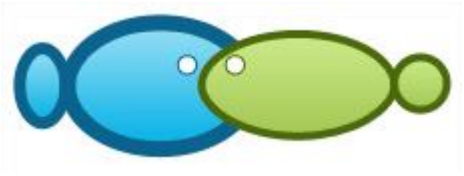

Aquatic weed *Ceratophyllum* sp. as a low-cost feed for brackishwater pond culture of tilapia *Oreochromis niloticus*

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Abstract. Two trials were undertaken to evaluate the potential for using the aquatic weed *Ceratophyllum* sp. as a feed source for tilapia (*Oreochromis niloticus*) culture in brackishwater ponds. The trials were undertaken in a brackishwater pond (salinity < 18 ppt) in Aceh, Indonesia. In both trials *Ceratophyllum* was fed to tilapia in 10 m × 10 m hapas in the pond and growth and productivity parameters compared with the unfed control fish. In the second trial, pellet feed was also compared as a feed source. The results showed that tilapia fed *Ceratophyllum* at the rate of 2 kg (wet weight) per day were 12–23% larger than the unfed controls at 115–120 days of culture. Although the fish fed pellets were 45% larger than the controls, the cost of the pellet feed makes this option economically unattractive.
Key Words: *Ceratophyllum*, tilapia, Aceh, growth, survival, economic evaluation.

Introduction. There is growing interest in culturing tilapia *Oreochromis* spp. in brackishwater, to open up new production areas (Cnaani & Hulata 2011; El-Zaeem et al 2012), to provide a polyculture option for shrimp farming (Wang et al 1998; Tendencia et al 2006; Cruz et al 2008), or to provide an alternative crop option to shrimp culture in brackishwater ponds (Kamal & Mair 2005; Putra et al 2013; Ninh et al 2014).

In Aceh and South Sulawesi provinces of Indonesia, brackishwater tilapia culture is being actively developed through a collaborative Australian–Indonesian project funded by the Australian Centre for International Agricultural Research (ACIAR). Previous research evaluated different strains of tilapia for production in brackishwater ponds in Aceh and in South Sulawesi (Putra et al 2013).

Although there is a ready market for brackishwater tilapia in Aceh (Putra et al 2013), the farm gate price is relatively low: around IDR 16,000 (~US$ 1.20) per kg at the time of writing. For farmers to be able to produce tilapia profitably, they need to minimise their feed costs. Tilapia can be produced extensively, with no or minimal feed inputs, or alternatively a cheap feed can be used to increase growth or support higher productivity.

The aquatic weed *Ceratophyllum* sp. grows prolifically in freshwater and brackishwater (up to 10 ppt) ponds in Aceh, and is readily available in quantities in areas where farmers are already trialling brackishwater tilapia culture. This study evaluated whether *Ceratophyllum* is a viable low-cost feed that would improve fish growth in brackishwater tilapia (*Oreochromis niloticus*) culture.

Material and Method. The two trials described here were carried out in a brackishwater pond at Arongan village, Simpang Mamplam sub-district, Bireuen district, Aceh province, Indonesia in April–October 2013 (Trial 1) and June–September 2014 (Trial 2). For these trials, the pond was rented from the owner and local farmers were hired to undertake routine tasks such as harvesting and feeding the *Ceratophyllum* and collecting and disposing of dead fish. *Ceratophyllum* was collected from adjacent ponds where it grows wild.

Samples of *Ceratophyllum* were gently rinsed with tap water to remove dirt, then dried and kept at -20°C before being sent to the Research Institute for Coastal Aquaculture (RICA) Maros, South Sulawesi, for proximate analysis. Proximate analysis of the dried samples was carried out according to AOAC (1999) methods. Moisture was determined after drying the sample using an oven (Memmert, Germany) at 105°C for 16 hours. Crude protein was determined according to micro-Kjeldahl procedure and lipid was extracted using chloroform and methanol. Ash was analysed using a muffle furnace (Barnstead, Thermolyne, CA, USA) at 550°C.

In the first experiment 12 hapas (enclosures fixed to the pond bottom), each 10 m × 10 m, were constructed in the pond. Pond preparation involved drying the pond for 2 weeks prior to filling, the application of saponin to remove potential predators and competitors, and the application of inorganic fertiliser at 100 kg ha^{-1} at initial filling. The hapas were arranged in two blocks of six, and treatments were randomly allocated to each block. Six hapas ('fed' treatment) were provided with 2 kg (wet weight) of *Ceratophyllum* daily; no *Ceratophyllum* was added to the six control hapas. Each hapa was stocked with 100 juvenile GIFT strain tilapia, averaging 6.1 g body weight.

Ceratophyllum was added to the 'fed' treatment hapas daily, at a rate of 2 kg wet weight of *Ceratophyllum* per hapa per day. This amount was equivalent to around 39 g of protein daily. The hapas were monitored daily and any dead fish removed. At harvest, all fish (F0 and F1) were measured for length and weight.

A second trial was undertaken to compare tilapia fed *Ceratophyllum* with fish fed a commercial pellet diet. As in the previous diet the *Ceratophyllum* treatment was fed 2 kg wet weight of *Ceratophyllum* per day, while the pellet treatment was given an equivalent weight of the pellet diet (20% crude protein) to provide approximately 39 g of protein per hapa per day, i.e. 195 g of pellets. The cost of the pellet diet was IDR 8,000 per kg. Pond preparation was as per the first trial.

Results and Discussion. Proximate analysis of *Ceratophyllum* samples showed that, like other aquatic weeds, *Ceratophyllum* has a very high moisture content, around 89% (Table 1). Crude protein content was about 1.9% on a wet weight basis (Table 1).

Table 1

Proximate composition of *Ceratophyllum* sampled from brackishwater ponds in Aceh

Component	*Percentage (wet basis)*
Moisture	89.1%
Ash	3.5%
Lipid	0.3%
Protein	1.9%
Fibre	1.5%

Water quality during the two trials (Table 2) was comparable with that usually found in 'traditional' brackishwater ponds. Because there is little water exchange in such ponds, moderate eutrophication is common and ponds typically exhibit low levels of dissolved oxygen in the morning (Putra et al 2013). Pond salinity in these trials ranged from 8 to 18 ppt (Table 2). In our experience this is a suitable range for brackishwater tilapia culture.

Table 2

Summary of water quality in the pond used for *Ceratophyllum* feed trials

Parameter	*Temperature (°C)*		*DO (mg L^{-1})*		*pH*		*Salinity*
	AM	PM	AM	PM	AM	PM	*(ppt)*
Mean	29.2	34.7	1.3	6.8	8.2	9.2	13.2
Minimum	28.5	32.8	0.2	6.1	6.5	8.6	8.0
Maximum	30.3	35.6	2.4	7.9	9.0	9.6	18.0

DO - dissolved oxygen.

Trial 1. In the first trial, fish in the hapas were observed to be breeding at around 100 days of culture (DOC). However, delay in harvesting the pond until 202 DOC resulted in continued breeding and rapid growth of the F1 fish, with the result that there was a large population of F1 fish in the hapas at harvest, and many had grown to overlap the size range of the larger F0 fish. Figure 1 clearly shows the bimodal distribution of fish at harvest. Most fish could be assigned to F0 and F1 populations based on a split at TL = 16 cm (Figure 1) but there was enough overlap between the F0 and F1 populations to confound the results of this first trial (Figure 1).

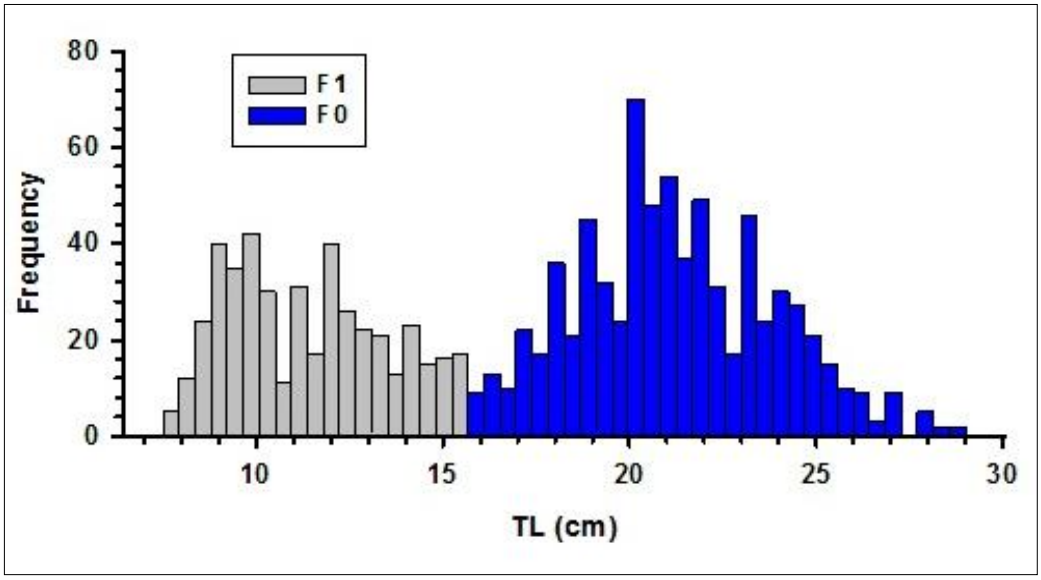

Figure 1. Tilapia harvested from Trial 1 at 202 DOC and allocated to F0 and F1 cohorts based on a size split at TL = 16 cm.

Analysing data from the fish assigned to the F0 group, i.e. those originally stocked, the growth of fish fed *Ceratophyllum* was faster than the unfed control (Figure 2). At harvest the fed group was 29% heavier than the control group (Table 3), a significant difference in weight (t-test, $p < 0.001$). Feed conversion ratios (FCRs) were high at 31.5:1 wet weight basis, equivalent to 3.4:1 dry weight basis (Table 3). Survival was similar (60–63%) for both treatment groups (Table 3).

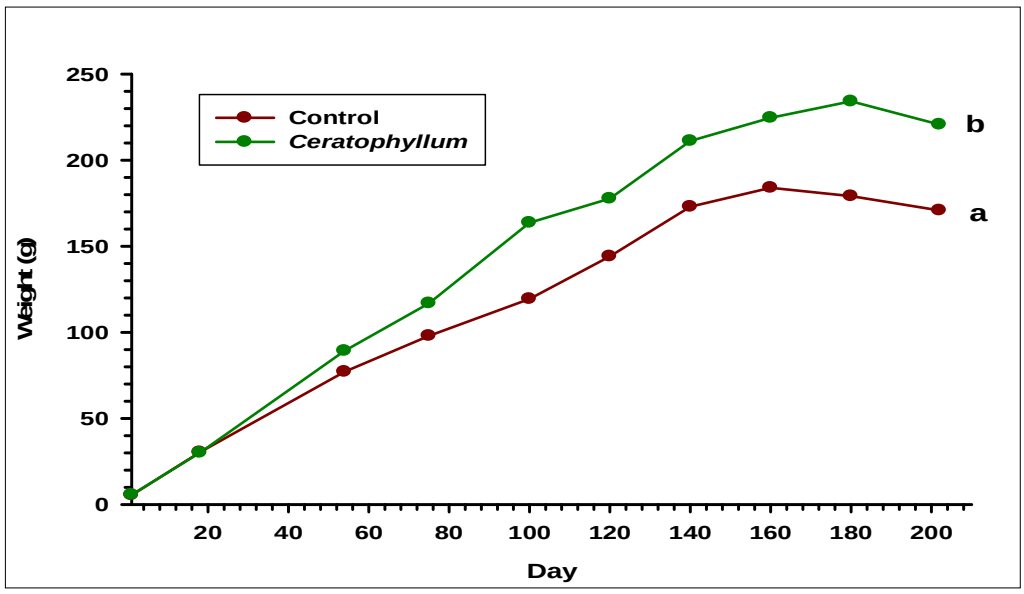

Figure 2. Average body weight of tilapia in Trial 1 fed *Ceratophyllum* compared with unfed control. Letters indicate significant differences between body weight at harvest ($p < 0.05$).

Table 3
Size, production and feed utilisation by tilapia harvested at 202 DOC from the first trial

Treatment	*Control*	*Ceratophyllum*
TL (mm)	20±2.4[a]	22±2.6[b]
Wt (g)	171±69[a]	221±77[b]
Biomass (kg)	10.7±4.1[a]	13.3±2.7[a]
FCR (WW)	–	31.5±7.1
FCR (DW)	–	3.4±0.8
Survival	63±19.5[a]	60±10.0[a]

Values are mean± SD. Different superscript letters across columns indicate significant differences between treatments (t-test, $p < 0.05$). FCR: food conversion ratio; WW: wet weight basis; DW: dry weight basis.

Trial 2. As in the previous trial, the tilapia began breeding at about 100 DOC. However, this trial was terminated at 115 DOC and the F1 tilapia could easily be discriminated from the experimental fish because of their small size, and were excluded from subsequent analysis. Survival in this trial was higher than in the previous trial, ranging from 85 to 93% (Table 4). Survival was highest in the two fed treatments. Fish fed pellets were 45% heavier than the control fish at harvest, while fish fed *Ceratophyllum* were 12% heavier than the control fish (Table 4, Figure 3). As in the first trial, the difference in average body weight between the control and *Ceratophyllum* treatments was not reflected in the biomass of fish harvested, although the biomass of fish from the pellet treatment was significantly higher (Table 4). FCRs were lower than in the previous trial, with 17.9:1 (wet weight basis) for *Ceratophyllum*-fed fish (equivalent to 2.0:1 dry weight basis) and 1.3:1 for pellet-fed fish.

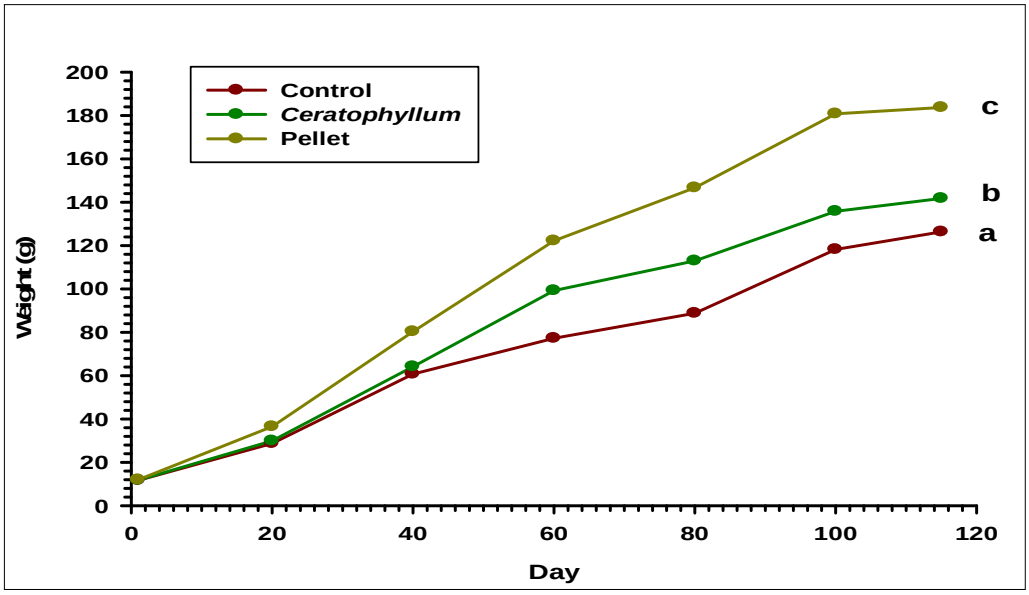

Figure 3. Average body weight of tilapia in Trial 2 fed pellets or *Ceratophyllum* compared with unfed control. Letters indicate significant differences between body weight at harvest ($p < 0.05$).

Several studies have shown that *Ceratophyllum* is not a preferred feed source for most fish. Chifamba (1990) found that *Ceratophyllum* was least selected of four aquatic plant species in redbreast tilapia, *Coptodon rendalli*. Grass carp, *Ctenopharyngodon idella* fed with *Ceratophyllum* had notably lower growth rates than those fed with other aquatic weeds (Venkatesh & Shetty 1978). Kapuscinski et al (2014) noted that the concentration of oxalic acid, which negatively affects palatability, was highest in *Ceratophyllum*, the least preferred of five macrophyte species given to rudd, *Scardinius erythrophthalmus* and Hajra (1987) described *Ceratophyllum* as having poor 'feed merit', possibly due to its lesser supply of digestible dry matter and protein-calorie for grass carp. Despite this, we found that feeding *Ceratophyllum* to tilapia improved growth, with no effect on survival.

An earlier study on feeding *Ceratophyllum* to tilapia (Tantikitti et al 1988) gave contradictory results. In this study, tilapia fed *Ceratophyllum* actually demonstrated lower weight gain (average 65 g cf. 88 g for unfed controls) over the 14 month duration of the experiment (Tantikitti et al 1988). Our experiments also demonstrated much faster growth with even the control fish reaching 125–145 g average body weight (ABW) within 4 months (Table 4).

Comparison of feeds. The results of these trials were used to calculate the relative value of a fish after taking into account feed costs. For the pellet feed, feed cost was IDR 8,000 per kg, while no cost was ascribed to the *Ceratophyllum* feed. *Ceratophyllum* was readily available in adjacent ponds and its collection represents a time commitment by the farmer(s). It can be argued that collecting and feeding *Ceratophyllum* involves an opportunity cost, because the farmer could use that time to undertake alternative income-generating opportunities. However, this is only the case when there are viable employment alternatives available to pond farmers.

Socio-economic evaluations of farmers adopting brackishwater tilapia culture in Aceh revealed that between 54 and 72% of farmers categorise their major employment as 'fish farmer' (Hasanuddin et al, unpublished data). For these farmers, there is no opportunity cost associated with gathering and feeding *Ceratophyllum*. Even for farmers whose primary employment is not farming, such as public servants (7–8% of those interviewed) there is no opportunity cost associated with feeding *Ceratophyllum* since the two employment options are not mutually exclusive. So in most cases of Acehnese traditional pond farmers, we feel that there is no opportunity cost associated with feeding *Ceratophyllum* and consequently *Ceratophyllum* can be considered a 'free' feed.

The use of *Ceratophyllum* as a feed boosts individual fish size by between 12 and 23% in fish harvested at about 115–120 DOC (Table 5). This directly increases the economic benefit to the farmer, who is harvesting larger fish. In contrast, the additional cost of the pellet feed used is not compensated for by the increased size of the fish, and fish fed the pellet diet were less profitable than those from the other treatments (Table 5).

Table 5

Size and relative value (i.e. profit) of fish from the different feed treatments

Treatment	*Control*		*Ceratophyllum*		*Pellet*	
	ABW (g)	*Value (IDR/fish)*	*ABW (g)*	*Value (IDR/fish)*	*ABW (g)*	*Value (IDR/fish)*
Trial 1 (120 DOC)	144	2,305	178	2,843	–	–
Trial 2 (115 DOC)	126	2,021	142	2,268	184	986

Trial 1 values are taken from a sub-sample of fish taken at 115 DOC to enable comparison with the Trial 2 harvest data (120 DOC). ABW: average body weight.

Conclusions. Overall, the results of the two trials indicate that the use of *Ceratophyllum* as a feed increases fish size by an average of 12% to 23% over a 115–120 day culture period. *Ceratophyllum* is readily available in low-salinity (< 10 ppt) brackishwater ponds in Aceh and provides effectively a free supplementary feed source for farmers culturing tilapia using traditional methods. Additional research on feed rates and other aspects of using *Ceratophyllum* as a feed source is warranted.

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