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ORIGINAL PAPER

Economic value of wild aquatic resources in the Ang Trapeang Thmor Sarus Crane Reserve, North-western Cambodia

Kesaro Loeung · Dietrich Schmidt-Vogt · Ganesh Prasad Shivakoti

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Abstract Wild aquatic resources are important for the livelihoods of rural communities in the Greater Mekong. This study assessed the economic value of wild aquatic animals and plants in the total mean annual net income of sample households in the study site which were divided into aquatics-non-dependent, and aquatics-dependent households. It was hypothesized that there is a significant difference in income between aquatics-non-dependent, and aquatics-dependent households, and among different sub-groups of aquatics-dependent households. Data was collected by direct structured questionnaire interviews and was analyzed using One-way analysis of variance; Independent sample *t* tests, and one-sample *t* test. Aquatics-dependent households have a greater total mean annual disposable income than their counterparts. Wild aquatics make a major contribution to the income of aquatics-dependent households. There was a significant difference of income among the three subgroups of aquatics-dependent households: full-time fishing provided a higher income than part-time fishing and non-fishing. Income from fish is the most important contribution to the total income of full-time fishing and part-time fishing households when compared with other aquatic animals and plants. We therefore conclude that among different groups of aquatics-dependent households, the full-time fishing households are more dependent on aquatics, especially fish compared with the part-time fishing and non-fishing counterparts.

Keywords Ang Trapeang Thmor Sarus Crane Reserve · Cambodia · Household income · Wild aquatic resources

K. Loeung · G. P. Shivakoti
School of Environment, Resources and Development, Asian Institute of Technology, P.O. Box 4, Khlong Luang, Bangkok, Pathumthani 12120, Thailand
e-mail: Loeung.Kesaro@ait.asia

G. P. Shivakoti
e-mail: ganesh@ait.asia

D. Schmidt-Vogt
Kunming Institute of Botany, Chinese Academy of Sciences, Heilongtan, Kunming 650201, China

D. Schmidt-Vogt (✉)
World Agro Forestry Centre, East and Central Asia Regional Office, Heilongtan, Kunming 650201, China
e-mail: schmidt-vogt@mail.kib.ac.cn

Introduction

Approximately 50 % of the world's wetlands have been completely lost. An important reason is that many decision-makers are unaware of their value to the rural poor, considering wetlands as 'wastelands', and paying little attention to their preservation and protection (Verma 2001). In the lower Mekong basin, the inland fisheries production may have been underestimated by 2.6–21 times (Coates 2002). This leads to

an underestimation of the socio-economic contribution of these resources to rural communities and households. Such underestimation further facilitates the un-checked degradation of aquatic ecosystems and biodiversity including endangered species e.g., Irrawaddy dolphins *Orcaella brevirostris* (Ryan 2012).

Wild aquatic resources are tangible products of wetlands and are generally known as direct use values of wetlands that can be directly derived for subsistence and sale (Stuip et al. 2002). These resources include all non-cultivated plants (e.g., submerged and floating water plants, emergent and surrounding trees and shrubs) and animals (e.g., amphibians, fish, invertebrates, mammals, reptiles, and waterfowls) that occur naturally in wetlands. Fish and other aquatic animals (OAAs) are the most reliable sources of income for poor aquatic resource-dependent communities and households with little alternative food production capacity in developing countries, including those in the Mekong river basin (Baran et al. 2007; Béné et al. 2009; Nonga et al. 2010; Manyatsi et al. 2010; Kawarazuka 2010; So and Touch 2011; Onadeko et al. 2011).

There is a lack of data, and thus inadequate documentation in national statistical reports, on the annual harvest size and economic value of harvested aquatic animal and plant species (Baran and Myschowoda 2008; Mainuddin et al. 2011). The aforementioned studies have focused only on one aspect of livelihoods i.e., aquatic resources to the exclusion of other aspects, especially agriculture. While large segments of the population in developing countries, especially the Mekong river basin, primarily depend on agriculture, they also rely on other activities such as harvesting wild aquatics to diversify their incomes. Little is known about the cumulative value of wild aquatic resources (WARs) and agricultural produce together in sustaining rural livelihoods.

This study assessed the economic value of wild aquatic animals and plants in rural household incomes in Ang Trapeang Thmor Sarus Crane Reserve, Northwestern Cambodia. For this purpose, households in the study area were divided into WARs non-dependent groups, and WARs-dependent households. The WARs-dependent group was further divided into three subgroups: full-time fishing, part-time fishing and non-fishing. To assess the economic value we (i) compared total annual net income between the WARs-dependent (full-time, part-time and non-fishing) households and WARs-non-dependent households; and (ii) compared total annual net income among different groups of the WARs-dependent (full-time, part-time and non-fishing) households. It was hypothesized that there was a significant difference in the amount of total mean annual net income between WARs-dependent and non-dependent households, and among different groups of WARs-dependent households, and that aquatics-dependent households are expected to have a greater mean annual net income than aquatics-non-dependent households.

Methods

Geographical setting

This study was conducted in Ang Trapeang Thmor Sarus Crane Reserve located in Phnom Srok District, Banteay Meanchey Province, North-western Cambodia. The province consists of 55,538 households comprising 250,809 persons (NIS 2009). The total population living in the Reserve is 55,048 people in 11,905 households, in 99 villages, in 11 communes, in the four districts of the province. People rely on aquatic habitats for fishing and harvesting other aquatic products to supplement household food and income (Kumaran 2001). The Reserve is situated in the basin of the Tonlé Sap great lake. The great lake significantly expands its volume in the rainy season starting from May and lasting until October. The volume of the great lake decreases in the dry season from November to April. The Reserve was selected as study site because it is a small and discreet management unit, and because it exemplifies many of the management features evident in wetland environments throughout Cambodia. The reserve supports up to half the population of the Indochinese endemic subspecies of the globally vulnerable Sarus crane *Grusantigone sharpie* (Bird Life International 2012) and other threatened wildlife (Kim Hout et al. 2003), including a population of the globally endangered Eld's deer *Rucervus eldii* (Timmins and Duckworth 2008). Because of these biological values, the reserve was designated as a conservation area in accordance with the Government decree No. 0200/10 dated 22 February 2000, declaring a total conservation territory of 12,650 ha. The wetlands system includes Trapeang Thmor reservoir which is a body of fresh and static water (784 ha), flooded forests (156 ha), grassland (2,453 ha), irrigated canals, creeks, ponds and

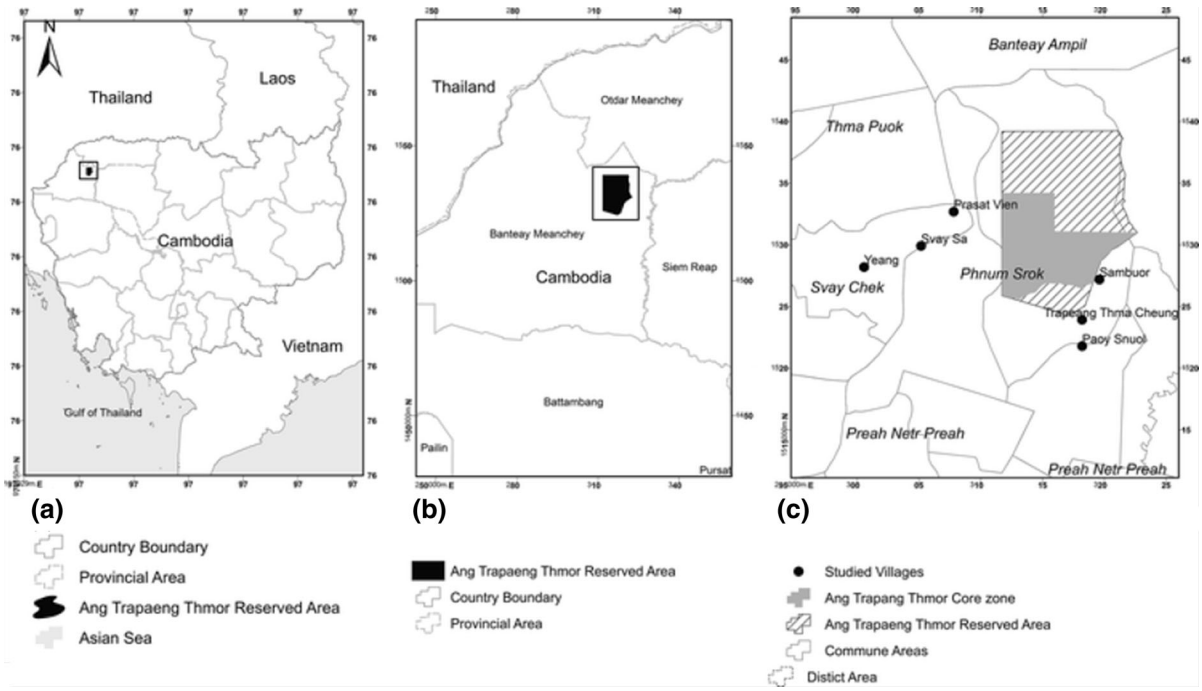

Fig. 1 *Map* showing location of study area **a** location of Cambodia **b** location of study area (Ang Trapeang Thmor Reserved Area) **c** location of study villages

around 20,000 ha of rice paddy fields (data from interviews with the District Governor, Mr. KY Chhuong in 2009) (Fig. 1).

Sampling sites, size and respondents

Study villages were selected from two communes: Paoy Char (located in the vicinity of the reservoir), and Phkoam ($\sim$10 km from Paoy Char by road) (Table 1). From Paoy Char commune, we selected three villages out of a total of eight, and from Phkoam commune three villages out of a total of 11. The six study villages are spread over the two communes and were selected to provide maximum coverage of the area. The sample size from each commune was determined following Yamane (1967). The total sample size consisted of 232 households. Sample households (respondents) from each village were randomly selected using MS Excel software from a list of total households obtained from village heads' registry books. For analysis, the households were divided into WARs-dependent and WARs-non-dependent households. WARs-dependent households were defined as those in which at least one household member (either husband, wife, children or other dependent member) had engaged at least once in harvesting WARs (fishing, catching OAAs and harvesting aquatic plants) either within the wet or dry season of the year, for either household consumption (as human food or animal feed), or sale to generate income, or for both purposes. WARs-non-dependent households are defined as households of which no household member engages in fishing or harvesting other aquatic organisms at any time or for any purpose. These households typically run small groceries, sell home-made desserts and foods, and provide services (e.g., communal policemen, primary and secondary school teachers, motorbike taxi drivers, wage laborers etc.). For comparison purposes, WARs-dependent households were divided into fishing and non-fishing households. Fishing households are those engaged in fishing (and possibly harvesting OAAs and aquatic plants) and were further divided into full-time and part-time fishing households. Full-time fishing households are those fishing for food consumption and for sale, while part-time fishing households fish for home consumption only. Non-fishing households do not fish, but catch OAAs or harvest aquatic plants.

Table 1 Sampling sites and sample households in Banteay Meanchey province, Cambodia

District	Commune	Village			Total HHs[a]	Total HHs from sample commune	Sample size (HHs)
		Name	Latitude	Longitude			
Phnum Srok	Paoy Char	Paoy Snuol	318200	1521800	337	595	(124 × 337/595) = 70
		Trapeang Thma Cheung	318190	1523934	147		(124 × 147/595) = 30
		Sambuor	319600	1527200	111		(124 × 111/595) = 23
Svay Chek	Phkoam	Prasat Vien	307800	1532700	67	370	(110 × 67/370) = 20
		Svay Sa	305165	1529924	204		(110 × 204/370) = 60
		Yeang	300556	1528208	99		(110 × 99/370) = 29
Total						965	232

Sample size from each commune is determined following Yamane (1967): $n_0 = N/(1 + N \times e^2)$

Where

n_0 sample size, N total population (households in each commune), e standard error (8 %)

Actual sample size from each village is determined following Yamane (1967): $n_1 = n_0 \times N_1/N$ Where

n_1 sample size, N_1 total population [households in each village]

[a] *Source* Banteay Meanchey (2010)

Data collection and analysis

This study was conducted through face-to-face interviews using structured questionnaires to assess sample households' backgrounds, sources of income, and associated production costs incurred from on-farm, off-farm and non-farm activities. Five or six face-to-face interviews with household heads were conducted per day from March through April 2012. Each interview lasted approximately 1 h. A total number of 232 sample households were interviewed.

We utilized IBM SPSS (statistical package for social studies) Statistics 19 Program to analyze data in combination with a narrative approach. Data from the four groups were statistically analyzed using One-way ANOVA (analysis of variance); data from each group was compared using independent sample *t* test. One-sample *t* test was used to compare data from each group with a given value from previous studies (Ahmed et al. 1998; NIS 2011). Extreme values or outliers provided by the sample households were excluded from analysis not because of incorrect data collection or entry, but because these few outliers were not representative of the communities and skewed the mean.

To estimate annual per household net income from on-, and off-farm sources, local average market prices per unit of goods were multiplied by the annual quantity of products produced/harvested and production/operation costs deducted (Bann 2003). Rice is the main staple food for Cambodians. Production cost for rice included cost of chemical substances (insecticide, herbicide, pesticide, etc.), fertilizers (NPK and urea), rental of tractor/power tiller to prepare paddy field, and thresher to harvest rice. However, we did not calculate cost of inputs for rearing livestock (mainly chicken, duck and cattle), except for swine which require intensive management. Livestock such as buffalo and cattle are reared free range, with no cost for feed, and also no cost for vaccination and other veterinary services. Swine, however, are raised in cages in the farm backyard. Costs for rearing swine include feed (rice, rice powder, vegetables, and processed feed), veterinary fees and medicines. During the data collection period, high costs of rice powder and low income from sale meant that farmers raised swine at an economic loss. If this trend continues, raising swine may decline in future.

In terms of off-farm sources of income, this study was focused on WARs. Non-timber forest products were excluded. Input costs for family-scale fishing consisted mainly of the purchase of nets (gillnets, cast nets) and hooks (baited hooks), which are made outside of the village. There was no entry fee required for fishing in the reservoir (resources are under communal management regime). There were no labor costs or costs for transport of fish catches from fish landing to local market because fishermen catch fish themselves and also transport the small amount of fish that is sold from the fish landing site to the nearest

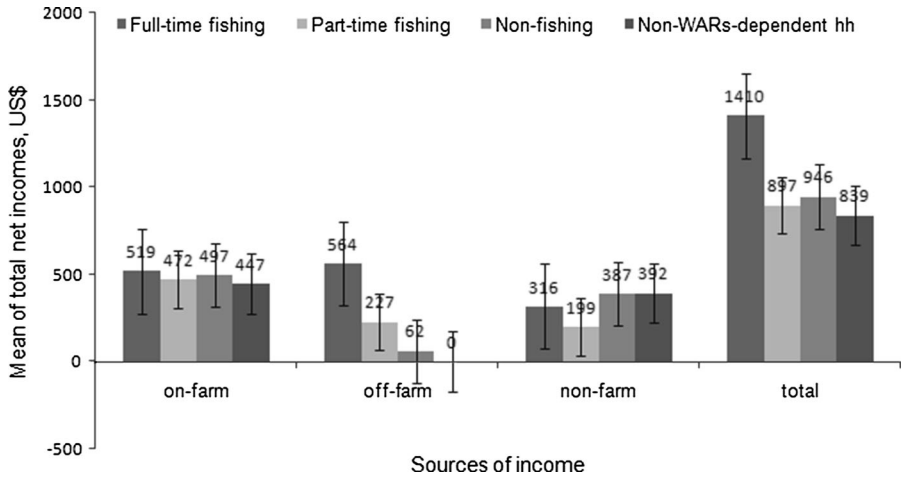

Fig. 2 *Bar chart* showing mean and SE of total net income per year per sample household, N = 232

village market by themselves and on their own bicycles.

Non-farm sources of income consisted of man-month salaries/incomes/remittances from household members working within and outside the village or the country (e.g., public servants such as communal policemen and local teachers; and wage laborers such as housekeepers, guardians, house maids, garment factory workers). These sources of income were deducted from living costs (food, accommodation, transportation, medicines etc.) to obtain household net income from non-farm sources.

Results

The average size of sample households was 5.02 persons (SD = 1.72) including parents, children and relatives who consumed food cooked in one kitchen and lived under one roof. Mean household labor force was 2.88 persons (SD = 1.41) excluding elderly, disabled people and school children (N = 232).Among the total sample households (N = 232), a group of 25 (10.8 %) were WARs-non-dependent, and 207 (89.2 %) were WARs-dependent households. The later consisted of full-time, n = 53 (22.8 %), part-time, n = 114 (49.1 %) and non-fishing households, n = 40 (17.2 %). The results of One-way ANOVA (Fig. 2) show that the total annual net income generated from the three sources (on-, off- and non-farm) was significantly different among the four groups (F = 2.893, p = 0.036, df = 3): aquatics-dependent (full-time fishing, part-time fishing and non-fishing) households have a greater mean annual net income than aquatics-non-dependent households. However, when compared within each source, only the total mean annual net income generated from off-farm was significantly different (F = 4.509, p = 0.005, df = 3): full-time fishing households > part-time fishing households > non-fishing households > aquatics-non-dependent households, while the other sources did not show a significant difference (on-farm: F = 0.127, p = 0.944, df = 3; non-farm: F = 2.577, p = 0.055, df = 3).

On-farm activity

Paddy rice is the main staple food and most important compared with other non-rice crops. Farmers rely on rainfall to grow early and late wet-season rice. In the dry season, they also plant irrigated dry-season rice. Average yield (ton/hectare) varied according to growing seasons: early wet-season (mean = 1.88, SD = 1.16); late wet-season (mean = 1.73, SD = 0.58); and dry-season (mean = 3.69, SD = 2.05). The results of One-way ANOVA show that the total average quantity of paddy rice produced (ton) per household per year was not significantly different among the four groups (F = 1.428, p = 0.235, df = 3): full-time fishing household, n = 53 (mean = 2.20, SD = 1.40); part-time fishing, n = 114 (mean = 2.88, SD = 1.97); non-fishing, n = 40 (mean = 2.96, SD = 2.82); and WARs-non-dependent households, n = 25 (mean = 2.63, SD = 2.78). The price of paddy rice (USD/ton)

was found to vary according to variety (and corresponding quality): early wet-season (mean = 205, SD = 30); late-wet-season (mean = 184, SD = 11); dry-season (mean = 193, SD = 3). Besides rice, farmers plant cassava, muang bean, water melon, melon, corn, and mango for home consumption.

Livestock (cattle, water buffalo and poultry- chickens and ducks) are raised as free-ranging animals, except for swine which are raised in cages in household backyards. Price (USD/head) of livestock varied according to size (and corresponding age): cattle and buffalo (mean = 238, SD = 52), poultry (mean = 3.12, SD = 0.19), and swine (mean = 136.57, SD = 21.60). The results of One-way ANOVA showed that there was no significant difference among the four groups in terms of the total average quantity (heads) of cattle and buffalo ($F = 2.267$, $p = 0.084$, $df = 3$), poultry (chicken/duck) ($F = 0.492$, $p = 0.689$, $df = 3$), and swine ($F = 1.597$, $p = 0.194$, $df = 3$) sold per household per year and shown in the Table 2 below.

The results of Independent sample t-test show that there was no significant difference between total mean annual net incomes from ***on-farm*** income sources when we compare the following household groups:

(i) Full-time fishing (n = 53, mean = 519, SD = 704) and WARs-non-dependent households (n = 25, mean = 447, SD = 663): $t = 0.433$, $p = 0.666$, $n = 78$, $df = 76$;
(ii) Part-time fishing (n = 114, mean = 472, SD = 425) and WARs-non-dependent households ($t = 0.240$, $p = 0.811$, $n = 139$, $df = 137$);
(iii) Non-fishing (n = 40, mean = 497, SD = 672) and WARs-non-dependent households ($t = 0.296$, $p = 0.768$, $n = 65$, $df = 63$);
(iv) Full-time and part-time fishing households ($t = 0.539$, $p = 0.590$, $n = 167$, $df = 165$);
(v) Full-time and non-fishing households ($t = 0.153$, $p = 0.878$, $n = 93$, $df = 91$);
(vi) Part-time and non-fishing households ($t = -0.275$, $p = 0.784$, $n = 154$, $df = 152$);

Off-farm activity

Different traditional fishing equipment was used by full-time and part-time fishing households in different seasons to target different species and sizes of fish. Gill nets and cast nets (mesh size ranged from 2.5 to 6.5 cm) are used in both rainy and dry seasons. Traps and baited hooks are mainly used in the rainy season. Traps are deployed to target fish, crabs, frogs, snails and insects while baited hooks are used to lure and catch fish. However, small-scale harmful fishing equipment (e.g. electrocution) was reported by villagers during the interviews, as being used in the reservoir, especially at the night time outside the no-catch zones despite prohibition under national and local laws. Besides fishing in the reservoir, people fish in streams, canals, creeks, ponds, paddy fields, but the catch was low in the dry season when fish stocks outside the reservoir were limited. When asked if fishing was presently difficult, 116 fishing households (69.5 %, n = 167) said it was difficult to catch fish and that size of fish catches were smaller compared to 5 years ago. Based on this perception/local knowledge, wild fish resources have declined with a negative impact on local livelihoods. The results of Independent sample t-test showed that there was no significant difference of total average number of household member (person) engaged in fishing ($t = -0.422$, $p = 0.674$, $n = 167$, $df = 165$) between full-time fishing, n = 53 (mean = 1.17, SD = 0.427) and part-time fishing households n = 114 (mean = 1.20, SD = 0.503). Fifty-one fish species were named by fishers during the interviews which included the

Table 2 Number of household and total average quantity (heads) of livestock sold per year per household

Household group	Cattle/buffalo			Poultry (chicken/duck)			Swine		
	N	Mean	SD	N	Mean	SD	N	Mean	SD
Full-time fishing	29	2.66	2.075	44	9.64	10.111	28	3.07	2.867
Part-time fishing	61	2.62	1.624	83	8.70	8.405	59	2.39	2.327
Non-fishing	24	2.17	1.239	26	11.04	8.929	16	1.62	0.885
WARs-non-dependent	11	1.36	0.674	16	9.62	6.098	10	1.90	1.287
Total	125	2.43	1.648	169	9.39	8.747	113	2.41	2.290

following economically valuable species that are sold to traders and not consumed locally: Bronze featherback *Notopterus notopterus*, Swamp eel *Monopterus albus*, Peacock eel *Macrognathus siamensis* and Sheat fish *Ompok sp.* Price of fish catches (USD/kg) varied according to species (and corresponding size). The results of Independent sample *t* test showed that there was no significant difference of average price (USD/kg) of fish catches between full-time fishing, $n = 52$ (mean = 1.45, SD = 0.47) and part-time fishing households $n = 114$ (mean = 1.45, SD = 0.00) ($t = -0.073, p = 0.942, n = 166, df = 164$). Selected fish species which are commonly on sale at the local market, and their corresponding size and price are presented in Annex 1.

The results of Independent sample t-test showed that there was a significant difference between full-time and part-time fishing households in terms of total mean annual fish catch ($t = 4.41$, $p = 0.000$, $n = 167$, $df = 165$), total mean annual cost of fishing ($t = 4.586$, $p = 0.000$, $n = 166$, $df = 164$), and total mean annual net income ($t = 3.54$, $p = 0.001$, $n = 166$, $df = 164$), with full-time fishing households having the higher values (Table 3).

Fish alone contributed 45 % (253/564) to the total mean net income from WARs of full-time fishing households, $n = 53$, and 41 % (93/227) to the income of part-time fishing households, $n = 113$.

Other aquatic animals and plants

OAAs other than fish and various species of aquatic plants which are seasonally available and collected by villagers for household consumption are presented together with their corresponding local market price (USD/kg) in Annex 1. Various species of waterfowl and mammals, especially the Lesser false vampire bat *Megaderma spasma* are plentiful, but unmarketable because they are protected by laws which are enforced by a local conservation team with assistance from International Crane Foundation and Wildlife Conservation Society Cambodia Program.

The results of Independent sample t-test show that total mean annual net income from off-farm sources was significantly different between the different groups of household category:

(i) Full-time fishing ($n = 53$, mean = 564, SD = 1235)and WARs-non-dependent households($n = 25$, mean = 0, SD = 0): $t = 2.276$, $p = 0.026$, $n = 78$, $df = 76$;
(ii) Non-fishing ($n = 40$, mean = 62, SD = 116)and WARs-non-dependent households ($t = 2.643$, $p = 0.010$, $n = 65$, $df = 63$);
(iii) Full-time and part-time fishing households ($n = 114$, mean = 227, SD = 744): $t = 2.233$, $p = 0.027$, $n = 167$, $df = 165$;
(iv) Full-time and non-fishing households ($t = 2.568$, $p = 0.012$, $n = 93$, $df = 91$);

However, there was no significant difference of total mean annual net income from off-farm source between the following groups:

(i) Part-time fishing and WARs-non-dependent households ($t = 1.519$, $p = 0.131$, $n = 139$, $df = 137$);
(ii) Part-time and non-fishing households ($t = 1.396$, $p = 0.165$, $n = 154$, $df = 152$);

OAAs and aquatic plants contributed 6.5 % (62/946) to the mean total annual net income of the non-fishing households, $n = 40$.

Non-farm activity

Villagers take up temporary, seasonal and long-term work as labourers at construction sites, factories, agricultural farms and fishing vessels, both within and outside the country. Data obtained from interviews show that from 172 households (74 % of the total sample, $N = 232$), at least one member was involved in wage labour activities. The results of One-way ANOVA show that the total average number of household members (person) engaged in wage labor per household per year was not significantly different among the four groups ($F = 0.062$, $p = 0.980$,

Table 3 Number of households, and total average quantity of fish catches, total mean fishing cost and net income per household per year

Household group	Fish catches (kg)			Fishing cost (USD)			Net income from fish (USD)		
	N	Mean	SD	N	Mean	SD	N	Mean	SD
Full-time fishing	53	215	326	53	45	40	53	253	446
Part-time fishing	114	80	95	113	24	17	113	93	135

df = 3): full-time fishing household, n = 43 (mean = 1.88, SD = 1.38); part-time fishing, n = 75 (mean = 1.80, SD = 1.04); non-fishing, n = 34 (mean = 1.85, SD = 0.925); and WARs-non-dependent households, n = 20 (mean = 1.80, SD = 0.951). Wages vary according to skill and location: 3–5 USD/day (construction and farm workers within the country), 7-10 USD/day (working on Thai fishing vessels or in food processing factories in Thailand). Wage rates include food and accommodation as well as transportation. During the interviews, it was found that the majority of Cambodians from the study area use illegal migration channels to enter and obtain work in neighboring Thailand. They use these channels as the majority of villagers are illiterate and have difficulty with the paper work required to obtain legal documents.

The results of the Independent sample *t* test showed that there was no significant difference between the total mean annual net incomes from non-farm source of the following groups:

(i) Full-time fishing (n = 53, mean = 316, SD = 545) and WARs-non-dependent households (n = 25, mean = 392, SD = 380): t = −0.626, p = 0.534, n = 78, df = 76;
(ii) Non-fishing (n = 40, mean = 387, SD = 637) and WARs-non-dependent households: t = −0.033, p = 0.974, n = 65, df = 63;
(iii) Full-time and part-time fishing households(n = 114, mean = 199, SD = 332): t = 1.722, p = 0.087, n = 167, df = 165;
(iv) Full-time and non-fishing households (t = −0.578, p = 0.564, n = 93, df = 91);

A significant differences of total mean annual net income from non-farm source was observed between the following groups:

(v) Part-time fishing and WARs-non-dependent households (t = −2.568, p = 0.011, n = 139, df = 137);
(vi) Part-time and non-fishing households (t = −2.381, p = 0.018, n = 154, df = 152);

Total net annual household income

The results of Independent sample *t* test further show that there was no significant difference of total mean annual net income from the three sources between the following groups:

(i) Full-time fishing (n = 53, mean = 1410, SD = 1,522) and WARs-non-dependent households (n = 25, mean = 839, SD = 710): t = 1.783, p = 0.079, n = 78, df = 76;
(ii) Part-time fishing (n = 114, mean = 897, SD = 968) and WARs-non-dependent households: t = 0.286, p = 0.776, n = 139, df = 137;
(iii) Non-fishing (n = 40, mean = 946, SD = 1,087) and WARs-non-dependent households: t = 0.438, p = 0.663, n = 65, df = 63;
(iv) Full-time and non-fishing households (t = 1.638, p = 0.105, n = 93, df = 91);
(v) Part-time and non-fishing households (t = −0.265, p = 0.791, n = 154, df = 152);

A significant difference of total mean annual net income from the three sources between the full-time and part-time fishing households (t = 2.635, p = 0.009, n = 167, df = 165) was observed.

Discussion

Cambodia's economy is based on agriculture. More than 80 % of the total population (currently ~14 million) live in rural areas, and depend on agriculture, and other activities related to natural resources as sources of household income. Villagers generally rely on three activities: (i) on-farm (cultivating rice and non-rice crops and rearing livestock); (ii) off-farm (fishing, catching OAAs, harvesting aquatic plants, collecting non-timber forest products), and (iii) non-farm (e.g., wage labor/services providers) to diversify their livelihoods.

On-farm activity

In the study site, people cultivate crops, especially different varieties of rice as a main staple food, and raise cattle, swine, chicken, and ducks in household backyards and on public communal grazing areas. On-farm activity contributes just over one third (37 %) of the total mean annual net income of full-time fishing households; and slightly more than 50 % to part-time, non-fishing and WARs-non-dependent households total mean annual net income (Figs. 2, 3). However, the production of crops and livestock is constrained by lack

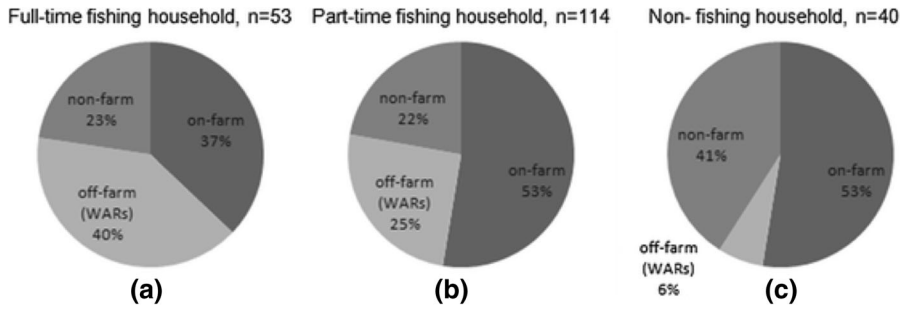

Fig. 3 *Pie chart* showing contribution of wild aquatic resources in total mean annual net income per household **a** full-time fishing, n = 53 **b** part-time fishing, n = 114 **c** non-fishing, n = 40

of input (money, water/irrigation, manpower, technical advice); natural factors (flood, drought, pests such as rats, crabs, caterpillars, fleas, grasshoppers, white ants, water birds and disease outbreaks); and non-competitive market systems (farmers lack access to markets and depend on middlemen coming to buy products). For example, average yield of the wet-season and dry-season rice in the study site was 1.8 and 3.7 ton/ha, respectively which is relatively lower compared with the yields reported by the NIS (2011): 2.8 (wet-season) and 4.2 t/ha (dry-season rice). In the study site, only 25 households (10.8 %, n = 232) cultivated dry-season rice. In Cambodia, farmers commonly rely on rainfall to grow rice (grow wet-season rice) because access to irrigation is limited. This common practice is in line with the report of NIS (2011) which reports that 232,200 ha (98.8 %) of total cultivable paddy rice for the year 2010 for the whole province of Banteay Meanchey (235,200 ha) was used for cultivation of the wet-season rice. NIS (2011) further stated that only 2,800 ha (1.2 %) of the total paddy field area in the Banteay Meanchey is used for cultivation of dry-season rice. Land tenure/ownership is an important factor relating to agricultural productivity at the household level, especially paddy rice cultivation. The interviews showed that 9 households (3.9 % of the total sample of 232 households) are paddy-field/farm landless families in which 6 households (67 %) of the total landless households (n = 9) are WARs-dependent households: full-time fishing (1), part-time fishing (2), and non-fishing households (3). For livestock productivity in the study site (e.g., poultry, pig, cattle and water buffalo) disease outbreak is one among a range of factors causing a loss of household revenue. For example, animals can become sick and die suddenly causing major loss for household income. None of the sample households were engaged in aquaculture. Literature suggests that aquaculture could help to improve household income and nutrition security, reduce out-migration, prevent poor households from selling cultivable land and becoming landless families, reduce pressure on natural resources, and contribute to biodiversity conservation (Friend et al. 2009; Kawarazuka 2010). In view of the results of our study, aquaculture could compensate for the declining wild fisheries. However, aquaculture produces negative environmental externalities such as water pollution and disease. For generations, rice and fish have been the two main food items for Cambodians, hence our focus on these items rather than on non-rice crops and non-fish animal protein food.

Off-farm activity

Rural households in the study area engage in activities other than agriculture to diversify their household income and to meet their food consumption needs. This includes harvesting of seasonally available WARs to supplement food from crops and livestock. Off-farm activity contributes two-fifth (40 %) of the total mean annual net income of full-time fishing households; one-fourth (25 %) to part-time and one fifteenth (6.5 %) to non-fishing households total mean annual net income. These differences showed that WARs including fish, OAAs and aquatic plants were found to make a major contribution to the income generation of the aquatics-dependent households.

Aquatics are important sources of household income in the study area and elsewhere in the country. Annual income per household (USD473) derived from aquatics in the nearby province of Battambang (Ahmed et al. 1998) is comparable to the rate found in this study: USD564 per full-time fishing, and

USD227 per part-time fishing household. It should be noted that the present study reported the mean annual *net* income which means fishing cost was deducted from the gross income. We were not sure if the assessment by Ahmed et al. (1998) was based on the mean annual net income, or gross income. However, millions of rural households with little alternatives for food production capacity rely on inland fisheries in Cambodia (Torell et al. 2004). In Asia, aquatics collected from the wild by rural poor families are sold directly to earn extra cash (Halwart and Gupta 2004).

A number of economically important fish species were caught including Bronze featherback (*Notopterus notopterus*), Swamp eel (*Monopterus albus)*, Peacock eel (*Macrognathus siamensis*), and Cutter fish (*Ompok* sp.). Bronze featherback was most abundant and caught by gill nets the whole year round from the reservoir. The Bronze featherback is found in Southeastern Asia, in lakes, floodplains, canals and ponds, and large numbers are transported by land on ice from fish landings around Tonlé Sap Great Lake to markets in Thailand (Rainboth 1996). Inland fisheries and aquatic resources offer prospects for Cambodian national development (Torell et al. 2004).In the study site, fish alone contributes more than 40 % of full-time fishing and part-time fishing households total mean annual net income from WARs. This confirms that fish is the most important animal compared with OAAs, which is partly due to fish being accessible the whole year round unlike other wildlife (e.g., waterfowls, turtles, poisonous snakes), some of which are protected by law. This is in line with the studies by Kawarazuka and Béné (2011), Frid and Paramor (2012),Olaoye et al. (2012) who state that fish represents an essential and irreplaceable source of high quality, cheap animal protein, containing important nutrients such as iron, zinc, calcium, vitamin A and vitamin C.

The average total annual fish catch per household reported from the nearby province of Battambang by Amilhat et al. (2005) of 108 kg which includes small species, is lower than the amount found in the study area (mean = 123 kg, SD = 208),but not significantly different ($t = 0.936$, $p = 0.350$, $df = 166$, $n = 167$). Villager-fishers sell big and fresh fish for relatively high prices, and consume the small less commercially valuable species. Even spoiled fish or by-catches are cooked with rice and vegetables for swine feed. This practice is in line with the study by Kottelat and Witten (1996) who report that fishers do not have a concept of "trash fish"; even poisonous fish are eaten after the poisonous organs have been removed, and small fish are eaten whole. In low-income food deficit countries, discarding trash fish was a minor practice (Frid and Paramor 2012).

Beside fish, Cambodians also consume a wide variety of OAAs (Annex 1) (Baltzer et al. 2001). Aquatic plants (Annex 1) are extracted for home consumption and animal (swine) feed (Kottelat and Witten 1996; Torell and Salamanca 2001; Lavit 2004).

WARs have declined in the study area and this has a direct impact on local livelihoods. Similar resource degradation can be observed in other parts of the globe (Zhou et al. 2010; Ryan 2012). Securing and improving the accessibility and availability of WARs for the poor is important (Ounsted and Madgwick 2008). To strengthen management, strict law implementation is necessary, for example operation of electrocuting devices must be eradicated in line with Government Declaration No. 02 (2 September 2003) on Measures to Eradicate the Operations of Electrocuting Devices and Mosquito-sized net Fishing Gears. Capacity building of local community fisheries management committees to undertake efficient management of communal resources is equally important. Raising local awareness to participate in resource management and understand the consequences of flooded forest destruction, misuse of pesticides and insecticides, operation of arrow set traps and barrages that block upstream passage of migratory fishes, which are all harmful to living aquatic organisms downstream (in the reservoir), are also important.

Non-farm activity

Non-farm activity contributes more than 20 % of the total mean annual net income of full-time and part-time fishing households; and more than 40 % to non-fishing and WARs-non-dependent households total mean annual net income. The results of the interviews show that in 172 households (74 % of the total sample, N = 232), at least one member was involved in wage labour activities. Wage labour is a last resort for poor, landless and illiterate people, and it is an insecure source of income. The majority of Cambodians working outside the country (Thailand) use illegal migration channels. They find the paper work to obtain

legal document was very difficult and complicated, and therefore decided to work as illegal migrant workers. According to a local TV (CNC) in the month of June 2014 the ruling Thai military government has send approximately 200,000 Cambodian (illegal) workers back to Cambodia through the Poi Pet international border checkpoint.

Total mean annual net income per household

The total disposable income of USD1620 per year per household in rural Cambodia, reported by the NIS (2011), is significantly higher ($t = -8.129$, $p = 0.000$, $df = 231$, $n = 232$) than the amount in the study area (mean = 1017, SD = 1131). One possible reason for this difference could be that non-timber forest products were not calculated in monetary terms and included in the total mean annual net income calculation of the present study. Villagers rely on seasonally available non-timber forest products such as firewood, grass for thatch, vines, vegetables, mushrooms, bamboo shoots, yams, wild fruit, weaver ant eggs *Oecophylla smaragdina*, toads *Rhinophrynus* sp., and rice-field rats *Rattus argentiventer* for both home consumption and sale to generate income. Another possible reason for under reporting by the present study may be that asking questions about household income can be a sensitive issue and respondents chose not tell the truth in order to avoid paying income tax (Gosselink and Strosser 1995).

Conclusions and recommendations

WARs contribute significantly to the total mean annual net income of the three groups of WARs-dependent (full-time, part-time and non-fishing) households in the study site: 40 % (full-time fishing), 25 % (part-time fishing) and 6.5 % (non-fishing). Wild fish was the most important resource compared with OAAs and plants. We therefore conclude that among different groups of WARs-dependent households, the full-time fishing households are more dependent on aquatics compared with the part-time fishing and non-fishing counterparts. WARs-dependent households account for 89 % (207) of the total sample size (232).

The Ang Trapeang Thmor Sarus Crane Reserve is one of a few remaining aquatic ecosystems in Cambodia from which people obtain multiple values (e.g., biodiversity, livelihood and culture). The Reserve has aquatic biological diversity value at the national and regional level because it is home to various globally threatened and critically endangered species (e.g., Sarus cranes). It is an important location for local communities to harvest aquatic products for their needs. The implications of our findings are that wetlands and their resources need to be managed and protected properly and effectively for present and future use. Mitsch and Gosselink (1993) described wetlands as "biological supermarkets" for their extensive food chain, but their rich biodiversity is being lost and degraded at an alarming rate. Destruction of wetland habitats and ecosystems will result in disappearance of the resources and, as a consequence, the poorest segments of the population will suffer most.

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Appendix

See Table 4

Table 4 Annex 1 Selective species of fish, OAAs and plants harvested

Common, species and family names	Average size, cm and unit price (USD/kg) on sale at the local market
Fish	
Bronze featherback *Notopterus notopterus* (Notopteridae)	12 (1.5)
Swamp eel *Monopterus albus* ()	40 (2.5)
Chevron snakehead *Channa striata* (Chanidae)	24 (2)
Broad head catfish *Clarias macrocephalus* (Clariidae)	20 (1.75)

Table 4 continued

Common, species and family names	Average size, cm and unit price (USD/kg) on sale at the local market
Climbing perch *Anabas testudineus* (Anabantidae)	12 (0.75)
Catopra *Pristolepis fasciata* (Nandidae)	11 (0.75)
Silver shark minnow *Osteochilus hasselti* (Cyprinidae)	15 (0.75)
Parachela siamensis (Cyprinidae)	10 (0.50)
White eye barb *Cyclocheilichthys repasson* (Cyprinidae)	12 (0.60)
Striped catfish *Mystus mysticetus* (Bagridae)	10 (0.60)
Swamp barb *Puntius brevis* (Cyprinidae)	9 (0.50)
Other aquatic animals	
Aeruginose snail *Sinotaia aeruginosa*	(0.16)
Asian giant frog *Hoplobatrachus rugulosa* synonym: *Rana*	(1.11)
Asian giant water bug *Lethocerus indicus*	(1.71)
Asian water beetle *Cybister limbatus*	(1.71)
Black-rice crab *Somanniathelpusa* sp.	(0.15)
Conic snail *Pila conica*	(0.16)
Freshwater clam/shell *Pseudodon vondembuschianus*	(0.16)
Ghost Shrimp/Glass Shrimp/ Grass Shrimp *Palaeomonetes kadiakensis*	(0.80)
Pila snail *Pila polita*	(0.16)
Water snake *Enhydris* sp.	(0.50)
Aquatic plants	
Water convolvulus *Ipomoea aquatic* (Convolvulaceae)—grows abundantly; villagers consume the young leaves and stalks	(0.36)
Water lily *Nymphaea lotus* (Nympheaceae)—commonly found, tubers and young flowers are edible	(0.31)
Kuntulet in Khmer language—grown in natural ponds and the wet regions, the young stalks are consumed	(0.25)
Hemp sesbania *Aeschynomene aspera* (Leguminosae)–a slender sub-shrub which is generally found in rice paddy fields and creeks during the wet season. The young leaves and yellow flowers are eaten	(0.25)
Four-leaf water clover/clover fern *Marsilea quadrifolia* (Marsileaceae)—naturally grown in the reservoir and wet regions of rice paddy fields, and ponds. The whole plant, roots excepted, is consumed	(0.75)
Broad-leaved plantain *Plantago major* (Plantaginaceae)—found in ponds and the wet regions of rice paddy fields during the wet season. The whole plant, roots excepted, is consumed	(0.38)
Elephant ear *Alocasia macrorrhiza* (Araceae)—grows wild and found along streams adjacent to the reservoir. The stems are cooked	(0.38)
Creeping water primrose/red ludwigia *Ludwigia adscendens* (Onagraceae)—an aquatic liana which grows in stagnant waters of reservoir, ponds and rice paddy fields. The young shoots are eaten	(0.75)
Esthwaite Waterweed or Hydrilla *Hydrilla verticillata* (*synonym include H. asiatica, H. japonica, H. lithuanica, and H. ovalifolica.*) Hydrocharitaceae—is a submersed, rooted aquatic plant that can grow in water up to depths of 20 ft. It is used for human food and animal (swine) feed	(0.38)
Water mimosa/sensitive neptunia *Neptunia oleracea* (Neptunia oleracea)—is legume. Young leaves and stems are eaten raw as a vegetable	(0.50)

Table 4 continued

Common, species and family names	Average size, cm and unit price (USD/kg) on sale at the local market
Water snowflake/floating hearts *Nymphoides indica* (Menyanthaceae)—is aquatic plants with submerged roots and floating leaves. Villagers consumed roots of the vegetable as raw topping with fish paste and other food	(0.50)
Oval-leaved pondweed *Monochoria vaginalis* (Pontederiaceae)—available only in the wet season and can be found in rice paddy fields. It is harvested by villagers to consume leaves and young stalks as human nutrition	(0.31)
Water hyacinth *Eichornia crassipes* (Pontederiaceae)—it grows wilds in natural ponds, streams, creeks and the reservoir. Flowers and young stalks are consumed as human nutrition as raw vegetables topping with fish paste or as cooked food mixing with other food	(0.75)

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