Appropriate Fishing Depths for Squid Longline Fishery in the Gulf of Tonkin, Vietnam

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Introduced before the end of 2012, squid longline fishery is a new industry in the Gulf of Tonkin of Vietnam, harvesting as much as 68 kg of the highly priced species per single set of longlines. The main products of this fishery are the cuttlefish (65%), squid (33%), and others (2%). Facing the northern part of the country, the Gulf of Tonkin which has a total area of 126,250 km^2 is shared between Vietnam and China, and is one of the most productive fishing grounds of Vietnam.

Vietnam has a coastline of 3,260 km and its Exclusive Economic Zone spans over an area of more than 1.0 million km^2. Based on its natural characteristics, the sea area of Vietnam is divided into four regions, namely: northern, central, southeast and southwest region (SEAFDEC, 2002). The northern region is most suitable for bottom trawl fisheries, while the central region with very narrow trawlable area is suitable for pelagic fisheries using purse seines, long lines and gillnets. The southeast and southwest regions are similar to that of the northern region, thus, are also suitable for bottom trawl fisheries that exploit pelagic and demersal fishes.

Marine Capture Fisheries of Vietnam

The total fisheries production of Vietnam in 2011 accounted for 16% of the total fisheries production of the Southeast Asian region, and seemed to continue increasing during the five-year period from 2007 to 2011 (**Table 1**). However, such fisheries data have been compiled without classifying by species, so that the country's actual production of cuttlefish and squid could not be determined.

Gulf of Tonkin

The marine fishing areas of Vietnam (SEAFDEC, 2008) are under Area 71 (Pacific, Western Central) and Area 61 (Pacific, Northwest), and the Gulf of Tonkin which embraces the northern region of the country's sea waters is under marine fishing areas 61a and 61b. Shared with China, the Gulf of Tonkin's total area of 126,250 km^2 is divided into two areas: the 67,203 km^2 area belongs to Vietnam (about 53% of the total area) while China owns the remaining 47% or 59,047 km^2 (National Assembly, 2004). This sharing was based on the Agreement on the Delimitation of the Territorial Seas, Exclusive Economic Zones and Continental Shelves in the Gulf of Tonkin between the People's Republic of China and the Socialist Republic of Vietnam signed on 25 December 2000. Ten provinces of Vietnam border the Gulf of Tonkin, namely: Quang Ninh, Hai Phong, Thai Binh, Nam Dinh, Ninh Binh, Thanh Hoa, Nghe An, Ha Tinh, Quang Binh, and Quang Tri (**Fig. 1**).

The Gulf of Tonkin is bordered in the west by the northern coastline of Vietnam, in the north by China's Guangxi Province and to the east by China's Leizhou Peninsula and Hainan Island. It is also considered as a northern arm of the South China Sea. The Gulf of Tonkin envelops more than 1,960 islands, and with the Red and Thai Binh Rivers emptying into the Gulf, an abundant biodiversity area is created with living and non-living marine resources (RIMF, 2006). Previous research indicated the existence of 960 fish species in this area belonging to 475 genus and 162 families and comprising about 80% demersal and 20% pelagic fishes. Although some fishes (20%) inhabit only the offshore areas
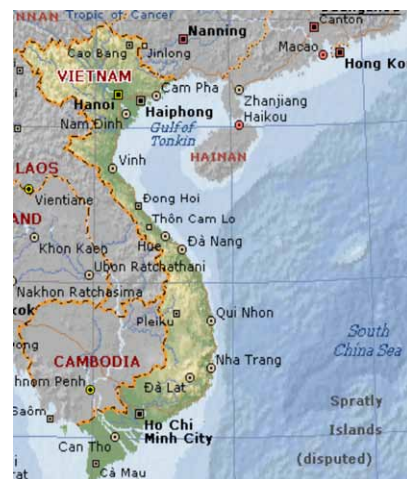
Table 1. Fisheries production of Vietnam (in mt)

	2007	2008	2009	2010	2011
Fisheries Production of Vietnam	4,315,500	4,559,720	4,782,400	5,127,600	5,432,900
Marine capture fisheries	1,987,400	1,946,600	2,098,300	2,226,600	2,300,000
Inland capture fisheries	133,600	144,800	144,800	194,200	202,500
Aquaculture	2,194,500	2,468,320	2,539,300	2,706,800	2,930,400
Fisheries Production of Southeast Asia	25,302,870	27,207,826	28,917,096	31,438,435	34,036,431
Marine capture fisheries	14,056,983	13,814,368	14,140,387	14,874,445	15,095,450
Inland capture fisheries	2,008,301	2,329,524	2,397,273	2,377,253	2,641,094
Aquaculture	9,237,586	11,063,934	12,379,436	14,186,737	16,299,887
Percent of Vietnam's Production to the region's	17.1	16.8	16.5	16.3	16.0

Source: Fishery Statistical Bulletin of Southeast Asia 2011 (SEAFDEC, 2013)

Fig. 1. Gulf of Tonkin shared by Vietnam and China

most fishes (80%) are found in coastal areas (RIMF, 2006). As a major fishing ground in Vietnam, the Gulf of Tonkin is known to hold a total marine fishery resources of about 681,200 metric tons (mt), of which the annual allowable catch is 272,500 mt including about 4,700 mt of squid and cuttlefish (Đặng Văn Thi, 2006). The number of fishing boats in the ten provinces that border the Gulf of Tonkin was recorded at 36,965 with total horse power (hp) of 1,240,383.

The average horse power per fishing boat of only 33.6 hp/boat implies that small-scale fisheries are a typical feature of these provinces. However, this area hosts multiple fisheries comprising 24 types, where trawl represents about 46%, gillnet accounts for 38%, stick-held falling net 11%, and other fisheries accounting for the remaining 5% (Trung and Tinh 2012). The Gulf of Tonkin is also the main fishing ground of longline fishers to capture of squid and cuttlefish especially around Bạch Long Vĩ Island, a common fishery zone between Vietnam and China. The main fishing seasons for squid and cuttlefish are in December to April (north season) and June to September known as south season (Đặng Văn Thi, 2006).

Squid Longline Fishery in Vietnam

Squid and cuttlefish are very sensitive to changes in environmental conditions such as weather, hydrography and light, and are usually submerged in seabeds during the day but surface at night depending on temperature and available light (FAO, 1986). Squid longline fishery practiced by fishers in Ba Ria-Vung Tau, Kien Giang and Ca Mau Provinces in Southeast Vietnam since 2009, was found to be highly profitable to fishers, earning for them an average income of 12.7-17.0 million VND/person/month (1 USD = 20,920 VND), a considerably huge amount for many fishers. Moreover, squid longline fishery requires low cost investment and utilizes simple fishing technology and few boat crew members while fishing can be done both day and night. The main target species are cuttlefish and squid, which are highly economic value species and commonly consumed domestically. Squid longlining is a highly selective fishery, so it contributes to fisheries resources protection and conservation (Hoàng Văn Tính, 2012). However, squid longlining is still new to the northern region of Vietnam having been introduced for the first time in the Gulf of Tonkin at the end of 2012 (Quang Ninh SDCFRP, 2013), thus, the method is still being improved by fishers in the Gulf.

The Survey

In order to determine the suitable fishing depths for squid longlining to improve fishing efficiency and increase the catch of cuttlefish and squid, a survey was conducted in the Gulf of Tonkin (**Fig. 2**) from October to December 2012. The survey was aimed at identifying the relationship between fishing depths and yields in squid longline fishery in the

Gulf. Changes in tide patterns and the uneven seabeds of the Gulf of Tonkin were taken into account during the survey, so that the "fishing depth" was calculated from the seabed to the surface. Two fishing boats that exploit the southern part of Bạch Long Vĩ Island, served as the sample units (**Box 1**).

Fig. 2. Gulf of Tonkin showing the survey area

Box 1. Characteristics of the fishing boats sampled in the Gulf of Tonkin		
	Fishing Boat 1	**Fishing Boat 2**
Basic features of fishing boats		
- Registration number	QN90183TS	QN90256TS
- Length of boat (m)	13.0	14.5
- Breadth of boat (m)	4.1	4.2
- Depth of boat (m)	1.6	1.75
- Engine capacity (hp)	130	90
- Number of crew	5	5
Information on longline used		
- Length of main line (m)	20,000; Material: PA φ 1.0	20,000; Material: PA φ 1.0
- Length of branch line (m)	25; Material: PA φ 0.8	25; Material: PA φ 0.8
- Number of artificial bait	1,200	1,200
- Length of brail line (m)	25; Material: PE φ 2.0	25; Material: PE φ 2.0
-Number of buoys	1,200; Material: PVC	1,200; Material: PVC

With 95% confidence interval, the total number of sampling was calculated, using the equation: $n = \dfrac{C}{(\Delta / \sigma)^2}$

(Israel, 2000), where n = the number of samples, C = constant that is identified from error I and II, Δ = acceptable error, and σ = standard deviation (SD). With acceptable error Δ = 4 kg (about 5% products of a single longline set), σ = 13.45 and Power = 95%.

Using R software (Nguyễn Văn Tuấn, 2008), n was calculated by: $n = \dfrac{C}{(\Delta / \sigma)^2} = 148$ (samples),

and to improve confidence of the research, 10% sampling numbers was added 148 + 10% x148 = 162 samples.

Since the survey was carried out at different depths, the lengths of the brail and branch lines were so-determined that their total lengths were equal to the sea depths. Using Echo-
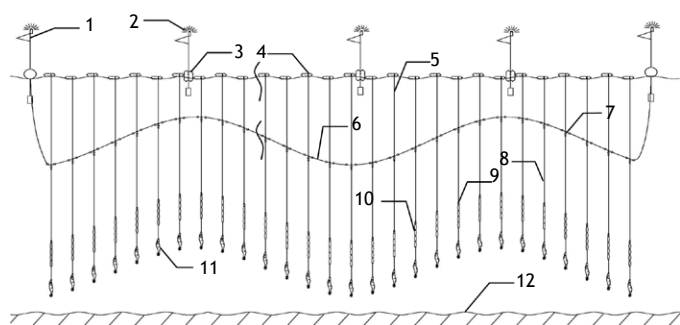
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Fig. 3. Set up of the squid longline: (1 – flag pole; 2 – light pole; 3 – buoy flag; 4 – buoys; 5 – brail line; 6 – main line; 7 – swivel snap; 8 – branch line; 9 – swivels; 10 – sinker; 11 – artificial bait; 12 – sea bed)

sounder, the depths at each fishing time were determined and based on such fishing depths, the suitable depths of the artificial bait were adjusted (**Fig. 3**). Branch lines were fixed while brail line and adjusted so that squid longline had a sinusoidal shape (**Fig. 3**). The first artificial bait was placed at a distance of 1.0 m from the seabed and the eighth artificial bait at the farthest or 8.0 m from the seabed. Each fishing depth was color-coded to facilitate easy counting of the number of individual species caught.

Measuring the length of squid and cuttlefish

The cuttlefish and squid were weighed and measured while the corresponding fishing depths from where they were caught were also recorded, and the relationship between the catch, length of cuttlefish and squid caught, and fishing depth was determined. Using a special ruler, the lengths of squid and cuttlefish were measured for their lengths expressed in terms of mantle lengths (**Fig. 4**).
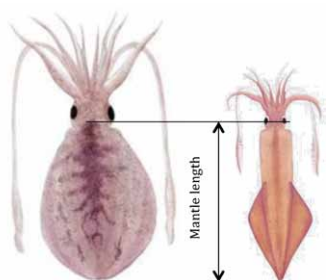

Fig. 4. Measuring cuttlefish (left) and squid (right)

In accordance with Vietnam's Circular No 02/2006/TT-BTS, the minimum allowable landing sizes of cuttlefish and squid should be 120 mm and 200 mm, respectively (Tạ Quang Ngọc, 2006). The 162 catches sampled from a single set and the corresponding fishing depths are shown in **Table 2**. At the end of the survey using 162 single set of squid longline, the results indicated that the main target species caught were cuttlefish (64%), squid (33%), and other species (3%), and that cuttlefish and squid are distributed at depths between 1.0 to 3.0 m (from the seabed).

Considering the biological characteristics of cuttlefish and squid that swim upward the water surface at night and downward to the seabed during the day, high quantity (average 28.0 kg/single set) was caught at fishing depth of 2.0 m while at 6.0 m no cuttlefish and squid were caught. The standard deviation of the catch ranging from 0.0 to ± 4.84 implies that there were no differences in catch in the survey areas, which is favorable for the development of squid longline fishery in the Gulf of Tonkin. Nevertheless, it should also be noted that the sizes of cuttlefish and squid caught also depend on the fishing depths (**Table 3**). The species caught farther from the seabed were small in size, in accordance with the biological characteristics of cuttlefish and squid (FAO, 1986). The length of cuttlefish caught

Table 3. Relationship between length of squid and cuttlefish and fishing depths

Main species / Fishing depth (m)	Cuttlefish		Squid	
	Average length (mm)	Number of sampling (individual)	Average length (mm)	Number of sampling (individual)
0	0		0	
1	150.92 ± 14.2	537	241.60 ± 18.1	180
2	149.68 ± 16.1	724	239.71 ± 17.6	151
3	148.71 ± 16.4	417	237.84 ± 16.8	148
4	101.03 ± 13.4	318	160. 82 ± 15.6	111
5	92.01 ± 0.7	202	140.21 ± 16.1	12
6	0	-	0	-

Table 2. Catch of cuttlefish and squid in different fishing depths (kg/single set) during the survey

Fishing depth (m)	Cuttlefish					Squid					Others		Total average catch (kg)
	Max. catch (kg)	Average catch (kg)	Min. catch (kg)	SD	Rate (%)	Max. catch (kg)	Average catch (kg)	Min. catch (kg)	SD	Rate (%)	Average catch (kg)	Rate (%)	
0	0.00	0.00	0.00	± 0.00	0.00	0.00	0.00	0.00	± 0.00	0.00	0.00	0.00	0.00
1	20.00	12.49	7.00	± 2.39	66.19	11.00	6.33	2.00	± 2.09	33.54	0.05	0.26	18.87
2	28.00	18.91	11.00	± 4.07	67.18	16.00	8.64	1.00	± 3.18	30.69	0.60	2.13	28.14
3	18.00	9.70	2.00	± 4.84	62.76	13.00	5.45	1.00	± 2.65	35.30	0.30	1.94	15.45
4	6.00	2.13	0.00	± 1.58	56.53	7.00	1.24	0.00	± 1.87	32.84	0.40	10.62	3.76
5	2.00	0.60	0.00	± 0.50	42.26	4.00	0.48	0.00	± 0.81	33.79	0.34	23.95	1.42
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	100	0.28
Total	74.00	43.83	20.00	-	64.51	51.00	22.14	4.00	-	32.59	1.97	2.90	67.92

during the survey ranged from 92.0 to 151.0 mm, of which 90% were longer than 120.0 mm, the minimum allowable landing size. Meanwhile, the average length of squid caught ranged from 140.0 to 241.0 mm, of which about 88% were longer than the minimum allowable landing size of 200.0 mm. Although squid longlining is a highly selective fishery, the fishers should comply with the allowable catch for squid and cuttlefish in accordance with the applicable regulations of the Ministry of Agricultural and Rural Development (Tạ Quang Ngọc, 2006).

Discussion and Conclusion

Although the potential of squid fishery in the Gulf of Tonkin appears good, the resources had not yet been properly exploited since squid longlining is still new in the north of Vietnam. While fishers continue to use non-selective fishing gear, such as trawl, drop net and stick-held falling net to capture such economically-important species, the country's fisheries management departments in particular and the Government of Vietnam in general, should craft and implement policies for the development of squid longline fishery in the Gulf of Tonkin to address the impacts of the fishery on the squid and cuttlefish resources, and promote the resources' protection and conservation. Many fishers reported that the sudden swarming of globefishes or puffer fishes in the Gulf of Tonkin had caused damages to the main and branch lines of the longline sets as the globefishes keep on biting the lines due to the twinkling and attractiveness of the artificial baits. During the survey, each single set was constantly changed and supplemented with at least 50-60 new artificial baits, increasing the cost of fishing operations and resulting in wastage of time and manpower. It is therefore necessary to conduct a research to improve the structure of the squid longline and the operation techniques to make squid longline fishery suitable for various types of fishing grounds especially in the Gulf of Tonkin as well as minimizing the cost of fishing while improving the efficiency, taking into consideration the fact that squid longlining is highly selective, and present practices result in the catch of about 90% that were greater than the minimum allowable fishing size (120 mm for cuttlefish and 200 mm for squid). Nevertheless, the almost uniform catches of squid and cuttlefish in the survey areas could mean that cuttlefish and squid densities are almost evenly distributed in the offshore areas of the Gulf of Tonkin. As observed, farther up from the seabed, the sizes of squid and cuttlefish seem to decrease, while cuttlefish and squid surround the seabed during the day, therefore, the most suitable fishing depth is at a distance of 1.0 to 3.0 m from the seabed, although the fishing depths could fluctuate between 1.0 and 3.0 m from seabed to the water surface. It should also be considered that it was at fishing depth of 2.0 m where the maximum catch of 24.2 kg/single set of the high-value species, was produced during the survey.

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