Effects of the 2013 Rayong Oil Spill on Gonadal Maturation of Reef Corals

Narinratana Kongjandtre* and Wansuk Senanan

ABSTRACT

After the oil spill incident in Rayong, Thailand in 2013, it was recognized that information on the toxicity and other effects of dispersed oil on reef organisms, and corals in particular, was very limited. This study examined the effects of the oil spill on gonadal maturation of reef corals in Rayong. We repeatedly sampled colonies of six coral taxa (*Favia* spp., *Favites* spp., *Goniastrea* spp., *Platygyra* spp., *Symphyllia* spp. and *Porites* spp.) at impacted and control sites during October 2013 and March 2014. The results showed no significant difference in gonadal development between impacted and control sites. However, we found that *Porites* spp. was very sensitive to the oil spill, and they responded by producing large amounts of mucus, with some colonies losing zooxanthellae and being bleached. The histological study revealed that most colonies contained oocytes and spermaries at stages II – IV both in October 2013 and March 2014. Long term monitoring at these sites should be done to monitor for chronic effects, and that data should include the average number of ovaria per colony and oocyte diameter from impacted sites compared to control sites.

Keywords: oil spill, coral reproduction, Rayong

INTRODUCTION

Coral reefs are subject to anthropogenic oil contamination from a variety of chronic and short-term sources (e.g. transfer and transportation of bulk oil, refinery operations, oil spills). The Red Sea was subjected to frequent oil spills during the 1970s and 1980s, therefore the harmful impacts of oils and their water soluble fractions on reef corals have been well documented (e.g. Loya 1975; Rinkevich and Loya, 1977, 1979; Loya and Rinkevich 1979; Epstein *et al*. 2000). Major oil spills have not yet affected Australian coral reefs, however shipping routes and drilling platforms have the potential to deliver petroleum hydrocarbons into coral reef ecosystems. Therefore, a number of authors have examined the toxic effects resulting from exposure to dispersed oil and dispersants on fertilization and larval metamorphosis (Harrison 1999; Lane and Harrison 2000; Negri and Heyward 2000). The effects of oil spills can be acute, as oil exposure can kill corals; however, impacts depend on the degree of exposure and varying

Department of Aquatic Science, Faculty of Science, Burapha University, Chonburi, 20131, Thailand
*Corresponding author; e-mail address: narinratana@buu.ac.th

time frames. Chronic effects may include histological, biochemical, behavioral, reproductive, and developmental effects. Stress responses shown by corals exposed to oil may include tissue death (Reimer 1975; Neff and Anderson 1981), increased mucus production (Harrison *et al*. 1990), change in calcification rate (Dodge *et al*. 1984), gonad damage (Rinkevich and Loya 1979), premature extrusion of planulae (Loya and Rinkevich 1979), larval death (Rinkevich and Loya 1977) and impaired larval settlement (Rinkevich and Loya 1977).

Exposure of corals to oil contamination may occur through direct contact with the oil and through the oil water accommodated fraction (WAF). However, the use of chemical dispersants in oil spill management may also be harmful to corals, and the dispersed oil itself may not be safe. A number of experiments have proven that both dispersed oil and dispersant are more highly toxic to planula larvae and inhibit fertilization than WAF (Epstein *et al*. 2000; Lane and Harrison 2000; Negri and Heyward 2000). For spawning coral species, *Acropora* spp. are far more sensitive to dispersed oil and dispersant than *Goniastrea aspera* and *Platygyra sinensis*, respectively (Lane and Harrison 2000; Mercurio *et al*. 2004; Negri and Heyward 2000). Although these studies have documented negative impacts to fertilization, larval metamorphosis and survivorship from oil contamination, these effects were only seen when the spawning and pollution events were synchronous. However, a few studies have been concerned with histopathological effects from fuel oil (Peters *et al*. 1981; Harrison *et al*. 1990). Peters *et al*. (1981) examined the correlation between bioaccumulation of hydrocarbons and histopathological changes in Caribbean coral *Manicina areolata*. They found that *M. areolata* incorporated petroleum hydrocarbons into their tissues during exposure to WAF for three months. This contamination was still present in the tissues after two weeks. The corals remained alive but had impaired development of reproductive tissue, degeneration and loss of symbiotic zooxanthellae, and atrophy of mucous secretory cells.

On July 27, 2013, approximately 50 tons of oil leaked into the Gulf of Thailand (GoT) from the pipeline owned by PTT Global Chemical, with a large amount drifting over the popular tourist destination, Ko Samet in Rayong province. PTT Global Chemical then used boats and airplanes to spray oil-spill dispersants including Slickgone NS and Super-Dispersant 25, as they have low toxicity, are biodegradable and do not bio-accumulate. After spillage reached Ao Phrao at Ko Samet, tourism operators, public and media expressed concern about the effects of crude oil and the dispersant on marine organisms, especially corals.

Rayong Province is located between latitude 12° 30' N-12° 38' N and longitude 101° 19' E-101° 45' E. There are several islands with coral reefs along the coastline which may be classified into two island groups, one is the Samet and Kudi Islands and the other is the Man Islands. These islands harbor coral reefs with a total area of approximately 5 km^2 (Department of Marine and Coastal Resources 2012). Coral populations in Rayong Province are known to spawn following the full moons of February/March (Kongjandtre *et al*. 2010). Recently Kongjandtre and Chankong (2015) reported a second spawning season occurring after the full moon of October.

The literature cited above indicates that contamination from oil spills can be accumulated in coral tissue and disrupt development of reproductive tissue. The Rayong oil spill incident occurred only a few months prior to the spawning season, and thus might have had the potential to cause immediate impact on the gonadal maturation of reef corals. Therefore, the aim of this study was to evaluate the effects of Rayong oil spill on gonadal maturation of common reef corals at Ko Samet and nearby islands.

MATERIALS AND METHODS

Study sites

Based on the movement of oil slick observed from aerial photography (GISTDA) from July 27-31, 2013, it was hypothesized that the concentration and movement of oil and oil slick might lead to various degrees of impact among sites around Ko Samet.

Ten study sites were selected and classified into three impact levels or used as control sites (Figure 1). Four out of ten sites were new (sites 1-4) which were chosen for monitoring after the oil spill incident, whereas the other six sites (sites 5-10) have been used for continuous monitoring since February 2011 (Kongjandtre and Chankong, 2015).

1) high impact sites included two sites; site 1, southern part of Ao Phrao (AP) and site 2, Laem Rue Tack (RT)

2) medium impact sites included two sites; site 3, Laem Phra (LP) and site 4, Ao Luk Yon (LY)

3) low impact sites included three sites; site 5, Ao Lung Dam (LD), site 6, Ko Kham (KM) and site 7, Ko Kudi (KD)

4) control sites (no impact) included three sites; site 8, NaaBaan, Ko Man Nai (NB), site 9, Ton Leab, Ko Man Nai (TL) and site 10, Ko Man Klang (MK).

Collection and Histological Processing

Study sites were assigned to predict the degree of impact from the oil spill as described above. At each site, three replicates of 30 meter permanent transects were established and coral colonies along transects were tagged for coral tissue sampling. To evaluate the sensitivity to the oil spill among taxa, common massive coral species belonging to the Poritidae, Faviidae and Mussidae were selected as representatives for this area. The process of sediment rejection depends on variations in the polyps and geometry of the calice, and large polyps are expected to have higher tolerance to sediment (Hubbard and Pocock 1972). Taxa groups were therefore categorized by size of their polyps as small polyp (2-4 mm in diameter) *Porites* spp., medium polyp (4-15 mm in diameter) including *Favia* spp., *Favites* spp., *Goniastrea* spp., *Platygyra* spp. and large polyp (> 15mm in diameter) *Symphyllia* spp. Coral tissue samples from tagged colonies were collected around the full moon prior to the October 2013 and March 2014 spawning seasons. In addition, bleached colonies at Ao Phrao (AP13, AP15, AP16) were tagged and compared with unbleached colonies at the same location (AP07, AP14), and with colonies from other sites.

At each site, at least two colonies from each taxon were tagged. Samples of one nubbin per colony (approximately 6-10 cm^2 of tissue containing 5-100 polyps depending

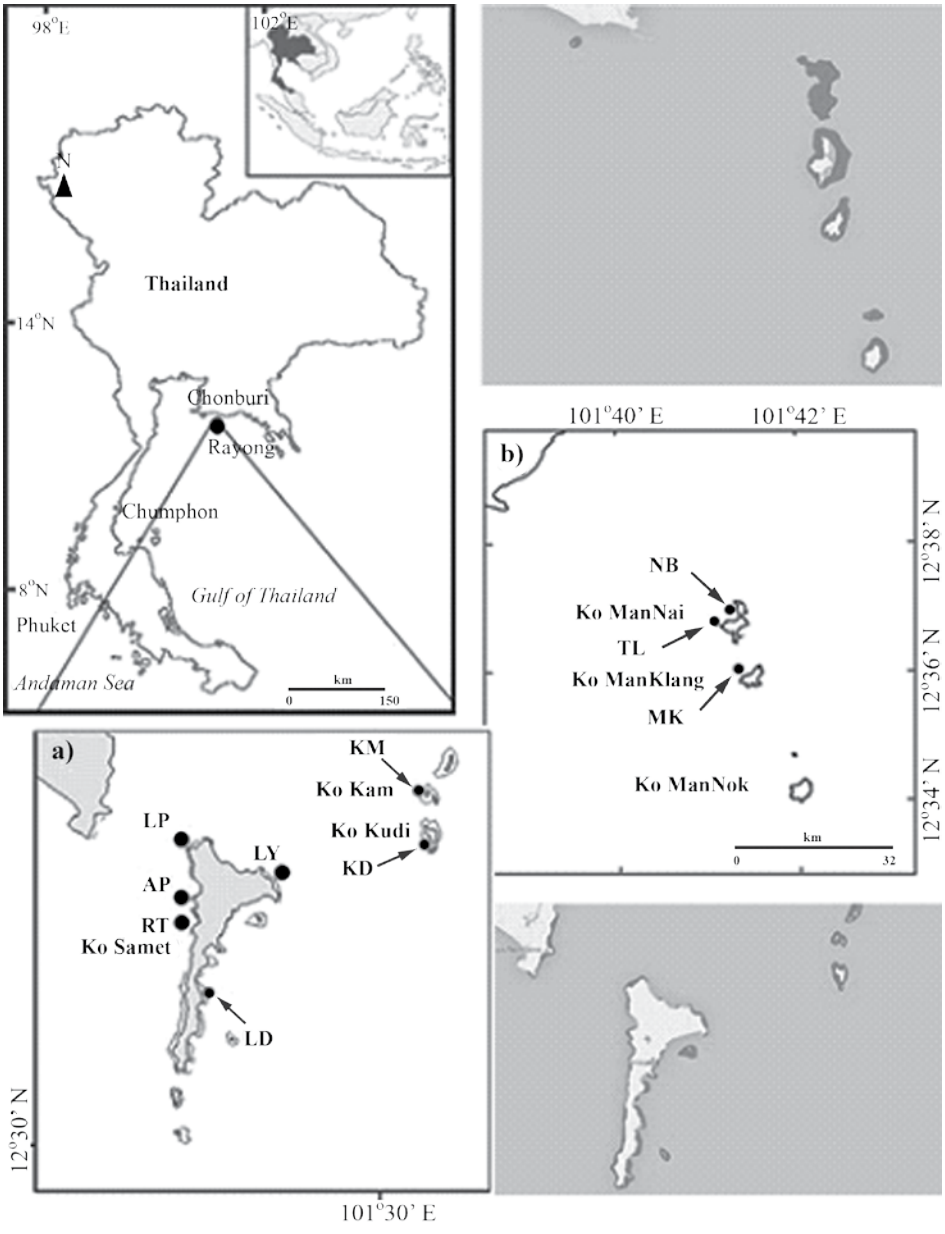

Figure 1. Study sites near Samet (a) and Man (b) Islands and predicted impact from the oil spill (red = high impact, yellow = medium, green = low, blue = no impact/control). Coral reef areas are highlighted in blue.

on the species) were removed using a hammer and chisel. Gametes usually develop with high synchrony among polyps, therefore one nubbin is sufficient to determine the reproductive condition of the colony, as well as sexuality and mode of reproduction (Baird *et al*. 2011). To avoid localized effects of repeated sampling on polyp fecundity, samples were taken from different parts of the colonies in the second sampling period (Oren *et al*. 2001). Collected samples were fixed in 10% sea water formalin before laboratory study. Samples were processed using standard histological procedures Szmant-Froelich *et al*. 1980; Glynn *et al*. 1991). The nubbins were decalcified in 10% formic acid, dehydrated using a series of ethanol and xylene, infiltrated with paraffin, and embedded in paraffin blocks. Samples were oriented in cross-section and cut with a microtome at 6-8 µm thickness. Four sections were mounted on slides and stained with Mayer's hematoxylin and eosin (H & E). Hematoxylin stains nuclei blue and the eosin stains cytoplasmic elements various shades of red. Slides were examined for the presence or absence of oocytes or spermaries under a binocular compound microscope (Leica ICC50 HD). The stage of maturity of the gametes in each histological section was classified using a modification of the characteristics outlined in Szmant-Froelich *et al*. (1980) and Glynn *et al*. (1994) (Table 1). Mature gametes (stage IV) were assumed to be released from colonies within a month.

At each sampling period, the colonies from each taxon were pooled among sites at each impact level (Table 2). Then stages of gonadal development were scored as absent (E0 or S0) or stage II-IV (E2-E4 and S2-S4). The number of colonies containing each developmental stage was compared to the total number of colonies as a percentage. One-way analysis of variance (ANOVA) was used to determine if there was any significant difference (p <0.05) in the gonadal development due to degree of impact from the oil spill. We also tested if there was any significant difference in the gonadal development among sampling periods and among taxa.

Table 1. Criteria for differentiating stages of gonadal development as seen in histological sections of the mesenteries

Stages	Female	Male
I	Oocytes observed as enlarged oval nuclei surrounded by a thin layer of cytoplasm	Small cluster of cells migrating into mesoglea
II	Accumulation of cytoplasm around nucleus located in mesoglea; oocyte diameter greater than those in stage I	Larger cluster of cells enveloped by mesoglea
III	Characterized by extensive yolk formation; cytoplasm filled with vesicles of orange to pink grainy substance	Cell proliferation occurring; lumen often present in this stage, usually circular in outline
IV	Spherical nucleus moved toward the periphery of the cell and triangular or saddle shaped	Cells containing dark, dense nuclei; spermaries with spermatocyte tails aligned in 'bouquet'

Table 2. Total number of colonies sampled in this study

Sampling date	Taxa	Control	Low impact	Medium impact	High impact
Oct-13	*Favia*	4	7	4	6
Oct-13	*Favites*	3	4	1	3
Oct-13	*Goniastrea*	5	8	5	8
Oct-13	*Platygyra*	12	9	4	4
Oct-13	*Symphyllia*	3	4	4	1
Oct-13	*Porites*	3	6	6	5
Mar-14	*Favia*	2	7	4	5
Mar-14	*Favites*	2	4	1	3
Mar-14	*Goniastrea*	4	11	5	7
Mar-14	*Platygyra*	13	9	7	4
Mar-14	*Symphyllia*	5	3	4	1
Mar-14	*Porites*	4	4	5	7

RESULTS

Reproduction in coral assemblages

After the spill, many colonies of *Porites* spp. showed signs of recent stress, including bleaching, swelling of tissue and conspicuous production of mucus. A large amount of mucus were present in the mesenteries of *Porites* specimens from impacted sites. However, no abnormalities in other taxa were observed.

A total of 119 colonies belonging to six taxa were sampled in October 2013, and 121 colonies in March 2014. Five of the six taxa were hermaphroditic broadcast spawners (*Favia* spp., *Favites* spp., *Goniastrea* spp., *Platygyra* spp. and *Symplyllia* spp.). Oocytes were numerous and consisted of stages II-IV; however, maturation stages were observed synchronously among colonies (Figures 2 and 3). Gametes were expected to be spawned both during October/November 2013 and February/March 2014 (Kongjandtre and Chankong 2015). In this study, *Porites* spp. were observed to be gonochoric (male and female are separate colonies), however *Porites* spp. are also known to be hermaphroditic, and colonies can be brooders as well as spawners (Glynn *et al*. 1994).

There was no significant difference in gonadal development or maturation among impacted and control sites during October 2013 and March 2014. However, a statistical significant difference detected among taxa in *Porites*, probably due to being gonochoric if colony is male was not observed any oocyte stages.

Figures 2 and 3, and Tables 3 and 4 show that, within *Favia* spp. (Figure 4), *Favites* spp. (Figure 5), *Goniastrea* spp. (Figure 6), and *Platygyra* spp. (Figure 7), more than one maturation stage of oocytes and spermarieswere found in the colonies both from October and March. *Symphyllia* spp. (Figure 8) showed a similar pattern; however, in many samples collected in March 2014, no spermaries were observed in the mesentery.

Table 3. Oogenesis in *Favia* spp., *Favites* spp., *Goniastrea* spp., *Platygyra* spp., *Symphyllia* spp. and *Porites* spp. as observed in histological sections from samples collected in Rayong during October 2013 and March 2014

Taxa	Stage I	Stage II	Stage III	Stage IV
Favia	Not observed	Accumulation of blue stained yolk around nuclei	Oocytes expanding as yolk cells and lipid granules accumulate; finely granular yolk stained pink; nucleus present at the center of oocytes	Oocytes full size; stained dark pink; nucleus at periphery; clear lipid globules; oocytes crowded, variable shapes
Favites	Not observed	Accumulation of blue staining yolk around nuclei	Oocytes expanding as yolk cells and lipid granule accumulate; finely granular yolk stained pink; nucleus present at the center of oocytes	Oocytes full size; stained dark pink; nucleus at periphery; clear lipid globules; oocytes crowded, variable shapes
Goniastrea	Not observed	Accumulation of blue staining yolk around nuclei	Oocytes expanding as yolk cells and lipid granules accumulate; finely granular yolk stained pink; nucleus present at the center of oocytes	Oocytes full size; stained dark pink; nucleus at periphery; clear lipid globules; oocytes crowded, variable shapes
Platygyra	Not observed	Accumulation of blue staining yolk around nuclei	Oocytes expanding as yolk cells and lipid granule accumulate; finely granular yolk staining pink; nucleus present at the center of oocytes	Oocytes full size; stained dark pink; nucleus at periphery; clear lipid globules; oocytes variable shapes
Symphyllia	Enlarged interstitial cells with large nuclei in mesoglea of mesenteries	Accumulation of small amount of cytoplasm around nuclei; yolk staining blue	Oocytes expanding as yolk cells and lipid granule accumulate; finely granular yolk staining pink; nucleus present at the center of oocytes	Oocytes full size; stained dark pink; nucleus at periphery; clear lipid globules; oocytes large, very crowded, variable shapes
Porites	Not observed	Accumulation of cytoplasm around nuclei, nuclei are granular; yolk staining blue remain in the center of oocytes; oocytes not crowded	Extensive yolk formation and accumulated lipid granules; cytoplasm filled with clear vesicles; finely granular yolk staining pink; nucleus present at the center of oocytes; oocytes crowded in the mesenteries	Oocytes very crowded, variable shapes

Table 4. Spermatogenesis in *Favia* spp., *Favites* spp., *Goniastrea* spp., *Platygyra* spp., *Symphyllia* spp. and *Porites* spp as observed in histological section from samples collected in Rayong during October 2013 and March 2014.

Taxa	Stage I	Stage II	Stage III	Stage IV
Favia	Not observed	Small clusters of interstitial cells near the mesoglea; staining deep blue	Number of cells within spermary is larger; conspicuous peripheral arrangement of spermatocytes and lumen present at the center; spermatocytes staining blue	Spermatozoa with tails; spermaries aligned between oocytes in the mesentery
Favites	Not observed	Small clusters of interstitial cells near the mesoglea; staining deep blue	Number of cells within spermary is larger; conspicuous peripheral arrangement of spermatocytes and lumen present at the center; spermatocytes staining blue	Spermatozoa with tails; spermaries aligned between oocytes in the mesentery
Goniastrea	Not observed	Small clusters of interstitial cells near the mesoglea; staining deep blue	Number of cells within spermary is larger; conspicuous peripheral arrangement of spermatocytes and lumen present at the center; spermatocytes staining blue	Spermatozoa with tails; spermaries aligned between oocytes in the mesentery; similar to those found in *Favia* and *Favites*
Platygyra	Not observed	Small clusters of interstitial cells near the mesoglea; staining deep blue	Number of cells within spermary is larger; conspicuous peripheral arrangement of spermatocytes and lumen present at the center; spermatocytes staining blue	Spermatozoa with tails; spermaries aligned close to oocytes
Symphyllia	Not observed	Small clusters of interstitial cells near the mesoglea; staining deep blue	Number of cells within spermary is larger Conspicuous peripheral arrangement of spermatocytes and lumen present at the center; spermatocytes staining blue; spermaries crowded in the mesentery	Spermatozoa with tails; spermaries aligned in different position from the oocytes in the mesentery
Porites	Not observed		Number of cells within spermary is larger; conspicuous peripheral arrangement of spermatocytes and lumen present at the center; spermatocytes staining blue	Spermatozoa with tails

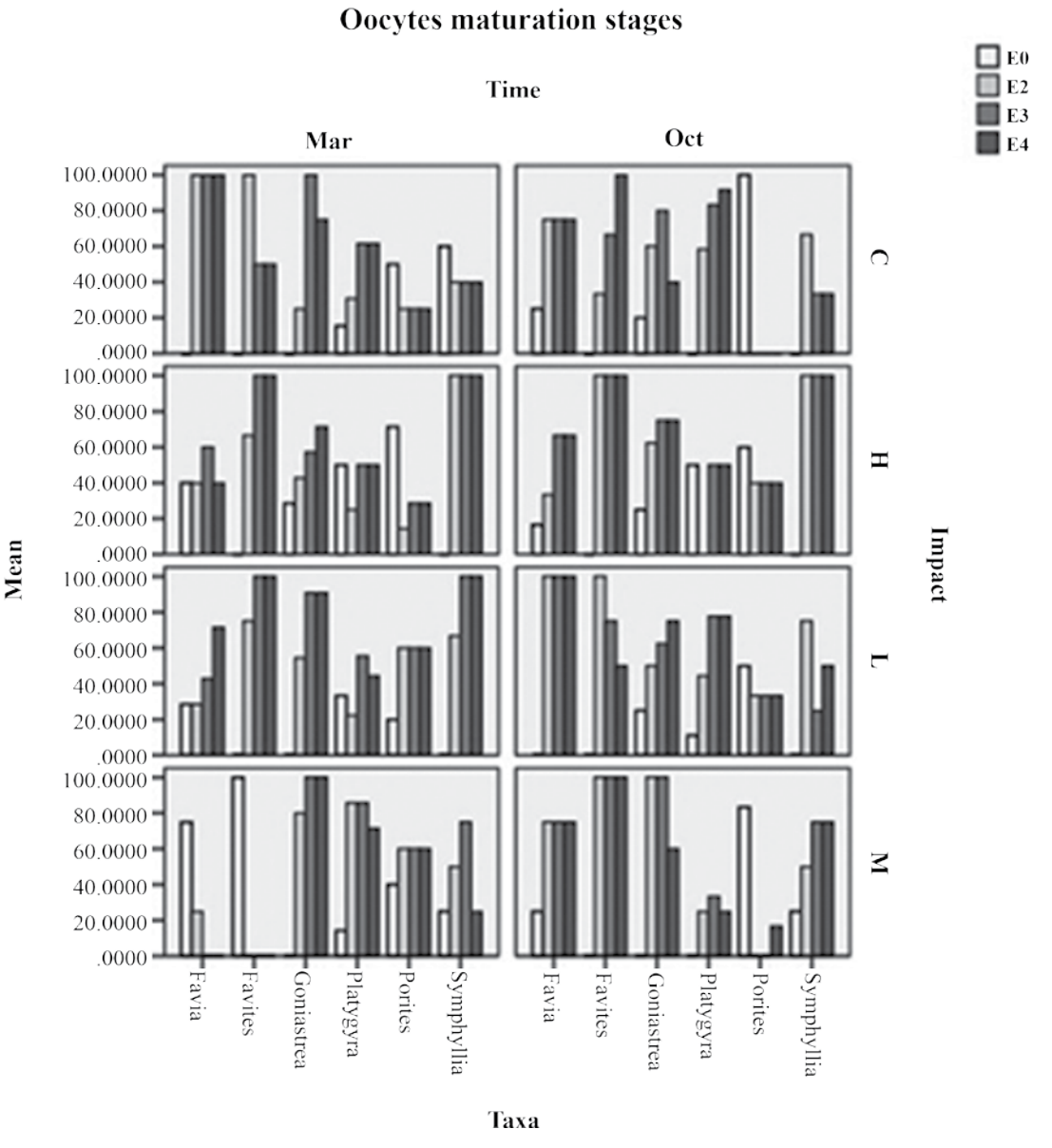

Figure 2. Mean percentage of colonies with oocyte stages II-IV (E2-E4) and absence of the oocyte (E0) from six coral taxa at control (C), high impact (H), low impact (L), and medium impact (M) sites. Sampling was between October 2013 and March 2014.

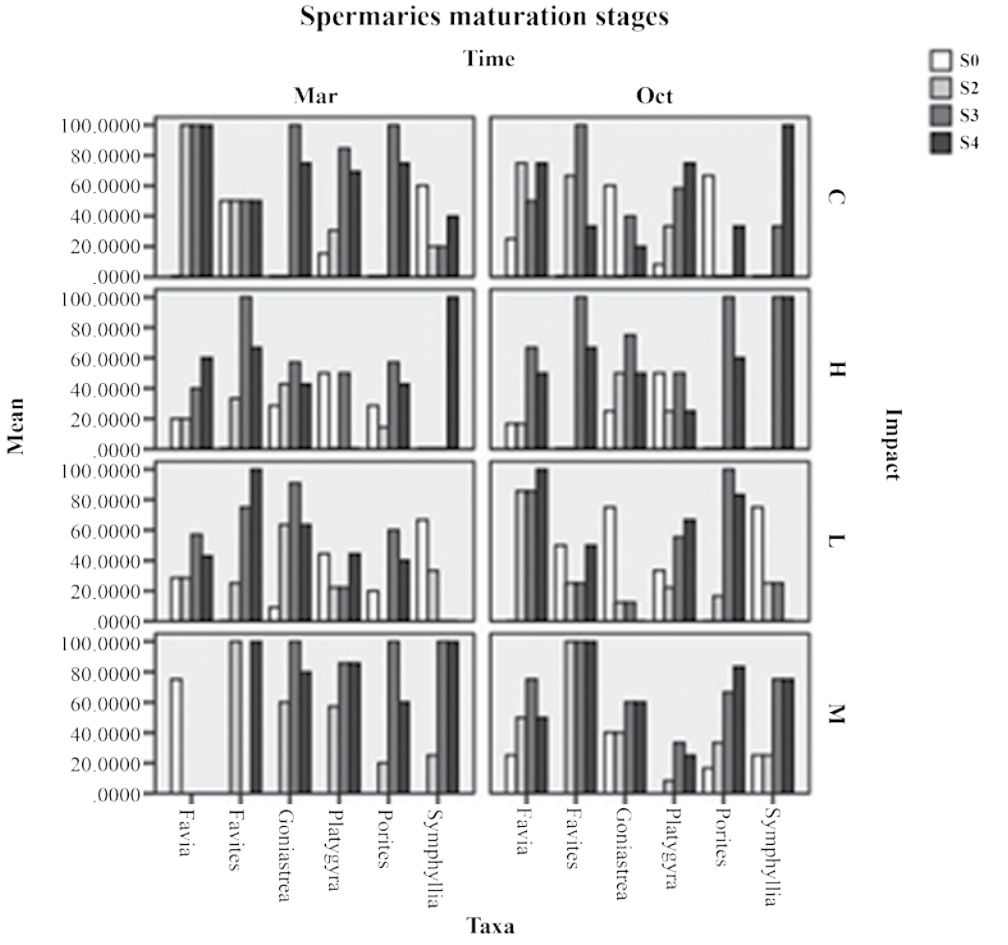

Figure 3. Mean percentage of colonies with spermaries stages II-IV (S2-S4) and absence of the oocyte (S0) from six coral taxa at control (C), high impact (H), low impact (L), and medium impact (M) sites. Sampling was between October 2013 and March 2014.

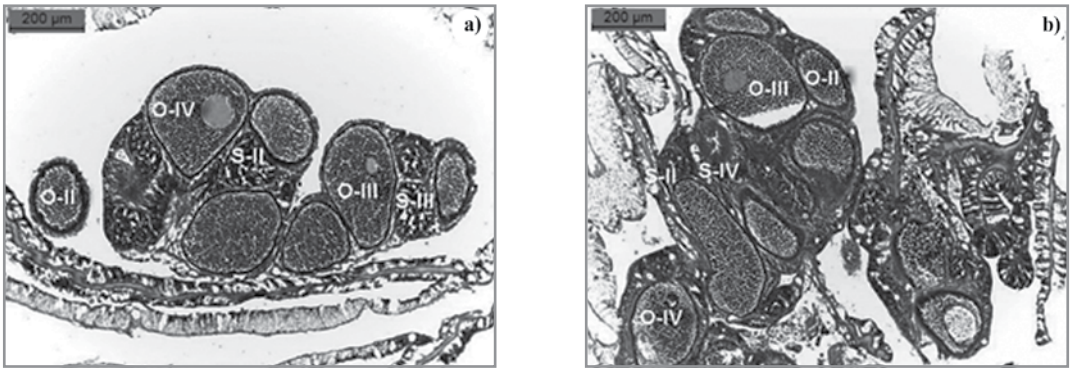

Figure 4. Oogenesis in *Favia speciosa* (LD14) Stage II - IV oocytes crowded within mesentery, nucleus towards the periphery of the oocyte. Spermatogenesis stages II - IV a) October 2013 b) March 2014; *S* spermary, *o* oocyte, *nu* nucleus, *scale bars* = 200 microns

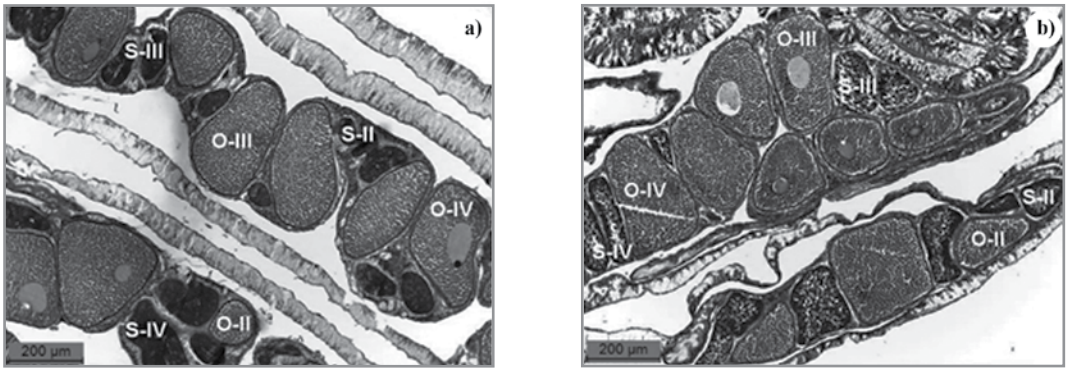

Figure 5. Oogenesis in *Favites abdita* (LD07) Stage II-IV oocytes crowded within mesentery, nucleus towards the periphery of the oocyte. Spermatogenesis stage II-IV a) October 2013 b) March 2014; *S* spermary, *o* oocyte, *scale bars* = 200 microns

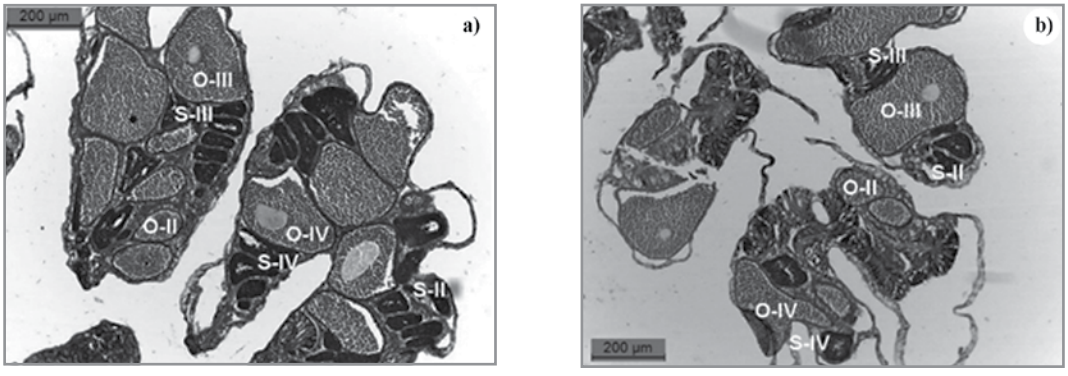

Figure 6. Oogenesis in *Goniastrea retiformis* (KD07) Stage II-IV oocytes crowded within mesentery, nucleus towards the periphery of the oocyte. Spermatogenesis stage II-IV a) October 2013 b) March 2014; *S* spermary, *o* oocyte, *scale bars* = 200 microns

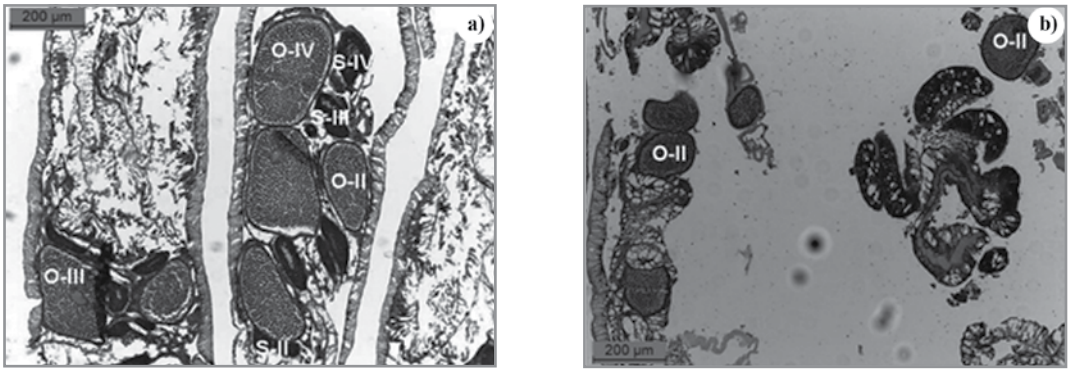

Figure 7. Oogenesis in *Platygyra sinensis* (KM07) Stage II-IV oocytes crowded within mesentery, nucleus towards the periphery of the oocyte. Spermatogenesis stage II-IV a) October 2013 b) March 2014; *S* spermary, *o* oocyte, *scale bars* = 200 microns

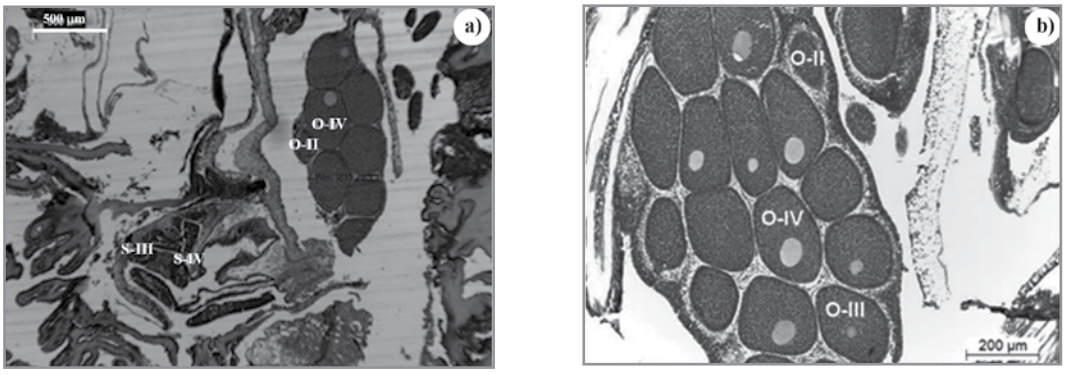

Figure 8. Oogenesis in *Symphyllia* (KM09) Stage II - IV oocytes crowded within mesentery, nucleus towards the periphery of the oocyte. Spermatogenesis stage III & IV a) October 2013 b) March 2014; *S* spermary, *o* oocyte, *scale bars* = 200-500 microns

In *Porites* spp., more than one maturation stage of oocytes and spermaries were found at all sites (Figures 2 and 3). In October 2013, bleached colonies AP15 and AP16 had signs of reproduction (Figure 9), but with only oocytes, whereas AP7 produced spermaries (Figure 10). However, a high number of mucus cells were observed inside the mesenteries. Neither oocytes nor spermaries were observed in colonies AP13 and AP14 but both colonies had a high number of mucus cells in the mesenteries (Figure 11). In one medium impact site, Ao Luk Yon (LY04), we did not observe gametes in October 2013; only mucus cells were observed inside the mesentery. However, this colony produced various stages of spermaries in March 2014 (Figure 12).

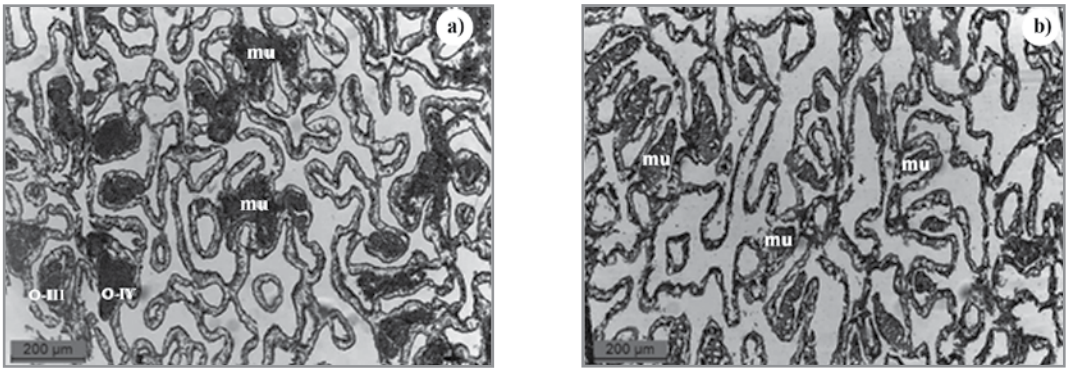

Figure 9. Oogenesis in bleached colony of *Porites* sp. (AP16) Stage III - IV oocytes crowded within mesentery, with mucus cells distributed inside the mesentery a) October 2013 b) March 2014; *S* spermary, *o* oocyte, *mu* mucus, *scale bars* = 200 microns

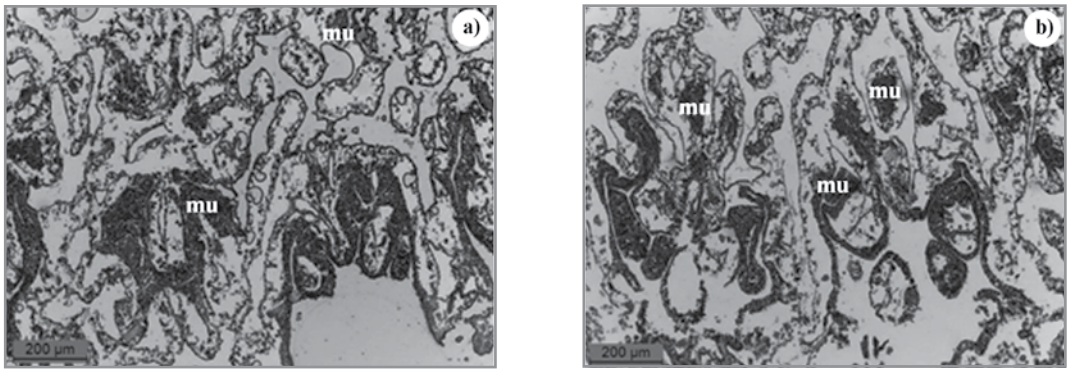

Figure 10. No reproductive output observed in colonies number AP13 and AP14 but all colonies contained high number of mucus cells in the mesenteries. a) AP13, October 2013 b) AP14, October 2013; *mu* mucus, *scale bars* = 200 microns

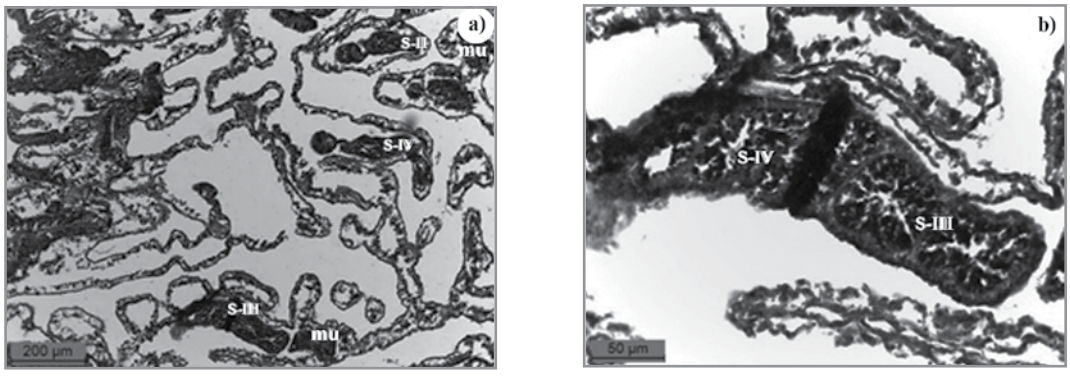

Figure 11. Spermatogenesis in unbleached colony of *Porites* sp. (AP07) (October 2013) a) Stage II - IV spermaries within mesentery, with mucus cells distributed inside the mesentery b) close-up of spermaries; *S* spermary, *mu* mucus, *scale bars* = 50-200 microns

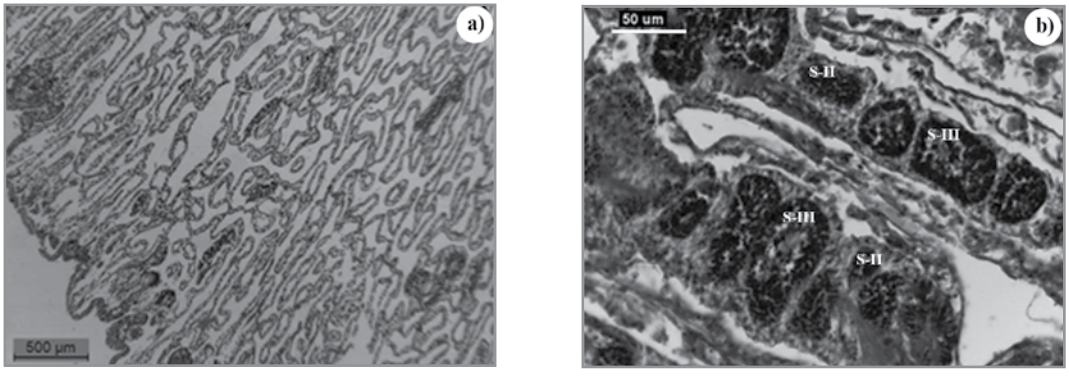

Figure 12. Spermatogenesis from medium impact site of *Porites* sp. (LY04) a) no gametes observed in the mesenteries during October 2013, only mucus cells presented in the mesentery b) stage II-IV spermaries observed in March 2014; *S* spermary, *scale bars* = 50-500 microns

DISCUSSION

The major purpose of this work was to evaluate the impact of an oil spill on gonadal development of reef corals around Ko Samet and nearby islands. There was no significant difference in gonadal development or maturation among impacted and control sites. All taxa studied contained mature gametes (Stages III-IV) and were ready to spawn during October/ November 2013 and also during a summer spawning season. Some of the population had already spawned in February 2014 as evidenced from the absence of gametes (Figures 2 and 3) and some of them were ready to spawn in March 2014. There are many gaps in our knowledge of the life history of corals, in particular concerning their sexual reproduction in Thai waters. It is not surprising, therefore, that very limited information exists on the effects of oil pollution on coral reproduction. A major source of information originates from studies in the Red Sea along the Gulf of Eilat. Loya (1975) suggested that frequent oil spills in Eilat resulted in one or a combination of impacts, including 1) damage to coral reproductive systems; 2) decreased viability of coral larvae; and 3) changes in physical properties of the reef flat which interfere with normal settlement of coral larvae.

In this study, for broadcast spawning corals we did not observe that the oil spill damaged coral reproductive systems; however, many colonies of *Porites* showed signs of stress by producing a large number of mucus cells in the mesentery. Mucus secretion by coral is a well-known protective mechanism in response to external perturbation. Corals with large and fleshy polyps with abundant mucus cleaned themselves within one day after colony submersion in clean water (Johannes *et al*., 1972). Harrison *et al*. (1990) reported that *Acropora formosa*, when exposed to 5 and 10 ppm of marine fuel oil, will produce massive amounts of mucus.

In a study of the effects of spilled oil and dispersant discharged in natural reef habitats in Eilat *et al*. (1977) investigated brood coral (*Stylophora pistillata*) in the field and compared a chronically oil-polluted area to a clean reef. In the polluted reef, coral showed higher mortality rate of colonies, smaller number of breeding colonies, decrease in the average number of ovaria per polyp, smaller number of planulae produced per coral colony and lower number of larvae settling on artificial objects. Similarly, in the laboratory Rinkevich and Loya (1979) used Iranian crude oil to simulate polluted conditions. Mature colonies of *S. pistillata* were cut in two, with one half placed in the polluted tank, and the other placed in a clean tank. After two months, a significant decrease in the number of female gonads per polyp was recorded in 75% of colonies in the polluted tank, compared with no change in the control (clean tank).

However, Lane and Harrison (2000) examined the effects of the water accommodated fraction (WAF) of fuel oil (a bunker oil, Fuel Oil 467^{TM}), dispersed fuel oil, and Ardrox 6120 dispersant on the survivorship of *Acropora tenuis*, *Goniastrea aspera*, and *Platygyra sinensis* coral larvae at Magnetic Island on the Great Barrier Reef. The results showed that the least toxic contaminant tested was the WAF, which caused increased mortality of *A. tenuis* and *G. aspera* larvae only at the higher concentration tested. Additionally, no toxic effects in Oil WAF treatments were

observed until at least 24 hours of exposure. On the other hand, dispersed oil was the most toxic (with hydrocarbon concentrations of ≥ 4.9 ppm) followed by dispersant (dispersant concentrations of ≥ 75 ppm). Both are highly toxic to planula larvae of *A. tenuis*, *P. sinensis* and *G. aspera*, resulting in 100% mortality of exposed larvae of all species within 96 hours, and with the majority of larvae dying within 24 hours.

CONCLUSION

Porites spp. can be considered as sensitive to oil spills compared to other coral taxa on reefs in Rayong, probably due to their small size of polyps. However, no significant differences in coral gametogenesis were observed among sites, for all taxa studied. Probably this is due to the small scale of this oil spill (50 tons) compared to other incidents around the world (500 - 25,000 tons; Loya and Rinkevich, 1980). Also, the impact of the dispersant was probably diluted due to the exposure to wind and waves at the impacted site. However, long term monitoring at these sites should be done, including data on average number of ovaria per polyp and oocyte diameter, as well as the ability of juvenile corals to recruit at impacted sites compared to control sites.

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