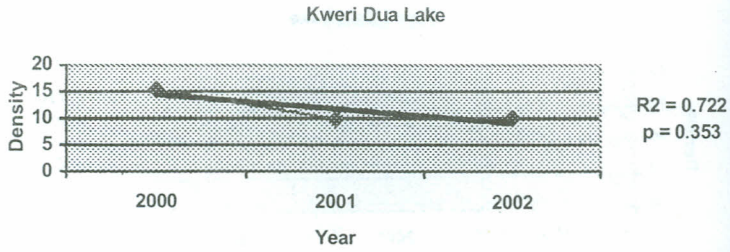


Figure 9a. Density of *C. novaeguineae* sighted during spotlight surveys in Kweri Dua Lake, 2000-2002. Solid line indicates the non-significant trend (see text).

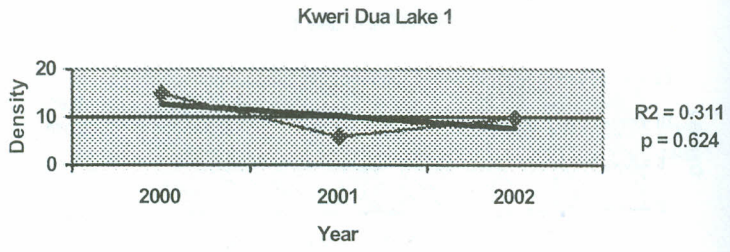


Figure 9b. Non-hatchling density of *C. novaeguineae* sighted during spotlight surveys in Kweri Dua Lake, 2000-2002. Solid line indicates the non-significant trend (see text).

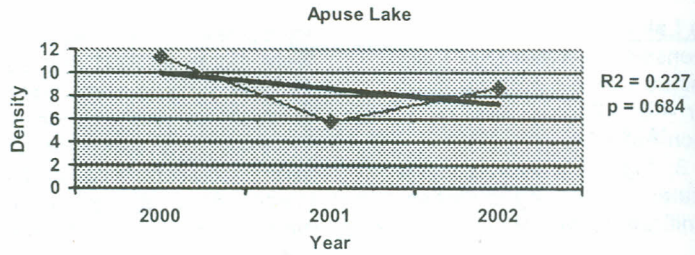


Figure 10a. Density of *C. novaeguineae* sighted during spotlight surveys in Apuse Lake, 2000-2002. Solid line indicates the non-significant trend (see text).

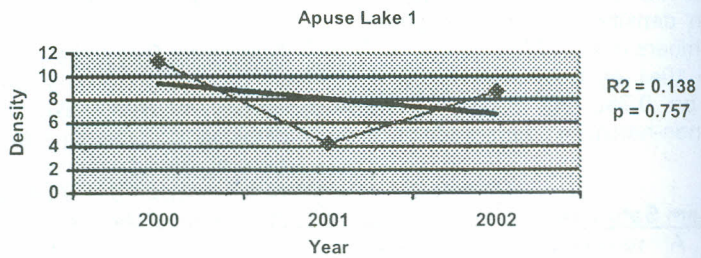


Figure 10b. Non-hatchling density of *C. novaeguineae* sighted during spotlight surveys in Apuse Lake, 2000-2002. Solid line indicates the non-significant trend (see text).

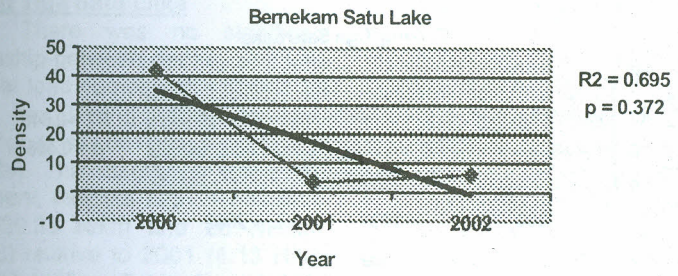


Figure 11a. Density of *C. novaeguineae* sighted during spotlight surveys in Bernekam Satu Lake, 2000-2002. Solid line indicates the non-significant trend (see text).

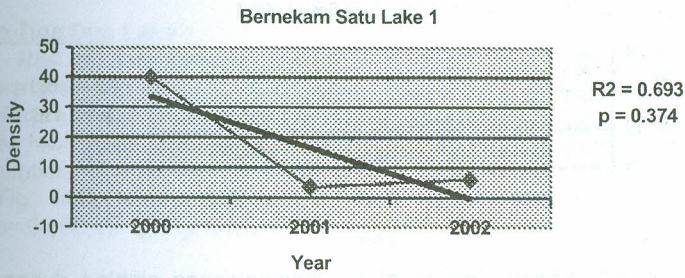


Figure 11b. Non-hatchling density of *C. novaeguineae* sighted during spotlight surveys in Bernekam Satu Lake, 2000-2002. Solid line indicates the non-significant trend (see text).

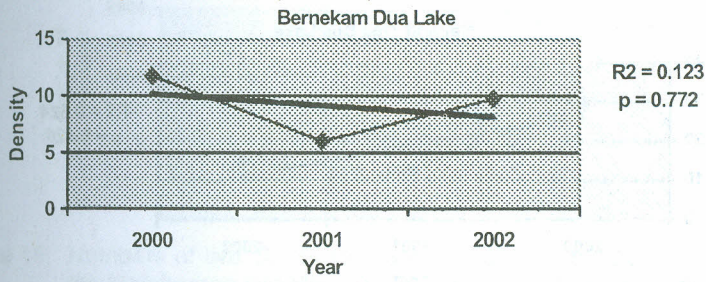


Figure 12a. Density of *C. novaeguineae* sighted during spotlight surveys in Bernekam Dua Lake, 2000-2002. Solid line indicates the non-significant trend (see text).

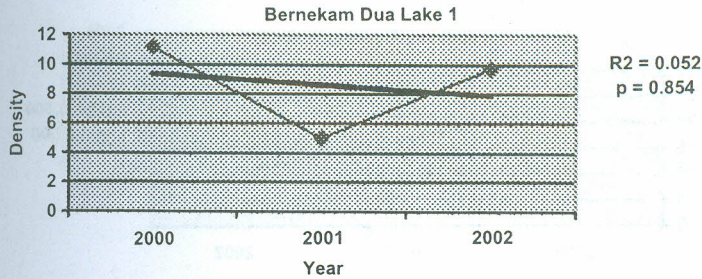


Figure 12b. Non-hatchling density of *C. novaeguineae* sighted during spotlight surveys in Bernekam Dua Lake, 2000-2002. Solid line indicates the non-significant trend (see text).

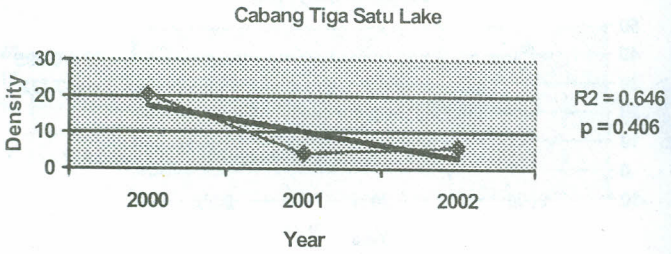


Figure 13a. Density of *C. novaeguineae* sighted during spotlight surveys in Cabang Tiga Satu Lake, 2000-2002. Solid line indicates the non-significant trend (see text).

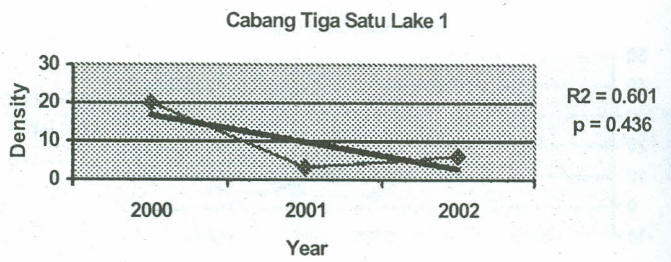


Figure 13b. Non-hatchling density of *C. novaeguineae* sighted during spotlight surveys in Cabang Tiga Satu Lake, 2000-2002. Solid line indicates the non-significant trend (see text).

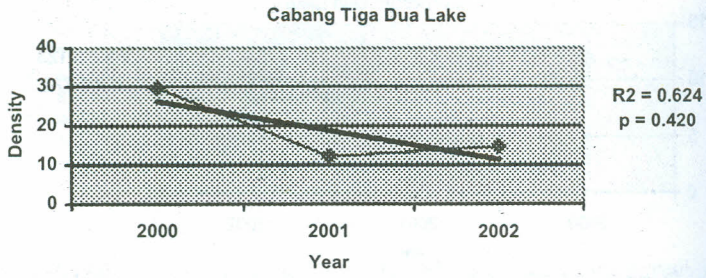


Figure 14a. Density of *C. novaeguineae* sighted during spotlight surveys in Cabang Tiga Dua Lake, 2000-2002. Solid line indicates the non-significant trend (see text).

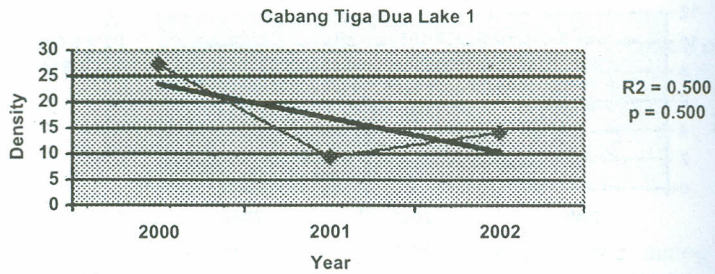


Figure 14b. Non-hatchling density of *C. novaeguineae* sighted during spotlight surveys in Cabang Tiga Dua Lake, 2000-2002. Solid line indicates the non-significant trend (see text).

Cabang Tiga Satu Lake

There was no significant relationship between density and time for either total numbers (r^2= 0.646, p= 0.406, n= 3; Fig. 13a) or non-hatchlings (r^2= 0.601, p= 0.436, n= 3; Fig. 13b). The results for this area, like others, indicate high densities in 2000 (20.33 N/km and 20 NH/km; Table 3) relative to 2001 (4.13 N/km and 3.27 NH/km; Table 3) and 2002 (6.13 N/km and 6.13 NH/km; Table 3). Again, conditions at the time of survey may be implicated in this trend.

Cabang Tiga Dua Lake

Results for Cabang Toga Dua were similar to those for cabang Tiga Satu Lake (see above). Densities have been stable over time [total numbers (r^2= 0.624, p= 0.420, n= 3; Fig. 14a), non-hatchlings (r^2= 0.500, p= 0.500, n= 3; Fig. 14b).

Crocodile Harvest

Harvest data from two of the three legal companies that purchased live crocodiles and skins from the Memberamo River were not available. However, the harvest data from CV Bintang Mas (one of these companies) (Table 4) can be used as an index of the *C. novaeguineae* population in the Memberamo River. The numbers of live crocodiles traded by CV Bintang Mas has decreased significantly between 1995 and 2002 (r^2= 0.76, p= 0.005, n= 8; Fig. 15). The number of skins traded increased significantly between 1995 and 2001 (r^2= 0.70, p= 0.02, n= 7; Fig. 16). This relationship reaches non-significance with the inclusion of the 2002 data (2440 skins; Table 4) (r^2= 0.36, p= 0.116, n= 8).

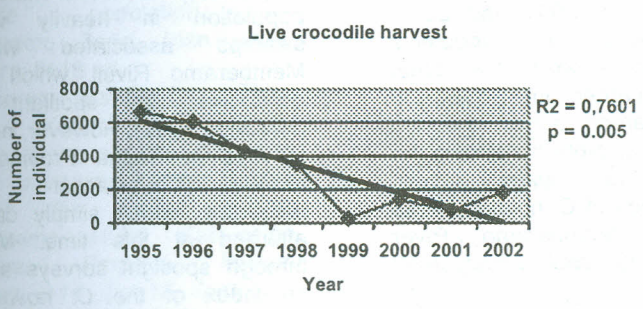


Figure 15. Numbers of live *C. novaeguineae* purchased by CV Bintang Mas from the Memberano and Rouffaer River systems, between 1995 and 2002.

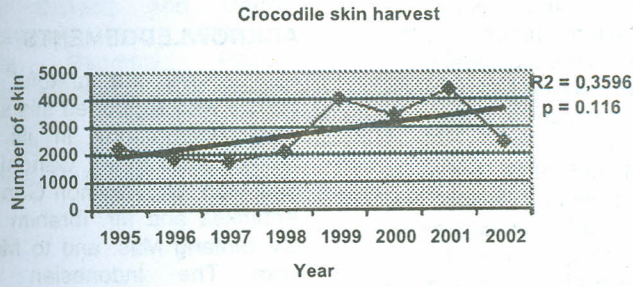


Figure 16. Numbers of wild *C. novaeguineae* skins purchased by CV Bintang Mas from the Memberano and Rouffaer River systems, between 1995 and 2002.

DISCUSSION AND CONCLUSION

Survey results from 13 areas (Memberamo Mati River, Jaro River, Baso River, Sobaki Lake, Kamika Lake, Waropen Lake, Kweri Satu Lake, Kweri Dua Lake, Apuse Lake, Bernekam Satu Lake, Bernekam Dua Lake, Cabang Tiga Satu Lake, Cabang Tiga Dua Lake) indicated no significant trends between non-hatchling density of *C. novaeguineae* sighted, and time. For one area, the Soi River, there has been a significant increase in non-hatchling density (Fig. 4).

High water levels (flooding) in 2001 and 2002 were not optimum for spotlight surveys, and most likely affected the sight ability of crocodiles (Messel *et al.* 1981). Trends in some areas [eg Bernekam Satu Lake (Fig. 11), Cabang Tiga Satu Lake (Fig. 13), Cabang Tiga Dua Lake (Fig. 14)], with high densities in 2000 followed by lower densities in 2001 and 2002, probably reflect the suboptimal conditions under which the latest surveys were carried out. Surveys in 2000 were carried out in the dry season (Table 2). Notwithstanding the effects of high water levels, population trends of *C. novaeguineae* in Mid-zone Memberamo River generally indicate stability from 2000 to 2002.

There has been an overall decrease in total harvest (live and skins) between 1995 and 1999, followed by a general increase after 1999 (Table 4). These trends are attributable to factors unrelated to the status of the crocodile resource. Specifically, the following factors need to be taken into account in assessing these harvest data :

- From 1994 and 1996, Indonesia had a moratorium in place, and the demand for live crocodiles for raising on farms, decreased.
- Demand for wild skins during the moratorium period also decreased, as many companies possessed stockpiles of skins purchased from Papua Province, which could not be sold.
- Between 1996 and 1999, the price of crocodile skins in the international market dropped, which did not encourage companies to sell accumulated skin stocks. It also discouraged live crocodile purchases.
- From 1999-2002, skin prices in the international market improved, and the demand for live crocodiles increased as a result.
- The drop in harvested skins purchased by CV Bintang Mas, from 4379 in 2001 to 2440 in 2002, was the result of an annual quota (2440 skins) imposed on the company by the Indonesian Ministry of Forestry.

Spotlight surveys are not always good indicators of population trends in heavily vegetated habitats (Montague 1983), and nest counts may perhaps be better indices of the population in heavily vegetated swamps associated with the Memberamo River, which are not conducive to spotlight survey (Hollands 1987). However, nest count surveys in Papua Province would require substantial financial resources, which simply cannot be afforded at this time. Monitoring through spotlight surveys still offers an index of the *C. novaeguineae* population in the Memberamo River, Papua Province, and will be the prime monitoring method for the wild population in the short-term.

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Table 2. Weather conditions recorded during spotlight surveys of *C. novaeguineae* in the Memberamo and Rouffaer River systems, 1987-2002. Information for surveys carried out in 2000-2002 is more detailed. Surveys were carried out by FAO-PHPA, Division of Natural Resources and Conservation Papua I (KSDA) and the Indonesian Institute of Sciences (LIPI).

No	River/Lake	Weather description	Personnel team	Reference
1	**Memberamo Mati River**			
	1/10/87	Low water level, dark moon, clear sky.	FAO-PHPA	KSDA (2000)
	20/2/88	High water level (flood), dark moon, clear sky.	FAO-PHPA	KSDA (2000)
	3/10/89	Low water level, dark moon, heavy rain.	FAO-PHPA	KSDA (2000)
	6/4/90	Low water level, dark moon, clear sky.	FAO-PHPA	KSDA (2000)
	1/10/90	Low water level, dark moon, cloudy sky.	FAO-PHPA	KSDA (2000)
	12/10/92	Low water level, full moon, cloudy sky.	KSDA	KSDA (2000)
	26/11/01	High water level, but more than half of survey distance the river bank could be seen clearly, full moon, clear sky. Survey started 2105 h, finished 2215 h.	LIPI-KSDA	Kurniati *et al* (2001)
	20/12/02	High water level, but all of survey distance the river bank could be seen clearly, no moon, cloudy and dark sky. Survey started 1905 h, finished 2240 h.	KSDA	KSDA (2002)
2	**Jaro River**			
	24/9/89	Low water level, dark moon, clear sky.	FAO-PHPA	KSDA (2000)
	30/7/91	Low water level, dark moon, clear sky.	FAO-PHPA	KSDA (2000)
	29/11/01	High water level (flood), but more than half of survey distance the river bank could be seen clearly, 3/4 full moon, cloudy sky and shower. Survey started 2105 h, finished 2205 h.	LIPI-KSDA	Kurniati *et al* (2001)
	19/12/02	High water level, flooding, full moon, clear sky. Survey started 1915 h, finished 2250 h.	KSDA	KSDA (2002)
3	**Baso River**			
	30/9/89	Low water level, dark moon, heavy cloudy sky.	FAO-PHPA	KSDA (2000)
	4/8/91	Low water level, dark moon, clear sky.	FAO-PHPA	KSDA (2000)
	4/12/01	High water level (flood), but most of survey distance the river bank could be seen very clearly, strong water current, heavy cloudy sky, no moon shine. Survey started 1930 h, finished 2100 h.	LIPI-KSDA	Kurniati *et al* (2001)
	21/12/02	High water level, less than half of survey distance the river bank could be seen clearly, full moon, cloudy sky. Survey started 1930 h, finished 2305 h.	KSDA	KSDA (2002)
4	**Soi River**			
	26/4/89	High water level (flood), full moon, cloudy sky.	FAO-PHPA	KSDA (2000)
	18/7/91	High water level (flood), full moon, clear sky.	FAO-PHPA	KSDA (2000)
	5/12/01	High water level (flood), but most of survey distance the river bank could be seen clearly, dark sky, no moon shine, shower to heavy rain. Survey started 1825 h, finished 2005 h.	LIPI-KSDA	Kurniati *et al* (2001)
	22/12/02	High water level, less than half of survey distance the river bank could be seen clearly, full moon, cloudy sky. Survey started 1915 h, finished 2200 h.	KSDA	KSDA (2002)
5	**Sobaki Lake**			
	26/9/89	Low water level, dark moon, cloudy sky.	FAO-PHPA	KSDA (2000)
	14/7/91	High water level (flood), dark moon, heavy cloudy sky.	FAO-PHPA	KSDA (2000)
	5/12/01	High water level, only about half of survey distance the river bank could be seen clearly, dark sky, no moon shine, shower. Survey started 2215 h, finished 2300 h.	LIPI-KSDA	Kurniati *et al* (2001)
	23/12/02	High water level, less than half of survey distance the river bank could be seen clearly, full moon, cloudy sky. Survey started 1900 h, finished 2115 h.	KSDA	KSDA (2002)
6	**Kamika Lake**			
	27/9/00	Low water level, dark moon, clear sky.	KSDA	KSDA (2000)
	30/11/01	High water level (flood), about half os survey distance the lake bank could be seen clearly, full moon, cloudy sky. Survey started 2130 h, finished 0040 h.	LIPI-KSDA	Kurniati *et al* (2001)

	14/12/02	High water level, less than half of survey distance the river bank could be seen clearly, half moon, clear sky. Survey started 1900 h, finished 2215 h.	KSDA	KSDA (2002)
7	**Waropen lake**			
	28/9/00	Low water level, dark moon, clear sky.	KSDA	KSDA (2000)
	30/11/01	High water level (flood), full moon, shower. Survey started 1930 h, finished 2000 h.	LIPI-KSDA	Kurniati *et al* (2001)
	15/12/02	High water level, flooding, half of survey distance the river bank could be seen clearly, half moon, cloudy and dark sky. Survey started 1905 h, finished 2220 h.	KSDA	KSDA (2002)
8	**Kweri Satu Lake**			
	29/9/00	Low water level, dark moon, cloudy sky.	KSDA	KSDA (2000)
	29/11/01	High water level (flood), full moon, clear sky. Survey started 1900 h, finished 2200 h.	LIPI-KSDA	Kurniati *et al* (2001)
	16/12/02	High water level, flooding, half of survey distance the river bank could be seen clearly, half moon, clear sky. Survey started 1850 h, finished 2140 h.	KSDA	KSDA (2002)
9	**Kweri Dua Lake**			
	30/9/00	Low water level, crescent moon, clear sky.	KSDA	KSDA (2000)
	1/12/01	High water level (flood), full moon, shower.	LIPI-KSDA	Kurniati *et al* (2001)
	15/12/02	High water level, flooding, less than half of survey distance the river bank could be seen clearly, half moon, cloudy sky. Survey started 1900 h, finished 2120 h.	KSDA	KSDA (2002)
10	**Apuse Lake**			
	30/9/00	Low water level, dark moon, cloudy sky.	KSDA	KSDA (2000)
	2/12/01	High water level (flood), full moon, clear sky.	LIPI-KSDA	Kurniati *et al* (2001)
	16/12/02	High water level, flooding, half of survey distance the river bank could be seen clearly, half moon, cloudy sky. Survey started 1900 h, finished 2140 h.	KSDA	KSDA (2002)
11	**Bernekam Satu Lake**			
	1/10/00	Low water level, crescent moon, clear sky.	KSDA	KSDA (2000)
	2/12/01	High water level (flood), but most of survey distance the lake bank could be seen clearly, dark sky, no moon shine, cloudy sky. Survey started 1805 h, finished 2050 h.	LIPI-KSDA	Kurniati *et al* (2001)
	17/12/02	High water level, flooding, half of survey distance the river bank could be seen clearly, half moon, heavy cloudy sky. Survey started 1830 h, finished 2130 h.	KSDA	KSDA (2002)
12	**Bernekam Dua Lake**			
	1/10/00	Low water level, dark moon, cloudy sky.	KSDA	KSDA (2000)
	1/12/01	High water level (flood), full moon, cloudy sky. Survey started 1815 h, finished 2010 h.	LIPI-KSDA	Kurniati *et al* (2001)
	17/12/02	High water level, flooding, less than half of survey distance the river bank could be seen clearly, half moon, heavy cloudy sky. Survey started 1830 h, finished 2130 h.	KSDA	KSDA (2002)
13	**Cabang Tiga Satu Lake**			
	2/10/00	Low water level, dark moon, cloudy sky.	KSDA	KSDA (2000)
	29/11/01	High water level (flood), full moon, cloudy sky, shower. Survey started 1900 h, finished 2200 h.	LIPI-KSDA	Kurniati *et al* (2001)
	18/12/02	High water level, flooding, less than half of survey distance the river bank could be seen clearly, half moon, cloudy sky, shower. Survey started 1905 h, finished 2215 h.	KSDA	KSDA (2002)
14	**Cabang Tiga Dua Lake**			
	2/10/00	Low water level, dark moon, cloudy sky, heavy rain.	KSDA	KSDA (2000)
	29/11/01	High water level (flood), full moon, cloudy sky, shower. Survey started 1900 h, finished 2200 h.	LIPI-KSDA	Kurniati *et al* (2001)
	18/12/02	High water level, flooding, less than half of survey distance the river bank could be seen clearly, half moon, cloudy sky, shower. Survey started 1905 h, finished 2215 h.	KSDA	KSDA (2002)

Table 3. Spotlight counts of *C. novaeguineae* in the Memberamo and Rouffaer River systems. H= hatchling; J= Juvenile; A= adult; EO= eyes only.

Date of Survey	Site	Area System	Boat/ Canoe	Distance (km)	Sightings				Total Crocodiles Sighted	Total Density (N/km)	Non-hatchling density (NH/km)
					H	J	A	EO			
1/10/87	Memberamo Mati River	Member amo	?	4	8	14	0	26	48	12.00	10.00
20/2/88			?	4	4	0	1	7	12	3.00	2.00
3/10/89			?	4	2	2	0	8	10	2.50	2.50
6/4/90			?	4	0	0	0	4	4	1.00	1.00
1/10/90			?	4	1	0	0	0	1	0.25	0.00
12/10/92			?	4	0	1	2	5	8	2.00	2.00
26/11/01			boat	20	0	0	1	40	41	2.05	2.05
20/12/02			boat	22	1	1	0	53	55	2.50	2.45
24/9/89	Jaro River	Member amo	?	47	4	0	0	14	18	0.38	0.30
30/7/91			?	47	0	0	0	6	6	0.13	0.13
29/11/01			boat	20	0	0	1	41	42	2.10	2.10
19/12/02			boat	20	0	2	0	39	41	2.05	2.05
30/9/89	Baso River	Member amo	?	2	1	0	0	3	4	2.00	1.50
4/8/91			?	2	0	0	0	2	2	1.00	1.00
4/12/01			boat	20	0	0	0	20	20	1.00	1.00
21/12/02			boat	20	0	0	0	24	24	1.20	1.20
3/5/89	Soi River	Rouffaer	?	0.5	2	1	0	9	12	24.00	20.00
20/7/91			?	0.5	9	0	0	2	11	22.00	4.00
5/12/01			boat	15	0	0	0	44	44	2.90	2.90
22/12/02			boat	12	0	0	0	39	39	3.25	3.25
26/9/89	Sobaki Lake	Rouffaer	?	5	1	1	0	10	12	2.40	2.20
14/7/91			?	5	0	0	0	12	2	0.40	0.40
5/12/01			boat	5	0	0	0	2	2	0.40	0.40
23/12/02			boat	6	0	0	0	14	14	2.33	2.33
27/9/00	Kamika Lake	Member amo	canoe	4	0	2	0	32	34	8.50	8.50
30/11/01			boat	30	0	47	41	316	404	13.46	13.46
14/12/02			boat	25	4	20	6	287	317	12.68	12.52
28/9/00	Waropen Lake	Member amo	canoe	5	0	9	0	23	32	6.40	6.40
30/11/01			canoe	1	8	0	0	13	21	21.00	13.00
15/11/02			canoe	2.5	0	3	0	32	35	17.50	17.50
29/9/00	Kweri Satu Lake	Member amo	canoe	3	0	11	0	16	27	9.00	9.00
29/11/01			boat	3.5	23	0	0	36	59	16.86	10.28
16/12/02			boat	4	1	2	0	47	50	12.50	12.25
30/9/00	Kweri Dua Lake	Member amo	canoe	3.5	2	15	0	37	54	15.43	14.86
1/12/01			boat	5	20	0	0	29	49	9.80	5.80
15/12/05			boat	5	1	4	0	45	50	10.00	9.80
30/9/00	Apuse Lake	Member amo	canoe	3	0	12	0	22	34	11.33	11.33
2/12/01			canoe	4	6	0	0	17	23	5.75	4.25
16/12/02			canoe	3	0	3	0	23	26	8.67	8.67
1/10/00	Bernekam Satu Lake	Member amo	canoe	2.5	4	17	0	83	104	41.60	40.00
2/12/01			boat	10	0	0	7	27	34	3.40	3.40
17/12/02			boat	6	0	4	0	32	36	6.00	6.00
1/10/00	Bernekam Dua Lake	Member amo	canoe	3.4	2	9	0	29	40	11.76	11.18
1/12/01			canoe	4	4	0	0	20	24	6.00	5.00
17/12/02			canoe	3.5	0	4	0	30	34	9.71	9.71
2/10/00	Cabang Tiga Satu Lake	Member amo	canoe	3	1	2	0	58	61	20.33	20.00
29/11/01			canoe	15	13	0	0	49	62	4.13	3.27
18/12/02			boat	8	0	5	1	43	49	6.13	6.13
2/10/00	Cabang Tiga Dua Lake	Member amo	canoe	2.5	6	11	0	57	74	29.60	27.20
29/11/01			canoe	10	27	0	1	93	121	12.10	9.40
18/12/02			canoe	6	3	10	1	74	88	14.67	14.17

Table 4. *Crocodylus novaeguineae* harvest data (live crocodiles and skins; 1995 to 2002) from mid-zone Memberamo River (Memberamo and Rouffaer River system), provided by CV Bintang Mas.

Category	1995	1996	1997	1998	1999	2000	2001	2002
Live >60 cm TL	6661	6076	4303	3519	273	1395	762	1804
Skin 12-20" (30-51 cm) belly width	2234	1868	1762	2101	3998	3400	4379	2440
Live + skins	8895	7944	6065	5620	4271	4795	5141	4244