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Fishing gears, fishing grounds, target species and labor forces of marine small-scale fishery in Kampot Province, Cambodia

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Abstract: As a first academic action, the field survey targeting marine small-scale fishery was conducted in Trapeang Ropov and Trapeang Sangkae villages of Tuek Chhou district, Kampot province, Cambodia. In the two villages, 56.43% and 16.69% of households conducting fishing as a main job, and data and information were collected from 60 out of 544 households of fishers. The data and information can show the current situation of their fishery including fishing gears, fishing grounds, target species and operations with their opinions regarding tolerance on the decline of fish by new regulations. There were 11 types of fishing gears including 5 different types of gillnets. 14 species were mainly targeted for the small-scale fishing, and it was found that these species have different profitability depending on the fishing grounds and fishing gear. In offshore fishing, large catches can be expected, but annual catch fluctuations were high. On the other hand, in near the shore, fishery catch would be stable at low level, but women can participate.

Keywords : *Marine fisheries in Cambodia*

Introduction

In Cambodia, the national fisheries agency named Fisheries Administration (FiA) reported that fishery products provide over 81.5% of animal protein in the Cambodian diet and is also a critical source of essential vitamins and micronutrients (FISHERIES ADMINISTRATION IN CAMBODIAN GOVERNMENT, 2010). So far, inland fishery has been highlighted as one of major industry in this country (e.g., ISHIKAWA *et al*., 2017), though, the importance of marine fishery products also recognized recently, because it was suggested that the marine products are contributing approximately 20% of the total capture fisheries production in Cambodia (FISHERIES ADMINISTRATION IN CAMBODIAN GOVERNMENT, 2020). Besides, Cambodian marine fisheries significantly contribute employments in coastal areas and economic growth through trading exchanges (FISHERIES ADMINISRATION IN CAMBODIAN GOVERNMENT, 2016).

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According to a 2018 report by the Ministry of Planning (MoP) of Cambodian government, this marine fisheries sector provides full-time, part-time, and seasonal employment for up to 141,244 people in Cambodia's four coastal provinces (Ministry of Planning in Cambodian Government, 2018).

In 2020, FiA reported that marine fishery catch production has dramatically increased over the past 19 years, with statistics suggesting that marine fish landings had tripled from 36,000 tons in 2000 to 122,250 tons in 2019. FiA highlighted the increase of small-scale or artisanal fishing contributing to the rapid incretion of total marine catch in the coastal area (Fisheries Administration in Cambodian Government, 2020). The small-scale fishery and artisanal fishing in Cambodia are conducting in open access situation, and those who conducts those small-scale and artisanal fishing are unable to undertake agricultural activities and therefore engage in open-access fishery (Imm *et al*., 2005), although the open-access fisheries are widely recognized as a threat to coastal fishery resources (Pirochana, 2007). Recently the country's population growth has led to an increase in fishing activity under open-access situation as well as a decrease in important habitats for marine life. This double burden of decline of fishery stocks and environmental deterioration in coastal area were suggested as quite serious problem in Cambodia's marine fishery by Gillett (2004) and the reports of Human Resource University (2014).

The current Cambodian fisheries has been regulated by "Law on Fisheries" settled in 2006, which covers both marine and inland fisheries. The Law includes general provisions, definitions of fishery domains, the continuity of fisheries management, the protection and conservation of fisheries, the management of mangrove areas, the management of fishery exploitation and specifically marine fishery exploitation, aquaculture management, the governance of community fisheries, and fishing licenses. However, it was suggested that the Law put high priority to the management of inland fishery, instead the marine fishery (Cacaud, 2017).

In 1999, the Mekong River Commission (MRC) found that approximately 60% of the total inland fisheries catch produced through small-scale fishing by farmers based on the household level interview survey (Van Zalinge and Thuok, 1999). After this report, the importance of the detail data and information regarding small-scale fishing in Cambodia and the reliability of the household level interview survey have been widely recognized. Then, many studies on inland fishery in Cambodia have been conducted in order to collect detail information for improvement the managements (e.g., Takahashi *et al*., 2005; Hori *et al*., 2006; Enomoto *et al*., 2011), and these data and information have been contributing to make some regulations for improvement the fishery management. However, as the latest governmental annual report published in 2019 suggested, the details information of the coastal marine fishery and the constraints of small-scale fishing had been in unclear (Fisheries Administration in Cambodian Government, 2019). Although general information of marine fishery was listed in several reports (e.g., total fish catch volumes, names of fishing methods, numbers of fishing fleets, powers of engines, numbers of fishers), in order to make rational management, the relationships among fishing gears, fishing grounds, target species, fish catch, and labor forces should be clarified. So far, such detail information which can contribute to improve management have not been reported, especially in small-scale marine fishery.

The difficulty for the data and information collection has been suggested in some papers

(ISHIKAWA *et al*., 2005; TAKAHASHI *et al*., 2005), due to the civil war and internal conflict extending until early 2000s resultant in Cambodia. And some of them also suggested the difficulty of household level interview survey to collect rational information from fishers, because it requires the mutual trust between fisher and interviewers (TAKAHASHI *et al*., 2005). Therefore, purpose of this research was to show the feasibility of the interview survey in coastal areas, and to collect current detail data and information regarding the small-scale marine fishery. In addition, general aspects of the fish trading/transportation systems and fishers' opinions on fish decline were targeted in the fields survey, aiming at improving the fishery laws and regulations of marine capture fisheries in the near future.

Materials and methods

Before starting data collection, interviewers had a meeting with the head of provincial fisheries lead agency called Kampot Fisheries Administration Cantonment (Kampot-FiAC) and officers in charge to collect general information and discuss about detail organization of survey interview.

Data and information collection were conducted in Trapeang Ropov and Trapeang Sangkae villages of Kampot province from December 15, 2019 to January 8, 2020. Kampot province is one of the coastal provinces holding 73 km coastline (Fig. 1), and the second largest marine capture fishery production from small-scale fisheries in Cambodia produced in this province (RIZVI and SINGER, 2011; FISHERIES ADMINISTRATION IN CAMBODIAN GOVERNMENT, 2019). And the two target villages, Trapeang Ropov and Trapeang Sangkae, were the first and second fishing areas located along the coastline of Kampot province and the fishers of the two villages have long history in fishing and there were small-scale fishers' organizations.

From Kampot-FiAC office, general aspects of the villages including number of households and information of fishery operation were collected, and these data were used for deciding the households interviewed and interview schedule. Interviewers visited each house and/or landing site to conduct interviews with the household heads and/or boat owners, with the assistance of Kampot-FiAC officers. When the interviewee was not available, the interview postponed until they were available. If the selected fisher as an interviewee declined to be interviewed, another was selected to replace him/her, taking account of an ethical consideration.

In the household interviews as a questionnaire conducting from December 16–31, 2019 in Trapeang Sangkae village for 44 respondents, and from January 1–8, 2020 in Trapeang Ropov village for 16 respondents, were randomly selected by the interviewers of Kampot-FiAC. In the selection of fisher as an interviewee, religion and social group of fishers were not considered as the selection criteria. The collected data and information consisted of household members and livelihood activities, data of fishing fleet, fishing gears, fishing grounds (including the data of water depth and distance from the landing site), target species, information of labors, fish catch amounts, fish trade, and fishers' perceptions on declining fish catch. The question of the perceptions of declining fish catch was made following the previous social survey conducted in Thailand (MIYATA, 2018).

Focus group discussions facilitated by Kampot-FiAC officers were held in each village. To organize the focus group discussion, the community fisheries heads of Trapeang Ropov and Trapeang Sangkae villages selected six and eight respondents, respectively. The selected

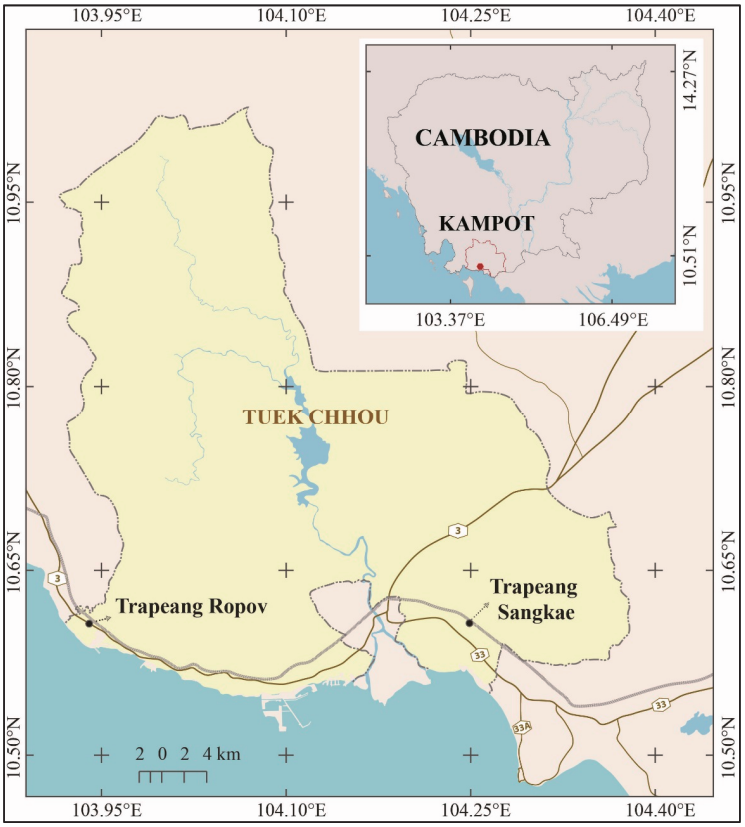


Fig. 1 Map of study areas: black circles indicate the village surveyed, red circle represents Kampot municipality, solid line with number 3 and number 33 shows the national road 3 and national road 33, respectively. The dash-dotted line indicates district boundary, red dot line indicates the provincial boundary.

fishers as the respondents seemed to know well about their fishing activities and can be representing their fishing gear group. The organization of the focus group discussion was separately carried out between the two villages after household interviews finished. Focus group discussion in Trapeang Sangkae was held on 23 December 2019 at Trapeang Sangkae community fisheries office and on 6 January 2020 convened in Trapeang Ropov village at its community fisheries office. The focus group discussion was held to clarify the data/information on fishing activities (including role of gender in fishing), fishing seasons, the market price of each species, price decision system, the fish trade and problems happened at the fishing ground, and to confirm the information pertaining to the size and unit price of target species in high and low fishing seasons that received quite abstract from household interviews (the details of questions for household interviews and focus group discussions, please see Appendix 1 and 2). Additionally, heads of community fisheries were contributed to verify the information related to fishing activities in their own jurisdictions at the time of group discussion.

Table 1. Population, households number (HH), religion and the interviewee of the household interview in Trapeang Ropov and Trapeang Sangkae villages

Name of village	Population * (Male : Female)	No. HHs*	Respondents (HHs)		Average no. of family members*	Religion (HHs)*	
						Buddhism	Muslim
Trapeang Ropov	4,548 (2,200 : 2,348)	829	16	(26.7%)	6.0	3	13
Trapeang Sangkae	2,846 (1,236 : 1,610)	453	44	(73.3%)	5.5	9	35
Total	7,394 (3,436 : 3,958)	1,282	60	(100.0%)	5.75	12	48

*Source: MoP, 2018, and research in 2019 and 2020

Chi-square test was adopted to test the differences in some collected data between the high and low fishing seasons, using SPSS and R software programs.

Results

General information and fishery seasons of the two villages

According the official record of the villages published in 2018, there were 829 households with 4,548 people (2,348 women and 2,200 men) in Trapeang Ropov village, and 453 households of 2,846 people (1,610 women and 1,236 men) in Trapeang Sangkae village (Table 1). In both villages, a few households were engaged in rice farming, 29.36%, and 20.25% respectively, while 56.43% in Trapeang Ropov and 16.69% in Trapeang Sangkae were involved in fishing. A total of 60 fisher households were selected for the interview in the two villages randomly based on the lists of fisher households in Trapeang Ropov and Trapeang Sangkae villages provided from Kampot-FiAC office. Focus group discussions were also held in each village.

Of the 60 fishers selected, 46 (76.7%) accepted the interview, four fishers (2.4%) went to sea, three fishers (1.8%) slept, three fishers (1.8%) were absent, and four fishers (2.4%) declined to be interviewed.

Kampot-FiAC officers and many of fishers in the two villages recognized their small-scale fisheries as main activities for livelihood, and commercial fishing being also conducted in the same fishing area. Fishing families in these villages faced several typical problems in fishing, such as illegal fishing, habitat degradation, and conflict between independent fishers and private companies.

The high and low fishing seasons in the coastal fishery of Cambodia were recognized by changes of the number of fishers' operation days, their catch volumes, and the catch prices (Table 2 and 3). The high fishing season is from November to June, and low fishing season is from July to October. The strong winds and heavy rains being dominate from July to October, therefore fishing using small fishing boats become very dangerous and the numbers of fishing operations go down in these months. Almost all respondent fishers said that they made 25 fishing trips a month in average during the high fishing season but 15 trips per month in the low fishing season, excepting two fishers of Trapeang Sangkae who used beach seine and halfbeak gillnets, they said no seasonal change in a year.

Fishing gears and target species

A total of 11 types of fishing gears: 1) hand

Table 2. Fishing gears, target species and seasonal changes of average fishery catches (per trip) according to type of fishing gears in Cambodian

Name of fishing gears	Target species	High season (Nov to Jun)	Low season (July to Oct)
Hand collection	- Blood cockles	5.3 kg	2.0 kg
	- Mud crab	3.0 kg	1.0 kg
	- Banana shrimp	1.3 kg	1.0 kg
Hand push-nets	- Banana shrimp	5.4 kg	2.6 kg
	- Swimming crab	2.3 kg	1.7 kg
	- Rabbitfish	1.0 kg	1.0 kg
	-(*Mixed fishes*)	1.3 kg	1.3 kg
Beach seine	- Banana shrimp	4.0 kg	4.0 kg
	- Swimming crab	3.0 kg	3.0 kg
	- Mantis shrimp	3.0 kg	3.0 kg
Crab gillnets	- Swimming crab	20.0 kg	15.0 kg
Halfbeak gillnets	- Halfbeak	4.0 kg	4.0 kg
	- Mullet	2.0 kg	2.0 kg
	- Wrasse	1.0 kg	1.0 kg
Mullet gillnets	- Mullet	10.0 kg	5.4 kg
	- Bay sillago	2.0 kg	1.0 kg
	- Halfbeak	2.0 kg	1.5 kg
	- Wrasse	2.0 kg	2.0 kg
	- Rabbitfish	1.3 kg	1.2 kg
	- Short mackerel	1.0 kg	1.0 kg
Shrimp gillnets	- Shrimps*	12.8 kg	9.5 kg
	- Mantis Shrimp	3.5 kg	2.5 kg
	- Swimming crab	3.3 kg	2.8 kg
	-(*Mixed fishes*)	2.5 kg	2.3 kg
Mackerel gillnets	- Short mackerel	55.0 kg	13.0 kg
	- Spanish mackerel	3.0 kg	1.0 kg
	- Indian threadfin	2.0 kg	1.0 kg
Trawler	- Banana shrimp	8.7 kg	5.1 kg
	- Squid and cuttlefish	8.4 kg	6.4 kg
	- Swimming crab	7.0 kg	5.1 kg
	- Mantis shrimp	5.0 kg	3.0 kg
	-(*Mixed fishes*)	3.3 kg	3.8 kg
Indian threadfin gillnets	- Indian threadfin	N/A	N/A
Rabbitfish gillnets	- Rabbitfish	N/A	N/A

* Shrimps (Banana, western king, green tiger, giant tiger)

Table 3. Seasonal changes of sizes and prices of fishery products in Cambodian marine fishery

Name of fish	Name of species	(*Fishing gear*)	Average Size (cm)	Unit Price (KHR/kg)	
				High fishing season (Nov to Jun)	Low fishing season (July to Oct)
Shell fish	- Blood cockles		2.8	15,000	20,000
Shrimp	- Green tiger shrimp		8.0	20,000	25,000
	- Giant tiger shrimp		8.0	25,000	30,000
	- Western king shrimp		7.0	20,000	25,000
	- Banana shrimp	(*Hand push-nets*)	2.0	10,000	15,000
		(*Beach Seine*)	7.0	15,000	20,000
		(*Hand collection*)	7.0	15,000	20,000
		(*Shrimp gillnets*)	8.0	18,000	22,000
		(*Trawler*)	8.0	18,000	22,000
Mantis shrimp	- Mantis shrimp		12.0	15,000	20,000
Squid	- Squid		12.0	15,000	20,000
Cuttlefish	- Cuttlefish		6.5	15,000	20,000
Crabs	- Mud crab		8.0	20,000	30,000
	- Swimming crab		8.0	15,000	20,000
Fish species	- Spanish mackerel		40.0	20,000	25,000
			28.0	13,000	15,000
	- Indian threadfin		32.0	20,000	25,000
			25.0	13,000	15,000
	- Mullet		27.5	15,000	20,000
	- Halfbeak fish		27.0	7,000	12,000
	- Wrasse		21.5	4,000	7,000
	- Short mackerel		20.0	10,000	15,000
	- Rabbitfish		16.5	8,000	10,000
	- Bay sillago		15.0	10,000	15,000
	-(*Mixed fishes*)		-	6,000	10,000

* US dollar 1.00 = 4,000 KHR

collection, 2) hand push-nets, 3) beach seine, 4) crab gillnets, 5) halfbeak gillnets, 6) mullet gillnets, 7) shrimp gillnets, 8) mackerel gillnets, 9) trawler, 10) Indian threadfin gillnets, and 11) rabbitfish gillnets were used in these two villages (Table 2).

Five types of gillnets were widely used in both villages (the details of gillnets differences, see Appendix 3), and they were identified by the differences in the shapes and materials of strings, number of yarns of strings, floats, and sinkers (Fig. 2). Almost all gillnets were made by polyamide yarns, excepting some types of shrimp gillnets (Fig. 2). Mackerel gillnet, mullet gillnet, and crab gillnet were made by monofilament yarn, but the thread of the crab gillnet was thicker (0.31mm) than those of others (0.15mm) (Fig. 2). Halfbeak gillnet was made by strings consist

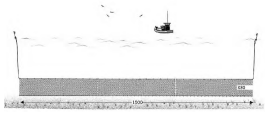
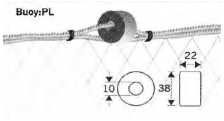
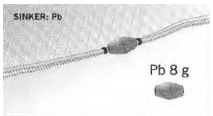
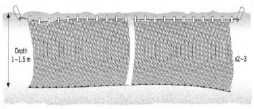
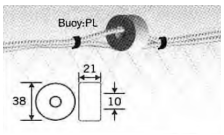
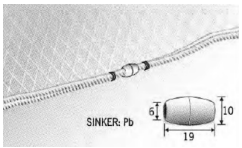
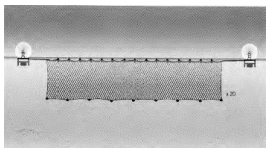
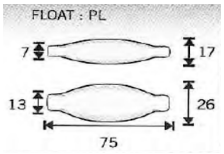
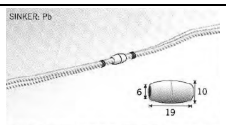
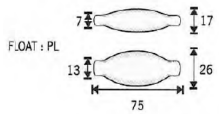
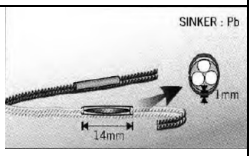
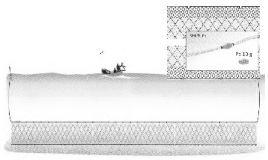
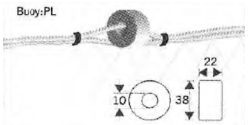
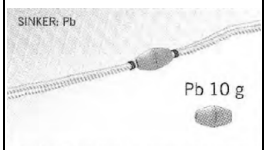
	Shape of gillnets	Line No. of string of net	Shape of buoy/float	Shape of sinker
Mackerel gillnets	 String materials: Polyamide	1	 Gap distances: 0.39 m	 Gap distances: 0.21 m
Mullet gillnets	 String materials: Polyamide	1	 Gap distances: 0.75 m	 Gap distances: 0.40 m
Halfbeak gillnets	 String materials: Polyamide	9	 Gap distances: 0.35 m	 Gap distances: 0.77 m
Crab gillnets	 String materials: Polyamide*	1	 Gap distances: 2.46 m	 Gap distances: 0.90 m
Shrimp gillnets	 String materials: Polyamide Polyamide Polyethylene	4 2 6	 Gap distances: 0.45 m 0.45 m 0.45 m	 Gap distances:0.30 m 0.30 m 0.30 m

Fig. 2 Shapes and features of 5 types of the gillnets used in Trapeang Ropov and Trapeang Sangkae villages and their identity according to the materials of strings and positions of floats and sinkers.

* Line used for crab gillnet is thicker than those of mackerel gillnet and mullet gillnet.

Source: Fishing gears and methods in Southeast Asia: VI. Cambodia. Fisheries Administration. Cambodia and SEAFDEC/TD, 2007.

of 9 polyamide yarns, and shrimp gillnets were also made by strings of polyamide or polyethylene yarns (Fig. 2). Fishers selected these gillnets based on their target species, fishing grounds, and the prices of the nets.

Nine of them were utilized as the main fishing gears that operated whole year round, three fishers used hand collection, 16 fishers used hand push-nets, one fisher used beach seine, one fisher used crab gillnets, one fisher used halfbeak gillnets, 10 fishers used mullet gillnets, 11 fishers used shrimp gillnets, two fishers used mackerel gillnets, and 15 fishers used trawler. On the other hand, two fishing gears (Indian threadfin gillnet and rabbitfish gillnet) are used as alternative (supplementary) fishing gears, these are used when the main fishing gears do not make good catch. A total of 13 fishers (21.67%) of 60 respondents in the two villages owned and used two types of fishing gears as main and alternative fishing gears.

Seven crustaceans including four shrimp and two crab, two mollusk of one shellfish, one squid and one cuttlefish, and eight fish species were recognized as major target species in the two villages; banana shrimp (*Penaeus merguiensis*), western king shrimp (*Penaeus latisulcatus*), green tiger shrimp (*Penaeus semisulcatus*), giant tiger shrimp (*Penaeus monodon*), mud crab (*Scylla serrata*), swimming crab (*Portunus pelagicus*), mantis shrimp (*Clarida decorata*), blood cockles (*Anadara nodifera*), squid (*Uroteuthis spp.*) and cuttlefish (*Sepiola spp.*), halfbeak fish (*Hemiramphus far*), *Moolgarda seheli* and *Moolgarda buchanani* mullets, bay sillago (*Sillago ingenuua*), rabbitfish (*Siganus guttatus*), short mackerel (*Rastrelliger brachysoma*), Spanish mackerel (*Scomberomorus lineolatus*), Indian threadfin (*Polydactylus indicus*), and two types of wrasse (*Anampses geographicus* and *Anampses caeruleopunctatus*) (Table 2).

The relationships among fishing gears and target species were clarified in this survey (Table 2). Banana shrimp were collected by five types of fishing gears: hand collection, hand push-nets, beach seine, shrimp gillnets, and trawler. Swimming crab was collected by beach seine, crab gillnets, shrimp gillnets, hand push-nets, and trawler. Mantis shrimp were caught using shrimp gillnets, beach seine, and trawler. Mullet and wrasse were collected using mullet gillnets and halfbeak gillnets. Rabbitfish were collected by hand push-nets, mullet gillnets, and rabbitfish gillnets. Short mackerel was collected by mackerel gillnets and mullet gillnets, while halfbeaks were collected by halfbeak gillnets and mullet gillnets.

In Trapeang Ropov, shrimp gillnets (7 fishers used; 43.75%) was most popular gear, and trawler was following (3; 18.75%). The hand push-nets, and mackerel gillnets were used by two fishers (12.50%), crab gillnets and mullet gillnets were used by one fisher (6.25%). The main fishing gear in Trapeang Sangkae was the hand push-nets (14; 31.82%) and the trawler was secondary popular gear (12; 27.27%). The mullet gillnets (9; 20.45%), shrimp gillnets (4; 9.10 %), hand collection (3; 6.82%), beach seine and halfbeak gillnets (1; 2.27%) were also used in this village (Table 4). The fishing gear differences derived the differences of fishery catch as follow, short mackerel, Indian threadfin, Spanish mackerel were caught mainly in Trapeang Ropov, and mud crab, blood cockle, bay sillago, halfbeak, and wrasse were mainly collected by Trapeang Sangkae fishers, though, the seven species (squid, cuttlefish, shrimp, swimming crab, mantis shrimp, mullet, and rabbitfish) were commonly caught in the two villages.

In the group discussions, the head of Trapeang Ropov community fisheries said that the 11 types of fishing gears (hand collection, hand

Table 4. Fishing gear used in Trapeang Ropov and Trapeang Sangkae villages

Name of fishing gears	Trapeang Ropov	Trapeang Sangkae
Hand collection	never used	used (6.82%)
Hand push-nets	used (12.50%)	used (31.82%)
Beach seine	never used	used (2.27%)
Crab gillnets	used (6.25%)	never used
Halfbeak gillnets	never used	used (2.27%)
Mullet gillnets	used (6.25%)	used (20.45%)
Shrimp gillnets	used (43.75%)	used (9.10%)
Mackerel gillnets	used (12.50%)	never used
Trawler	used (18.75%)	used (27.27%)
Indian threadfin gillnets	used	never used
Rabbitfish gillnets	never used	used

push-nets, mullet gillnets, shrimp gillnets, crab gillnets, beach seine, halfbeak gillnets, mackerel gillnets, trawler, Indian threadfin gillnets, and rabbitfish gillnets) being available in Trapeang Ropov village (Table 4), however, halfbeak gillnets and beach seine were not used due to the low profitability as those require a large number of workers. On the other hand, in Trapeang Sangkae village (Table 4), fishers have never used crab gillnets, mackerel gillnets, and Indian threadfin gillnets, because the fishing grounds of short mackerel and Indian threadfin are located far from the village and require more time as well as bigger boats with larger engines to reach. Thus, fishers in this village prefer to fish in areas nearby and devote shorter times (between six and 10 hours) for one fishing trip, in accordance with the limited capacity of their fishing boats. Many fishers conduct fishery using one particular fishing gear.

It should be noted that 100% of the fishing boats in the two villages consisted of wooden boats. Both the largest (15 m in length) and the smallest boat (5.5 m in length) were used for mullet gillnets in the villages, and the second largest boats (14 m) were used for trawler, mackerel gillnets, and halfbeak gillnets (Table 5). Boat lengths for shrimp gillnets varied from 7 to 13 m (Table 5). There were no big differences in width of the boats (from 1 to 2m) excepting for mullet gillnets (from 0.5 to 3.7) and trawler (from 1.9 to 2.8) (Table 5). The boat lengths in Trapeang Ropov village were longer (from 8 to 15m) than those in Trapeang Sangkae (from 5.5 to 14 m) (Fig. 3). The largest engine was used for trawler (42.0 HP) and the average of the engine power of the trawler was also biggest (37.6 HP), followed by beach seine (22 HP) (Table 4). For crab gillnets, smallest engine (6 HP) was used, the engine powers for other gillnets varied from 10.0 to 18.0 HP (Table 5).

Fishing Grounds

The fishing grounds of the two villages consisted of mud- and sand-bottom seabed extending 60 km offshore from the landing sites (Fig 4, Table 6). The water depths of the fishing grounds varied from 0.1 m to 18 m (Table 6). Mackerel gillnets were used in the far offshore and deep areas, its depths of up to 18 m. Hand

Table 5. Lengths, widths of fishing boats, and engine powers operated by fishing gears in Trapeang Ropov and Trapeang Sangkae villages

Name of fishing gears	Number of fishers	Length (m)			Width (m)			Engine power (HP)		
		Max	Min	Ave.	Max	Min	Ave.	Max	Min	Ave.
Hand collection	3	-	-	-	-	-	-	-	-	-
Hand push-nets	16	-	-	-	-	-	-	-	-	-
Beach seine	1	10.5	10.5	10.5	1.5	1.5	1.5	22.0	22.0	22.0
Crab gillnets	1	10.0	10.0	10.0	1.2	1.2	1.2	6.0	6.0	6.0
Halfbeak gillnets	1	14.0	14.0	14.0	1.5	1.5	1.5	13.0	13.0	13.0
Mullet gillnets	10	15.0	5.5	8.1	3.7	0.5	1.3	24.0	5.0	13.9
Shrimp gillnets	11	13.0	7.0	7.5	2.0	1.0	1.2	16.0	10.0	12.8
Mackerel gillnets	2	14.0	10.5	11.5	2.0	1.4	1.5	18.0	6.0	10.0
Trawler	15	14.0	9.0	12.2	2.8	1.9	2.2	42.0	30.0	37.6

* No data from two fishing gears, Indian threadfin gillnets and rabbitfish gillnets due to these are supplementary fishing gears.

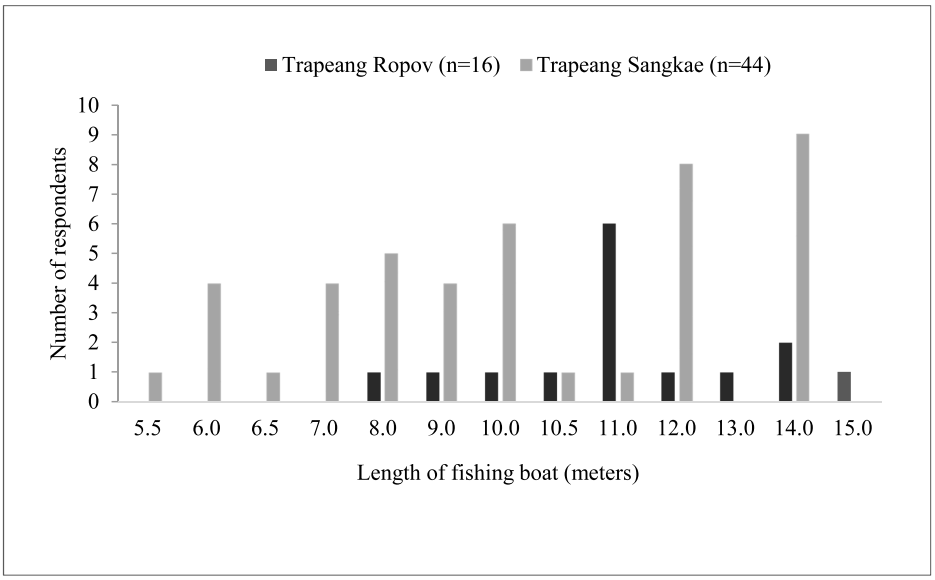


Fig. 3 Length of fishing boats in Trapeang Ropov and Trapeang Sangkae villages, Kampot province.

push-nets, beach seine, crab gillnets, and halfbeak gillnets were used in 8 km offshore areas where the depth less than 4 m. In mangrove habitats and tidal flats area which depth less than 0.5 m, fishers conducted hand collection.

Although, coastal fishers realized the importance of the habitats of mangrove, seagrass, and coral reef as spawning habitats for many marine organisms, offshore area extending 1.5 km from coastal line including habitats of mangrove and

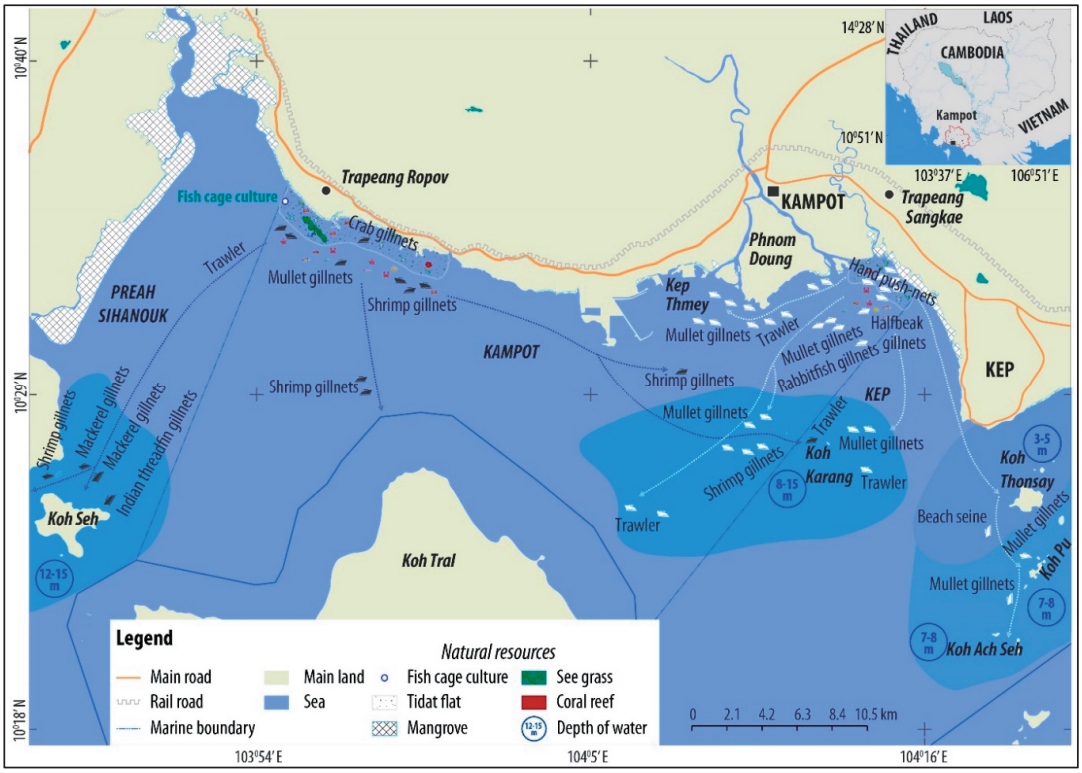


Fig. 4 Map of fishing grounds for Trapeang Ropov and Trapeang Sangkae villages.

seagrass beds except coral reef, are used intensively by all types of fishing gears, excluding trawl (Fig. 4).

Members of focus group discussions in Trapeang Ropov reported that the area's fishing grounds were mud- or sandy-bottomed, while those from Trapeang Sangkae reported that their fishing grounds were muddy-bottomed. In terms of the distance of their fishing grounds from the shore, while no fisher from Trapeang Sangkae fished more than 35 km from the shore, three fishers (18.8%) from Trapeang Ropov fished in just such distant fishing grounds (Table 6). In relation to the water depths of fishing grounds, only one fisher of Trapeang Ropov conducted fishing at deep area (the depth more than 15 m), while no fisher in Trapeang Sangkae conducted fishing at that depth (Table 4 and 6).

Indian threadfin and Spanish mackerel were caught from the depth of water between 12–18 m, short mackerel in the areas not deeper than 18 m, and squid, cuttlefish, shrimp, swimming crab and mantis shrimp were caught in the grounds within 14 m (Table 7). As the prices of these species usually high, so deep area fishery would greatly contribute to high incomes.

Labor forces

Each type of fishing gear requires a certain number of people to operate it. Hand collection or hand push-nets can be operated by one person, all types of gillnets can be conducted by two or three persons, trawler requires three or four persons, and beach seine needs four or five persons to operate (Table 6). Hand push-nets, beach seine, mackerel gillnets, and trawler were conducted by male labors only.

In the both villages, small boats were used for

Table 6. Costs, profits, fishing grounds, and operators of 11 fishing gears in Trapeang Ropov and Trapeang Sangkae villages

Name of fishing gears	Operation time (hours)	Cost per trip (KHR)	Profit per trip (KHR)		Fishing grounds				Main operators	Number of operators per trip or operation
			High season	Low season	Distance from landing sites (km)		Water depth (m)			
					Max	Min	Max	Min		
Hand collection	4–6	6,000	153,000	84,000	7	0.1	0.5	0.1	Male (*mangrove area*) Female, male and girl (*tidal area*)	1 person 1 person
Hand push-nets	3–6	10,500	93,800	85,500	8	1	1.5	1.0	Male	1 person
Beach seine	7–8	100,000	50,000	100,000	4	2	4.0	2.0	Male	4–5 persons
Crab gillnets	8–10	50,000	250,000	250,000	3	1	2.5	1.5	Female, male and boy	2–3 persons
Halfbeak gillnets	6–8	50,000	12,000	45,000	4	2	4.0	2.0	Female, male and boy	2–3 persons
Mullet gillnets	6–8	32,500	184,900	154,500	30	3	8.0	2.0	Male (*distance > 10.0 km*) Female, male and boy (*distance < 10.0 km*)	2–3 persons 2–3 persons
Shrimp gillnets	9–10	90,000	274,040	267,000	50	3	14.0	2.0	Male (*distance > 10.0 km*) Female, male and boy (distance < 10.0 km)	2–3 persons 2–3 persons
Mackerel gillnets	9–10	60,000	847,500	240,000	60	50	18.0	15.0	Male	2–3 persons
Trawl	7–13	152,000	305,200	269,000	35	3	15.0	2.0	Male	3–4 persons
Indian threadfin gillnets	N/A	*Supplement*			N/A	N/A	N/A	N/A	N/A	N/A
Rabbitfish gillnets	N/A	*Supplement*			N/A	N/A	N/A	N/A	N/A	N/A

* US dollar 1.00 = 4,000 KHR

transportation of the catch by hand push-nets, although boats were never used in the operation of these gears (Table 5). Hand collection was conducted by one male fisher in the mangrove areas, however, women or girls conducted hand collection in the tidal flats during low tide. Crab gillnets and halfbeak gillnets were conducted by men, women, and boys, not girls. Mullet gillnets and shrimp gillnets were also conducted by men, women and boys, though in the far offshore areas (more than 10 km away from the coast), only men operated them (Table 6).

There were some differences of utilization of fishing areas among men, women, boys, and girls. In the fishing areas expanding from 10 to 60 km far from the landing sites, only male fishers conducted fishing, though, women and children conducted fishing in the fishing area within 10 km from landing sites (Fig.4, Table 6). The absences of women and children from far offshore fishing were explained as following two reasons, 1) as women should care for elderly members and children as daily roles in the household, so women have to back to in a day, 2) women cannot join the far offshore fishery. And as children have to attend a half-day school, the young labors cannot also join far offshore fishery. In addition, the lack of ablution facilities on fishing boats disables women to participate in long trip fishing activities.

Table 7. Relationship between species, income, size of boats, and fishing grounds in Trapeang Ropov and Trapeang Sangkae villages

Name of target species	Average income (KHR/trip)	Boat length (m)	Fishing grounds	
			Maximum distance (km)	Maximum depth (m)
Short mackerel	442,500	11–14	60	18
Squid and cuttlefish	350,000	9–14	35	14
Shrimp*	275,800	6–14	50	14
Swimming crab*	272,650	7–14	35	14
Mantis shrimp	207,800	11–13	5	14
Indian threadfin	210,000	14	60	18
Spanish mackerel	210,000	14	60	18
Mullet	168,000	6–15	30	8
Mud crab	165,800	Not used	7	0.5
Blood cockles	116,000	Not used	7	0.5
Bay sillago	110,400	6–14	3	8
Rabbitfish*	79,500	6–15	10	8
Halfbeak	73,000	6–14	4	4
Wrasse	49,500	10–14	3	8
*Mixed fish**	114,480	7–14	50	14

*Boats are sometimes not used.
USD 1 = KHR 4,000

The fishery catches, prices and profits

Although fishing takes place at different times in a day, all fishing trips ended in one day in all year around (Table 6). However, the average amounts of fish catch per trip of each fishing gear varied depending on the fishing seasons (Chi-square Test: $P < 0.05$): mackerel gillnets (60.0 kg in the high season and 15.0 kg in the low season, respectively), hand collection (9.6 kg and 4.0 kg), mullet gillnets (18.3 kg and 12.1 kg), hand push-nets (10.0 kg and 6.6 kg), trawler (32.4 kg and 23.4 kg), crab gillnets (20.0 kg and 15.0 kg), and shrimp gillnets (22.1 kg and 17.1 kg), excepting beach seine and halfbeak gillnets (Table 2).

Regarding the average sizes of fishery catches, there was no big differences between high and low seasons (Table 3). On the other hand, the unit prices of each fish catch in the low fishing season was higher than those in high season in all species and size classes though there were varying degrees (Table 3). The heads of community fisheries in the two villages told in the focus group discussion that high demands for seafood at particular times, such as during the Chinese New Year and national holidays, caused high unit prices of their fish catch, and in the low fishing season, the unit prices also were raised due to small amounts of their catch, especially high-value products such as all kinds of shrimp, mud crab, swimming crab, squid, and mantis shrimp.

Highest profitability per trip (one day per trip) was shown in the mackerel gillnets in high fishing season (847,500 Khmer riels, which hereinafter referred to as KHR), and the profitability

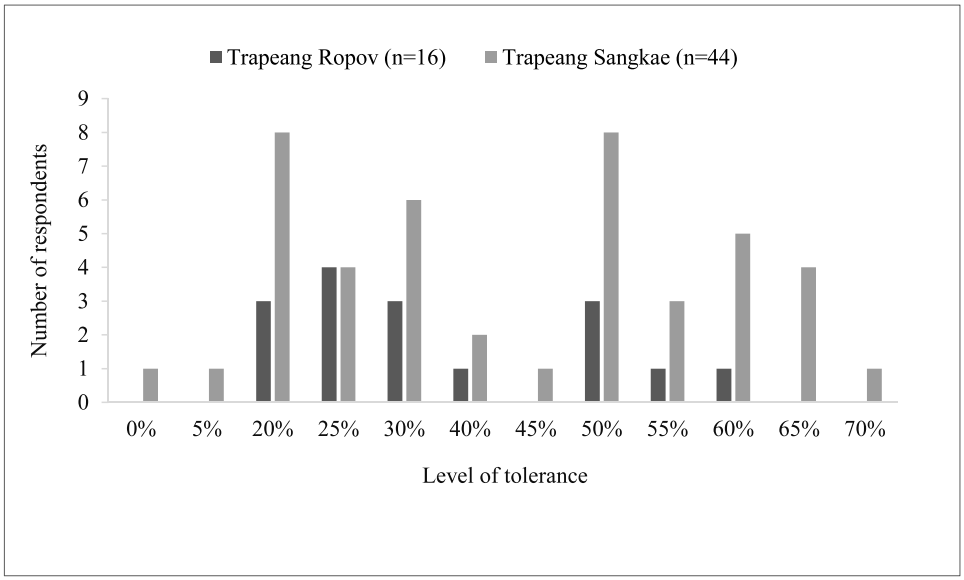


Fig. 5 Perception of fishers on tolerance to fish catch reduction in Trapeang Ropov and Trapeang Sangkae villages.

drastically go down in the low fishing season (240,000 KHR). For other fishing gears, higher profitability was appeared in the high fishing season excepting beach seine net and halfbeak gillnets (Table 6). The profitability of shrimp gillnets, crab gillnets and mullet gillnets were similar to that of trawler and those varied from 154,500 to 305,200 KHR with little differences between the high and low fishing seasons (Table 6). Indian threadfin gillnet was used only in Trapeang Ropov village and rabbitfish gillnet was used only in Trapeang Sangkae village for supplemental fishery, in other words, all fish catch by these two fishing gears were consumed for household consumption in each village (Table 4 and 6). As mackerel gillnets and crab gillnets were used only in Trapeang Ropov village, those fish catch contributed to stable and high income to the village. On the other hand, in Trapeang Sangkae village, high incomes were brought by the fishery catch of shrimp gillnets and mullet gillnets (Table 4 and 6). And as beach seine and halfbeak gillnets were used only Trapeang Sangkae village, those catches contributed to the incomes during the low fishing season of the village (Table 4 and 6).

Tolerance to the catch decline

There is a need to understand the fact may occur and effect on wellbeing of the fisher and fisher's family before regulating and implementing marine fishery management measures. Thus, an opinion of the fisher concerning level of tolerance in declining fish catch when the realistic marine fishery regulations be implemented was checked through this survey in order to produce recommendation to inform the policy maker to prepare suitable arrangements beforehand. As the result, through the focus group discussion and household interviews, it was confirmed that the fishers in Trapeang Ropov and Trapeang Sangkae believed that a good management of coastal fishery resources is important and should be put in place to maintain the marine ecosystem, which is

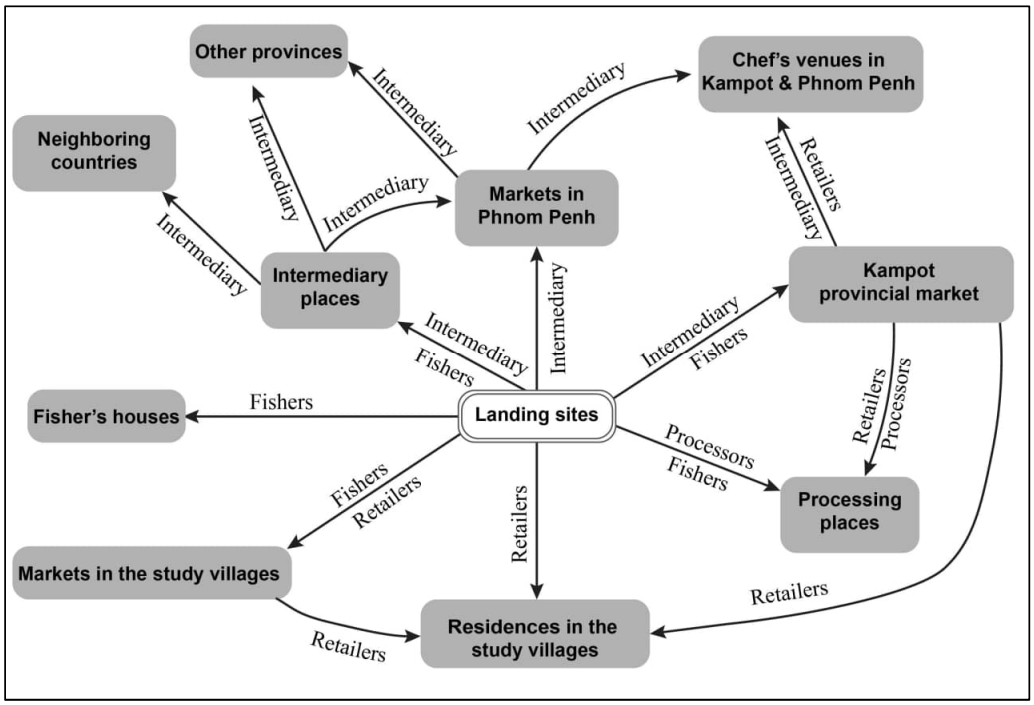


Fig. 6 Distribution roots of marine fish catch in Trapeang Ropov and Trapeang Sangkae villages: black arrows show the fish transported by the traders. Four types of fish trader (such as intermediary, retailer, processor, and fisher) transport fishes from the fish landing sites.

beneficial for the local residents, especially who do not have alternative livelihood apart from fishery. However, the tolerance level of decreased fish catches for management of them varied from 0% to 70% reduction (Fig. 5). It would be noted that there was no significant difference by major fishing gear used and tolerance level of decrease in fish catch (Chi-square Test: $P > 0.05$). In Trapeang Sangkae, one fisher who operated hand push-nets cannot tolerate any reduction of his fish catch, but another fisher conducted mullet gillnets can tolerate 70% catch reduction for one year (Fig. 5). And other five fishers using trawler, hand push-nets and beach seine in this village respond to be able to tolerate 60% reduction of fish catches for seven months. And almost all fisher from Trapeang Sangkae village responded they could accept a high reduction or a small decrease in their catch volume. The tolerance level of fishers from Trapeang Ropov village varied from 20 to 60% for one year (Fig.5). However, many of them (all type of fishing gear users) do not have any alternative income sources and some of them hesitated to respond to the questions regarding set a fishery regulation.

The trading of fishery catches

In the focus group discussions, all respondents in Trapeang Ropov and Trapeang Sangkae villages suggested four kinds of traders of marine fishery catches in Cambodia: 1) intermediary, 2) retailer, 3) processor, and 4) fisher (Fig. 6). The intermediaries come from Trapeang Ropov and

Fig. 7 Sorting, icing, re-packing, and boxing of fishery products before re-transporting by intermediaries.

Trapeang Sangkae, Kampot town, and neighboring provinces. The retailers and processors come from the two villages and Kampot town. The fishers who acted as traders treated not only their own catch but also the fish catch caught by relative fishers of the two villages in sometimes.

In Trapeang Ropov, seven fishers (43.8%) sold their fishery catches to intermediaries, other four fishers (25.0%) sold their catch to the retailers, two fishers (12.5%) sold the fish to the processor, and three fishers (18.8%) sold fish to local residents at landing sites and the village market. In Trapeang Sangkae, 24 fishers (54.5%) sold their fish catch to intermediaries, seven fishers (15.9%) sold fish to retailers, two fishers (4.5 %) sold the fish to intermediaries or consumers, two fishers (4.5%) sold the fish to both intermediaries and retailers, and one fisher (2.3%) sold the fish to both retailers and consumers in the village.

In the trading system by intermediaries, there were three steps, 1) first intermediary purchased fish catch (all kind of fish species as listed in table 2) at landing sites from fishers and transport it to Kampot provincial markets and the other places like roadsides in Kampot province, 2) secondary intermediaries sort the fish catch by species and size and re-pack the fish with ices, then they transported the re-packed fish to retail markets in other provinces, 3) third-level intermediaries distributed the re-packed marine fishery products (shrimp, squid, swimming crab, mud crab) to restaurants, to hotels and to venders in neighboring countries (Fig. 6 and 7).

Both retailers and fishers who conduct transportation of fishery product, usually used village markets and fishers' houses as final markets to

sell the fishery catches (Fig. 6). Retailers bought fish (rabbitfish, mullet, halfbeak, wrasse, bay sillago, and blood cockle) from fishers or intermediaries, and then sold the fish to villagers at markets or on roadsides. In some cases, retailers also use motorcycles to transport and sell the fish in remoted communities. The fishers who conduct transportation of fish catch involving female fishers or fishers' wives, they sold fish (small size of shrimp, blood cockle) at their own houses. In some cases, fishers' wives or daughters collected catch at landing sites and transport them to Kampot provincial markets using motorcycles. Intermediaries and retailers purchased fishery catch (shrimp, squid, cuttlefish, and mantis shrimp) at provincial markets and transport them to the venues at special events (for example, wedding and birthday parties).

Processor purchased the fishery catch (short mackerel) at landing sites from fishers and they sold their products by themselves to Kampot provincial market and Phnom Penh, but in case of exporting the marine processed products are traded by intermediaries. All participants to the focus group discussion said that exports of fishery products to Thailand and Vietnam were conducted by professional intermediaries who use trucks to transport the catch across the border after proper packaging from second intermediaries and processors stationed in Kampot province. For steamed mackerel, the intermediary based in Preah Sihanouk province transferred the product to Thailand. All types of catch species were sold for human consumption, except mixed fish which is used as baits in marine aquaculture or as feeds for livestock.

Discussion

The national fisheries government of Cambodia (FiA) compiles the information and formulates annual report on marine fisheries every year. The content of the report is greatly general which comprised the volumes of marine catch productivities, fishing gears used, numbers of fishing vessels, engine powers, and numbers of fishers engaged in marine fisheries. Furthermore, due to least interest among researchers on marine fisheries of Cambodia, limitation of literature is raised up. Hence, following discussion is made to contribute to fulfill some gaps, in particular fishing activities of small-scale fisheries in coastal area of Cambodia focusing on current status of fishing operation. The perception of fisher in fish catch decline is also highlighted in the discussion.

Variety of small-scale fishing in Cambodian marine fishery

The 11 fishing gears found in this study are categorized into two types of fishing gears according to the current fishery law on Cambodia, 1) small-scale/family-scale fishing gears (hand collection, halfbeak gillnets, mullet gillnets, crab gillnets, shrimp gillnets, mackerel gillnets, beach seine, hand push-nets, Indian threadfin gillnets, and rabbitfish gillnets) and 2) one item of medium-scale fishing gear (trawler). Of the 11 fishing gears, five gears including mackerel gillnets, crab gillnets, shrimp gillnets, push-nets, and trawler are commonly used in Thailand (Southeast Asian Fisheries Development Center, 2007; Department of Fisheries in Thai Government, 2018). However, hand collection, halfbeak gillnets, mullet gillnets, beach seine, Indian threadfin gillnets, and rabbitfish gillnets are not officially listed in Thailand marine fishery (Southeast Asian Fisheries Development Center, 2007; Department of Fisheries in Thai Government, 2018), though, hand collection and beach seine are still unofficially in operation in some parts of Thailand including western, eastern and upper Gulf of Thailand, and upper Anda-

man sea (JARIYA SORNKLIANG pers. Comm, 2020). The similarity of fishing gears utilization was shown with in some village in Vietnam, excepting hand collection, (NGUYEN *et al*., 2019) However, there are some differences regarding the boat sizes and engines power, in case in Vietnam, hand collection conducted with no engine boats or small engine boats less than 9 HP (SON and THUOC, 2003). Therefore, the variety of fishing gears in coastal area of Cambodia would not be unique comparing with those of neighboring countries. But we have to pay much attention to collect precise data of sizes of fishing boats, engines and gears, to grasp an accurate impact of coastal fishery on the fisheries resources and environments, and fishing efficiency of coastal fishing.

Previous survey reported that fishers wanted to replace their usual fishing gears in favor of more effective fishing gear (such as trawler or push-nets), aiming to catch a larger variety of fish species (IDRC *et al*., 2006). However, in this survey, only 13 fishers (21.67%) in the two villages used plural types of fishing gears as main and alternative fishing gears, and many fishers conducted fishery using only one particular fishing gear. Besides, without mullet gillnets and shrimp gillnets, as their fishing grounds being decided by the fishing gears (Table 6), diversification of fishing gears seems to be important to prevent concentrated use of particular fishing grounds. As briefly mentioned in the results part, fishers in Trapeang Ropov fished further away (up to 60 km from landing sites) than those of fishers in Trapeang Sangkae (up to 35 km from landing sites). In the connection of fishing gears and fishing grounds, the fishing boats in Trapeang Ropov were longer than those in Trapeang Sangkae (Fig.3). So far, the government of Cambodia has not promoted diversification of fishing gears in marine fishery domain. However, obviously fishing gears diversification had been observed in the two coastal villages in low technique. For instance, some fishers in Trapeang Ropov changed their fishing operations from beach seine to crab gillnets due to labor shortage, availability of the resource, and market needs. And some shrimp gillnets fishers modified the length of fishing gears to be longer as much as possible aiming to catch more shrimp. Other fishers in the same village who used mackerel gillnets shifted their fishing ground from coastal areas to far offshore area with 60 km far away from their own villages, due to trying to find new fishing grounds to catch more fish and bigger size of short mackerels. In Trapeang Sangkae village, due to the lack experience in using crab gillnets, the fishers conducted crab trap to get swimming crabs. These modification and fishing gear changes were reported in the coastal area of the Philippines (Jennifer *et al*., 2018). In the Philippines, hook and line was dominated as main fishing at the several decades ago, however it had been gradually decreased and replaced by diving. Therefore, diversification of fishing gears seems to be one of the survival strategies for local fishers in the coastal areas of developing countries. Some policy makers of FiA have the tendency to promote fishing gear diversification in small-scale marine fisheries. So, it was suggested to fishery officers would try to collect sufficient scientific data and information to confirm the effectiveness and efficiency of the fishing gear diversification to contribute to the wellbeing of fishers and healthy marine ecosystem (Buoy Roitana, Deputy Director-General of FiA pers. Comm, 2021). It was also said, the strategy of diversifying fishing gears has to be carefully designed in order to minimize the challenges coming from lack of skills and low-level adaptability of the fishers (EUROPEAN UNION, 2011), and complexity of the changed strategy

and nature of fishers' behavior should be well studied (YLETYINEN *et al*., 2018).

Fishers in the study areas had different tolerance levels of fish catch decline even they have high dependency and light reliance on fisheries resources (Table 7). All most all fishers who were interviewed did not have secondary livelihoods beside fishing activities, except few of those who have engaged in ecotourism and construction activities. As clearly addressed by BERCHIE and NUNOO, 2013, provision of alternative livelihood opportunity to fisher is the vital approach to restore natural fish stock and improve income of local small-scale fishers. Obviously, fishers in target areas do fishing both for household consumption and for sale which provides an income for supporting fishers' necessary living expenses. Thus, many fishers may get suffer if their catches continually decline resulting poverty deterioration and/or malnutrition. Poverty would cause overfishing and illegal fishing, more reduction of fish stock and fish catch, and the many vulnerabilities of the fisher would be appeared. Therefore, balancing livelihood of fisher and conservation of marine ecosystem should be taken into consideration before formulating management measures for marine fisheries of Cambodia.

In the focus group discussions in Trapeang Sangkae and Trapeang Ropov villages with regard to the change of fishing gears, and the fishers had a hope to extend the length and numbers of fishing nets to increase fish catch in one trip and/or operation, instead of changing fishing gears and/or owning plural fishing gears. In current situations, fisher should decide their fishing gears with their constraints of their boat sizes and the distances of the fishing grounds from their landing sites. As fishing boats being very expensive for fishers, thus they cannot easily change fishing boats. So, in case fishers could own new type of fishing gears, without changing the boats, they cannot utilize the new fishing gears effectively, because they cannot select suitable fishing ground for the new fishing gear. In current situation, fisher of Trapeang Ropov owned a longer fishing boats, then they can conduct fishing in far offshore using mackerel gillnets and shrimp gillnets those are suitable for deeper areas and large amounts of fish catch being expected during high season (Table 2, 4, Fig. 3). On the other hand, the fishers in Trapeang Sangkae holding small boats conduct beach seine and others those are usually used in shallow area and constant amounts of fish catch are expected from them in a year (Table 2, 4, Fig.3). In addition, these fishing gears require a lot of labors (Table 6). Therefore, it was suggested that data and information regarding ability of fishing boats and number of labor forces are necessary to take some actions to diversify the fishing gears in order to avoid overuse of particular fishing grounds. As the recent finding showed that four benefits gaining from implementation of diversified fishing gears in small-scale fisheries such as: 1) targeting many species and improving an economic value of catches, 2) catching new species when original targets decline, 3) providing a competitive advantage to catch original target species in an innovative way, and 4) modifying appropriate gear can improve its efficiency and long life (Jennifer *et al*., 2018).

Roles of women, boys and girls in coastal fishery in Cambodia

In Cambodia, men, women, boys, and girls play essential roles in contributing to the development of the fisheries sector (FISHERIES ADMINISTRATION IN CAMBODIAN GOVERNMENT, 2015). The results of this study suggested that women and girls have multiple roles in marine fishing-related activities, particularly in the post-

harvest stage and trading fishery products. On the other hands, women play a key role in looking after household members, particularly the elderly (parents) in the traditional custom of Cambodia. For the children, they have to attend primary school classes for four hours in a day, either in the morning or in the afternoon under national rules. So, there are some constraints for women and children in participating fishery activities, in current situations.

Cambodian citizens have open access rights to marine fishery resources. However, actually, women and children have limited access to more distant fishing grounds due to safety concerns and other household or educational duties and responsibilities (Table 6). For future study, details information regarding the women, boys and girls' constraints for fishery related activities should be heighted in order to make good balance between safety and capability of them on the sea.

Trading of fishery products

In Cambodia, marine fish trade was beginning at landing sites and fishery products were transported to local markets, roadsides, and at fishers' houses, as well as into neighboring provinces and countries (Fig. 6). However, there was no formal system or wholesale fish market systems for marine fishery products in Cambodia as a whole. The results of the study indicated there are four kinds of traders have important roles in the fishery trade, and especially the intermediaries carry out multiple functions in the marine fish trade from the first starting point to the final destinations. Hence, the intermediary is the key distributor of marine fish and fishery products inside the country and in cross-border trade, while the retailer and fisher sell to consumers at the provincial level, and processors are the main customers for short mackerel fish species. Fishers mainly operate individual trades or sell their fish catch products to customers at the landing sites. This catch was intended for human consumption, while of the trash fish and small fish being used for animal feeding. Therefore, to grasp detail differences among several kinds of intermediary is quite important to understand the marine product trade system in Cambodia.

Suggestions for future research on marine fishery in Cambodia

Recently, several papers suggested that cap control of fishery catch is not enough for sustainable fisheries management, and the conservation of coastal environments are indispensable, especially for the species which being spawning and/nursing in the coastal areas (e.g., SZUWALSKI *et. al*., 2015). In this context, impact evaluation on coastal environments of each fishing gear should be highlighted in the target of the field survey, though many former researches did not pay much attention on this aspect. And to grasp the actual impact of fishing gears would require detailed and careful investigations. As the results of this survey, fishing gears used in the marine fishery of Trapeang Ropov and Trapeang Sangkae could be characterized by the impacts on the environments. Hand collection could be recognized as a traditional method, is widely known as eco-friendly fishing gear because it does not harm the marine environment, including the living organisms and their habitats. Beach seine and hand push-nets could be classified as medium-level eco-friendly and destructive fishing gears, because the size of their mesh can cause moderate injuries to smaller aquatic animals as they escape from the fishing nets (FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, 2020a), while operations conducted inshore can destroy habitats for several marine organisms. The serious environmental problem derived

from push net operation would be the use of a small mesh and operation in coastal areas, because it could capture many juvenile specimens, particularly shrimp larvae, which end up being discarded and disturbing bottom conditions (Food and Agriculture organization of the United Nations, 2020b). However, halfbeak gillnets, crab gillnets, mullet gillnets, shrimp gillnets, and mackerel gillnets (Fig. 2) could be classified in the semi-eco-friendly group, having some potential to injure and cause infection in sea turtles who encounter nets left in the water (Prado, 2000).

As Jones reported, trawler operated in shallow waters could be recognized as a destructive fishing gear (Jones, 1992). The use of trawler in threatens not only the sustainability of fish resources but also their critical habitats. There have been serious concerns about the bycatch from shallow-water trawl fishery, as it is comprised of juvenile specimens and causes overfishing (Southeast Asian Fisheries Development Center, 2014). Even though the use of destructive trawler is actively taking place in the two villages, the fluctuation level of fish catches of trawler was middle (27.8%) between in the high and low fishing seasons (Table 2). The fluctuation levels of semi-eco-friendly gears such as halfbeak gillnets and beach seine showed much stable than that of trawler, and that of eco-friendly gears like collection was high due to the reduction of catch in low season (5.6 kg; 58.3%) (Table 2). Stable catch is quite important for coastal small-scale fishery for their food safety and income generation. Therefore, the fluctuation level of fishery catch of each fishing gear should also be considered for the field survey as much as the impact on environments. And each kind of fishing gear should be categorized on the basis of its impact on the environment, fluctuation of income, and the availability of fish caught between high fishing season (November to June) and low fishing season (July to October) in Cambodia.

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Appendix 1 Questionnaire for fishing household survey

Questionnaire for fishing household survey

1. Interview date and time:_____ Interviewer name:_____
2. Survey site: village: _____commune: _____/district:_____
3. Province:
   ① Kampot
   ② Kep
   ③ Preah Sihanouk

1) Target individual of this questionnaire: fishing community households (head/members, must live in local areas and engage in fishing/fishing related activities)

2) Introduction of interview: Greetings, I am _____and we are conducting a survey in your community fisheries. The aim of this survey is to find out the characteristic of fishing in marine fisheries domain, your actual conditions of fishing, and living as well as works related fisheries resources management. The conclusion of this survey depends on your responses. Could you give us sometime and cooperate with us?

3) Name of respondent: _____relationship with household head:_____
Name of household head: _____sex:_____
My name is: _____sex: _____ I live in village:_____
_____commune:_____district:_____

*Phone number:_____

I am participating voluntarily in the survey titled "*Understand the Characteristics of Fisheries in marine domain of Cambodia"*

I know and understand that:

a) This survey is for PhD study of Ms. CHIN Leakhena, under Tokai University of Japan.
b) The main purpose of this survey is to describe the profile of fisheries/fisheries related activities in the area.
c) All information collected and respondent's personal information will be treated with confidentially, and will only be used for PhD research purpose. Research results will be publicly revealed.

_____ _____

Signature of respondent Name of respondent

_____

Date (day/month/year)

1. Family profile

(a) About respondent

Name	Sex	Status	Age (years)	Educational background
	☐ Male ☐ Female	☐ Married ☐ Single ☐ Divorce		1. No 2. Pri 3. Sec 4. High 5. Voc 6. Bac 7. Oth

* **Education:** 1. Illiterate; 2. Primary school; 3. Secondary school; 4. High school; 5. Vocational school; 6. Bachelor degree; 7. Other

(b) What is your religion? ☐ Buddhism ☐ Muslim ☐ Christian ☐ Other _____

(c) How many family members do you have _____members.

(d) About respondent address and respondent occupation

	Where were you residing prior?	Why did you move to this area?	How many years have you been in this village?	Experience in fisheries (year)
Respondent		1. Spouse hometown 2. Job available here 3. Good environment 4. Near children's school 5. Other, specify		

(e) Answer questions below:

No.	Question	Answer	
1	How many families living in this house?	_____family (s)	
2	Do you separate the household budget per family or all the family keeps together?	Yes	1
		No	2
3	How much do you spend for your family living per month?	……..	KHR
4	What source of drinking water? In dry season	Rain water	1
		Wells	2
		City water	3
		Delivery water by van	4
		Other, specify	5
	In rainy season	Rain water	1
		Wells	2
		City water	3
		Delivery water by van	4
		Other, specify	5
5	What source of energy/electric supply?	Electricity supply	1
		Battery	2
		Generator	3
		Candle	4
		Other, specify	5

(f) Main, alternative, and subsistent livelihood opportunities.

		Percentage of self-consumption weight of products (kg)	Calendar (what month-month)	Amount of estimated annual income and cost (KHR)		Percentage of income in family budget (%)	Who is in charge?
				Income (KHR)	Cost (KHR)		
1. Fishing							
2. Agriculture							
3. Aquaculture							
4. Labor		x					
5. Eco-tourism		x					
6. Handicraft		x					
7. Livestock							
8. Trading		x					
9. Marine product processing							
10. Other processing							
11. Government							
Other	12. Income from remittance	x					
	13. Income from lending boney	x					
	14. Saving	x					
15. Other sources not listed above							

2. Fisheries

(a) Experience fishing activities

No.	Question	Answer	
1	At what age did you start to fish?	……. years old	
2	Was there a time you stopped fishing?	Yes	1
		No	2
	If yes, for how long did you stop?	_____ years (stopped fishing)	
	Why did you stop fishing?	Working in another occupation	1
		Back to school	2
		Sick	3
		Others _____	4
3	Where do you usually fish in your commune territory water and province?	*Use map to guide*	
4	Do you fish in other province waters territory?	Yes	1
		No	2
5	If yes, why?		
6	What province (s)	Kampot	1
		Kep	2
		Preah Sihanouk	3
		Koh Kong	4

(b) About fishing boat (s) and gears (s)

Number and types of boats	Width and Length (m)	Power	Engine	Engine Power (HP)	Cost (KHR)	License/ registration
1	L: W:	☐ Non-power ☐ Power (☐out-board ☐in-board)	☐ Diesel ☐ Gasoline/benzene			
2	L: W:	☐ Non-power ☐ Power (☐out-board ☐in-board)	☐ Diesel ☐ Gasoline/benzene			

(c) Fish production schedule

Name and number of types of fishing gears		Mark X in operation season		Major target species (local name)	Catch (kg/trip)	Amount of consumption out of catch (kg/trip)	Average price* received (R/kg)	Average cost incurred (R/trip)	No of fishing hour/trips	No of fishing day/trip	No of fishing days/ month	No. labor (s)/trip (persons)	Fishing ground/Distance from shore
		Rainy season	Dry season										
Gear 1 Name: Number	High			1. 2. 3. . .									
	Low			1. 2. 3. . .									
Gear 2 Name: Number	High			1. 2. 3. . .									
	Low			1. 2. 3. . .									
Gear 3 Name: Number	High			1. 2. 3. . .									
	Low			1. 2. 3. . .									

1	Why do you use aforementioned gear (s)?		…….	
2	Why do you choose to fish in these area (s)?		Boat capacity	1
			Zoning limit	2
			Fuel available	3
			Fish path	4
			Others, specify:	5
3	How do you determine distance from the shore?		Use of island as guide	1
			Use of stars	2
			Use of suns rays as guide	3
			Experience as guide	4
			Others, specify:	5
4	Relationship between you and your laborers (multiple answers allowed)		Family	1
			Relative	2
			Fellow fisher	3
			Neighbor	4
			Foreign employee	5
			Other, specify:	6

(d) Market, transportation, price of fish catches

No.	Question	Answer	
1	Where do you land your catch?	Landing site in commune	1
		Landing site outside commune	2
		Landing site in other provinces	3
		Other, specify:	4
2	Where do you sell your fish catch?	Local market	1
		Landing site	2
		Fishing ground	3
		Provincial market	4
		Others, please specify:	5
3	Who is your main customer?	Intermediary	1
		Final consumer	2
		Retailer	3
		Others, please specify:	4
4	How to transport your catch to sell?	Motor bike	1
		Van	2
		No transport required	3
		Others, please specify:	4

(e) Fish price by main species and its size

Name of species	Size of catch	Price/kg (KHR)			Final destinations
		High season	Low season	High demand season	
1.	1st size (……..…g/head)	1.	1.	1.	1.
	2nd size (……..…g/head)	2.	2.	2.	2.
	3rd size (……..…g/head)	3.	3.	3.	3.
2.	1st size (……..…g/head)	1.	1.	1.	1.
	2nd size (……..…g/head)	2.	2.	2.	2.
	3rd size (……..…g/head)	3.	3.	3.	3.
3.	1st size (……..…g/head)	1.	1.	1.	1.
	2nd size (……..…g/head)	2.	2.	2.	2.
	3rd size (……..…g/head)	3.	3.	3.	3.
4.	1st size (……..…g/head)	1.	1.	1.	1.
	2nd size (……..…g/head)	2.	2.	2.	2.
	3rd size (……..…g/head)	3.	3.	3.	3.
5.	1st size (……..…g/head)	1.	1.	1.	1.
	2nd size (……..…g/head)	2.	2.	2.	2.
	3rd size (……..…g/head)	3.	3.	3.	3.
6.	1st size (……..…g/head)	1.	1.	1.	1.
	2nd size (……..…g/head)	2.	2.	2.	2.
	3rd size (……..…g/head)	3.	3.	3.	3.

3. Problems and fisheries management

(a) Perception on problems related fishing activities

1	What problems do you have with the fishing grounds? State **3** problems and level of the difficulty to continue fishery *Single Answer for level of difficulty	**What: (1)** _____	
		Very difficult	1
		Difficult	2
		Somewhat difficult	3
		Do not know the level of difficulty	4
		What: (2) _____	
		Very difficult	1
		Difficult	2
		Somewhat difficult	3
		Do not know the level of difficulty	4
		What: (3) _____	
		Very difficult	1
		Difficult	2
		Somewhat difficult	3
		Do not know the level of difficulty	4
2	Are there human activities that harm the resource?	Yes	1
		No	2
	If yes, what activities harm the resource? *Multiple response	Use of fine meshed net	1
		Use of fishing practices in prohibited areas *e.g* use of trawler in shallow water	2
		Use of illegal fishing gear	3
		Use of cyanide	4
		Use of dynamite/blast fishing	5
		Garbage throwing	6
		Chemical Pollution	7
		Poaching	8
		Others _____	9
	Why do people do these destructive activities? *Multiple response	Easy way to have big harvest	1
		Competition among fishers	2
		Others _____	3
3	Do you agree that your fishing activities have effect on the changes in fisheries resources over the past five years?	Strongly disagree	1
		Disagree	2
		Somehow disagree	3
		No pinion	4
		Somehow agree	5
		Agree	6
		Strongly agree	7

4	What are the ways to protect this resource? *Multiple response	Implement fisheries law enforcement	1
		Compliance to rules and regulations	2
		Limit the number of fishers	3
		Closed season	4
		Ban destructive gears	5
		Provision of alternative livelihood	6
		Others _____	7
5	Do you think fisheries management is necessary in and around your fishing ground? (Single Answer)	Very necessity	1
		Necessity	2
		Neither necessity nor unnecessity	3
		Unnecessity	4
		Very unnecessity	5
		Don't know	6

(b) Perception on the importance of fisheries resources

No.	Question	Answer	
1	At what percent decline in the catch of the important fish increases should fisheries management (law) be enforced?	About _____ %	1
		Don't know	2
2	If the regulation is already enforced but there is still decrease in catch, what volume/percentage of catch reduction that can you accept? (Single Answer)	About _____ %	1
		Can't accept	2
		Don't know	3
3	How many years of lower catch can you accept?	About months/years _____	1
		Can't accept	2
		Don't know	3
	Reasons:		

Check list for the observation

Immovable Property		**Movable Property**	
Concrete house		TV	Electric fan
Wooden house		Motor bike	Smart phone
Leave roof house		Generator	Normal mobile phone
Fiber cement roof house		Vehicle	Computer/laptop
Large land area		Air conditioner	Tractor
Rice field area		Washing machine	Cattle
		Refrigerator	

The end

Appendix 2 Questionnaire for Group Discussion

Questionnaire for Group Discussion

2. Interview date and time:_____

2. Survey site: Fishing village/commune/district:_____

3. Province:

① Kampot
② Kep
③ Preah Sihanouk

1) Target group discussion of this questionnaire: fishers' group discussion (representatives of fishing gears, must have experiences and know well about their fishing activities)

2) Introduction of interview: Greetings, I am _____and we are conducting a survey in your village. The aim of this survey is to clarify some points related to fishing in marine fisheries domain, your actual conditions of fishing and fishing related activities. The conclusion of this survey depends on your responses. Could you give us sometime and cooperate with us?

3) Name of group representative: _____ sex:_____

position:_____

*Phone number:_____

We are participating voluntarily in the survey titled "*Understand the Characteristics of marine fisheries in Cambodia."*

I know and understand that:

d) This survey is for PhD study of Ms. CHIN Leakhena, under Tokai University of Japan.
e) The main purpose of this survey is to describe the profile of fishing/fishing related activities in the area of fishery resources.
f) All information collected will be treated with confidentially, and will only be used for PhD research purpose. Research results will be publicly revealed.

_____

Name of representative

_____

Signature of representative

_____

Date (day/month/year)

1) Time use and responsibility of male female and children in fishing

Activities	Responsibility					
Crab gillnet ⇨…… km from shore (month-month)	<10 km			10->60 km		
	M	**F**	**Time**	**M**	**F**	**Time**
Preparation of fishing gear			……-……			……-……
Travelling to fishing ground			……-……			……-……
Deploy fishing net			……-……			……-……
Harvest, rubbering crab and take to landing site			……-……			……-……
Sorting and selling crab			……-……			……-……
Money keeping			……-……			……-……
Look after children, elder at home			……-……			……-……
Beach Seine ⇨…….. km from shore (month-month)	<10 km			10->60 km		
	M	**F**	**Time**	**M**	**F**	**Time**
Preparation of fishing gear			……-……			……-……
Preparation of food			……-……			……-……
Travelling to fishing ground			……-……			……-……
Fishing			……-……			……-……
Carrying fish to land site			……-……			……-……
Sorting and selling catch			……-……			……-……
Money keeping			……-……			……-……
Look after children, elder at home			……-……			……-……
Fish gillnets (mackerel/halfbeak/mullet) ⇨…….. km from shore (month-month)	<10 km			10->60 km		
	M	**F**	**Time**	**M**	**F**	**Time**
Preparation of fishing gear			……-……			……-……
Preparation of food			……-……			……-……
Travelling to fishing ground			……-……			……-……
Fishing			……-……			……-……
Sorting catch			……-……			……-……
Riding boat back to landing site			……-……			……-……
Selling catch			……-……			……-……
Money keeping			……-……			……-……
Look after children, elder at home			……-……			……-……
Hand collection ⇨ ……km (during low tide) (month-month)	Morning			Afternoon		
	M	**F**	**Time**	**M**	**F**	**Time**
Preparation of tools and materials			……-……			……-……
Preparation of food			……-……			……-……
Travelling to fishing ground			……-……			……-……

Fishing			……-……			……-……
Sorting and selling catch			……-……			……-……
Money keeping			……-……			……-……
Look after children, elder at home			……-……			……-……
Hand push net ⇨ ……. km (month-month)	Morning			Afternoon		
	M	**F**	**Time**	**M**	**F**	**Time**
Preparation of fishing gear			……-……			……-……
Preparation of food			……-……			……-……
Travelling to fishing ground			……-……			……-……
Fishing			……-……			……-……
Travelling back to landing site			……-……			……-……
Sorting and selling catch			……-……			……-……
Money keeping			……-……			……-……
Look after children, elder at home			……-……			……-……
Shrimp gillnet ⇨ ……km (month-month)	<10 km			10->60 km		
	M	**F**	**Time**	**M**	**F**	**Time**
Preparation of fishing gear			……-……			……-……
Preparation of food			……-……			……-……
Travelling to fishing ground			……-……			……-……
Fishing			……-……			……-……
Sorting catch			……-……			……-……
Riding boat back to landing site			……-……			……-……
Selling catch			……-……			……-……
Money keeping			……-……			……-……
Look after children, elder at home			……-……			……-……
Trawler ⇨ ……. Km (month-month)	<10 km			10-60 km		
	M	**F**	**Time**	**M**	**F**	**Time**
Preparation of fishing gear			……-……			……-……
Preparation of food			……-……			……-……
Travelling to fishing ground			……-……			……-……
Fishing			……-……			……-……
Icing and sorting catch			……-……			……-……
Travelling back to landing site			……-……			……-……
Selling catch			……-……			……-……
Money keeping			……-……			……-……
Look after children, elder at home			……-……			……-……

2) Fish price by species

Name of species	Size of catch	Price/kg (KHR)			Seasons
		High season	Low season	High demand season	
1.	1st size (……..…g/head) 2nd size (……..…g/head) 3rd size (……..…g/head)	1. 2. 3.	1. 2. 3.	1. 2. 3.	
2.	1st size (……..…g/head) 2nd size (……..…g/head) 3rd size (……..…g/head)	1. 2. 3.	1. 2. 3.	1. 2. 3.	
3.	1st size (……..…g/head) 2nd size (……..…g/head) 3rd size (……..…g/head)	1. 2. 3.	1. 2. 3.	1. 2. 3.	
4.	1st size (……..…g/head) 2nd size (……..…g/head) 3rd size (……..…g/head)	1. 2. 3.	1. 2. 3.	1. 2. 3.	
5.	1st size (……..…g/head) 2nd size (……..…g/head) 3rd size (……..…g/head)	1. 2. 3.	1. 2. 3.	1. 2. 3.	
6.	1st size (……..…g/head) 2nd size (……..…g/head) 3rd size (……..…g/head)	1. 2. 3.	1. 2. 3.	1. 2. 3.	
a. Who decides to set final price? b. Among the traders you have responded to individual interview, who has more skill to do trading and transport marine fisheries products? Name of destinations.					

3) Understand fishing activities, fishing grounds and problems

1. Can you describe general feature of fishing grounds in this village?

2. Are you happy with volume of fish catch you produced per trip? Why?

3. Is there any type of fishing gear (s) that are not listed here being used in this village? Please name them.

4. Is there any other types of fishing gear (s) that no longer used in this village? Reason (s)?

5. What problems do fishers in this village often face at the fishing ground? How to solve the problems?

6. Do you think implement the management measures could help increase the fishery resources? Should the measures put in use?

7. Do you have opinion on how to improve the current situation of your fishing activities?

Appendix 3 Pictures of shrimp gillnets, crab gillnets, mackerel gillnets, halfbeak gillnets, and mullet gillnets.

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魚類における環境ストレスの解明と健康な養殖魚の育成への応用*

中　野　俊　樹**

Elucidation of environmental stress in fish and its application for farming healthy fish*

Toshiki NAKANO**

1. はじめに

世界的な漁業資源と漁獲量の減少のため養殖に対する需要は年々増加しており，FAO によると現在では全漁業生産量の約半分が養殖によると報告されている。世界の養殖生産量は 8,200 万トン強であるが，そのうち約 6 割を魚類が占めている（FAO, 2020）。そして 2050 年までに養殖水産物が水産物の主要タンパク質源になると推定され，適正なモニタリングと評価による養殖環境と養殖魚の健康と品質の管理は今後ますます重要になると思われる（COSTELLO *et al.*, 2020; STENTIFORD *et al.*, 2020）。気候変動，赤潮，医薬品，過密，化学物質などローカルとグローバルな要因が複合した環境ストレスは，漁獲量や養殖生産性，そして漁獲物の品質に影響を与える。我々は国内外の共同研究者や学生らとともに，養殖対象魚種を用いて遺伝子，細胞，個体のレベルで環境ストレスに対する反応（応答）と防御の解明に取り組み，その結果を養殖魚の健康に応用する研究を行ってきた。本稿ではその概要について紹介する。

2. ストレスとは

Everybody knows what stress is and nobody knows what it is.

この言葉は，ストレスの概念を初めて生物に適用したハンス・セリエによるものである（SELYE, 1973）。彼は，外的刺激要因に反応する生体内の状態をストレス，そしてそれを引き起こす刺激をストレッサーと定義した。しかし，現在では，生体に様々な反応を起こす外的ならびに内的な刺激，すなわち本来はストレッサーと呼ぶべきものを我々はストレスと捉えており，それに対する生体変化をストレス反応と呼んでいる。図 1 に示すように，ストレスとはゴムボールを指で押し圧力をかけてへこんだ状態に似ていて，圧力のようにストレスを誘導する外的（または内的）要因がストレッサーである。ストレスを受けると体内では「中枢神経系」，ホルモン分泌の「内分泌系」，生体防御の「免疫系」の三つの系がクロストークしてストレス反応をする。そしてこの反応は，個体，組織，細胞のレベルで起こる（IWAMA *et al.*, 2006; NAKANO, 2020; 中野, 2021）。

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図 1　ストレスの定義
　ストレスはゴムボールを指で押した状態に似ている。左写真は大きな鷲に押さえ付けられる人間を表したトーテムポール。ストレスに押し潰されそうな我々現代人の日常に似ている。（カナダ・ブリティッシュコロンビア大学人類学博物館所蔵）

3.　環境ストレスに対する反応

3.1　ストレス反応－ストレスタンパク質への影響

　個体レベルにおける生理学的ストレス反応は，一次反応，二次反応，三次反応に分類される。一次反応は，視床下部－下垂体－副腎皮質系（コルチゾル系，HPA 系）と視床下部－交感神経－副腎髄質系（アドレナリン系，SAM 系）の二つの神経内分泌系を介して，ストレスホルモンであるコルチゾルやカテコールアミン（ドーパミン，ノルアドレナリン，アドレナリンなど）が分泌される。なお，アドレナリンはエピネフリンとも呼ばれる。二次反応は，ストレスホルモンによる生理・生化学的な変化で，代謝が活性化され血中のグルコースレベルが上昇する。従って，血中のグルコース濃度はストレスの指標となる。三次反応は，ストレスによりエネルギーが消費されることで生殖や成長の抑制などの形で一般的に現れる（Iwama *et al.*, 2006; Nakano, 2020; 中野, 2021）。

　細胞における特徴的なストレス反応は，一群のストレスタンパク質の発現である。代表的なストレスタンパク質はヒートショックタンパク質（HSP）で，熱により誘導されることから HSP と命名された。しかしその後，熱以外の様々なストレスでも発現することが分かり，近年ではストレスタンパク質と呼ばれ，分子量 70kDa の HSP70 の研究が最も進んでいる（Iwama *et al.*, 2006; Nakano, 2020; 中野, 2021）。ストレスホルモンの一種コルチゾルを冷水性のニジマスに投与し熱ストレス後の反応を調べたところ，HSP の発現が抑制されることを見出だした。この挙動は熱帯性のティラピアでは異なっており，魚種や棲息環境による反応の違いに興味が持たれる（Basu *et al.*, 2001）。また，養殖現場で汎用される代表的な抗生物質の一つオキシテトラサイクリンの過剰投与による化学的ストレスでも，ギンザケにおける HSP の発現が抑制されることが分かった（Zounkova *et al.*, 2011; Nakano *et al.*, 2018）。さらに，養殖ヒラメに甚大な被害を及ぼす *Edwardsiella* 属細菌によるエドワジエラ症では，感染魚の組織で HSP や活性酸素消去系の第一ステップに働く重要な酵素スーパーオキシドディスムターゼ（SOD）の発現が増大することを明らかにした（Iida *et al.*, 2016; Nakano *et al.*, 2020）。以上のようにストレス反応とは，生体が様々な機能を動員して恒常性を維持しようとする防御と適応のための反応である。つまり多くの生命現象は，

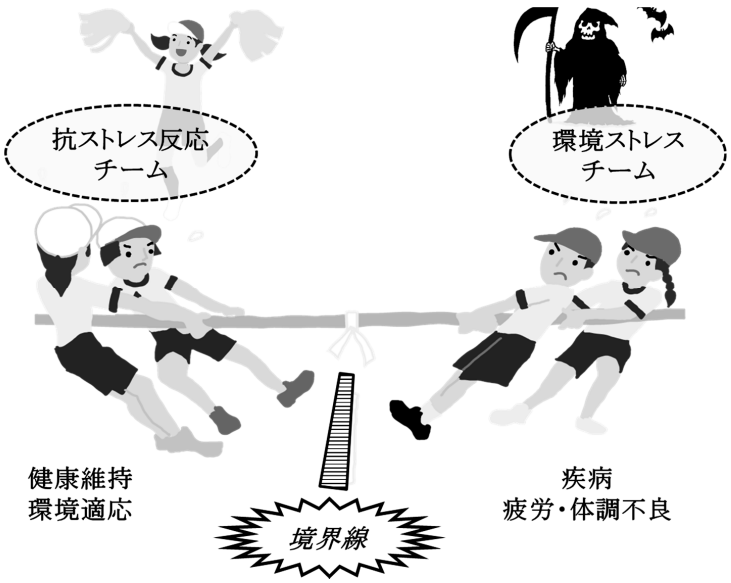

図 2　体内におけるストレスのバランス
抗ストレス反応チームと環境ストレスチームの綱引きが拮抗しているが，健康な時は抗ストレス反応の方が勝っている。

図 2 に示すような抗ストレス反応チームと環境ストレスチームによる綱引きのバランスの上に成り立っており，健康であれば抗ストレス反応の力が勝っていると考えられる。

3.2　成長関連因子への影響

魚類など脊椎動物の成長は成長ホルモン（GH）とインシュリン様成長因子（IGF-I）による GH/IGF-I 系で制御されている。水槽内の追い回しや空中暴露などのハンドリングによる生理学的ストレスが，組織の IGF-I や GH 受容体など成長関連遺伝子の発現に影響を与えることを認めた（Nakano *et al.*, 2013）。このことは，比較的マイルドでコントロールされたストレスであれば良いストレス（ユーストレス Eustress）として，魚類の成長関連因子の発現を調節できる可能性を示唆している（Okebe *et al.*, 2012; Aschbacher *et al.*, 2013; Kupriyanov and Zhdanov, 2014; Nakano, 2016）。

3.3　体内で誘導されるストレスの質の評価

組織中の HSP，SOD，生体における重要な水溶性抗酸化物質グルタチオン（GSH），過酸化脂質などの挙動に及ぼすストレスの影響の総合的な解析の結果，前述のような種々のストレスにより生体内の酸化還元バランスが酸化側に傾き酸化が促進されていることが分かった。すなわち，体内で誘導されるストレスの多くが活性酸素の関与する酸化ストレスであると推察される（Nakano, 2020; Nakano and Wiegertjes, 2020; 中野, 2021）。このことは，環境ストレスに対する抗ストレス性物質としては抗酸化物質が有効である可能性を示唆しており，その効能と作用機序に科学的根拠を与えるものである。そして，ストレスの関与が疑われる疾患の治療には限界があるが，その予防は数知れないことを期待させる（図 3）。さらにストレスのバイオマーカ（生化学的パラメータ）としては HSP，SOD，GSH，過酸化脂質などが優れており，それらマーカを組合せることにより体内で誘導されるストレスの質と量（程度）が評価できると思われる。

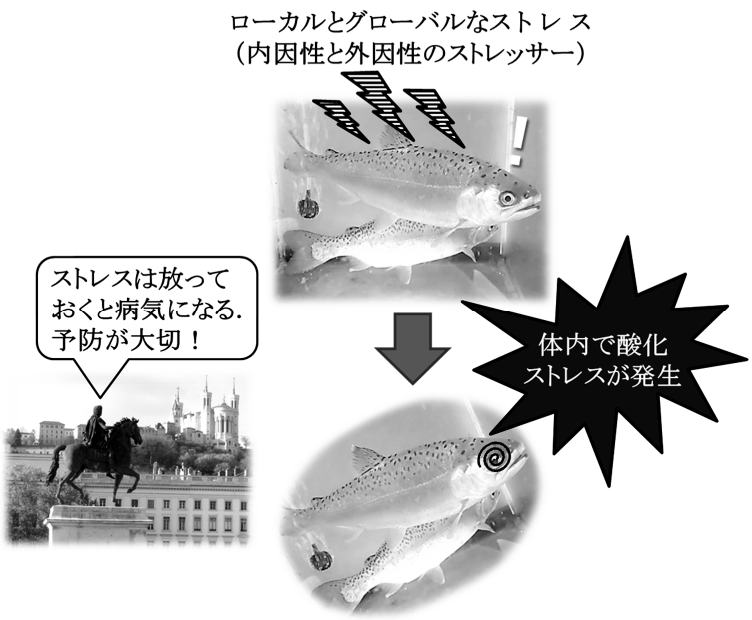

図 3　ストレッサーにより体内では酸化ストレスが誘導される
写真の魚は著者が飼育するギンザケ（*Oncorhynchus kisutch*）。試験魚たちにも感謝したい。左写真は le Roi Soleil（太陽王）と呼ばれたルイ 14 世の騎馬像。（フランス・リヨン市の旧市街中心部にあるベルクール広場）

4.　健康な養殖魚の育成への応用（Nakano *et al.*, 1995, 1999a, 1999b, 2004, 2012; Nakano, 2007, 2020; 中野, 2018, 2021; Nakano and Wiegertjes, 2020; 佐藤, 2018）

脂溶性色素のカロテノイドや植物性ポリフェノールでブドウ種子に多く含まれるプロシアニジンなどが，魚類におけるストレスによる組織傷害に効果のあることを明らかにした。例えば，サケ科魚類の筋肉に特徴的な色調を与えるアスタキサンチンやそれを豊富に含む赤色酵母 *Xanthophyllomyces dendrorhous*（旧学名：*Phaffia rhodozyma*，ファフィア酵母）が，ストレスによる肝臓の機能不全を改善し，組織における過酸化脂質の蓄積やトコフェロール（ビタミン E）の消費を抑えることを発見した。このことはアスタキサンチンが有する高い抗酸化活性を中心に酵母に含まれる複数の成分が相乗的に働いて酸化ストレスを効果的に抑制したものと推察される。これらの成果の一部は，養魚用飼料に応用され，体色（肉色）の改善に加え抗ストレスおよび肝機能向上のためのサプリメントとして商品化されている。

5.　おわりに

「海は生命のゆりかご」（フランスの海洋生物学者 M.フォンテーヌの言葉）。この素晴らしい海に関わる秘密を少しでも解き明かしたいと，我々は魚類を対象に環境ストレスに関するユニークな環境生化学的研究を推進してきた。最近では従来の研究に加え，北米で市販が開始され同い歳の野生型に比べ数十倍に成長する GH 遺伝子組換えスーパーサーモンのリスク評価のための生理生化学的特徴に関する分析とメタボローム解析を行っている（Devlin *et al.*, 2001, 2009, 2015; Nakano *et al.*, 2011, 2019）。さらに，採血を伴わず非侵襲的かつリアルタイムにストレスを測定して見える化するグルコースバイオセンサデバイスの考案（Wu *et al.*, 2015, 2019），ストレスと腸内細菌叢との相関，放射光（シンクロトロンビーム光）X 線 CT イメー

ジングによる魚類の組織や品質の非破壊分析（中野 2019）などについて研究を展開している。今後も SDGs の達成に向けた持続可能な海洋の利用を目指し，様々な分野の知識と研究者との交流を通して，科学的根拠に基づいた魚類のストレスマネジメントによる健康な魚類の育成とその品質の向上について総合的にアプローチしていきたい。

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この度は，思いもかけず栄えある日仏海洋学会賞を頂くことになり身に余る光栄です。大学院修了後に教育研究者として大学に勤める機会を得て以来，多くの共同研究者と学生に恵まれ基礎と応用の狭間で地道に行ってきた研究がこのような形で認められたことは望外の喜びであり，それらの共同研究を代表してこの賞を頂いたものと思っております。改めて，本賞に推薦して頂きました先生，そして会長をはじめ選考委員の方々に感謝申し上げます。

本研究の一部は，文部科学省や日本学術振興会による科学研究費補助金ならびに研究拠点形成事業（A：先端拠点形成型）「食の安全性の飛躍的向上を目指した農免疫国際研究拠点形成」，農林水産省 農林水産技術会議 農林水産分野の先端技術展開事業のうち現地実証研究「多様な漁業種類に対応した操業情報収集・配信システムの構築」，農林水産省 農林水産政策研究所「国産農水産物の国内外の需要動向を踏まえた供給体制に関する研究」，仙台市既存放射光施設活用事例創出事業「放射光トライアルユース事業」などの支援により行いました。

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