# Loss of economic value from coral bleaching in S.E. Asia

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**Abstract.** In 2010, a rise in sea water temperatures off Thailand, Indonesia and Malaysia resulted in substantial coral bleaching. An ecological and economic survey was undertaken to determine the extent of this bleaching and also the economic implications, particularly for scuba divers. As part of the survey, a choice experiment was undertaken to determine the loss in non-market economic value (in terms of consumer surplus) to divers from the coral bleaching. In this paper, we present the results of this analysis, and implications for ongoing monitoring and management of the reefs. We estimate the loss in economic value due to the 2010 coral bleaching event to be on the order of $50m to $80m.

**Key words:** Coral bleaching, South East Asia, Economic value, Choice experiment.

## Introduction

In mid 2010, a region of increased water temperature was observed off Thailand, Indonesia and Malaysia that led to widespread thermal stress (Fig. 1). At the same time, coral bleaching in key tourism areas was also reported (Thomas and Heron 2011).

Dive tourism is a major source of income for many coastal and island communities in Southeast Asia (Burke et al., 2002). A key attractor to the region is the abundance of coral reefs and the rich diversity of marine life they contain. Benefits accrue to both local communities through expenditure during the dive trips, as well as divers themselves in the form of consumer surplus. Consumer surplus is the difference between what individuals would be willing to pay for a good experience and what it actually costs them in monetary terms, and is the most commonly used measure of economic use-value benefits in non-market valuation studies relating to environmental assets (Costanza *et al.* 1997; Haab and McConnell 2002; Grafton *et al.* 2008). A loss in consumer surplus as a result of coral bleaching is a real economic loss even though no monetary losses may have been experienced. Such loss may drive divers to change destination, leading to longer-term changes in levels of visitation to the region.

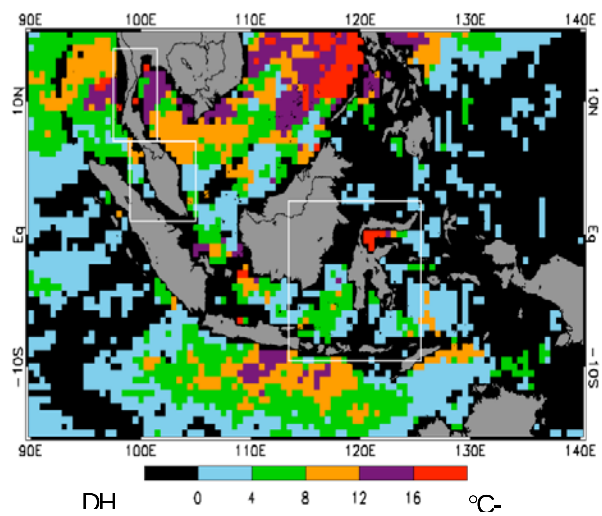



Figure 1. Maximum accumulated thermal stress across the South-East Asia region during 2010 as determined by the Degree Heating Week (DHW) near real-time monitoring of NOAA Coral Reef Watch. Source: (Thomas and Heron 2011).

Relatively few studies of non-market benefits associated with dive tourism have been undertaken in the South East Asia region, and those studies were very site specific (Arin and Kramer 2002; Seenprachawong 2003; Ahmed *et al.* 2007; Tapsuwan and Asafu-Adjaye 2008). These studies, however, suggest that coral reefs provide substantial benefits to divers well in excess of their local expenditure. Further, studies elsewhere have suggested that coral bleaching has a significant negative impact on non-market benefits derived from coral reefs (Ngazy *et al.* 2004; Andersson 2007).

In this study, the change in consumer surplus as a result of the coral bleaching event in South East Asia in 2010 is estimated through a choice experiment approach. A survey of divers was undertaken during 2010, in which respondents were presented with a range of scenarios involving different costs for diving on reefs of different quality. From this, the loss in benefits associated with coral bleaching could be determined.

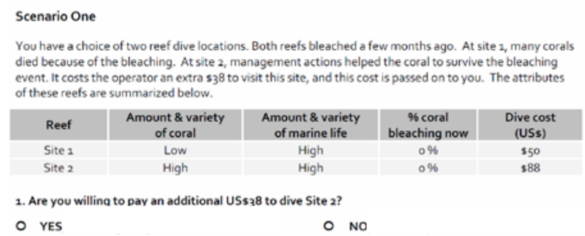
## Material and Methods

Face-to-face interviews were conducted between 29 June 2010 and 13 August 2010 at a range of popular dive sites in the affected regions by research teams located in each country. In total, 578 divers were interviewed, of which 434 provided complete data necessary for the analysis (Table 1).

Table 1. Survey sites and summary characteristics

| Country | Dive Site | International visitors | Domestic visitors | All visitors |
|---|---|---|---|---|
| Indonesia | Bali | 45 | 13 | 58 |
| | Lombok Isles | 53 | | 53 |
| | Nth Sulawesi | 34 | 2 | 36 |
| | Total | 132 | 15 | 147 |
| Malaysia | Perhentian | 34 | 2 | 36 |
| | Redang | 16 | 24 | 40 |
| | Tenggol | 3 | 1 | 4 |
| | Tioman | 29 | 13 | 42 |
| | Total | 82 | 40 | 122 |
| Thailand | Ko Phi Phi | 55 | 2 | 57 |
| | Ko Rach | 18 | | 18 |
| | Ko Tao | 72 | 1 | 73 |
| | Pattaya | 6 | 11 | 17 |
| | Total | 151 | 14 | 165 |
| Total | | 365 | 69 | 434 |

Information on diver demographic characteristics (i.e. sex, age, education, local or visitor, etc.), travel costs, dive history and previous visits to the area was collected. Divers were asked to choose between diving on one of two alternative sites with differing quality in terms of amount and variety of coral and marine life, different percentages of coral bleaching and differing costs. Each diver was asked to make a choice in each of three scenarios. In total, 45 different scenarios were examined through 15 different variants of the questionnaire administered randomly. An example of one scenario is given in Fig. 2.


**Scenario One**

You have a choice of two reef dive locations. Both reefs bleached a few months ago. At site 1, many corals died because of the bleaching. At site 2, management actions helped the coral to survive the bleaching event. It costs the operator an extra $38 to visit this site, and this cost is passed on to you. The attributes of these reefs are summarized below.

| Reef | Amount & variety of coral | Amount & variety of marine life | % coral bleaching now | Dive cost (US$) |
|---|---|---|---|---|
| Site 1 | Low | High | 0 % | $50 |
| Site 2 | High | High | 0 % | $88 |

1. Are you willing to pay an additional US$38 to dive Site 2?

O YES O NO

Figure 2. Example of one scenario used in the choice experiment

The willingness-to-pay for different attributes was derived from a conditional logit model, which estimates the probability that individual diver $i$ chooses a given alternative $j$ based on the characteristics of the alternative and a set of unknown parameters (Haab and McConnell 2002), given by:

$$\Pr_i(j|X) = \frac{e^{X_{i,j}\beta}}{\sum_j e^{X_{i,j}\beta}} \quad (1)$$

where $X_{i,j}$ is a vector of attributes of alternative $j$ and individual $i$, and $\beta$ is a vector of the unknown parameters to be estimated. The parameters of the model are estimated through logistic regression analysis, where the observed choice (either a zero or a 1) is regressed against the attributes of the alternative and the individual making the choice.

The average willingness-to-pay for an attribute is given by $-\beta_j/\beta_c$ , where the numerator is the estimated coefficient on the attribute of interest and the denominator is the coefficient related to the cost variable. The associated standard deviation of the willingness-to-pay is given by $-\sigma_j/\beta_c$ , where the numerator is the standard error associated with the attribute under consideration (Hensher *et al.* 2005). The negative sign is necessary as the expected sign of $\beta_c$ is negative (i.e. probability of choice is expected to decline as the cost increases).

## Results

The logit regression results and derived willingness-to-pay for the different attributes are presented in Table 2. Multiple versions of the model were tested including different approaches to incorporating the alternative and individual attributes, with model choice based on the Akaike information criterion (AIC).

While the Pseudo-$R^2$ of the model is relatively low (0.136), this is relatively common for such models. A more appropriate measure of goodness of fit of the model is the number of correctly predicted choices. In this case, the model was able to correctly estimate the individual choice over 70% of the time given the attributes of the choice set (Table 3).

Table 2. Logistic regression results and derived willingness-to-pay

| | Coeff | Stder | P[\|Z\|>z] | WTP | Standard dev |
|---|---|---|---|---|---|
| Constant | -0.683 | 0.248 | 0.006 | | |
| Price | -0.043 | 0.005 | 0.000 | 23.26 | |
| Coral | 1.830 | 0.111 | 0.000 | 42.11 | 2.58 |
| Marine life | 0.213 | 0.060 | 0.000 | 4.90 | 1.40 |
| Bleaching | -3.174 | 0.222 | 0.000 | -73.04 | 5.16 |
| Local | -0.015 | 0.115 | 0.896 | | |
| Pseudo-$R^2$ | 0.136 | | | | |
| $Chi^2$ | 477.13 | | | | |
| AIC | 1.200 | | | | |
| % Correct | 70.522 | | | | |

Table 3. Analysis of binary choice model predictions based on threshold = 0.50

| Predicted | Observed choice | |
|---|---|---|
| choice | 0 | 1 |
| 0 | 66.4% | 33.6% |
| 1 | 22.5% | 77.5% |

For the dive willingness-to-pay logit model, three different levels of the amount and variety of coral and marine life (low, medium and high) were included in the analysis, while two levels of the percentage bleaching were included (0% and 75%). Several variants of the model were examined using different combinations of dummy variables representing each level, as well as different types of effects coding (Bech and Gyrd-Hansen 2005). Based on the AIC, the model that was the most appropriate effectively treated the level of coral and marine life as a continuous variable,[1] with low having a value of 1, medium having a value of 2 and high having a value of 3. Hence, the derived willingness-to-pay measure represents the value of moving from one level to the next.

Given this, improving the amount and diversity of coral adds the greatest value to a dive, substantially more than improving marine life quantity and diversity. Further, the willingness-to-pay increases linearly with the improvement in the resource. From Table 2, a low quantity of coral would add around $42 to the value of a dive,[2] while a high value would add $126 to the value of a dive (i.e. 3 times $42). While this is to some degree an artifact of the specification of the attribute, alternative specifications were not as good (in terms of the AIC). Conversely, diving per se – irrespective of site quality – provides non-market benefits of around $23/dive. The total non-market benefit of diving at a site with high quantity and diversity of coral and marine life is estimated to be around $164/dive. These benefits are experienced as consumer surplus. That is, they are above what the divers are currently required to pay.

The amount and diversity of fish added substantially less value to the dive than that of coral ($5 vs $42). This result is unexpected considering the results of previous studies into diver preferences (Urraya et al. 2009 and references therein). These studies in the Caribbean and on the Great Barrier Reef indicated a general consensus that fish abundance and coral condition are two of the main factors influencing diver preference for dive sites.

No individual attributes were found to be significant in the analysis. While there was an a priori expectation that local divers would have a significantly lower willingness-to-pay than international visitors, this was not the case, although the sign on the coefficient relating to the local diver dummy variable was negative as expected. The local diver attribute was maintained in the model although not statistically significant to demonstrate that willingness-to-pay did not differ based on the origin.

The key result of the analysis is the effect of coral bleaching on willingness-to-pay. From the model (Table 2), 100% bleaching would reduce willingness-to-pay by $73, ceteris paribus.[3] The ecological survey found areas of bleaching of between 1% and 80% in the different dive sites, with most sites experiencing between 60% and 80% bleaching. Again, assuming linearity, loss of non-market benefits to divers in most areas may have ranged from $44 to $58 each dive.

Information on total dive numbers is limited, so the total loss of benefits from the bleaching event is highly uncertain. Based on projections of total dive visits in each country in 2010 (SMART 2008), total consumer surplus generated assuming all sites were “high coral and high marine life” reef systems may have been as high as $550m, while the cost of the coral bleaching event may have ranged from $98m to $147m (40–60% bleaching) depending on the magnitude of the event in each country (Table 4).

The figures in Table 4 assume that benefits are lost throughout the year. The bleaching event in 2010 spanned up to five months in these countries (Thomas and Heron 2011), not including the recovery time of surviving corals. Even if the economic impact of bleaching is assumed to have lasted for a total of six

[1] Although the actual variable is categorical and the levels are identified by discrete numerical values, the econometric model treats these values as continuous cardinal values. That is, a value of 3 (High) is considered to be three times the value of 1 (Low).
[2] All currency values are USD in 2010 values.

[3] The scenarios examined only included up to 75% bleaching (represented as 0.75 in the analysis). The willingness-to-pay estimate represents the marginal benefit (or cost) of a one unit change, which in this case represents 100% bleaching.

months, the cost of the bleaching event remains substantial ($49m to $74m).

Table 4. Estimated value of pristine reef and the potential cost of coral bleaching ($m)

| | Dive visits ('000) | Total consumer surplus | Bleaching cost Lower estimate | Bleaching cost Higher estimate |
|---|---|---|---|---|
| Thailand | 1,288 | 211.3 | 37.6 | 56.4 |
| Malaysia | 1,715 | 281.3 | 50.1 | 75.2 |
| Indonesia | 352 | 57.7 | 10.3 | 15.4 |
| Total | 3,355 | 550.3 | 98.0 | 147.0 |

Notes: lower and higher estimates assume 60% and 80% bleaching respectively.

## Discussion

The non-market value of recreational dive use of coral reefs in this study is similar in magnitude to those in other regions (Brander *et al.* 2007). Relatively few studies have considered the cost of coral bleaching *per se*, with estimated costs ranging from $85/dive (Ngazy *et al.* 2004) to between $110 and $300 per dive (Andersson 2007). Given this range, the estimate costs of coral bleaching from this study of between $44 and $58 may be conservative.

There is little marine resource managers can do to prevent coral bleaching *per se*, although the resilience of coral reefs to bleaching events can be enhanced through appropriate management (Hughes *et al.* 2003). Reducing reef pressures by preventing unsustainable fishing, protecting herbivorous fish, and protecting water quality are the most important management actions for promoting reef resilience. Even with these actions, reef recovery can take decades and result in a loss of biodiversity (Marshall & Schuttenberg 2006).

Effective marine resource conservation requires some form of funding mechanism. From this study, the consumer surplus associated with healthy reefs is substantial, with divers on average willing to pay up to $164 more per dive for reefs of high quality. Implementing a user fee to assist in the management of the marine resources in these areas is therefore feasible. Within South East Asia and globally, there are several examples of user fees being successfully implemented to address environmental and equity issues, notably at Bunaken National Marine Park in Indonesia (Erdmann *et al.* 2004), and Tubbataha World Heritage Site in the Philippines (Tongson and Dygico 2004). A meta-analysis of diver willingness-to-pay confirms widespread diver support for conservation fees if users have confidence the fee will go toward improved management (Peters and Hawkins 2009).

It is important to note that self-reported (i.e. aspirational) willingness-to-pay may not perfectly translate into actual purchasing behavior. Charging user fees requires a balance between the amount of the fee charged and its impact on visitor numbers. Given the existence of alternative dive areas, alternative destinations for international tourists and also alternative activities in each country, too high a charge may result in a reduction in diver numbers and an overall loss of benefits. However, research in related domains of conscientious consumption (sweatshop products) shows that more than three quarters of the market may follow their conscientious aspirations through with actual purchasing behavior (Kimeldorf *et al.* 2006)

Getting the balance right is a challenge, and additional analysis of recreational diving travel demand is required. Adopting a regional perspective on such an analysis would provide important insights regarding the benefits of a coordinated approach across areas and countries in this domain.

The results of this study, however, suggest that the non-market cost of coral bleaching may be substantial, and hence user fees to prevent or minimize the damage from future bleaching events, and/or support recovery from events, may be justifiable and accepted by divers in these areas.

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