POPULATION SIZES OF BRYDE'S WHALE (*BALAENOPTERA EDENI*) IN THE UPPER GULF OF THAILAND, ESTIMATED BY MARK AND RECAPTURE METHOD

PhaothepCherdsukjai,SurasakThongsukdeeSurachaiPassada and TheerawatPrempree

Marine and Coastal Resources Research and Development Center (The Upper Gulf of Thailand)
120/1 Moo 6 Bangyaprak, Mueang, SamutSakhon, 74000
Email: phaothep1313@hotmail.com

ABSTRACT

The population size of Bryde's whale (*Balaenoptera edeni*) in the Upper Gulf of Thailand was estimated using mark and recapture method,during the period of January 2010 to December 2013. Forty-five whales were observed by identifying distinctive markings. Using the M(bh)-Pollock and Otto model in the Program CAPTURE and CJS model in the Program MARK, Bryde's whale population size and survival rate probability estimations were 63±8.48 (S.E.) animals and 0.88±0.04 (S.E.) respectively. Although the size of Bryde's whales population in the Upper Gulf was small,the likely trend is towards population increasing. Program MARK and CAPTURE have been utilized as tools for summarizing the status of animals after long-term monitoring.

Keyword: Bryde's whale, Mark and recapture, Upper Gulf of Thailand

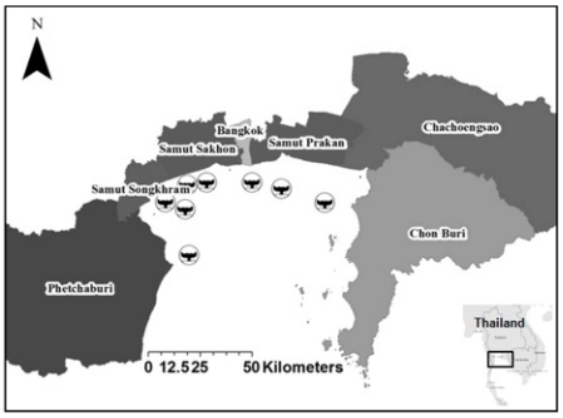
INTRODUCTION

The Bryde's whale (*Balaenoptera edeni*, Anderson, 1879) is a medium size rorqual found in tropical and subtropical areas of both hemispheres. Its distinctive characteristics are three prominent ridges on the rostrum and streamlined body (Jefferson et al, 2008). According to sighting information and stranding records from coastal waters on both sides of the Thai peninsula gathered by Phuket Marine Biological Center (PMBC) since 1993 (Adulyanukosol., 1999; Chantrapornsyl et al., 1996, 1999; Marine and Coastal Resources Research and Development Institute, 2012), the Bryde's whales can be most frequently found in the Upper Gulf of Thailand. The photo-identification technique has been used to study Bryde's whales in the Upper Gulf of Thailand to understand biology, behavior and number of whales (Adulyanukosol et al, 2011; Thongsukdee et al, 2014). The mark and recapture method can help estimate population size and trends (Hammond, 1995), which can further assist in evaluating status of Bryde's whales in the Upper Gulf of Thailand.

MATERIALS AND METHODS

Study area is the Upper Gulf of Thailand, bordered by 7 provinces in the central part of Thailand, Phetchaburi, Samut Songkhram, Samut Sakhon, Bangkok, Samut Prakan, Chachoengsao and Chon Buri, located from west to east respectively (Fig. 1). The shoreline distance is around 400 km. and the total area of the Upper Gulf is 9,565 km^2 with a width of 109 km. The maximum depth of water is 56 m. (Adulyanukosol et al, 2014).

Fig 1. Study area and main Bryde's whale sighting areas



The surveys were conducted from January 2010 to December 2013. Each monthly survey, using

a twelve meters long fishing boat, lasted 4-5 days depending on weather conditions. When the Bryde's whales were sighted, the boat was kept at a distance of 100-300 m. Photographs were taken using Nikon D7000 with 70-300mm. and 80-400mm. telephoto zoom lenses. Weather conditions and the Bryde's whale behavior were also recorded. The pictures used for whale identification were the lateral view of their dorsal fins, showing different markings and shapes. Other distinctive marks were also useful for individual identification, such as color pattern on the tip of the head, or scar/color patterns inside the mouth. Scars or any irregular appearances on their bodies were also useful.

Subsequently, the capture history of each identified individual was set and defined as a string of 1(found) or 0 (not found) in a series of sampling occasions.

Then, Chapman's modified Petersen estimator (Eq. 1) was used to analyze the number of animals between years to see the trends in population size (Hammond, 2009). The population size for four years was estimated by using the Program Capture; the basic program was tests to select a model from 11 possible models, and then the population estimate for mark and recapture data on closed populations (short term study, no birth-death animals), however, the data set an open model (long term study, have birth-death animal) can be applied in Program Capture as well, but results demonstrated some positive bias (slight over estimation) (Rexstad and Burnham, 1992). Then Program MARK (a newly developed program providing parameter estimates from marked animals when they are re-sighted at a later time; re-sights can be from dead recoveries, live recaptures, including radio tracking, or from some combination of these sources of re-encounters) was used to analyze the survival rate with the CJS model, because the mortality and permanent emigration of whale cannot be distinguished. Additionally, some models in Program MARK, such as the Jolly-Seber model can analyze both population size and survival rate but requires a large data set (Cooch and White, 2007; Lindberg and Rexstad, 2002). The data set analyzed here is notsufficient for population size estimation using Program MARK, and therefore Program Capture was used instead.

$$\hat{N} = \frac{(n_1 + 1)(n_2 + 1)}{(m_2 + 1)} - 1$$

Eq. 1 Chapman's modified Petersen estimator, abbreviated throughout this paper as 'Chapman's equation'. The population size estimate is $\hat{N}$; the total number of individuals captured, marked and released for the first time is n_1 and n_2 is the number of individuals captured for the second time. The number of animals already marked is m_2.

Table 1 Capture history of the whales found in the study area in each year. The string "1" refers to "found", and the string "0" refers to "not found". The symbol "*" stands for "calf". The whale Be_UGT001, found in 2009, was identical with Be_UGT022; so, their capture histories were combined.

ID	year			
	2010	2011	2012	2013
Be_UGT002	**1**	**1**	**1**	**1**
Be_UGT003	**1**	**1**	**1**	**1**
Be_UGT004	**1**	**1**	**1**	**1**
Be_UGT005	**1**	**1**	**1**	**1**
Be_UGT006	**1**	**1**	**1**	**1**
Be_UGT007	**1**	**1**	**1**	**1**
Be_UGT008	**1**	**1**	**1**	**0**
Be_UGT009	**1**	**1**	**1**	**1**
Be_UGT010	**1**	**1**	**1**	**1**
Be_UGT011	**1**	**1**	**1**	**1**
Be_UGT012	**1**	**1**	**1**	**1**
Be_UGT013	**1**	**1**	**0**	**0**
Be_UGT014*	**1**	**1**	**0**	**0**
Be_UGT015	**1**	**1**	**1**	**1**
Be_UGT016	**1**	**1**	**0**	**1**
Be_UGT017	**1**	**0**	**0**	**0**
Be_UGT018	**1**	**1**	**0**	**1**
Be_UGT019	**1**	**1**	**1**	**0**
Be_UGT020	**1**	**1**	**1**	**1**
Be_UGT021*	**1**	**1**	**1**	**1**
Be_UGT022	**1**	**1**	**1**	**1**
Be_UGT023*	**0**	**1**	**1**	**1**
Be_UGT024*	**0**	**1**	**1**	**1**
Be_UGT025*	**0**	**1**	**0**	**0**
Be_UGT026	**0**	**1**	**1**	**1**
Be_UGT027	**0**	**1**	**1**	**1**
Be_UGT028	**0**	**1**	**1**	**1**
Be_UGT029	**0**	**1**	**1**	**0**
Be_UGT030*	**0**	**1**	**1**	**1**
Be_UGT031	**1**	**1**	**1**	**1**
Be_UGT032*	**0**	**0**	**1**	**1**
Be_UGT033	**0**	**0**	**1**	**1**
Be_UGT034*	**0**	**0**	**1**	**1**
Be_UGT035*	**1**	**0**	**0**	**0**
Be_UGT036	**0**	**0**	**1**	**1**
Be_UGT037	**0**	**1**	**0**	**0**
Be_UGT038	**0**	**1**	**1**	**0**
Be_UGT039	**0**	**1**	**1**	**1**
Be_UGT040*	**0**	**0**	**0**	**1**
Be_UGT041*	**0**	**0**	**0**	**1**
Be_UGT042*	**0**	**0**	**0**	**1**
Be_UGT043*	**0**	**0**	**0**	**1**
Be_UGT044*	**0**	**0**	**0**	**1**
Be_UGT045*	**0**	**0**	**0**	**1**
Be_UGT046*	**1**	**0**	**0**	**0**

RESULTS

From 2010 to 2013, 45 whales were identified, including 29 adults and 16 calves. Six of the calves were born in 2013. One-time found whales numbered 11 individuals or 24%, and three- or four-times found whales numbered 26 individuals or 57% (Fig. 2).

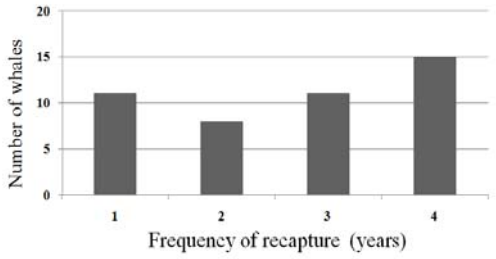


Fig.2 Frequency of recapture. Half of the whales that were found only 1time were the 6 newborns in 2013.Whilethe whales that were found 3 and 4 times were assumed to be a resident group in the Upper Gulf of Thailand.

The number of whales found in each year was 24, 32, 30, and 34, respectively, based on a photo-identification catalogue. The estimated population size between years calculated by the Chapman equation were 37±1.56 (S.E.), 37±1.09 (S.E.), 40±1.30 (S.E.), respectively (Table 2). The population size estimated throughout the study period using the Program CAPTURE was 63±8.48 (S.E.) based on the M(bh) model which behaved the best among the various models. The M(bh) model was selected as the best model in Program Capture, due to the **b**ehavior of the whale and **h**eterogeneity of the data set owing to the high rate of calving in last year and varied capture probability of individuals. Furthermore, the survival rate of the Bryde's whale specifically calculated by the CJS model in the Program MARK was 88%.

Table 2 Values of capture and recapture of the Bryde's whales in each year that were applied inChapman's modified Petersen estimator

	year		
	2010-2011	2011-2012	2012-2013
n_1	24	32	30
n_2	32	30	34
m_2	21	26	26
N-hat	37	37	40
SE	1.56	1.09	1.30
CV	0.04	0.029	0.03

The cumulative number of identified Bryde's whales throughout the 4 years was constantly raised by new members, 16 calves and a non-resident group that was found only one time (Fig. 3).

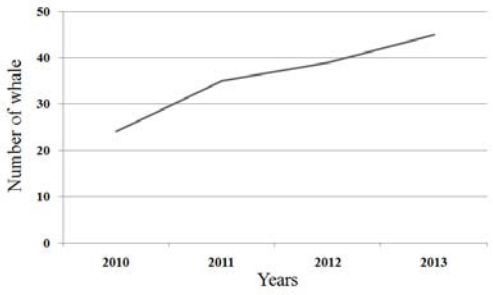


Fig. 3 Cumulative number of the Bryde's whales in each year.

Discussion

Many studies on population size of the Bryde's whale using mark and recapture method use only markings on the dorsal fin (Tershy et al.,1990, Penry, 2009, Wiseman et al., 2011). In contrast, as the Bryde's whales in the Upper Gulf of Thailand engulf prey by lunging their heads above the water for a period of time, additional markings on heads and mouths could be used for identifying whales because some whales do not have markings on their dorsal fins (Thongsukdee et al., a; b 2011). As a result, using both markings on dorsal fins and additional markings provides easier identification and more accurate capture history, meaning more recaptures and less unidentified whales. Furthermore, it helps understand their distribution, abundance and some behaviors, for example, migration, mating, and nursing behaviors, (Thongsukdee et al., 2013) which contribute to a more comprehensive understanding of the status of the Bryde's whale in the Upper Gulf of Thailand.For example, every year almost all whales disappeared for few months and came back again. By2013, no whales were found in January and February (Table 3). This re-sighting pattern shows a semi-resident group in study area.

As four whales died and sixteen calves were born during study period, the population trend should show an increase. However, with a population size smaller than 100, the Bryde's whales in the Upper Gulf of Thailand are still in endangered status because of low genetic variability (Caughley et al., 1996).

Year 2013	Month									
	3	4	5	6	7	8	9	10	11	12
Be_UGT 002	0	1	0	0	0	0	1	1	1	1
Be_UGT 003	0	0	1	1	1	1	0	1	1	0
Be_UGT 004	0	0	0	0	0	1	1	1	1	0
Be_UGT 005	0	1	0	0	0	0	0	0	0	0
Be_UGT 006	0	0	1	1	0	0	0	0	0	0
Be_UGT 007	0	0	0	0	0	0	0	1	1	0
Be_UGT 008	0	0	0	0	0	0	0	0	0	0
Be_UGT 009	0	0	0	0	0	0	1	0	1	0
Be_UGT 010	0	1	0	0	1	1	0	1	0	1
Be_UGT 011	0	0	0	0	0	1	0	1	0	0
Be_UGT 012	0	1	1	0	0	0	0	0	1	1
Be_UGT 013	0	0	0	0	0	0	0	0	0	0
Be_UGT 014	0	0	0	0	0	0	0	0	0	0
Be_UGT 015	0	1	0	0	0	0	1	0	1	0
Be_UGT 016	0	0	0	0	0	0	0	0	0	0
Be_UGT 017	0	0	0	0	0	0	0	0	0	0
Be_UGT 018	0	0	0	0	0	0	1	0	0	0
Be_UGT 019	0	0	0	0	0	0	0	0	0	0
Be_UGT 020	0	0	0	0	0	0	1	1	0	0
Be_UGT 021	0	0	0	0	0	0	1	0	1	0
Be_UGT 022	0	0	1	0	1	0	1	0	1	1
Be_UGT 023	0	0	0	0	0	1	0	0	1	1
Be_UGT 024	0	0	0	0	0	0	0	1	1	0
Be_UGT 025	0	0	0	0	0	0	0	0	0	0
Be_UGT 026	1	0	0	0	0	0	1	0	1	0
Be_UGT 027	0	0	0	0	0	0	1	1	1	1
Be_UGT 028	0	0	0	0	0	0	0	0	0	1
Be_UGT 029	0	0	0	0	0	0	0	0	0	0
Be_UGT 030	0	0	1	1	1	1	0	1	1	0
Be_UGT 031	0	0	0	0	0	0	0	0	1	0
Be_UGT 032	0	0	0	0	0	1	0	0	0	0
Be_UGT 033	0	0	0	0	0	1	1	0	1	0
Be_UGT 034	0	0	0	0	0	0	1	0	0	0
Be_UGT 035	0	0	0	0	0	0	0	0	0	0
Be_UGT 037	0	0	0	0	0	0	1	0	1	0
Be_UGT 038	0	0	0	0	0	0	0	0	0	0
Be_UGT 039	0	0	0	0	0	0	0	0	0	0
Be_UGT 040	0	1	0	0	0	1	1	0	0	0
Be_UGT 041	0	1	0	0	1	1	0	1	0	1
Be_UGT 042	0	0	0	0	0	0	1	0	1	0
Be_UGT 043	0	0	0	0	0	0	1	1	1	0
Be_UGT 044	0	0	0	0	0	0	1	0	1	0
Be_UGT 045	0	0	0	0	0	0	0	1	0	0
Be_UGT 046	0	0	0	0	0	0	0	0	1	1
Number of whale were found in each month	1	7	5	3	5	10	17	13	21	9

Table 3 Capture history of the whales found in each month in 2013. In January (1) and February (2) the whale were not found. The string “1” refers to “found”, and the string “0” refers to “not found”

However, to create a conservation and area management plan, additional important information, related to fishery activities and seismic surveys are required. For example, Adulyanukosol et al. (2011) conducted line transect survey to discover the Bryde’s whale habitat, and found that the area was 4-30 km. away from the shoreline at the shallowest depth of 4 m. which is the same area for fishery activities. While noise from seismic surveys can harm the listening organ and disturb the behavior of whales, as was reported for baleen whales that experienced mass stranding in areas of seismic survey (Gordon et al., 2004; Jasny et al., 2005). In the Upper Gulf of Thailand there have not been reports of baleen whale stranding from seismic surveys, but other parts of the Gulf of Thailand do have seismic survey (Annual report of Department of Mineral Fuels, 2014). Thus, appropriate conservative measures must be collaboratively devised by parties involved the area.

CONCLUSION

The number of Bryde’s whales in the Upper Gulf of Thailand between 2010 and 2013 was 45 individuals, as identified by photo-identification techniques. The population size estimated by the mark and recapture method was 63individuals and the survival rate was88%. The trend in the population size was increasing, however, long term monitoring will be required because the group size was considerably small. Although the mark and recapture method is suitable for studying the status of Bryde’s whales,

proposing a conservation plan and area management also requires further research on other related topics.

REFERENCES

Adulyanukosol, K. (1999). Dugong, dolphin and whale in Thai waters. In: *Proceeding of the first Korea-Thailand Joint Workshop on Comparison of Coastal Environment*: Korea-Thailand. 1: 5-15.

Adulyanukosol, K., Sutibut, S., Thongsukdee, S., andPrempree, T. (2014). *Bryde's whales and the Upper Gulf of Thailand*. Department of Marine and coastal Resources. Bangkok.

Adulyanukosol, K., Thongsukdee, S., Passada, S., Wannaransri. T., and Prempree, T. (2011*). Bryde's whale in Thailand*. Department of Marine and Coastal Resources. Bangkok.

Caughley, G., and Gunn, A.(1996). Conservation Biology in Theory and Practice. *Blackwell Science*. Oxford.

Chantrapornsyl, S., Adulyanukosol, K. and Kittiwatanawong, K.(1996). Records of cetaceans in Thailand.*Phuket Marine Biological Center Research Bulletin*. 61, 39-63.

Chantrapornsyl, S., Adulyanukosol, K. and Kittiwatanawong, K.(1999).Stranded cetacean from Thailand. *IBI Rep*. 9,55-72.

Cooch, E., and White, G.(2007). *Program MARK "A Gentle Introduction". (13th edition).*Retrieved from http://www.phidot.org/software/mark/docs/book/

Department of Mineral Fuels (2014).Annual report 2013 of Department of Minerals Fuels. Bangkok.

Gordon, J., Gillespie, D., Potter, J., Frantzis, A., Simmonds, MP., Swift, R., and Thompson, D. (2004). A Review of the Effect of Seismic Survey on Marine Mammals. *Marine Technology Society Journal*.37 (4),16-34

Jefferson, T. A., Webber, M. A., and Pitman, R. L.(2008). *Marine Mammals of the World: A Comprehensive Guide to their Identification*. Elsevier. Canada.

Jasny, M., Reynolds, J., Horowitz, C., and Wetzler, A. (2005). *SOUNDING THE DEPTHS II: The Rising Toll of Sonar, Shipping and Industrial Ocean Noise on Marine Life*. NRDC. New York.

Hammond, P.S.(1995). Estimating the abundance of marine mammals: a North Atlantic perspective. In: Blix, A.S., WallØe&Ultang, Ü. *Whale, seals, fish and man*. Elsevier Science B.V.. Amsterdum. 4, 3-12.

Hammond, P.S. (2009). Mark-Recapture., In: Perrin, W.F., WÜrsig, B., and Thewissen, J.G.M., *Encyclopedia of Marine Mammals second edition*. Elsevier. Canada.

Lindberg, M., and Rexstad, E. (2002). Capture-recapture sampling designs. In: El-Shaarawi, A.H., and Piegorsch, W.W. *Encyclopedia of environmetrics*.John Wiley & Sons, Ltd. 1, 251-262.

Rexstad, E., and Burnham, K. (1992). User's Guide for Interactive Program CAPTURE. *Colorado State University*. Fort Collins.

Tershy, B.R., Breese, D. and Strong, C.S. (1990). Abundance, Seasonal Distribution and Population Composition of Balaenopterd Whales in the Canal De Ballenas, Gulf of California, Mexico.*Rep. intwhal.Commn*(special issue 12), 349–376.

Thongsukdee, S., Adulyanukosol, K., Passada, S., Prempree, T., and Inpaeng. A. (2011a). Distribution of Bryde's whale (*Balaenopteraedeni*) in the Upper Gulf of Thailand.*Marine and Coastal Resources Magazine*. 1(1), 14-23.

Thongsukdee, S., Adulyanukosol, K., Passada, S., Prempree, T., and Wannaransri, T. (2011b). Photo Identification of Bryde's whale in the Upper Gulf of Thailand. *Marine and Coastal Resources Magazine*. 1(2), 18-27.

Thongsukdee, S., Adulyanukosol, K., Passada, S., Prempree, T.(2014). A study of the Bryde' s whale in the Upper Gulf of Thailand.*The 1st Design Symposium on Conservation of Ecosystem (SEASTAR2000)*. 1, 26-31.

Thongsukdee, S., Passada, S., Prempree, T. (2013). Distribution, Abundance and Nursing Behaviour of Bryde's Whale in the Upper Gulf of Thailand.*Proceeding of Marine science conference 2012*. 3, 354-363

Penry,G. S., (2009).*The Biology of South African Bryde's whale*. Thesis of Doctor of Philosophy, School of Biology, University of St. Andrews.

Wiseman, N., Parsons, S., Stockin, K. A., and Baker, C. S., (2011).Seasonal occurrence & distribution of Bryde's whale in the Hauraki Gulf, New Zealand.*Marine Mammal Science*.27(4)**,** E253–E267

Marine and Coastal Resources Research and DelvelopmentInstitue.(2012). *Status of Marine and Coastal Resource 2007-2011*. Department of Marine and Coastal Resources. Bangkok.