Reserarches of Environmental Creation from Disaster, presented at IAIA16

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Foreword

This booklet provides introduction to some of the current topics of "Environmental Emergency Research" undertaken at the National Institute for Environmental Studies (NIES), Japan. "Environmental Emergency Research" has been undertaken at NIES since the Fukushima Daiichi Nuclear Disaster in 2011, aiming to contribute to the environmental recovery and renovation of disaster areas. In this booklet, researches related to the following four topics are presented: 1) disaster effect on the ecosystem in Fukushima Prefecture, 2) regional activities concerning to energy saving in Fukushima Prefecture, 3) the assessment of ecosystem services at urban area, and 4) the impact of the 2011 tsunami on tidal flat ecosystem.

The papers in this booklet were presented in the session "Environmental creation from disaster" (Session proposal ID:128) at the 36th Annual Conference of the International Association for Impact Assessment (IAIA), or IAIA16, held in Nagoya city on 11-14 March, 2016. IAIA is the leading global network on best practice in the use of impact assessment for informed decision making regarding policies, programs, plans and projects (http://www.iaia.org/about.php). IAIA16 focused on "Resilience" and "sustainability" in environmental impact assessment, social and health impact assessment, international development, and climate change, as well as natural and man-made disasters, following the experience of the severe earthquake and nuclear accident in 2011. NIES hosted the session "Environmental creation from disaster" to introduce some of the NIES's research on monitoring and simulations for environmental recovery, and to discuss suggestions for environmentally sound reconstruction planning and policy suggestion.

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Contents

1. Tackling biodiversity monitoring of the Fukushima evacuation zone

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1.1 Introduction

A serious nuclear accident at the Fukushima Daiichi power plants in 2011 was followed by mass and long-term evacuation from highly contaminated area. Although radiation levels in the most of the evacuation zone were considered not to be acutely lethal for wildlife (Garnier-Laplace et al. 2011), it has been hypothesized that land use change by decontamination and the cessation of usual anthropogenic activities such as farming and gardening significantly affect the biodiversity and ecosystem services in the zones. A meta-analysis of farmland abandonment suggests that this phenomenon has frequently had a negative effect on biodiversity in Africa, Asia, and Europe (Queiroz et al. 2014), where the history of anthropogenic land use is relatively long.

Furthermore, the most of the evacuation zone in Fukushima is assumed to have been historically covered by forests and farmlands, and the residents had been benefited from ecosystem services from SATOYAMA, Japanese traditional agricultural landscapes, characterized by rich biodiversity (Kadoya and Washitani 2011). Therefore, scientific monitoring of ecosystems and biodiversity is required to lead the return and reconstruction to success.

However, there are some difficulties for the effective biodiversity monitoring in the Fukushima. The evacuation zone is large and environmentally heterogeneous. Furthermore, entry to the evacuation zone has been strictly regulated. In addition, long-term monitoring including data sampling after return and reconstruction will be need to appropriately know what the evacuation has brought, because biodiversity data before the nuclear accident are quite limited. In order to conduct systematic and rigorous monitoring and obtain ecologically reliable data, monitoring protocols must be considerably-designed. Furthermore, the result of monitoring should be as transparent and open as possible to residents, because scientific conclusion based on unpublished data induce misleading and/or less credible for residents and fail to support decision-making.

In this paper, we will report protocols and current status of terrestrial biodiversity monitoring conducted as a part of the Environmental Emergency Research project in the National Institute for Environmental Studies, Japan (NIES), which aims to provide scientific supports of recovery and recreation of environment in the Fukushima disaster area.

1.2 Monitoring system

The terrestrial biodiversity monitoring by NIES has started from 2014, aiming to obtain knowledge on what the large-scale and long-term evacuation brought on biodiversity and ecosystems in the area, which can support return of residents once had been benefited from various ecosystem services before the accident. The monitoring was conducted mainly by ecologists and experts on remote-sensing and geo-informatics, including authors of the paper as core members. In order to conduct relatively long-term (at least about ten years) monitoring effectively by limited effort, we determined to focusing on Mammals, Birds, Frogs, Insects, Vegetation and Land Cover/Land Use Change. Not only they are quite important indicators of biodiversity and ecosystems, but also monitoring protocols of them can be improved to be automatic, cost-effective, and standardized, using digital devices that are remarkably developing. Digital devices can also make it easier to sharing data with local residents. We will show

our attempt to establish monitoring protocols and the current status below.

1.3 Monitoring protocols and current status

(1)   Mammals

In 2014, monitoring faunal assemblages inside and outside of the evacuation zone using infrared camera traps (Fig. 1.1) has been started. Infrared camera traps can automatically take pictures or movies in response to reflected infrared from homothermal animals and present a well-standardized and cost-effective method for monitoring mammal dynamics (Ahumada et al. 2011). In particular, this automatic method is well-suited to monitoring in the restricted access area such as Fukushima evacuation zone, because they can dramatically reduce time and frequency of visitations for monitoring the area; investigators only have to visit the camera trap for data collection and maintenance a few times a year. Due to usefulness of the camera trap technique, the protocol for monitoring for mammals, which has been almost established, is as follows.

The 46 monitoring sites for mammals covering 9 municipalities were set for monitoring inside and outside the evacuation zone. All the monitoring sites are located in closed forest, and the most of them belong to the national forest as a socially stable place and suitable to long-term monitoring (landowner and land use of private land are relatively changed often.).

In 2014, the first year of the monitoring, an infrared camera was set at each monitoring site from May to August 2014. Then, the data collection and maintenance were conducted in October and partially in July. From the collected movie files, mammals that appeared in the movies were identified to species level as possible and recorded as data of detection. In addition, as the indicator of sampling effort, the duration between battery exchanges for each camera (called "occasion") were also compiled. If a camera had become inactive due to a depleted battery or mechanical trouble, its end time was defined as the time when the last video was recorded.

In the monitoring until October 2014 at the 45 sampling sites, fourteen species of large or middle-size mammals including invasive alien species such as raccoon *Procyon lotor* were recorded. Within the evacuation zone, large animals such as black bear *Ursus thibetanus*, Wild boar *Sus scrofa*, and Japanese serow *Capricornis crispus* were recorded. Indeed, most of large mammals distributing northeast Japan except for Sika Deer *Cervus nippon* were recorded in the monitoring for half a year. We are aiming to compile the data set once a year and published a data paper (Fukasawa et al., 2016) in a way that make the data open, discoverable, and usable. In addition, we started providing a web service that you can browse distribution of mammals in the east Fukushima on Biodiversity Web Mapping System (BioWM) created by Center for Environmental Biology and Ecosystem Studies, NIES (http://www.nies.go.jp/biowm/index.php?lang=en).

Fig. 1.1 (left) Infrared camera for monitoring mammals
Fig. 1.2 (right) IC recorder for monitoring birds and frogs

(2) Birds

Birds are good indicators for various environmental changes and a relatively popular taxon for general public. On the other hand, some studies on birds argued that some effects of radiation on birds after the nuclear accidents

(Møller et al. 2015; Murase et al. 2015). Therefore, data-sharing with general public and the residents are particularly important.

As a measure for monitoring, we adopted recording song of birds using IC recorders with timer function (Fig. 1.2). Although this method is automatic and suitable to monitoring in the restricted access area, extracting data of presence of bird from amount of sound files is a challenge.

From 2014, the Bird monitoring by NIES has started at 52 sites covering 9 municipalities, including the evacuation zone. All the monitoring sites were located within schoolyards (including those that had been converted to community centers), which are relatively socially stable and can minimize differences in the local conditions.

The IC recorders record surrounding sound including song of birds for twenty minutes per day around sunrise from middle May to end of June. Then, from a part of sound files, presences of each bird species were checked by experts and documented.

Furthermore, we conducted an event called "Bird Data Challenge" collaborating with local branches of Wild Bird Society of Japan and extract and identified a part of the sound data with bird watchers in Fukushima prefecture. This was a new and important attempt to compile the data sampled by researchers simultaneously sharing with citizens. In addition to a data paper, we are preparing a paper reporting details of the event.

(3) Frogs

Frogs need inland water ecosystems to complete their life-cycle. Thus, cessation of management of rice paddy fields within the evacuation zone can be problematic.

Their croaking has been also monitored using same IC recorders for bird monitoring in the same locations. Sound for ten minute per day around 20:00 on each day has been recorded from middle May to the end of June in 2014. As well as bird song, extraction of frog song is a challenge, though their song is relatively simple. Now, we are extracting song as training data and trying constructing automatic song detection system based on machine learning method.

(4) Insects

Although insects play an important role in ecosystem functions and serve as pollinators, pests, and prey for birds and mammals, their diversity and small size make it difficult to conduct cost-effective and automatic monitoring. At first, we focused on flying insects, including important pollinators such as Apidae, and medically important pests, such as flies and hoverflies.

In 2014, we conducted sampling by Malaise traps (Fig. 1.3a) from the middle May to the early July in the location where the IC recorders for bird monitoring were set in order to survey a broad range of flying insects. In result, the abundance of carpenter bees *Xylocopa appendiculata* was detected to be lower within the evacuation zone. In contrast, those of most of the collected taxa including pollinators were even higher in the evacuation area, or not different between these areas. Please see Yoshioka et al. (2015) for further details of the data in 2014.

From the 2015, in order to make the monitoring more efficient, the flight intercept traps (Fig. 1.3b) were introduced in the all monitoring sites. In addition, malaise traps were also set in a part of monitoring sites. Furthermore, development of other sampling technique using digital devices was under consideration to cover insect groups which could not be detected by these traps.

Fig. 1.3 (a) Malaise trap and (b) flight intercept trap for monitoring flying insects such as pollinators

(5) Vegetation and LCLUC

Vegetation and Land Cover/Land Use Change (LCLUC) were also a target of monitoring in our project. They are hypothesized to be dramatically changed by decontamination and land abandonment in the evacuation zone, and affect biodiversity and ecosystem services.

From 2014, we are compiling satellite images and ground-truth data by cameras with GPS and/or drive recorders sampled per year, in addition to aerial photos as supplement data. Using these data, we are developing model predicting and mapping vegetation based on machine learning method, focusing on dynamics of croplands. Publishing compiled map in future is also under consideration.

1.4 Conclusion

Although continuous biodiversity monitoring in the Fukushima is quite a challenge and it may take a time to obtain the outcome, our project has been developing cost-effective and automatic protocol to conquer these problems. These protocol will be support not only effective biodiversity monitoring in the Fukushima, but also effort-saving biodiversity monitoring at any other restricted access areas.

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2.   Effect of Energy Saving Campaign in Fukushima

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2.1 Introduction

Expectation of a distributed local energy system is growing to utilize local energy sources and to develop resilient energy supply system after the Great East Japan Disaster of 2011. Especially some municipal governments in Tohoku region promote to develop it not only for development of the resilient energy system but also for the reconstruction from the disaster (Tohoku Regional Advancement Center, 2013). The data related to energy demand, such as the amount of demand, price elasticity, and energy saving potential, are useful to design adequate system for the area. These data are also expected to mitigate brown out during the peak demand period.

There are some existing empirical studies focusing on the energy demand side in Japan. Ito et al. (2015) investigated the influence of moral suasion and economic incentives to electricity demand by using household-level consumption data in Keihanna area of Kyoto prefecture. Mukai et al. (2015) estimated the peak and daily demand saving effect by the four interventions; economic incentives, real time feedback, weekly advice report, and peak alert. However, these studies are focused on the urban area. Thus it is necessary to identify the effect of demand side management in the rural area where the development of the distributed local energy system is expected.

In this study, we estimated the effect of energy saving campaign, which encourage reducing electricity demand by visualizing their demand data and providing advice reports, in Shinchi Town in Fukushima prefecture, Japan. In the Great East Japan Disaster of 2011, this town has suffered enormous human and physical loss. In 2012, it was selected as an FutureCity, and are reconstructing with harmonizing regional society, economy, and environment. A distributed local energy system is also planned in this town. Thus, the result of this study can help it as local energy demand data.

2.2 Methods

Effect of energy saving campaign was estimated by following three steps. First, we recruited the household who adopt the electricity monitoring and distributed the monitoring system. Next, the energy saving campaign was conducted to the household who confirmed their participation. Finally, effect of energy saving campaign was estimated by statistical analysis using monitoring data.

(1) Installing the electricity monitoring system

We distributed power monitoring system and tablet computer to about 62 households lived in detached houses in Shinchi Town in Japan from June 2014 to March 2015. Electricity consumption of household total and 6 selected lines were measured by 15 minutes' step. Hourly electricity consumption of individual household is visualized by the dedicated application in the tablet computer. The dedicated application has seven functions; the electricity visualization, the regional information map, the regional bulletin board, health support advice, disaster information, the online questionnaire, and the What's New in the local municipality. The frequency of using each

function in the application is also monitored. Note that although the number of participants is relatively small for the statistical analysis, the participants had already reached more than 2% of total households in Shinchi Town. Thus, it is future task to recruit large scale sample not only Shinchi Town but surrounding municipality to increase the possibility of statistical analysis.

(2) Designing the energy saving campaign

Energy saving campaigns was implemented three times in the fiscal year 2014; September 8th to 21st, November 5th to 18th, and March 8th to 21st. We asked the households about the participation in the energy saving campaign through the tablet for approximately one week before the campaign. 22 and 12 households of 50, and 24 households of 57 were participated to each campaign, respectively.

Households can browse the campaign webpage, shown in the Fig. 2.1, during the campaign periods. The webpage includes four contents; the mean energy saving rate for individual household and all participants, the trend of electricity consumption for individual household, the latest ranking in all participants, and the ranking trend during the campaign for individual household. Non-participated households can only see the mean energy saving rate for all participants and other contents are not available. The energy saving rate are calculated based on the mean daily electricity consumption of each household in one week before the campaign. Note that the above energy saving rate is calculated just for providing the information to the household and not equal to the effect of energy saving campaign estimated by the method explained in the next section. The flower circle mark is given to the households whose energy saving rate is positive and whose ranking is higher than the sixth to mitigate the boomerang effect, the phenomenon that the households whose energy consumption is lower than the average get relaxed and increase their energy consumption by learning that their energy consumption is lower than the average in a household energy conservation context. The regional coupons, equivalent to 1,600, 1,200, and 800 yen, respectively, are given to the top three households for the incentive of energy saving. Specific information about the reward is not announced to the participants before the campaign excluding the third campaign.

Before the third campaign, the advice report of electricity use, shown in Fig. 2.2, is provided. The advice report is customized for each household using the electricity monitoring data collected before the campaign. The advice report includes the following contents; (a) trend of daily electricity consumption per person, (b) the mean hourly electricity consumption per person in winter, (c) the proportion of electricity consumption by intended purpose in autumn and winter, and (d) the suggested electricity saving measures for individual household. The data of all participants and non-all-electric home / all-electric home are also depicted for the contents (a) and (b).

Mean energy saving rate (individual household, all participants)

Trend of electricity consumption

Latest ranking

Flower circle*

Ranking trend

* This mark is equivalent to the "gold star" in Japan
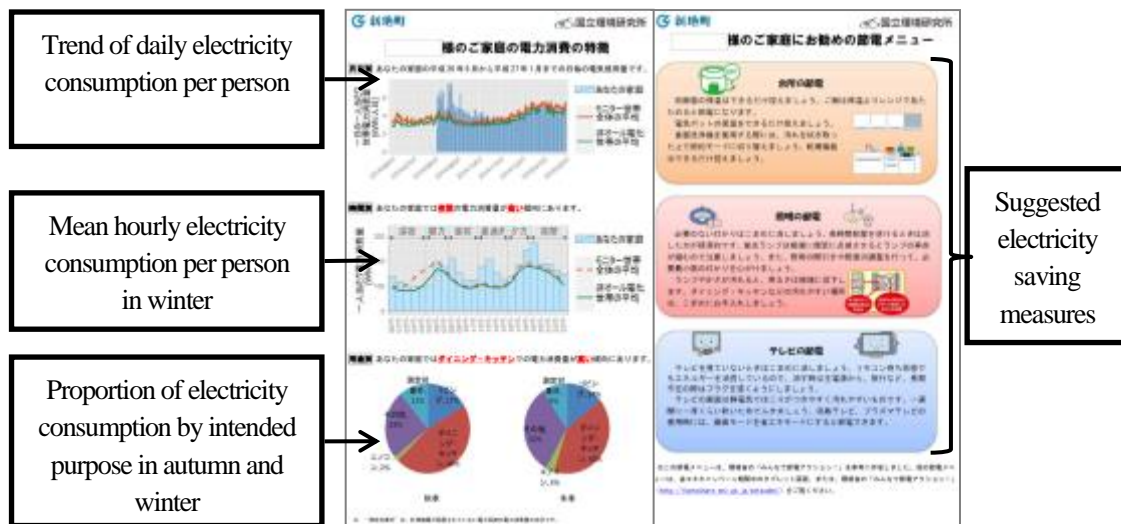
Fig. 2.1 Campaign webpage

Fig. 2.2 Example of advice report for electricity use

(3) Estimating the effects of energy saving campaign

Effect of energy saving campaign was estimated by following fixed-effect model following the existing study [2]:

$$\ln y_{it} = \alpha + \beta x_{it} + \gamma W_t + \theta_i + e_{it}$$

where y_{it} is total daily electricity consumption in household i in day t. x_{it} equals 1 if household i participate the energy saving campaign in day t. W_t is a matrix which related to electricity consumption such as mean temperature in day t, mean temperature in previous three days, mean humidity in the day t, and weekday dummy. θ_i is fixed effect of household i. α is intercept, β and γ are estimated coefficients for each variable, and e_{it} is error term.

Daily electricity consumption data of 48, 45, and 53 households were used in the analysis after the exclusion of the household with missing value although the numbers of participated households were 50 in the 1st and 2nd campaign and 57 in the 3rd campaign. We employed the difference-in difference design and the data from the pre-experiment days and treatment days were included in the fixed-effect model.

2.3 Results and discussion

Table 2.1 shows the results of regression analysis. The number in the brackets is the standard error. Because we use the natural log for the explained variable, the values in the table are log points. The effects in the exact percentage term can calculated by $\exp(\beta) - 1$. The variables which related to electricity consumption are statistically significant excluding mean temperature in the previous three days in the second campaign. Row 1 in Table 2.1 shows the effects of energy saving campaign on daily electricity use. The first energy saving campaign in September has a negative effect to the electricity consumption by 0.01 log points (0.96 percent) with statistically insignificant. The second campaign in November has a positive effect by 0.05 log points (5.09 percent). One of the reason may be due to the wearout effect according to the analysis with the application use data explained in the next paragraph. The third campaign which distributes the advice report of electricity use caused a reduction in daily electricity consumption by 0.029 log points (2.86 percent) with statistically significant (1 percent level).
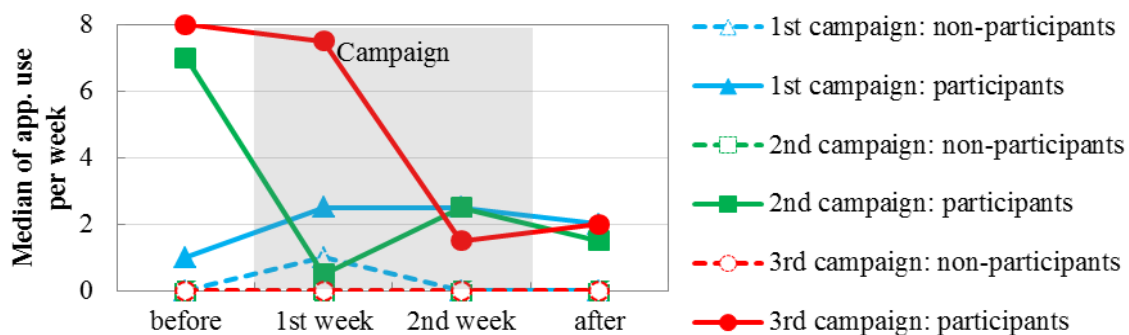
Table 2.1 Effects of Energy saving campaign on daily electricity use

	1st campaign	2nd campaign	3rd campaign
Energy saving campaign	-0.010	0.050***	-0.029***
	(0.012)	(0.016)	(0.009)
Mean temp. in the day	0.008***	-0.018***	-0.025***
	(0.002)	(0.002)	(0.001)
Mean temp. in the previous three days	0.020***	-0.001	-0.006***
	(0.003)	(0.002)	(0.002)
Mean humidity in the day	0.001***	0.002***	0.001***
	(0.000)	(0.000)	(0.000)
Weekday dummy	-0.031***	-0.023***	-0.046***
	(0.007)	(0.007)	(0.006)
Intercept	1.844***	2.714***	2.940***
	(0.051)	(0.028)	(0.017)
N (# of household)	48	45	53

Significant code: *** 1%, no symbol >10%. The number in the brackets is the standard error.

Fig. 2.3 shows the median of application use per week by participants and non-participants in each campaign. Basically, the frequencies of application use of participants are higher than that of non-participants in every period. This implies that the participants have higher interests in the application use includes checking their electricity consumption. Comparing to the application use by participants among the campaigns, the frequency of application use in first week in the second campaign was low (0.5 times in a week). This may be caused by the decrease of interest due to repeating the same campaign. The increase of application use in second week in the second campaign may be attributed to the checking their final ranking because most of application use were concentrate near the last campaign day. The use in the first week in the third campaign was high. This may occur due to two reasons; visiting to each household in the week before the campaign and distributing the advice report of electricity use.

The application use in the second campaign period which has positive effect to the electricity consumption was low and that in the third campaign which has negative effect was high. In addition, the application use may be related to the interests in the application and campaign. Thus, the application use may explain the effect of energy saving campaign. It is useful to analyze causal connection with the application use, the energy saving conscious, and the effect of the energy saving to identify the way to promote the energy saving effects.

Fig. 2.3 Median of app. use per week by participants and non-participants

This study which focused on detached houses in the rural area shows relatively small effect compare to the existing study which reported 10.1 percent decrease in the multiple dwelling houses in urban area (Mukai et al.,

2015). The reason of the difference may attribute to the household size. The average household size in this study was 4.3 while that in the existing study was 2.6. Some participants argued that some members in their house were not interested in and uncooperative to the campaign in the hearing survey. The possibility of uncooperative participants would rise by increasing household size. Thus the incentive for the uncooperative participants might be the key to increase the effect of the campaign detached houses in the rural area.

2.4 Conclusion

In this study, we present the results of monitoring survey to evaluate the effect of energy saving campaign in Shinchi Town in Fukushima prefecture, Japan. The campaigns were implemented three times in the fiscal year 2014 and effect of energy saving campaign was estimated by fixed-effect model. The results showed that the first and third campaigns have 0.96 percent and 2.86 percent of negative effect to the electricity consumption. The advice report of electricity use may enhance the negative effect. The second campaign has 5.09 percent of positive effect to the electricity consumption. This may be due to the "wear-out" effect. The application use in the second campaign period which has positive effect to the electricity consumption was low and that in the third campaign which has negative effect was high. It is necessary to establish the system to continuously promote the energy saving motivation of household.

Acknowledgment

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3. Assessment of ecosystem services with land use maps: Conservation priority under several greening scenario in Nagoya City

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3.1 Introduction

Population decline causes multiple problems in also urban area: shrinking resident area, infrastructure and security problems, difficult to maintain shrunk area. While well-being of resident living in urban area related to not only artificial services such as transportation, accessibility of communal and commercial facilities, and security but also natural services from ecosystem (landscape, recreation, and so on) and rich biodiversity.

Aichi prefecture installed the mitigation system, "Aichi method" that is the first system of ecosystem offset in Japan. The quantitative assessment tool was provided by the prefecture and the mitigation recommended to create ecological network by compensation between development and offset sites. However quantitative spatial statistics and ecosystem services are not referred by the tool.

Geographic Information Systems (GIS) in particular are often used to spatially evaluate ESs, however, it can be stated that integrated quantitative evaluation tools which would encompass all ES concepts are still at the research and development stage. A number of conservation planning support softwares were developed and applied that use GIS to conserve certain specified species. For example, Moilanen et al. (2011) have used Zonation to show biodiversity, carbon storage services, agricultural supply services and competitive land use analysis of land use in cities in Great Britain. In this study, we depict an application of spatial assessment scheme by using of relatively simple method to estimate ES in Nagoya City (Ooba et al., 2015), and the methodology is clear and input data mainly depended on landuse map. This information may be useful for mitigation systems such as "Aichi method".

The objective of this study was assessment of ecosystem services and comparison among current and future with scenarios. Quantitative and geographical evaluation of ecosystem services is useful for finding high-priority conservation sites. By using of a geographical information system (GIS), ecosystem services were estimated from proxy variables using primary values almost same as the previous study (Ooba et al., 2015). To validate the scenarios, conservation priority maps were compared.

3.2 Methodology

(1) Study area

Nagoya City is located in central Japan. Nagoya City (ca. 32,600 ha) represents urban Japan with a population of about 2,260,000, and is the fourth largest city in Japan (Yokohama City, 2016).

(2) Methods of ES estimation

Methodology is the almost same as the previous study (Ooba et al., 2015). Digital land use map of Nagoya in 1997 at 10 m mesh level was used to categorize five types of land use: water surface, residential and industrial

area (urban area), road, agricultural field, and forest (Fig. 3.1a, b).

The following variables were selected as proxy for ecosystem services (Table 3.1). Five variables were considered, carbon sequestration, food supply, soil erosion, cultural variable, and biodiversity variable. The cultural services were estimated by internet questionnaire survey. Recreation economic value is estimated by generalized round-trip costs per capita were calculated based on required costs such as transportation and transfer facility usage costs (Ooba et al., 2016). Four major green areas (area: 6.18 to 84.9 ha) in Nagoya City were selected and the generalized round-trip costs to green areas and the other attribute from a questionnaire survey in 2014 (2,800 samples from Aichi Prefecture). The results of the result were used to estimate the economic values of cultural services. The economic value V (10^6 JPY ha^{-1} y^{-1}) per unit of area was estimated as follows:

$$V = a\,A^b \tag{1}$$

Where A is area (ha), a and b are parameters obtained by a regression calculation ($b < 0$). For a green space of 1 ha or greater, respective services were evaluated.

These variables were estimated at the Japanese standard mesh defined by Japan Industrial Standard, corresponding to about 1 km-grid.

The estimated values are shown by different unit, so for inter-comparison purposes, values were convert into [0, 1] scale by maximum and minimum value. Soil erosion variables have negative effect (high variables means high negative ecosystem services), then the variable was converted into [0, 1] scale. Although all of distributions of ES variables have exponential distributions, variables are convert by logarithmic conversion to be normal distribution before the [0, 1] conversion. 0-value of variable is replaced a minimum value of corresponding ES distribution due to the logarithmic conversion.

Table 3.1 Variables of proxy for ecosystem services and summary of estimation methods

ES	Estimation	Method details[1]	Unit	Weight[2]
Support	Carbon sequestration	3.09(F)	t/y ha	0.200
Provision	Food production	2.98(A)	t/y ha	0.180
Regulation	Reduction of soil erosion coefficient compared to bare soil	$S = 65.41\sin^2\theta + 4.56\sin\theta + 0.065$ $C = 1$ (U), 0.33(A), 0.0085(F)	-	0.207
Culture	Economic value of green space	Value per unit area as green belt area A(ha) $V = 3.0184A^{-0.437}$	10^6 JPY/y	0.209
Habitat	Continuity of green space	ArcGIS tool (Focal statistics) proximity as 2 km radius	-	0.205

[1] Land-use codes—U: Roads and urban areas, F: Forestland, A: Agricultural land: The detailed description of parameters and equation can find in Ooba et al. (2015)
[2] The values that are an average of importance to ES are used for an integration of ES

Table 3.2 Landuse change scenarios

Scenario	Change of agricultural and forest area
BAU	Business as usual (no change)
(1) Greening	Increase forest area in every grid (Total increase is 5% in the city)
(2) Corrido	Increase forest in the eastern area of the city. Restoration of semi-natural ecosystem and development of natural corrido for biodiversity near water surface (rivers and ponds). Incensement is the same as (1) (5%)

(3) Scenario and conservation priority

Compare to the current evaluation of ES in Nagoya (BAU scenario, Table 3.2), two future scenarios are

considered, scenario-1 Greening: Increase of the area rate of green space in all grid of the city by a future land planning (Fig. 3.1c), and scenario-2 Corrido: Increase of the rate to be high continuousness of green space in the east region of the city (Fig. 3.1d). In the both scenarios, the net rate of increase of green space is assumed to be about 5%. In the scenario-2, it is assumed that ES in the waterside areas is enhanced in future by afforestation or greening over relatively large area (larger than 1 ha) to design a restoration of semi-natural ecosystem and development of natural corrido for biodiversity conservation inside the city.

Using the calculated proxy variables of ES and biodiversity, the integrated evaluation was carried out by the Zonation software, which calculates conservation priorities (Moilanen et al., 2012). It identifies the mesh with the greatest overall loss when one grid is removed. By repeatedly removing the mesh, that was identified and searching among the remaining grids for the grid with the maximum loss, conservation priority is determined by the Core Area Zonation algorithm that minimizes loss by assigning high rank to spatial continuous and high weight ecosystem services. For evaluation of species biodiversity, then number of species is calculated to evaluate loss of e species diversity. In this study, the value of ES is calculated to evaluate the loss.
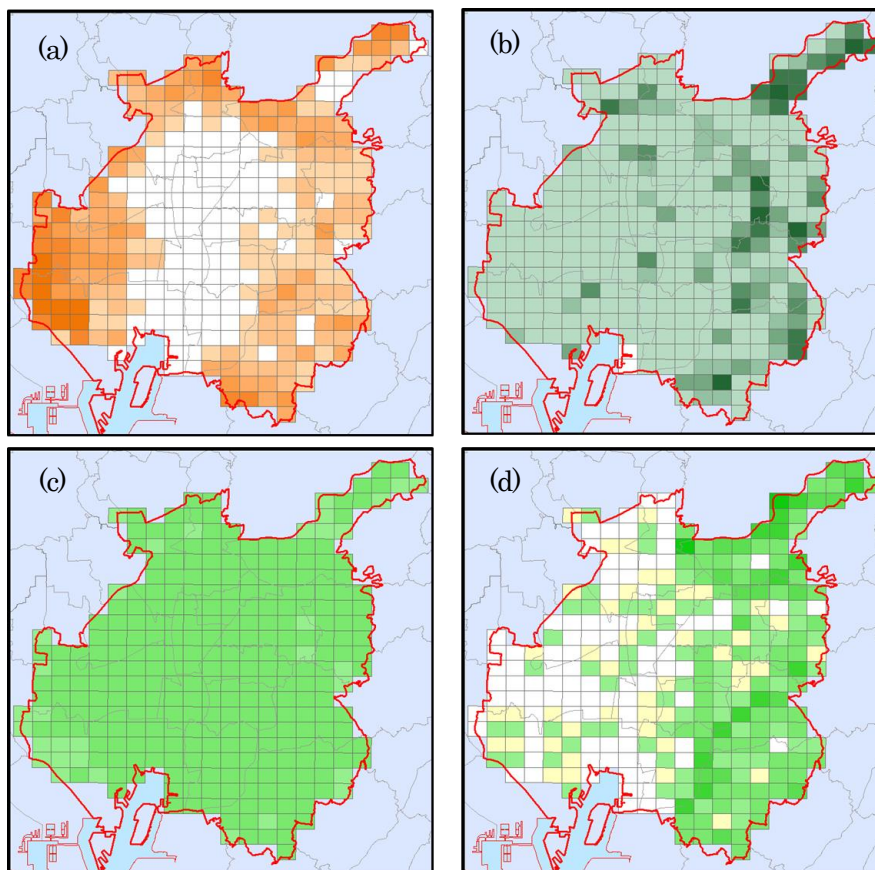

Fig. 3.1 (a) Grid area rate of agricultural area in Nagoya City (b) Rate of forest area (c) increase rate in scenario-1 Greening and (d) increase rate in scenario-2 Corrido

3.3 Results and discussion

Weight of the ES that obtained through the web questionnaire was estimated from a five-point scale (Ooba et al., 2016) is used to integrate each ES value in this study (Table 3.1). The costs and other Zonation parameters were set to the default values.

ES map of Nagoya is indicated in Fig. 3.2. Cultural services were estimated based on Equation-1, $a = 3.0184$, $b = -0.437$ ($R^2 = 0.63$). If the area increases, the value per unit area decreases, but because this is multiplied by the area, the area and value of the cultural services increases gradually. Carbon sequestration was high in Eastern

Nagoya City and Moriyama, where there are many woodland areas. Food production was high in western Nagoya, where there are relatively large areas of paddy and farmland. Cultural services and habitat quality tend to be low in the central area but higher in the surrounding areas.

The conservation priority that is calculated by the Zonation software are shown in Fig. 3.2. Priority tends to be high in the surrounding areas such as Higashiyama, Moriyama, and western Nagoya City. Serval green spaces such as Atsuta Shrine, which is isolated inside the city, also earned high priority.

In detail, in the scenario-1, forest landuse increases in every mesh (but continuity is not recalculated), while water-surface landuse that is located the selected mesh (Fig. 3.2) is replaced into forest landuse and recreation value and continuity are recalculated in the scenario-2. It is note that labor cost for management of green space in the both scenarios is the same.

Comparing to the current map (Fig. 3.3), priority of the scenario-1 is almost the same then relatively continuous forest and the isolated forest have the same values. However, in scenario-2, the isolated forest was relatively less important compared to that in scenario-1 and the green space in the east-region of Nagoya is assigned more high priority that covered wide area compared to map of scenario-1.
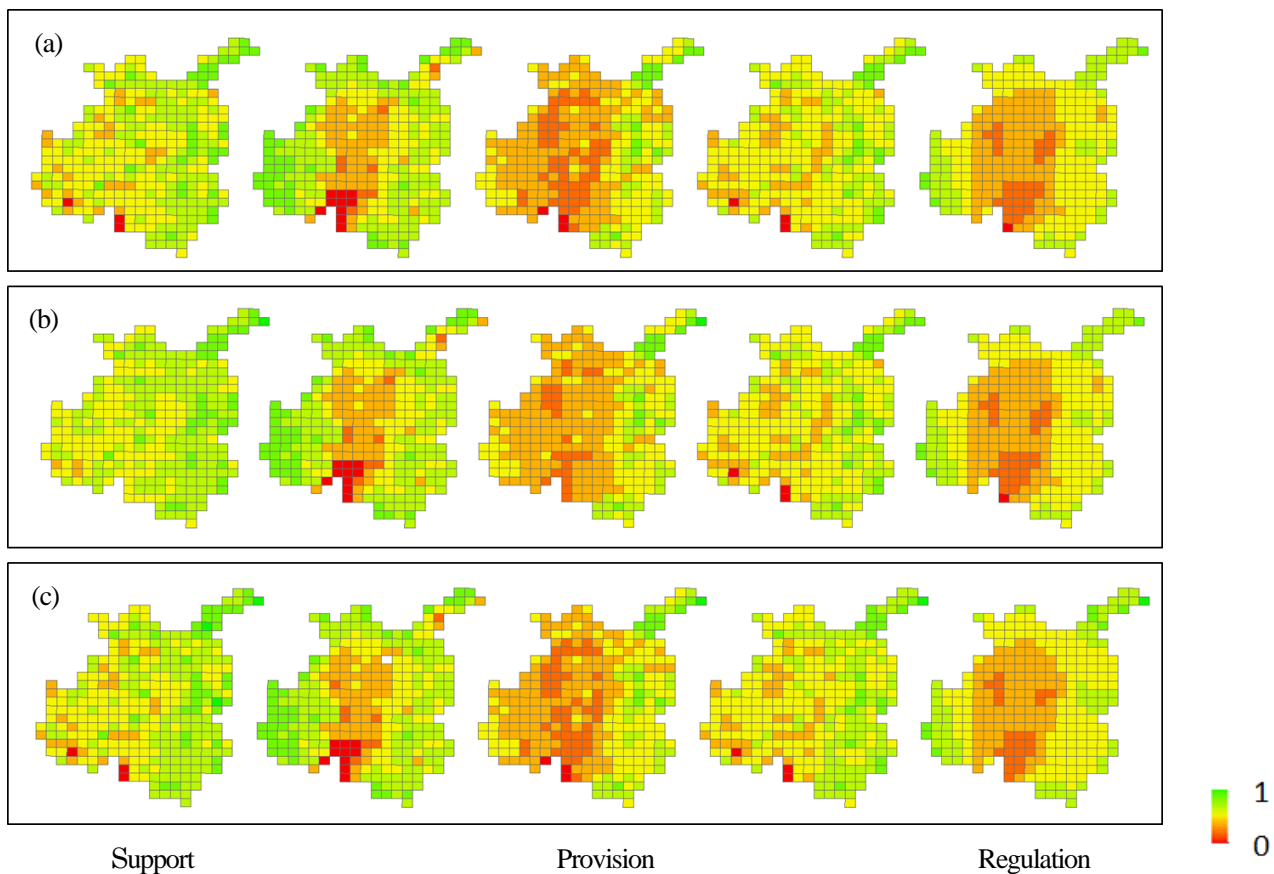

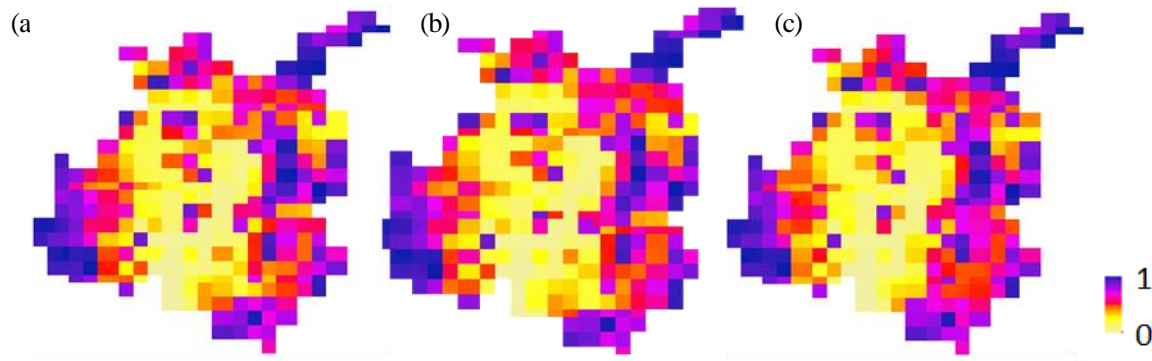**Fig. 3.2** Relative values of ES under scenarios (a) BAU (b) Greening-1, and (c) Corrido-2

Fig. 3.3 Conservation priority maps of ES under scenarios (a) BAU (b) Greening-1, and (c) Corrido-2

3.4 Conclusion

The following issue should be argued about future greenspace after shrinking urban area. In the current situation of cities, it is difficult to reserve continuous green space inside urban area. If population decrease inside urban area in future, sparse green space that have been residence, business area, or industrial area may appear. From the result of the scenario (1), increase the sparse green space inside city does not give a change of whole state of ES. However, if aggregation plan like the scenario (2) is applied, situation of ES inside the city may change.

Acknowledgements

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4. Impacts of the 2011 tsunami on tidal flat ecosystems: future perspectives for conservation of macrozoobenthic biodiversity

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4.1 Introduction

The Pacific coast of northeastern Japan was struck by a huge tsunami generated by the M 9.0 Great East Japan Earthquake on 11 March 2011 (Okada et al. 2011). The earthquake and tsunami intensively disturbed tidal flats, salt marshes, and sandy shores in the area (Kanaya et al. in press). Drastic changes in the community composition of macrozoobenthos have been reported from tidal flats across large spatial scales. For example, Miura et al. (2012) noted a sharp reduction of the dominant gastropod *Batillaria attramentaria* on five tidal flats in Sendai Bay. Urabe et al. (2013) also reported a taxon-specific reduction in species diversity of macrozoobenthos on tidal flats.

Biotic communities in the affected areas have been recovering gradually over the past 5 years. However, anthropogenic disturbances associated with ongoing restoration projects (e.g., reconstruction of huge sea walls) have become a potential threat for biotic communities (Okoshi 2015; Kanaya et al. in press). In this study, we classified the types of habitat alterations caused by the 2011 disaster. We also assessed the tsunami impacts on five endangered macrozoobenthic taxa in Sendai Bay. Finally, we discuss the potential threats of ongoing restoration projects on tidal flats in Japan.

4.2 Methodology

On 11 March 2011, an M 9.0 megathrust earthquake occurred in the western Pacific (38.322°N, 142.369°E), centered about 130 km east of Sendai City, Miyagi Prefecture. Huge tsunami up to 20 m high hit broad areas of the eastern Japanese coast (Okada et al. 2011). Seismic subsidence occurred intensively near the epicenter, with surfaces shifting up to 90 cm near the Oshika Peninsula (Kanaya et al. in press).

First, we summarized the types of disturbance associated with the earthquake, tsunami, and restoration projects based on the findings of Kanaya et al. (in press). Second, population sizes of four endangered Cerithioidea gastropods, *Batillaria multiformis* (NT in Miyagi Prefectural Red List), *B. zonalis* (CR+EN), *Cerithidea moerchii* (VU), and *Cerithideopsilla djadjariensis* (VU), and the marsh crab *Chasmagnathus convexus* (CR+EN) were surveyed at the Tsuya River, Samegawa River, and 25 sites in Sendai Bay (see Figs. 4.1 and 4.2).

At each site, a 30-minute field observation was conducted on a tidal flat by two or more researchers to assess the population sizes; these surveys were performed from one to several times at each site during 2011–2015. A pre-tsunami survey was conducted at each site from 2001 to 2010. The population size was classified into five categories: abundant, few (2–10 individuals), one (only 1 individual), extirpated (present pre-tsunami but absent post-tsunami), and absent (both pre- and post-tsunami). Finally, a detailed census focusing on all macrozoobenthos taxa was conducted in August 2014 and August 2015 at four sites in the estuary of the Samegawa River. Surveys at each site combined a 30-minute field observation plus a sampling using a 1-mm mesh sieve and a 15 cm φ × 20 cm deep core.
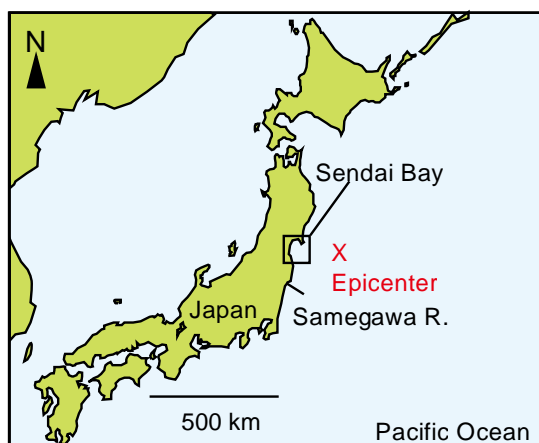

Fig. 4.1 Map of the Sendai Bay and Samegawa River.

Table 4.1 Classification of habitat alterations induced by the 2011 disaster in intertidal habitats along the eastern Japanese coast. Modified from Kanaya et al. (in press).

Causes	Impacts
Tsunami	Sediment scouring caused submergence of tidal flats
	Sediment deposition led to the creation of new tidal flats
	Vegetation loss in marshes, sand dunes, and coastal forests
	Destruction of coastal structures
Seismic subsidence	Submergence of existing tidal flats
	Creation of new tidal flats
Liquefaction	Sand/mud boiling led to changes in sediment type
	Lateral flow led to both submergence of existing tidal flats and creation of new tidal flats
	Destruction of coastal structures
Restoration projects	Reclamation and excavation led to coastal habitat destruction
	Seawall construction led to coastal habitat destruction
	Mitigation of tidal flat damage

4.3 Results and Discussion

(1) Disturbance of tidalflats after the 2011 earthquake

The disaster-linked changes in Japanese tidal flats are summarized into four major categories (Table 4.1). First, the tsunami induced scouring, sediment deposition, vegetation losses, and destruction of coastal structures. For example, the tsunami washed away marsh plants and sand dune vegetation in Gamo Lagoon (Kanaya et al. in press). Tsunami currents also deposited a huge amount of drifting sea sand on coastal areas in Sendai Bay (Szczuciński et al. 2012). Intense physical disturbance induced extirpation of macrozoobenthos on tidal flats (Miura et al. 2012; Urabe et al. 2013). Second, seismic subsidence induced the elimination and/or creation of tidal flats. In Mangoku-ura Inlet, most of the tidal flat became subtidal and a part of the land behind the shore became intertidal (Okoshi 2015). Third, liquefaction caused mud boiling, lateral flow, and destruction of coastal structures. Okoshi (2015) described the mud/sand boiling in inner Tokyo Bay. In some cases, liquefaction induced a massive lateral flow, resulting in submergence of the intertidal zone (Kanaya et al. in press). Finally, restoration projects have become potential threats for biodiversity on the tidalflats in the area (see below).

(2) Changes in population size of endangered *macrozoobenthos*

Intensive physical disturbances and changes in habitat structure drastically modified the associated biota. Fig. 4.2 shows the changes in population sizes of the five endangered taxa. The marsh-associated species *C. moerchii* was extirpated at four of seven sites and maintained the pre-tsunami population size at only two sites in inner Matsushima Bay. *C. djadjariensis* was extirpated at three of six sites, and it occurred abundantly only in Mangoku-ura Inlet and inner Matsushima Bay. Before the tsunami disaster, *B. multiformis* had occurred abundantly at most of the studied sites (20 of 27 sites), but except for populations in Mangoku-ura and inner Matsushima Bay most of these populations were extirpated. *B. zonalis* had been found only at Hatsutsu-ura. Fortunately, the population was maintained after the tsunami, and three additional populations were newly discovered in Matsushima Bay. It was possible that new recruitment of *B. zonalis* occurred in the 3 habitats after the tsunami. The marsh-associated crab *C. convexus* was nearly extirpated, whereas two new populations were found in the Tsuya River and Samegawa River.

These findings indicate that tidal flats in the sheltered bay areas where the tsunami was distinctively attenuated, namely inner Matsushima Bay and Mangoku-ura Inlet, are important sources of planktonic larvae of the endangered taxa for other disturbed habitats. Such key tidal flats should be conserved for future restoration of endangered macrozoobenthos in Sendai Bay.

(3) Endangered species in Samegawa River

During the 2014 and 2015 survey, we found 30 endangered taxa in the Samegawa River estuary (Table 4.2). Stenohaline marine taxa such as the bivalves *Acharax japonica*, *Macoma praetexta*, *Moerella jedoensis*, *Nitidotellina hokkaidoensis*, and *Soletellina boeddinghausi* and echiuran and sipunculan worms occurred at a seawater-dominated lagoon on the northern side of the river mouth. Marsh-associated and/or polyhaline brackish taxa such as assiminid gastropods, the bivalve *Corbicula japonica*, the polychaetes *Tylorrhynchus osawai* and *Notomastus* sp., and the crabs *C. convexus*, *Chiromantes haematocheir*, *Deiratonotus cristatus*, and *Sestrostoma toriumii* occurred at marshes and tidal flats in the freshwater-affected estuary.
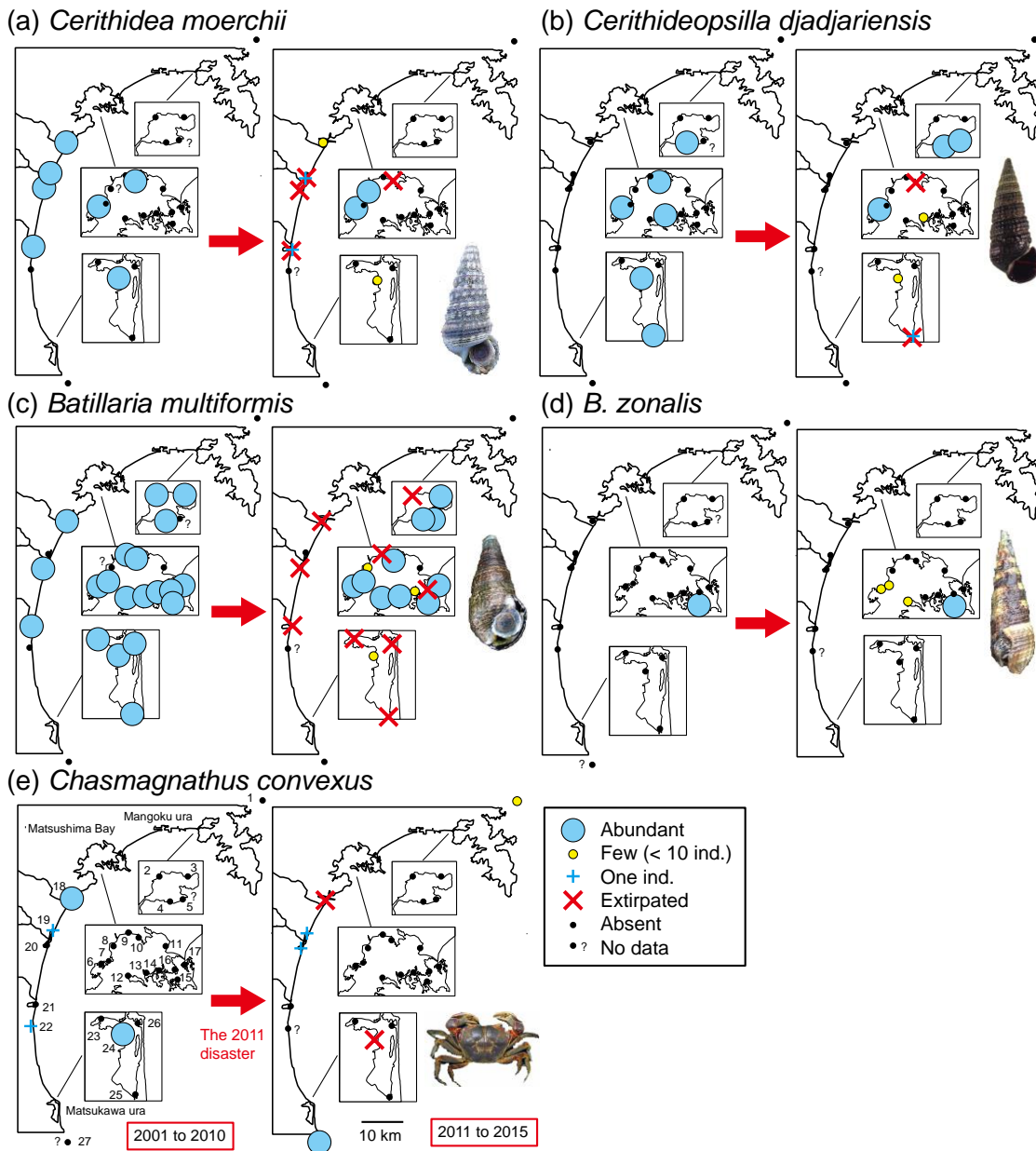
Fig. 4.2 Tsunami-induced changes in population sizes of the 5 endangered taxa in Tsuya River (38.766 N, 141.513 E), Samegawa River, and 25 tidalflats in Sendai Bay. [1] Tsuya R., [2] Sawada, [3] Urashuku, [4] Ohama, [5] Inodoshi, [6] Hitsuga ura, [7] Sokanzan, [8] Fukuura Is., [9] Nishinohama, [10] Zenigami, [11] Tona, [12] Katsura Is., [13] Nono Is., [14] Sabusawa Is., [15] Hatsutsu ura, [16] Otakamori, [17] Katsugiga ura, [18] Gamo, [19] Ido ura, [20] Hiro ura, [21] Torinoumi, [22] Ushibashi, [23] Obamahara, [24] Uda R., [25] Isobe, [26] Uno, [27] Samegawa R

Table 4.2 List of endangered macrozoobenthos recorded in the Samegawa River estuary during the 2014-2015 survey

Taxa	Red list category			Taxa	Red list category		
	MP [a]	MOE [b]	JAB [c]		MP [a]	MOE [b]	JAB [c]
Anthozoa				**Polychaeta**			
Edwardsiidae sp.			DD	*Tylorrhynchus osawai*	NT		NT
Synandwakia hozawai	NT		NT	*Chaetopterus cautus*	NT		VU
				Notomastus sp.	NT		NT
Gastropoda							
Nozeba ziczac	CR+EN	NT	NT	**Echiura**			
Retusa insignis	NT			*Arhynchite* cf. *arhynchite*			DD
Assiminea aff. *parasitologica*	NT	NT	NT				
Angustassiminea castanea		NT	NT	**Sipuncula**			
An. yoshidayukioi	VU	NT	NT	*Sipunculus nudus*			NT
				Siphonosoma cumanense	NT		NT
Bivalvia							
Acharax japonica		VU	VU	**Decapoda**			
Arthritica reikoae		DD	DD	*Chasmagnathus convexus*	CR+EN		NT
Macoma contabulata		NT	NT	*Chiromantes haematocheir*	NT		LP
Ma. incongrua	NT			*Deiratonotus cristatus*	NT		VU
Ma. praetexta		NT	NT	*Sestrostoma toriumii*	VU		NT
Moerella jedoensis		NT	NT				
Mo. rutila	NT	NT	NT				
Nitidotellina hokkaidoensis	NT	NT	NT				
Soletellina boeddinghausi		CR+EN	CR+EN				
Corbicula japonica		NT	NT				
Nipponomysella subtruncata		NT	NT				
Mya arenaria oonogai	NT	NT	NT				
Solen strictus	NT						

[a] Miyagi Prefecture (http://www.pref.miyagi.jp/uploaded/attachment/207586.pdf), [b] Ministry of the Environment (https://www.env.go.jp/press/files/jp/20555.pdf, https://www.env.go.jp/press/files/jp/20556.pdf), [c] Japanese Association of Benthology (http://benthos-society.jp/red_list_benthos_20150623.pdf). Red list category: CR+EN, critically endangered or endangered; VU, vulnerable; NT, near threatened; DD, data deficient; LP, threatened local population.

Some of the endangered taxa rarely occurred at other tidal flats in northeastern Japan (Ministry of the Environment 2015; authors' unpubl. data), and the population size of *C. convexus* in the Samegawa River estuary was the largest among those in Fukushima and Miyagi prefectures (Fig. 4.2e). Since the ocean current flows northward (i.e., toward Sendai Bay; Higashi et al. 2015), macrozoobenthos in Samegawa River would be a significant source of planktonic larvae for the meta-population network in Sendai Bay

(4) Impacts of restoration works on coastal biodiversity

Anthropogenic disturbances associated with ongoing restoration projects are now of increasing concern (Okoshi 2015; Kanaya et al. in press). We found that the tidal flat and marshes in the Samegawa River were damaged by construction of huge sea walls (Fig. 4.3a). Reed marsh habitat for *C. convexus* was intensively disturbed by the reconstruction of a floodgate (Fig. 4.3b). In the Tsuya River, habitat of *C. convexus* is also threatened by ongoing sea-wall construction (authors' pers. obs.). Along the Sendai Bay coast, huge sea walls (7.2 to 16 m high; Fig. 4.3c) are now being constructed at a broad spatial scale, leading to loss of the natural coastline in the area. Reclamation projects have also damaged the habitats of intertidal macrozoobenthos such as *B. multiformis* (Kanaya et al. in press). In Matsukawa-ura, construction of a flood wall devastated the local population of batillarid gastropods on the landward edges of the tidal flats. In this case, however, compensative

creation of the tidal flat was done after the bank revetment (Fig. 4.3d), which may allow for future recolonization of macrozoobenthos after a certain period of time.
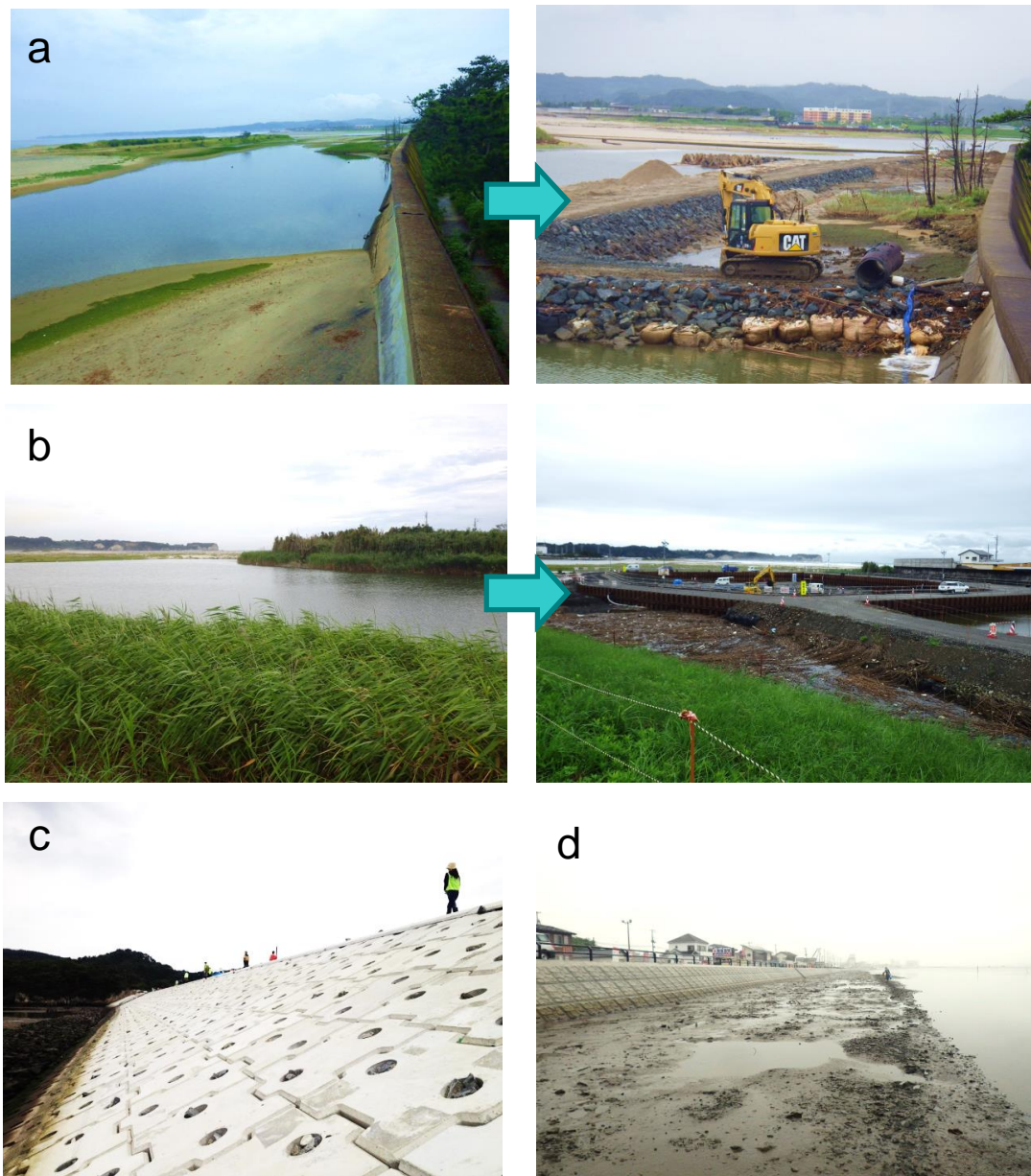

Fig. 4.3 Disturbance caused by restoration projects after the 2011 tsunami: (a) construction of sea wall on the tidal flat in the Samegawa River, (b) destruction of reed marsh by construction of a floodgate in the Samegawa River, (c) huge sea wall (height; +6.4 m T.P.) in Hatsutsu ura, and (d) mitigation of tidal flat damage after construction of the bank revetment in Obamahara, Matsukawa ura.

4.4 Conclusions

Our surveys revealed disaster- and restoration-induced changes in tidal flat habitats along the northeastern Japanese coast. Endangered macrozoobenthos were extirpated at many tidal flats along Sendai Bay, but populations still remained in Matsushima Bay, Mangoku-ura Inlet, and at several other sites. These remnant populations are important source populations for future restoration of biodiversity. At present, ongoing restoration projects are becoming a threat to the coastal biotic community. Appropriate assessment and adaptive management are required for future restoration of coastal biodiversity in the tsunami-disturbed areas.

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