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PEST MANAGEMENT IN CRISIS

Area-wide fly management in the tsunami-affected zones of Tohoku region, Japan

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Pest managers are interested in developing best practices to address pest issues—from sudden outbreaks, to serious chronic infestations—with the goals of safe and healthy outcomes and minimal economic, social, and environmental consequences. No single best practice would be suitable for every pest management scenario, as situations vary over time and space. Pest managers should, as part of daily operations, be proactive and strive to prevent pest infestation using an integrated pest management (IPM) approach that includes regular inspections, reducing sources of food, water and shelter (source reduction), as well as pest-proofing, using ecologically acceptable methods rather than simply reacting after an infestation is reported. However, when pest management is required to avert a public health crisis, such as in the aftermath of a natural disaster, pest management measures may need to quickly address an extreme situation.

On 11th March 2011 at 14:46 hrs, the Great East Japan Earthquake occurred. This earthquake, which registered magnitude 9 on the Richter scale, was so powerful that Honshu Island moved 2.44 m eastward and the Earth shifted 10–25 cm from its axis (New York Times 2011). The earthquake triggered tsunami waves of up to 40.5 m in height in Miyako (NHK 2011) that moved as far as 10 km inland. The World Bank estimated the economic damage to be US$235 billion, making it the most expensive natural disaster in world history (Los Angeles Times 2011). It resulted in 19,335 deaths, 6,219 injuries, and 2,600 missing people. In addition, 124,690 private homes were completely damaged, 275,118 half-damaged, while another 764,843 partially damaged (Japan Fire & Disaster Management Agency 2015). The disaster also left 450,000 people homeless immediately after the disaster and there are still some 228,000 people living in shelter homes up to today (Kobe Shinbun 2015).

The earthquake and tsunami created 25 million metric tons of garbage, equivalent to what would normally be generated over the course of 9 - 14 years (MOEJ 2015). The 400 km coastline of northeast Honshu Island (Tohoku region) ranging from Miyako in Iwate Prefecture to Minamisouma in Fukushima Prefecture were badly affected by the tsunami (Plate 1). This area contains many cities and towns with fishing ports, seafood and marine product processing plants, and freezer warehouses. The Japan Annual Marine Industrial Statistics estimated that these areas produced ~443k metric tons of fish, as well as ~100k metric tons of fish-based products in 2010 (Tabaru et al. 2014). Following the tsunami, these seafood products, including oyster rafts, fishing and scallop breeding nets were strewn all over this coastal region (Plate 2).

Plate 1: Map showing the range of tsunami-affected coastline by the Great East Japan earthquake in March 2011.

Plate 2: Large amount of seafood products were strewn all over the affected cities creating a massive amount of resources for flies to breed.

The abundance of food sources led to an explosion of fly populations in these cities. In addition, household debris and ruined structures served as containers for standing water that allowed mosquitoes to breed. The cold weather in March/ April delayed fly breeding and larval development, Blow Fly (Calliphoridae) maggots started to appear in early May. Large numbers of adult Blow Flies subsequently began to appear in the affected cities, followed by House Flies. Cases of food poisoning increased, and emergency pest management operations had to be executed to prevent a possible serious public health crisis.

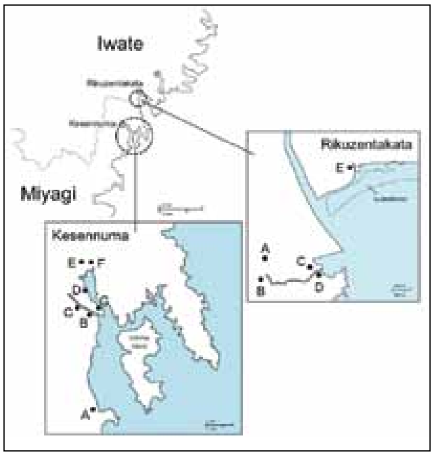
In the months following the disaster, the Japanese government and local municipalities gave priority to managing the well-being of resid*ent*-evacuees housed in temporary shelter homes. The Nippon International Cooperation for Community Development (NICCO), a Japanese non-profit and non-governmental organization, stepped in to help with the pest problem. NICCO raised Yen 190m from the private sector to support emergency pest management operations in Tohoku. The fly management operation started by NICCO and the Japan Pest Control Association (JPCA) also included a financial contribution from the Japanese government.

In this paper, we describe the fly management operation conducted by the JPCA in two cities impacted by the tsunami, Kesennuma and Rikuzentakata, from June to December 2011. We also discuss the effort involved and challenges faced during the area-wide fly management program in addition to the IPM principles employed during the entire operation.

Materials and methods

Locations: The cities of Kesennuma (N38.908133o, E141.5699960) and Rikuzentakata (N39.015182o, E141.629391o) were chosen for this evaluation because of the serious fly problems they experienced due to damage to the seafood processing industry. Seven and five sampling locations were selected for Kesennuma and Rikuzentakata, respectively (Figure 1).

Figure 1: Fly sampling locations in Kesennuma and Rikuzentakata, Japan



Fly monitoring: Three pieces of cut glue sheet traps (30 x 30 cm) (Pitatto Box, Sumika Green Co. Ltd., Tokyo, Japan) were placed in each sampling location at a distance of up to 10 m from one another (Plate 3). Sampling locations were selected based on visual sighting of flies. Glue sheet traps were left in the field for 20–180 minutes, brought back to the laboratory, and all captured flies identified. Monitoring was conducted every week from early June until early December 2011.

Treatment: Five surveillance teams explored the entire affected area on a weekly basis. In areas where fly infestations were sighted, the surveillance team coordinated and brought the JPCA treatment teams to those locations. The debris where maggots were found, rubble heaps, damaged/abandoned freezers in seafood processing factories, fishing nets, and other rubble (Plate 4A to 4C) were sprayed with two insecticide formulations: Lenatop (containing etofenprox) (Mitsui Chemicals Agro,

Plate 4: (A – top): Fly larvae on damaged seafood products, (B – middle): The abundance of fly larvae found in a damaged warehouse freezer, (C – bottom): Large quantity of fly larvae found in a seafood processing plant in Kesennuma.

Plate 3: Adult flies of P. regina captured on a cut glue sheet trap during one sampling period in Kesennuma city.

Inc.) and Sumithion SV (containing fenitrothion-dichlorvos mixture) (Sumika Environmental Science Co. Ltd.). The chemicals were applied using a vehicle-mounted power sprayer with a 1000 L tank. Sumithion SV was used only in locations where no residents or wildlife (e.g., seagulls) were present.

Source reduction: We also were interested in examining the impact of source reduction on fly populations. As we could not obtain data on the amount of seafood products removed at each location, we used data on the total number of rubble heaps moved from each location (Plate 5). The heaps of rubble were mixed with rotten fish products and other trash generated during the tsunami and we therefore assumed those data would represent removal of larval food/breeding sites. These data were obtained from Ministry of the Environment, Japan website (MOEJ 2011). The data was correlated with the fly catch data using Pearson correlation.

Results

Thirty-one species of flies from 13 families were trapped from June to early December 2011 during the monitoring operations (Table 1). The dominant species were the Blow Flies (*Calliphora nigribarbis* Vollenhoven) and *Phormia regina* (Meigen), House Fly (*Musca domestica* L.), and flies from the family Spaeroceridae. Fly larvae started to appear as early as May 2011 (about 2 months after the disaster). They were found under rotten fish when the outside temperature was still below 14oC. These larvae were identified as the Blow Fly species *C. nigribarbis*. This species is common in early spring and late autumn in Japan. In early June 2011, adult *C. nigribarbis* were present in large numbers. Municipality offices were swamped with phone calls from concerned residents about fly infestations and requests concerning control methods. Another species of the Blow Fly, *P. regina*, gradually succeeded *C. nigribarbis* from late June onwards. In some cities, *P. regina* adults were so abundant that they looked like a dark almost bluish-black colored carpet covering the street (Plate 6). In July 2011, *P. regina* was the dominant species, followed by *M. domestica* (Tabaru et al. 2012; Tabaru et al. 2014).

Plate 5: The movement of rubble heaps by the local municipality.

Table 1: Species of flies collected on glue sheet traps during sampling.

Family	Species
Calliphoridae	*Calliphora nigribarbis* Vollenhoven
	Phormia regina Meigen
	Lucilia sericata Meigen
	Aldrichina grahami (Aldrich)
Fanniidae	*Fannia edentula* Nishida
	Fannia scalaris (Fabricius)
Muscidae	*Musca domestica* Linnaeus
	Muscina stabulans (Fallen)
	Muscina angustifrons (Loew)
	Hydrotaea ignava (Harris)
	Lispe orientalis Wiedemann
Anthomyiida	*Fucellia apicalis* Kertesz
	Chirosia sp.
Coelopidae	*Fucomyia frigida* (Fabricius)
Drosophilidae	*Scaptomyza* sp.
Heleomyzidae	*Tephrochlamys japanica* Okadome
Sciomyzidae	*Pherbellia schoenherri* (Fallen)
Sphaeroceridae	*Ischiolepta pusilla* (Fallen)
	Crumomyia annulus (Walker)
	Coproica hirtula (Rondani)
	Coproica vagans (Haliday)
	Spaerocera curvipes Latreille
	Spelobia sp. 1
	Spelobia sp. 2
	Thoracochaeta johnsoni (Spuler)
Ephydridae	Unknown
	Scatella obsoleta Loew
Syrphidae	*Sphaerophoria macrogaster* (Thomson)
	Cheilosia sp.
Sepsidae	*Meroplius fasciculatus* (Brunetti)
Dolichopodidae	Unknown

Plate 6: In some cities, P. regina adults were so abundant that they looked like a dark almost bluish-black coloured carpet covering the street.

Pearson correlation indicated a significant negative relationship (P < 0.05) between the *P. regina* and spaerocerid populations and the removal of rubble heaps in Kesennuma; the same was true for the *C. nigribarbis* and *P. regina* populations in Rikuzentakata (Table 2).

Fly treatments conducted by the JPCA began in early June and continued until October. Dead flies were present in large numbers after each insecticide treatment, but within days adult flies were back, and so treatments were sometimes conducted on a weekly basis for several weeks.

Generally, *C. nigribarbis* populations decreased, and were gone by the end of July 2011 in both Kesennuma (Figure 2A) and Rikuzentakata (Figure 3A), but reappeared again in November and December. However, *P. regina*'s activity remained high until the end of August 2011 in both cities (Figure 2B and 3B). House Fly populations in both cities exhibited peaks in July and in September but were gone by October 2011 (Figure 2C and 3C). Lastly, populations of spaerocerid flies were the highest in July but gradually declined in the subsequent months (Figure 2D and 3D). Overall, fly populations dramatically declined in early September 2011, likely due to the combination of insecticide treatments, removal of rubble heaps and declining temperatures.

Discussion

The succession of fly species observed in this study was similar to that reported for pig carcasses (Heo et al. 2008). Blow Flies were the first to visit a carcass, followed by flesh flies and House Flies. However, no flesh flies were captured on the glue sheet traps in this study.

C. nigribarbis reappeared in November and December 2011 in Kesennuma and Rikuzentakata. Arakawa et al. (1991) reported that adult females of this species normally return to lowlands to overwinter after spending the summer in the highlands. This pattern may in part explain the sudden disappearance of this species after July and its reoccurrence toward the latter part of the year.

NICCO and JPCA records indicated that approximately 9000 man-days were spent on the fly management operation in the Tohoku region. The cost of the entire operation was Yen 570m. In total, 1,403 pest management professionals from 109 pest management companies from all over Japan participated in this project that took place across 23 disaster-affected cities, and which was probably the most labour-intensive, area-wide fly management operation

Figure 2: Number of flies per sticky trap in Kesennuma city between June and November 2011: (A) C. nigribarbis, (B) P. regina, (C) M. domestica, (D) flies from family Spaeroceridae

Figure 2a

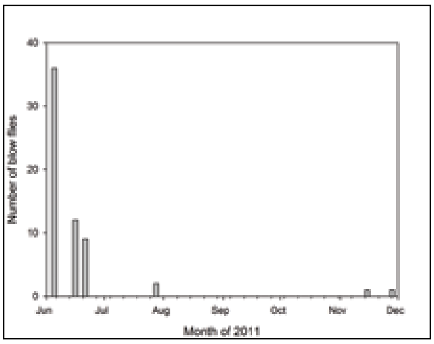


Figure 2b

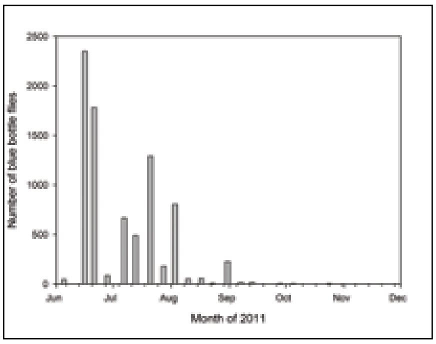


Figure 2c

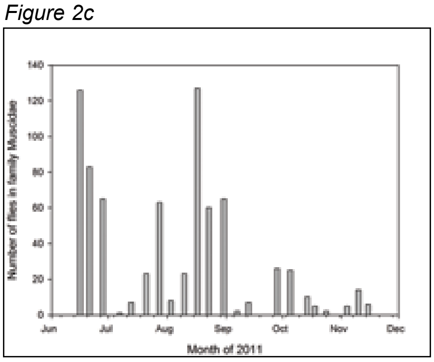


Figure 2d

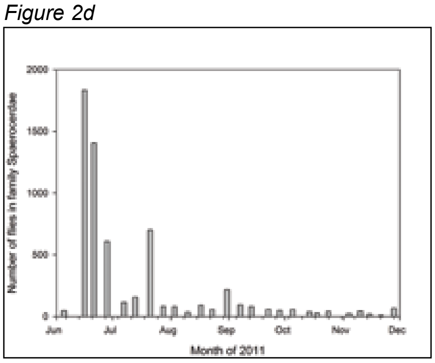


Table 2: Pearson correlations between rubble removal and fly number in Kesennuma and Rikuzentakata.

City	Flies	r	P
Kesennuma	*C. nigribarbis*	–0.718	P > 0.05
	P. regina	–0.977	P < 0.01
	M. domestica	-0.605	P > 0.05
	Spaerocerids	–0.851	P < 0.05
Rikuzentakata	*C. nigribarbis*	–0.912	P < 0.05
	P. regina	–0.988	P < 0.01
	M. domestica	–0.256	P > 0.05
	Spaerocerids	–0.860	P > 0.05

ever conducted globally. Approximately 1500 kg of active ingredients for etofenprox, 1200 kg for fenitrothion, and 500 kg for dichlorvos were used to treat the fly infestations across the entire region.

Numerous challenges were encountered. First, as the Japanese government and the municipalities were focused on dealing with the well-being of evacuees, their family members and victims of the tsunami, fly management was not a top priority. Second, as Japan has a strict recycling policy that requires all refuse and trash be separated into reusable resources, no exceptions were made during this disaster situation. Thus, dealing with the decomposing fish within the rubble heaps, which served as a breeding source for the flies, was a huge challenge. Other countries that had experienced a similar disaster situation (e.g., Indonesia) resorted to burning waste and refuse generated by the tsunami to quickly eliminate potential problems associated with refuse and trash, but this was not an option in Japan. Third, the affected areas were extensive. During the earthquake and tsunami, roads were damaged and bridges destroyed, which made travel on regular roads difficult (Plate 7). In some situations, our teams were forced to detour to another city before reconnecting to the intended destination because the shortest highway route was impassable. Numerous areas along the coastline were flooded during high tide, which prevented access to buildings and warehouses that were badly infested with flies. This situation was caused by the land subsidence that occurred during the earthquake (Plate 8). According to the Geospatial Information Authority of Japan (2012), land subsidence ranged from 0.29 to 1.2 m in Iwate, Miyagi, and Fukushima prefectures.

In this project, we adhered to the principles of IPM for fly management. Five surveillance teams conducted detailed surveys and monitoring programmes throughout all affected zones. Each team assessed the necessity for insecticide treatment to avoid unnecessary applications based on the monitoring data, in addition to considering the presence of wildlife and proximity to residential areas (Plate 9). This informa-

Plate 7: Roads were impassable due to damage and accumulation of a large amount of debris (photo taken in Kesennuma).

Figure 3: Number of flies per sticky trap in Rikuzentakata between June and November 2011: (A) C. nigribarbis, (B) P. regina, (C) M. domestica, (D) flies from family Spaeroceridae.

Figure 3a

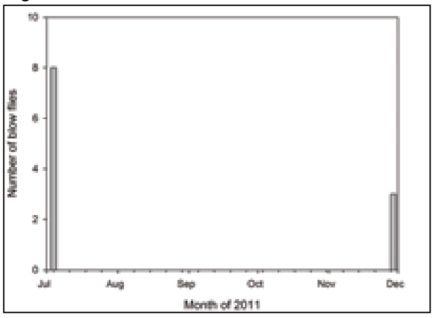


Figure 3b

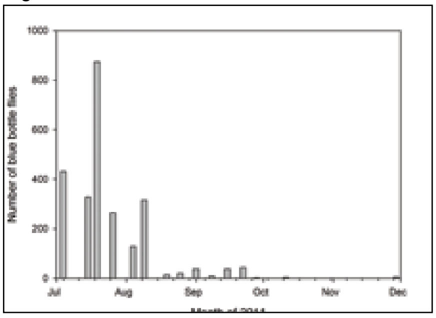


Figure 3c

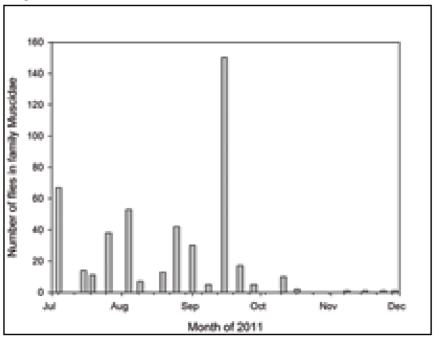


Figure 3d

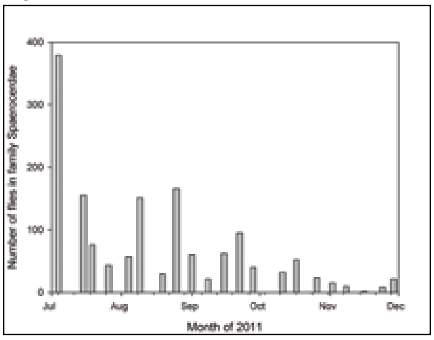


Plate 8: (A – top) Flooding in an area near the coastline due to land subsidence (photo taken in Minami-sanriku), (B – bottom) and a road underwater (photo taken in Ishinomaki).

tion was provided directly to the JPCA teams regarding the treatment requirements. The resulting variability in the surveillance data (Figures 2 & 3) are a reflection of the difficulties in area wide management using a local or spot treatment approach, against a mobile pest, with a short life cycle, that is provided with cryptic (hidden in rubble heaps) larval food sources. In addition, we had no control over the removal of treated rubble as well as incoming untreated rubble at each location and yet it was this data from the surveillance team that directed treatment teams to hot spots of fly activity, which subsequently reduced the health-threat impact of those infestations.

Plate 9: An inspection officer surveys the necessity for an insecticide treatment and the risk of affecting wildlife and nearby residents.

Japanese law requires that permission from building or site owners be obtained before any pesticide intervention can be implemented. This was a challenging task during the initial stage of the process, as phone lines and internet access were limited in this region due to earthquake and tsunami damage. These services were not restored for several months. During this period, the surveillance teams made direct visits to the homes of factory owners or to their next of kin (if the owners had perished in the disaster) to request permission to treat affected warehouses and properties. Residents who were staying in close proximity to the areas to be treated also were visited. Accurate and clear communication was extremely important to ensure that owners and local residents understood the need for treatment, and photographs and videos of the fly outbreaks were shown during these visits. In addition, coordination and permission from the authorities in local municipality offices were obtained.

Insecticide treatments were administered by pest management professionals who came from different prefectures of Japan. Each week, the JPCA sent out four groups, each consisting of a leader and eight technicians. As most of these technicians were not residents of Tohoku, they were not familiar with the locations that required treatment. Careful briefing and coordination were conducted to ensure that all operations were performed properly, safely and smoothly (Plate 10).

Plate 10: Detailed briefing to pest management technicians and proper coordination were done before any insecticide treatment was carried out.

A major challenge that we faced during the insecticide treatment operation was the availability of water for insecticide dilution and rinsing after the treatment. Because the water supply network was destroyed during the disaster, clean water had to be brought into the treatment areas. Water wagons and fire trucks were used to source water from as far as Tokyo for this operation, and water from nearby rivers was used in some instances (Plate 11).

We also were concerned about the health risks to the pest management technicians carrying out the insecticide treatments. During the summer of 2011, the temperatures reached 35oC, thereby posing the risk of heat stroke to technicians who were wearing personal protection equipment and working in the sun. Resting areas were set-up with water and food provided to the technicians, as these resources were not readily available in the disaster areas. Technicians also faced the risk of stepping on nails and broken glass as they braved the rubble and heaps of debris to administer the insecticide applications (Plate 12). To address this problem, steel insoles were provided to all technicians. In addition, off-limit treatment zones were designated in certain structurally unsound buildings.

After each insecticide application, weekly monitoring of the fly population was conducted, and areas where treatments failed to reduce the fly catch by at least 70% were re-treated. Because flies are highly mobile, some locations required multiple re-treatments. We chose to use power sprayers to direct the insecticide on and into the rubble heaps and infested areas instead of resorting to aerial spraying in an attempt to prevent insecticide drift to nearby residential premises (Plate 13). The choice of registered insecticide formulations for treating flies in the urban setting also was limited by law. If given a choice, we would have used thermal fogging with etofenprox integrated with an insect growth regulator (e.g., pyriproxyfen) to manage the adult flies and the immature stages at the same time. We would also have placed fly baits near and around the shelter homes, however these options were not legally available and no provisions were made for an exemption to existing registrations.

Key lessons learnt and the future

The area-wide fly management operation in this large disaster area would not have been possible without the following components in place:

1) proper surveillance and monitoring,
2) consultation and coordination with all stakeholders,
3) decision-making about the choice of treatment, with focus on reduced impact on wildlife and the environment,
4) risk assessment management regarding the ground personnel involved in the treatment operation, and
5) continuous surveillance and monitoring after treatment for the possible need for re-treatment.

Based on the number of major disasters that have occurred over the past several years, there is an urgent need to establish IPM best management practices for large-scale pest management operations after a major disaster such as earthquake, tsunami, flood, hurricane, or typhoon. We suggest that the World Health Organization work to establish a multi-national expert panel to oversee the establishment of such guidelines in the near future. In this context, the JPCA could play an important role by imparting its experience with the large-scale fly management operation conducted in Tohoku, Japan after the 2011 earthquake and tsunami.

Acknowledgement

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Plate 11: Water was sourced from a nearby river for dilution of insecticide used in the treatment.

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Plate 13: Application of insecticide directly onto and into a rubble heap using a power sprayer by a pest management technician.

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Plate 12: A high-risk job – a technician applying insecticide at the top of a hill-high rubble heap.