Pangasius djambal : A NEW CANDIDATE SPECIES FOR FISH CULTURE IN INDONESIA

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ABSTRACT

Until recently, although 12 pangasiid species were recognized in the Indonesian ichthyofauna, the only *Pangasius* cultivated in Indonesia was the "jambal siam" or "patin Bangkok", *Pangasius hypophthalmus*. With the view of utilizing the biological diversity of the local ichthyofauna, the potentialities of some Indonesian *Pangasius* species for fish culture have been studied since 1996 during the "Catfish Asia" research program supported by the European Union. Among these pangasiids, *Pangasius djambal* Bleeker reaches large size (more than 20 kg individual body weight) and is one of the fish species most appreciated by consumers in Sumatra and other Indonesian areas. The zootechnical evaluation of this species has shown its valuable characteristics for aquaculture. The mastering of artificial propagation of *P. djambal* in captivity has permitted to overcome the major bottleneck to its culture by offering new possibilities of fry availability for fish farms. This paper provides a synthesis of the present knowledge on the biology and culture of *P. djambal*, considering the following topics: natural distribution, morphological and genetic characteristics, broodstock management and induced breeding, larval development and rearing, growth at different stages of development, environmental tolerance, pathology, and flesh characteristics and composition. All together, the results represent the first biological bases to the promising culture of *P. djambal* in Indonesia.

Keywords: *Pangasius djambal*, morphometry, genetic, artificial propagation, aquaculture.

ABSTRAK

Pangasius djambal: Calon Spesies Baru untuk Budi Daya Ikan Indonesia

Sampai saat ini dari 12 spesies patin yang dikenal dalam fauna ikan di Indonesia, baru *Pangasius* yang dibudidayakan, yaitu "jambal Siam" atau "patin Bangkok" *(Pangasius hypophthalamus)*. Dari keanekaragaman hayati fauna ikan patin lokal, potensi untuk budi daya dipelajari sejak tahun 1996 dalam proyek penelitian "Catfish Asia" yang dibiayai oleh Masyarakat Ekonomi Eropa. Di antara spesies patin yang ada, *Pangasius djambal* Bleeker dapat mencapai ukuran lebih dari 20 kg bobot badan dan merupakan salah satu spesies yang paling diminati konsumen di Sumatra dan daerah lain di Indonesia. Hasil evaluasi biologi menunjukkan bahwa ikan ini mempunyai karakter yang menguntungkan untuk budi daya. Kemampuan untuk membenihkan melalui pemijahan buatan dapat membantu memecahkan masalah ketersediaan benih untuk budi daya. Makalah ini menggambarkan hasil sintesis biologi dan budi daya *P. djambal* dengan menekankan pada pokok bahasan mengenai distribusi di alam, karakter perkawinan buatan, morfologi dan genetik, pengelolaan induk dan pemijahannya, perkembangan dan perawatan larva, pertumbuhan pada berbagai stadia, toleransi lingkungan, patologi, karakter dan komposisi dagingnya. Hasil sintesis tersebut merupakan informasi biologi dasar yang dapat digunakan untuk mengembangkan *P. djambal* di Indonesia.

Kata kunci: *Pangasius djambal*, morfometri, genetik, propagasi artifisial, budi daya perairan.

Catfishes of the family Pangasiidae are of great economic importance in Indonesia. Although 12 pangasiid species were reported to belong to the Indonesian ichthyofauna (Roberts and Vidthayanon, 1991; Pouyaud *et al.*, 2000), their biology and potential for aquaculture remain largely unknown. Up to now, *Pangasius hypophthalmus* Sauvage, 1878, (senior synonym of *Pangasius sutchi*) initially introduced from Thailand in 1972, remained the only pangasiid catfish produced in aquaculture in Indonesia. Before the systematic revision of Pangasiidae by Roberts and Vidthayanon (1991) and the study of phylogenetic relationships among pangasiid species by Pouyaud *et al.* (2000), *P. hypophthalmus* ("jambal Siam" or "patin Bangkok") was known as *Pangasius sutchi.*

Among the local pangasiids, *P. djambal* Bleeker, 1846, is one of the fish species most appreciated by consumers in Sumatra and other Indonesian areas. It reaches large size with individual body weight of more than 20 kg. However, up to now its culture has not been possible due to the lack of fry. Contrarily to the statement of Roberts and Vidthayanon (1991), *P. djambal* has never been utilized in aquaculture so far. This confusion may result from the fact that "jambal" is a common name given in Indonesian language to several *Pangasius*.

Since 1996, as a part of the "Catfish Asia" Project supported by the European Union, the Franco-Indonesian collaborative research program has led to significant basic and applied results in the fields of pangasiid systematic, biogeography, biology, and aquaculture. Among these results, it has been shown that *P. djambal* presents valuable zootechnical performances in comparison to the introduced species *P. hypophthalmus*. The first success of hormonal induced ovulation, artificial fertilization and larval rearing of *P. djambal* was achieved in 1997 (Legendre *et al.*, 1999a). Since that time, the feasibility of fry production from captive broodstock has been demonstrated repeatedly and now allows the aquaculture production of *P. djambal* to be initiated.

This paper provides a synthesis of the present knowledge on the biology and culture performances of *P. djambal.*

NATURAL DISTRIBUTION

The numerous sampling campaigns of pangasiid catfishes carried out all over Southeast Asia during the "Catfish Asia" program provided a detailed information on the geographical distribution of species.

P. djambal Bleeker (Figure 1) is presently known from most of the major drainage's of Sumatra, where it was observed in the Musi, Batang Hari, and Inderagiri Rivers. The species also occurs in Java, respectively, in Brantas and Solo Rivers and in South Kalimantan in Barito, Mendawai, and Kahayan Rivers. Although the type locality of *P. djambal* is Batavia (former name of Jakarta), nowadays the species seems to have disappeared from all river basins of West Java as a probable result of over-fishing, water pollution, and dam construction. By contrast, the presence of *P. djambal* in Sumatra's rivers was reported for the first time during the "Catfish Asia" program.

MORPHOLOGICAL CHARACTERISTICS

External morphological description was performed using a dial caliper for 19 measurements taken point to point on the carcass of 36 specimens and by counts of fins rays and gill rakers on the first arch (Table 1).

Referring to Roberts and Vidthayanon (1991) and personal observations, the maximal size of *P. djambal* exceeds 1,000 mm standard length (SL).

Genetic Characteristics and Morphologic Affinities with Other Pangasiid Species

In Indonesia, *P. djambal* could be easily distinguished from other *Pangasius* species with the allozymic locus Fructose biphosphatase (FBP, E.C. 3.1.3.11, liver) or from the sequence of its cytochrome b gene (Pouyaud *et al.*, 2000).

Another enzymatic system (protein total) allowed to differentiate easily and quickly *P. djambal* (allele 100 for locus Prot1; allele 105 for locus Prot2) from *P. polyuranodon* (allele 90, Prot1; allele 105, Prot2), *P. hypophthalmus* (allele 100, Prot1; allele 100 and 150, Prot2), *P. nasutus* (allele 90, Prot1; allele 160, Prot2) and *P. kunyit* (allele 90, Prot1; allele 50, Prot2).

An allozymic study (25 loci) performed on 42 specimens originating from Sumatra, Kalimantan, and Java revealed that *P. djambal* was characterized by a

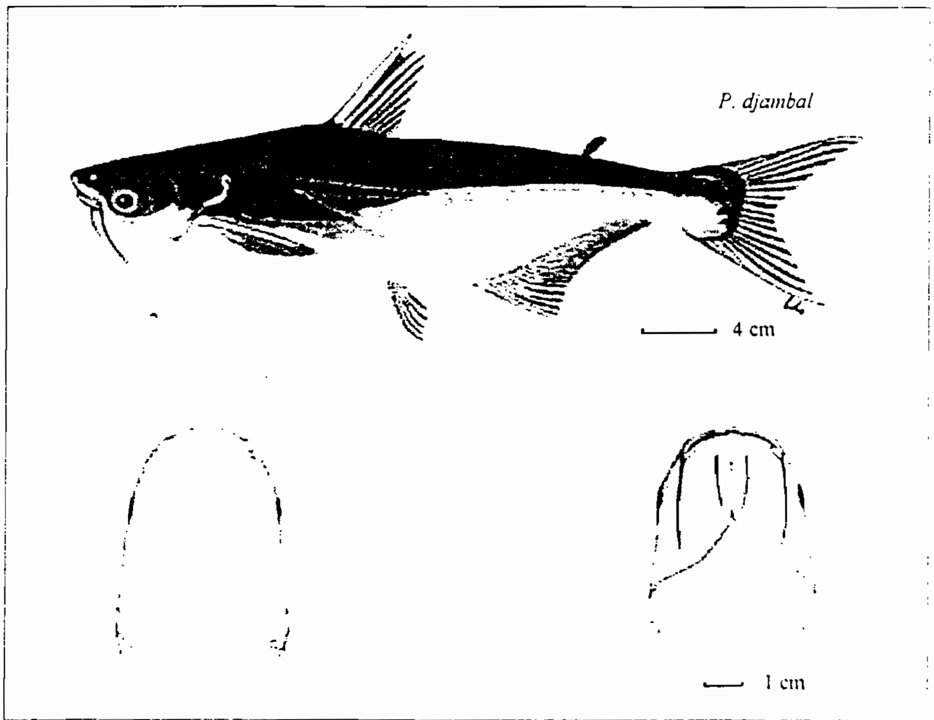

Figure 1. **P. djambal,** ***with dorsal and ventral views of the head.***

Table 1. Measurements and meristic counts for specimens of P. djambal *from Java, Sumatra, and Kalimantan. Measurements based on specimens ≥ 227 mm SL.*

Measurements	n	mean	min.	max.	SD
Standard length (mm)	36		227	633	
Head length (%SL)	36	23.6	22.4	24.1	0.5
Snout length (%HL)	36	43.9	37.5	50.0	2.9
Head depth (%HL)	35	50.4	44.3	60.2	3.5
Predorsal length (%SL)	36	37.2	34.7	40.0	0.9
Caudal peduncle depth (%SL)	36	8.1	6.9	9.2	0.5
Eye diameter (%HL)	36	14.8	11.3	18.3	1.7
Width mouth (%HL)	36	43.6	36.7	48.2	2.7
Interorbital distance (%HL)	36	58.8	52.2	69.6	3.6
Distance snout to isthmus (%HL)	34	49.6	40.6	56.3	4.0
Postocular length (%HL)	35	35.2	30.4	40.4	2.6
Body width (%HL)	34	78.3	70.1	84.3	3.7
Prepectoral length (%SL)	35	20.9	19.0	22.5	0.8
Prepelvic length (%SL)	36	47.9	44.9	52.0	2.0
Vomerine width (%HL)	36	21.0	17.2	26.4	1.9
Vomerine length (%HL)	36	53.9	24.4	66.7	10.5
Palatine length (%HL)	36	13.9	11.3	15.6	1.2
Palatine width (%HL)	36	4.2	3.1	6.4	0.6
Dorsal spine width (%DSL)	36	21.3	10.2	26.8	2.9
Gill rakers number	34		27	41	
Dorsal rays	36		6	8	
Pectoral rays	35		9	13	
Pelvic rays	34		6	7	
Anal rays	34		27	32	

SD : standard deviation
SL : standard lenght
HL : head lenght
DSL : dorsal spine lenght

high level of genetic polymorphism (average allelic heterozygosity close to 10% and average number of polymorphic loci up to 24%).

The phylogenetic relationships performed among all the *Pangasius* species in Indonesia (Table 2), revealed that *P. djambal* was genetically closely related to *Pangasius rheophilus* Pouyaud and Teugels, 2000 and *P. nasutus* Bleeker. 1862 (Pouyaud *et al.*, 2000).

From the morphological study, *P. djambal* appeared to be closely related to *P. polyuranodon* Bleeker, 1852; *P. nasutus* Bleeker. 1862; *P. kunyit* Pouyaud *et al.*, 1999 ; and *P. rheophilus* Pouyaud and Teugels, 2000 . These species share many morphological characters allowing high probability of misidentification. As an example, the palatal teeth share an identical pattern (Figure 2).

To avoid such misidentification, an identification key is given for those species:

1a. Predorsal length and head length short (Figure 3) ...... *P. polyuranodon*
1b. Predorsal length long (Figure 3) 2
2a. Body width narrow combined with short head (Fig.4) .... *P. rheophilus*
2b. Body width large combined with long head (Figure 4) 3
3a. Eye small combined with a slender caudal peduncle depth (Figure5) .. .. *P. nasutus*
3b. Eye large combined with a large peduncle depth (Figure5) 4
4a. Snout length inferior or equal to distance from snout to isthmus (Figure 6) .... *P. kunyit*
4b. Snout length superior to distance from snout to isthmus (Figures 6 and 7) .... *P. djambal*

Table 2. Nei's genetic distance (calculated from allozymes) between P. djambal *and its closely related species.* P. hypophthalmus *is given as a reference.*

	P. nasutus	*P. rheophilus*	*P. hypophthalmus*
P. djambal	0.292	0.315	1.074

BROODSTOCK MANAGEMENT AND INDUCED BREEDING

Origin and Status of Broodstock

Between March and May 1997, a captive stock of *P. djambal* has been constituted. The wild fish (0.2 - 1.5 kg), captured by fishermen in the Inderagiri River (Riau province, Sumatra), were firstly stocked in floating cages in the river area of capture, then transferred by car (about 8 hours transportation) to the Sungai Gelam Station (Regional Center for Freshwater Aqua culture Development = RCFAD) in Jambi, Sumatra, where they were adapted to pond environment during 2 to 4 weeks.

In June 1997, a part of these fish remained at the Sungai Gelam Station, while 75 individuals weighing between 190 and 1,100 g (mean body weight of 555 g) were transferred by plane and car to the Sukamandi research station of Research Institute for Freshwater Fisheries (RIFF) (about 15 hours transportation) to serve as future experimental broodstock. Fish were transported in plastic bags, under oxygen atmosphere, using a specifically adapted packing technique avoiding bags to be cut by the sharp pectoral and dorsal spines of fish (Pouyaud and Sudarto, unpubl.). This technique was fully satisfactory and 100% of the fish remained alive after transportation. Based on growth

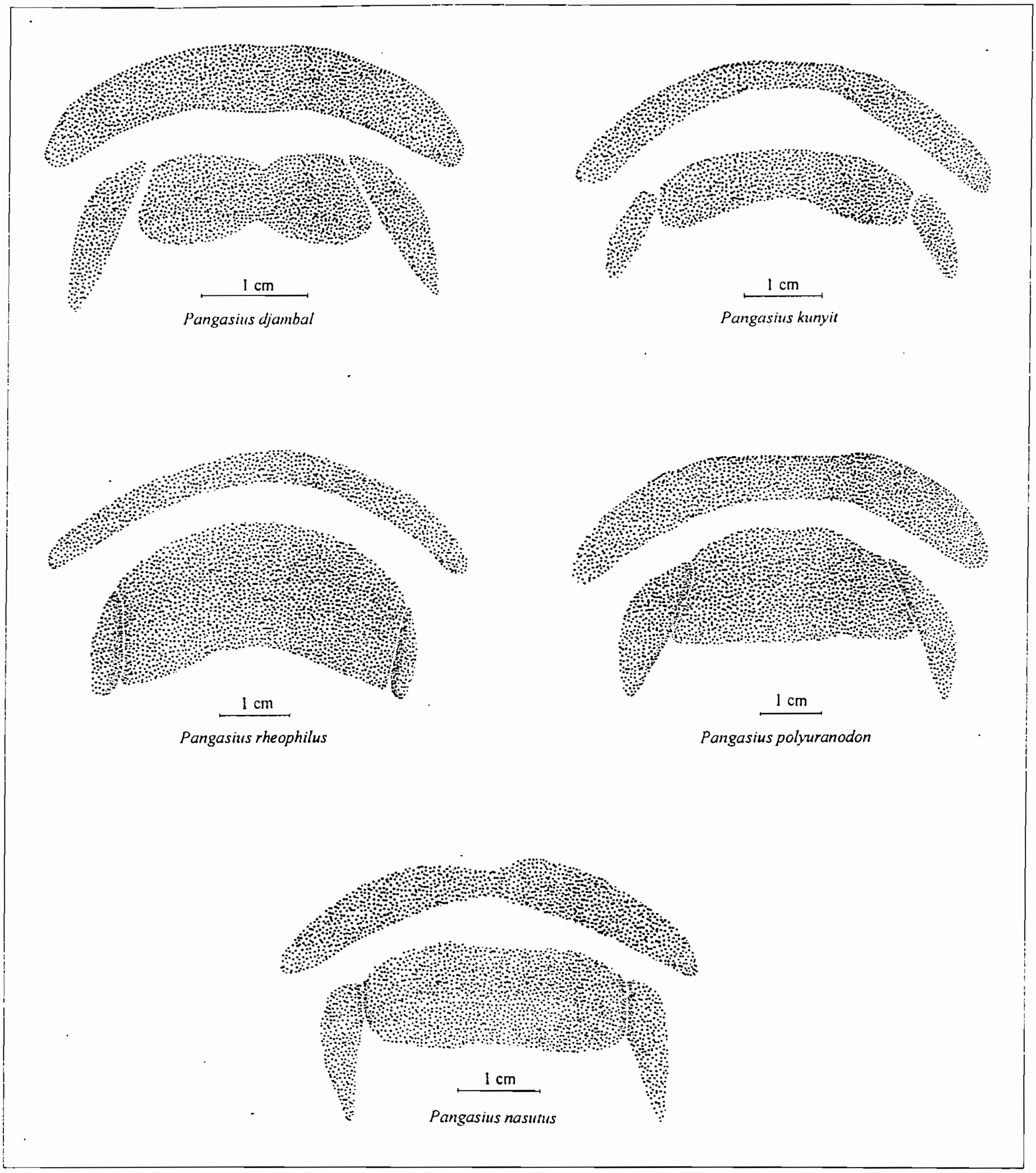

Figure 2. ***Mandibular teeth (above) and palatal teeth (below) of*** **P. djambal, P. kunyit, P. rheophilus, P. polyuranodon,** ***and*** **P. nasutus.** ***Palatal teeth include a central patch (vomerine teeth) and two lateral patches (palatine teeth).***

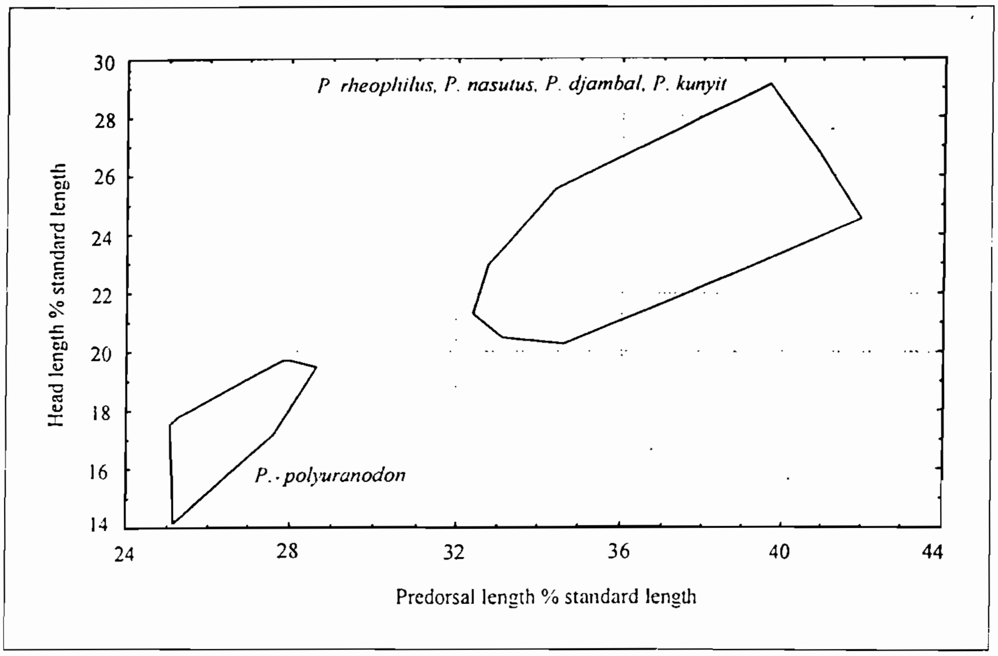

Figure 3. *Discrimination of* P. polyuranodon *from* P. rheophilus, P. nasutus, P. djambal, *and* P. kunyit, *using the combination of the following characters: predorsal length in % of standard length and head length in % of standard length.*

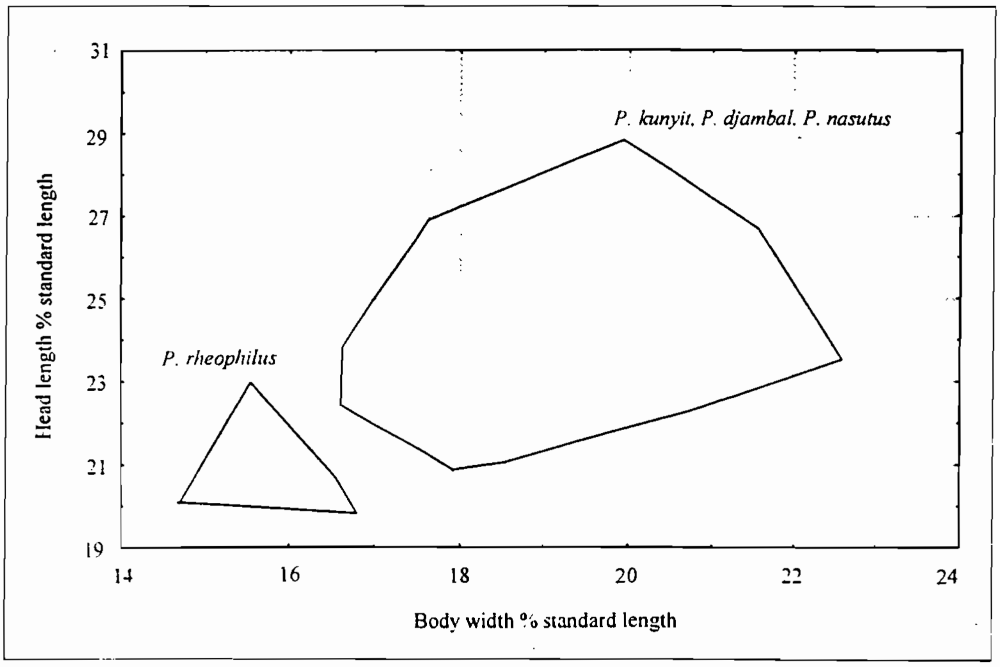

Figure 4. *Discrimination of* P. rheophilus *from* P. nasutus, P. kunyit, *and* P. djambal *using the combination of the following characters: body width in % of standard length and head length in % of standard length.*

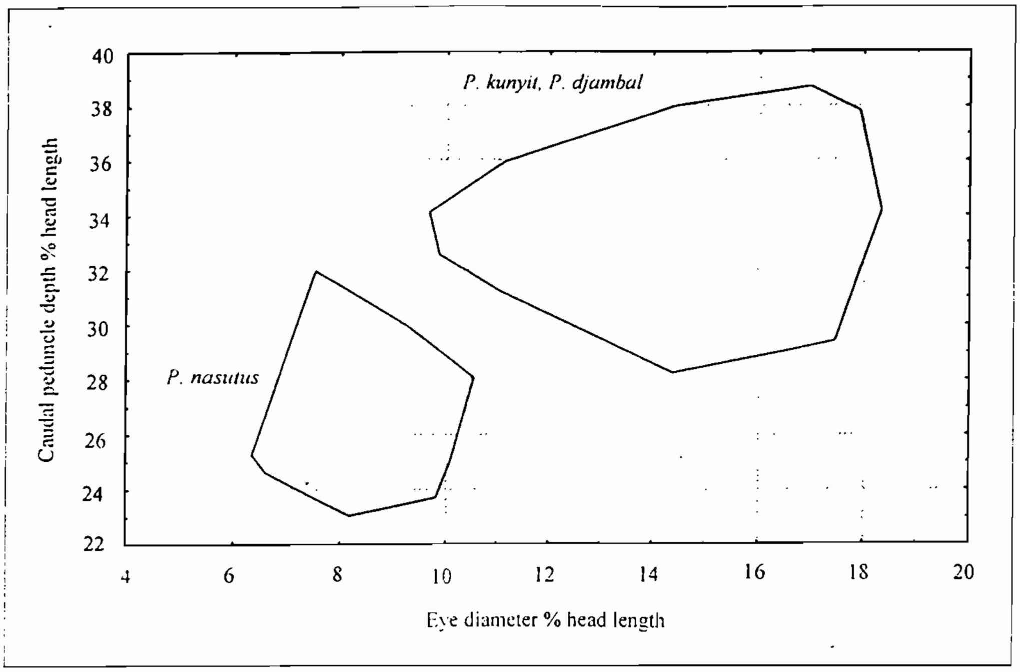

Figure 5. *Discrimination of P. nasutus from* P. kunyit *and* P. djambal *using the combination of the following characters: eye diameter in % of head length and caudal peduncle depth in % of head length.*

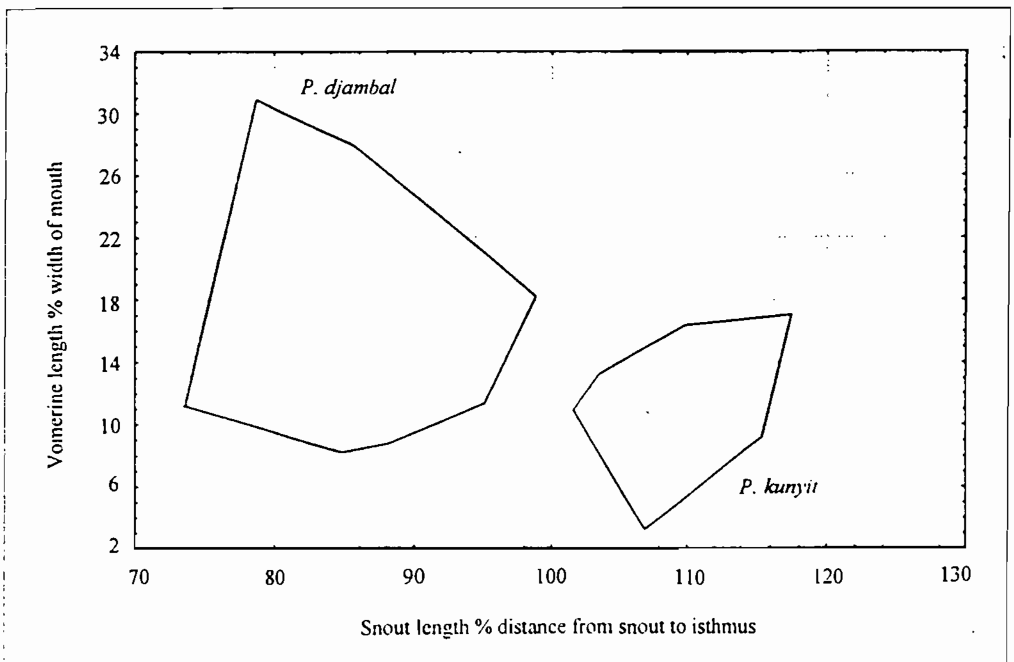

Figure 6. *Segregation between* P. djambal *and* P. kunyit *using the combination of the following characters: snout length in % of distance from snout to isthmus and vomerine length in % of mouth width.*

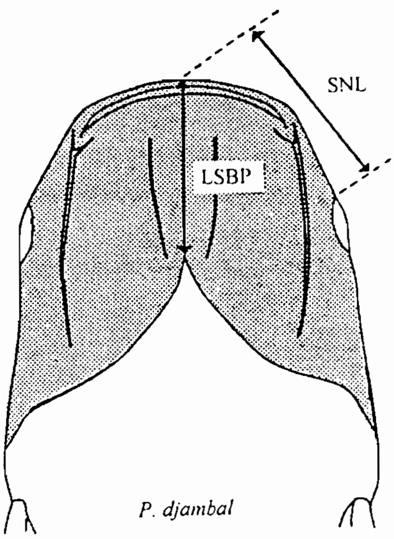

Figure 7. ***Measurements taken on the head to differentiate* P. djambal *from* P. kunyit *(mouth must be closed and branchial process visible).***
SNL : snout lenght
LSBP : lenght from snout to isthmus

rate observed subsequently in culture conditions they were estimated to be 0.5-1.0 year old.

The status of the available mature broodstock in RIFF Sukamandi and RCFAD Jambi in April 2000 is presented in Table 3.

Besides these mature broodstock, other fish stocks born in captivity from induced breeding in March 1998 (about 300 individuals) were grown on both stations to constitute future *P. djambal* broodstock. In April 2000, these fish were 2.6-3.5 kg mean body weight and males were already sexually mature.

Rearing Conditions and Sexual Maturation of Broodstock

Stocking density, feeding, and tagging of fish

At Sukamandi, between June 1997 and July 1998, the fish were placed in 200 m^2 ponds, at a stocking density of 0.4-0.5 fish/m^2. Since October 1999, the broodstock has been reared in two separate 200 m^2 ponds at a stocking density of 0.2 fish/m^2. During the whole rearing period, the fish were fed with a 35-40% crude protein pelleted feed, distributed two times per day and six days a week at a daily ration decreased gradually from 2 to 0.8% of fish biomass. In January 1998, each fish was implanted with a PIT tag (Passive Inductance Transponder, Fish Eagle ™) in order to allow individual identification.

At Sungai Gelam, the broodstock was stocked in a 400-m^2 pond at a stocking density of about 0.4 fish/m^2. The fish were fed with different pelleted feed containing 25 to 35% crude protein, distributed at a daily ration decreased gradually from 2 to 0.8% of fish biomass. The broodfish were individually tagged with blue spots on the skin of the belly, corresponding to Alcyan blue solution injected using a Dermojet. Such tagging method was initially used by Institut de Recherche pour le Developpement (IRD) for other catfish (Slembrouck and Legendre, 1988).

Table 3. ***Number and mean body weight of sexually mature females and males of* P. djambal *available in RIFF (Sukamandi) and RCFAD (Jambi) stations in April 2000.***

	RIFF Sukamandi		RCFAD Jambi	
	Female	Male	Female	Male
Fish number	28	41	87	71
Mean body weight (kg)	6.9	5.1	9.4	6.7
Extreme values (kg)	[4.3 - 10.0]	[2.8 - 6.8]	[4.5 - 15.5]	[4.0 - 11.0]

Sexual dimorphism

No external characteristics allowed for distinction of sexes (absence of sexual dimorphism). Males could be identified only when sexually mature by emission of sperm upon hand-pressure onto the abdomen and females when oocytes could be sampled by intraovarian biopsy. For a detailed evaluation of sexual maturity, measurements of oocyte diameter were done using binocular microscope (x 25) equipped with a micrometer.

First sexual maturation

In June 1997, when the fish caught in the wild were brought to the Sukamandi station some males were already observed as fluent (oozing milt with slight abdominal pressure), while no females were found with developing oocytes. At this moment, the age of fish was estimated from their size between 6 and 12 months. The evolution with time of the proportions of fluent males, maturing and mature females are presented in Figure 8.

The proportion of fluent males increased quite rapidly and reached more than 80% in October 1998 (estimated age of about 2 years), then reached 100% in September 1999. In females, the development of gonads (assessed by intraovarian biopsy) was slower. The first maturing females were observed in October 1998 and it is only about one year after (fish age of about 3 years) that high proportions of females were found with post-vitellogenic oocytes (diameter $\geq$ 1.6 mm), apt to ovulate after hormonal treatment. A similar evolution of sexual maturity was observed at the Sungai Gelam Station. Therefore, sexual maturity of *P. djambal* occurs earlier in males (1-2 years) than in females (3 years). All together, the results indicate that about three years are necessary to constitute a fully mature broodstock of *P. djambal*.

It is noteworthy that a high proportion of fluent *P. djambal* males was observed all year round and gonad

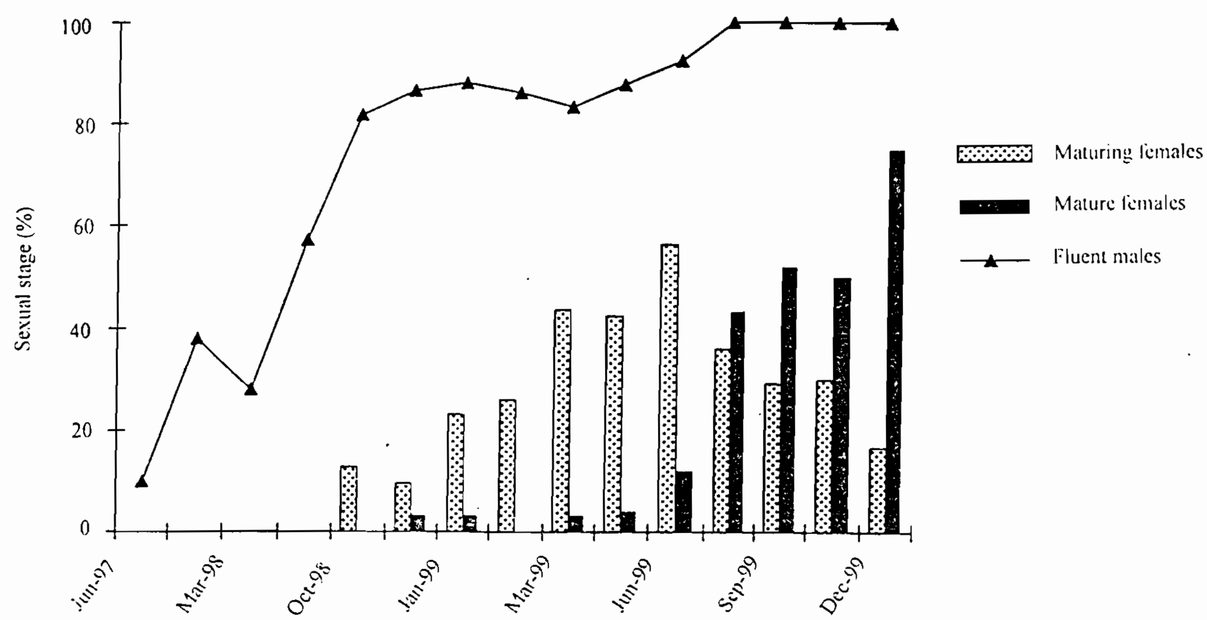

Figure 8. Changes in the proportion of fluent males, maturing females (with vitellogenic oocytes of 0.4-1.5 mm in diameter) and mature females (with maximum oocyte diameter ≥1.6 mm) of P. djambal *caught in the wild and reared in Sukamandi ponds (estimated age of fish in June 1997: 6 to 12 months).*

maturation of females appeared as a continuous process without apparent influence of seasons (Figure 8).

Induced Ovulation, Artificial Fertilization, and Egg Incubation

The artificial propagation of *P. djambal* was obtained for the very first time in captivity by the "Catfish Asia Project" in November 1997 in Jambi (Legendre *et al*., 1999a,b). Since that initial success, a total 23 *P. djambal* females were used for induced breeding trials.

Induced breeding procedure

Females found with oocytes at an advanced stage of vitellogenesis after intraovarian biopsy (modal diameter of oocytes ≥ 1.6 mm), were chosen to induce ovulation. They were treated with two successive injections of Ovaprim (GnRH + domperidone) applied at 8 hours interval with respective doses of 0.3 and 0.6 mL/kg. Males received a single Ovaprim injection (0.4 mL/kg) given at the same time as the second Ovaprim injection of females. The sperm was collected by stripping and directly kept in a syringe containing a sperm immobilizing saline solution (NaCl 175 mM), in order to prevent activation of spermatozoa due to possible mix with urine. After ovulation, the stripped eggs were fertilized with sperm mixed from several males. Egg incubation was generally carried out in McDonald type incubators ("*corong*") after treatment with clay to suppress stickiness of eggs. In comparison to other incubation techniques (e.g. in stagnant water on the bottom of tanks or aquarium), incubating *P. djambal* eggs in McDonald jars presents several advantages: limitation of occupied space in the hatchery, maintenance of high levels of water dissolved oxygen and limitation of infection by fungus (e.g. *Saprolegnia* sp).

Results of induced breeding

The data on broodfish used, ovulation percentage, fecundity, and hatching rates obtained in Jambi and Sukamandi are summarized in Table 4. So far, ovulation of *P. djambal* females was successfully induced in January, February, March, June, September, October, November, and December, during both the rainy and dry seasons. This strongly suggests that an all-year-long production of fry of this species is possible, as it is the case in *P. hypophthalmus* (Legendre *et al*., 1999c).

The female body weight ranged between 2 - 10 kg and the initial oocyte diameter of fish which ovulated after hormone treatment was comprised between 1.66 - 1.92 mm. Ovulation has been obtained in 20 of the 23 treated females, corresponding to an ovulation success of 87%. The three females that did not respond to the hormone treatment had an initial oocyte diameter smaller than 1.65 mm (modal value). The fish fecundity (number of ova stripped) was similar in Sukamandi and Sungai

Table 4. Body weight, initial oocyte diameter, ovulation percentage, fecundity and hatching rates for P. djambal *females treated with Ovaprim at the Sukamandi research center and Sungai Gelam Station.*

Location	N treated females	Female body weight (kg)	Initial oocyte diameter (mm)	Ovulated females (%)	N egg per kg female (x 1000)	Hatching rate (%)
Jambi (Sumatra)	12	6.1 ± 2.2 [1.9-9.5]	1.70 ± 0.10 [1.58-1 88]	83	9.1 ± 5.3 [2.7-20.5]	31 ± 26 [0-64]
Sukamandi (Java)	11	6.1 ± 1.2 [4.5-8.0]	1.79 ± 0.10 [1.60-1.92]	91	7.9 ± 2.7 [3.1-11.7]	43 ± 21 [10-74]
Grouped data	23	6.1 ± 1.7 [1.9-9.5]	1.75 ± 0.10 [1.58-1.92]	87	8.5 ± 4.0 [2.7-20.5]	38 ± 24 [0-74]

Mean ± sd; [extreme values]

Gelam. The mean fecundity of *P. djambal* was of 8,500 egg/kg, but an individual value of more than 20,000 egg/kg was observed.

The mean diameter and weight of ova at stripping were of 1.85 ± 0.11 mm and 3.3 ± 0.4 mg, respectively. Hatching of egg begun 28.5 to 34 hours after fertilization at a water temperature of 26-30°C.

LARVAL DEVELOPMENT AND REARING

The morphological changes of *P. djambal* larvae from 10 hours up to 11 days of age are presented in Figure 9. A remarkable point was the early dark pigmentation of the larvae which even appeared in embryos before hatching. By comparison, *P. hypophthalmus* was totally lacking pigmentation during its two first days of life.

During the first week, the pigmentation of *P. djambal* larvae was restricted to the anterior half of the body. After 11 days of age the fins were almost totally formed and the fish presented the general morphology of the adult.

In contrast to the situation prevailing in *P. hypophthalmus*, no cannibalism was observed in *P. djambal* during the larval rearing which does not appear as a critical phase of the breeding cycle of this species. Due to a larger egg size and amount of yolk reserve, the larvae of *P. djambal* were bigger (4.5 mg) than those of *P. hypophthalmus* (1.5 mg) at the onset of exogenous feeding. As a consequence, they were easier to cultivate and high survival and growth rates were obtained when larvae were fed *Artemia* nauplii. The characteristics of eggs and larvae of *P. djambal* and *P. hypophthalmus* are compared in Table 5.

As *Artemia* represents a rather expensive feed, other types of feed were tested as possible substitutes for larval rearing of *P. djambal*. The comparison

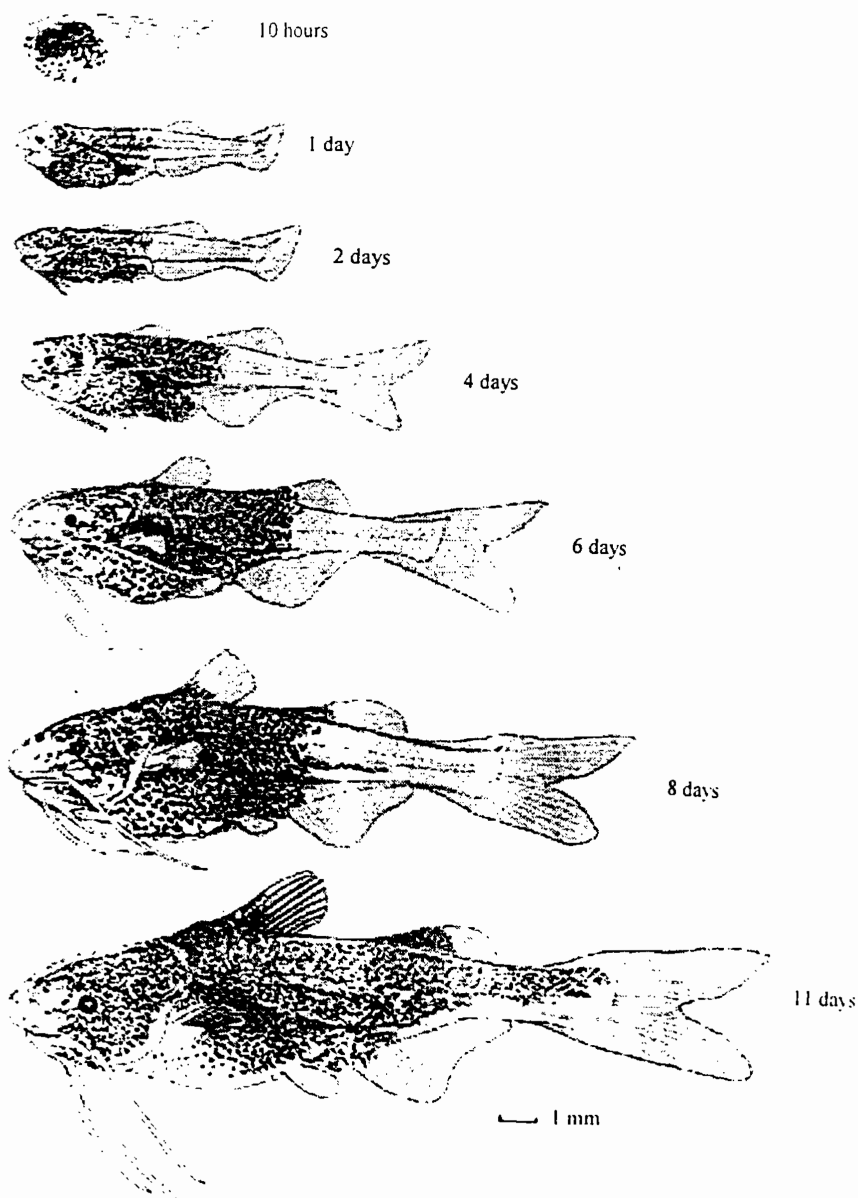

Figure 9. Different stages in the larval development of P. djambal *up to 11 days of age.*

Table 5. Comparison of characteristics of P. hypophthalmus *and* P. djambal *egg and larvae.*

Characteristics	*P. hypophthalmus*	*P. djambal*
Ova diameter before fertilization (mm)	1.2	1.9
Weight of ova (mg)	0.6	3.3
Range of incubation duration at 27-30°C (hours)	20-28	29-40
Total length of larvae at hatching (mm)	2.5	4.7
Duration of yolk sac absorption at 28-29°C (days)	1.5	2.5
Total length of larvae at first feeding (mm)	5.6	8.6
Body weight of larvae at first feeding (mg)	1.5	4.5
Behavior of larvae	Cannibalism	No cannibalism
Survival rate larvae at 8-11 days of age (%)	50-70	80-90

of growth and survival rates of larvae fed either *Artemia*, *Moina* sp., *Daphnia* sp., tubifex worms or a 40% protein dried diet is presented in Table 6. Each feed type was tested on two replicated groups of larvae, reared at a stocking density of 10 fish/L in the 30 liters tanks of a water recirculation system. The larvae were fed in excess with a feeding frequency of 7 meals/day.

At 11 days of age, larvae fed *Artemia* nauplii presented the highest growth and survival rates. The survival rate was not significantly different for larvae fed the different feed types, except for a lower survival of fish fed *Daphnia*. The final mean weight of larvae fed *Artemia* nauplii was about 3 times greater than that of fish fed with the other feeds (Table 6). Therefore, even if the best results were obtained using *Artemia* as a first feed, it appears clearly that *P. djambal* larvae can be successfully reared in hatchery with cheaper feed types (survival rate greater than 80%). So far, more than 60,000 larvae of *P. djambal* have been produced at the Sukamandi and Sungai Gelam, and fingerlings have been distributed to different fish farms in Sumatra and Java.

GROWTH OF *P. djambal* AT DIFFERENT STAGE COMPARED WITH *P. hypophthalmus*

Data on growth of *P. djambal* are presented hereafter for different phases of the rearing cycle, and compared to those obtained in *P. hypophthalmus*.

Larval and Early Fingerling Stage

The growth of *P. djambal* larvae was compared to that of *P. hypophthalmus* in two successive experiments carried out in a water recirculation system at the Sukamandi station (stocking density of 10 larvae/L). The larvae were firstly fed with *Artemia* nauplii, then gradually weaned to a 40% protein dried diet after 8-9 days of age. During the experiments, oxygen concentration ranged between 4.6-7.9 mg/L, pH between 8.1-8.6, temperature between 27.3-29.0°C, ammonia between 0.0-0.2 mg/L and nitrite between 0.005-0.1 mg/L.

At the age of 15 days, *P. djambal* reached a mean body of 261 and 394 mg in the first and second experiments, respectively. In all cases, the final body weight of *P. djambal* was significantly greater than that of *P. hypophthalmus* (Figure 10).

Fingerling and Pre-adult Stage

Fingerlings of *P. djambal* and *P. hypophthalmus* of a same age were grown in ponds for 145 days at a stocking density of 2 fish/m^2. They were fed with a 35% crude pelleted feed distributed at a daily rate decreased gradually from 3 to 2% of fish biomass. The mean growth rate of *P. djambal* was of 1.7 g/day, while that of *P. hypophthalmus* was of 0.9 g/day (Figure 11).

Pre-adult and Adult Stage

The growth of *P. djambal* caught from the wild was followed on the long term in ponds at the Sukamandi station. The fish were reared at a stocking density of 0.3-0.5 fish/m^2 and fed with a 35% crude pelleted feed distributed at a daily rate decreased gradually from 2 to 0.8% of fish biomass.

Starting from a mean body weight of 550 g, *P. djambal* reached 6,354 g after 990 days of rearing. This corresponded to a mean growth rate of 6.0 g/day. The shape of the growth curve presented an almost linear shape during the whole rearing period (Figure 12). This represented an important difference with *P. hypophthalmus*, the growth of which slowed down drastically after reaching 2.5 kg of mean body weight (Figure 12).

In *P. djambal*, although the sex of some individuals could not be

Table 6. Final mean body weight and survival rate of P. djambal *larvae fed different types of feed (mean ± SD).*

Feed type	Initial mean body weight (mg)	Final mean body weight (mg)	Survival rate (%)
Artemia nauplii	4.5 ± 0.8	92.7 ± 10.9c	91 ± 7b
Moina sp.	4.5 ± 0.8	20.2 ± 2.9a	79 ± 5b
Daphnia sp.	4.5 ± 0.8	30.6 ± 2.0ab	34 ± 1a
Tubifex	4.5 ± 0.8	34.6 ± 0.5b	86 ± 5b
Dried diet	4.5 ± 0.8	21.5 ± 2.6ab	82 ± 5b

Values with different superscript in the same column are significantly different ($p < 0.05$).

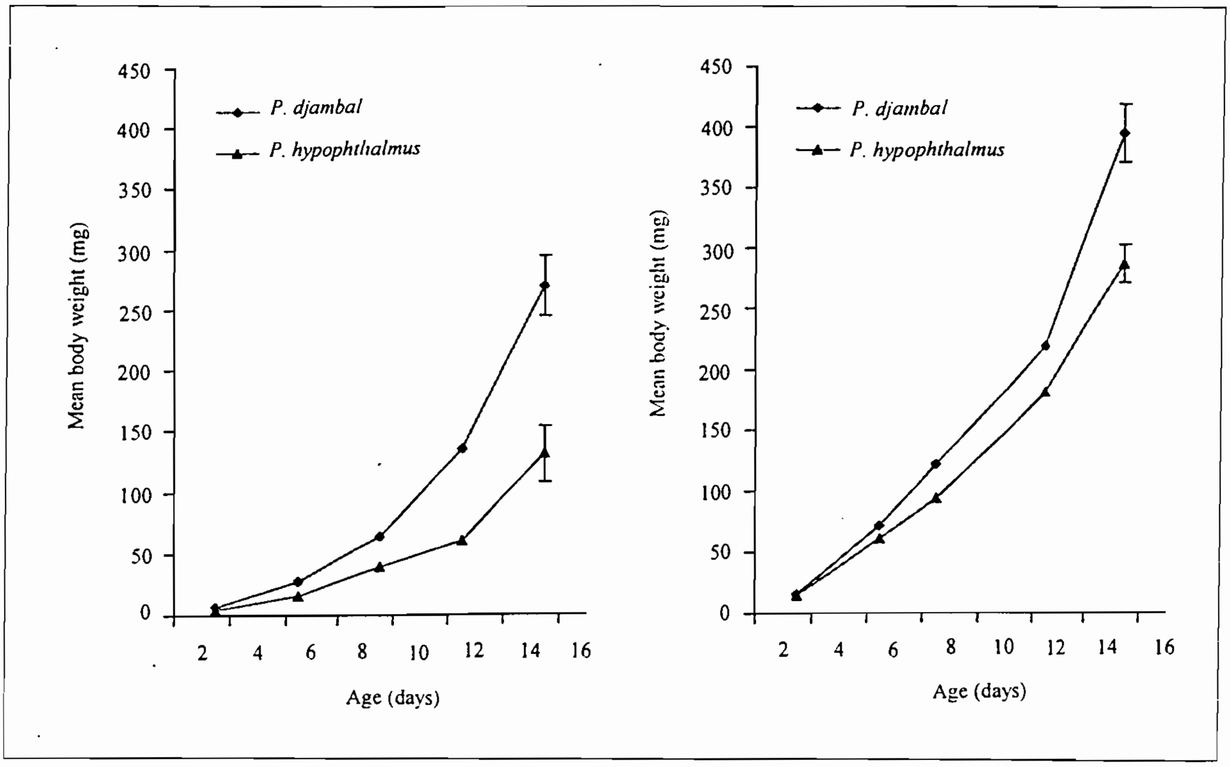

Figure 10. Growth of P. djambal *and* P. hypophthalmus *larvae reared in a water recirculation system for two different experiments. Vertical bars correspond to range between four replicates.*

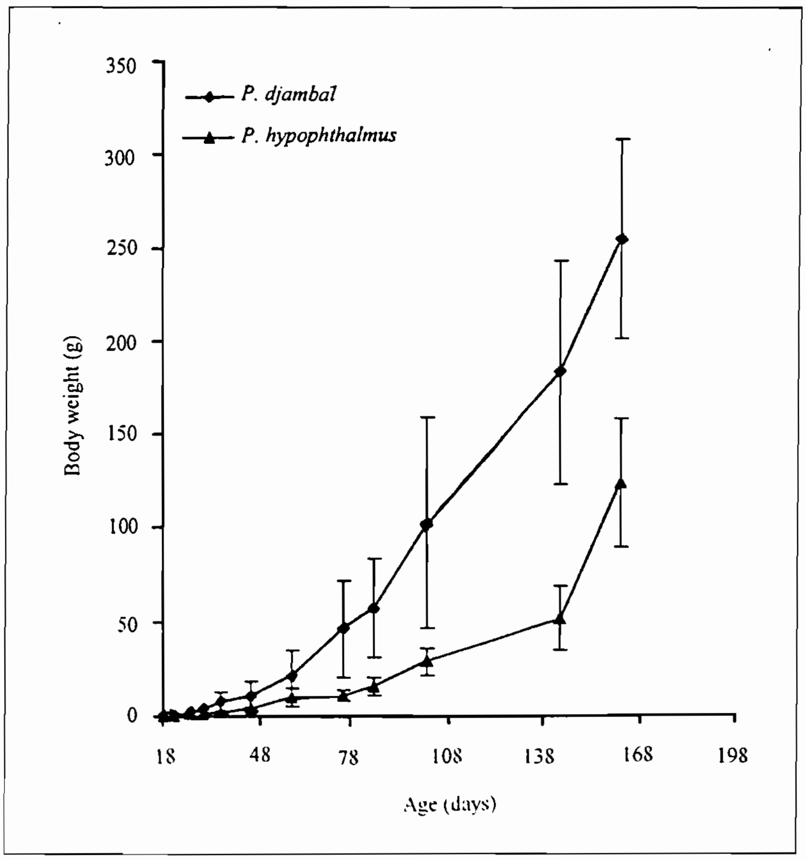

Figure 11. Growth of fingerlings of P. djambal *and* P. hypophthalmus *reared in ponds. Vertical bars correspond to standard deviation.*

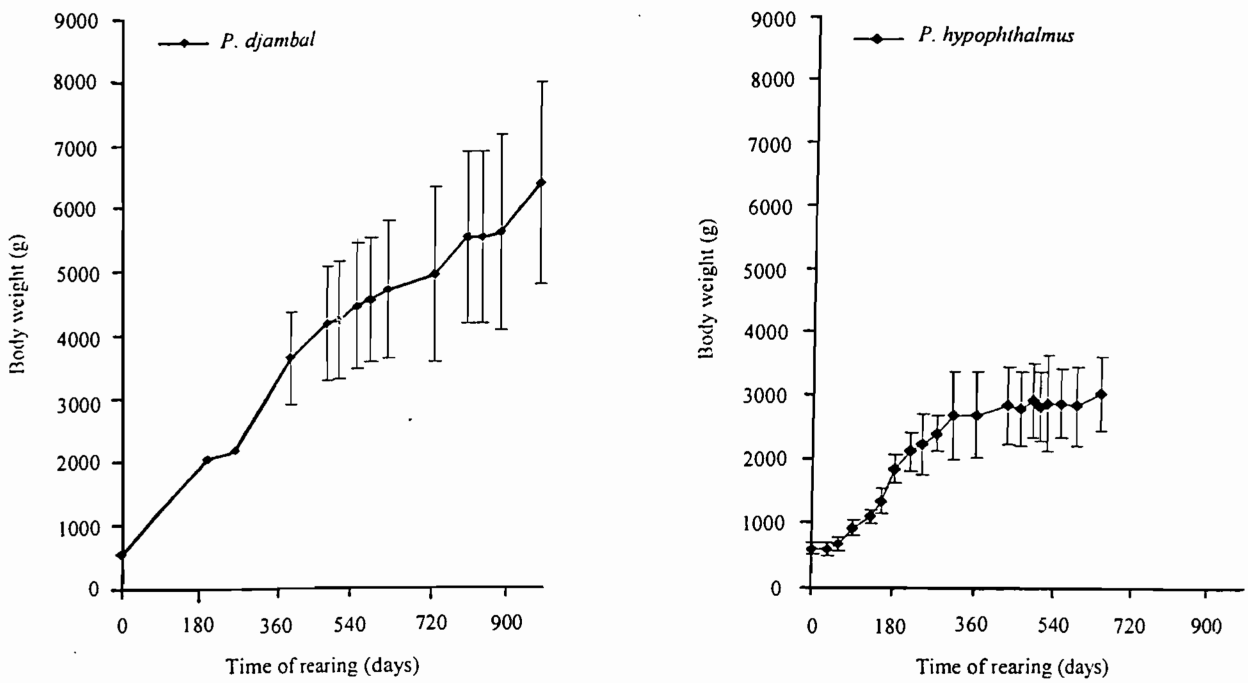

Figure 12. Growth of **P. djambal** *and* **P. hypophthalmus** *reared in ponds up to the adult stage. Vertical bars correspond to standard deviation.*

identified at an early stage due to the absence of sexual dimorphism, the respective growth of males and females could be compared because all of them were individually tagged (PIT tags). In this species, the females presented a much faster growth rate than males above 3 kg mean body weight (Figure 13). In males, the lowering of growth corresponded to the period at which most of them reached full sexual maturity.

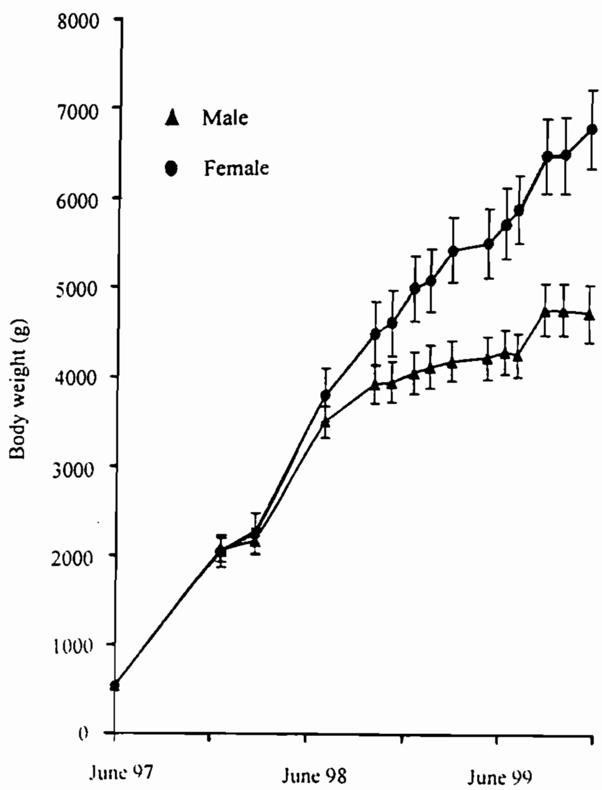

Figure 13. Growth of males and females of **P. djambal** *in pond. Vertical bars correspond to standard deviation.*

TOLERANCE TO ENVIRONMENTAL FACTORS

The tolerance of *P. djambal* to environmental parameters is not fully known yet and remained to be assessed experimentally. However, first indications can be given from rearing trials already carried out. These data are presented in Table 7 with reference to the corresponding development stage of fish.

Table 7. *Observed range of variation of some environmental parameters tolerated by* P. djambal.

Environmental parameters	Observed range	Stage of fish
Temperature (°C)	27-31	All
pH	6.0-8.9	All
Oxygen (mg/L)	> 3	Eggs and larvae
Oxygen (mg/L)	0.6-9.6	Fingerlings and broodstock
Salinity (g/L)	0-4	larvae

Oxygen data for fingerlings and broodstock correspond to day/night variations in pond.

PATHOLOGY

So far the only pathological problem encountered with cultivated *P. djambal* is "white spot disease" due to infection by *Ichtyophthirius multifilis* which occurred only at the fingerling stage for fish between 1 and 6 weeks of age. Against this infection, applications of formalin containing 4 g/L of malachite green oxalate (FMGO) has been shown to be efficient for both preventive and curative treatments of fish. The preventive treatment was a 24 h immersion in FMGO at a dose of 5 to 10 mL/m^3 applied once a week. The dose of 5 mL/m^3 was applied for fish younger than 3 weeks, while older fish tolerated a dose of 10 mL/m^3.

The curative treatment consisted of two consecutive applications of 10 mL / m^3 of FMGO at 24 hours interval. The water was renewed and the fish kept without medicine for the subsequent 24 hours. This procedure was repeated three times consecutively.

FLESH CHARACTERISTICS AND COMPOSITION

Analyses of edible portion, flesh quality, and proximate composition were carried out for *P. djambal* and *P. hypophthalmus* at the nutrition laboratory of the Research Institute for Freshwater Fisheries at Sukamandi .

The dressing and fillet percentages of 1 to 2 kg fish were very similar in both species (Table 8). The proximate analysis indicated that the flesh of *P. djambal* contained less water and more fat than that of *P. hypophthalmus*, while protein contents of the two species were not significantly different (Table 9). Sensory evaluation of the color, odor, and texture of the flesh of *P. djambal* and *P. hypophthalmus* was made by 30 panelists, using an arbitrary scale from 1 (worst) to 9 (excellent) (Table 10). For *P. hypophthalmus*, the panelists expressed a neutral opinion for color and odor (score of 5). *P. djambal* was slightly more appreciated due to its whitish flesh color. The texture evaluation was similar in both species.

P. djambal is genetically closely related to *P. bocourti* and shares several biological characteristics with this species, such as size of ova and larvae (Legendre *et al.*, 1999a; Pouyaud *et al.*, 2000). *Pangasius bocourti*, not represented in the Indonesia ichthyofauna, is found mostly in the Mekong River where it is cultivated in floating cages. In Vietnam, most of the aquaculture production of this species is processed as fillet for export to different Asian countries, Europe and United States (Cacot, 1999). The whitish color of *P. bocourti* fillet is more demanded by export market than the yellowish one of the *P. hypophthalmus*. Considering the flesh color similarity between *P. djambal* and *P. bocourti*, it is highly probable that the flesh of *P. djambal* will be suitable for export market.

Table 8. *Edible portion (dressing and fillet percentages) for* P. hypophthalmus *(n=3) and* P. djambal *(n=3).*

Fish	Weight of fish (g)	Dressed weight (g)	Dressing* (%)	Weight of fillet (g)	Fillet* (%)
P. hypophthalmus	1272 ± 28	971 ± 18	76.3 ± 0.3	779 ± 15	61.3 ± 0.5
P. djambal	1853 ± 101	1475 ± 96	79.7 ± 4.5	1143 ± 80	61.7 ± 1.9

*Fish dressed by evisceration and removing head and fins. Fillets correspond here to the flesh from behind the head up to the base of caudal fin, including skin and ventral part of the body.

Table 9. *Proximate analysis of flesh of* P. hypophthalmus *and* P. djambal *(mean ± SD).*

Fish	Protein (% d.w.)	Lipids (% d.w.)	Ash (% d.w.)	Water (%)
N	3	2	2	2
P. hypophthalmus	68.7 ± 0.1	3.3 ± 0.1	3.6 ± 0.1	66.9 ± 0.3
P. djambal	68.6 ± 0.1	5.8 ± 0.1	3.5 ± 0.1	59.3 ± 0.1

Table 10. *Sensory evaluation of fresh flesh of* P. hypophthalmus *and* P. djambal *(mean ± SD for 30 panelists).*

Fish	Color	Odor	Texture
P. hypophthalmus	5.0 ± 1.9	5.1 ± 1.0	6.3 ± 1.6
P. djambal	6.1 ± 1.5	5.8 ± 1.0	6.2 ± 1.7

Score: 1 (worst); 9 (excellent)

CONCLUSION

P. djambal is among the catfish most appreciated by consumers in Indonesia. The good adaptation of this species to pond environment, as well as its resistance to handling, high growth rate and ability to become sexually mature in captivity, confirm its great potential for aquaculture. The methods developed recently for induced ovulation, artificial fertilization and larval rearing of *P. djambal* offer new possibilities of fry availability for fish farms. All together, the results synthesized in this paper represent the first biological bases to the culture of *P. djambal* which appears promising in Indonesia.

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